DOCUMENT RESUME

ED 056 858 SE 012 046

TITLE Science Grade 9, Science Curriculum Materials.
INSTITUTION Rochester City School District, N.Y.
PUB DATE 70
NOTE 551p.

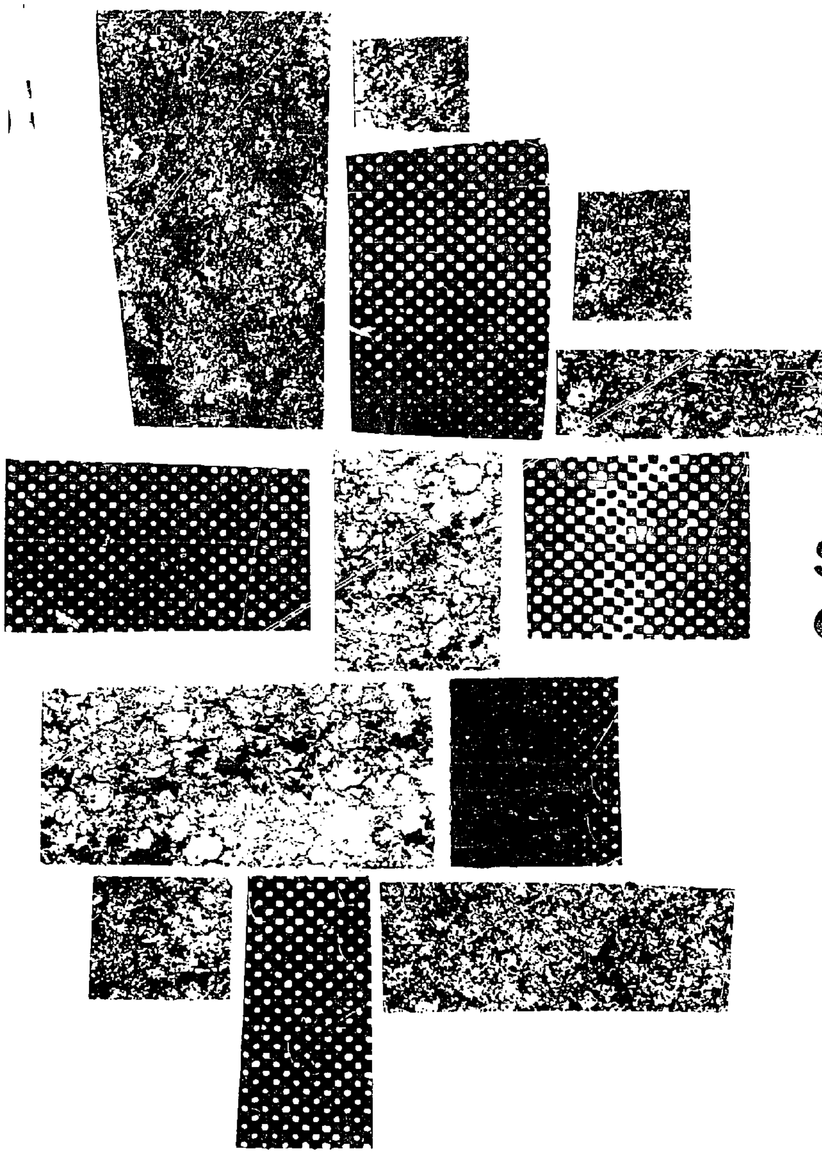
EDRS PRICE MF-$0.65 HC-$19.74
DESCRIPTORS *Curriculum Guides; *General Science; Grade 9; Laboratory Experiments; Laboratory Procedures; *Physical Sciences; Resource Materials; *Science Activities; Secondary School Science; *Teaching Guides

ABSTRACT

This curriculum guide is the third in a series of general science guides modified from the New York State Experimental Syllabus, Science 7-8-9 to meet the needs of students whose interests are in areas other than science. The guide is laboratory-oriented and contains many open ended, pupil activities in five activity blocks: orientation, forces at work, the chemistry of matter, energy at work, and living with the atom. This collection of activities is intended for use by teachers as a suggested course of study, reference source, and topical outline, and is not a series of lesson plans. The five activity blocks may be followed in any sequence. Introductory discussion presents topics and suggestions for the teacher concerning areas such as the outcomes from a science program, the basic skills used in science, time sequence, teaching slow learners, teaching rapid learners, developing reading skills in the science program, and multimedia instructional materials. (PR)

CITY SCHOOL DISTRICT • ROCHESTER, NEW YORK

SCIENCE CURRICULUM MATERIALS



SCIENCE
GRADE 9

1970

SCIENCE

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Division of Instruction
City School District
Rochester, New York

ACKNOWLEDGMENT

This ninth grade curriculum guide is the third in a series of general science outlines which has been designed to follow the State Experimental Syllabus, Science 7-8-9. Adaptations and modifications were made from the State outline so that the citywide program in science at the ninth grade level would more nearly meet the needs of an urban school system. Emphasis throughout, is placed on teacher flexibility in selecting, modifying and using this guide as determined by appropriate classroom interests.

Material changes in content and sequence were suggested by teachers and members of the Science Council during the 1967-68 and 1968-69 school years. These suggestions were reviewed and revised by Mr. Hartman Pogue of West High School and Mr. James Nicols of Monroe High School, both experienced ninth grade teachers. Dr. Samuel W. Bloom, director of Science, edited and prepared the final manuscript for publication

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INTRODUCTION

These tentative curriculum materials for the ninth grade general science program included in this curriculum guide are an extension of the experimental syllabus in Science 7-8-9 developed by the State Education Department and modified through experience and use in the Rochester schools. The general pattern followed in grades 7-8-9 is toward biological orientation at the seventh grade, a modified earth and space science course at the eighth grade, and a physical science emphasis at the ninth grade.

The units or blocks suggested in this curriculum guide have been prepared to introduce a number of science concepts considered essential in the development of scientific literacy for all children. In addition, these units are designed to lay a strong foundation for the more specialized science areas offered at the upper grade levels.

This curriculum guide is intended solely for use by teachers as a suggested course of study, reference source, and a topical outline. The teacher should feel free to deviate from the guide as necessitated by the need for individual instruction and by the interests of the class. THIS GUIDE IS NOT A SERIES OF LESSON PLANS. The blocks may be followed in any sequence. For supplemental information, the teacher is referred to the State Blocks I, J, K, L and Experimental Part I.

All starred (*) items refer to enrichment materials to be used at the discretion of the teacher. This symbol (#) denotes an activity. Although the units of measurement used in the metric system are preferred in scientific fields, the English system of measurement remains the more meaningful to our pupil population. Teachers should use that system of measurement which has the most meaning to pupils and which relates more nearly to their everyday life. However, emphasis should be placed increasingly on the use of the metric units of measurement.

Since most classes in the high schools contain pupils with a range of ability, varied reading skills, different degrees of motivation and occupational expectations, the teacher is urged to select from the many suggested activities those that are more suitable and relevant to the particular class. A large number of interest developing activities are provided to implement the development of major understandings. Considerable more activities have been provided than can be performed during the regular school year. The teacher should be selective...choose the appropriate activities which will broaden the science interests of the class and individuals within the class.

At this point in the child's development, it may be educationally more defensible to enlarge a pupil's horizon than to concentrate in narrow fields of science. A child's interest may be more easily aroused if stress is placed on concepts which have the greatest general interest such as those concerning machines, aircraft, space exploration, drug use, and consumer application. Relating scientific concepts to the everyday environment and experiences of the pupil will make such understandings more meaningful. Thus, the pupil will become increasingly aware of the role of science to his everyday world experiences.

Teaching emphases should include a considerable opportunity for laboratory experiences, individual project opportunities, and individual and small group involvement. It is the expectation that these ninth grade students will develop and be guided to a basic understanding of concepts through many varied activities: independent study, class discussions, demonstrations, and experimentation. The teaching situation should provide for a high degree of flexibility in the selection of science experiences, choice of concepts to emphasize, and the use of multimedia instructional materials.

A great deal of flexibility is given teachers in the selection of course content from the suggested topical outline. Although numerous science teachers consider preparation for later science courses to be the principal or only aim of science instruction, this is not a primary goal within the City School District. While goals relating to preprofessional preparation in science are appropriate for students planning to become scientists, physicians, and engineers, only a small minority of the total population is engaged in these professions. Well in excess of 90 percent of adults are not engaged in occupations directly related to science. Thus, the choice of subject content and the methodology used in the classroom should be made chiefly for its contribution to the child's scientific literacy. Literacy in science is essential for every individual who hopes to function effectively in our twentieth-century society.

Even though an individual does not plan to engage in science or science-related occupations, he needs some basic understanding of scientific ideas to be able to comprehend the phenomena and changes in the natural world in which he lives. He needs to become aware of the changes that science is making in his environment, its long range ecological effects, and its effect upon him as an individual. The selection of science content at the high school level should contribute to this general goal by providing the base upon which the individual may become increasingly more literate.

The impact that science now exerts upon all aspects of living is continuous and ever-increasing. At the high school level, science instruction should be concerned primarily with the observation and interpretation of the common phenomena of the environment. At this level, science instruction should be centered around those materials which seem most significant for everyday living. Pupils should be encouraged to explore the environment for themselves, become familiar with career opportunities in science, and every effort should be made to achieve a familiarity with the world of science outside the classroom.

In the present age of expanding technology it is a curious paradox that science teaching is still largely a matter of the memorization of content, much of which is rapidly becoming obsolete. The possibilities of experimental procedures, of direct observation, and of first hand experiences have been only partly explored.

The science teaching methods must be creative and open-ended. Traditional approaches should be minimized in favor of pupil-oriented activities. A comparative guide follows:

TRADITIONAL APPROACH	INQUIRY APPROACH
information	INQUIRY
telling	ASKING
reading about	DOING
structured learning	OPEN END
demonstration	EXPERIMENTATION
rigid procedure	FLEXIBILITY
dogmatic assertions	QUESTIONING, ASSUMPTIONS
facts and principles	PROCESS

The goal of an effective science program would be to provide a learning situation which facilitates some favorable form of student behavior after instruction has been completed. The liklihood of a student putting his knowledge to use is influenced by his attitude for or against science. Teachers do influence pupil attitudes toward subject matter and toward learning itself. Therefore, an overall objective of science teaching is the extent with which pupils leave a class as favorably inclined toward science as possible. If a pupil is favorably inclined toward science, he will remember what has been taught, and will willingly learn more about science.

Outcomes from a Program in Science

Outcomes that can evolve from a high school science program include the ability to:

- question the what, the how and the why
- form independent judgment
- make careful plans for solving problems
- make careful observations
- locate and use reference materials effectively
- read science content with understanding
- develop a scientific vocabulary
- interpret accurately simple charts, tabl3s, and graphs
- communicate with exactness and precision
- follow instructions and directions
- recognize and use safety principles
- apply principles of science to new situations
- cooperate effectively with others
- live and work in one's environment

BASIC SKILLS USED IN SCIENCE

One of the major objectives of any course in science is to develop the basic skills used by working scientists. The following skills should be considered vital to the proper development of a scientific attitude.

- Ability to identify and define a problem
- Ability to collect data
- Ability to organize data
- Ability to interpret data
- Ability to observe carefully
- Ability to collect evidence
- Ability to formulate an hypothesis
- Ability to test an hypothesis
- Ability to predict the effects of known causes
- Ability to establish causes from known effects
- Ability to generalize conclusions
- Ability to devise a new experiment
- Ability to develop a control for an experiment

Time Sequence

The units or blocks included in this curriculum guide have been designed for maximum flexibility by teachers in planning the year's work. A working guide to a time sequence might be:

Block O - Orientation	1 week
Block I - Forces at Work	9-10 weeks
Block J - Chemistry of Matter	3-11 weeks
Block K - Energy at Work	10-11 weeks
Block L - Living With the Atom	5- 7 weeks
	33-40 weeks

A. Block O - Orientation

The Orientation Unit (Block O) is review material. Teachers should review this material only to the extent of assuring a degree of competency by pupils in understanding the scientific approach and in the students' facility in using measuring instruments. Some teachers may wish to devote time to the nature of science at the beginning of the term; others will prefer to weave the activities and understandings into their program throughout the year. The section on measurement may be used when it is most appropriate for the quantitative treatment of the content which follows.

Although mathematics is the basic component for a real understanding of scientific concepts, the minimum use of mathematics is advised at the ninth grade level. The experienced teacher will adapt his teaching methods to include mathematical manipulations when the child is ready and able to think symbolically. With many children, the approach at the ninth grade level should be qualitatively.

B. <u>Block I - Forces at Work</u>

Block I has been designed for approximately 10 weeks of instruction. Because of time limitations, not all of the activities listed can be performed. The teacher should select appropriate activities which will broaden the interests of a particular class. In classes where this course may be a terminal course in the physical sciences, it is suggested that stress be placed on concepts and understandings which have an immediate relationship to the environment of the individual: automobiles, aircraft, space exploration, machines, etc.

Approximate time intervals are suggested as a guide for the average class:

Forces	2 weeks
Forces and work	2-3 weeks
Forces and fluids	2 weeks
Forces and motion	3 weeks
	9-10 weeks

Block J - The Chemistry of Matter

This unit is designed to accomplish several objectives:

...to present a reasonable amount of content in the area of chemistry which may be useful to pupils in their everyday life

...to prepare students with some insights into the mechanisms of chemical reactions and chemistry in preparation for future courses in biology and chemistry

...to give students a first-hand experience with laboratory apparatus and techniques

Judicious selections of content should be made to avoid such meaningless activities as the memorization of chemical symbols, formulas and uses of isolated compounds, and the balancing of chemical equations by rote. Emphasis should be placed on the applications of chemistry in the everyday experience of students with illustrations meaningful to the consumer.

This block has been designed for 8-11 weeks of instruction. The approximate times given below suggests the stress to be given for the various areas.

Introduction and Role of Chemistry in Society	2-3 weeks
Properties and changes in matter	1-2 weeks
Introduction to atomic structure	1-2 weeks
Common chemical changes	2 weeks
Common compounds and mixtures	2 weeks
	8-11 weeks

D. Block K - Energy at Work

The topical outline included in this block permits many interpretations. Any major topic could be the basis for instruction for a full year course. It is important that teachers present both the content and the appropriate activities at the level of their pupils' competencies. Teachers should select activities appropriate to the abilities of their pupils and to provide ample opportunity and time for the quantitative treatment of some concepts. Review the previous preparation of pupils in the area of magnetism, sound and heat energy to avoid needless duplication of content.

Approximate time intervals suggested as a guide for average classes:

Electrical Energy	4 weeks
Magnetism	1 week
Light	2-3 weeks
Sound	1 week
Heat Energy	2 weeks
	10-11 weeks

Block L - Living with the Atom

Increased public interest in nuclear energy, radioactivit, the atomic structure of matter has led to the development of s unit as an important part of the science curriculum and the d for students to understand the effects of nuclear transfor- ions on society and the environment.

The unit is designed to accomplish several objectives:

...to develop and expand the pupils' natural curiosity about this topic

...to develop an appreciation of the present and potential uses of radioactivity and nuclear energy

...to foster an intelligent understanding of the dangers of radiation exposure

...to provide pupils with a basic understanding of the future role that atomic energy may play in society

Block L has been designed for approximately six weeks of struction with one to two weeks devoted to a survey of organic emistry. It is suggested that emphasis be placed in the class- om on the constructive and creative uses of radioactivity, dioisotopes, and nuclear reactions. The depth of treatment of is topic must vary, obviously, with the abilities, needs and terests of the pupils. Pupils should be given the opportunity observe as many phenomena as possible through demonstrations or periments as long as they may be done safely.

Teaching Science to Slow Learners

In working with the slow learners, one must be aware that they show a wide range of ability within a given class. Many persons think they know a slow learner when they see one, so thought the teachers of Edison, Churchill, Einstein and a good many other geniuses.

It is a great injustice to assume that because a student is slow in reading, he is necessarily slow in everything. If such an attitude is taken, a pupil's best talents may go unnoticed and his possibilities unrealized.

The most important factor in the success of the course for slow learners is the teacher. No matter how soundly based any or all of the material is, unless the teacher is prepared to accept slow learners as fellow human beings, unless his expectation of what they can do is realistic, unless he is willing to try to see the world as the slow learner sees it, unless he really wants to teach slow learners, a successful year's science course is not likely. Slow learners are slow about many things, but they are not slower than anyone else in their sensitivity to the way in which the teacher feels about them.

Behavioral goals are part of the course. True learning is more than acquisition of knowledge. It involves change in behavior of the learner.

Characteristics of Slow Learners and Guiding Principles for Teaching:

The slow learner has a short attention span.

Make class activities and discussions brief. Divide class time into short (10 to 15 min.) segments. Set minimum requirements that cover essential aims.

He has a poor memory.

Focus class attention on major ideas and concepts. Relate the course to his needs and environment. Make it meaningful to him. Be firm but fair.

He has a poor vocabulary. His reading is usually two or more years below grade level.

Do not expect him to read material beyond his capacity. Give clear and simple explanations of words which he is unlikely to understand.

His ability to follow directions is poor.

Think through all explanations for all assignments. Present them briefly, clearly, and as specifically as possible. Show him or write them rather than tell him.

His study habits are disorganized.

Keep homework assignments at a minimum, preferably none. Plan work to be started in the class period, finished at hom.

He has generally made a poor adjustment to school life and often has little understanding of conventional standards of behavior.

Do not expect overnight changes in behavior. Do not expect much success on the basis of lectures. Plan situations in which he can learn what the standards are and why most people accept them.

He has little ability to use standard reference works.

Work with the most simple reference tools and give him help and instruction on their use. There are many firms that give good free material.

He finds great difficulty in sitting still and listening for a whole class period.

Make provisions for activity which will give him an opportunity to talk to other students and move around for part of the period.

He has frequently experienced failure.

Provide opportunities to experience success. Praise him for even minor accomplishments. Give him encouragement along the way. Have him win.

He does not grasp general and abstract ideas.

Relate work to first hand experiences. Be specific and concrete. Help him make specific applications.

He can learn.

Don't expect him to learn rapidly. Know his mental and achievement levels. Keep the assignments at his mental level. Repetition is important.

He has the same fundamental needs and emotions as the bright pupil.

Because he frequently has less satisfaction in having his needs met, strive to give him affection, praise, a sense of belonging, and to re-establish confidence in himself. Create an atmosphere of warmth and acceptance. Take time to discuss problems even if they are not part of the science curriculum.

Teaching Science To Rapid Learners

The nature of the academically able student provides some guide lines which apply to his education. He learns rapidly, has varied interests, and is adventuresome.

The academically able student needs to be encouraged to work with science materials and to acquire competency in laboratory techniques and methods. The student should be encouraged to work independently while under the guidance of the teacher.

The introduction of the quantitative approach to science should be encouraged as the able younster can deal readily with mathematical calculations. The concept and practice of dimensional analysis can be incorporated in the high school science program.

Characteristics of Rapid Learners and
Guiding Principles for Teaching:

The material presented must meet his needs and his already established interests.

Since he is academically able, the teacher must present materials in accordance with this level of ability. This does not mean that he has interests in every topic nor that all able students have the same interests.

He needs activity.

Listening and watching do not provide an adequate outlet. Plan for individual differences, provide independent study opportunities and extensive laboratory experiences.

The teacher must assess each student.

The teacher must learn the specific skills, facts, attitudes, and understandings each one has or does not have.

He needs to have a knowledge of his progress and results.

Help the pupil achieve a sense of success and confidence by providing a clear-cut knowledge of his success or failure.

The academically able student has a point of saturation.

Saturation may happen when the teacher attempts to teach the subject too long, in too great a depth, or with relatively meaningless rote activities.

He needs competition.

Competition operates as one of the outstanding incentives in his school learning.

Creativity.

The rapid learner is generally creative, innovative, and learns to do things in an unorthodox manner. However, the teacher cannot assume that the bright child will develop creativity on his own. He needs guidance and support.

Too frequently teachers reward memory work and divergence is discouraged. Teachers should avoid requiring meaningless tasks, over-repetition, too much drill and looking simply for rote memorization. Creative children do not function well in such an atmosphere.

Motivation is not a bag of tricks which the teacher uses to produce learning.

Motivation depends on such factors as the child's purpose or intent to learn, his self-concept and self-confidence, his levels of aspiration, and his knowledge and appraisal of how well he is doing in relation to his goals.

Class atmosphere.

Class atmosphere and democratic leadership of the teacher will go a long way to accomplishing goals with superior students. Inflexible schedules, threats or autocratic control cuts off communication of pupils with each other and the teacher.

DEVELOPING READING SKILLS IN THE SCIENCE PROGRAM

Teachers cannot assume that children entering a ninth grade science class are reading at the ninth grade level of comprehension. The facts are different. In an average ninth grade classroom, teachers will find a reading range from the fourth grade level to eleventh or higher levels. Moreover, readings and reading skills in the sciences are unique to the subject and pupils must be taught how to read the science text, how to follow instructions, how to study science. Science has a special, technical vocabulary which must be understood before the science concepts can be comprehended.

Many of the problems of reading science materials are common problems in all the content fields. These problems appear exaggerated in science due to the specialized science vocabulary. If a teacher is to be successful teaching the concepts in science, she must also be a reading teacher and teach pupils how to approach readings in science. Five steps should be considered in the basal, science reading lesson:

a. developing reading readiness

b. the initial reading of the material

c. developing word recognition skills

d. discussion and rereading

e. follow-up activities

Ways of Meeting Problems in Reading Science Material

a. Difficulties of Vocabulary

In order to develop the concepts of science through the use of language, the learner must use the exact language of science and relate it to his own experience and his reading.

A science book contains a considerable vocabulary of scientific words in addition to the basal vocabulary and these words must be taught and understood. It is important that the teacher anticipate vocabulary difficulties at any level.

Most science textbooks have some means of calling the attention of the pupil to a technical word when it is first introduced: bold-face or italicized type. The teacher's job is to convince students that they cannot consider the reading completed until they have mastered the spelling, pronunciation, and the meaning of the terms. Students must stop, look at the word, vocalize it, read the definition, read and reread it until they are able to assign a definite meaning to it in their minds.

Probably the single most significant aid to students in mastering vocabulary is the precept and example of the teacher in the use of terms. Scientific terms are rigorously defined and teachers should be precise in their use of such terms.

b. Difficulties of Concepts

Explanation of scientific experiments that can be observed by the pupil is often difficult. Some students accept what they observe without trying to understand the explanation. Others will try to understand but need help, while still others will perform experiments and will read and understand the explanation without help. Each of these groups need a different means of instruction. Diagrams, similes and every aid possible should be used to make clear those concepts that cannot be made clear by experiments. Guided discussions often aid in clarifying concepts.

c. Difficulties Due to Following Reading Related to Diagrams

Many diagrams are found in science material. In order to understand the discussion the diagram must be read. Some pupils find reading diagrams difficult because they do not connect the discussion of a diagram to the diagram itself. The teacher can often help the student who is in difficulty by showing him that pictured in the diagram is a fact that has come within his experience. She will need to give direct teaching in reading diagrams, beginning with very simple concrete illustrations and proceeding to more abstract generalized ones. The pupil may try to express some of his experiments in the form of a diagram.

d. Difficulties Due to Need to Follow Directions

In science many experiments are performed which make it necessary for the student to read to follow directions. These directions should be read slowly and thoughtfully so that the experiment may be followed step by step in the proper order. Specific training will need to be given. As the student reads directions and does experiments, the teacher can detect any difficulty he may be having and give him added instruction.

e. Difficulties in Seeing Relationships and Formulating Generalizations

Seeing relationships and forming generalizations may be difficult for some pupils. They will need many opportunities to consider relationships and reach conclusions or generalizations.

The rate of reading science materials will need to be slower than the rate at which children read stories in other content areas. It is important to help students adjust their rate of reading to the purpose at hand.

f. Difficulties in Differentiating Facts from Opinions

Students' reading experiences in science should be guided toward developing abilities to differentiate between fact and opinion in their reading, to recognize the difference between books written for entertainment and those which are sources of accurate science information, to learn the importance of copyright dates and authors in determining whether reading materials are authentic or not, to question the accuracy of what appears in print, and to check conflicting statements with other reliable sources.

Skill in reading science materials will need to be developed. Teachers have the responsibility of teaching pupils to read science materials, meaningfully.

Multimedia Instructional Materials

Finding a suitable textbook for ninth grade science is a difficult task. The reading levels of most general science textbooks together with the excessive technical vocabularies are beyond the range of most ninth grade students except the more able. There is no one textbook currently available that combines the concepts to be learned at a reading level that can be easily comprehended. Moreover, teachers will find that it is unlikely that any single textbook follows the city or the state course outline. Teachers should plan, therefore, to use multiple textbooks written for different reading levels, films, filmstrips, single concept films, tapes, and other instructional media in developing their day-to-day series of activities.

Appropriate multimedia materials are available from the Educational Communications Department. A film catalog listing current films is available in each school. A special listing of science films is prepared for each science teacher early in the school year. Be certain to obtain your copy. New science films are continually being added to the film library. As new films are received, schools are notified. Similarly, special programed learning materials are available for individual pupil use. A list of such materials may be obtained from the Programed Learning Office, 410 Alexander Street.

Many other types of instructional aids are available to assist teachers to enrich and improve their instructional programs. Plan a visit early in the school year to the Preview Center at 410 Alexander Street to examine the latest materials available for teacher use.

Message to Teachers

This ninth grade general science curriculum guide has been revised in terms of classroom needs. The content emphasis in the regular State Education Department program in ninth grade general science is toward the science oriented student. It does not effectively meet the needs of students whose goals, interests and objectives are in areas other than science. For such pupils, a modification of the State program is necessary.

It is desirable and quite essential that the non science major be familiar with the basic concepts and understandings inherent in the physical sciences at a level which he can comprehend. All students, as individuals and as members of society, should have functional knowledge of their immediate environment in terms of fundamental basic science principles. These principles and understandings should be related to the pupil's needs, interests, activities, daily experiences, degree of sophistication, and future occupational objectives.

Flexibility of Programing

As a teacher, you have latitude and flexibility in developing your program in ninth grade general science. This printed course of study should be considered only as a guide; it is not a series of lesson plans. It is the expectation of the curriculum committee that the basic concepts and understandings listed will be covered through the year. Many more activities and concepts have been listed than can possibly be covered during the year. Feel free to change, delete or modify the pupils' experiences and activities listed in this guide as determined by the class or by individual students.

Laboratory Orientation

This is a laboratory oriented program. Plan to provide as many different student activities as possible within the time period. Teacher demonstrations should be kept to a minimum with individual pupils or small groups performing the exercises for the larger group. The science classroom and laboratory should be considered a workshop area with many different types of activities taking place. If possible, student stations should be made available for individual project work.

The units and laboratory suggestions contained in this science guide are designed on a five time a week basis for an entire school year.

Mathematical Computations

Mathematical computations should be kept at a minimum and used only as a tool to develop understandings. When mathematical manipulations are needed, teach the class the fundamentals. Do not assume that every class member can manipulate numbers or relate to arithmetical concepts. Avoid any manipulations more complex than a simple ratio, two or three number multiplication or division, solving for one unknown, and the construction of graphs along the positive x-y quadrant.

Relevancy

Illustrations, sample activities, field trips, laboratory experiences, classroom discussions, should be related closely to the everyday activities, interests and environment of the individual. Draw science analogies, examples and illustration from the immediate neighborhood of the school and the home. Get pupils interested in their immediate environment to which they can relate through knowledge and familiarity. Teachers should not hesitate to alter the prepared lesson of the day if the interests of the class indicate a change of emphasis.

BLOCK O

THE NATURE OF SCIENCE, TOOLS, AND MEASUREMENT

ORIENTATION

The ... of Science, Tools, and Measurement

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
I. Science as a ... od	Note to teacher: This Orientation Unit may serve either as an introductory unit; or the concepts and skills introduced when appropriate throughout the school year.
A. Question	
1. defin... oblem	
B. Explore	
1. reaso... for gathering data	
2. reasons for analyzing data	
3. suggest possible solutions	
4. select a reasonable solution	
C. Experiment	
1. according to plan	
a. state hypothesis	
b. li... material required	
c. outline procedure	
(1) define controls	A control is a clearly defined standard by which one can compare or measure an experimental object, condition or process with a known and unaltered reference.
(... define ...ariables	

Important ... pts are indicated by the symbol (#). Materials considere... n enrichment nature are indicated by an asterisk (*).

MATERIALS

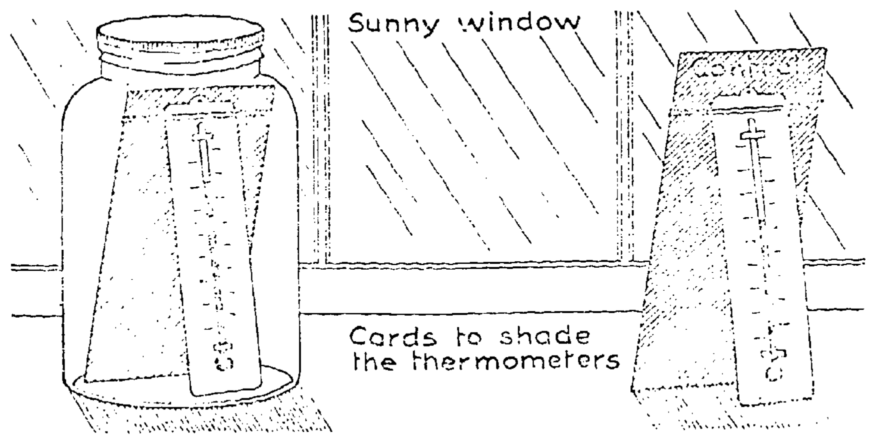
jar with
screw top
thermometers
cards
rubber bands
pitcher
ice water
candle
optical illusions

KEY WORDS

analyze
control
data
define
hypothesis
procedure
solution
variable

ACTIVITIES

#Set up a "heat trap" as shown in the diagram to illustrate the principle of the greenhouse, cold frame, or solar house. The shorter infrared radiation from the sunlight passes through the glass and heats up the material inside. The longer heat waves that are reradiated cannot get out through the glass, hence the temperature rises.



#Given a pitcher of ice water. Note the appearance of drops of water on the outside of the pitcher.

(1) List those facts which you think are related to the observed phenomena.

(2) Theorize as to whether the moisture on the pitcher comes from the water inside or from the air outside.

(3) Substantiate your theory by gathering more facts.

#Light a candle. Give a minute or so for observation. Extinguish. Write observations. Differentiate between observation and conclusions which may be drawn. Fallacy of basing observations on prior experience.

REFERENCE OUTLINE | MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

d. perform experiment; record observations

e. take measurements
   (1) offset illusions
   (2) diminish biased observations
   (3) insure accurate conclusions or generalizations

f. relate observations

g. draw conclusions (tentative)

h. repeat procedure

Scientists repeat experiments to determine the accuracy and reliability of the original observations.

   (1) danger of a single test
   (2) danger in generalizing

D. Conclusion(s)

1. correlate evidence

2. summarize observations

3. relate to hypothesis

MATERIALS

cardboard
beakers
water
thermometer

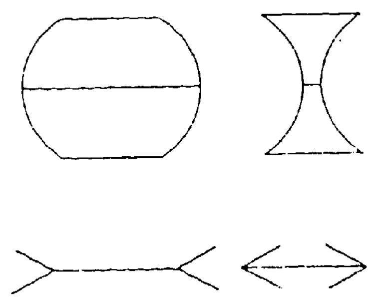
KEY WORDS

biased
conclusion
correlate
generalization
illusion
observation
summarize
tentative

ACTIVITIES

In both top figures in the diagram the top and bottom lines are all equal. Both lines are of equal length in the bottom figures.

Pupils will find it interesting to redraw these figures in their notebooks. Lines on which the illusions are based should be measured very carefully to make sure that they are really equal in length.



#Cut out a piece of cardboard about two inches square. On one side draw a bird cage. On the other side draw a bird and color it red or some other bright color. Slit the eraser of a pencil with a knife, insert the card and lock it in position with a short pin. Rotate the pencil rapidly between the palms of the hand and the bird will appear inside the cage.

When we look at something the image persists on the retina of the eye for a fraction of a second. If the light from two objects enters the eye in rapid succession they appear to be superimposed because of this persistence of vision.

Moving pictures are projected at the rate of 24 frames per second. The rapid succession of images creates the illusion of smooth motion because of the persistence of vision. Much the same thing happens when we watch television.

#Feel the water in a glass to determine its temperature. Guess its warmth. Compare with the estimate of your classmates, then test with a thermometer.

Place one hand in a beaker of fairly hot water. Keep it there. Place the other hand in a beaker of lukewarm water. How would you describe your sensation of heat and cold?

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
E. Application(s) 1. develop relationships 2. determine extensions and limitations	Scientists try to apply their conclusions to other situations involving similar problems.
F. Communication(s) 1. share discoveries 2. encourage additional investigation 3. substantiate results	Scientists share data, discoveries, and theories in order to encourage others to further investigate and verify or disprove their work.
II. Provision for universal references; standards for measurement	Note: Whenever possible emphasize the MKS system, not CGS. Scientific instruments provide universal methods to observe and/or measure angles and direction, length and distance, weight, capacity, rate and time, temperature, pressure and various kinds of energy.
A. Numbers and units	All measurements have two distinct parts; a number and a unit of reference. The unit tells what is to be counted; the number tells how many units are contained in the subject being measured. Many "units" originated in relation to the human body; thus early standards influenced the development of present standards. Early Egyptians defined the cubit as the distance from the point of the elbow to the tip of the middle finger of the outstretched hand.

MATERIALS

ACTIVITIES

Develop a workable experiment/demonstration outline with students. It should include a standardized heading with the other pertinent information as outlined by the basic scientific method.

One suggestion might be:

Name_______________Experiment/Demonstration*

Class_____Period_____

Problems/Hypothesis:_______________________

____

Materials:_________________________________

____

Procedure:__________Observation:___________

____

____

(Note: It is suggested that each observation follow the procedure step it accompanies. Observations where made are to be numbered with the same number as the particular procedure step. e.g.;

1.	1.
2.	2.
3.	3.

Conclusions(s):____________________________

____

*(Fold in center of paper)

Application(s):____________________________

____

(practical applications wherever necessary. The "why" of it all.)

KEY WORDS

application
communication
extensions
investigation
limitations
relationship
standard
substantiate
universal

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

This was standardized in about 4000 B.C. at what is now 46.3 cms.

. Span - distance between tip of thumb and little finger of the outstretched hand.

. Palm - the breadth of four fingers.

. Nail - distance between the last two joints of the middle finger.

. Digit - the breadth of the middle finger measured at the middle.

. Foot - the length of a foot.

. Fathom - distance between outstretched arms.

B. Fundamental quantities

The primary of fundamental dimensions are length, mass and time.

The metric system (France 1790) is a decimal system in which larger or smaller units are expressed by moving the decimal point the proper number of places when multiplying or dividing by ten or a multiple of 10.

1. length; distance

a. definition

Length may be defined as the distance between two defined points.

b. metric units

The standard of length in the metric system is the meter.

1 meter	(m.)=length stand bar
1 decimeter	(dm.)=0.1 meter
1 centimeter	(cm.)=0.01 meter
1 millimeter	(mm.)=0.001 meter
1 kilometer	(km.)=1,000 meters

MATERIALS

rulers
1 mm. grid paper
paper
meter sticks

KEY WORDS

decimal system
fundamental
length
mass
primary
time

ACTIVITIES

#Understanding Subdivisions of Meter Sticks

Have each pupil make a 10 cm. ruler. The procedure for making the ruler should be illustrated by the teacher, step by step, on the board.

Each pupil should have a half sheet of 1 mm. grid graph paper and a rectangular piece of stiff paper whose dimensions are at least 10 cm. x 3 cm.

Ask the pupils to outline a 10 cm. x 3 cm. rectangle on their grid graph paper. Then have them mark off on the graph paper divisions for centimeters, .5 centimeters and millimeters in order, with different length lines for each type of subdivision; the lines for the centimeters should be the longest and those for each different subdivision shorter than those for the preceding one. The teacher should illustrate this by drawing it on the board. Call attention to the relationship between the different subdivisions on the ruler and discuss the advantages of this scale. Have the pupils cut out the ruler and paste it on the stiff paper for use later in measuring.

#Measuring Distances Directly with a Meter Stick

Before the class period make a list of well-defined distances in the classroom that are easily accessible. Avoid using distances over 1 meter which would necessitate moving the meter. The selection of common objects, of which there are several in the room, will eliminate the possibility of congestion as a result of several pupils wanting to make the same measurement at the same time. Using meter sticks and the 10 cm. rulers that the students have made, measure other distances, decide on a reasonable degree of accuracy for each, and make a separate list of the answers or answer that you would accept as correct.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS	ACTIVITIES
meter sticks metric scales yardsticks poster board	Illustrations:

Illustrations:

1. The longest dimensions of the cover of the textbook.
2. The height of a chalkboard.
3. The thickness of a door.
4. The width of a floor board of floor tile.
5. The length of an unused piece of chalk.
6. The width of a pupil's desk.

Write the list on the board or make duplicate copies of the list and give each pupil a copy. Ask the pupils to make the measurements and to write the answers to each item, to the required accuracy, after the number of the item written on the board of in the space provided on the duplicate form. Check the answers for correctness and discuss further those which presented any difficulty.

#Comparing the Metric and English Systems of Measurement

Obtain a meter stick, or a metric scale, and a yardstick. Have a pupil read the first 16 division lines on each scale. Note that in the English system the denominator varies (1/16", 1/8", 1/4",........1") while in the metric system, the denominator is always tenths (.1 cm., .2 cm., .3 cm......1.6 cm.)

On a large poster board, draw a rectangle whose length is more than 12 inches and label its dimension correct to the nearest 16th of an inch. On a second poster draw a congruent rectangle, and label its dimensions in metric units, correct to the nearest 10th of a centimeter; i.e., millimeter. Have the pupils compute the perimeter and the areas of the two rectangles. Note that multiplying metric units is frequently easier than multiplying fractions.

Have the perimeters and areas expressed in two different units, such as square inches and square millimeters and square centimeters. Note that to change a unit in the metric system it is necessary to change only the decimal point; in the English system, however, it is necessary to multiply or divide fractions.

Ask pupils to contrast the difficulty of measurement and computation in the two systems.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. instruments for measuring	The use of scientific instruments (including measuring devices) helps us to accumulate more accurate data and makes possible more highly developed and universal methods of research.
(1) meter-stick (2) dividers (3) calipers	
2. mass (and weight)	
a. definitions	Although the terms "mass" and "weight" are frequently used in a manner which seems to imply they are synonymous, there is a fundamental difference between the two.
(1) mass *	Mass is the quantitative measure of the inertia of an object; it is independent of the varying effects of gravity. Mass is the quantity of matter in an object.
(2) weight	Weight is an expression of force; it represents the pull of gravity on the mass of an object. (Quantitatively this force (weight) is equal to the mass of the object times its acceleration due to gravity). The mass of an object always remains constant.
b. metric units	The standard of mass is the kilogram. The gram is the common measurement. 1 kilogram (kg.)=Standard mass 1 gram (gm.)=0.001 kg. 1 milligram (mg.)=0.000001 kg.= 0.001 gm.

*optional

MATERIALS

books
rubber bands
cardboard
marbles
paper clips
string

KEY WORDS

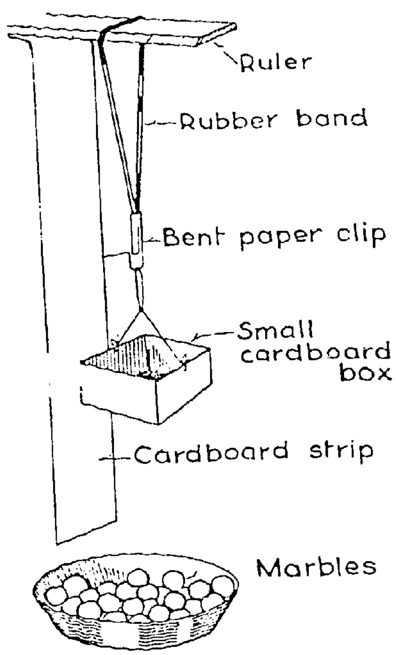
acceleration
constant
expression
force
gravity
independent
inertia
instruments
matter
measure
quantitative
synonymous
weight

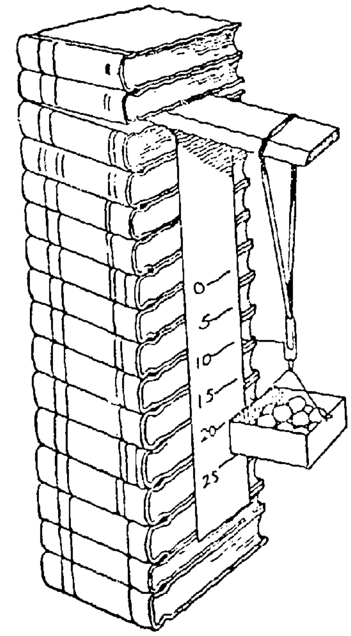
ACTIVITIES

#How do we measure the gravity of the earth?

Demonstrate the principle of a spring balance scale by using a rubber band for the spring and one marble as the unit of weight. Suspend the scale from the end of a ruler inserted near the top of a stack of books. Slip a strip of cardboard under the ruler so that the end hangs down along one side of the stack of books. Assemble the rubber band balance as shown and adjust the position of the rubber band over the ruler so that the pointer is near the strip of cardboard. Make a mark on the cardboard at this point and indicate it as zero.

Calibrate the scale by dropping marbles into the cardboard box and marking it off into convenient divisions. The pointer should return to zero after the scale has been calibrated and all marbles have been removed from the box.





#Weigh some object, such as a piece of rock, on the rubber band scales and note its weight in marbles. Discuss possible means of calibrating the scale in ounces.

REFERENCE MATERIAL

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

books
spring (slinky)
cardboard
marbles
paper clips
string
spring balance
various metric containers

KEY WORDS

ACTIVITIES

#Substitute a light spring for the rubber band, such as the spring from an old window-shade roller. Recalibrate the scale, using units appropriate to the tension and elasticity of the spring.

#Weigh common objects found in the classroom in English and metric units. Spring balances with both scales are inexpensive to buy or may be borrowed. Pupils should become familiar with metric weight units.

#Weigh out definite amounts of several substances, such as a pound of sand and a pound of water. Notice that a pint of water weighs one pound. Develop the understanding that the weight of a body is the force of attraction between that body and the earth. Spring balances and beam balances really measure the pull of gravity. To lift a heavy object it is necessary to exert an upward force which will overcome the pull of gravity.

#Understanding the Metric Units of Weight

Ask the pupils to bring to class containers that illustrate the use of metric units of weight such as 8-ounce (226 gm.) food containers.

Have the pupils learn the following common metric units of weight:

Basic unit	= 1 gram	
1 milligram	= .001 gram	1,000 milligrams = 1 gm.
1 kilogram	= 1,000 grams	1,000 grams = 1 kg.

One kilogram is a little more than 2 pounds.
(1 kg. = 2.2 lb.)

One pound is a little less than 500 grams.
(1 lb. = 454 gm.)

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. instruments for measuring	
(1) scales	Spring scales and spring balances are used to determine the force with which the earth attracts a constant mass (weighing).
(2) balances	Platform and pan balances are used to compare masses. They are used to determine the mass of an object by comparing the unknown mass with known masses (massing).
3. time	
a. definition	Qualitatively, time may be described as our sense of things happening one after another.
b. units	The unit of time is the second. It is approximately equal to the interval between "ticks" on a clock which makes 86,400 ticks while the sun moves from its noon position on one day to its noon position the next day.
c. instruments for measuring (1) clocks, watches (2) pendulum (3) metronomes	
C. Derived quantities	
1. area	
a. definition	Area is a function of two dimensions (L^2); it is measured in square centimeters or square meters.

MATERIALS

stopwatch
globe
chalk
U.S. map
cardboard
drawing materials

KEY WORDS

area
balance
derived
interval
qualitative
scale
unknown

ACTIVITIES

#The study of time can be approached in an interesting way by showing how the ability to estimate time varies. Divide the class into two groups and ask one group to sit quietly with their eyes closed and to raise their hands at the end of two minutes. Members of the other group can observe the variation in the estimates. Repeat the procedure with the groups interchanged.

Discuss ways of estimating time, using pulse rate or respiration rate and repeat the procedure after pupils have recognized the need for using some rhythmic procedure such as counting seconds by saying "one thousand and one," "one thousand and two," etc.

#Calculate the number of degrees in a band representing an hour's difference in time ($360^\circ \div 24 = 15^\circ$). Lay out the 24 standard time meridians on a slate globe. Point out that these meridians extend through the centers of the time zones.

#On a map of the United States showing the standard time zones locate the meridians that determine the standard time used in each zone. Discuss the reasons why time zones are necessary and why the borders are very irregular. Ask pupils to give examples of radio and television programs that illustrate time differences across the country.

Make a diagram explaining how the time zones shift when daylight saving time is used.

#Developing a Formula for the Area of a Parallelogram

Have two congruent parallelograms cut from cardboard and backed with #00 sandpaper for use on a flannel board. Recall that the area of a parallelogram depends upon its base and its height. As shown in a, draw a line perpendicular to its base at one end and cut off the right triangle formed. Place the triangle along the other side of the original parallelogram to form a rectangle as shown in b. Identify the dimensions of the rectangle and the formula for its

REFERENCE OUTLINE

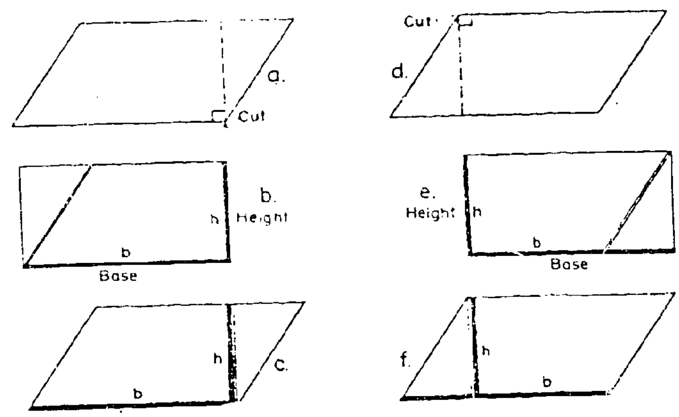
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

cards
scissors

ACTIVITIES

area. Develop the formula A = bh for this parallelogram. Color with crayon the lines which are used to find the dimensions. Then, as shown in c, place the triangle in its original position to re-form the original parallelogram. Note where the dimensions may be measured in a parallelogram.



Variation: Keep the upper base of the second parallelogram and cut off the right triangle shown in d. Continue in the same manner as shown in e and f to show that height may be measured in more than one place.

KEY WORDS

#Deriving a Formula for the Area of a Triangle

Collect several rectangular cards. Use scissors to cut into triangles as shown in a In each separate figure, leave one triangle one position and place the remaining triangl triangles over it, as shown in b, so that it completely covered, and so that the equal si coincide. Consider what fractional part of original rectangle must be contained in the triangle. (one-half). Also consider the dim sions (length and width) of the original rec tangle and the formula for its area. (A =lw Develop a formula, $A = 1/_2lw$, for the area c triangle. Show that the base and height of triangle are the length and width of a corre ponding rectangle. The more convenient form $A = 1/_2bh$ can then be used.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

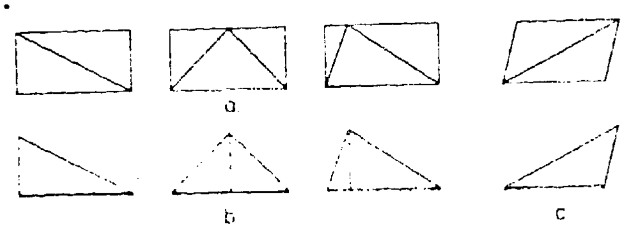
steel tape
graph board

KEY WORDS

ACTIVITIES

To obtain obtuse triangles, prepare the cards ahead of time by cutting them into parallelograms of various sizes and shapes. Then cut along the longer diagonal, as shown in c, and place the top triangle so that it completely covers and coincides with the bottom triangle. Relate the area of the obtuse triangle to the area of the parallelogram.

If the rectangles and parallelograms are backed with #00 sandpaper, this demonstration can be easily and effectively performed on a flannel board.



#Significant Circle Dimensions

To illustrate that the area of a circle depends on the circumference of the circle, pull out a steel tape and bend it into a circle whose circumference is 30 cm. Hold this circle against the graph board as shown. Estimate the area of the circle. Now pull out the tape and form a circle whose circumference is 60 cm. Estimate the area of this circle. Repeat with larger circles. Discuss the effect of the variation of the circumference of a circle on the area of the circle.

To illustrate that the area of a circle depends upon the radius of a circle, draw on a graph board with a compass three circles whose radii are 5 cm., 10 cm., and 15 cm., respectively. Estimate the area of each circle by counting the number of square cm. enclosed in each. (if the graph board represents square inches, find the square inches and convert to square centimeters). The number of square centimeters enclosed are 78.54 sq. cm., 314.16 sq. cm. and 706.86 sq. cm. respectively.

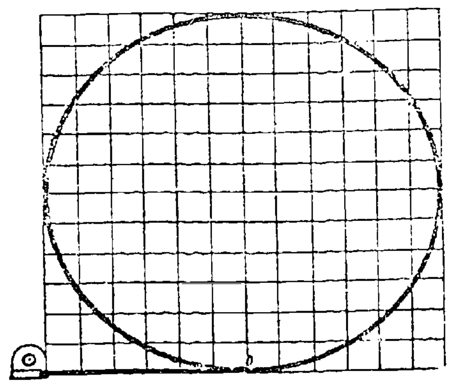
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

geometric shapes of a common usable nature
metric measuring devices

ACTIVITIES



Discuss the effect of this variation of the radius on the area of the circle. When the radius is doubled the area is multiplied by 4; that is 2^2; when the radius is tripled, the area is multiplied by 9; that is 3^2. Note that a variation of a radius or diameter results in variation in two dimensions, length and width.

Problems: How many times the amount carried by a 10 cm. diameter pipe can be carried by the same length of (1) 20 cm. diameter pipe? (2) 30 cm. diameter pipe?

KEY WORDS

capacity
irregular
pure number
ratio
regular
volume

#Appreciation of Volume Measurements in Daily Life

As a class demonstration, have some pupils measure the dimensions of an object in the classroom and then have the class compute its volume.

Discuss items in common use whose volumes are important. Identify the geometric shape or combination of shapes which are apparent in each of the items. Tell what dimensions are needed to compute the volume of each and what instruments or tools are needed to measure these dimensions.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

cotton
lead
cm. rule

ACTIVITIES

ITEM	SHAPE	SIGNIFICANT DIMENSIONS	INSTRUMENTS
Pile of Coal	Conical Solid	Height, diameter of its base	Meter Stick Steel Tape
Cement Conduit	Cylindrical Shell	Outer diameter, [illegible]er diameter, Length	Outside calipers Inside calipers Steel Tape
Cupboards	Rectangular Prism	Length, width height	Steel Tape
Refrigerator	Rectangular Prism	Length, width height	Steel Tape

#Comparing "Weights"

KEY WORDS

a. "Weigh" out approximately 454 grams (one lb.) of cotton and approximately 454 grams of lead. Then, using a centimeter rule, estimate the volume occupied by each substance.

How do your observations help you to know more about "density?"

b. Compare the "weights" of equal volumes of cotton, lead and water.

(1) How do your observations relate to an understanding of the term "specific gravity?"

(2) How are density and specific gravity alike; unlike?

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. volume (solids)	
a. definition	Volume is a function of three dimensions (L^3); it is measured in cubic units e.g., cubic centimeters or cubic meters, and describes the amount of space an object occupies.
b. metric units	
c. instruments for measuring (see length)	*The relationship between mass and volume of an object is known as its density. Density may be expressed in lbs./ft.^{3} (Weight density in the English system may be expressed in lbs./ft3). The specific gravity of a substance is a ratio represented by a pure number which tells the number of times a substance is as heavy as an equal volume of water.
d. regular solids	
e. irregular solids (optional)	The volume of irregular solids may be measured indirectly. (Any displacement demonstratior
3. capacity and liquid volume	
a. definition	Capacity is a measure of liquid or dry content.
b. metric units	In the metric system, the standard of volume is the liter; it is used for both liquid and dry measure.
c. instruments for measuring graduated cylinders	

*optional

MATERIALS	ACTIVITIES

ACTIVITIES

#Capacity of Common Liquid Containers

MATERIALS

various liquid containers
graduate
serving containers

a. Have ready several different common liquid containers for individual use whose capacity should be known - drinking glasses, fruit glasses and cups. Fill each with water to the customary level and pour the contents into a graduated measure to learn the capacity of each in milliliters. Make a list of the containers and their capacities.

b. Have ready several different serving containers whose capacity should be known - pitchers, bowls, teapot and coffemaker. Add known quantities of water to each container until various desired levels are reached. Make a chart listing the capacities of the various containers measured.

c. Set up problems:

1. A 12-ounce can of frozen lemonade concentrate mixed with three cans of water will fill a pitcher of what capacity? How many 8-ounce glasses can be filled with this mixture?

2. A woman is going to serve iced tea at a dinner for eight people. She plans to serve the tea in 8-ounce glasses with ice cubes that take up 2 oz. in each glass. If she allows two glasses for each person, how many potfuls of strong tea should she make beforehand, assuming that the teapot holds three standard measuring cups? (1 cup = 8 oz.)

3. Plan to serve hot cocoa to a group of 10 friends after skating. If the cups hold 7 oz., about how many quarts of milk should be on hand? Allow for extra cups if desired.

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

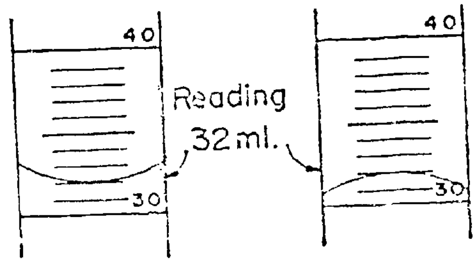
MATERIALS

mercury
water
graduates

ACTIVITIES

#Measuring Small Quantities of a Liquid

Reading should be made at the center of the surface of the liquid because of the meniscus (the curved upper surface) caused by capillary action. The graduate should be held level and the reading should be made at eye level. The diagram at the left shows a liquid such as water in a graduate. The one at the right shows a liquid such as mercury.



#Understanding Metric Units of Capacity

a. Help the pupils make a list of common items which are measured in liters, milliliters or kiloliters.

KEY WORDS

b. Have the pupils learn the following metric units of volume which are useful in measuring small quantitites and which are used for both liquid and dry measure.

1,000 milliliters	=	1 liter
1,000 liters	=	1 kiloliter
1 liter	=	1.06 quarts (liquid) and .91 quarts (dry) or approximately one quart.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. temperature	
a. definition	Temperature may be regarded as the degree of hotness (or coldness) that a body possesses. It may be measured in degrees of Fahrenheit or degrees of Celsius. The temperature of an object depends on the motion (average kinetic energy) of its molecules.
b. units (1) °F;°C (Conversions)*	
c. instruments for measuring (1) thermometer (2) thermocouple	Note: Teacher option to employ graphs. The development of and the use for predictability, etc.
5. pressure*	
a. definition	Pressure is the force per unit area.
b. units (1) $gm/cm^2.kg/m^2$	
c. instruments for measuring (1) barometer (2) manometer	
6. rates - speed; frequency (optional)	Speed has dimensions of both time and length (distance).
a. definitions	Speed represents the magnitude of velocity (velocity possesses both magnitude and direction). Frequency may be regarded as the number of vibrations per second or the number of waves that pass a given point per second or the number of events occurring per given interval of time.

*optional

MATERIALS

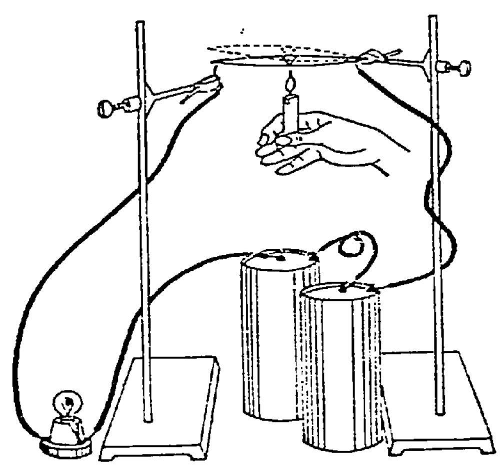
bi-metal strip
wire
batteries
lamp
source of thermal energy
ring stands
various wires of different metals
galvanometer

KEY WORDS

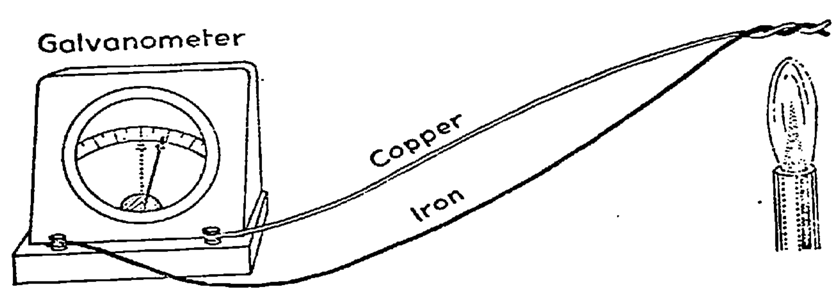
Celsius
dimension
energy
event
Fahrenheit
frequency
kinetic
molecule
pressure
rate
speed
temperature
thermocouple
thermometer
velocity
vibration
waves

ACTIVITIES

#The principle of the type of thermostat used to regulate room temperature can be demonstrated very easily, by means of the apparatus shown in the diagram. A bimetallic bar (unequal expansion bar) is clamped in horizontal position to a support. A wire attached to the bimetallic bar is placed in a circuit with dry cells and a small lamp. The end of a wore leading from the lamp is attached to another support so that it touches the end of the bimetallic bar. Heating the bar with a candle causes it to bend upward and break the circuit. As soon as the bar cools, it bends downward again and completes the circuit. The lamp, of course, represents the motors that drive the furnace and circulators.



#Scrape the paint from a piece of coat wire. Twist together one end of this wire and the end of a copper wire. Connect the opposite ends



FERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

of these wires to a sensitive galvanometer. Heat the junction of the iron and the copper wires with a candle flame. Note the deflection of the galvanometer needle. Try a bunsen burner flame.

This device is a simple thermocouple. The principle illustrated is made use of in electric thermometers for measuring temperature inside engines and in other inaccessible places.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. units	
c. instruments for measuring (1) see time (2) see length	
7. angles (direction; location)	A degree is a unit which is equivalent to 1/360th part of the circumference of a circle.
a. definition	
b. units (degrees, minutes, seconds)	
c. instruments for measuring- protractor (1) magnetic compass (2) sextant * (3) clinometer	

*optional

MATERIALS

various thermometers
cork
magnetized needle
water
cardboard

KEY WORDS

angles
circle
circumference
degree
equivalent
protractor
sextant

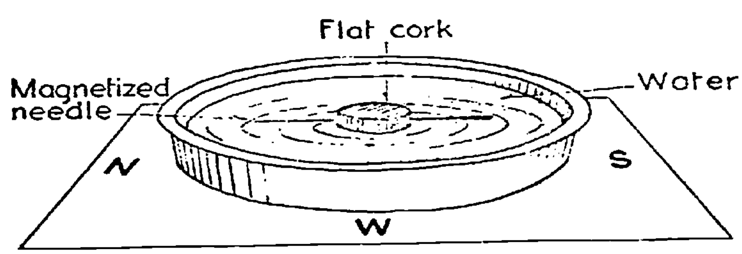
ACTIVITIES

#Understanding Scales Used in Temperature-Measuring Devices

Invite the pupils to bring to class some instruments or sketches of scales of such instruments used to measure temperature. The teacher should point out the many kinds of thermometers, such as centigrade, Fahrenheit, clinical, candy, deep-fat, meat, oven, and car radiator thermometers. Thermostat scales will vary on these instruments.

During the class period, have individual pupils explain the different scales used. They should note the units used, the method of showing subdividions and the upper and lower limits of the scale. Encourage the use of the chalkboard for showing subdivisions. Have the pupils explain how to decide on the value of each subdivision, why some subdivisions are not numbered and why the upper and lower limits differ according to the use of the thermometer.

#A compass can be made by pushing a magnetized needle through a cork and floating it horizontally on water in a vessel made of glass, aluminum or pottery.



#Show pupils how to use a watch for a compass. Point the hour hand in the direction of the sun. South will then be midway between this and the figure 12 on the watch.

Set up a simple problem in dead reckoning and solve it with only a watch for an instrument.

BLOCK I

FORCES AT WORK

FORCES AT WORK

Forces
- direction and amount
- balanced and unbalanced forces
- gravitation

Forces and Work
- work
- energy
- power
- machines

Forces and Fluids
- density
- pressure
- Pascal's Law
- Archimedes' Principle
- Bernoulli's Principle

Force and Motion
- speed
- velocity
- acceleration
- Newton's Laws of Motion
- conservation of momentum

Important concepts are indicated by the symbol (#). Materials considered of an enrichment nature are indicated by an asterick, (*).

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
I. Forces	A force is a push or a pull.
	A force is any action that produces or tends to produce a change in the motion of an object.
A. Direction and Amount	The effect that a force has on an object is determined by both the magnitude of the force and the direction of the force.
1. magnitude	The magnitude is the size or amount of a force.
	In the meter, kilogram, second (MKS) system of measurement, the magnitude of a force is expressed in units of newtons.
2. direction	The direction of a force is the direction that the force tends to move an object.
	Two forces equal in magnitude and acting in the same direction are equal to one force with twice the magnitude of a single force and acting in the same direction as the two forces.
	Two forces equal in magnitude and opposite in direction cancel each other.
B. Balanced and unbalanced forces	
1. balanced	A balanced force is a force that is opposed by one or more forces so that they cancel each other.
	A balanced force cannot produce a change in motion.

MATERIALS

ACTIVITIES

*At this point teachers should introduce or review appropriate material. It is suggested that most pupils be given the experience of using the MKS system in which the meter, kilogram, and second are the fundamental units of length, mass, and time, respectively, and the newton is the derived unit of force. Pupils should also have some opportunity to use the more familiar English (FPS) system in which the foot, pound, and second are the fundamental units of length, force, and time, respectively.

One newton is equal to 0.224 pounds or just a little less than 1/4 pound.

One pound is equal to 4.46 newtons or just a little less than 4 1/2 newtons.

#To become familiar with the magnitude of a newton force in relation to the familiar lifting, pushing, and pulling forces, have pupils calculate forces such as their own weight in newtons. This is done by multiplying weight in pounds by 4.46.

There will be only insignificant errors in indicating on laboratory scales 100 grams as being equivalent to 1 newton and 1 pound as being equivalent to 4.5 newtons.

KEY WORDS

force
magnitude
direction
newton
balanced force

#If equal and opposite forces act on a cord, it is difficult for students to understand that the tension in the cord is the same as either force and not their sum. Clamp a pulley at each end of the front edge of the demonstration table. Hang a 200-g. mass on the end of each of two pieces of cord, pass the cords over the pulleys and attach them at the center with wire hooks, easily made from paper clips. After suitable airing of opinions as to the tension in the cord, disconnect the hooks and insert a spring balance. Then let the class discuss the probable readings of two spring balances, end-to-end between the hooks, and then demonstrate this. Ask what the

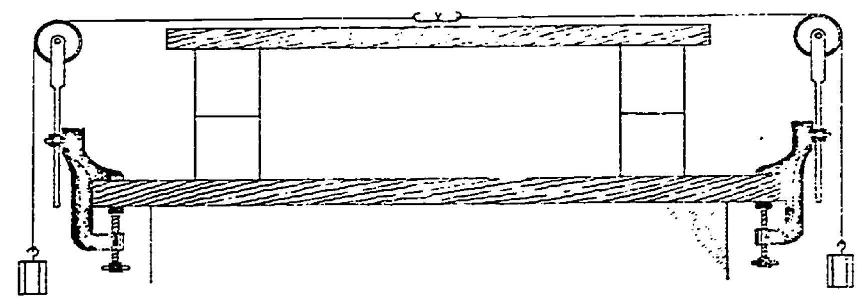
*The use of the MKS system is optional

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. unbalanced	An unbalanced force is a force that is not completely opposed by one or more forces, leaving a net force to act. An unbalanced force always produces a change in the motion of a body.

MATERIALS

ACTIVITIES

balance reading would be if one of the masses were replaced by a rigid connection. To try this, attach the spring balance to a clamp fastened at the middle of the front edge of the table.



At this point the concept of a force as a push or a pull should be established, but its association with motion should be minimized until consideration of the laws of motion. Call attention briefly to various familiar forces: weight, muscular contraction, molecular forces resulting in material strength and elasticity, and friction.

KEY WORDS

unbalanced force
equilibrium

Especially, identify weight as a force and justify the use of weight units in expressing the magnitude of forces. Hang a weight from a coiled spring and show that extensions of the spring caused by other forces can be expressed in weight units since they produce the same effect as weights.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Gravitation	Gravitation is a weak force of attraction between any two objects.
1. universal nature	All objects in the universe attract each other.
2. mass	Mass is the amount of matter in a body.
	The greater the mass of two bodies, the greater the gravitational attraction between them.
3. distance	The greater the separation between two bodies, the smaller the gravitational attraction between them.
4. weight	Weight is the amount of the gravitational attraction between a body and the earth.

MATERIALS

ACTIVITIES

*Gravity is a special case of gravitation, and is the force of attraction between the earth and an object. Gravity is the force with which pupils are most familiar. Not all textbooks make this distinction; the two terms are often used interchangeably.

It is difficult if not impossible, to demonstrate the gravitational attraction between small objects with the apparatus available in most school laboratories. In 1798, Henry Cavendish used a torsion balance to measure the gravitational attraction between lead balls having diameters of two inches and eight inches. Compared to the force of gravity on the lead, the force of gravitational attraction between the balls was in the order of magnitude of 10^{-8}. This means that the first force was 100,000,000 (10^8) times that of the second.

#Teachers should introduce the use of "powers of 10" when applicable. This is a review of material studied in the mathematics courses in grades 7 or 8.

#Disregarding relativistic effects, the amount of matter in a body (its mass) always remains the same, even when the body is weightless.

KEY WORDS

gravitation
gravity
mass
weight

Since weight is the gravitational force between the earth and a body, the body's weight will decrease with increasing distance from the earth.

Since weight is a force, it can be completely opposed by another force or set of forces to produce a weightless body.

#Comparison of Masses and of Weights

The relative masses of several objects can be determined by using a constant force to accelerate the objects. The device shown on the following page is designed to provide this constant force by allowing the rubber band to be stretched the same amount each time. Similar devices using a spring or rubber band are satisfactory.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

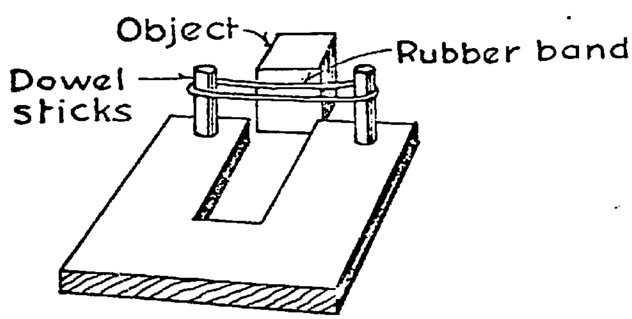
MATERIALS

ACTIVITIES

Rest the apparatus on a flat table. Place an object in the cut-out portion to stretch the rubber band. Release the object and note its maximum speed and distance of travel. A variety of objects can be used, but empty milk containers partially filled with sand and gravel are especially recommended. (When the same types of containers are used, the effects of friction are essentially the same each time.) Objects having greater masses will travel slower than objects having less mass. Instruct the pupils to arrange the objects in a sequence from the smallest mass to the largest mass. (The same type of comparison is theoretically possible on any planet or in space.)

Use scales or spring balances to weigh the objects. Line them up in order of increasing weights. Compare with the previous results. (On another planet the comparisons of the weights would be the same, but the weights indicated on the spring balances would differ.)

KEY WORDS



#Mass and Weight on the Different Planets

Use the chart below to help calculate your weight on the surface of each of the planets of the solar system. Multiply your present weight by the value in the second column to find your probable weight on the associated planet. Columns 3 and 4 of the chart refer to a typical person having a mass of 50 kilograms and a weight of 490 newtons (110 pounds) on Earth.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Planet	Multiply your weight by	Mass on Planet	Weight on Planet
Mercury	.3	50 Kg	147 nt (33 lb)
Venus	.9	50 Kg	441 nt (99 lb)
Earth	1.0	50 Kg	490 nt (110 lb)
Mars	.38	50 Kg	182 nt (42 lb)
Jupiter	2.65	50 Kg	1300 nt (292 lb)
Saturn	1.14	50 Kg	557 nt (125 lb)
Uranus	.96	50 Kg	470 nt (106 lb)
Neptune	1.1	50 Kg	538 nt (121 lb)
Pluto	(?)	50 Kg	(?)

These tables are for reference. Pupils should not be expected to memorize this information but should know how to use it.

#Using a Platform Balance to Determine Mass

A platform balance provides a precise and rapid means of comparing the relative masses of two objects. Since the force of gravity is greater on large masses than it is on smaller masses, two objects may be suspended from opposite ends of an equal arm balance, and any difference between the pull of gravity on each becomes readily apparent.

KEY WORDS

A crude balance made by using common materials such as a dowel stick, string, and two empty milk containers will give results that are surprisingly accurate. Have the pupils make their own balances and determine the mass of a number of small objects, by balancing the unknowns against known masses.

#Metric Mass and Weight Measures

Weigh objects in both the English and the metric systems to show the relationships between the mass and weight units in both systems. Express familiar masses in grams and kilograms and weights in newtons.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

A search of most kitchen storage cupboards will provide many cans and boxes whose masses are expressed in grams and whose weight is expressed in ounces or pounds. Display examples.

Point out that one of the major merits of the metric system lies in the relationship between its units of length and mass; one cubic centimeter of water has a mass of one gram.

Develop the idea that the size of units is not in itself an advantage and that one system is not capable of greater accuracy than the other. Also stress that both systems are based on arbitrary standards since the original intention to base the meter on the circumference of the earth has never been achieved.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
II. Forces and Work	
A. Work	
1. definition	Work is done whenever a force acts to move an object through a distance.
2. measurement	Work is measured by the product of the force and the displacement in the direction of action of the force.
3. units	* One joule is the work done when a force of one newton acts through a distance of one meter.

*Until the metric system is more commonly used in everyday affairs, teachers may teach either the preferred MKS system or the English system

MATERIALS

ACTIVITIES

#Regardless of the difficulty of a task, there is no work done in the scientific sense unless a force or a force component causes a displacement in the direction of action. Thus, no work would be done in merely holding a weight regardless of how heavy it is, whereas work would be done lifting the smallest atomic particle.

Joule is pronounced "jool". Other units of work are the erg (a force of one dyne acting through a distance of one centimeter) and the foot-pound (a force of one pound acting through a distance of one foot).

It is suggested that pupils also have some experience with problems dealing with the foot-pound. However, the dyne and erg should not be discussed at this level.

Whenever an object does work, it loses energy. Conversely, when work is done on an object, it gains energy.

*Work and energy are scalar quantities since they are independent of direction. The basic units for energy and work are the joule, the erg, and the foot-pound. In addition to these units, the electron volt is a useful energy unit for atomic phenomena and is equal to 1.602 x 10^{-19} joule.

KEY WORDS

*Work
Joule

#Comparing Amounts of Work

Place a box on a table. Assume that the table top is 1 meter above the floor and the box is 1/4 meter high. Make several piles of books or notebooks with each pile weighing a newton each. Place them on the floor at the base of the table. Remind the pupils that a joule of work is performed when a newton of force is exerted over a distance of a meter. Have the pupils perform various amounts of work such a 2, 2.5, and 5.75 joules by lifting one or more piles from the floor to the table or to the top of the box.

*optional

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

*Point out that most of the pupils' exertion is lifting their own weight as they bend and stand erect, rather than the relatively small amounts of work that are done in lifting the light books. Continue this activity until the pupils have developed a secure feeling for the relative values of the newton force and the joule of work.

* After pupils have computed the work involved in lifting an object weighing 2 newtons to a height of one meter, challenge them to compute the work done in carrying it a horizontal distance of 10 meters from the point one meter above the ground. The answer is <u>not</u> 20 joules since the 2-newton force is <u>not</u> in the direction of motion. Actually the work <u>is</u> negligible but there is insufficient information to solve the problem.

KEY WORDS

*optional

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. Energy	Energy is the ability to do work.
1. potential energy	Potential energy is the energy possessed by an object because of its position or condition. Potential energy is equal to the quantity of work that was performed to bring it to that position or condition. By restoring an object to its original position, potential energy is transformed into kinetic energy and work is done.
2. kinetic energy	Kinetic energy is the energy an object has because it is moving.

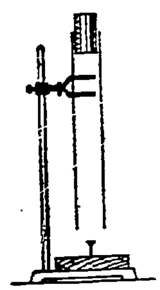
MATERIALS

ACTIVITIES

#Energy and the Piledriver

Potential energy and the work done by a falling object can be shown with a simple device. Drive a nail into a piece of soft wood by allowing a weight to fall on it. Guide the cylindrical steel or brass weight by a large diameter glass tube, or a cardboard mailing tube 1/2 or 1 meter long. Start the nail straight with a hammer. Measure the original height of the nail and its height after a blow from the falling weight. From the original height of the driver and its weight, compute its potential energy. Using these figures, calculate the average force with which the nail resists being driven (weight of object x height fallen = average force x distance nail moves).

In the discussion, point out that this resistance is the force necessary to decelerate the falling weight in a short distance in which it is stopped.



KEY WORDS

energy
potential energy
kinetic energy

#Work Done by a Falling Object

Drive a finishing nail halfway into each end of a short wooden dowel. Attach a paper pinwheel to one of the nails with masking tape and suspend the apparatus so that the dowel rotates freely. Tape one end of a string to the stick and attach a weight to the bottom of the string. Demonstrate that work is done on the apparatus by rotating the stick with the fingers until the string is fully wound. At this point, the work done has increased the potential energy of the weight. Releasing the weight rotates the pinwheel and the original work is recovered.

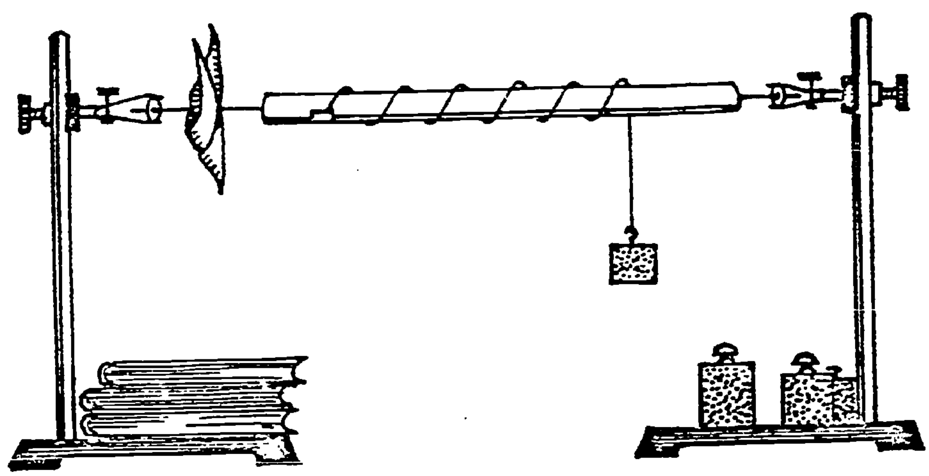
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

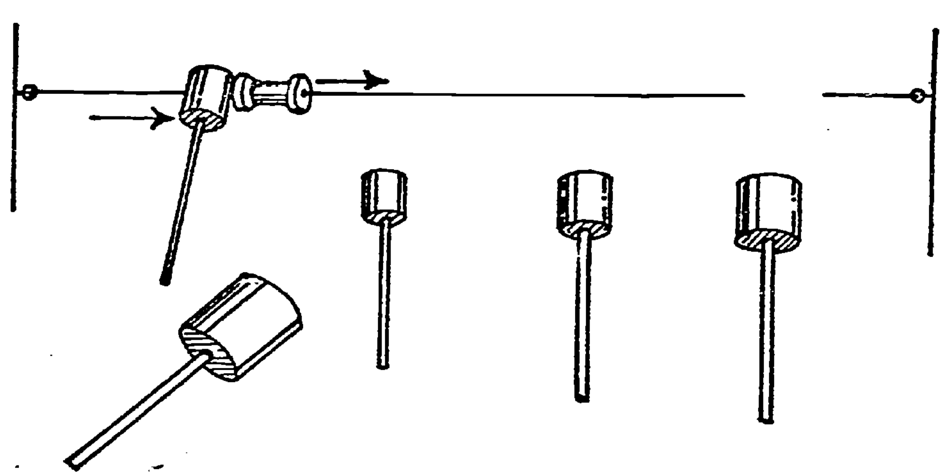
Show that more work can be stored and recovered as heavier weights are substituted in this demonstration. Point out that some of the work done was used to overcome friction and cannot be recovered easily.



#Effects of Mass and Velocity on Kinetic Energy

KEY WORDS

Place a string through an empty thread spool and stretch the string across the classroom. Strike the spool with a rubber stopper on a dowel stick to propel the rider along the string. Show that the greater the mass of the rubber stopper and/or the greater its velocity as it hits the spool, the greater will be the kinetic energy applied.



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. conservation of energy	Energy is neither created nor destroyed during the process of transformation from one form to another.
	Recall, however, that there is an equivalency between mass and energy according to Einstein's equation: $E = mc^2$

MATERIALS

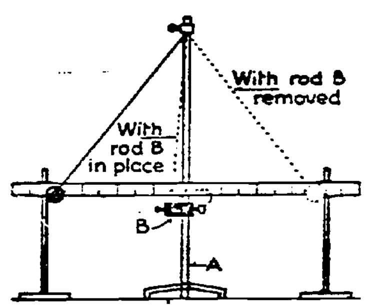
ACTIVITIES

#Conservation of Energy--Galileo's Experiment

Hang a pendulum from a clamp attached to a vertical support rod, and behind it mount a meter stick which is perfectly hortizontal. A tightly-stretched horizontal string can be used instead of the meter stick. Show that if a pendulum is started on one side at the level of the meter stick, it will swing as high on the other side, ignoring friction losses. Discuss the change from potential, to kinetic, and back to potential energy, making clear their equivalence.

Clamp a horizontal rod B to the pendulum support A, so that it will project and interrupt the motion of the pendulum to make it swing in an arc of smaller radius. If started at the level of the meter stick, the bob will swing to the same height.

Ask the pupils to predict the height of this rod when it will force the pendulum to loop around it. Demonstrate this.



KEY WORDS

conservation of energy

#Potential and Kinetic Energy

The "cum-bak" is an interesting child's toy which can be used to illustrate energy concepts. It consists of a cardboard cylinder containing a rubber band stretched between its ends and along its axis. From the center of the rubber band hangs a weight. When the cylinder is rolled, the weight winds up the rubber band and when the initial kinetic energy has been used, the rubber band unwinds, making the toy come back. When wound up,

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Power	Power is the time rate at which work is done. *Two units of power are the watt and the joule per second. *One watt equals one joule per second.

*optional

MATERIALS

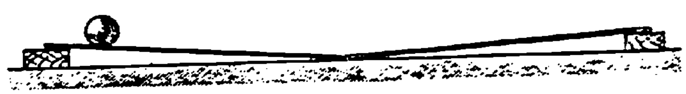
ACTIVITIES

it will roll up an incline. If slightly wound, and started down an incline, it will gradually slow down to a stop and may reverse itself.

Compare its behavior with that of an identical cylinder in which the weight and rubber band have been replaced by an equal weight of lead shot held in place against one end by paraffin.

A simple pendulum, or a weight bobbing up and down on the end of a coiled spring can be used as a device in which energy is repeatedly transformed. Ask where the energy is entirely potential, entirely kinetic, and a combination of the two types. Have pupils explain why the motion eventually ceases.

A double incline can be made of strips of glass and a cylindrical weight allowed to roll back and forth. Glass strips up to 30 centimeters in length and several centimeters wide are often available from glaziers as discards. The slope of the inclines should be very gentle, perhaps 1 in 50. The period of such an arrangement is long enough to permit identification of the various energy states as they occur.



KEY WORDS

power
watt

#Other units of power are the kilowatt, the foot-pound per second, and the horsepower. One kilowatt equals 1000 joules per second. One horsepower equals 746 watts (or 550 foot-pounds per second).

Although the horsepower is well established as a power unit in the English system of units, introduction of the watt as a mechanical unit of power is gaining in popularity because it provides an immediate conversion between mechanical power and electrical power.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#Power Developed by Humans

Pupils may measure the power they can develop in running upstairs. The work done is the product of the student's weight, the number of steps and the height of the risers. The teacher should make sure that pupils doing this are in good health before allowing the trial.

Point out that such a large power (in many cases more than one horsepower) can only be developed by a human being for brief and infrequent periods. Suggest that the same test attempted on the stairs of the Empire State Building, or of some tall local building or monument, would prove this conclusively.

Have pupils calculate their power in watts by multiplying their weight in newtons by the height of the stairs in meters, and then dividing the product by the time in seconds. Each 746 watts is equivalent to 1 horsepower.

#Measuring the Power Developed by an Electric Motor

KEY WORDS

Using a simple prony brake to measure the power that is developed by an electric motor is a good culminating activity for reviewing the concepts of force, work, and power in a practical industrial application. This activity is probably best performed as a demonstration with the pupils performing the computations. It is desirable to have a revolution counter which may be available in the physics laboratory.

Frictional force. Apply a frictional force to an electric motor by suspending two scales (calibrated in newtons) from a horizontal support and connecting a rope between the scales and the motor pulley as shown in diagram below. Adjust the tension of the rope so that there is a noticeable difference in scale readings when the motor is operating. This difference in readings is caused by friction between the rope and the pulley.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

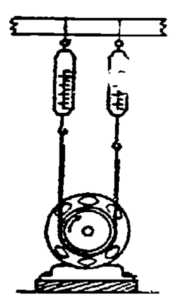
ACTIVITIES

Work. Permit the motor to perform a quantity of work by applying the frictional force while the pulley rim travels a measurable distance. This distance is determined by multiplying the circumference of the pulley by the number of revolutions that it makes during the trial period. One way for pupils to measure the circumference is by cutting a length of string to fit around the pulley and then stretching the string out against a meter stick. Because the motor will probably be turning too fast to count revolutions, it is suggested that a small revolution counter by used. The work (in joules) = force (in newtons) x distance (in meters).

Power. Use a stop watch (or a watch with a sweep second hand) to time the period during which the motor is performing the measured quantity of work.

The power (in watts) = work (in joules) divided by the time (in seconds). Because the motor is not 100% efficient, the mechanical power, measured by the prony brake method, will be somewhat less than the electrical power which is consumed in operating the motor.

KEY WORDS



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Machines in General	Machines are devices which transform work into a more useful form by changing the speed, direction, distance, and/or the amount of a force.
1. effort	Effort is the force that is applied to a machine.
2. resistance	Resistance is the force which a machine can overcome with a given effort.
3. work input	The work input of any machine is the product of the effort and the distance through which this force acts.
4. work output	The work output of any machine is the product of the resistance and the distance through which this force acts.
5. the law of machines	If there were no friction, the amount of work that is put into a machine (work input) would be equal to the amount of work that the machine accomplishes (work output).
6. uses of machines	Some machines increase the amount of a force by decreasing the speed and distance through which the force acts. Some machines increase the speed and distance through which a force acts by decreasing the amount of a force. Some machines change the direction of a force.
7. the mechanical advantage of a machine	The mechanical advantage of any machine is the number of times that it will multiply the effort.

MATERIALS

ACTIVITIES

#In discussing this area teachers should use the law of machines to stimulate thinking. This equation is: effort x effort distance = resistance x resistance distance. It can be shown that if the effort is smaller than the resistance, then the effort distance is larger than the resistance distance.

Mechanical advantages are ratios and therefore are never accompanied by a scientific unit of measurement. Thus, a mechanical advantage of "5" would indicate that the effort is multiplied five times by the machine and a mechanical advantage of 1/5 would indicate that the effort is being reduced by a factor of 5. A fractional mechanical advantage is useful in situations where it is desired to sacrifice force to gain increased distance or increased speed. A mechanical advantage of 1 is not useful in multiplying force, speed, or distance, but can be helpful in changing direction. For example, it is easier for people to push downward than upward.

KEY WORDS

machine
effort
resistance
work input
work output
mechanical advantage

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
E. Simple Machines *	All simple machines are variations of the lever and the inclined plane. Simple machines include the lever, wheel and axle, pulley, inclined plane, wedge, and screw. Complex machines are made of two or more simple machines.
1. lever	The lever is a rigid bar which is rotated about a pivot (pivotal point) called a <u>fulcrum</u>. The <u>effort arm</u> is the perpendicular distance from the fulcrum to point where the effort is applied at right angles to the lever. The <u>resistance arm</u> is the perpendicular distance from the fulcrum to the point where the resistance is applied at right angles to the lever.
a. mechanical advantage	The mechanical advantage of a lever is the ratio of the length of the effort arm to the length of the resistance arm.
b. work output	The work output is the product of the resistance and the resistance arm.
c. work input	The work input is the product of the effort and the effort arm.

*Review only ...pupils have been exposed to a study of simple machines in their elementary science program.

MATERIALS

ACTIVITIES

Machines of the lever type utilize the principle of the turning effect produced by a force about a pivotal point. The torque, or turning effect, is the product of the perpendicular force and the pivotal arm length. Thus, many combinations of forces and pivotal arm lengths can be multiplied together to obtain a given product. The machine is the mechanism which changes the relative values of force and distance to those desired.

Machines of the inclined plane type resolve a force into two or more components. The effort is applied to overcome one of these components and thus move the resistance in the general direction that is desired by along a path that is usually longer than that which would be necessary without the machine.

Teachers may wish to refer to Block B, The Body in Action, pp. 6-13 for resource material on forces, levers, and work. If this topic has been previously studied in Block B, it should be reviewed briefly. If the topic has not been previously taught, include examples of the parts of the human body which serve as levers.

KEY WORDS

simple machine
lever
wheel and axle
pulley
inclined plane
wedge
screw
fulcrum
effort arm
resistance arm

Pupils should be given the opportunity to work with levers to discover the various relationships. Most pupils should discover that, when a lever is in equilibrium, the torque which tends to produce motion in one direction is essentially equal to the torque which tends to produce motion in the opposite direction. The computed torques are usually not equal because the weight of the lever has been disregarded.

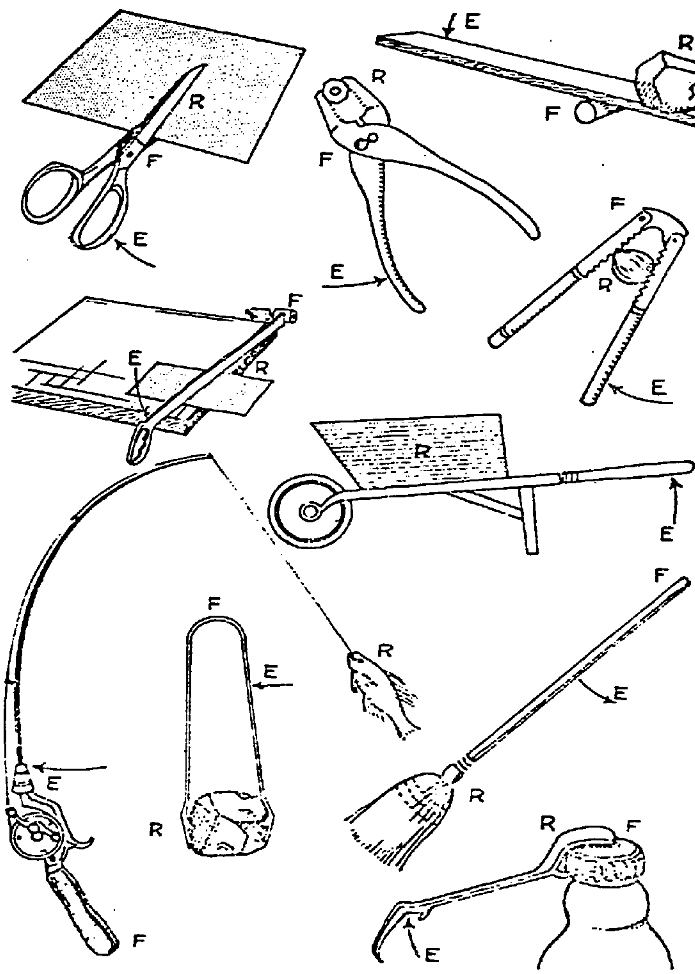
#Levers may be found operating in many devices which are in daily use. Have pupils determine the location of the fulcrum and the points of application of the resistance and effort. Some of these devices are shown in the following diagrams.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES



KEY WORDS

#First Class Lever

Tie a strong rope around a heavy object such as a box filled with rocks or sand. Challenge the pupils to lift the object from the floor by pulling upwards on the free end of the rope using only one hand that is fully extended. CAUTION: Place padding at the fulcrum to avoid marring the desk. Use a long rigid stick (such as a window pole) set up as a first class lever tc demonstrate the advantages of this simple machine. Permit the pupils to calculate the mechanical advantage by dividing the length of the effort arm by the length of the resistance arm and then check their results

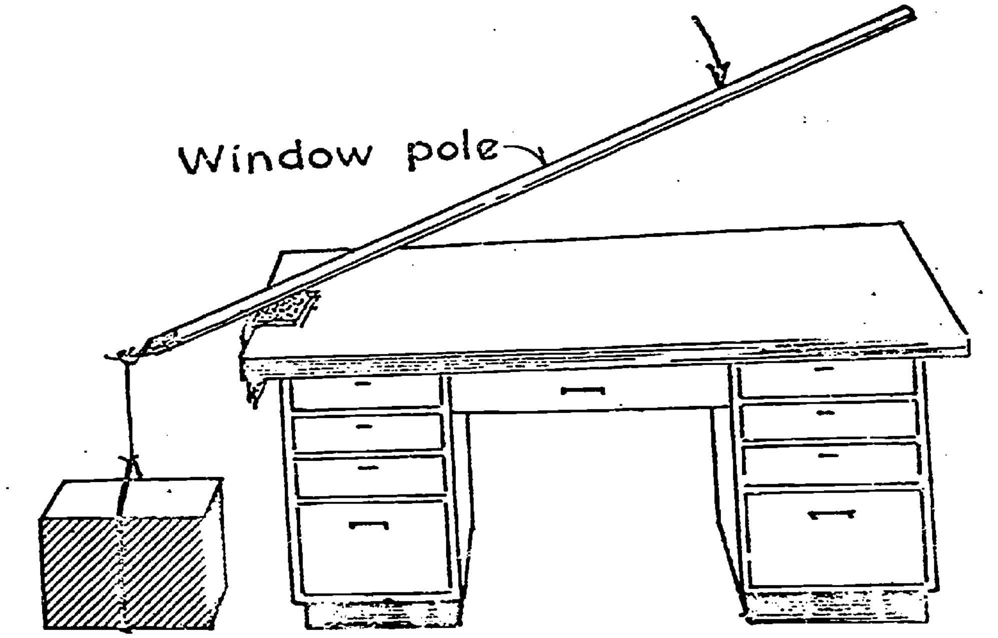
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

by comparing the distance that the resistance is raised when the effort moves 10 centimeters downward.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. inclined plane	An inclined plane is a flat surface that is slanted so that one end is higher than the other. The distance along the slant between the ends is called the length of the plane. The difference in elevation between the ends is called the height of the plane.
a. mechanical advantage	The mechanical advantage of an inclined plane is the ratio of the length of the plane to its height.
b. work output	The work output is the product of the resistance and the height of the plane.
c. work input	The work input is the product of the effort and the length of the inclined plane.

MATERIALS

ACTIVITIES

#Mechanical Advantage of the Inclined Plane

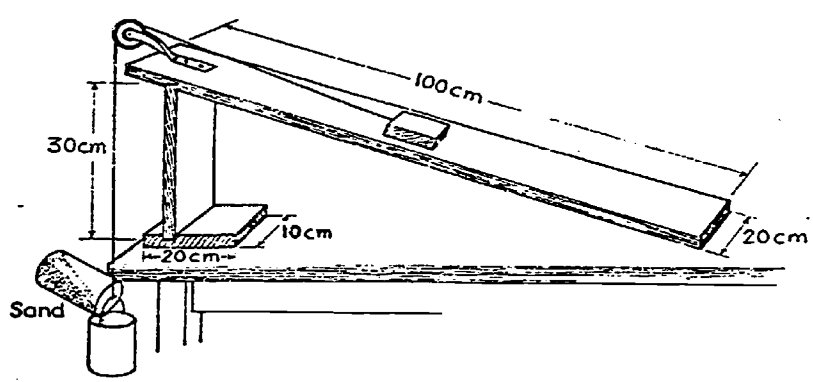
A commercially-made inclined plane with variable height is often available in the laboratory.

A simple, inexpensive, and rugged arrangement for demonstrating an inclined plane is shown here. The plane is a 2 x 20 x 100 cm. smooth board with a pulley at one end. A notch is cut across the plane on the underside at the pulley end. The support which fits into this notch is made of a piece of wood 2 x 10 x 30 cm., nailed at right angles to a piece 2 x 10 x 20 cm. as shown.

This support can be used in three positions to give three different heights to the incline. Either the long or the short member of the support may elevate the end of the plane, or the support can be laid on its side so that the 10-cm. dimension is vertical.

KEY WORDS

Place a wooden block on the incline to act as the resistance and pour sufficient sand into a small tin can to provide the effort. Adjust the amount of sand so that the block moves with a slow uniform velocity up the incline when started. The magnitude of the resistance and effort may be then determined with precision by weighing them on an accurate balance that is centrally located in the laboratory. Determine the mechanical advantage of the inclined plane in each position.



REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

*Weight always acts in a downward direction towards the center of the earth. When an object is resting on an inclined plane, the weight is resolved into two smaller components. One of these components is acting in a direction that is parallel to the inclined surface. The other component is at right angles to the incline and is fully supported by the surface of the plane. Thus, the effort to move the object along the plane can be relatively small because it only has to overcome the weight component that is parallel to the incline.

When an object is lifted, work is done. The object has a greater potential energy due to its position at a greater height. This increase in potential energy is numerically equal to the work output.

The work input would be equal to the work output under ideal conditions. Under actual conditions, however, an additional amount of work is always required to overcome the frictional forces between the object and the surface of the inclined plane.

*Variations of a Lever--The Wheel and Axle

KEY WORDS

Models of a wheel and axle designed for laboratory use are sold by science supply companies. Laboratory manuals describe numerous experiments in which they may be used.

The wheel and axle comprise a lever capable of continuous rotation. Its ideal mechanical advantage can be obtained from its lever arms (the radii) or from the distances moved by effort and resistance (the circumferences). Its value lies not only in its numerous traditional applications but also in the usefulness of its variants--the crank, and gear systems of all sorts.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. variations of the lever	The pulley and the wheel and axle may be considered variations of the lever.
4. variations of the inclined plane	A screw is an inclined plane that is twisted into a spiral shape. A wedge consists of two inclined planes back to back.
F. Compound Machines	Compound machines are composed of two or more simple machines which act together to overcome a resistance.

MATERIALS

ACTIVITIES

*Variations of the Inclined Plane--The Screw

The old-fashioned, screw-adjustment piano stool makes a good demonstration. Pass a turn of cord around the top of the stool, seat a student on it and pull the cord. Use a spring balance to measure the force necessary to keep it turning once started. The useful weight lifted is the weight of the pupil. These figures determine the actual mechanical advantages.

Calculate the ideal mechanical advantage from the pitch of the screw and the circumference of the stool. Compute the efficiency from the mechanical advantages.

Call attention to the importance of friction in increasing the usefulness of most screws. Also point out that a screw is always used in combination with some sort of lever and is never used by itself as a simple machine.

#Actual Machines

KEY WORDS

compound machines

Pupils should have an opportunity to handle and analyze real machines which are not merely laboratory models. If an overhead support has been built in the classroom, the block and tackle or chain hoist can be used to lift large weights. The jackscrew and the automobile jack in their numerous versions also lend themselves well to the analysis.

The load to be lifted may be a student, or it may be a bucket of wet sand or plain water. Compute the ideal machanical advantage from the dimensions of the machine or the distances moved by effort and resistance. Calculate the actual mechanical advantage from the forces actually used. Then calculate the efficiency from these mechanical advantages.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

II. Forces and Fluids

A. Density

Density is a measure of the amount of matter in a given space.

Density is the relationship between the mass of an object and its volume.

The density of some liquids can be increased by dissolving substances in them.

Note: There has been some confusion between the comparison of ml and cm^3 in volume measurements. The International Conference on Weights and Measures in 1964 re-defined the liter to avoid confusion:

1 milliliter (exactly)=
1 cubic centimeter (exactl[y])

$$1 \text{ ml} = 1 \text{ cm}^3$$

Similarly, a ml of pure water at its maximum density now has a mass of 0.999 972 008 grams, not exactly 1 gm. The difference is so slight that except for very precise scientific work, one ml of H_2O weights one gram.

Either ml or cm^3 may be used by pupils at this level in relating volume relationships.

MATERIALS

ACTIVITIES

#Density is sometimes confused with weight. Iron is more dense than wood, but it would be incorrect to say that iron is heavier than wood. This distinction becomes apparent when we compare the weight of a wooden door with the weight of an iron needle. Although an iron ship is heavy, the matter is dispersed so that the average density of the ship is actually less than that of the water on which it floats.

If the density of a liquid is less than the density of a substance to be dissolved in it, the density of the solution will usually increase when the solute is added.

Densities of Various Liquids and Solids

Solid	Density (g/cm^3)	Solid	Density (g/cm^3)
Bone	1.7-2.1	Porcelain	2.4
Brick	1.4-2.2	Rubber	1.2
Camphor	0.99	Sandstone	2.1-2.4
Clay	1.8-2.6	Slate	2.6-3.3
Cork	0.2-0.3	Wax, sealing	1.8
Granite	2.6-2.8	Wood:	
Ice	0.92	Apple	0.6-0.8
Limestone	2.7-2.8	Balsa	0.1
Marble	2.6-2.8	Bamboo	0.3-0.4
Paraffin	0.9	Birch	0.5-0.8
		Hickory	0.6-0.9
		Maple	0.6-0.8
		Oak	0.6-0.9
		Pine	0.4-0.9
		Poplar	0.3-0.5

KEY WORDS

fluid
density

Liquid	Density at Room Temperature (g/cm^3)
Alcohol	0.8
Carbon tetrachloride	1.6
Glycerine	1.3
Kerosene	0.8
Mercury	13.6
Milk	1.03
Sea Water	1.03
Turpentine	0.9
Water	1.0

Metal	Density (g/cm^3)
Aluminum	2.7
Brass	8.2-8.7
Copper	8.9
Gold	19.3
Iron	7.8
Lead	11.3
Silver	10.5
Zinc	7.1

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. Pressure *	Pressure is the force per unit area. Pressure is calculated by dividing the total force by the area over which the force is applied. Pressure is exerted by solids, liquids, and gases.

*optional

MATERIALS

ACTIVITIES

*Units of measurement become especially important in differentiating among various physical terms. Pressure is indicated by notations such as 5 newtons per square meter (5 nt/m^2) or 2 centi-newtons per square centimeter (2 cnt/cm^2). Have pupils realize the importance of habitually stating the magnitude accompanied by the appropriate unit of measurement. Thus, it would be correct to state that a force is 5 newtons, but stating that a pressure is 5 newtons would be meaningless.

*Concept of Pressure

Have a student lift a weight, such as a 1-kg. standard mass, by a fine wire looped to form a handle. Then relieve his discomfort by using a roll of stiff cardboard for the handle--causing the same weight to act on a larger area and reducing the pressure.

Cite such examples of high pressure as:

- The pressure under the tip of a phonograph needle may be over one ton per square inch, even though the force exerted by the tone arm is only a fraction of an ounce.
- A girl teetering on one high heel exerts more pressure on the ground than the Empire State Building does.

KEY WORDS

pressure

Have pupils compute the pressure they exert on ice when ice skating. If snow shoes (or their approximate dimensions) are available, repeat the computation.

*Force Developed by Air Pressure

Pupils may have seen this demonstration before. Do not repeat if this is the case.

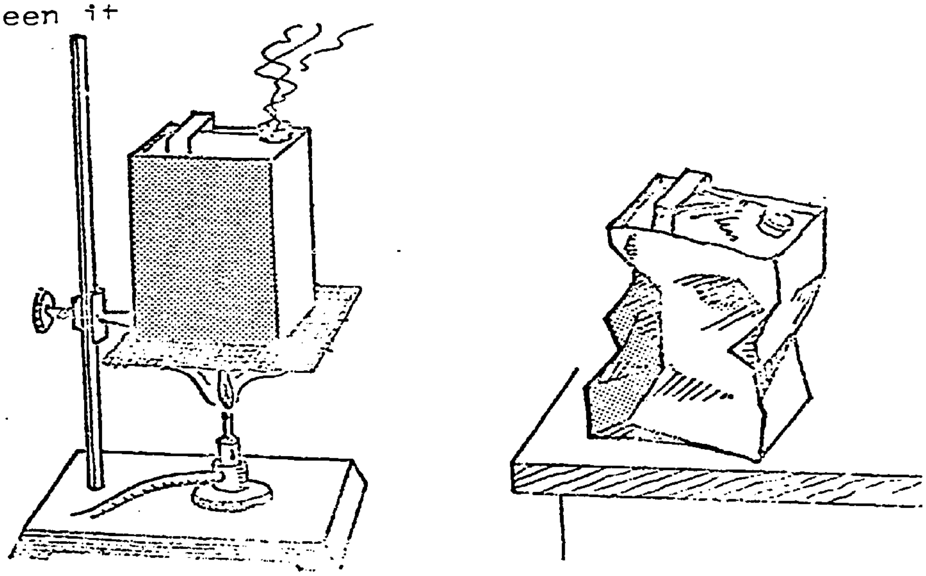
Normal air pressure is approximately 10 newtons per square centimeter. After calculating the surface area of a large can and the force of the air on its surface, remove the air from the inside by boiling a small amount of water and

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
1. variation of liquid pressure with depth.	The weight of a liquid causes it to exert a pressure. Liquid pressure increases in direct proportion to the distance below the surface of the liquid.

MATERIALS

ACTIVITIES

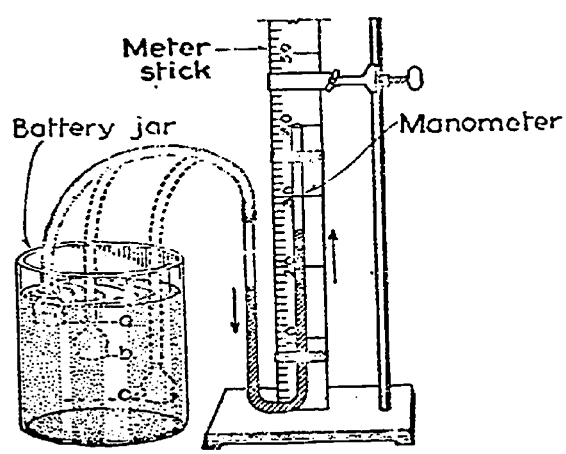
allowing the steam to fill the interior. Remove the heat and seal the can by screwing on its cap. When the steam cools, it will be observed that the can is twisted and collapsed by an invisible force that is comparable to the weight of an automobile. This is an old classroom demonstration that never fails to impress those who have not seen it.



KEY WORDS

#Variation of Water Pressure with Depth

The principle that water pressure depends upon its depth can be demonstrated with the apparatus shown in the diagram below.



REFERENCE OUTLINE

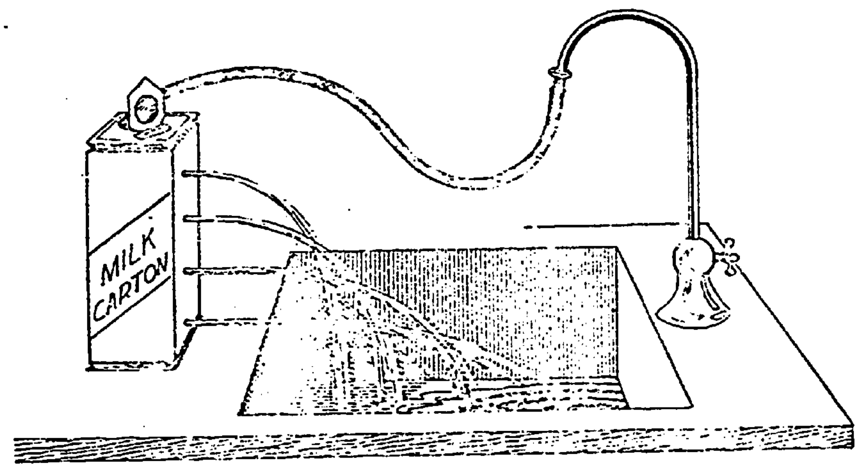
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#The difference in water pressure on different floors in some buildings is frequently very noticeable. The milk carton demonstration shown in the diagram should provide a basis for understanding the reason. Adjust the supply entering the carton so that water continues to flow from all four holes in the side of the carton.

Some pupils may not know that very tall buildings have water supply tanks above the top floor. A picture showing the rooftops of any older city will reveal many of these tanks. In more modern buildings these tanks are enclosed by the roof or placed in a tower.



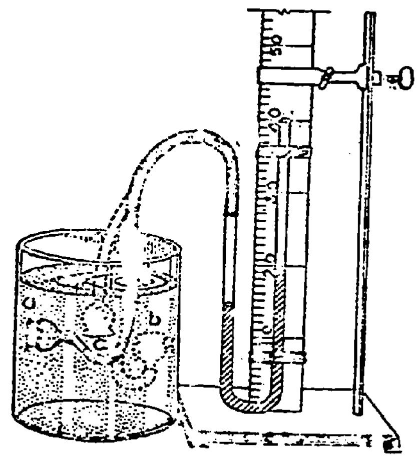
KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
*2. variation of liquid pressure with density	Liquid pressure varies directly with density.
*3. direction of pressure	At any point pressure is the same in all directions.

MATERIALS

ACTIVITIES

#The principle that water pressure at any depth is the same in all directions can be demonstrated with the apparatus shown in the diagram below.



KEY WORDS

* Measuring the Upward Pressure of Water

The following is a technique which might be used as an individual laboratory exercise for measuring the upward pressure of water at various depths.

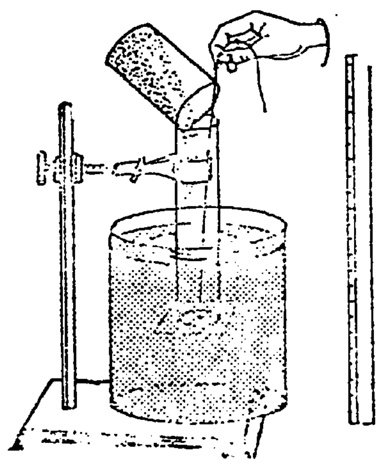
Obtain a wide glass tube that is between 2 and 5 centimeters in diameter and is at least 15 centimeters long. If the end of the tube is not perfectly flat when purchased, it may be prepared by grinding it with emery or carborundum powder. Then attach a thread to the center of a thin square of glass (which should be just a little larger than the hole in the glass cylinder) using a water-proof quick-drying cement. Weigh the glass square and string. Set up the apparatus as shown in the diagram, holding the glass square to the bottom of the cylinder with the thread until the upward pressure of the water is sufficient to support the weight of the square. Weigh a small container of sand. Release the thread and slowly pour sand into the cylinder until its weight

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. effect of the shape of the container	Pressure is not affected by the volume of the liquid or by the shape of the container.

MATERIALS

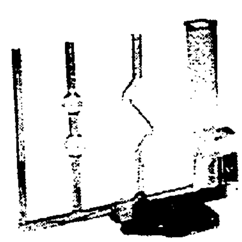
ACTIVITIES

overcomes the upward force of the water and glass square and the added sand will equal the upward force of the water at the measured depth. Dividing this force by the cross sectional area of the cylinder may be used to determine the water pressure. If sufficient time is available, it is suggested that this be repeated for various depths of water. Graph the data.



KEY WORDS

#Intuitive thinking might lead us to believe that a large container of water would exert more pressure than a small container of water filled to the same depth. However, if a hollow tube joins the two containers at the same depth, it is observed that the water levels in the containers will be exactly equal. This would be true only if the pressures were equal.



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Hydraulics and *Pascal's Law	
1. transmission of pressure	Pressure that is applied to a fluid is transmitted equally in all directions without loss.
2. application of pressure	Comparatively large pressures may be exerted on a confined fluid by applying a force to a piston of small cross sectional area.

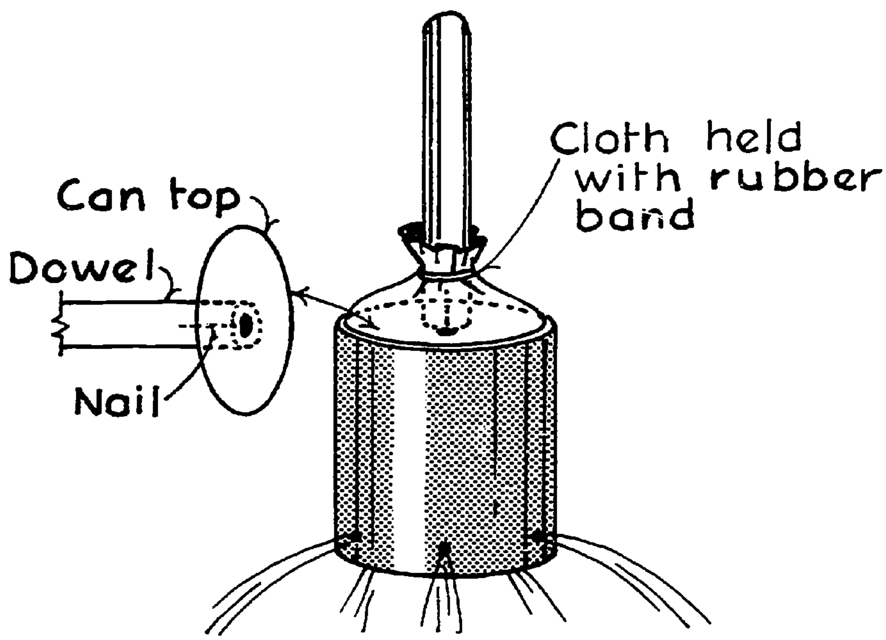
*Optional

MATERIALS

ACTIVITIES

#Hydraulic Pressure Transmission

To illustrate that pressure applied to a fluid is transmitted equally in all direction, drill several tiny holes around the walls and in the bottom of a small empty can such as used for frozer orange juice. Make a close fitting piston by nailing the top that was removed from the can to a dowel stick and covering it with several thicknesses of cloth secured with a rubber band. When the can is filled with water and pressure is applied to the piston, streams of water will shoot out in all directions.



KEY WORDS

Pascal's Law

#Use a hot water bottle to show the principle of the hydraulic lift. Insert a one-hole stopper and a piece of glass tubing in the mouth of the bottle. Make it as secure as possible. Attach a 5 or 6 foot length of rubber tubing to the glass tubing and connect a funnel on the other end.

Now lay the bottle on the floor and place a flat piece of board on it. Ask a pupil to stand on the board. Hold the funnel as high as possible and pour water into it. Note the results. This demonstration presents a good opportunity to discuss the difference between force and pressure.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. multiplication of force	Transmitted pressure can exert a great force on a large surface that is in contact with the fluid. The magnitude of this force can be increased indefinitely by increasing the surface area affected.
D. Archimedes' Principle	
1. displacement	When an object is submerged, it will displace a volume of fluid (liquid or gas) that is equal to the volume of the object.
*2. buoyancy	An object partially or entirely immersed in a fluid has more force (due to the fluid) pushing up on the bottom than force pushing down on the top. The uplifting force of a fluid, called buoyancy, is equal to the weight of the liquid that the object displaces.

MATERIALS

ACTIVITIES

#Determine the volume of a small solid by dropping it into a graduated cylinder that is partially filled with water. Observe the difference in water levels.

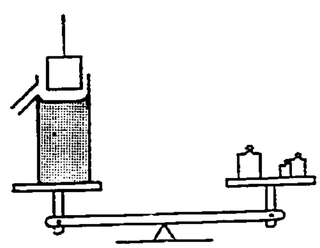
Lower larger solids into a can or tub that is filled to the brim with water. Have the pupils collect all of the displaced water and measure its volume with a graduated cylinder. When the object is fully submerged, the volume of displaced water will be equal to the volume of the object. If a laboratory-type overflow can is used for this experiment, a little vaseline should be rubbed at the end of the spout to prevent seepage in order to obtain accurate results.

#Archimedes' Principle for Floating Objects

Put an overflow can on one pan of a balance, fill it with water, and balance it accurately, after allowing the excess to flow off into a beaker. Now lower into it a block of wood and when the wood is floating freely and the water has stopped overflowing, the apparatus will again be balanced, showing that the weight of the wood exactly equals the weight of the water displaced.

KEY WORDS

Archimedes' Principle
displacement
buoyancy



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
*3. apparent loss of weight	While an object is submerged in a fluid, it will "appear" to weigh less.

MATERIALS

ACTIVITIES

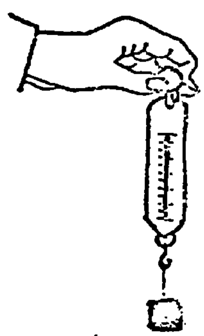
*Apparent Loss of Weight

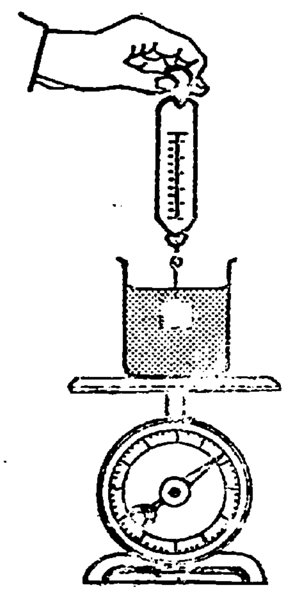
Does an object immersed in a liquid really lose weight? Or is its weight merely transferred to some other support?

Weigh the object in air. Note the reading when the object is in water as shown. Compare the change in reading of the platform scale with the decrease in reading of the spring balance.

Mark the new water level with a rubber band around the outside of the container, and after removing the sinker, add water to the container until the scale reading is the same as when the sinker was under water. The new water level will be even with the rubber band, showing that the apparent difference in weight is the same as the weight of the displaced water.

KEY WORDS





REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. flotation	An object will float when the buoyant force is equal to the weight of the object.

MATERIALS

ACTIVITIES

*Buoyancy Puzzles

a. How can you change the condition of equilibrium of the balance without touching the balance or beaker, or adding or removing water? (Dip finger into water.)

b. Push several thumbtacks into the base of a short piece of candle so that it just floats. Float the candle in a beaker of water, light it and ask the class to predict whether the candle will sink, float higher, or remain at the same level as the wax is burned. Of course, this demonstration should be started at the beginning of a period.

c. Can an object float in less than its own weight of water? Use two containers of almost the same diameter, so that the smaller one fits freely in the larger, but without much space between. Load the smaller of the two so that it floats deep in water, then float it in water contained in the other. Show by weighing that it is possible for it to float in less than its own weight of water. Have the class explain this apparent violation of Archimedes' Principle.

KEY WORDS

d. What happens to the water level in a pond if a boy drops a rock off a raft into the water? Put enough lead shot in the bottom of a beaker so that it will float in water without overturning.

Add as heavy a brass weight as the beaker will hold while remaining afloat. The weight should have a piece of string attached to it so that it can easily be removed from the beaker after the water level in the jar has been marked. Remove the weight from the beaker placing it in the battery jar. How do the water levels compare? If this experiment had been performed on the pan of a triple beam balance, what changes in indicated mass would have occurred?

Variation: What happens to the water level in a pond if a boy jumps off the raft he has been on

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
E. Bernoulli's Principle	The pressure of a moving column of fluid is affected by the velocity of the fluid. The greater the velocity of fluid the lower will be the pressure at the sides.

MATERIALS

ACTIVITIES

and floats? Instead of the brass weight use a block of wood in the above experiment.

Variation: What happens to the water level in the ocean when a ship sinks? Tip the beaker containing the weight so that it fills with water and sinks to the bottom. Or use a thick cafeteria-type coffee cup as the ship.

e. What happens when the ice cubes floating in a brim full glass of water melt?

#Application of Bernoulli's Principle

Observing applications of the Bernoulli effect in the science laboratory presents an unusual opportunity for the pupils to "discover" one of the major principles of science from firsthand evidence.

a. Hold a plastic (or glass) soda straw vertically with the bottom immersed in a beaker of water. Use a second straw to blow air horizontally across the top. Note what happens to the height of the water through the transparent straw.

KEY WORDS

A low pressure is created below the moving air column in accordance with the Bernoulli principle. Pupils should be able to draw the conclusion that the height of the liquid varies directly with the speed of the horizontal air movement.

b. Insert a funnel into a 20 to 30 cm. length of rubber tubing. Holding the funnel upright, challenge the pupils to blow the ball out of the funnel.

The harder the pupils blow, the faster the air moves about the sides of the ball. The comparatively high pressure of the surrounding air prevents the ball from leaving the low pressure area which is formed in the funnel.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

If an air compresser or vacuum cleaner is available to deliver a steady stream of air into the tube, the funnel may be inverted without having the ball fall out.

c. Insert a pin through the center of a small square of cardboard and rest it on a thread spool so that the pin extends into the hole and prevents the cardboard from sliding off. Using a straw, have pupils blow upward into the spool hole and try to dislodge the cardboard.

The air moving outward along the bottom of the cardboard creates a low pressure in accordance with Bernoulli's Principle making this apparently simple task very difficult. While blowing in the hole, have pupils try to invert the spool without losing the cardboard. Have them explain why the cardboard falls off as soon as the blowing stops.

KEY WORDS

Bernoulli's Principle

d. Demonstrate another application of Bernoulli's Principle by folding the ends of an index card down to make a small bridge. Place the bridge on a table and challenge the pupils to upset the bridge by blowing under it as hard as they are able. Blowing underneath the bridge reduces the air pressure and the comparatively high air pressure from above holds the bridge down with increasing force as the speed of the air below increases.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
IV. Force and Motion	
A. Speed	Speed is the rate at which distance is covered in a unit period of time. (The direction of travel is not considered in measuring speed.)
B. Velocity	Velocity is the speed of an object in a given direction.

MATERIALS

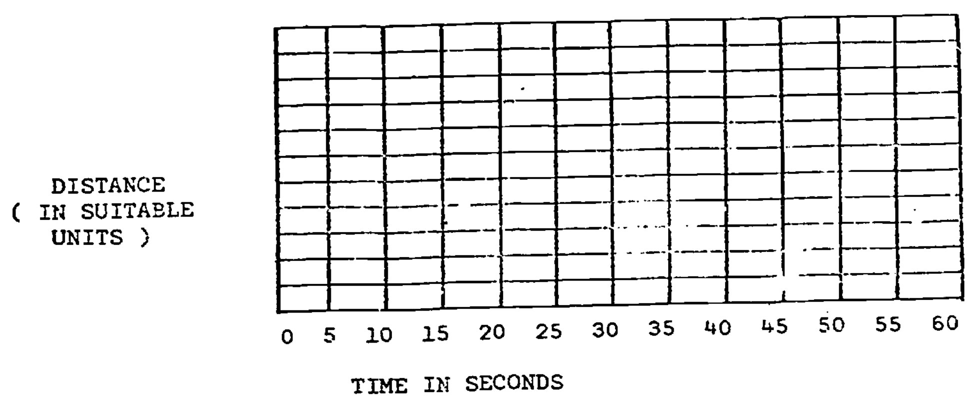
ACTIVITIES

#Determining the Speed of a Moving Object

An object should be moving slowly at a uniform rate when pupils measure the distance traveled and the elapsed time. Suitable devices that meet these specifications are toy electric trains and many battery operated toys.

Have one of the pupils act as timekeeper calling time every 5 seconds while another pupil marks the position of the moving object at each time interval. If the object is moving at a uniform rate, it will be found that consistent results for the speed will be obtained by dividing any of the measured distances by the corresponding interval of time.

Some pupils in the class should be able to plot a simple graph of distance versus time using the measured data. When the various points are connected, the curve should be essentially a straight line.



KEY WORDS

speed
velocity
displacement

Velocity is a vector quantity that incorporates both speed and direction.

#Difference Between Velocity and Speed

Have the pupils calculate the average speed of a slowly moving toy electric train by dividing the distance measured along a semicircular track by the time it takes the train to cover the distance. Now

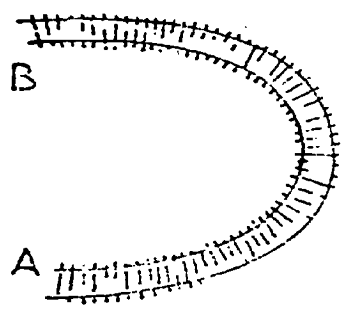
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

measure the straight line distance between the initial (A) and final (B) position of the train. This straight line distance is called the displacement. The average velocity of the train is obtained by dividing the displacement by the time it took the train to go from A to B. Note that the values of the average speed and average velocity are different for this situation.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Acceleration	Acceleration is the change of velocity in a given time period. Acceleration is also defined as any change in a velocity.
1. units of measurement	Acceleration is expressed as a velocity change per unit of time. A unit of acceleration is any unit of velocity divided by a unit of time.

MATERIALS

KEY WORDS

ACTIVITIES

#In non-scientific usage, the term acceleration has been limited solely to the change of velocity by increasing speed. Be careful to point out that decreasing speed and changing direction are also implied in the scientific definition of velocity change. In performing calculations, it is customary to use a + sign for positive acceleration and a - sign for negative acceleration.

*Have the pupils practice reciting acceleration units for a brief time so that they will have greater meaning. This may be done by stating a velocity, "centimeters per second" followed by a pause, then adding "per minute." Caution the pupils not to state units of square seconds. For example, 2 cm/sec^2 is stated, "two centimeters per second...per second." This pronunciation enhances the concept that an object is gaining speed so that for each second of travel the speed is increasing so that it is 2 centimeters per second faster than it was the previous second.

Examples of a variety of units of acceleration are:

- After blast-off a rocket which is increasing its speed at the rate of 4 kilometers per hour each second, is accelerating at 4 km/hr/sec.

- Friction which reduces the speed of a sliding object by one centimeter per second for each second, results in an acceleration of -1 cm/sec^2.

Acceleration is a vector quantity, but it is customary to state the direction only in cases where confusion would result or where the direction is not obvious.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. examples	
a. increased speed	A positive acceleration occurs when the speed of an object increases.
b. decreased speed	A negative acceleration occurs when the speed of an object decreases. This is also known as a deceleration.

MATERIALS

KEY WORDS

acceleration

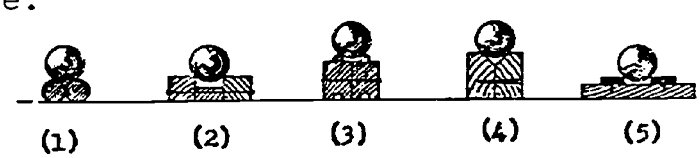
ACTIVITIES

#Uniform Acceleration

Positive acceleration is the rate of increase of velocity with the result that greater distances are traveled during successive time intervals. This is difficult to show with free fall because of the magnitude of the acceleration. The acceleration of gravity may be "diluted" however, in several ways, so that the decreased motion and increased time make observation easier.

It may be desirable to use a metronome or pendulum to measure equal time intervals. Distances traveled in successive equal intervals can be marked.

a. One of the simplest methods of studying acceleration is by use of a roller on an incline. If a ball is to be used, it may roll in a groove between: (1) two steel rods, (2) two strips of wood, (3) tongues of two flooring boards, (4) corners of two chamfered boards nailed together, or (5) two parallel pieces of bandiron screwed to a board. Such an incline should be 6-8 feet long with one end elevated enough so that the ball rolls smoothly and slowly in the groove.



A cylinder such a 100-gm. brass weight, if started accurately, will roll smoothly down a flat plank. A strip of glass 2 or 3 feet long and 5 inches wide makes a low-friction incline down which a weight will roll very easily.

In either case, measure the length and time and compute the final velocity and the acceleration.

The ball also can be permitted to roll onto a section of track which has been previously adjusted to slope just enough so that the ball

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

neither accelerates or decelerates. Measure both the time it spends on this section of the track and the length of the track. Compute the final velocity. From this find the average velocity on the incline. By using the length of the incline, calculate the time spend in accelerating and the acceleration. This can be compared with the acceleration measured previously.

b. The incline mentioned above may terminate in a horizontal section on which the ball will be retarded for a study of deceleration.

c. A large, low-friction pulley can be arranged to support two masses which differ slightly. By adjusting the difference in mass, acceleration can be made very slow.

d. A low-friction car can be accelerated by the dropping of a weight at the end of a cord passing over a pulley.

e. Determine the acceleration of an automobile by measuring the time it takes to achieve a certain speed from a standing start. If it is possible to measure or make a reasonably accurate estimate of the distance traveled while accelerating, compare this with the distance calculated from the time and the acceleration. Disagreement may be caused by the fact that the acceleration of an automobile is not usually uniform.

KEY WORDS

f. Have students prepare a graph of a uniformly accelerating object by plotting distance traveled against time.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. change in direction	A central acceleration occurs whenever an object is moved in a path that is not a straight line.
3. acceleration due to gravity	
a. universality	The attraction between the earth and some other body is known as gravity.
	Because of the pull of gravity, all objects near the surface of the earth accelerate during free fall.
b. direction	The direction of the gravitational acceleration is towards the center of the earth.
c. magnitude	The magnitude of the gravitational acceleration is approximately 9.8 m/sec^2 in the MKS system of measurement. (32 ft/sec^2)
d. effect of air resistance	Air resistance decreases the acceleration of objects during free fall.

MATERIALS	ACTIVITIES

#A good example of a central acceleration is an object revolving at a constant speed of one revolution per second. Its velocity is constantly changing and it is being accelerated at all times. The acceleration is directed toward the center of revolution and so is called a central acceleration.

#Acceleration of Gravity Independent of Mass

Suspend two balls of the same size as high as possible above the floor by means of electromagnets. One ball should be iron; the other should be wooden with a nail in it. (Two steel balls of different sizes may also be used.) Cover the pole of each magnet with a piece of cellulose tape. Connect the magnets through a switch to a dry cell. Place a metal pan or metal wastebasket under the balls. Open the switch. Note that only one sound is heard when the balls strike the metal.

The letter "g" is an abbreviation for the acceleration of gravity.

KEY WORDS

acceleration of gravity

At increased altitudes, the pull of gravity decreases and the value of g varies accordingly. Within a few hundred meters of the surface of the earth, this effect is small and cannot be detected with the usual laboratory instruments. Therefore, for practical purposes, the acceleration of gravity may be considered to be a constant value for laboratory experiments.

#Effect of Air Resistance on Acceleration

a. The dependence of air resistance on area and the concept of terminal velocity can be shown with a sheet of paper. Dropped in a horizontal position, it quickly reaches its terminal velocity. Dropped edgewise, it plummets to the floor. Crumpled loosely, it falls quickly, but does not keep pace with a metal ball or coin dropped at the same time. Wadded into a tight ball and dropped with a metal object, it falls along with the other, and strikes the floor at about the same time.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Newton's Laws of Motion	
1. Newton's First Law--inertia	An object resists efforts to change its velocity. An object at rest resists efforts to start it in motion. A moving object resists efforts to increase its speed. A moving object resists efforts to decrease its speed or stop it. A moving object resists efforts to change its direction of movement from that of a straight line. Inertia is that property of matter which enables matter to resist efforts to change its velocity.

MATERIALS

ACTIVITIES

b. The "guinea-and-feather" tube is used to show that the acceleration of freely falling objects is independent of mass if air resistance is eliminated. This is a large glass tube containing a feather and a coin. At normal pressure the feather flutters and the coin plunges as expected when the tube is inverted. But when the air is removed, the feather and the coin drop together.

#Demonstrations of Inertia

There are many relatively simple demonstrations which pupils can use to illustrate the principle of inertia. The following are illustrative:

a. Snatch a piece of paper from underneath a glass of water after showing that the glass can be dragged along by gently pulling the paper.

b. Stand a book on edge on a strip of paper and show that, if pulled slowly the book will move along with the paper, if pulled more quickly the book will fall over, and if the paper is snapped out, the book remains standing. Have pupils explain how the laws of motion account for the behavior of the book in each of the three cases. Discuss the part played by inertia when subway "strap hangers" lurch as the train starts or stops suddenly. Call attention to inertia as the cause of injury and damages. in automobile accidents.

KEY WORDS

Newton's First Law
inertia

c. Rest a coin on a card placed flat on the tip of one finger. Flick the card out from under the coin with a finger of the other hand. The card should be about the size of a calling card, and the coin a quarter or larger in order to make the demonstration effective.

d. Make a stack of 5 or 6 checkers and knock the bottom one out by striking it with a ruler. Repeat until you are down to the last checker. Coins can be used, and a hacksaw blade or knife blade used flat to strike out the bottom one.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

e. Suspend a massive ball such as a 25 kg. shot by a cord. The ball should be drilled at ends of a diameter for hooks. A similar cord is attached to the bottom. A gentle pull on the lower cord breaks the one supporting the weight. The falling ball may be caught in the hand or allowed to drop into a bucket of sand or onto a pad of rags. A sudden pull achieved by swinging the arm breaks the lower cord. Have pieces of string of the proper length and with loops tied in the ends ready for quick replacement.

f. Hang a heavy ball, with a hook on one side, as a pendulum. Using a length of light cord, show that the pendulum can be drawn aside if pulled gently, but that the cord breaks if yanked suddenly, resulting in almost no displacement of the pendulum. Attach the side string to a fixed upright, using a length that will be slack until the pendulum reaches the bottom of its arc. Draw the pendulum toward the upright and release. Note that the cord will break when it is pulled taut.

KEY WORDS

g. Use a large knife to cut part way through an apple or a potato. Then strike the knife, cutting blade up, on the edge of the table to slice through completely. Or with the knife part way through the object, hold it in the air and strike the back of the knife a sharp blow to finish the cut.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Newton's Second Law--overcoming inertia	An unbalanced force will cause an object to accelerate.
a. the inertia of objects at rest	An unbalanced force applied to an object at rest will result in an acceleration in the direction of the force.
b. the inertia of objects in motion	A force applied to a moving object will cause it to increase speed, decrease speed, or change direction of the force with respect to the direction of the original motion.
c. magnitude of mass	Other things being equal, the greater the mass of an object, the more difficult it is to overcome its inertia.

MATERIALS

ACTIVITIES

#According to Newton's second law of motion, the acceleration is inversely proportional to the mass and directly proportional to the applied force. Expressed mathematically, $a = \frac{f}{m}$ where

a is the acceleration in m/sec^2
f is the force in newtons
m is the mass in kilograms.

A thorough qualitative development of all these concepts is important for all pupils. Numerical problems should be reserved for pupils with a good grounding in elementary algebra.

#Newton's Second Law

To illustrate Newton's Second Law support two pulleys as high above the floor as possible, pass a piece of cord over them long enough so that a weight hanger at one end touches the floor when a hanger at the other end is near the pulley. Put 150 gm. (made up of 100 gm., 20 gm., 10 gm., 5 gm., and 5 gm. standard masses) on one side and adjust the other to just enough more than 150 gm. so that it descends with uniform speed once started. (If boxes are used to hold the weights rather than weight hangers, it will avoid the necessity of picking up dropped weights during the experiment.)

KEY WORDS

Newton's Second Law

Now if a 5-gm. standard mass is transferred from the first side to the second, there is an unbalanced force acting on a total mass of somewhat more than 300 gm. and the system will accelerate. Use a stopwatch to determine the time it takes the mass to drop from its highest position to the floor. Measure the distance and calculate the acceleration. Transfer another 5-gm. standard mass to double the unbalanced force and again compute the acceleration. Continue increasing the force and calculating the acceleration until the speed is so great that timing is unreliable. Show that the acceleration is proportional to the force by plotting the data on graph paper. Account for any irregularities in the curve drawn.

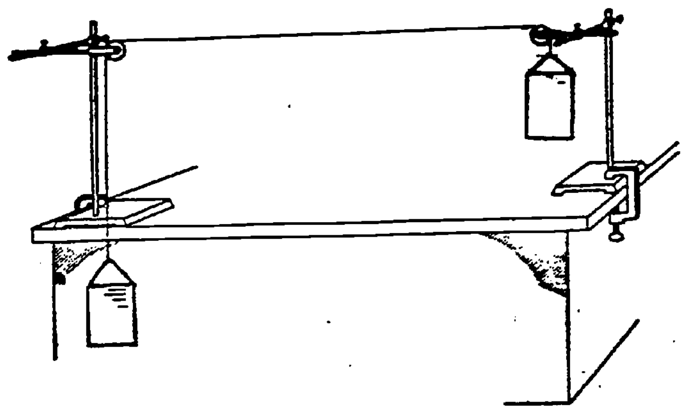
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

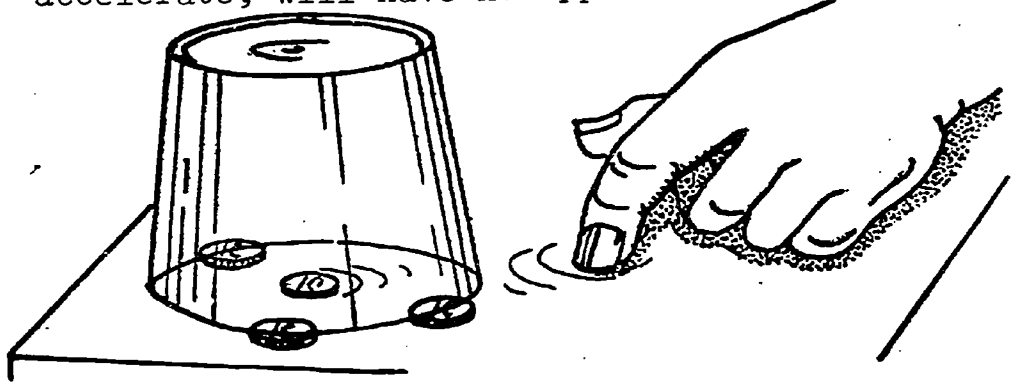
In similar fashion, by keeping the unbalanced force constant, the total mass can be varied and the acceleration shown to be inversely proportional to the mass. Variation in friction loss makes this inaccurate, but correcting for friction at each trial is tedious.



#Coaxing a Coin with Inertia

KEY WORDS

A given force will produce a greater acceleration on a small mass than on a larger one. An amusing parlor trick is based on this principle. Lay a handkerchief on a table and set an inverted glass tumbler in the center. Place a dime under the tumbler and support the rim with three pennies so that there is a small open slit between the handkerchief and the glass. Challenge the pupils to remove the dime without disturbing or making any contact with the tumbler. If the handkerchief is scratched with a fingernail, the short jerks of the cloth will cause the dime to accelerate towards the beckoning finger. The larger mass, consisting of the glass and pennies, being more difficult to accelerate, will have no apparent movement.



REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

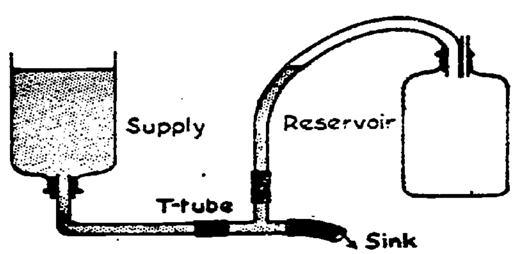
#The Laws of Motion and the Hydraulic Ram

The hydraulic ram may be used as an illustration of inertia and also to help with energy concepts. Glass models are sold by science supply companies, but a homemade version can be constructed.

Invert a large bottle from which the bottom has been cut. In its mouth insert a stopper fitted with a bent section of large diameter glass tubing. Couple a glass T to this and terminate over the sink with a three-inch piece of thin-walled rubber tubing. A delivery tube to carry water to a beaker (representing a home supply of water) is connected to the third arm of the T.

It is essential that there be no constrictions between the bottle and the sink so that flow of water is rapid. Pinch the rubber outlet suddenly and the water rises in the delivery tube. With sufficiently rapid water flow, the water in the delivery tube can be raised higher than the supply level, so that some water can be transferred to the reservoir.

KEY WORDS



Discussion of the first and second law usually involves the effect on passengers when an automobile slows down or speeds up rapidly. It should be stressed that the passenger is not propelled forward or pushed backward when the brakes are applied or the car accelerates. The inertia of the passenger tends to keep him in motion or at rest. Unless seat belts or something similar are used, the force between the clothing and the seat alone is not large enough to bring about the change in motion in the time available.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. Newton's Third Law--action and reaction	Every action is accompanied by a reaction this is equal in magnitude and opposite in direction.
a. relation to forces	It is impossible to exert a force in a given direction without having an equal force in the opposite direction at the same time.

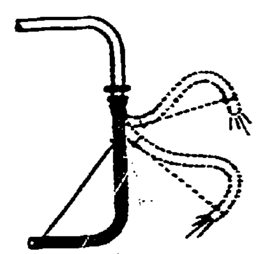
MATERIALS

ACTIVITIES

#Newton's Third Law

A correct statement of Newton's Third Law is: When two particles (or bodies acting like particles) interact, the force acting on the first is equal in magnitude but opposite in direction to the force action on the second.

To show the recoil due to a water jet, use a 100 cm. length of light, flexible rubber tubing. Tie a piece of string about 10 cm. long on the tube at two points, so as to pull it into an approximate right angle turn. Attach the tube to the water faucet and turn on the water cautiously. With the water flowing gently, the tube stands out in a most unnatural position. If the water is turned on hard for a moment, its writhing is most instructive, but will shower water on a good portion of the classroom.



KEY WORDS

Newton's Third Law
action
reaction

#Action, Reaction, and Acceleration

Connect two small cars, such as are often used with the inclined plane, by a long, thin rubber band. Now if they are drawn apart to stretch the rubber band, equal and opposite forces are exerted on the front of each car to reduce the shattering effect of the collision. Results will be most reliable if the cars are identical and wheel-bearing adjustments and lubrication make the friction in them as nearly alike as possible.

If equal masses are carried by the cars, their point of meeting will be equally distant from the two starting points. If the total mass of one is twice that of the other, it will travel half as far before the collision. (The forces

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. relation to momentum	Momentum is the product of the mass and its velocity.
	An increase in momentum is accompanied by an equal increase of momentum in the opposite direction.
*E. Conservation of momentum	Momentum cannot be created nor destroyed.
1. increasing momentum	The momentum of an object may be increased by decreasing the momentum of another object.
2. decreasing momentum	The momentum of an object may be decreased by increasing the momentum of another object.

*optional

MATERIALS

ACTIVITIES

are the same except for small differences in friction, and the acceleration must be inversely proportional to the mass. The distance is proportional to the acceleration.) Use upright cardboard indicators on the table to mark the starting points of the cars.

Bring out the point that this might be used as a method of measuring mass, a method which does not involve weight in any way.

#Action and Reaction with a Skateboard

a. Have a pupils stand with his left foot on the ground and his right foot on a skateboard. Call the attention of the class to the backward motion of the skateboard as the pupil steps forward with his left foot and attempts to keep the right foot still. This demonstration works best with a smooth floor.

b. Have two pupils stand on skate boards facing each other. Show that it is impossible for either pupils to move the other without moving himself in the opposite direction. If the two pupils are approximately the same size, they will move with equal velocities and coast the same distance. If one pupils is very much smaller than the other he will always move faster whether he is pushing the larger pupil or is being pushed.

KEY WORDS

momentum
conservation of momentum

This relatively complicated topic may be discussed qualitatively. Excellent examples are collisions of billiard balls, two automobiles, travelling in the same or different directions, and so forth.

#Recoil and Conservation of Momentum

a. The effect of recoil can be simply demonstrated by this experiment. Put some water in a small bottle, stopper it with a solid rubber stopper, hang it horizontally by two strands of light wire (no. 30) and heat it cautiously. When the stopper pops out, the

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

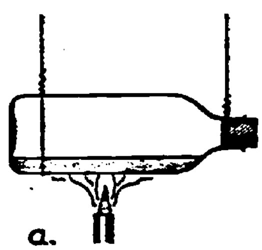
ACTIVITIES

bottle will recoil and some of the hot water will be spilled vertically below the support. All three of these phenomena should be discussed and explained in terms of Newton's law of motion and the law of conservation of momentum.

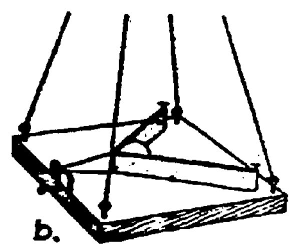
b. A more complex device to show the influence of recoil is constructed as follows. Prepare a platform approximately 1 x 4 x 5 ". Suspend it as a swing by thin wire (no. 30) from four screw eyes in the corners. Attach a strip of rubber (a heavy rubber band will do) to two nails near one end of the platform and hold it back with a loop of string passing over a support made of a bent nail, and down to a nail on the opposite side of the swing. If a ball such as a heavy pendulum bob is placed in the pocket formed by the rubber band, and the string is burned by a match flame held below the nail, the ball will be shot out and the platform will recoil.

Prepare loops of string of the same length so that the "gun" can be reloaded quickly to compare the effect on the bullet and the swing when balls of different masses are shot.

KEY WORDS



a.



b.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. exchange of momentum	Momentum can be exchanged by two objects that collide, but the total momentum after such an interaction is always equal to the momentum before the event.

MATERIALS

ACTIVITIES

#Conservation of Momentum and Kinetic Energy

The construction of this device is an interesting extra-class project for some pupils. It is doubtful that the teacher should spend the time on constructing it.

Make a wooden frame 40 cms. long, 30 cms. high and 10 cms. wide. Suspend seven steel balls of equal size from the top edges of the frame. (An eighth ball somewhat larger in size may be added later to make the demonstration more complete.) The balls should be at least 3 cms. in diameter or preferably larger. The cord is passed through and knotted on two metal "ears" soldered to the ball. The points of support are screw eyes with two loops of cord taken around the shank so that the position of each ball can be adjusted by turning the screw eyes from which it is suspended. The positions of the points of support for adjacent balls should be exactly as far apart as the diameter of the balls used. If a larger ball is used, suspend it the same way at the end of the line with its points of support a little farther from the others to make up for its greater diameter.

KEY WORDS

Bore 2-cm. holes in a line through the top; these can be used to hold the balls not being experimented with. Make tabs of cardboard bent at a right angle and cut to a point on top, and high enough so that they almost touch the balls. These tabs are used as indicators to mark the positions of the balls at various parts of the tests.

If the large ball is placed on top of the frame, with the remaining ones accurately lined up, and one of the small ones drawn back and allowed to strike the line of balls, a single ball will be driven out from the other side. The impact of two balls will cause two to swing out, and so on.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

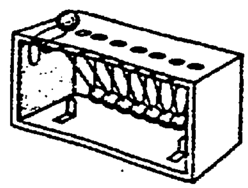
MATERIALS

ACTIVITIES

If all the balls except two adjacent ones are put on the top out of the way, it can be shown that when two equal balls strike, there is an exchange of velocities.

If the large ball is stationary and is struck by the small one next to it, it can be shown that the smaller one does not transfer all its kinetic energy to the large one, but rebounds.

This rebounding can be used to help explain the choice of material for moderators in a nuclear reactor since the transfer of energy is greatest when a neutron strikes an atom most nearly its own mass.



* #The Laws of Motion and Conservation of Momentum

KEY WORDS

The laws of motion and conservation of momentum may be illustrated in the following manner. Hang a weight from a spring supported by a clamp on a ringstand. Choose the length and strength of the spring, and the size of the mass to provide for as long a period of oscillation as practical. With the apparatus resting on the desk and the weight bobbing up and down, discuss the part played in the oscillation by the inertia of the weight, as its extension changes. When this has been thoroughly discussed, ask the pupils whether the table supporting the ringstand is playing any part in the oscillation. After an expression of opinions, place the apparatus on the platform of a balance designed to handle large weights, and balance it with the weight quiet. Holding the balance stationary, start the oscillation

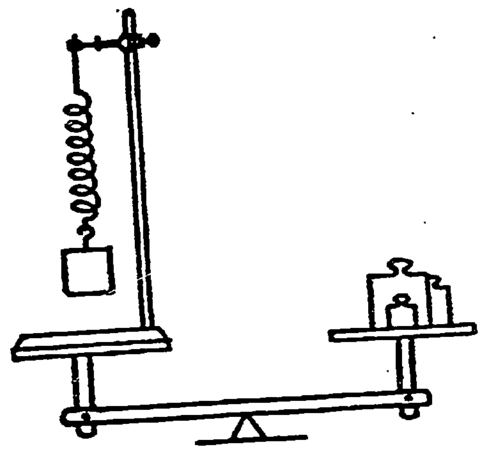
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

and then release the balance. Explain the result in terms of the forces and also in terms of conservation of momentum.



The principle of conservation of momentum is presently having considerable applications in predicting reactions that occur after collisions of sub-atomic particles. It has also been determined that electromagnetic waves such as X-rays and photons interact with small particles of matter which results in changes of momentum of the matter. If the energy in the electromagnetic wave is equated to mass in accordance with Einstein's equation, $E = mc^2$, the law of conservation of momentum has been found to hold true even in these special cases.

KEY WORDS

BLOCK J

THE CHEMISTRY OF MATTER

BLOCK J - CHEMISTRY OF MATTER

Introduction
- safety in the laboratory
- tools of the chemist

Properties and Changes in Matter
- physical and chemical properties
- physical and chemical changes

Introduction to Atomic Structure
- protons, electrons, neutrons
- simple atomic model (Bohr)
- periodic table
- arrangement - atomic numbers

Common Chemical Changes
- simple representative examples (laboratory)
- simple explanation based on periodic table
- chemical shorthand

Common Compounds and Mixtures
- acids, bases, and salts
- solutions and suspensions
  - interpretation of solubility charts

Introduction to Organic Chemistry

Role of Chemistry in Our Society
- chemical advances
- conserving chemical resources

REFERENCE OUTLINE	MAJOR UNDERSTANDING AND FUNDAMENTAL CONCEPTS
I. Introduction	
A. Safety in the laboratory	A laboratory is as safe as the least safe person. It is the responsibility of each pupil to avoid accidents. Prevention of accidents requires knowing what to expect and how to perform the experiments as well as maintaining a quiet, business-like manner.
1. rules of safety	
a. general rules	Read, understand, and follow directions; when in doubt, ask the teacher. Work quietly, thoughtfully, and avoid rushing but also avoid wasting time.
b. prevention of injury	A laboratory is no place in which to eat or drink. Avoid any situation which may lead to any chemical being taken internally. Most chemicals are poisonous. Keep your face away from the work area. Protect your clothing and eyes by wearing rubber aprons and goggles or eye shields, Many chemicals "eat" holes in clothing. Spattering of liquids or flying particles from a shattering substance can cause serious eye injuries, cuts, and chemical burns. Wash away with quantities of water any chemical spilled on the skin, clothing, or desk. Many substances can burn or irritate the skin; others can cause fires or other reactions to occur. Keep the desk, equipment, and hands clean at all times. Use only a clean spatula to transfer solid chemicals.

MATERIALS

ACTIVITIES

SAFETY REMINDERS

Ask some of the more artistically talented pupils to prepare safety charts. Hang the charts in the room to remind pupils of their responsibility for safety.

Collect and exhibit cartoons based upon laboratory safety. The cartoons are most often found in science papers and magazines.

UNIVERSAL ANTIDOTE

Mix thoroughly one part by weight of magnesium oxide, one part tannic acid, and two parts powdered charcoal. Place the mixture in a clean, dry container and label it with the name and dosage: one heaping spoonful in a small glass of warm water.

Store the antidote in the first aid supply area.

KEY WORDS

burn
business-like
internally
irritate
spatula

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	While pouring liquids, hold the bottle stopper or cork so that liquid will not get on the desk or other materials get on the cork.
	Traces of chemicals can cause some other materials to react or decompose violently.
	When observing the odor of a substance, fan the gas toward your nose. Do not put the nose directly over the material. Some substances are poisonous, others can irritate the membranes of the respiratory system.
c. accident procedures	Know how and when to use the safety devices. Use the fire blanket when a person's hair or clothing is on fire. Use the carbon dioxide fire extinguisher for other fires.
	Report all accidents, even the smallest ones. An injured person may not realize he needs first aid.
	Knowing what caused an accident can help prevent its reoccurring.

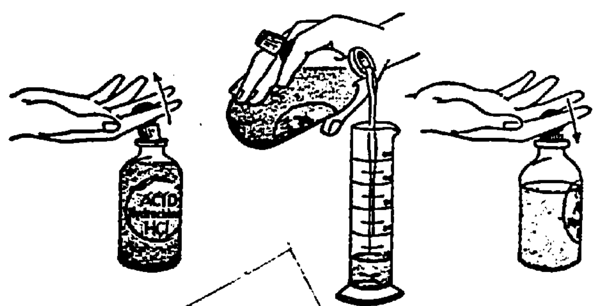
MATERIALS

graduates
reagent bottles
water

ACTIVITIES

POURING LIQUIDS

Demonstrate the proper procedure to use when pouring liquids from a bottle. Then have the pupils measure specific amounts of the liquids from the reagent bottles.



(Colored water makes a good starter.)

OPERATING SAFETY DEVICES

Be sure that pupils know when and how to operate a fire extinguisher or apply a fire blanket.

Demonstrate how to use the carbon dioxide fire extinguisher. Point out that it is never directed at a person because serious cold burns can result from the solid dry ice touching the skin. If a person's clothing gets on fire, a fire blanket is used.

TEACHER NOTE:

Always use goggles when there is a danger of spattering, chipping, breakage, snapping, etc.

KEY WORDS

decompose
extinguisher
membrane
odor
respiratory tract
stopper

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. Laboratory tools	
1. burners	
a. structure	The parts of the burner are the spud or gas opening, the air holes or ports, and the barrel. Operation of the burner is based upon Bernoulli's principle. As the gas under pressure is released through the small opening of the spud, there is an increase in the velocity of the gas causing a reduced pressure in the gas stream. Air rushes in through the air ports due to pressure differences, and a combustible air-gas mixture passes up the barrel.
b. function	Controlling the rate of burning of a fuel provides a safe supply of heat energy for laboratory use. In order for burning to occur, there must be a fuel, oxygen, or air, and sufficient heat to reach the reaction temperature called the kindling temperature.
c. nature of the flame	When a proper air-gas mixture is obtained, the gas burns with a pale blue flame and has a cone-like appearance. There is enough air being supplied to the burner for the fuel to be completely burned. The hottest point of the flame is at the tip of the inner blue cone. The hottest part of the flame is called the reducing flame. The tip of the outer flame is relatively rich in oxygen and is referred to as the oxidizing flame.

MATERIALS

ACTIVITIES

KEY WORDS

Bernoulli's Principle
burning
heat
kindling temperature
luminous
oxidizing
pressure
reaction temperature
reduced
reducing
spud
velocity

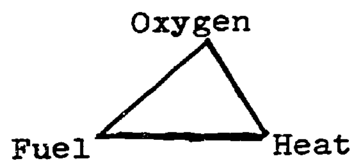
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	The coldest part of the flame is inside the inner blue cone which consists of unburned gas and air. Things held inside the cone will not get hot.
	If the air openings of a burner remain closed or not sufficiently opened, the flame will be yellow, luminous, and sooty. The fuel is not being completely burned.
	If too much air is admitted, the burner "roars" and the flame may strike back causing the gas to burn inside the barrel. The barrel gets very hot.
	When a burner strikes back, turn off the gas, close the air ports, relight the burner, and readjust the air intake.
d. safety rules	Light the match, then turn on the gas. If too much air-gas mixture accumulates, an explosion can occur when a match is lighted.
	When lighting the burner, keep the face and other parts of the body to one side of the burner. Never reach across a burner. Hair and clothing can be set on fire.
	Always apply heat gradually and evenly.
	When heating a test tube, point the mouth of the test tube away from yourself and others. As the liquid begins to boil, it may spurt out across the desk and burn someone.
	Keep materials being heated at the back of the desk. If anything breaks or spills, there is less opportunity for someone to get hurt.

MATERIALS

asbestos pad
water
potassium
 permanganate
glycerine
tripod stand

ACTIVITIES

FIRE TRIANGLE



1. Discussion of Fire Triangle in fire prevention

2. Discussion of spontaneous combustion

3. Introduce terminology such as
   oxidation (slow and rapid)
   combustion
   kindling point
   flash point

   Discuss their interrelationships

Demonstrate spontaneous combustion as a result of slow oxidation. Make a small cone-shaped pile of potassium permanganate crystals on an asbestos pad. Moisten it slightly and add a drop or two of glycerine. In a minute or so it should burst into flame.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ringstand
beaker
water
burner
splints

KEY WORDS

accumulate
explosion

ACTIVITIES

THE BURNER AND ITS FLAME

Allow each pupil to examine, dismantle, and reassemble a burner to identify its parts.

Demonstrate the proper way to ignite and adjust the burner.

Emphasize the need for lighting the match first and not reaching across the burner.

Have the pupils study the different flames produced when the amount of air is varied.

Place a Pyrex beaker of cold water on a ring stand. Direct the blue flame toward the outside of the beaker. Gradually decrease the air intake. The flame will deposit carbon only when the flame is yellow. In this case, there is not enough air intake to completely burn the fuel.

Let the pupils investigate the nature of the blue flame.

Place a wooden splint across the barrel of a burner which is producing a blue flame. As the splint starts to scorch, remove it from the flame, and study the pattern left on the splint. Compare the result with scorch patterns produced when the splint is held at different levels in the flame. Explain the reason for each pattern.

If the splint starts to burn, quickly remove the splint from the burner flame and extinguish the fire. The splint will always catch on fire at the tip of the blue cone. Point out that this area is the hottest part of the flame.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	Heat chemicals only when told to do so. Then carefully follow all directions regarding the amount of heat to use.
	As a general rule, the rate of a reaction increases rapidly with an increase in temperature.
	When using a bunsen burner, always apply the heat gradually.
2. glassware - test tubes, beakers, flasks, bottles, graduated cylinders, and funnels	Glassware labeled Pyrex or fire resistant can be heated directly. However, one should apply the heat gradually to avoid unnecessary extremes of temperature.
	Most glass is a poor conductor of heat and has a high degree of expansion as the temperature increases. As glass is heated it expands unevenly since the glass does not have a uniform temperature due to its poor ability to conduct heat. The uneven expansion causes strains which make the glass break or shatter when heated directly. However, glass may be heated in a water bath without breaking.
	Pyrex or fire resistant glass expands to a very small degree as it is heated. Therefore, it is not apt to break when direct heat is applied gradually.
	Bottles, funnels, and graduated cylinders that are not Pyrex or fire resistant will shatter when subject to the sudden change in temperature that occurs when direct heat is applied.
3. porcelainware - evaporating dishes, mortars and pestles	Evaporating dishes should be placed on an asbestos gauze or heated over a water bath.
	Remove the heat source before all of the liquid has been evaporated. The contents may spatter if too much heat is applied. Keep the face away from the dish.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Mortars and pestles should never be heated or used for anything except pulverizing solids. Some solids explode upon being ground.

MATERIALS

ACTIVITIES

IDENTIFICATION OF EQUIPMENT

Have pupils examine and identify each of the following pieces of equipment:

- test tubes
- test tube holders
- test tube rack
- clamps
- ring stand
- iron ring
- forceps
- tongs
- wire gauze
- clay triangles
- beakers
- flasks
- funnels
- evaporating dishes
- graduated cylinders
- thistle tubes
- mortars and pestles

KEY WORDS

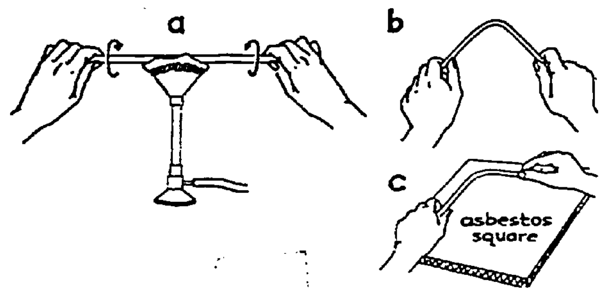
asbestos
conductor
directions
evaporating
expands
pulverizing
Pyrex
reaction
resistsnt
shatter
temperature

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. assembling apparatus	
a. cutting, fire polishing, and bending glass	Etching the glass with a file produces strains which reduce the force (stress) required to break or shear the material.
	Newly cut glass tubes or rods should be fire polished to round the ends and reduce the possibility of injury.
	Glass becomes more fluid upon being heated. When fire polishing glass, hold the tubing at an angle, and rotate it so that gravity will not cause the heated end to bend toward the ground.
	When bending glass, use a wing top on the burner since it is necessary to have a larger amount of glass heated than in fire polishing.
	Glass that has been heated in a flame cools slowly. Set the hot glass on an asbestos square to cool.
(1) safety rule	Do not let any one pick up glass that has been heated until it has had sufficient time to cool. Hot glass can cause very serious skin burns.
	Discard any glass bend in which the bore has been pinched during bending or fire polishing.

MATERIALS

ACTIVITIES

GLASS TUBING



(a) Cutting glass tubing. At the desired distance from one end of a length of glass tubing make a deep scratch by drawing the file across the glass as it is held firmly on a flat surface. Hold the tubing so that the cut is away from the body. Grasp the glass so that the thumbs are behind the scratch and the fingers are extended over the glass. Using the thumbs as a fulcrum, gently pull with the fingers toward the body. The glass should break easily at the scratch mark.

If the scratch is not deep enough, a clean break will not be made. The glass tubing may be held in a towel to avoid injury to the hands and fingers.

After breaking the glass tubing, immediately fire polish the cut end.

(b) Fire polishing glass. The ends of glass tubing should always be fire polished.

Hold the tubing so that one end is just above the blue cone of a burner. Rotate the glass, and remove it from the flame as soon as the end appears to be smooth. Too much heating may result in the tube becoming sealed.

Caution pupils about touching hot glass as serious burns may occur. Do not allow more than one pupil to heat glass in a burner at the same time.

KEY WORDS

etching
force
shear
strains
stress
wing top

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

(c) Bending glass. Fire polish the ends of an 8-inch length of glass tubing. Now with a wing top on the burner, hold the glass tubing lengthwise above the blue cone as shown in diagram a. Rotate the tubing with both hands, and heat the center section until it becomes soft and pliable. Remove the glass from the flame and bend it to form a right angle. If the hot glass is placed on an asbestos square, the corner of the square can be used as a guide for making the bend. Discard any bend in which the glass bore has been pinched.

Emphasize the need for rotating the glass with both hands while it is being heated. Demonstrate what happens when the glass is held firmly in one hand and rotated with the other hand during the heating. The glass will coil up and can not be bent.

Compare glass bends made by using the blue cone of a burner with those made with a flame coming from the wing top. Note the bore of the tubing in the bent part of each right angle bend. Ask the pupils to explain why the "wingtop" bend is preferable.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDING AND FUNDAMENTAL CONCEPTS
b. using delivery and thistle tubes	A thistle tube acts as a safety device in a generator producing a gas. If any pressure should build up, the liquid in the generator will be pushed up the thistle tube, and the pressure reduced. Unless the thistle tube allows for a reduction of pressure, the generator may "blow up."
(1) safety rules	Always wet both the glass and the stopper before trying to insert tubing into a stopper. The water or glycerin used to wet the tube acts as a lubricant.
	Never push a glass thistle tube or tubing into a stopper. A twisting, turning motion should be used to insert glass into the stopper. Pushing the glass may result in the tube snapping and glass being pushed up through the palm of the hand.
II. Properties and changes in matter	Matter is anything that occupies space and has mass. Under the influence of gravity, mass has weight.
	Three clases of matter are elements, compounds, and mixtures.
	Elements are not able to be broken down into more simple substances by ordinary chemical means, but may be broken down into simpler substances by nuclear reactions.
	<u>Most</u> elements are classed as metals.
	Compounds are composed of two or more elements, chemically united, in a definite proportion by weight.
	Elements and compounds are often called pure or homogeneous substances.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Mixtures contain two or more substances in varying amounts but the individual substances can be recognized because they are not chemically united.

Mixtures are said to be heterogeneous

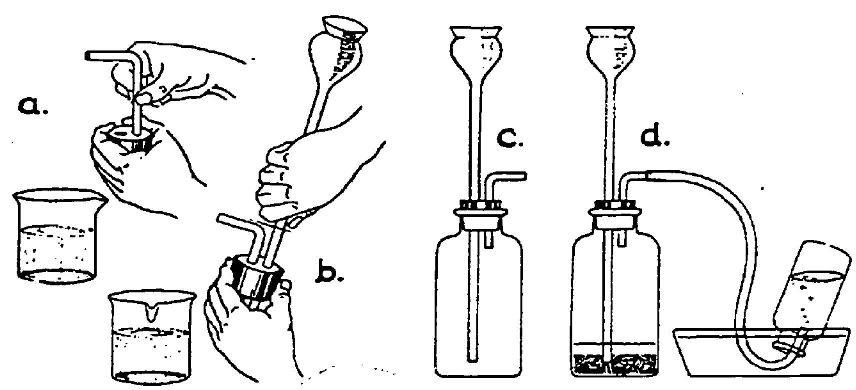
MATERIALS

gas collecting bottles
thistle tube
2-hole rubber stopper
glass tubing
marble chips
hydrochloric acid
rubber hose
pneumatic trough

ACTIVITIES

Set up a gas generator as shown in the diagram. Use the apparatus to generate and collect carbon dioxide. Show how to insert a thistle tube into a stopper safely. Explain that the end needs to be under the surface of the liquid so that the gas does not escape through the thistle tube. Place marble chips in the generator and slowly add dilute hydochloric acid. Show how to handle the bottle of acid and the stopper properly. Explain the reason for holding the stopper between the index and middle fingers.

Collect the gas in gas bottles that have been filled with water and inverted. In a vessel of water or a pneumatic trough insert the delivery tube under each bottle until it fills with gas. Test the gas by inserting a burning splint.



KEY WORDS

chemically united
compounds
elements
generator
homogeneous
heterogeneous
lubricant
metal
mixtures
nuclear
proportion
space

Exhibiting Matter

Make an exhibit of the different kinds of matter. Such a display might include the following:

Elements	Compounds	Mixtures
copper	water	copper sulfate and marble chips
sulfur	copper sulfate	salt and sand or sawdust
aluminum	table salt	muddy water
iron	sand	iron filings and chunks of roll sulfur
mercury	table sugar	
tin	marble chips	
zinc		

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
A. Physical properties	All substances have special physical properties, e.g.; mass, weight, inertia, impenetrabilit;
1. Phases of matter	The phase in which matter exists depends upon how close together its particles are and how fast they move.
	When a change of phase occurs, energy is either absorbed or liberated.
	Heat energy can be converted into kinetic energy of motion and/or potential energy of position of the particles.
	Kinetic and/or potential energy can be converted into heat.
a. solids	The particles of a solid are relatively close together and move relatively slowly.
	The particles of a solid resist a change of position.
	A solid has a definite shape and volume.
b. liquids	The particles are farther apart and move more rapidly in the liquid phase than in the solid phase.
	Energy is absorbed when a solid liquefies and is released when a liquid becomes a solid.
	A liquid takes the shape of the container but has a definite volume.
c. gases	The particles are farther apart and move much faster in the gaseous phase than the particles in a liquid or a solid.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Energy is absorbed when a liquid turns into the gaseous phase. Energy is liberated when the gas condenses into a liquid.

Gases have neither a definite shape nor a definite volume. They assume the shape and volume of the container.

In the gaseous phase matter can generally be considered to be in the molecular form.

MATERIALS

ACTIVITIES

PHASES OF MATTER

Use an overhead projector to help develop the concept of particle position and velocity in the phases of matter.

Obtain a supply of marbles and three clear plastic boxes of unequal sizes. Into the smallest box put as many marbles as can be packed into a single layer. Put an equal number of marbles into each of the remaining boxes.

Set each box on the stage of the overhead projector. Gently jiggle each box so that the marbles move. Note the degree of movement and the distance between the marble particles in each case. Relate the demonstration to particles in states of matter.

Best results for illustrating the gaseous phase can be obtained when the box is much larger than that used to represent the other two phases.

KEY WORDS

absorbed
converted
energy
gas
heat
inertia
impenetrability
kinetic
liberated
liquid
liquefies
mass
matter
molecular
motion
phase
potential
solid
weight

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Other physical properties	Certain substances have special characteristics of tenacity, ductility, malleability, elasticity, brittleness, hardness, and color. The properties vary in degree from substance to substance.
	If a material resists being pulled apart, it has tenacity.
	Malleable material can be beaten or rolled into thin sheets.
	Ductile substances can be drawn into fine wires.
	Brittle material tends to fracture under shock or pressure.
	Hard materials have the ability to scratch, etch, or cut other materials.
	The color of a solid is the same as the color of the light being reflected from it.
B. Physical changes	All matter can be changed physically.
	There is no change in composition during a physical change, but there may be a change in form, phase, or energy.
	After a physical change has been brought about, the original substance(s) involved in the change can still be recognized by its properties.

MATERIALS	ACTIVITIES
Wire Weights	**TESTING TENSILE STRENGTH** Illustrate the differences in tensile strength between different metals. Use two wires of the same length and diameter (No. 24 or 28 gauge). Support the wires from one end. Add weights until each breaks. The tensile strength varies directly with the force needed to break the wire, and is a measure of the cohesive force between adjacent molecules over the entire cross-sectional area. CAUTION: Be sure to wear safety goggles.
	MALLEABILITY AND DUCTILITY OF SOME METALS
(a) sheet copper	(a) Malleability of Copper. Demonstrate the malleability of copper. With a ball peen hammer pound a sheet of light-gauge copper into an ashtray. The wooden form for ashtrays is usually available from the art department or school shop. CAUTION: Be sure to wear safety goggles.
(b) piece of lead	(b) Malleability of Lead. With a ball peen hammer pound a lead fishing sinker into a "sheet."
(c) wire of different sizes and gauges	(c) Ductility of Metals. Illustrate ductility by passing around wires of different gauges and composition.
(d) heat source bobby pin or substitute	(d) Changing Ductility by Heating. Bend a bobby pin back and forth several times to show its ductility. It is difficult to break it by bending and flexing. Heat the pin to redness in the bunsen flame and quench by plunging the pin into cold water. The bobby pin is brittle now and can be broken easily into pieces.
	TESTING HARDNESS
Moh's scale nail file copper penny glass	Ask pupils to look up in an earth science or geology textbook the hardness scale used to test minerals. Then, using the hardness standards, determine the hardness of several materials. Include some metals like copper, iron, and aluminum.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

If the hardness scale testing outfit is not available, some hardness ratings can be roughly obtained by the following:

Matter is scratched by a fingernail -
    Hardness rating 1 - 2
Matter is scratched by a copper penny -
    Hardness rating 3 - 4
Matter is scratched by a steel knife -
    Hardness rating 5
Matter scratches glass -
    Hardness rating over 6

KEY WORDS

brittleness
color
composition
ductility
elasticity
form
hardness
malleability
phase
physical
properties
reflected
substance
tenacity

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
1. Separating by magnets	A magnetic substance can be removed from a mixture by means of a magnet.
2. Dissolving substances	Some substances are soluble; others are not.
	The degree of solubility of a substance at different temperatures may be shown by a chart or graph.
3. Filtering suspensions	An insoluble substance can be separated from a soluble one by filtering. The insoluble material is left on the filter paper. The soluble material is in the filtrate.

MATERIALS

magnet
iron filings
copper sulfate
plastic bag
filter paper
funnel
ring
ring stand
watch crystal or evaporating dish

KEY WORDS

filter paper
filtering
filtrate
insoluble
magnet
magnetic
soluble

ACTIVITIES

PHYSICAL CHANGES

In each of the following cases, pupils should observe the original properties exhibited by the material and later explain why they know that a physical change has occurred.

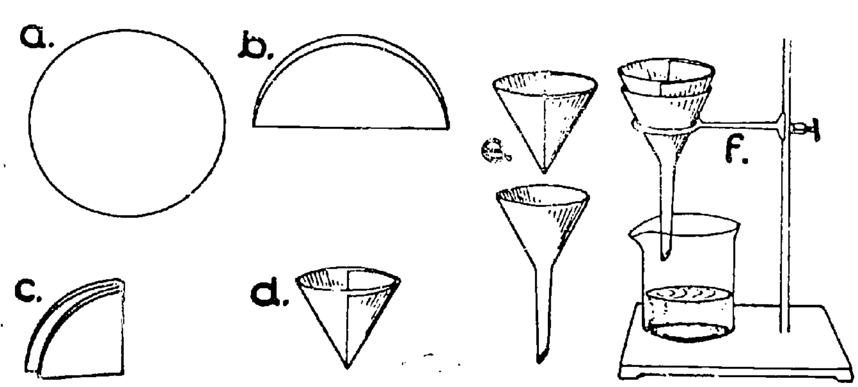
USING A MAGNET. Use a magnet to separate a mixture of iron filings and copper sulfate crystals. Limestone, sodium chloride or any nonmagnetic substance may be substituted the copper sulfate.

If a small plastic bag is slipped over the end of the magnet to be brought near the mixture, the iron will cling to the bag instead of the magnet. As the magnet is taken out of the bag, the iron filings will drop off the bag.

FILTERING AND EVAPORATING. Add enough water to a mixture of copper sulfate and iron filings so that the copper sulfate is completely dissolved. Filter and evaporate the filtrate.

Marble chips or any insoluble substance may be substituted for the iron filings in the mixture.

Demonstrate the method of folding and using filter paper. A piece of paper towel can be used instead of filter paper. If possible all pupils should have the opportunity to carry out this activity.



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. Evaporating solutions	A soluble substance can be recovered from a solution by evaporation.
5. Changing phase	A change of phase is a physical change since there is no change in the composition.
C. Chemical properties	All substances have special chemical properties.
1. Ability to react with	Substances show varying degrees of ability to react with other substances.
a. oxygen	When substances combine with oxygen and there is noticeable light and heat given off, rapid oxidation or burning is occurring.
	Some substances react with oxygen without any noticeable heat and light being given off. Such reactions are examples of slow oxidation.
b. water	Some substances react with water.
c. an acid	Some substances react with acids.
d. a base	Some substances react with bases.

MATERIALS	ACTIVITIES

MATERIALS

watch crystal or evaporating dish
heat source
sodium chloride
Wood's metal
test tube

KEY WORDS

acid
light
oxidation
react
solution

ACTIVITIES

EVAPORATING SOLUTION

Assemble apparatus needed for evaporating a solution.

Recall the safety rules to be observed during the evaporation of a solution: Keep equipment being heated at the back of the desk. Keep the face away from the work area.

Rapidly evaporate a saturated sodium chloride solution. Call the pupils' attention to the spattering of the solid salt particles. Remind the pupils that the salt particles are "boiling" hot.

Have pupils evaporate about 20 ml. of sodium chloride or copper sulfate solution. Remind pupils to remove the heat before all the liquid has been evaporated to prevent possible decomposition of the solid.

CHANGING PHASE. Melt a few grams of Wood's metal in a Pyrex test tube. Pour the liquid metal into a lightly greased dish or on the demonstration desk. Compare the properties of the alloy as it changes from a liquid and back to a solid.

Wood's metal can be obtained from most chemical supply houses.

VARYING DEGREES OF CHEMICAL ACTIVITY

TEACHER DEMONSTRATION ONLY. Show that elements and compounds have varying degrees of chemical activity.

Using a copper strip, an iron nail, an aluminum strip, a magnesium ribbon, calcium metal turnings, charcoal lumps, and copper sulfate crystals, demonstrate the following reactions and compare the results. In no case use more than one small piece of calcium turnings.

(a) Ability to Combine With Oxygen. Heat a small piece of each substance in the oxidizing flame. Use long handle tongs to hold the substances as they are heated. Note the rate of reaction.

Caution pupils not to look directly at the flame in which the object is being heated. Vigorous reactions, such as those with magnesium or calcium, can produce harmful rays which may injure the eyes.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

(b) Ability to Combine With Water. Drop a piece of each substance into a few milliliters of cold water. Note any evidence of a chemical action.

(c) Combining With an Acid. Put a tiny piece of each substance into a few milliliters of dilute hydrochloric acid. Note any evidence of chemical action.

(d) Reacting With Bases. Add a tiny piece of each material into a few milliliters of dilute sodium hydroxide solution.

(e) Comparing Results. Tabulate the results of each of the above reactions so that pupils may compare the differing degree, if any, with which each substance reacts with oxygen, water, an acid and a base.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Chemical changes	Matter can be changed chemically.
	Chemical change results in the formation of one or more mew substances, each having its own properties by which it is recognized. The properties of the original material can no longer be detected since the material no longer exists.
	Chemicals react according to a definite combining ratio. If the correct ratio is not used, the excess reagent will not combine and may be identified.
1. energy needed	A chemical reaction involves a specific amount of energy before the reaction can occur. The energy may be taken in or given off and may be in such forms as heat, light, or electricity.
a. heat	When heat is absorbed during a chemical change, the action is called endothermic. Some or all of the products formed by endothermic reactions tend to be unstable and explosive. Nitrogen compounds are in this class.

MATERIALS

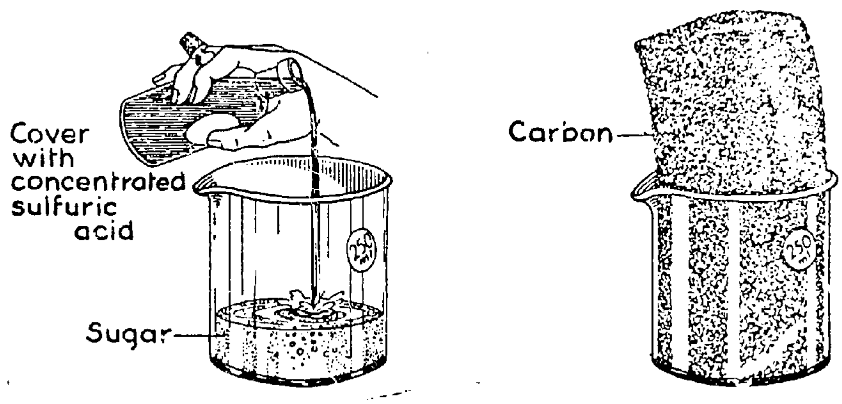
sugar
concentrated
 sulfuric acid
beaker
test tube
mercuric oxide
heat source
copper sulfate
rock salt
washing soda
alum

KEY WORDS

chemical change
combining rate
definite
detected
electricity
endothermic
formation
identified
original
reagent
specific
unstable

ACTIVITIES

Put four tablespoonfuls of ordinary sugar into a 250-ml. beaker. Add sufficient concentrated sulfuric acid to thoroughly wet the sugar. After the reaction occurs discuss the evidences of a chemical change, including the heat produced by the reaction. Observe care in handling the sulfuric acid and in disposing of the black mass of porous carbon that results.



Demonstrate the decomposition of mercuric oxide by heating. Put about one-half teaspoonful of mercuric oxide in a Pyrex test tube and heat with a Bunsen burner. Use a test tube holder and clamp it next to the mouth of the tube. Call attention to the little drops of mercury that form on the sides of the tube. Test the gas produced with a glowing splint to show that it is oxygen.

Heat some dry copper sulfate (blue vitriol) crystals in a Pyrex test tube, supporting it so that the mouth is pointed slightly downward. Steam (water) is driven out as the crystals are heated. Heat the entire tube as uniformly as possible to prevent condensed water from running back and cracking the glass. Notice that the copper sulfate has lost its blue color and is almost white. If some water is added to the white powder after it has cooled, the blue color returns.

Repeat this procedure with some rock salt crystals, washing soda, alum and other crystalline substances. Notice that some of these substances contain water and others do not. This combined water is known as water of crystallization.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

b. eelectricity

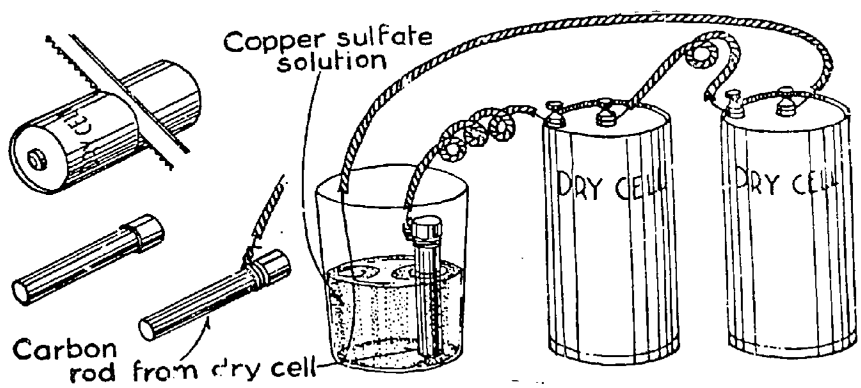
MATERIALS

carbon rods
dry cells
beaker
wire
copper sulfate solution
test tubes
water
dilute sulfuric acid

KEY WORDS

ACTIVITIES

Electricity is used in many ways to produce chemical changes. Attach a carbon rod from an old dry cell or flashlight cell to the negative terminal of a battery by means of a wire. Lower this rod into a beaker of copper sulfate solution. Connect a wire to the positive terminal of the cell and place the opposite end in the solution. A coating of copper will be deposited on the carbon. Metal objects may also be plated with copper in this way.



Show that water can be taken apart by energy of electricity. Remove the carbon rods from two old flashlight cells and connect these by means of wires to four dry cells in series, as shown in the diagram. Pour half a test tube full of dilute sulfuric acid into half a glass of water. Fill two test tubes with this solution and invert them over the carbon rods. Notice the bubbles of gas that rise and collect in the tubes.

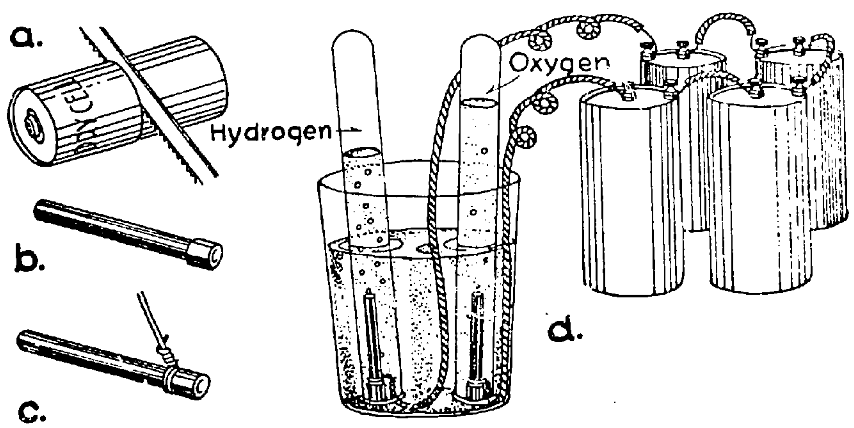
When the first tube is filled with gas, cover the mouth with your thumb; remove the tube and replace it with another. Test this gas with a burning splint. The gas is hydrogen, which ignites when it combines with oxygen from the air. Notice that water forms on the inside of the test tube.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Test the gas in the other test tube, when it is full, with a glowing splint. The oxygen causes the splint to burst into flame and burn brightly. Point out that two test tubes of hydrogren are produced to every one of oxygen.



Note: Where available, a source of low voltage D.C. current should be substituted for the dry cell batteries.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. light	
2. energy produced	Heat, light, or electricity may be produced by chemical action.
a. heat	When heat is produced by a chemical change, the action is called exothermic. The products formed by exothermic reactions tend to be stable.
b. light	
c. electricity	

MATERIALS

matches
candle
beaker

KEY WORDS

exothermic

ACTIVITIES

LIGHT AND CHEMICAL CHANGE

Obtain a precipitate of silver chloride by adding some dilute silver nitrate to sodium chloride solution. Note the white color of the silver chloride solid. Set the silver chloride in sunlight. Observe how the color changes over a period of time. The sun causes the silver chloride to decompose. Relate the activity to the use of silver chloride in the film used in cameras.

CAUTION. Silver nitrate makes a caustic solution which can cause serious burns. Use only very dilute solutions and be careful not to get the silver nitrate on the skin.

Light a candle and point out some of the physical and chemical changes that are taking place. Emphasize the role of heat in changing the solid paraffin to liquid, the capillary action of the wick, the change of the liquid to vapor and the final chemical change as the vapor burns. Point out that all liquid and solid fuels change to a vapor before burning.

Hold a cold glass vessel over a candle flame so that moisture condenses upon it.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

copper strip
zinc strip
wire
galvanometer
water (tap and distilled)
sodium chloride
sugar
vinegar
eye
alcohol
baking soda
tin strip
steel strip
lead strip
aluminum strip

ACTIVITIES

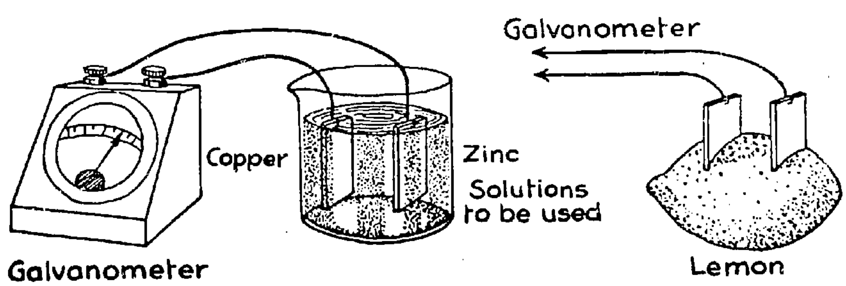
Burn magnesium ribbon. (The light from burning magnesium contains harmful ultra-violet rays. Do not look directly at any vigorous reaction producing light.)

Cut a strip of copper about 8 cm. long and 1¼ to 2 cm. wide. Cut a similar strip of zinc. Fasten a wire to each and connect the wires to a galvanometer. Touch the copper and zinc together. Observe that there is no indication of an electric current. Dip the strips into a jar containing distilled water. Repeat the procedure, using in succession, tap water, salt water and solutions of other common substances such as sugar, baking soda, vinegar, lye and alcohol. Rinse in clean water after each trial. Make a list of solutions by which the galvanometer indicates that a current is produced.

Try two strips of other metals such as tin, steel, lead and aluminum. For one experiment use two strips of the same metal. List the essential parts of a simple cell.

As a final step insert the strip of copper and the strip of zinc into a lemon and observe the action of the galvanometer. Use other fruits which contain acid and compare the results.

KEY WORDS



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. changing the rate of reaction	The rate at which a reaction occurs can be changed.
a. catalyst	A catalyst is a substance which can change the rate of a chemical action without its own composition being changed at the end of the reaction. A catalyst may be <u>any</u> substance which accelerates or decelerates a chemical reaction. (Some catalysts temporarily enter into the reaction to form complex substances which immediately produce new substances and release or reform the catalyst. Other catalysts do not directly enter the reaction but collect gas molecules to their surfaces. The gas molecules coming into closer contact combine with each other more rapidly.)
b. concentration	As the concentration of the materials increases, the rate of the reaction generally increases and may get cut of control. For this reason use only small amounts of reacting substances. According to the law of mass action, tne reaction velocity varies directly with the product of the concentration of the reactants.

MATERIALS

dilute solution of sulfuric acid
beaker
copper strip
zinc strip
voltmeter
wire
bell/buzzer

ACTIVITIES

Prepare a dilute solution of sulfuric acid by slowly adding one part acid to 10 parts of water in a Pyrex beaker. When the acid is cool put a fresh copper strip into the solution. Observe that there is little evidence of chemical action. Next put a new strip of zinc into the solution. Observe the formation of bubbles of a gas which indicates that chemical change is taking place. Also examine the surface of the zinc after it is removed from the acid.

Put both the copper and zinc strips into the acid and connect to a voltmeter. Observe the voltage and then connect the wires to an electrical bell or buzzer.

The explanation should be limited to the idea that as a result of chemical action the zinc tends to develop a negative charge (an excess of electrons) and the copper a positive charge (a scarcity of electrons). When connected by a conductor, electrons flow from the zinc to the copper.

MATERIALS

hydrogen peroxide (3%)
manganese dioxide
splint
graduate

USING A CATALYST IN A CHEMICAL CHANGE

Put 10 ml. of 3 per cent hydrogen peroxide into a test tube. After a few minutes observe the bubbles which have appeared. Insert a glowing splint into the mouth of the test tube and note that little or no oxygen is given off.

Sprinkle about one-quarter teaspoonful of manganese dioxide into the hydrogen peroxide. Observe that the gas bubbles form faster. Test the gas with a glowing splint.

The use of any hydrogen peroxide stronger than 3 per cent is not recommended. The 3 per cent hydrogen peroxide is the solution used as an antiseptic and may be obtained at drug stores.

MATERIALS

sodium thiosulfate
water
graduate
beakers
hydrochloric acid
lined paper

EFFECT OF CONCENTRATION UPON VELOCITY OF REACTION

Make a solution containing approximately 10 gm. of sodium thiosulfate (hypo) in 100 ml. of solution.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Into three 150-ml. beakers, place 10.0 ml., 5.0 ml., and 2.5 ml. of solution. In the second and third beakers add 5.0 ml. and 7.5 ml. of water respectively so that each beaker contains 10 ml. of solution. Place the beakers over a sheet of lined paper on a table.

Add 10 ml. of hydrochloric acid (approximately 1N) to each beaker. View the lines on the paper by looking down through the solution. White colloidal sulfur forms in each case. With a stop watch determine the times required for the mixture to become opaque enough to make the lines invisible. Pretest the experiment and adjust the normality of the HCl if the time of reaction is not satisfactory.

(Traces of poisonous sulfur dioxide may be observed from this reaction. Be sure to have the room well ventilated while the experiment is being done.)

KEY WORDS

accelerate
catalyst
complex
concentration
decelerate
law of mass action
rate

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. temperature	As the temperature increases, the rate of the reaction usually increases and may get out of control. For this reason, do not heat chemicals unless told to do so. Then carefully follow all directions for heating.
d. surface area	The smaller the particles of reactants are, the faster they combine.
	Many reactions are safely carried out by using solutions of the reactants.
e. other factors	There are other factors such as pressure of combining gases and the nature of the reactants that affect the rate of reaction.

MATERIALS	ACTIVITIES
	EFFECT OF TEMPERATURE ON VELOCITY OF REACTION
	Use the procedure listed in the previous activity, but keep the volume of hypo constant at 10 ml. Vary the temperature of the hypo. Graph the results.
	To get the varying temperature of hypo, bring some of the solution to a boil. As the solution cools, the desired quantities of hypo solution can be removed at different temperatures.
can with friction top funnel rubber tube candle lycopodium powder/ cornstarch	Cut a round hole in the bottom of a large metal can having a friction top. Put a funnel through the hole from the inside and attach a rubber tube to it. Put a teaspoonful of lycopodium powder or cornstarch into the funnel. Set a lighted candle beside it and put on the cover. Attach the end of the rubber tube to a small air pump and blow a sharp blast of air into the can. A dust explosion results because the surfaces of many particles of powder are in contact with the oxygen of the air and the flame spreads quickly. The lid of the can is blown off because of the rapid expansion of air due to sudden heating.
steel wool asbestos pad bunsen burner iron powder magnesium ribbon copper strip	Heat several different metals to illustrate some of the conditions which cause them to oxidize. Place some shreds of steel wool on an asbestos pad and ignite them with a bunsen burner. Try to ignite solid pieces of iron. Sprinkle some iron powder into a bunsen burner flame. Call attention to the relation between the amount of surface exposed to the air and the ability of a metal to burn.
KEY WORDS combining gases nature pressure reactants	Hold a strip of magnesium ribbon and a strip of copper in the flame and compare the reactions and the products.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
III. Introduction to Atomic Structure	Atoms occur singly as the smallest particles of an element that can exist and still retain the physical and chemical properties of the element.
	An atom consists of a nucleus around which one or more electrons may be found.
	An atom can be considered to be mostly empty space.
	For most practical purposes, the entire mass of an atom may be considered to be in the nucleus.
	There is no balance sensitive enough to weigh an atom. The atomic weight is the weight of an atom as compared with the weight of a carbon atom taken as 12 units.
	The atomic weight of an atom is a relative weight in comparison to the weight of an arbitrary standard. (Atomic weight is more properly called atomic mass.)
	One standard is the 12.00000 units taken as the weight (mass) of the carbon-12 isotope. Chemists and physicists use this standard.
	Another standard is the mass number which is based upon the sum of the nucleons (protons and neutrons) each with a mass of one unit. Nuclear scientists use the mass number standard.
A. Some Atomic Particles	An atom contains protons, neutrons, and electrons.
1. nucleons	The protons and neutrons are concentrated in the central part of an atom called the nucleus. They are called nucleons.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
a. protons	
(1) charge	The proton carries a single positive charge.
(2) mass	The proton has a mass equal to one unit. (The mass of a proton or of a neutron is considered to be one unit. An "isolated" proton actually has a mass of 1.0081 units, and an "isolated" neutron has a mass of 1.0087 units. However, when the protons and neutrons make up a nucleus, some of their masses have been converted into energy.)

MATERIALS

ACTIVITIES

KEY WORDS

arbitrary
atom
atomic weight
charge
electron
isolated
mass number
neutron
nucleus
nucleon
positive
proton
standard
structure

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
(3) atomic number	The atomic number of an atom indicates the number of protons the atom contains. This is also equal to the number of electrons in the atom. Each kind of element has its own atomic number. No two elements can have the same number of protons in the nuclei of its atoms.
b. neutrons	
(1) charge	A neutron has no electrical charge; it is neutral.
(2) mass	The neutron has a mass equal to one unit.
(3) number of neutrons	The number of neutrons can be found by subtracting the atomic number from the mass number of the atom.
2. electrons	
a. charge	The electron has a single negative charge.
b. mass	The mass of an electron is so small in comparison to the mass of a proton that the mass of the electron is usually disregarded in determining the mass of an atom. The mass of the electron may be considered to be $\frac{1}{1836}$ of the mass of the proton.
c. location in an atom	Electrons are located outside of the nucleus and are distributed in the space which makes up most of the atom. In any atom there are as many electrons as protons.

MATERIALS

ACTIVITIES

KEY WORDS

atomic number
comparison
nuclei
neutral

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. The Bohr atom	Bohr's model of an atom is only one of a number of atomic models that have been proposed.
	There are more recent models of atoms which help explain more about the behavior of atoms than the Bohr model can.
	The Bohr model has been proved only as far as the hydrogen atom is concerned.
	The Bohr model serves quite well to illustrate atomic number, atomic weight, the principal valences, and many chemical combinations of the first twenty elements.
	The statements in this outline concerning the Bohr atom refer only to atoms with atomic numbers 1 - 20. Representations of atoms with atomic numbers greater than 20 are complicated by exceptions to the simple rules stated.
1. the nucleus	The atomic number indicates the number of protons in the nucleus. (This is often represented by the symbols, P or +.)
	The difference between the mass number and the atomic number represents the number of neutrons in the nucleus. (This is often represented by the symbol, N.)
2. energy shells	The electrons are located outside of the nucleus. Where they are depends upon how much energy they have.

MATERIALS

ACTIVITIES

CONSTRUCTING ATOMIC MODELS

Using the chart below, pupils should be instructed how to prepare atomic model diagrams. Reference should be made at this point to the use of the Periodic Table in supplying the information given in the chart.

Atomic Number	Element	Symbol	Atomic Weight	Protons	Neutrons	Electron Arrangement
1	Hydrogen	H	1	1	0	1
2	Helium	He	4	2	2	2
3	Lithium	Li	7	3	4	2,1
4	Beryllium	Be	9	4	5	2,2
5	Boron	B	11	5	6	2,3
6	Carbon	C	12	6	6	2,4
7	Nitrogen	N	14	7	7	2,5
8	Oxygen	O	16	8	8	2,6
9	Fluorine	F	19	9	10	2,7
10	Neon	Ne	20	10	10	2,8
11	Sodium	Na	23	11	12	2,8,1
12	Magnesium	Mg	24	12	12	2,8,2
13	Aluminum	Al	27	13	14	2,8,3
14	Silicon	Si	28	14	14	2,8,4
15	Phosphorus	P	31	15	16	2,8,5
16	Sulfur	S	32	16	16	2,8,6
17	Chlorine	Cl	35	17	18	2,8,7
18	Argon	Ar	40	18	22	2,8,8
19	Potassium	K	39	19	20	2,8,8,1
20	Calcium	Ca	40	20	20	2,8,8,2

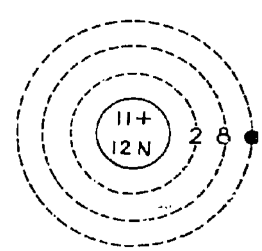
Although the pupil should realize that the probable arrangement of the electrons is three-dimensional and rather vague, the two-dimensional diagram is generally satisfactory for elementary explanations and is easier to draw.

KEY WORDS

Bohr
energy shell
illustrate
symbol

In order to prevent misinterpretation due to vague or crowded diagrams, a relatively uniform system of representation should be used. It is suggested that acceptable diagrams include the following features.

- A title beneath each diagram such as "Sodium Atom"
- The nucleus represented as a circle at least ½ inch in diameter
- In the nucleus the numbers of protons and neutrons clearly indicated by number and code such as protons (11+ or 11P) and neutrons (12N)



Sodium Atom

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

The completed inner shells represented by dashed arcs or circles about ¼ inch apart with numbers placed on each arc or circle to represent the number of electrons in each completed shell

The outer (valence) shell represented by a dashed circle with a radius about ¼ inch larger than the radius of the preceding arc and electrons in the valence shell clearly shown as solid circles or by "e"

(a) Draw circles on a large sheet of paper. Paste or fasten the paper on tackboard or heavy cardboard. Use thumbtacks of three colors to represent the particles.

(b) For use with an overhead projector draw circles on a sheet of clear acetate with acetate-type ink (available in art stores). With a paper punch, punch out the particles from pieces of colored acetate or cellophane. Static electricity helps hold the particles in position. The entire set may be conveniently stored in an envelope.

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

In the Bohr model electrons are considered to revolve around the nucleus in one of several concentric circular orbits.

In newer models of the atoms, the orbits (energy levels) are neither concentric nor always circular.

The orbits are called shells or rings and can be denoted by the letters K, L, M, N, O, P, or by the numbers 1, 2, 3, 4, 5, 6.

Electrons in orbits near the nucleus have less energy than those in orbits farther from the nucleus.

Electrons may be raised to a higher energy level by the addition of energy. When the electron drops back to a lower level, the energy which it has absorbed is released in the form of light. This accounts for the different colored flames which are produced when certain substances burn or are heated to incandescence.

MATERIALS

ACTIVITIES

TEACHER NOTE:

(The quantum-wave mechanics model of the atom is beyond the depth and background of most general science pupils. Teachers should be interested in this newer model since it gives more useful information than the Bohr atom. College and some high school chemistry textbooks describe this model in detail.)

KEY WORDS

concentric
energy level
incandescence
orbit
revolve
rings

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
a. electron distribution	There is a maximum number of electrons which each orbit can hold.
(1) K-shell	The first (K) shell can hold no more than two electrons.
(2) L-shell	The second (L) shell can hold no more than eight electrons.
	Atoms with atomic numbers 1 - 20 can have no more than eight electrons in the third (M) shell.
b. classification of elements	Elements may be classified as metals, nonmetals, or inert elements depending on the number of electrons in the outermost shell.
(1) metals	Atoms with 1, 2, or 3 electrons in the outermost shell are classified as metals. They will react with nonmetallic atoms.
(2) nonmetals	Atoms with 5, 6, or 7 electrons in the outermost shell are classified as nonmetals and they will react with metallic atoms.
(3) metalloids	Some elements with 3, 4, or 5 electrons in the outermost ring may have properties of both metals and nonmetals. (These should probably not be discussed as a class topic at this point in the study of chemistry.)
(4) inert elements	Atoms with full outside shells are classified as inert elements since they seldom enter into any chemical action.

MATERIALS

ACTIVITIES

KEY WORDS

classification
distribution
inert
metalloids
non-metals

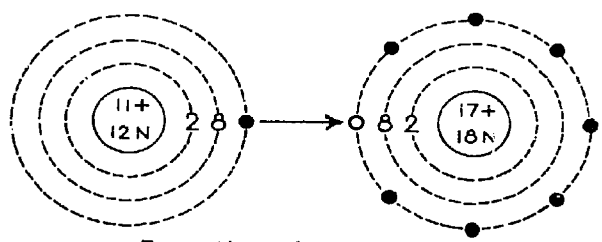
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. chemical action	The number of electrons in the outermost shell determines the way in which an atom will react chemically. During chemical action, the atoms of metals and nonmetals try to form complete outer rings in which condition they are the most stable. Metals tend to lend all of the electrons in the last shell in order that a completed outermost shell remains. Nonmetals tend to borrow electrons in sufficient quantities to bring the electron number to the maximum amount for the outside ring. The particle gets ring completeness. When an atom either borrows or lends electrons, it becomes a charged particle (ion) because the number of electrons no longer equals the number of protons. There are always two oppositely charged kinds of ions formed during the lending and borrowing of electrons. The two particles arrange themselves in such a manner that they form a new compound. A loss of an electron produces a positively charged ion, while the gain of an electron produces a negatively charged ion. A deficiency of electrons (s) is noted by a plus sign; an excess of electrons (s) by a minus sign. In the solid state the ions assume definite positions in a crystal lattice. The oppositely charged particles are held in place by electrostatic attraction.

MATERIALS

ACTIVITIES

REPRESENTING A CHEMICAL CHANGE WITH ATOMIC MODEL DIAGRAMS

In diagraming the probable structure of ionic compounds, use an arrow to show the shifting of a valence electron to its new position. The shifting electron(s) may be shown as solid circles in the original position and as open circles in the new position.



Formation of Sodium Chloride

KEY WORDS

attraction
borrow
chemical action
chemically
crystal lattice
deficiency
electrostatic

lend
sufficient

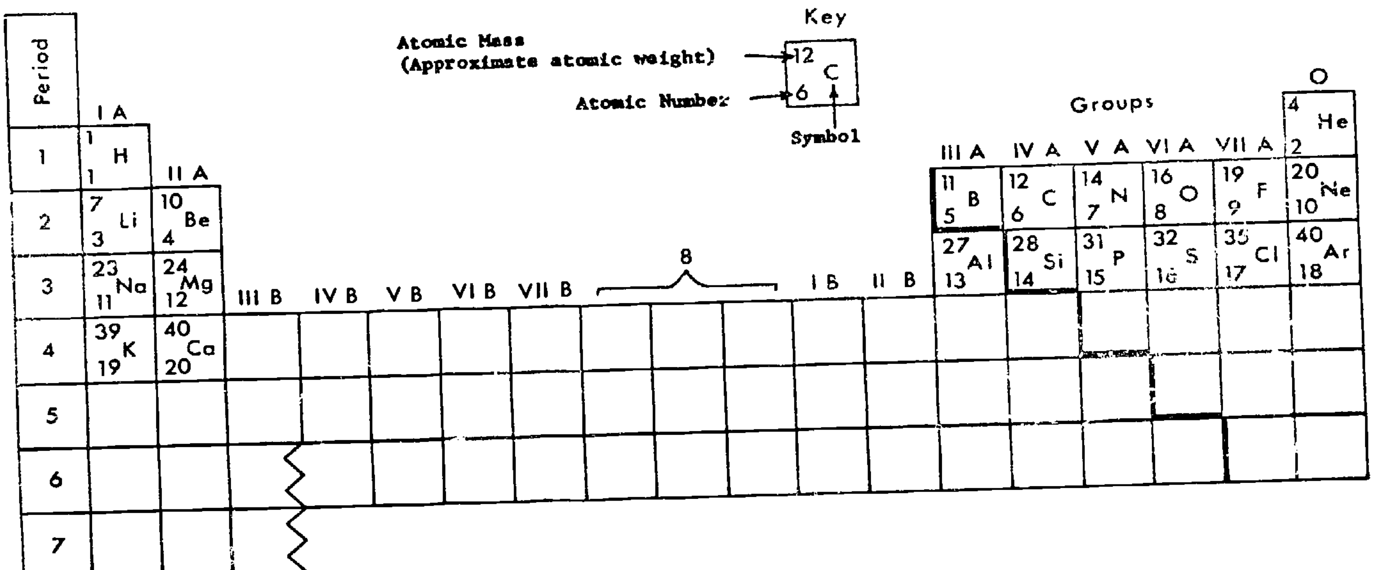
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. The periodic table	The value of the periodic table lies in its usefulness to scientists and others who study chemistry.
	Early periodic tables based upon atomic weights led to predictions of properties of elements that were not known at the time. These predictions led to the discovery of many elements.
1. purpose	The periodic table is used to organize and classify a large body of information about the elements.
	The elements in the modern periodic table are arranged according to increasing atomic numbers in such a way that similarity is shown between numbers of shells and numbers of electrons in the outermost shells.
2. key	Before the table can be read correctly, its key must be understood.
	The key shows the symbol of an element, its atomic number, and its atomic mass (weight). (Any reference table may have a key and the table cannot be correctly used until the key is understood.)
	Since isotopes in different concentrations may be present within a sample of an element, any determination of atomic weight may represent an average rather than a specific atomic weight. The mass number of the most common isotope of the element can be usually obtained by rounding off the atomic weight to the nearest whole number.

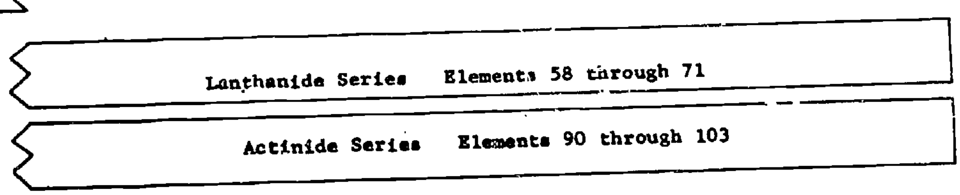
MATERIALS

ACTIVITY

THE PERIODIC TABLE

Trace the outline and boxes of the periodic table shown. Transfer the "skeleton" to a stencil or ditto master, and duplicate enough copies so that each pupil may have one. Refer to the activity on page J-61 for the electron arrangement of the first 20 elements.





KEY WORDS

average
classify
isotope
key
organize
periodic table
prediction
rounding-off
whole number

REFFRENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Have the pupils number the periods and groups and mark the zig-zag line running from boron to the bottom of period 6. With a crayon or colored pencil shade in the area between the period numbers and the zig-zag line. Label the area metals. The area between the zig-zag line and group 0 should be shaded with another color and be labeled non-metals. A third color may be used to tint group 0 which is labeled inert gases.

Name several elements and ask the pupils to use the periodic table to determine whether the elements are metallic, nonmetallic, or inert gases.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. arrangement	The elements are arranged in columns and rows. The columns going down the table are called groups. The rows going across the table are called periods.
a. groups	Groups contain elements which have similar chemical properties.
	Elements within a group have the same number of electrons in the outermost shell.
	Some groups have special names such as group 7A which is known as the halogens and IA as the alkali metals.
b. periods	The horizontal rows are called periods. Each period contains all the elements which have the same number of electron shells.
	Sometimes a period is called a series.
	The period number corresponds to the number of shells or orbits.
4. use of table	
a. predicting properties of elements	The location of an element on the table generally indicates the type of element it is. Knowing the type of element, one can expect the element to have chemical properties similar to the other elements of the same group.

MATERIALS

ACTIVITY

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
(1) metals	Elements found left of the heavy black line, which runs step-wise from boron (B) to the bottom of period 6, are generally classified as metals. More elements are classified as metals than as nonmetals.
(2) nonmetals	Elements between the heavy black line and group 0 are classified as nonmetals.

MATERIALS

ACTIVITIES

KEY WORDS

alkali
families
groups
halogens
periods
series

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
(3) metalloids	Elements found along this line are classified as metalloids for they exhibit both metallic and nonmetallic properties. These elements act as the "turning point" within groups such as 5A and 6A which contain typical nonmetals at the top and metals at the bottom of the group.
(4) inert elements (rare gases)	Elements in group 0 constitute a special group which do not readily react. They are called noble gases, rare gases, or inert gases. Members of group 0 are unique in that they are the only elements to have both electrical balance (equal number of protons and electrons) and a full electron load in the outermost orbit. Other atoms have electrical balance but do not have a full electron load in the outside orbit. When these atoms react, they tend to complete the outer orbit in some way.
b. predicting activity of elements	
(1) metals	Metals usually react because they lend electrons. In those metals whose outer electrons are furthest from the nucleus, the outermost electrons are attracted least by the nucleus and are most easily lost. Therefore, the metals at the bottom of the table are the most active.
(2) nonmetals	When nonmetals react with metals, the nonmetals gain electrons. In those nonmetals whose outer electrons are nearest the nucleus, additional electrons are attracted to the nucleus most easily. Therefore, the nonmetals at the top of the table react most easily with metals.

MATERIALS

ACTIVITIES

KEY WORDS

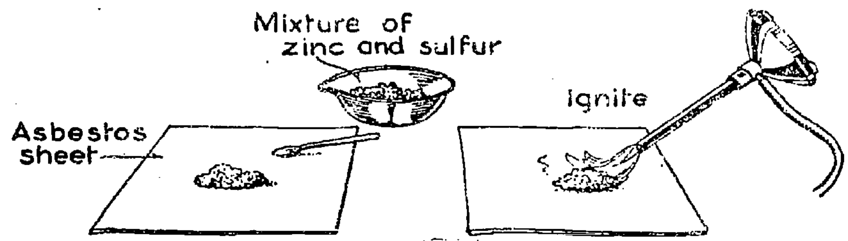
chemical balance
electrical balance
inert gases
metallic
noble gases
non-metal
rare gases

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
IV. Common chemical changes	A chemical change produces one or more new substances, each having its own set of properties by which it can be recognized.
A. Reacting substances	Two substances may react to form one or more new substances. The products formed depend upon the nature of the reacting substances.
1. two elements combining to form a single compound	Two elements may combine to form a single compound.
a. product formed	A metal combines with a nonmetal to form a compound known as a salt. The metallic atoms lend electrons to the nonmetallic atoms during the reaction.
	A nonmetal may combine with another nonmetal. Electrons are not loaned but are shared by both kinds of atoms. Carbon dioxide, sulfur dioxide, and the oxides of nitrogen are examples of compounds formed by two nonmetals sharing electrons in covalent bonding.
	Oxygen unites with most elements to form oxides.
	There are instances where a metal will combine with another metal. During the formation of an alloy, some metals combine. Some examples are copper and tin forming CuSn and copper and aluminum forming $CuAl_2$.

MATERIALS

asbestos sheet
zinc
sulfur
bunsen burner

ACTIVITIES



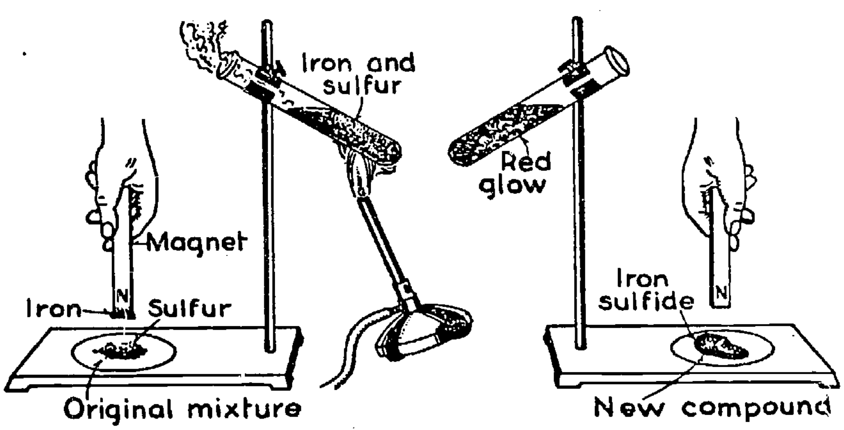
The chemical union of a metal and a nonmetal is shown effectively by the reaction between zinc and sulfur. Mix a pinch of powdered zinc with a pinch of powdered sulfur and place the mixture in the middle of a large asbestos pad. Ignite the mixture with a bunsen burner flame after making sure that pupils are at a safe distance from the desk. Discuss the evidences of a chemical change and develop the word equation for the reaction.

magnet
ringstand
clamps
test tube
iron powder (filings)
sulfur
heat source

KEY WORDS

alloy
chemical combination

Mix 7 gm. of iron powder or iron filings and 5 gm. of powdered sulfur. Test the mixture with a magnet and point out that the iron and sulfur may be separated in the mixture. Pour the mixture into a Pyrex test tube and support the test tube in a clamp on a ringstand. Heat the mixture gently at first and then strongly. Keep the flame in motion so as to heat the tube uniformly. When the contents of the tube begin to glow, remove the heat and call attention to the evidence



of a chemical change. When the tube is cool, wrap it in a piece of cloth and break it with a hammer. Test the mass with a magnet to show that a new nonmagnetic substance, iron sulfide, has been formed.

EFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. naming the product	If a compound is composed of only a metal and a nonmetal, the name of the compound contains two parts. The first part is the name of the metal; the second is the name of the other element with its name ending changed from -ine or -en to ide. (Examples - chloride, oxide) Compounds ending with the letters -ite or -ate contain three or more elements, one of which is oxygen.
2. an element and a compound reacting	In some chemical reactions, one of the elements in a compound replaces another element. When a metal and a compound containing a metal react, the metal replaces the metal in the compound and a different compound is formed. When a nonmetal and a compound containing a metal react, the nonmetal may replace the nonmetal in the compound and a different compound is formed.

MATERIALS

beaker
copper sulfate solution
iron nails

test tubes
evaporating dish
splints
heat source
copper
zinc
iron
aluminum
dilute hydrochloric acid

KEY WORDS

chemical replacement

ACTIVITIES

TEACHER NOTE:

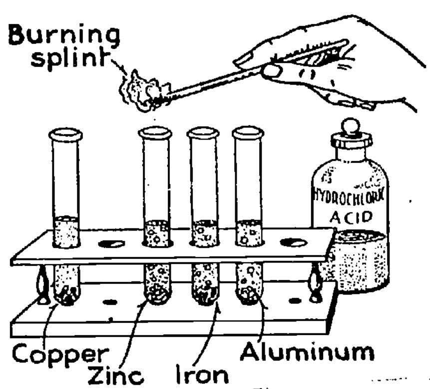
It is not advisable at this level to consider any situation in which a metal replaces a nonmetal.

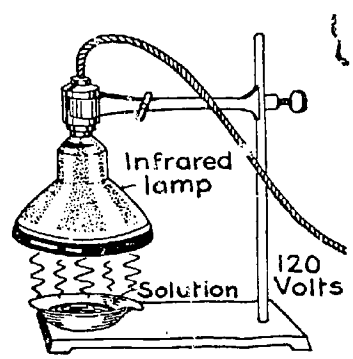
Although hydrogen may be classed as a nonmetal, it is advisable at this level to consider it as a metal since it has many chemical properties similar to those of a metal.

Drop a few iron nails into a beaker containing copper sulfate solution. After a short time remove the nails and dry them with a soft cloth. Pass the nails around the class and ask for explanations of the chemical change.

Develop the idea that some metals are able to displace other metals from certain compounds in solution.

Demonstrate that some metals are able to displace hydrogen from acids. Put pieces of zinc, iron, aluminum and copper in four separate test tubes in a rack.





Add an equal amount of dilute hydrochloric acid to each. Observe the reaction in each tube and test the gas produced with a burning splint. Develop a word equation for the reaction.

Since pupils will not see evidence of the salt formed, filter the solution from one test tube in which a reaction has taken place and evaporate the dissolved salt to dryness.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

An effective way to evaporate a solution is shown in the diagram. An infrared lamp is supported as shown and the material being evaporated is poured into a watch glass or evaporating dish and placed a few inches below the lamp.

USING AN OVERHEAD PROJECTOR TO SHOW REACTIONS

Many interesting details of the reaction between an element and a metallic compound can be observed when they are projected on a screen by an overhead projector.

Silver Trees. Put some silver nitrate solution in a petri dish set on the stage of an overhead projector. Drop a length of copper turning or wire into the solution. After a few minutes a silver "tree" will grow and a blue copper nitrate area will appear around the "tree." The speed with which the "tree" grows depends upon the concentration of the silver nitrate solution.

Similar trees can be grown from zinc, magnesium, or lead placed in a silver nitrate solution. The rate of growth will vary with the activity of the metal. Since the nitrates of these metals make colorless solution, no color will appear around the trees.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
a. activity of elements	Each element has its own degree of chemical activity. An element can replace only those elements which have a lower degree of activity than it has. An element in a compound can be replaced by any element more active than it is.
b. predicting the reaction	The elements may be listed according to their degrees of activity. The list is called an activity or electrochemical series. The activity series may be used to predict whether an element and a compound will react. The most active metals are found at the top of the series. A metal can replace any metal listed below it in the activity series. The most active nonmetal is found at the bottom of the activity series. A nonmetal can replace only those nonmetals listed above it in the electrochemical series.

MATERIALS

ACTIVITIES

REACTION RATE VARIES WITH THE ACTIVITY OF A METAL

Place two petri dishes on the overhead projector, and into each dish pour the same amount of dilute hydrochloric acid. Simultaneously drop a small piece of zinc into one dish and a small piece of magnesium into the other dish. Compare the size and number of gas bubbles that are formed. (If the metal is tarnished, it should be cleaned before adding it to the acid.)

Other combinations of metals may be used. Copper wi l not react with the acid. Relate its behavior to the activity series.

SINGLE REPLACEMENT REACTIONS

Give each pupil a piece of copper, zinc, lead, and iron nails. Also have available the following solutions: silver nitrate (2 grams/liter), copper sulfate, ferrous (iron) chloride, and sodium chloride.

Instruct the pupils to place a clean piece of one of the metals into 5 to 10 ml. of any one of the solutions in a test tube. After five minutes observe the metal and note any formation of a deposit or change in the color of the solution. Identify the products by writing a word equation. Check the activity chart shown below to determine if the reaction should occur.

KEY WORDS

activity
activity series
chemical replacement
souble replacement
electrochemical series
simple replacement

ACTIVITY SERIES

Metals

(K) Potassium
(Ca) Calcium
(Na) Sodium
(Mg) Magnesium
(Al) Aluminum
(Zn) Zinc
(Fe) Iron
(Ni) Nickel
(Sn) Tin
(Pb) Lead
(H) Hydrogen
(Cu) Copper
(Hg) Mercury
(Ag) Silver
(Au) Gold

Nonmetals

(F) Fluorine
(Cl) Chlorine
(Br) Bromine
(I) Iodine

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

(A complete electrochemical series includes the nonmetals. In this case the most active nonmetal appears at the bottom of the chart.

The nonmetals are sometimes listed in a separate activity list with the most active nonmetal at the top of the list.)

For example, if iron and copper sulfate are placed together, there will be a reaction which forms iron sulfate and copper. Iron is more active than the copper and replaces the copper. If, however, copper and ferrous(iron) chloride are placed together, no reaction will occur since copper is less active than iron.

Pupils may repeat the procedure using different combinations of metal and solution. UNDER NO CIRCUMSTANCES should pupils be given potassium, calcium, or sodium for any laboratory activity. Require the identification of products to discourage pupils "playing" with chemicals.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. two compounds reacting to form two compounds	Two compounds may react to form one or more compounds. Usually two compounds exchange parts to produce two new compounds.
a. precipitation	When the solutions of two compounds are combined, one or both of the products formed may be insoluble. A precipitate is an insoluble substance formed during the reaction between two solutions.
(1) solubility table	A solubility table tells the degree of solubility of many substances. A substance can be described as soluble, slightly soluble, or insoluble. Actually any substance will dissolve to some extent in water. If, however, only a trace dissolves, it is said to be insoluble.
(2) predicting precipitation	The table of solubilities can be used to predict if a precipitate will be formed during a reaction between two solutions. After determining the possible products, use the solubility table to see if either product is insoluble. An insoluble product will appear as a precipitate and can be separated from the remaining solution by filtration.
B. Decomposition	A single substance may break up to form more than one substance.

MATERIALS

ACTIVITIES

PREPARING PRECIPITATES BY REACTING TWO COMPOUNDS

Make solutions of various compounds such as copper sulfate, barium chloride, potassium iodide, sodium bromide, aluminum sulfate, potassium dichromate, iron II (ferrous) sulfate, silver nitrate (2 grams/liter), and sodium hydroxide (4 grams/liter).

Tell the pupils that they can combine any of the solutions they wish as long as they do not use more than 5 ml. of any solution and use no more than two solutions at a time.

Require the identification of the precipitate. Pupils should write a word equation and then check the solubility of each product by referring to a table of solubilities. More advanced pupils may refer to a handbook for solubility of any substance not listed on the table of solubilities in the textbook.

TEACHER NOTE:

Pupils can predict the products to be formed by writing a word equation. Have the pupils draw a line between the two parts of each compound's name. The two "ends" combine and the two "middle" ones combine. Remind the pupils that the metal's name is always first in the name of the compound formed.

KEY WORDS

chemical decomposition
exchange
insoluble
precipitate
soluble
solubility table

REFERENCE OUTLINE

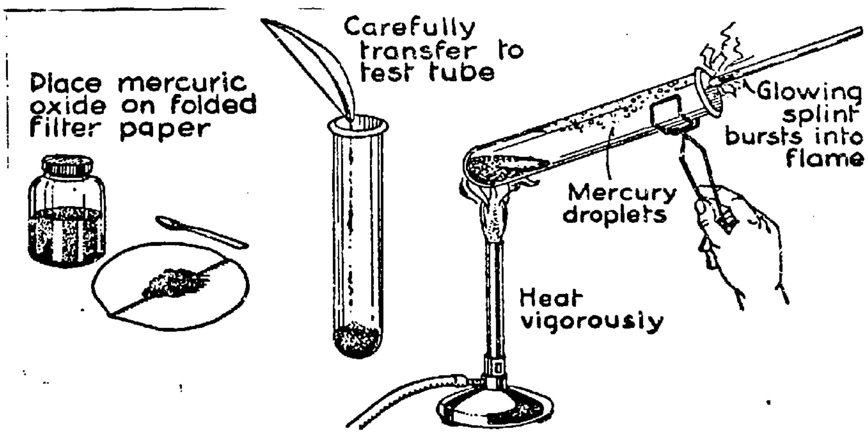
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

mercuric oxide
test tubes
heat source
splints

ACTIVITIES

Many new substances are produced by chemical changes in which compounds are "taken apart." The

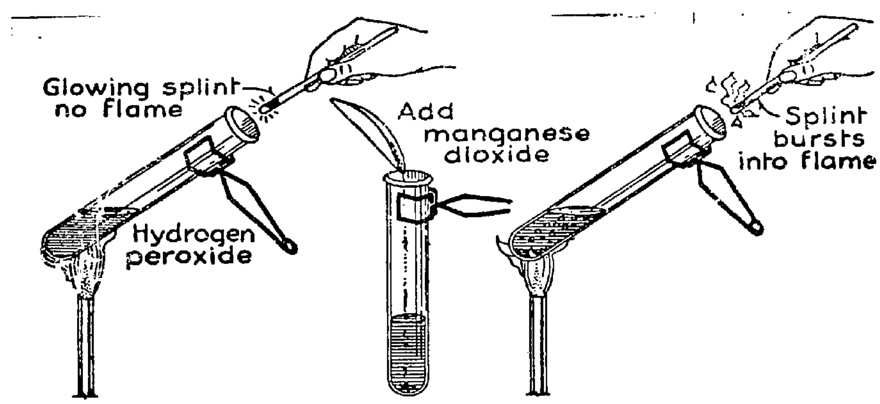


heating of mercuric oxide may be repeated with emphasis on the chemical change that occurs during the decomposition of the compound.

Demonstrate the proper way to transfer the mercuric oxide to the test tube without getting it on the sides of the tube. Heat to a high degree the lower part of the tube but keep it moving slightly as it is held in the flame. Call attention to the mercury deposit on the cooler portions of the tube and use a glowing splint to show the presence of oxygen. Develop the word equation to represent the chemical change.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
1. formation of two elements	Compounds containing only two elements may decompose to form a metal and a nonmetal.
	Compounds containing more than two elements may decompose to form new compounds or an element and a compound.
2. formation of other compounds	Some substances decompose to form one or more compounds.
3. use of energy	The energy lost during the formation of the compound must be restored during the decomposition process, therefore, decomposition reactions usually require energy in the form of light, heat, or electricity.
C. Chemical symbols	Symbols are used to represent elements and quantities of elements.
1. representing a name	A chemical symbol stands for the name of a specific element.
	A symbol is a contraction of a name of an element. The symbol may consist of a single capital letter or two letters, the first of which is always a capital letter and the other letter is always a small letter.

MATERIALS	ACTIVITIES
hydrogen peroxide test tube splints bunsen burner	Pour some hydrogen peroxide into a test tube and heat it gently. Insert a glowing splint into the mouth of the test tube and note that little or no oxygen is given off. Now add a little manganese dioxide and again heat the contents gently. Test with a glowing splint to show that oxygen is being liberated. Mention that the manganese dioxide is a catalyst and accelerates the decomposition of the hydrogen peroxide.



test tubes Hoffman apparatus	Water can be "taken apart" by an electric current. If a commercial Hoffman apparatus is available, it can be used to show the exact volume relation of the two gases produced, the extremely small amount of water that is decomposed and the slow burning of hydrogen at the jet.
KEY WORDS contraction symbol	

* LEARNING SOME OF THE MOST FREQUENTLY USED SYMBOLS

Pupils should learn the following symbols which are most frequently used in the science laboratory.

aluminum	Al	nitrogen	N
calcium	Ca	oxygen	O
chlorine	Cl	phosphorous	P
copper	Cu	potassium	K
hydrogen	H	sulfur	S
iodine	I	tin	Sn
magnesium	Mg	uranium	U
mercury	Hg	zinc	Zn

*Learning occurs best through association and use than through rote memorization.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

NAMING ELEMENTS

For enrichment have some pupils do library research to find how elements were named. Include in the list of elements the following: polonium, germanium, francium, americium, europium, einsteinium, fermium, indium, mendelevium, oxygen, plutonium, uranium, neptunium, curium, and helium. Ask the pupils to find why the symbol for tungsten is W.

Similarly, why the symbol for:

Iron is Fe

Silver is Ag

Gold is Au

Sodium is Na

Mercury is Hg

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	Some symbols are derived from the Latin names for the elements, e.g.; silver - Ag (Argentum), iron - Fe (Ferrum), lead - Pb (Plumbum), sodium - Na (Natrium), potassium - K (Kalium), gold - Au (Aurum), etc.
2. representing a quantity	A symbol stands for one atom of an element.
a. subscripts	A subscript placed after and slightly below a symbol indicates that there is more than one atom of the element. The number of atoms equals the numerical value of the subscript. When a subscript is not written after a symbol, it is understood that the subscript is 1. Cl_2 mean 2 atoms of chlorine. H_2O means 2 atoms of hydrogen and one atom of oxygen. However, H_2O_2 is an entirely different substance since it has two atoms of hydrogen and two atoms of oxygen. CO has 1 carbon atom and 1 oxygen atom but is not the same substance as CO_2 which has 1 carbon atom and 2 oxygen atoms. Other examples that might be used are H_2, N_2, O_2, NH_3, C_6H_6, CH_4, and NO_2.

MATERIALS

ACTIVITIES

USING SYMBOLS TO REPRESENT THE COMPOSITION OF COMPOUNDS

Select a few substances that have been used and display each one in a reagent bottle which bears the formula for the substance. Provide also a list of elements and their symbols. Ask the pupils to name the elements represented by the symbols in each formula and to give the number of atoms of each element as shown by subscripts.

TEACHER NOTE:

(Avoid using the formula for any ionic compound such as a salt. The formula indicates a ratio of ions in the crystal lattice, not the formula for a single molecule. Limit examples to formulas for gases or molecular compounds such as benzene (C_6H_6), methane (CH_4), or octane (C_8H_{18}).)

KEY WORDS

numerical
subscript

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. brackets or parenthesis	If a group of symbols are enclosed within brackets or parenthesis, each symbol is multiplied by the subscript following the brackets or parenthesis.
c. coefficients	A number preceding a symbol or a group of symbols is called a coefficient.
	A coefficient acts as a multiplier for all of the symbols following it in the compound.
	Coefficients are often used in chemical equations.
	Coefficients are usually found in an equation which is a chemical shorthand for expressing the amount and kinds of combining materials and products formed during a chemical action.
	2CO means 2 carbon and 2 oxygen atoms.
	$2\ CO_2$ means 2 carbon and 2 x 2 or 4 oxygen atoms.
	$2HgO \rightarrow 2\ Hg + O_2$ states that two groups each consisting of 1 mercury atom and 1 oxygen atom forms (decomposes) 2 mercury atoms and 2 oxygen atoms. The different kind of atoms are no longer chemically combined.
	$2HgO \rightarrow 2\ Hg + O_2$ can also be read: 2 moles of mercuric oxide decompose to yield 2 moles of mercury and 1 mole of oxygen.

MATERIALS

ACTIVITIES

KEY WORDS

EFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
. Common compounds and mixtures	
A. Compounds	A compound contains two or more elements chemically united.
	A compound has properties unlike its individual component parts; it is a homogeneous substance.

MATERIALS

ACTIVITIES

For enrichment the most capable pupils may be taught formula and equation writing. Consult a chemistry textbook for details.

KEY WORDS

brackets
coefficients
equation
expressing
formula
moles
multiplier
parenthesis

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
*1. weight of components	*Elements making up a compound have been united according to a definite proportion by weight.
	One way of finding the combining ratio uses the correct formula for a compound. Multiply the subscript by the atomic mass (weight) of each element. Set the values obtained in ratio form and reduce the ratio to its simplest value. Then set up the proportion, but be sure to keep the order consistent.
	Example: H_2O
	weight of hydrogen = 2 x 1 = 2 weight of oxygen = 1 x 16 = 16
	The ratio of 2:16 reduces to 1:8; therefore, $\frac{\text{weight of hydrogen}}{\text{weight of oxygen}} = \frac{1}{8}$
2. separation of compounds	The component parts of a compound can be separated by a chemical change.
3. classes of compounds	A compound may be an acid, a base, or a salt.
a. acids	The properties of a compound determine if it is an acid.
	Acids turn litmus red.
	Acids neutralize the effect of bases.
	Acids combine with many metals.

*optional

MATERIALS

dilute hydrochloric acid
water
graduate
test tubes
zinc
magnesium
copper
iron
splints
dilute sulfuric acid

KEY WORDS

acid
base
litmus
salt

ACTIVITIES

ACIDS COMBINE WITH SOME METALS

Before classtime prepare a quantity of dilute hydrochloric acid. Slowly pour, while stirring, a given quantity of concentrated acid into three times its volume of water. Plan on 50 ml. of dilute acid per pupil.

To calculate the volume of acid needed for a class, multiply the number of pupils by 12.5 ml. of acid. Add this acid to three times as much water.

(Before they start the exercise, instruct pupils to put baking soda on any acid spilled on the desk to neutralize the acid. A box of baking soda may be kept on each laboratory desk for such emergencies. Acid or base spilled on the skin should be washed off immediately with quantities of water.)

Label four test tubes 1, 2, 3, and 4. Put a piece of zinc in number 1, a 1-2-inch strip of magnesium ribbon in number 2, copper in number 3, and an iron nail in number 4. Pour 10 ml. of the diluted hydrochloric acid into each tube and note the relative speeds of the reactions. Test the gas formed by bringing a flaming splint to the mouth of each test tube. If there is a slight explosion, or if the gas burns, it is probably hydrogen. The word equation for the reaction in test tube number 2 is:

magnesium + hydrochloric acid $\longrightarrow$ hydrogen + magnesium chloride

Note that not all metals replace hydrogen.

This activity may be repeated using dilute sulfuric acid instead of hydrochloric acid. Vinegar may also be used but the reactions tend to be very slow.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

dilute hydrochloric acid
vinegar
limestone/marble chips
any soluble carbonate compound

ACTIVITIES

ACIDS REACT WITH CARBONATES

Pour a few milliliters of dilute hydrochloric acid or vinegar into a 10-ml. solution of washing soda or any soluble carbonate compound. Note the effect when a few drops of acid are placed on limestone or marble chips (calcium carbonate). Point out that geologists use the acid test to identify many rocks as carbonates.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
(1) sources of acids	Acids are found in a variety of natural products.
	Acids can be made by chemical changes, such as reacting a nonmetallic oxide with water or combining a salt with concentrated sulfuric acid. (For further details consult a high school chemistry textbook.)
(2) uses of acids	Acids play an important part in the manufacture of many products.
	Some acids are important in the digestion of our foods.
b. bases	The properties of a compound determine if it is a base.
	Bases can turn litmus blue and colorless phenophthalein red.
	Bases can counteract or neutralize acids.
	The solution of a base feels slippery or soapy.
	pH paper makes an excellent indicator for bases.

MATERIALS

pH paper
beakers
fruit juices
baking soda
washing soda
vinegar
household ammonia
sink cleaner
soap
milk of magnesia
soil-testing kit
various samples of soils
litmus

KEY WORDS

counteract
digestion
indicator
neutralize
nonmetallic oxide
phenopthalein

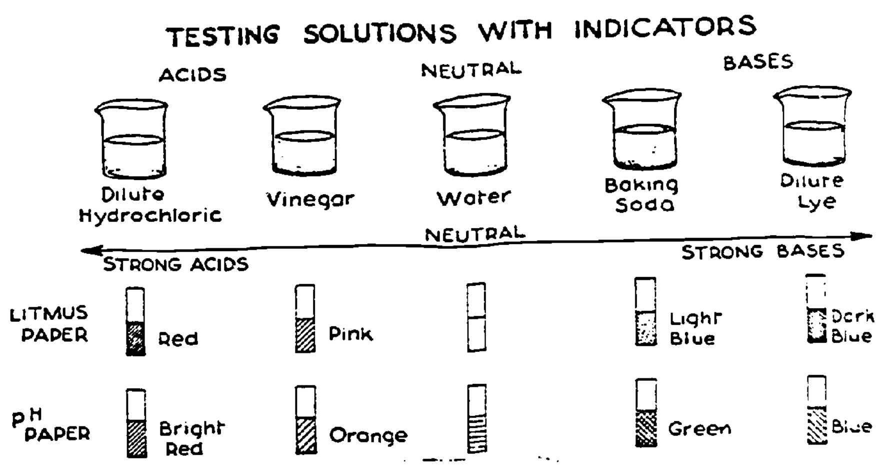
ACTIVITIES

TEACHER NOTE:

Acids have a sour taste. However, the testing of compounds for this property should not be undertaken by pupils. pH paper makes an excellent indicator.

In many ways pH paper, which is obtainable from any supply house, is a much more suitable indicator than litmus paper. This indicator goes through a wider range of color changes and can be used to indicate the relative strength of acids and bases.

Using pH paper, test fruit juices and other common substances, such as baking soda, washing soda, vinegar, household ammonia, sink cleaner, soap and milk of magnesia.



Carry on a soil-testing experiment, using a regular soil-testing kit if one is available. Follow the directions included with the kit and discuss the importance of maintaining correct soil conditions for various crops. Point out reasons why some soils become too acid and explain why lime is used to neutralize the acid.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

If a regular soil-testing kit is not available, satisfactory results can be obtained by adding a sample of soil to some water in a beaker. Allow the mixture to settle until there is a layer of clear water at the top. This water will contain dissolved matter and can be tested with litmus or pH paper.

TEACHER NOTE:

(An hydroxide compound such as ethyl alcohol (C_2H_5OH) should not normally be classified as a base since it does not affect litmus and phenophthalein or neutralize acids.)

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
(1) formation of bases	Bases are made by chemical changes. Bases are made by combining some metals like calcium with water, by reacting a metallic oxide with water, or by a double replacement between a soluble base and a metallic salt solution.
(2) uses of bases	Bases are used in a variety of industrial processes requiring the neutralization of an acid. Some bases are used to make soap. Milk of magnesia is a suspension of magnesium hydroxide and water. It is used to neutralize acid and as a cathartic.

MATERIALS	ACTIVITIES
magnesium ribbon test tube water litmus paper (or some indicator)	**BASE-FORMING ELEMENTS** Caution: Remind pupils not to look directly at burning magnesium.
litmus or pH paper various laundry and hand soaps	Burn 10 cm. of magnesium ribbon and add the white magnesium oxide that is formed to 10 ml. of water in a test tube. Heat the water to the boiling point in order to dissolve as much oxide as possible. Determine whether the solution is basic by means of the litmus paper, phenophthalein, or pH paper. The word equation for burning magnesium is: magnesium + oxygen magnesium oxide $2Mg + O_2 \quad 2MgO$
lye (sodium hydroxide) solution fat (olive or coconut oil) alcohol (rubbing) evaporating dish bunsen burner beaker	The oxide reacts with water as follows: magnesium oxide + water → magnesium hydroxide The teacher may wish to demonstrate that metals tend to form bases by reacting various oxides with water. Compare the amount of free alkali in various laundry soaps and hand soaps, using litmus or pH paper. Discuss the differences between laundry soaps and hand soaps.
KEY WORDS cathartic industrial processes suspension	Soap can be made quickly in the laboratory by using alcohol as a solvent for the lye and fat. Add 10 ml. of rubbing alcohol to two teaspoonfuls of olive or coconut oil in an evaporating dish. Add 5 ml. of a 20 percent solution of sodium hydroxide solution. Heat the mixture gently with a small flame. Continue heating and stirring it until the odor of alcohol has disappeared.

REFERENCE OUTLINE

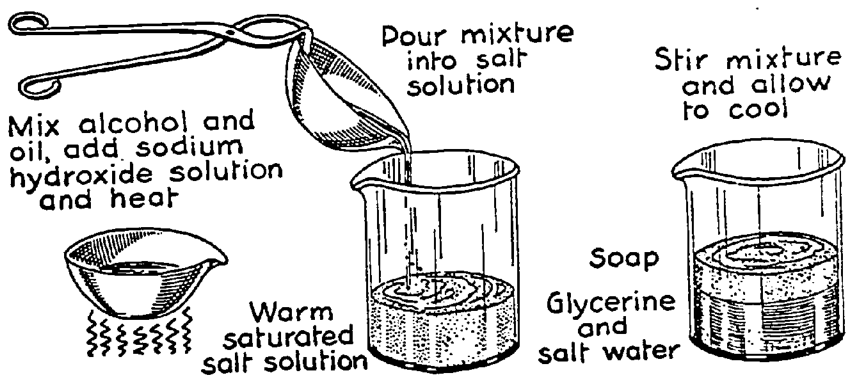
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

The pasty mass remaining is a mixture of soap and glycerine. The soap may be separated from the glycerine by pouring the mixture into a beaker containing a warm saturated solution of salt. Stir this mixture for one minute and allow it to settle. The soap collects at the top and may be ladled off. Try making suds by shaking a small amount of the soap with some tapwater in a test tube. Test the soap with red litmus paper.

Point out that the commercial process is slower than this method because it is too expensive to use alcohol as the solvent. Discuss the uses for the by-product glycerine.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. salts	A salt contains the positive ion from a base and the negative ion from an acid.
	The properties of salts vary widely.
(1) source of salts	Most salt compounds are found in the minerals of the earth and in sea water.
	Salts may be made by neutralization of an acid by a base. However, normally commercial quantities are not made in this way. The salts are usually found in nature or produced by other chemical reactions.
(2) uses of salts	The uses of salts vary from seasoning and preserving food to softening water, making acids or bases, fertilizers, drugs, and explosives.
B. Mixtures	A mixture contains two or more elements and/or compounds which may be separated into its constituent parts by physical means.
	The composition of a mixture may vary.
	Some mixtures have properties similar to both solutions and suspensions because the size of the suspended particles lies between those in a solution and those in a suspension. Mixtures exhibiting dual properties are called colloids.
1. suspensions	Suspensions are mixtures containing particles which readily settle out of the water (liquid).
	Suspensions can be separated into their constituent parts by filtering.
	Like all mixtures, a suspension can be made in varying proportions.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	True suspensions are opaque to the passage of light and their particles are visible. If during filtration of a suspension the filtrate appears to be cloudy, some suspended particles are small enough to pass through the filter and the filtrate is really a colloidal dispersion. The original mixture was, therefore, both a suspension and colloid.

MATERIALS	ACTIVITIES
muddy water alum	TEACHER NOTE: Although salts have a salty taste, most of them are poisonous so the property should not be tested. Put some of the impure muddy water in a tall jar and add a small amount of alum crystals. Stir the mixture and allow it to settle. The alum forms a jellylike mass which entangles the dirt particles and carries them down as it settles. This process, which is called coagulation, is used by many cities in removing suspended matter from the water supply.
	MAKING SUSPENSIONS
insoluble material silver nitrate sodium chlorude water graduates test tubes filter paper funnel ring ringstand	Suspensions can be made by the pupils from water and any insoluble material providing the solid particle size is large enough to allow separation by filtration. Fine sand, coarse dirt, and water can be mixed to form a suspension. If necessary, add a pinch of alum crystals to coagulate the mud particles so they can be filtered. The action between silver nitrate and sodium chloride solutions produces a suspension of silver chloride in sodium nitrate solution. Any chemical reaction producing a precipitate can be used to make a suspension.
KEY WORDS coagulation colloidal dispersion colloids commercial drugs explosives fertilizers minerals opaque preserving seasoning suspension visible water softener	After the suspension has been made, call the pupils' attention to the cloudy nature of the suspension. Allow the suspension to settle. Then shake the mixture to reform the suspension; filter it.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. solutions	The particles in a solution are too small to be filtered or to settle out of the liquid. A solution is clear and uniform. A solution can be made in varying proportions.
a. parts of a solution	The solute is the part of a solution that dissolves, while the solvent is the dissolving medium. Water is the most common solvent. The solute may be in the gaseous, liquid, or solid state. Likewise, the solvent may be in any one of the three states. Therefore, there are nine different types of fundamental solutions.
b. saturating a solvent	A given amount of solvent can continue to dissolve solute until a point is reached where no more solute can dissolve. Before that point the solution is unsaturated. At that point the solution is saturated at that temperature. A supersaturated solution contains more solute than it can dissolve at the existing temperature. It was prepared by dissolving of solute at a higher temperature. As a crystal starts to dissolve, the ions going into solution migrate so slowly throughout the solution that the solvent in the vicinity of the crystal rapidly becomes saturated. The rate of dissolving decreases noticeably. Stirring or agitating the solvent allows unsaturated solvent to approach the crystal, and the rate of dissolving increases. Dissolving stops when the entire solvent becomes saturated or when the solute has all dissolved.

MATERIALS

ACTIVITIES

USING AN OVERHEAD PROJECTOR TO SHOW THE FORMATION OF A SOLUTION

Place a petri dish containing some water on the overhead projector. In the center of the dish place a tiny crystal of potassium permanganate. Have the pupils watch the action for a few minutes. Gently swirl the dish, and again have the pupils observe the crystal. Ask for a possible explanation of the action.

If pupils are given enough time to observe the formation of the solution, they usually will come to the conclusion that the crystal is dissolving to produce a pink solution and that the pink solution becomes darker as more of the crystal dissolves. Some pupils will note that the color moves outward from the crystal. The darkening and spreading stops when the water near the crystal cannot dissolve any more solute. When "new" water comes near the crystal, more solute is dissolved until the darkening and spreading action stops again.

Introduce the term, saturated, to describe the situation which is present when no more solute can dissolve. Point out that eventually all the water in the dish can become saturated, if enough solute is present, and that no more solute can be dissolved at that temperature.

The term, concentrated, can be used in connection with the darkest portion. As more solute dissolves, the solution becomes more concentrated. Do not use the words strong or weak, in connection with solutions. The two terms refer to the strength of acids and bases.

All pupils at this grade level should consider the solutions in which the solvent is a liquid. Discuss some of the other types as enrichment for the better students.

KEY WORDS

agitating
concentrated
dissolving
formation
fundamental
saturated
solute
solvent
stirring
supersaturated
uniform
unsaturated

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

SATURATED AND UNSATURATED SOLUTIONS

On the stage of the overhead projector set two petri dishes, one containing some water, the other an equal volume of a saturated sodium thiosulfate (hypo) solution. Drop a single hypo crystal into each dish. After the action has been observed for a few minutes, drop another hypo crystal in each dish. Stir each solution. Ask the pupils to explain why the crystal disappears in one dish and not in the other.

If an overhead projector is not available, use larger quantities of liquids in 250-ml. beakers.

USING AN OVERHEAD PROJECTOR TO SHOW SUPERSATURATION

Place two petri dishes, each containing one crystal of hypo on the overhead projector. Into one dish pour a saturated hypo solution; into the other dish pour supersaturated hypo solution. The latter solution will form excess crystals upon being poured into the dish. The seed crystal present in the dish makes the excess solute immediately leave the supersaturated solution which then becomes saturated. Relate the demonstration to the way in which unsaturated, saturated, and supersaturated solutions can be identified.

KEY WORDS

For best results, prepare the supersaturated solution just before classtime and store the solution in the container in which it was prepared until using it.

If an overhead projector is not available, use larger quantities of reagents and larger beakers.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. factors affecting solubility	The amount of solute that can be dissolved in a definite quantity of solvent depends upon several factors. Polar solvents such as water can dissolve polar solutes such as salts of sodium and potassium. Nonpolar organic chemicals such as grease dissolve best in nonpolar solvents. Some nonpolar solvents are carbon tetrachloride, chloroform, and kerosene. Alcohol has a molecule, one end of which is polar, the other nonpolar. Alcohol dissolves many polar and nonpolar substances.
(1) nature of the substances	Solutes vary in their ability to be dissolved in a solvent. Solvents vary in their ability to dissolve different solutes.
(2) size of particles	If other factors are the same, small particles of a solute dissolve more rapidly than large particles. Pulverizing the solute increases the surface area that can be exposed to the solvent.
(3) agitation	If other factors are the same, solutes dissolve more rapidly if they are stirred.
(4) temperature	Solids usually become more soluble in a given amount of solvent as the temperature increases. Gases become more soluble if the temperature of the solvent decreases providing the pressure remains the same. Increasing the temperature increases the ability of the solute to dissolve since molecular action at the surface of the crystal is increased as the temperature increases.

MATERIALS	ACTIVITIES
test tubes water potassium per-manganate	Colored solutions enable pupils to see both the uniform distribution of particles and varying degrees of concentration. Arrange six test tubes of water in a test tube rack and add increasing amounts of a colored substance such as potassium permanganate and shake until each is completely dissolved. If only a few crystals are used in the first, the colors will range from faint pink for dilute to a deep purple for concentrated.
beakers sugar water	Fill each of two small beakers with granulated sugar to a depth of one-half inch. Add water to each beaker until it is nearly full. Stir one but do not stir the other and note the time required for each to dissolve. Point out that enormous quantities of sugar are wasted in the bottom of cups of tea and coffee as a result of not stirring.
lump sugar beakers water	Obtain two pieces of loaf sugar and crush one in a mortar. Place the lump of sugar and the crushed sugar in separate beakers and add an equal amount of water to each. Stir the contents of each beaker and note in which the sugar dissolves faster. Point out that more surface is exposed to the water when the lump is broken up into small particles and therefore the dissolving action takes place faster.
	EFFECT OF SURFACE AREA ON RATE OF DISSOLVING
KEY WORDS nonpolar polar pulverizing	Obtain a large crystal and an equal weight of tiny crystals of potassium dichromate or copper sulfate. Place two petri dishes containing equal volumes of water on the overhead projector. Into one dish drop the large crystal, into the other dish the small crystals. Observe the action in each dish for several minutes. Compare the color of the solution in the dishes. Ask the pupils for a possible explanation of the results. Usually they will suggest that more water comes in contact with the small crystals than with the large crystal.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

EFFECT OF TEMPERATURE ON THE SOLUBILITY OF SOLIDS

To 100 grams of potassium bromide in a beaker add 100 ml. of distilled or deionized water. Stir until no further solution seems to take place. Observe the temperature. Ask the pupils to determine the weight of the salt now in solution by referring to solubility tables. Have them predict how warm the solution would have to be to dissolve all of the salt. While stirring frequently, heat the solution to the selected temperature. Place a little of the warm solution in a test tube or in a petri dish to cool. With an overhead projector show what occurs within the petri dish as the solution cools. Ask the pupils to explain why crystals appear in the dish as the temperature of the solution decreases.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
*(5) pressure	*If other factors are the same, the solubility of a gas in a solvent varies directly with the pressure to which a gas is subjected.
d. solubility curves	A solubility curve (graph) is a mathematical picture which shows that a definite amount of solvent can dissolve different amounts of solute at various temperatures. The solution in each case is always saturated since no more solute can be dissolved at the given temperature.
	The horizontal axis of the graph represents (unless stated otherwise) the centigrade temperature of the solvent.
	The vertical axis of the graph represents (unless stated otherwise) the grams of solute that can dissolve in a specific amount of solvent, usually water.
	The amount of solvent may be expressed in 100 ml. or 100 grams of solvent. Be sure to check the introduction to any data found in handbooks to learn which system is being used.
	Several curves may be set up using the same set of axis. However, the name of solute must be written on each curve since each solute has its own individual solubility curve.

*optional

MATERIALS

ACTIVITIES

EFFECT OF TEMPERATURE ON THE SOLUBILITY OF GASES

Place a bottle of soda water in ice water, chill and open. Allow a second bottle to remain open at room temperature during the period. At the end of the period pour the contents of both into two glasses. Compare the amount of foam and the temperature of both solutions. The amount of foam is a rough approximation of the amount of gas that was dissolved in each solution.

EFFECT OF PRESSURE ON THE SOLUBILITY OF GASES

Display two bottles of soda water that have been standing at room temperature for a period of time. Take the cap off of one bottle. Ask the pupils to explain why gas escapes from the solution in the open bottle and why there are no bubbles of gas seen in the liquid in the capped bottle.

TABLE OF SOLUBILITIES IN WATER

i-nearly insoluble ss-slightly soluble s-soluble d-decomposes n-not isolated	acetate	bromide	carbonate	chloride	hydroxide	iodide	nitrate	oxide	phosphate	sulfate	sulfide
aluminum	s	s	n	s	i	s	s	i	i	s	d
ammonium	s	s	s	s	s	s	s	n	s	s	s
barium	s	s	i	s	s	s	s	s	i	i	d
calcium	s	s	i	s	ss	s	s	ss	i	ss	d
copper II (cuprous)	s	s	i	s	i	d	s	i	i	s	i
iron II (ferrous)	s	s	i	s	i	s	s	i	i	s	i
iron III (ferric)	s	s	n	s	i	s	s	i	i	ss	d
lead	s	ss	i	ss	i	ss	s	i	i	i	i
magnesium	s	s	i	s	i	s	s	i	i	s	d
mercury I (mercurous)	ss	i	i	i	n	i	s	i	i	ss	i
mercury II (mercuric)	s	ss	i	s	i	i	s	i	i	d	i
potassium	s	s	s	s	s	s	s	s	s	s	s
silver	ss	i	i	i	n	i	s	i	i	ss	i
sodium	s	s	s	s	s	s	s	d	s	s	s
zinc	s	s	i	s	i	s	s	i	i	s	i

KEY WORDS

axis
curve
graph
solubility curve
solubility graph
solubility table

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

USING A SOLUBILITY TABLE

After showing pupils a solubility table, ask them to list the solubilities of substances such as sodium chloride, barium sulfate, potassium nitrate, copper sulfate, zinc hydroxide, and calcium sulfate.

Have the pupils decide which classes of compounds seem to be always soluble. (The ammonium, nitrate, sodium and potassium compounds are always soluble.)

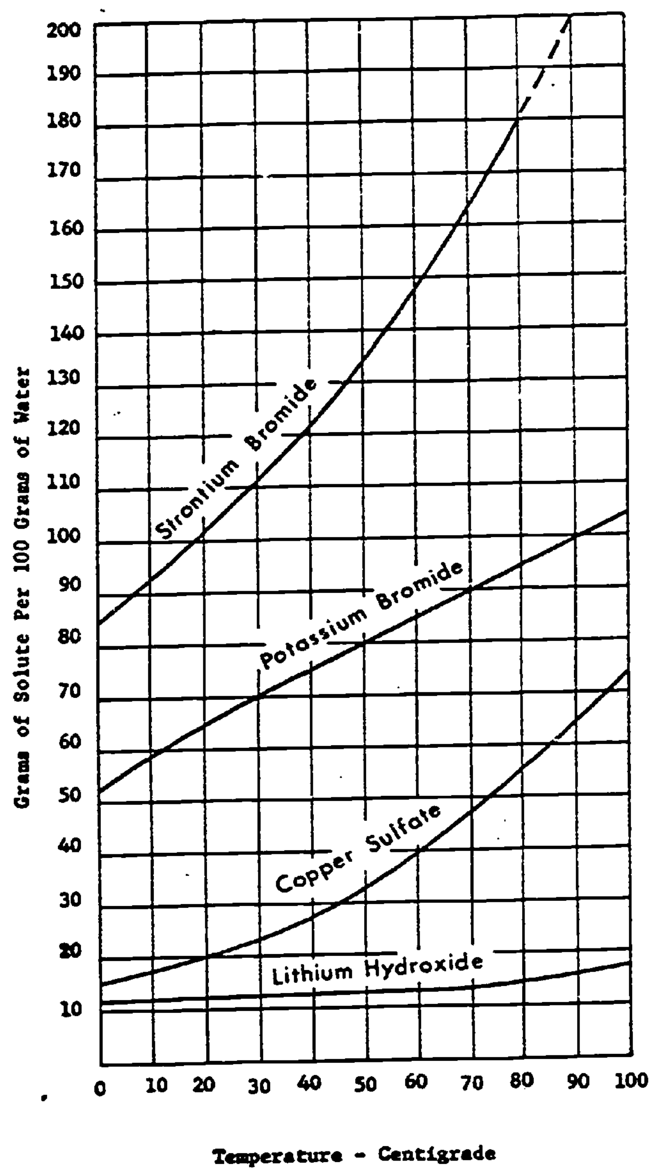
KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	The data used to make solubility curves have been obtained by experimentation.
(1) uses	Solubility curves are used to predict the amount of solute that may dissolve in, or precipitate out of, solution as the temperature is changed.
	A solubility curve shows the temperature at which a given amount of solute will saturate 100 grams of water.
	A solubility curve can be used to show how much additional solute is needed to keep a solution saturated as the temperature increases.
	A solubility curve can be used to show how much solid will crystallize out as a saturated solution cools.

MATERIALS

ACTIVITIES

Solubility Curves



KEY WORDS

crystalize
cool

SOLUBILITY CURVES

(a) Introducing Solubility Curves. Before class time prepare a solubility curve to be shown to the pupils. The curve may be drawn on the blackboard, mimeographed, or printed on a transparency for projection on an overhead projector.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Introduce the pupils to the graph by telling them that a solubility curve is a mathematical picture or story about how the solubility of a substance changes as the temperature changes. Since the "story" concerns only two variable characters, the amount of solute and the temperature, all the other factors such as the amount of water or other solvent used must remain the same.

Have the pupils study the curve for a few minutes. Ask the pupils to tell what information they have found about the axes. Review with them the way in which to read a graph: Read crosswise between the weight of solute axis and the curve; read up and down between the curve and the temperature axis.

Have the pupils determine how much solute is needed to saturate 100 grams of solvent at different temperatures.

KEY WORDS

Remind the pupils that if a solution does not contain as many grams of solute as the curve indicates it can, the solution is unsaturated. More solute must be added to saturate it. On the other hand, a supersaturated solution would have more grams of solute dissolved than the curve indicates it can at the existing temperature. The difference between the amount of solute present in a supersaturated solution and the amount the curve shows is the weight of crystals that would come out of the supersaturated solution as the solution returned to the saturated condition.

TEACHER NOTE:

Material in section (b) is an optional device depending upon the depth to which the teacher desires to go or the ability of the group to understand.

(b) Plotting a Solubility Curve. Pupils can plot a solubility curve from data obtained from references or from experimental data they obtain.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

KEY WORDS

ACTIVITIES

(1) Using Data from Resources. Give the data shown which is needed to plot the solubility curve of copper sulfate. Have the pupils set up the temperature scale on the horizontal scale. The data are plotted and a curve drawn connecting the points. Unless a straight line curve is clearly indicated, do not have the pupils use a ruler to connect consecutive points. A line should be lightly drawn free hand connecting the points, smoothed out and then darkened to give a satisfactory curve. Label the curve with the name of the solute.

It may be wise to review the plotting of points. Stress the need to check each point plotted. Read down the line from a point to check the temperature; read across the line to check the weight of solute.

Solubility of certain anhydrous compounds in grams per 100 grams of H_2O

Temperature - degrees centigrade	LiOH	$CuSO_4$	KBr	$SrBr_2$
100°	17.5	75.4	104.0	222.5
90°	--	--	99.2	--
80°	15.3	55	95.0	181.8
70°	--	--	90.0	--
60°	13.8	40	85.5	150
50°	13.3	33.3	80.2	135.8
40°	13	28.5	75.5	123.2
30°	12.9	25	70.6	111.9
20°	12.8	20.7	65.2	102.4
10°	12.7	17.4	59.5	93
0°	12.7	14.3	53.5	85.2

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
VI. Introduction to Organic Chemistry	
A. Definition	Organic chemistry is the chemistry of the compounds of carbon.
B. Some Differences Between Organic and Inorganic Compounds	Organic compounds <u>generally</u> differ from inorganic compounds in that: there are many more organic compounds than inorganic compounds. organic compounds are more easily decomposed by heat. organic compounds char when heated. solutions of organic compounds are usually poor conductors of electricity. organic compounds are usually slightly soluble in water. organic compounds tend to react more slowly than do inorganic compounds.
C. Bonding in Organic Compounds	
1. Covalent bonds	Some atoms tend to combine by sharing electrons. A pair of electrons shared between two atoms constitutes a bond between the atoms. Atoms tend to share electrons in sufficient quantity to bring the electron number to the maximum amount for the outside ring.
2. Formation of molecules	Some molecules are formed by covalent bonding.
a. hydrogen molecule	Two hydrogen atoms join by a covalent bond to produce a molecule.

MATERIALS

ACTIVITIES

Note to Teachers

This unit on organic chemistry is optional.

Although the new methods of teaching biology presupposes a prior knowledge of chemistry and chemical principles, the time element during the ninth grade usually permits only a superficial review of organic chemistry.

In classes where the pupils have shown a good grasp of inorganic chemistry, teachers may elect and should extend these chemical experiences of their pupils into the field of organic chemistry. Where classes are slower moving, this unit may well be omitted.

It is anticipated that biology teachers will evaluate the background knowledge that pupils have in chemistry and will proceed to teach the principles of biochemistry from this base.

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

A pair of shared electrons may be represented by a dash (-) or by two dots (:).

A structural formula represents the atoms present in a molecule and the bonds joining them.

Other gases with molecules having covalent bonding include oxygen, nitrogen, fluorine, and chlorine.

MATERIALS

ACTIVITIES

KEY WORDS

bonding
char
conductor
covalent
decomposed
formula
inorganic
molecule
organic
soluble
structural

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

b. methane molecule

The carbon atom has four electrons in its outer shell. Carbon tends to form compounds with other atoms by four covalent bonds.

In methane (CH_4) the carbon atom is joined to each of four atoms of hydrogen by a covalent bond.

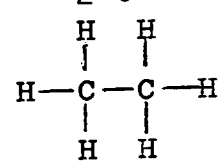
c. formation of long chains

Carbon atoms have the ability to produce long chains or rings by forming covalent bonds with other carbon atoms.

d. saturated and unsaturated compounds

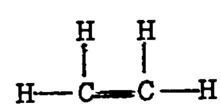
Each carbon atom in a compound may be joined to another carbon atom by sharing one pair of electrons (one covalent bond). This compound is considered saturated.

An example of a saturated compound is ethane (C_2H_6) represented as:



Note that there is only one bond between the carbon atoms.

Examples of unsaturated compounds are C_2H_4 and C_2H_2. Their structural formulas are:



and

Note the double and triple bonds between the carbon atoms.

MATERIALS

ACTIVITIES

KEY WORDS

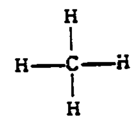
atom
bond
compound
ring
saturated
shell
unsaturated

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Some Classes of Organic Compounds	Classes of organic compounds may be recognized by the number and arrangement of certain atoms or groups of atoms in their structural formulas.
1. Hydrocarbons	Hydrocarbons are compounds of hydrogen and carbon. Hydrocarbons may be in the form of straight chains or rings, and may contain from one to over forty carbon atoms. The most abundant sources of hydrocarbons are petroleum and natural gas.
2. Alcohols	Alcohol may be formed by oxidizing hydrocarbons. Alcohols may be derived from saturated hydrocarbons by substituting one or more -OH groups for one or more hydrogen atoms. Alcohols may result from the addition of OH groups to unsaturated hydrocarbons.
a. methyl alcohol	The formula for methyl alcohol (methanol) is CH_3OH. Methyl alcohol is used to make other organic compounds, and as a solvent and automobile antifreeze.

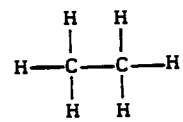
MATERIALS

ACTIVITIES

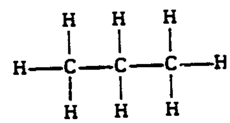
methane
(CH_4)



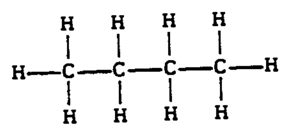
ethane
(C_2H_6)



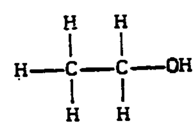
propane
(C_3H_8)



butane
(C_4H_{10})



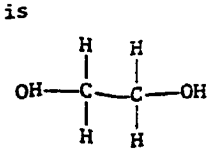
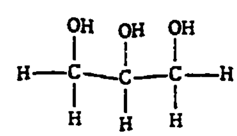
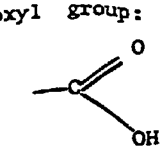
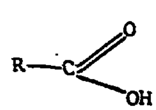
Show by diagram or molecular models how one H atom in ethane (C_2H_6) is replaced by an -OH to produce ethyl alcohol (ethanol). The structural formula of ethyl alcohol is



Discuss alcohol as a narcotic and the physiological effect on the human organism.

KEY WORDS

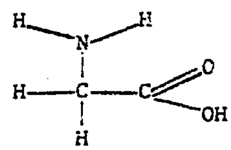
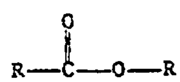
antifreeze
derivative
hydrocarbon
natural gas
oxidizing
petroleum
solvent
substitution

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. ethyl alcohol	The formula for ethyl alcohol (ethanol) is C_2H_5OH. Ethyl alcohol is used to make other organic compounds and is a solvent. Alcohols are among the earliest known organic compounds. Grain alcohol (ethanol) has been obtained from fermented starches (grains) since the beginning of recorded history. Fermentation is still an important source of ethanol.
c. other alcohols	Ethylene glycol, $C_2H_4(OH)_2$, and glycerol, $C_3H_5(OH)_3$ are examples of other alcohols. Ethylene glycol is used as an automobile antifreeze. The structural formula of ethylene glycol is  This compound has 2 -OH groups. The structural formula of glycerol is  This compound has 3 -OH groups. It is a part of all body fats.
3. Organic acids	Organic acids may be prepared by oxidizing alcohols. Organic acids have a characteristic carboxyl group:  The general formula for an organic acid is 

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
a. amino acids	Amino acids are organic acids in which an amino (— NH_2) group has replaced a hydrogen atom. Amino acids are units which make up proteins.
	The amino acid derived from acetic (ethanoic) acid is represented by the formula: 
b. esters	Esters can be formed by the reaction of an organic acid and an alcohol. The general formula for an ester is  Animal and vegetable fats and oils are esters which are made up of glycerol and fatty acids.

MATERIALS

test tubes
beaker
bunsen burner
ring tripod
wire gauze/
asbestos pad

KEY WORDS

amino acids
fats
fatty acids
ester
oils
protein
reaction

ACTIVITIES

Discuss the commercial uses of esters, especially in the food industry.

ESTERIFICATION

Esters are most frequently prepared by the reaction of alcohols and acids in the presence of concentrated sulfuric acid. When the acid used is an organic acid, many of the esters resulting from such reactions have odors characteristic of certain fragrances produced by plants. It is possible to prepare various esters in the laboratory which pupils may readily recognize.

In separate test tubes place the amounts of acids and alcohols as indicated below. Add a few drops of concentrated sulfuric acid to each tube. Heat by placing the tube in a beaker of heated water. Try to identify the fragrance.

a. 5 ml. of methyl alcohol and 2 gm. of salicylic acid (wintergreen fragrance results).
b. 5 ml. of ethyl alcohol and 5 ml. of butyric acid (pineapple odor results).
c. 5 ml. of n-amyl alcohol and 5 ml. of acetic acid (banana fragrance results).

Essence	Ester	Essence	Ester
Apricot	Amyl butyrate	Pineapple	Ethyl butyrate
Banana	Amyl acetate	Raspberry	Isobutyl formate Isobutyl acetate
Grape	Ethyl formate Ethyl heptoate	Rum	Ethyl butyrate
Orange	Octyl acetate	Wintergreen	Methyl salicylate

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
VII. The role of chemistry in society	
A. Use of chemicals	Every living organism depends on chemical processes.
B. Conservation of natural resources	Most of our natural resources are being rapidly consumed (or made difficult to reuse) as the demand for chemical products increases. Scientists are constantly searching for ways to conserve our stockpile of resources.
1. using substitutes	Using a substitute conserves a resource in short supply.
2. using protective coatings	Protective coatings prevent or slow down chemical reactions which reduce the usefulness of a substance.
3. salvaging waste products	The effective use of waste products reduces the drain on our resources.
4. proper disposal of waste products	Proper disposal of waste products prevents pollution of our natural resources in the air, water, and the earth.
C. The balance of nature	The use of chemicals to improve some feature of man's environment may affect seriously some other feature.

MATERIALS

ACTIVITIES

The corrosion of metal is a serious problem. Since most pupils are interested in automobiles, the corrosion of metal on automobiles and ways to prevent corrosion provide a motivating approach to the topic of conserving metals.

Advantages and disadvantages of the use of salt on city streets should be discussed.

Water pollution is a serious problem in the Rochester area. What steps have been taken or are planned to reduce the pollution of the environment in the Monroe County area?

How do the use of pesticides affect the balance of nature?

KEY WORDS

corrosion
conservation
salvage
protective covering
pesticides

BLOCK K

ENERGY AT WORK

K-1

ENERGY AT WORK

Electric energy
- static electricity
- current electricity

Magnetism
- kinds of magnets
- magnetic fields
- direct current motor
- induced voltage

Light
- electromagnetic radiation
- intensity and illumination
- reflection of light
- refraction of light
- color

Sound
- sources
- characteristics of sound waves
- reflection
- resonance

Heat Energy
- internal energy
- temperature
- heat
- transmission of heat energy
- phases of matter
- expansion
- conservation of heat energy

Important concepts are indicated by the symbol (#). Materials considered of an enrichment nature are indicated by an asterisk (*).

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
I. Electric Energy	Electric energy is one form of energy.
	Under proper conditions, electric energy may be transformed into other forms of energy, and vice versa.
A. Static electricity	Static electricity may be defined as a collection of similar electric charges "at rest".
1. structure of matter	Matter is composed of particles called atoms.
a. subatomic particles	The atom is composed of three fundamental particles: the proton, the electron, and the neutron.
	The proton is a positively charged particle.
	The electron is a negatively charged particle with a mass 1836 times smaller than the proton.
	The neutron has no charge and is about the same size as the proton.
b. atomic structure	The nucleus is a dense mass consisting of protons and neutrons.
	Electrons move about the nucleus in various shaped orbits.

MATERIALS

ACTIVITIES

#It is important to point out that "at rest" does not mean that the charges arennot in motion. The electrons involved are in motion, but the motion is random rather than in a particular direction, as in current electricity.

An atom is the smallest unit of a substance (matter) that can take part in a chemical change. A molecule, usually, is a combination of two or more atoms. (Exceptions: mono-atomic molecules such as Hg, He, Ar, etc.) An ion is a charged atom or group of atoms.

It is important to point out that the arrangement of electrons is three-dimensional.

The radius of the atom is at least 10^4 (10,000) times the radius of the nucleus. Most of matter is empty space.

KEY WORDS

electric energy
static
electricity
atom
electron
proton
neutron
nucleus

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. uncharged and charged objects	Uncharged objects have an equal number of positive and negative charges. Uncharged objects normally do not attract small bits of matter. Charged objects have unequal numbers of positive and negative charges. Charged objects have gained or lost electrons so that the numbers of positive and negative charges are unequal. Charged objects normally attract small bits of matter.

MATERIALS

ACTIVITIES

#Touch a bit of paper with a hard rubber rod, comb or fountain pen. Stroke the rod vigorously with a piece of wool or fur and bring it near the paper. Ask the class for explanations of the effect produced. Invite pupils to recount their experiences with static electricity.

There are many other interesting demonstrations for producing static electric charges and observing their effects. Pupils may already be familiar with some of these, but at least a few should be repeated for the purpose of developing the concept of the electrical nature of matter. The distinction between neutral and charged bodies should be pointed out; and the explanation of how objects become positively or negatively charged should be made in terms of gain or loss of electrons. A reasonably dry day should be selected for theee demonstrations.

#Rub a hard rubber rod with wool or fur and plunge it into a box of puffed rice. Withdraw the rod from the box and observe the effect. The first attraction is followed by mutual repulsion and the effect is quite spectacular.

KEY WORDS

#Lay two books on the table several inches apart. Place small bits of paper between the books and lay a pane of glass over them. Now rub the glass with a piece of silk and the paper will jump up to the under surface of the glass.

#Hold a piece of paper against the wall or chalkboard and rub it briskly with a piece of cloth. If the relative humidity is low enough, the electric charges will hold the paper in position for some time. On humid days the charges will leak off too rapidly to permit a charge to be built up.

#Stroke a rubber rod with fur and bring it near the glass of a neon glow lamp. Move the rod slowly past the lamp and observe the discharges.

K-6

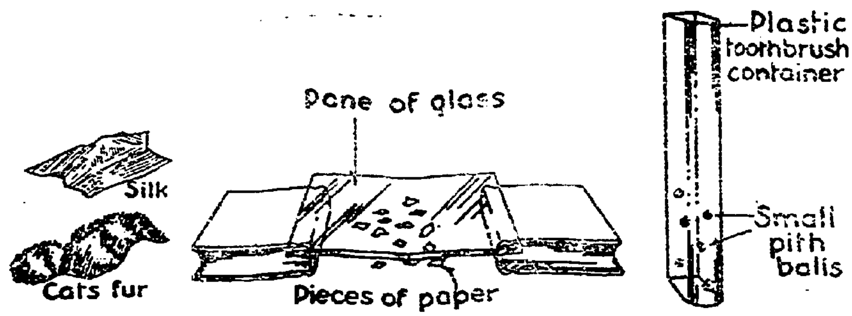
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#Put several small pith balls in a plastic toothbrush container. Rub the container with fur and stand it on one end. Observe the action of the pith balls. Suggest that pupils try other materials in a plastic container.



#Adjust a faucet so that a thin stream of water flows from it. Now give a comb a charge by running it through the hair several times. Hold the comb 2 or 3 cm. from the stream of water. The water is strongly attracted by the charge on the comb.

#Make a list of situations where static charges can be dangerous. Emphasize the danger of dry cleaning with highly volatile, combustible solvents at home. Discuss the reason for using the chain that dangles from the rear of a gasoline truck.

KEY WORDS

Discuss the nature of lightning, how charges are formed, what the flash represents and what causes the thunder. Emphasize the rules of safety that should be observed during an electical storm.

#The topic of electrostatics presents many opportunities for spectacular and intriguing demonstrations. Paradoxically, this is one of its major pitfalls, since the explanations of many of the most interesting experiments involve rather obscure or advanced scientific principles, or perhaps principles which are better taught in other ways or in other parts of the course. If

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

these explanations are incompletely understood, the whole lesson takes on the atmosphere of a fascinating magic show, and entertainment rather than learning becomes the prime objective of the class. In general, an experiment should not be given class time unless (1) it demonstrates some principle which either is fundamental to concepts to be studied later, has some "daily life" application or satisfies some other accepted objective of the course, (2) it can be explained understandably at the level of the class being taught and (3) its entertaining and spectacular features can be used directly to focus attention on its values for teaching and learning.

Experimenting with static electricity is most successful is most successful in cool dry weather,

Some pieces of equipment, particulary the glass rod, silk threads supporting electroscope balls and the like, will work best if heated just before use. Place them over a hot radiator before class, or have a radiant heater in operation at one end of the demonstration table.

KEY WORDS

#The Electrophorus

The electrophorus may be purchased or constructed. It consists of a shallow plate which contains insulating material and a metal disk with an insulated handle. To make one, place some melted sealing wax in a pie or cake tin about 6 inches in diameter. Allow the wax to harden. If desired, a discarded vinylite phonograph record can be melted and used instead of the sealing wax. A sheet of metal or a circular can lid may be used for the metal disk. Attach a 4 inch piece of wood to the center of the disk to serve as an insulated handle.

Rub the wax or vinylite briskly with fur or wool to charge it well. Set the disk on the wax and ground the disk with the finger. Remove the

REFERENCE OUTLINE

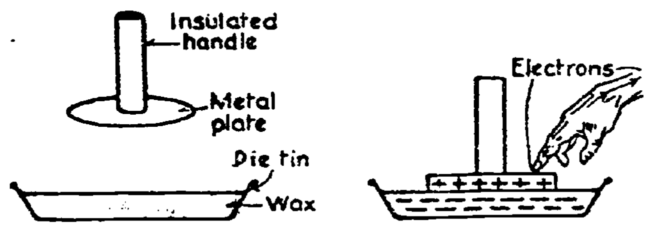
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

finger and lift the disk, which is now charged and can be used to charge other objects. The charge on the disk is positive and opposite to the charge on the wax.

The charge on the disk is sufficient to discharge in the form of a spark when held close to another object. This discharge can cause a neon glow lamp to flash.



#Several activities involving static charges should be suggested for pupils to do at home. Suggest that pupils comb their hair in front of a mirror in a completely darkened room to observe the sparks. Ask them to observe any effect on radio reception. They can also observe the spark discharge when they scuff across a rug and touch a doorknob or a radiator. A wide variety of activities using toy balloons can be suggested.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. electrostatic forces	If a charged object is placed near another charged object, there is an electrostatic force between them.
a. force between like charges	Like-charged objects repel each other.
b. force between unlike charges	Unlike-charged objects attract each other.

MATERIALS

ACTIVITIES

Forces between charged objects are caused by electric fields. The shapes of the bodies, the amount of charge on the bodies, and the medium in which the bodies are located, determine the shapes and the strengths of the fields.

Electrostatic forces are large as compared to gravitational forces.

The electrostatic force between an electron and a proton is about 10^{40} larger than the gravitational attraction between them.

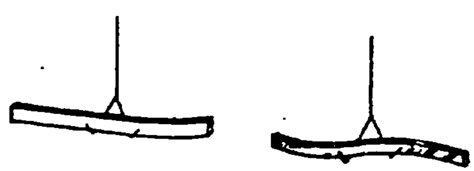
#Electrostatic Forces

Rub two glass rods with silk. Will the rods pick up small bits of paper? Are the rods charged? Are the rods charged alike? Suspend each rod from its center by a thread. Bring the two rods near each other. Note the effect: Repeat the process with two rubber or plastic rods rubbed with fur.

Charge a glass rod with silk and a rubber rod with fur. Suspend the rods; bring them near each other. Note the effect.

KEY WORDS

electrostatic forces
attract
repel
electroscope



#Several simple electroscopes can be made for studying electric charges. Suspend two pith balls or two grains of puffed rice by light threads from a support. Touch each simultaneously with a charged object. Note the repulsion of two bodies having a like charge. Observe the behavior of the grains when a positive or a negative body is brought between them.

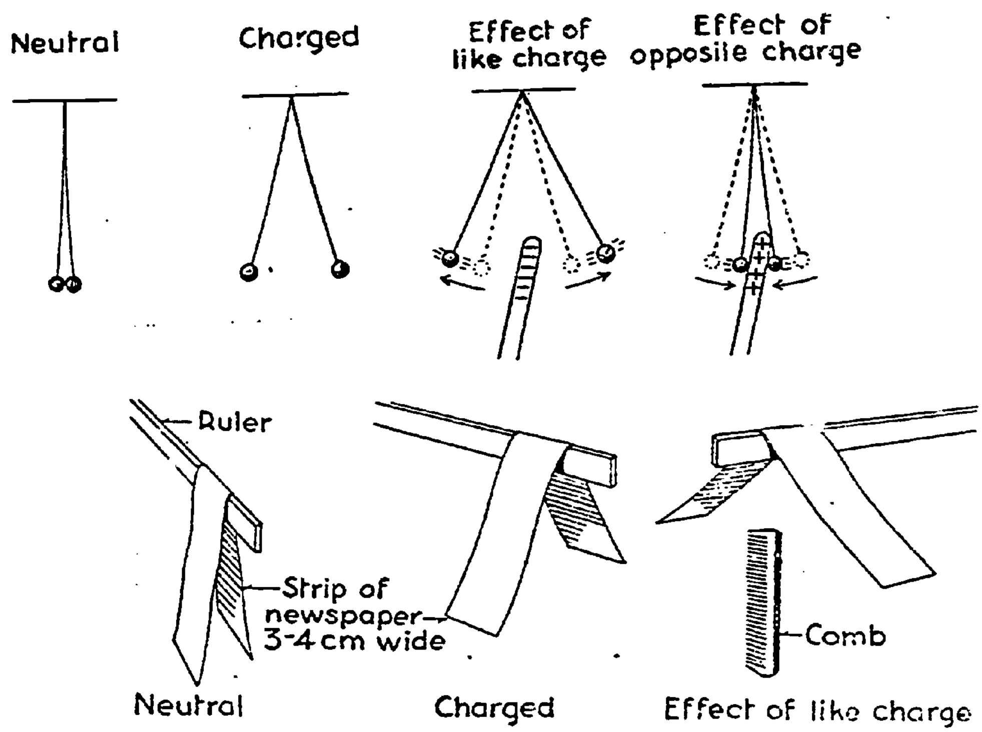
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Ping-pong balls painted with aluminum paint, small balloons and many other light objects can be used equally well. Balloons can be charged by rubbing on a coat sleeve.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. transfer of charges	Electrons may be transferred from one object to another.
a. conservation of energy	When electrons are transferred from one object to another, the net charge remains the same.
b. charging by contact	When a charged object touches an insulated uncharged object, the uncharged object becomes charged.
	When an object is charged by contact, it acquires the same charge as the charging body.
c. charging by induction	Objects are charged by induction when there is a transfer of electrons between the body and the ground.
	When an object is charged by induction, it acquires a charge opposite to that of the charging body.
5. storing electrical charges	Electrical charges may be stored by a device known as a capacitor.

MATERIALS

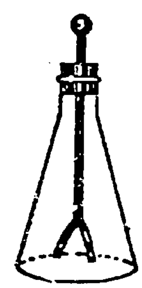
ACTIVITIES

#Charging By Contact

Charge a rubber rod by rubbing with fur. Touch the rubber rod to the knob of an electroscope. Note the effect. Determine if the electroscope is positively or negatively charged by bringing a rod of known charge near the knob. Repeat the entire process by charging the electroscope with a charged glass rod.

#Charging By Induction

Charge a rubber rod. Bring the rod near the knob of an uncharged electroscope. Touch the knob of the electroscope with the finger. Remove the finger and the rod. Determine the charge on the electroscope by means of a rod of known charge. Repeat the entire process with a charged glass rod.



KEY WORDS

transfer of charges
conservation of charges
charging by contact
charging by induction
capacitor

#The term "condenser" has been replaced by the term "capacitor." A capacitor is a device composed of alternate layers of conductors and insulators.

Capacitors are rated according to charge per volt. A coulomb/volt is called a farad. The farad is such a large unit that most capacitors are rated in microfarads or micro microfarads (μf or $\mu\mu f$).

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#The Leyden Jar (Demonstration Capacitor)

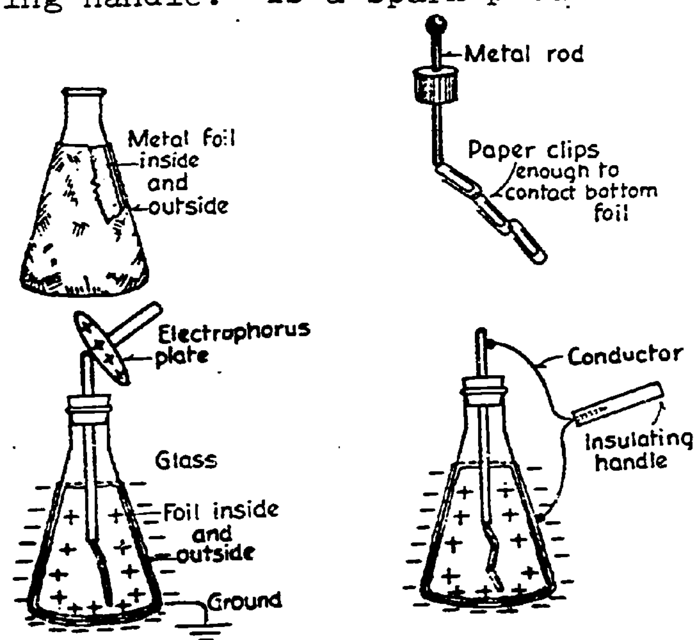
The Leyden jar is a simple form of capacitor which consists of two pieces of metal foil separated by a glass container. Leyden jars are found on electrostatic machines. If a Leyden jar is not available in the laboratory, one may be easily constructed from aluminum foil and an Erlenmeyer flask.

The foil is placed inside and outside of the lower half of the flask. A metal rod is inserted through a one-hole rubber stopper, and a wire is used to attach a chain of paper clips to the lower end of the rod. When the stopper is placed in the flask, the paper clips must reach the bottom of the flask and make contact with the aluminium.

Ground the outside metal of the Leyden jar with a wire attached to a radiator, water faucet, or electric ground. Charge the metal rod by touching it several times with a charged electrophorus disk. (If desired, the rod may be connected to one electrode of a static electricity machine.) When a positively-charged electrophorus plate touches the rod, electrons leave the rod and the metal insdie the jar. Electrons are attracted from the ground and collect on the metal outside the jar. Disconnect the ground. Discharge the capacitor by touching the rod and the outside metal with a metal conductor attached to an insulating handle. Is a spark produced?

KEY WORDS

Leyden jar



REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#Charge a one-microfarad capacitor by connecting it for a short time to a 45-volt "B" battery. Disconnect the battery and touch together the two wires leading to the capacitor. Observe the spark that represents the electrical discharge. Discuss the action of the capacitor in building up and storing an electrical charge. Relate this effect with the electrical discharge that takes place during a thunderstorm.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. Current electricity	Current electricity involves the flow of electric charges.
1. sources of current electricity	Chemical energy may be transformed into electrical energy by such devices as the ·voltaic cell ·dry cell ·storage battery ·fuel cell

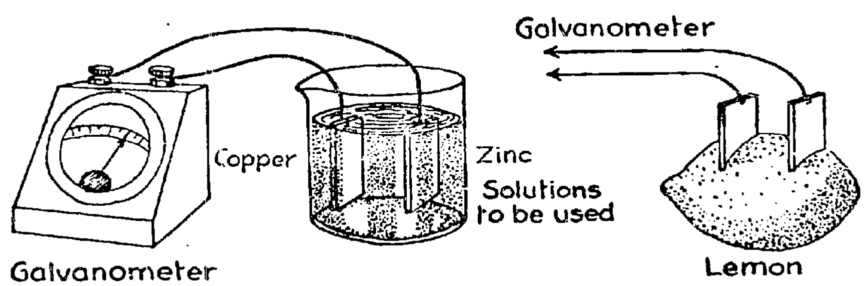
MATERIALS

ACTIVITIES

#Cut a strip of copper about 8 cm. long and 1 1/2 to 2 cm. wide. Cut a similar strip of zinc. Fasten a wire to each and connect the wires to a galvanometer. Touch the copper and zinc together. Observe that there is no indication of an electric current. Dip the strips into a jar containing distilled water. Repeat the procedure, using in succession, tap water, salt water and solutions of other common substances such as sugar, baking soda, vinegar, lye and alcohol. Rinse in clean water after each trial. Make a list of solutions by which the galvanometer indicates that a current is produced.

Try two strips of other metals such as tin, steel, lead and aluminum. For one experiment use two strips of the same metal. List the essential parts of a simple cell.

As a final step insert the strip of copper and the strip of zinc into a lemon and observe the action of the galvanometer. Use other fruits which contain acid and compare the results.



KEY WORDS

current electricity
voltaic cell
dry cell
storage battery
fuel cell
galvanometer

#Prepare a dilute solution of sulfuric acid by slowly adding one part acid to 10 parts of water in a Pyrex beaker. When the acid is cool put a fresh copper strip into the solution. Observe that there is little evidence of chemical action. Next put a new strip of zinc into the solution. Observe the formation of bubbles of a gas which indicates that chemical change is taking place. Also examine the surface of the zinc after it is removed from the acid.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Put both the copper and zinc strips into the acid and connect to a voltmeter. Observe the voltage and then connect the wires to an electrical bell or buzzer.

The explanation should be limited to the idea that as a result of chemical action the zinc tends to develop a negative charge (an excess of electrons) and the copper a positive charge (a scarcity of electrons). When connected by a conductor, electrons flow from the zinc to the copper.

#Using a hacksaw cut lengthwise through a dry cell. Examine this cross section of the cell. Point out the essential parts and discuss the use of each.

Emphasize the limitations of dry cells and point out that they should be used intermittently for longer life.

Discuss the reasons why a dry cell goes "dead" and demonstrate how an old cell can be revived. An effective way to do this is to punch several holes in the container and set it in a solution of salt or sal ammoniac.

KEY WORDS

#Exhibit several different types of dry cells and test the voltage of each with a voltmeter. Connect each to a miniature lamp and note the brilliance in each case.

Open a "B" battery, "Hotshot" or some other battery of this type, to see how voltages greater than 1.5 volts are achieved. "B" batteries for hearing aids or portable radios are suitable for such dissection.

Make a list of the uses for dry cells and dry batteries.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

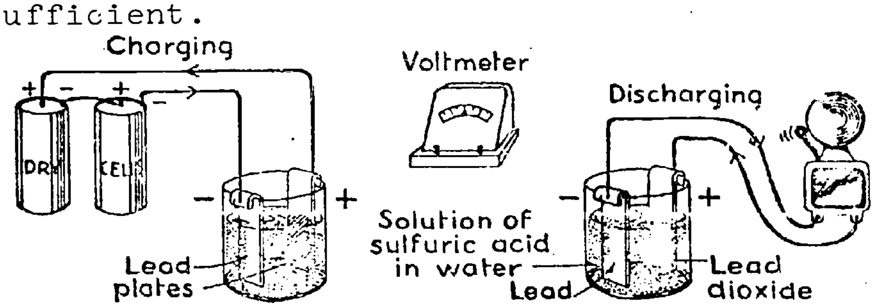
#Make a lead storage cell to illustrate the type of cell that can be recharged. Cut two strips of sheet lead about 5 cm. by 20 cm. and sandpaper their surfaces. Fasten wires to each, connect them to a galvanometer or voltmeter and put the strips in a solution of dilute sulfuric acid. Point out that there is no evidence of an electric current.

Now connect the strips to a 6-volt d.c. source. Pass current through the solution for several minutes. Observe the evidence of chemical action which results in a change in the appearance of the electrode connected to the positive terminal.

Disconnect the charging source and read on a voltmeter the voltage of the storage cell you have made. Connect the new cell to an electric bell and allow the cell to "run down."

No attempt should be made to develop a complete understanding of the chemical action involved in the charging and discharging of a storage cell. A simple explanation in terms of electrodes becoming more unlike when the cell is charging and more alike on discharging is sufficient.

KEY WORDS



#Suggest that pupils examine storage batteries in automobiles. Most of these are 12-volt batteries although 6-volt batteries are common.

Discuss why batteries require periodic inspections. Investigate other kinds of storage batteries and discuss the advantages and disadvantages of different types.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Light energy may be transformed into electrical energy by a photoelectric cell.

Heat energy may be transformed into electrical energy by a thermocouple.

Mechanical energy can be used to turn generators.

MATERIALS

ACTIVITIES

#It is important to stress that some devices transform one form of energy to electrical energy. It is suggested that teachers minimize details of construction of these devices.

The solar cell is used on many space vehicles. Information concerning the solar cell may be found in recent encyclopedias and high school textbooks as well as publications of the National Aeronautics and Space Administration.

#Demonstrate photoelectric cell in a light meter, exposure meter or in a sound movie projector. Explain that selenium and some other metals change light into a flow of electricity. Point out that the electron flow increases as the intensity of the light increases.

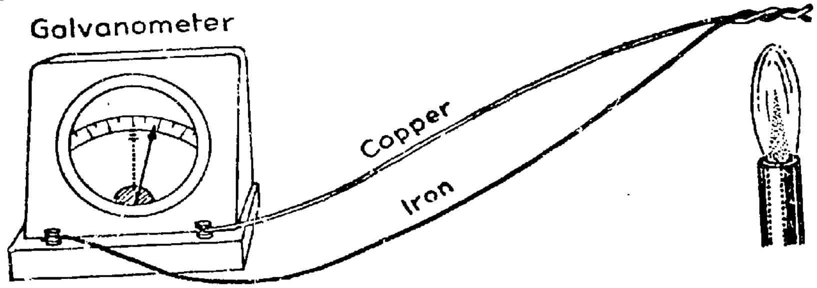
If a demonstration photocell unit is available, pupils are fascinated by simple circuits in which the device is used to ring a bell, turn on a light or start a motor. Make a list of places where photoelectric cells are used.

KEY WORDS

photoelectric cell
thermocouple

#Scrape the paint from a piece of coat-hanger wire. Twist together one end of this wire and the end of a copper wire. Connect the opposite ends of these wires to a sensitive galvanometer. Heat the junction of the iron and the copper wires with a candle flame. Note the deflection of the galvanometer needle. Try a bunsen burner flame.

This device is a simple thermocouple. The principle illustrated is made use of in electric thermometers for measuring temperature inside engines and in other inaccessible places.



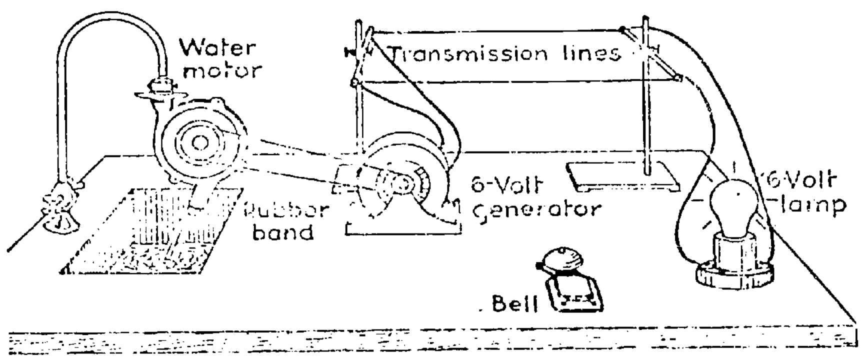
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#Assemble a model generating station, consisting of a water motor and a 6-volt generator. Connect the pulleys on the motor and the generator with a large rubber band to serve as a drive belt. Use the output of the generator to light 6-volt lamps or to ring a bell. A transmission line from the desk to the rear of the room can be used to make the model more realistic. This model illustrates the energy transformations involved in the commercial production and use of electrical energy.



KEY WORDS

generator

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. conductors	Conductors are materials through which charges move readily.
a. solids	Metals are generally the best solid conductors.
	Good metal conductors are silver, copper, and aluminum.

MATERIALS

ACTIVITIES

#The pupils should realize that under normal conditions charges travel readily through conductors but not readily through insulators.

A conductor must have charges which are free to move. The availability of these charges determines how well the material will conduct electricity. The amount of electric current which can be conducted depends upon the material.

A good conductor is a poor insulator; a good insulator is a poor conductor.

Materials in which electrons are closely bound to their atoms are insulators. Some good insulators are rubber, mica, and dry air.

In a metal conductor the free electrons move when a source of potential difference (such as a battery) is connected across the metal. The electrons move toward the positive pole of the energy source.

It is possible that simple experiments with the electrical conductivity of solids have been performed in previous grades. In this case, do not repeat.

KEY WORDS

conductor
insulator

#Conductivity of Solids

If no apparatus for determining the conductivity of solids is available in the laboratory, a simple form may be devised. Obtain two pieces of bell wire about two feet long. Remove the insulation from about three inches of the ends of the wires. Connect the wires in series with a flashlight lamp and one or two dry cells, as shown. Test the connections by bringing the two bared ends of the wire together briefly. Separate the bared ends and place a piece of copper wire across them. Note whether the lamp lights. If so, indicate whether it is bright or dim. Repeat the procedure using wires or small pieces of

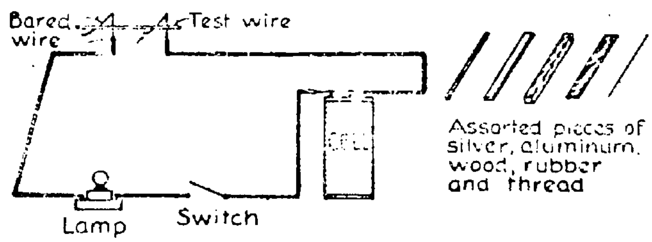
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

silver, aluminum, wood, rubber and thread. If accurate measurements are desire, substitute an ammeter for the lamp.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. liquids	Some good liquid conductors are solutions of acids, bases, and salts.

MATERIALS

ACTIVITIES

#Certain liquids, called electrolytes, are good conductors of electricity.

Electrolytes have both positive (+) and negative (-) ions available. Under the influence of a potential difference (such as a dry cell or battery) both positive and negative ions move toward the terminals of opposite charge.

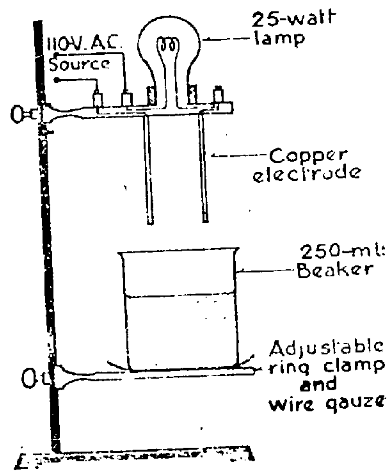
#Conductivity in Liquids

Use an electrical conductivity apparatus similar to that shown in the diagram. Because of the considerable shock hazard involved when operated from a 120-volt source, it is strongly recommended that the teacher demonstrate the procedures.

KEY WORDS

electrolytes

Prepare solutions of dilute sulfuric acid, dilute hydrochloric acid, acetic acid, ammonium hydroxide, sodium chloride (table salt), and table sugar. Also obtain tap water, distilled water, and alcohol. Place one liquid in the container until it is about three-quarters full. Insert the electrodes. Connect to the voltage source. Note whether the lamp is bright, dim, or does not glow. If more accurate results are desired, use an ammeter in place of the lamp. Disconnect from the voltage source. Use a series of beakers of the same size, or empty and and rinse the beaker each time. Repeat, using other solutions. Do liquids vary in their ability to conduct electricity?



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. gases	Ionized gases conduct electricity

MATERIALS

ACTIVITIES

#Uncharged molecules of gas become charged (ionized) by a loss or gain of electrons. Gases may be ionized by high energy radiation, by collisions with high energy electrons, and by electric fields.

In fluorescent tubes, electrons are accelerated by a high voltage. The electrons collide with molecules of mercury vapor which become ionized and conduct electricity. The ions bombard the fluorescent material which lines the surface of the glass. This material absorbs energy and then reemits it in the form of visible light energy.

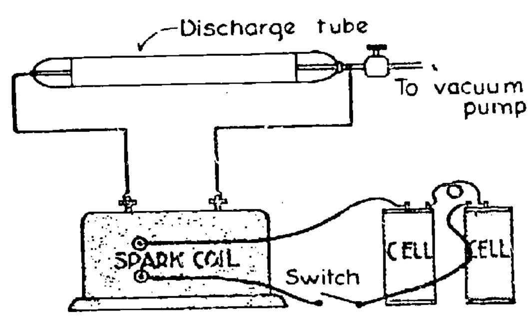
In gas discharge tubes, a high voltage ionizes the gas molecules. The molecules absorb energy which is later reemitted as visible light energy.

#Conduction in Gases

Connect a demonstration discharge tube to a vacuum pump. Connect the terminals of the secondary coil of an induction coil to the ends of the discharge tube. Connect the primary terminals of the coil to a 6-volt d.c. source. Start the vacuum pump and observe the discharge tube. The demonstration may include the use of commercial, gas-filled discharge tubes.

KEY WORDS

ionized gases



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. characteristics of an electric current	A source of electric potential energy and a continuous path (conductor) for charges are necessary for a complete electric current.
a. voltage	The energy per unit charge is measured in volts.

MATERIALS

ACTIVITIES

#The potential energy source (such as an electric cell) provides a force (electric field) on each charge which causes it to move through the conductor.

A continuous conducting path is called a closed circuit. An open circuit is one in which there is no complete path.

#At this level, potential difference, voltage difference, and voltage will be considered to be synonymous.

Batteries provide a source of electric potential difference. A voltmeter connected across the terminals of a cell or battery measures the potential difference between the terminals.

#Potential Difference

Connect the terminals of a 0-5 d.c. voltmeter to the positive and negative terminals of a large dry cell. Repeat with a flashlight cell. The reading of the voltmeter represents the difference in potential (voltage) between the terminals.

KEY WORDS

volt
voltage

Support a 2 or 3 foot length of bare resistance wire and attach the ends to the terminals of a dry cell. Connect one terminal of a voltmeter to one end of the wire and make the other connection by means of a clip lead which can be slid along the wire. As the lead moves along the wire, note the readings of the voltmeter. At any point along the wire the reading represents the potential difference between the terminal and that point on the wire.

To add variety, wires properly identified as positive and negative may be connected to the terminals of a variety of cells which are enclosed in boxes. Challenge pupils to determine the potential differences of the cells and to predict what combinations of cells are involved.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. electric current	The amount of charge flowing in any conductor is called electric current. The unit of electric current is the ampere.
c. resistance	The unit of electric resistance is the ohm. The resistance of a conductor • depends upon the material of which the conductor is made • increases as the length of the conductor increases • increases as the area of the cross-section decreases • usually increases as the temperature increases

MATERIALS

ACTIVITIES

The ampere is defined as one coulomb per second. If there is a current of one ampere, there are 6.25×10^{18} charges passing a point in one second.

One volt/ampere is equal to one ohm.

The relationship between voltage and current may be expressed as $V = IR$.

This statement, known as Ohm's Law applies primarily to metal conductors at a constant temperature. The law does not apply to electrolytic cells, to gas discharge tubes, and other devices.

KEY WORDS

electric current
ampere
resistance
ohm

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. electric circuits	Electric circuits are continuous conducting paths provided with a source of electric potential energy.
	Two types of electric circuits are series circuits and parallel circuits.
	*One other type of electric circuit is a combination of a series circuit and a parallel circuit.
a. series circuits	A series circuit is a circuit with only one conducting path.
*(1) voltage	The total voltage across a series circuit equals the sum of the voltages across the components of the circuit.
*(2) current	The current in a series circuit is the same at all points.
*(3) resistance	The total resistance of a series circuit equals the sum of the resistances in the circuit.

*optional

MATERIALS

ACTIVITIES

#Although a series circuit contains only one conducting path, the path may contain several components.

Students should be able to draw a simple series circuit with several components and be able to recognize a series circuit when seen.

#Characteristics of a Series Circuit

A series circuit may be studied by connecting two 10-ohm resistors to a source of voltage (5-6 volts) as shown on the next page. If a voltage source is not available, four dry cells in series will serve. Spring clip connectors with attached wires may be placed as shown to make it easy to break into the circuit at various points. If these connectors are not available, alligator clips may be inserted at the six points with each pair of clips hooked together to complete the circuit.

a. Voltage in the circuit. Connect a voltmeter between B and C to measure the voltage drop across R_1. Repeat by connecting the voltmeter between D and E. To determine the voltage drop across an entire circuit, read the voltmeter attached to the source or connect a voltmeter across the terminals. What is the relationship among the three voltages recorded?

KEY WORDS

electric circuit
series circuit

b. Current in the circuit. Remove the wire between A and B. Connect a d.c.-ammeter between A and B. Record the reading. Replace the wire and connect between C and D, then between E and F. Compare the readings. Is charge conserved in the circuit?

c. Resistance in the circuit. After removing the wire connection, insert an ammeter between points A and B. Connect a voltmeter between points B and C. The meters will give the current through R_1 and the voltage drop across it. Calculate the resistance of R_1 by using Ohm's Law, $V = IR$. In a similar manner calculate the

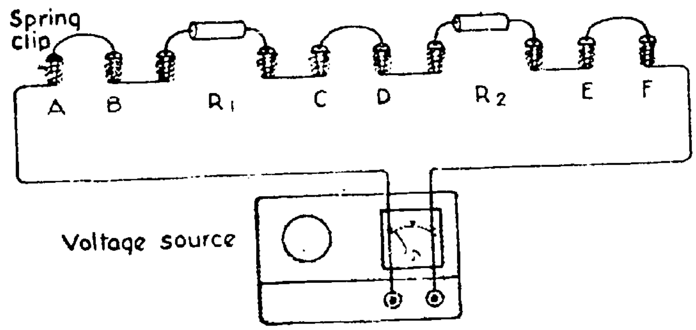
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

resistance of R_2. Calculate the resistance of the entire circuit by determining the voltage across both resistors (reading of the voltmeter attached to the source) and the current through the resistors. How does the total resistance compare with the sum of the individual resistances?



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
b. parallel circuits	A parallel circuit is a circuit in which there are two or more conducting paths.
*(1) voltage	The voltage across each branch of a parallel circuit is the same as the voltage across the source.
*(2) current	The sum of the currents through the branches of a parallel circuit equals the total current in the circuit.
*(3) resistance	The combined resistance of a parallel circuit is less than the resistance of any of its branches.

*optional

MATERIALS

ACTIVITIES

#Students should be able to draw a simple parallel circuit with several components and be able to recognize a parallel circuit when seen.

#Characteristics of a Parallel Circuit

A parallel circuit may be studied by connecting two 10-ohm resistors to a source of voltage (not over 5 volts) as shown on the next page. If a voltage source is not available, two dry cells in series will serve. Spring clips may be used at points A through J to permit easy access to the circuit. If a meter is not connected between two clips, a wire should be connected to complete the circuit. If spring connectors are not available, alligator clips may be inserted with each pair of clips hooked together to complete the circuit.

a. Voltage in the circuit. Connect a voltmeter between D and G. This gives the voltage drop across resistor R_1. Connect a voltmeter between F and H. This gives the voltage drop across resistor R_2. Connect a voltmeter between A and J. This gives the voltage drop across the entire circuit. Compare the three readings.

KEY WORDS

parallel circuit

b. Current in the circuit. Remove the co connecting wire and insert a 0-1 ampere ammeter between A and B. Note the reading. This is the current in the entire circuit. Insert an ammeter in a similar manner between C and D, and between E and F. These readings give the currents through resistors R_1 and R_2 respectively. Compare the current in the circuit with the sum of the current in the branches.

c. Resistance in the circuit. Use the three values of voltage with the three values of current just measured to calculate the combined resistance of the circuit and the resistances of the two branches. Is the combined resistance

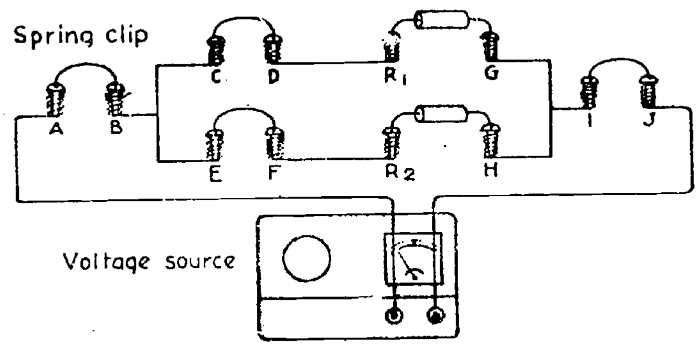
REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

equal to, greater than, or less than the resistance of either branch? Calculate the reciprocals of the three resistances. What is the relationship between the reciprocal of the combined resistance and the sum of the reciprocals of the resistances in the branches?



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
5. electric power	The rate at which the components of a circuit use electric energy is called power. The unit for electric power is the watt.
6. electric energy	The electric energy used by a circuit is the product of power and time. Two units of electric energy are the watt-hour and the kilowatt-hour.
II. Magnetism **	Magnetism is a phenonmenon exhibited by charges in relative motion. Some magnets are temporary magnets; others are permanent magnets.
A. Magnetic fields	Magnetic fields exist around magnetized objects.
1. detection of magnetic fields	One magnetic field may be detected by another.
2. direction of magnetic fields	The direction of a magnetic field is the direction in which the north-seeking pole (N-Pole) of a magnetic compass needle points when in the presence of the magnetic field.
3. magnetic field of the earth	The earth is a large magnet. The direction of the magnetic field of the earth is shown by a compass needle.

**Pupils may be familiar with the principles of magnetism from previous science work. Do not repeat unless necessary.

MATERIALS

ACTIVITIES

The power consumed by a circuit (in watts) equals the product of the voltage (in volts) and the current (in amperes).

* One joule/second equals one watt.

Power = volts x amperes

$$* \quad = \frac{\text{joules}}{\text{coulomb}} \times \frac{\text{coulombs}}{\text{second}}$$

$$* \quad = \frac{\text{joules}}{\text{second}}$$

Electric appliances are rated in terms of the rate at which they use energy.

Teachers should stress that one pays for electrical energy not electrical power.

The magnetic properties of substances are related to the locations and spins of electrons in the atom, and to the ease with which the electron spins can be aligned. Iron and its alloy, steel, have strong magnetic properties. Nickel, cobalt, and some of their alloys can be magnetized quite readily.

KEY WORDS

electric power
watt
electric energy
kilowatt-hour
magnetism

Steel retains its magnetism longer than soft iron, and can be used to make "permanent" magnets. A steel knitting needle may be magnetized by stroking it in one direction with one end of a bar magnet. The strength of permanent magnets may be decreased by (1) striking them, (2) heating them, or by (3) storing them with two like poles together.

*optional

REFERENCE OUTLINE	MAJOR UNDERSTANDING AND FUNDAMENTAL COMCEPTS

MATERIALS

ACTIVITIES

When two or more magnetic fields are in the presence of one another, the fields interact. Magnetic fields account for the operation of electric motors, electric generators, the acceleration of subatomic particles, and the propagation of electro-magnetic waves such as light and radio waves.

Magnetic fields of permanent magnets may be studied by placing paper or glass over the magnet and sprinkling iron filings on it. The iron filings become magnetized and align themselves with the magnetic fields of the permanent magnets.

[Since this phenonemon has undoubtly been demonstrated on several occasions, a passing reference to it should be sufficient.]

A compass needle on the surface of the earth aligns its N-pole in the direction of the field. There may be variations due to the nearness of certain metals.

A deviation of an ordinary compass needle from true north is known as magnetic declination.

A compass needle balanced around a horizontal axis is called a dip needle. The angle which the needle makes with the horizontal, the angle of inclination, varies with the latitude.

KEY WORDS

permanent magnets
temporary magnets
magnetic fields

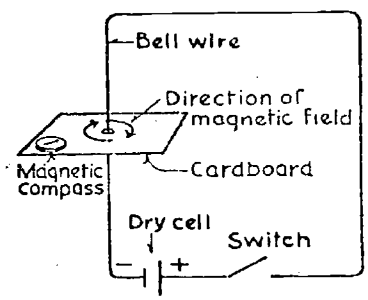
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. magnetic field around a straight metal current-carrying conductor	The magnetic field around a straight metal current-carrying conductor is cylindrical.
5. magnetic field around a coil	If a straight current-carrying conductor is bent into a coil, the ends of the coil become magnetic poles.

MATERIALS

ACTIVITIES

#FIELD AROUND CURRENT-CARRYING METAL CONDUCTORS

Fasten a piece of cardboard near the end of the table. Connect several feet of bell wire. as shown in the diagram below. Place several small compasses on the cardboard near the wire. Close the switch and note the directions of the N-poles of the compasses. Reverse the connections on the dry cell. Note the directions of the N-poles.



#THE SOLENOID COIL AND THE ELECTROMAGNET

KEY WORDS

electric coil

a. Connect about four feet of No. 18 insulated copper wire in series with a dry cell and switch as shown. Wrap about 1 foot of the wire around a pencil or wooden dowel to form a coil. Remove the pencil. Close the switch. By means of a compass determine the polarity of the coil. Trace the direction of the electron flow (-to+) through the coil. Wrap the fingers of the left hand around the coil in the direction of electron flow. To what pole does the thumb point? Reverse the connections and repeat. How can the left hand be used to predict the polarity of the eletro-magnet?

b. Place a compass about 1-3 inches from one end of the coil. Note the deflection when current is passing. Add an additional dry cell in series. Note the deflection of the needle. How does current affect the strength of the pole?

REFERENCE OUTLINE

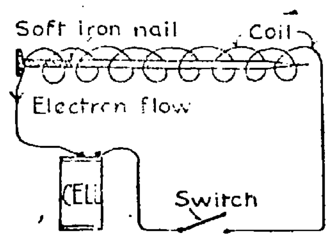
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

c. Connect only one dry cell in series. Note the deflection of the compass needle. Wind additional wire around the pencil as in a previous page. Place the compass the same distance from the end of the longer coil. Note the deflection. How does the number of coils affect the strength of the pole?

d. Insert an iron nail through the coil. Compare the deflection of the compass needle when the nail is in and when the nail is out of the coil.



KEY WORDS

REFERENCE OUTLINE

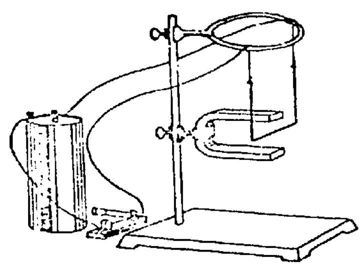
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#FORCE ON A CONDUCTOR IN A MAGNETIC FIELD

Suspend a swing of stiff copper wire by hooks so that the swing is between the poles of a horseshoe magnet as shown. The swing must have good electrical contact at the hooks and also be able to swing freely. Connect a dry cell and switch in series. Close the switch. What happens to the swing? Reverse the connections or reverse the poles of the magnet. What causes the motions?



#EFFECT OF MAGNETIC FIELD ON ELECTRON BEAM

KEY WORDS

The effect of a magnetic field on an electron beam may be shown by this apparatus. The tube, commonly known as a cathode-ray tube, is available commercially. The tube contains a fluorescent screen which is illuminated when struck by electrons emitted from one of the electrodes. A slit which is part of the assembly forms a straight beam from the electrons emitted by the electrode. The bean is visible on the fluorescent screen.

Connect the tube to the secondary terminals of an induction coil which is connected to a 6-volt power source or four dry cells in series. When operating a green line will appear on the screen.

REFERENCE OUTLINE

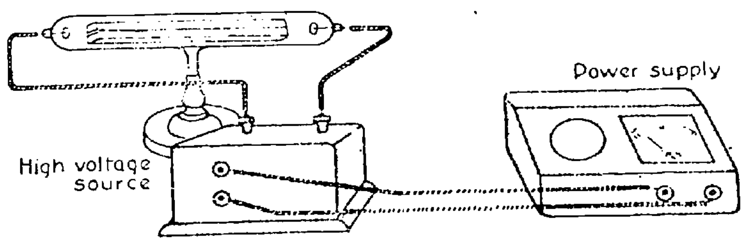
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Place a horseshoe magnet over the tube. Note any deflection on the electron beam. Reverse the poles of the magnet. Is the effect the same? Touch the N-pole of a bar magnet to the top of the tube. Repeat with the S-pole of the bar magnet.

An oscilloscope may be used in place of the cathode-ray tube shown.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. *Direct current motor	#When a current-carryigg loop is placed in a maggnetic field, a force is exerted on the loop.

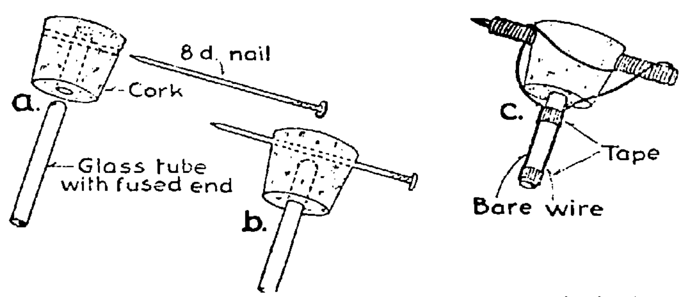
*optional

MATERIALS

ACTIVITIES

#DIRECT CURRENT MOTOR

An electric motor may be constructed to demonstrate the principle of a current-bearing wire moving in a magnetic field. The motor shown below uses electromagnets instead of permanent magnets.



Assemble the armature as the first step. For the bearing, cut a 2-inch piece of 6mm. glass tubing and seal one end in a bunsen burner flame. Drill holes vertically and horizontally through a cork as shown. A size 14 cork with a top diameter of about 1 1/4 inches is suitable. Insert the glass tube and an 8-penny nail as shown in steps a and b on the previous page.

KEY WORDS

electric motor

Wind the armature with No. 20 or No. 22 copper magnet wire. Wind both coils in the same direction. Strip the insulation from each end of the wire and tape as shown in step c.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

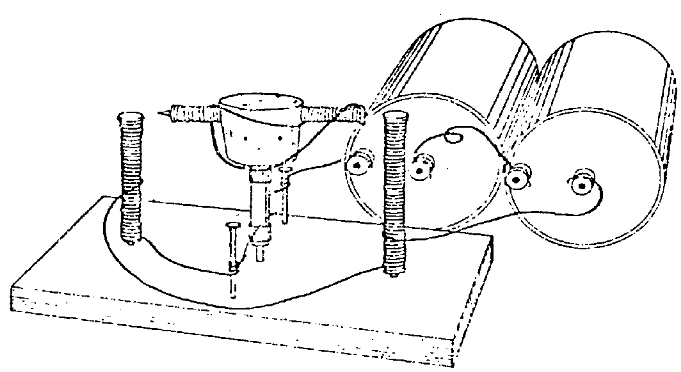
ACTIVITIES

Drive a 10-penny finishing nail through the center of a small board (about 4" x 6") and place the armature in position. The point of the nail in the glass makes a bearing of low friction. Drive two 10-penny naild into the board about 1/8 inch away from the ends of the nail of the armature. Each will be about 1 3/4 inch from the center nail. Wind these two nails in the opposite direction. Use two thumbtacks, small nails or screws to support the ends of the wires which act as brushes, as shown in the diagram of the motor.

Wire two or three dry cells in series or use a power pack and connect to the motor. Give the armature a spin. It may be necessary to adjust the brushes and the wires that touch the armature.

Determine the polarity of each pole of the field magnet by a compass or hand rule. Determine the polarity of each pole of the armature. Account for the turning of the armature.

KEY WORDS



Simple Motor

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

An electric motor transforms electric energy into mechanical energy.

MATERIALS

ACTIVITIES

#THE D.C. MOTOR

Use a demonstration type d.c. motor, or for individual student work, use small dissectible motors of the "St. Louis" type. Trace the circuit through brushes, commutator and armature. Remove the field magnet and use a compass to show the change of magnetic polarity of the armature as it is rotated. Using the permanent magnet field, show the effect of field strength on the speed of the motor by moving the magnet away while the motor is running. Change the applied voltage and note effect on speed. Reverse the connections to the brushes to reverse the direction of rotation. Connect an ammeter in series with the motor and note the current when the motor is running full speed, and when it is slowed down by a finger held against the shaft.

If an electromagnet field is available, operate the motor with field in series and in parallel. Show the method of reversing.

Operate the motor on a.c. supplied by a small transformer.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. *Induced voltage	When a metal conductor is moved perpendicular to a magnetic field, or a magnetic field is moved perpendicular to a metal conductor, an electric potential difference is produced (induced) across the conductor. If this conductor is part of a closed circuit, there will be a current in the conductor. When a current is induced, some of the mechanical energy of the moving conductor is transformed into electric energy.

*optional

MATERIALS

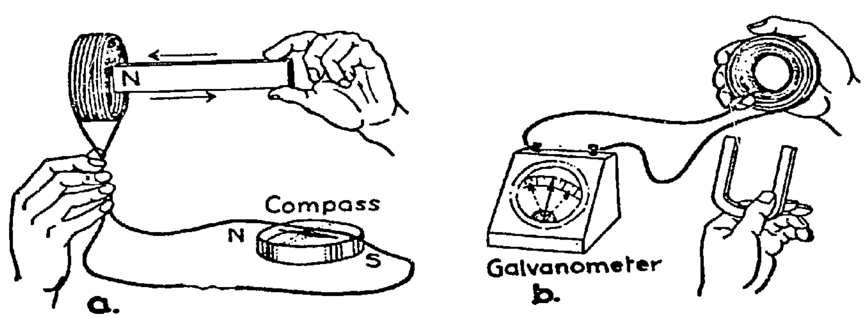
ACTIVITIES

Make a coil of several turns of insulated wire. Join the ends of the wire together and support the coil as shown in a with a section over a compass. Thrust one pole of a bar magnet into the coil and observe the action of the compass needle. Next hold the magnet motionless in the coil. Now remove the magnet from the coil and observe the action of the compass. Repeat this prodedure using the opposite pole of the magnet.

Separate the ends of the coil and connect the coil to a galvanometer as shown. Repeat the above steps using the bar magnet and also a U-magnet. Note the action of the galvanometer needle. Hold the magnet stationary and move the coil. Try moving the magnet or the coil faster. Use a coil having a different number of turns. Substitute a weak magnet for a strong one.

On the basis of their observations, pupils should develop some understanding of the simpler relationships between magnetism and induced electric currents.

KEY WORDS



REFERENCE OUTLINE

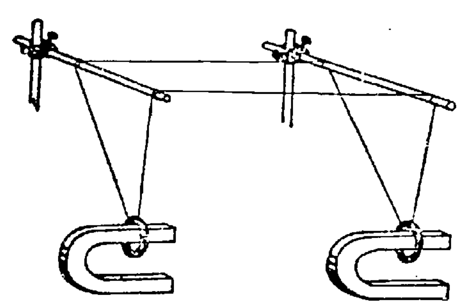
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

#Wind a coil of about 50 turns of No. 26 enameled copper wire around three fingers of the hand, wrap it with the free end of the wire to hold the coil in place. Without cutting the wire, take three or four feet of extra wire off the spool and wind a similar coil, leaving another length for the return connection. With the coils in series, hang each by its own leads just high enough above the table top to swing freely over the pole of a strong horseshoe magnet. The points of suspension must be the same height so that the coils acting as pendulums have the same period.

When one coil is set swinging the other quickly responds. In addition to illustrating electrical relationships, this experiment can be used to help establish the concept of resonance. It is instructive to reverse the polarity of one of the magnets and discuss the result.



KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
III. Light	Light is a form of energy. Light is electromagnetic radiation that produces the sensation of sight.
A. Electromagnetic radiation	Energy transferred through a vacuum (free space) travels in the form of electromagnetic waves.
1. sources	Electromagnetic radiation may arise from . accelerating electrons in an electric field or circuit . electric discharges . incandescent objects

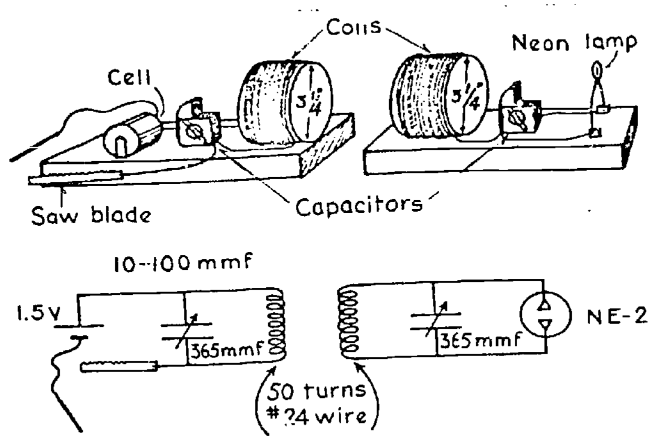
MATERIALS

ACTIVITIES

#2 DETECTION OF ELECTROMAGNETIC RADIATION

a. Assemble the apparatus as shown in the diagram below. The switching mechanism is an iron saw blade and a stiff piece of copper wire. Draw the wire across the saw blade to make and break the circuit rapidly. Observe any change in the neon lamp.

The dry cell supplies the energy to accelerate the electrons originally. A magnetic field builds up in the vicinity of the coil connected in series to the dry cell. When the switch is open, the current oscillates through the coil with the magnetic field building up and decaying alternately. Energy lost by heat is replaced by the cell when the switch is again closed.



KEY WORDS

light
electromagnetic
radiation

b. Connect an induction coil to a 6-volt source. Place an operating A-M radio near the points of the coil where discharge occurs. Is there any evidence of radiation during discharge?

c. Heat a piece of copper wire in the flame of a bunsen burner until the wire glows. Remove and place the wire near the hand. Is there evidence of two kinds of electromagnetic radiation?

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. characteristics	All electromagnetic radiation is a form of energy.
a. frequency	The number of waves passing a point in a unit of time (second) is the frequency of the waves.
	Frequency may be expressed in cycles per second or hertz.
b. wavelength	The distance from one point in a wave to the corresponding point in the next wave is the wavelength.
	Wavelength may be expressed in any unit of length.
c. speed	Electromagnetic radiation travels in a vacuum at a speed of 3×10^8 meters per second (300,000 km/sec) or 186,000 mi/sec.

MATERIALS

ACTIVITIES

Common examples of evidence that light is energy are photographic light meters (light energy to electric energy) and photosynthesis (light energy to chemical energy).

Recently the term "cycles per second" has been given a name, "hertz". Many recent publications use this term. For example, 20 cycles per second are 20 hertz.

The color of light depends upon the frequency of the wave.

Wavelength of light is usually expressed in Angstroms (Å). An Angstorm is 1 x 10-10 meter or 1 x 10-8 centimeter (0.00000001 cm).

The speed of a wave is the product of its frequency and wavelength.

Since electromagnetic waves in a vacuum all travel at the speed of light, the equation is written as $c=f\lambda$, where c is the speed of light and λ is the wavelength/

KEY WORDS

frequency
hertz
wavelength

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. classification	Electromagnetic waves are classified according to their wavelengths: . electric waves . television and radar waves . microwaves and radar . infrared . visible light . ultraviolet . gamma rays and x-rays . cosmic rays
	The electromagnetic spectrum consists of all frequencies of electromagnetic radiation from those radiations with very long wavelengths to those with very short wavelengths.
	The visible light portion of the electromagnetic spectrum is relatively narrow.
B. Intensity and illumination	The amount of light falling on a surface (illumination) depends on the intensity of the source and the distance that the surface is from the source.
1. path of light	Light travels away from a source in straight lines.
2. illumination	The amount of illumination on a surface decreases as the distance between the source and the surface increases.

MATERIALS

ACTIVITIES

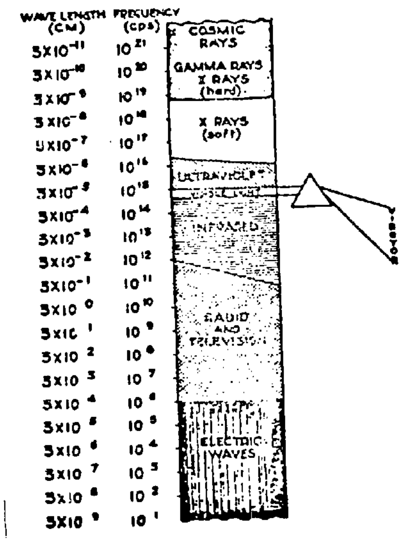
Supplementary Information
For Teachers

It is important to point out that there is no definite dividing line between "adjacent" categories of electromagnetic radiation. The chart of the spectrum shown represents only approximations.

[Pupils should not be expected to memorize the approximate frequencies or wavelengths of these radiations.]

It is particularly important to point out that only a small portion of the spectrum can be directly detected by the eyes. Other devices must be used to detect radiations not visible to the eye.

THE ELECTROMAGNETIC SPECTRUM



KEY WORDS

electromagnetic spectrum

REFERENCE OUTLINE

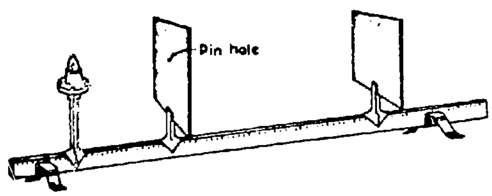
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

RIALS

ACTIVITIES

INTENSITY OF ILLUMINATION

Allow light from a small source (such as a "germ of wheat" lamp) to pass through a pinhole in a cardboard. (This simulates a point source of light.) Place a screen at a measured distance from the pinhole. Determine the diameter of the spot of light and compute the area of the spot. If a light meter is available determine the reading. Double and triple the distance from the source. Make similar measurements. Does the area of the spot change as the distance from the source (pinhole) changes? If so how? Does the intensity of illumination change? If so, how?



WORDS

A light meter placed in front of an automobile headlight will not illustrate the inverse square law since the light is not a point source. Acutally, the virtual or apparent source of light which has been reflected by a mirror is several feet behind the headlight.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Reflection of light	When a beam of light strikes a surface, some light will be reflected and some will be absorbed and some may be transmitted.
1. laws of reflection	Two laws associated with reflection of light are: • When light rays strike (are incident upon) a reflecting surface, they are reflected in the same plane as the incident rays. • When light strikes a surface and is reflected, the angle of incidence equals the angle of reflection.

MATERIALS

ACTIVITIES

Supplementary Information for Teachers

If an optical disk is used, the laws of reflection may be illustrated quite easily.

Certain reflecting surfaces, such as mirrors, reflect the image of the object providing the incident light. This is known as specular reflection. Other reflecting surfaces are irregular, and light is reflected in many different directions although the laws of reflection apply to each ray of light. This is known as diffused reflection. Diffused reflected light is particularly good for reading since it reduces shadows.

When light is reflected by a planeemirror to "form" an image, the reflected rays appear to have come from behind the mirror. This is where the virtual image appears to be. Since it is impossible for the rays of light to pass through the mirror, no image will be formed on a screen placed where the image appears to be.

KEY WORDS

Reflection
Angle of Incidence
Angle of Reflection

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

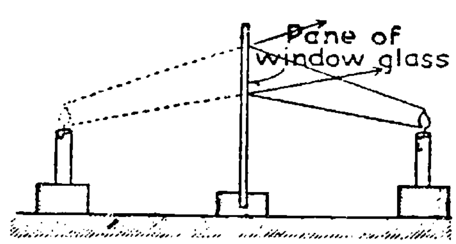
ACTIVITIES

#VIRTUAL Nature of Plane Mirror Image

A very instructive and entertaining illusion may be assembled with two candles and a pane of window glass. The candles, as nearly identical as possible, are mounted on opposite sides of the vertical piece of glass. The rear candle is carefully placed at the position of the image of the front one formed by the glass. When only the front candle is burning, both appear to be lit, the virtual image of the flame appearing on the unlit candle. The glass plate must be large enough so the image can be seen from all parts of the classroom. The instructor can hold his finger in the "flame" of the rear candle without burning it, or expound a new method of "fireproofing" paper. When the rear candle or the glass is moved, the fact that only one candle is lit is immediately obvious. When the illusion is adjusted for best coincidence of candle and image, the object and image distances to the reflecting surface can be measured and of course will be equal. The fact that the image and object lie on a line perpendicular to the glass and that the image is virtual, erect and the same size as the object should be noted.

For an amusing variation, mount the unlit candle in a beaker, and pour water into it. Finally the flame appears to be under water.

KEY WORDS



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Refraction of light	A light ray moving obliquely from one medium to another is refracted (bent)
E. Color	The color of light depends upon the frequency (or wavelength) of its waves.
1. reflection	The color of light reflected from a surface depends on the color of the incident light and the nature of the reflecting surface.
2. transmission	The color of light transmitted by transparent materials is determined by the color of the incident light and the wavelengths of light to which the materials are transparent.

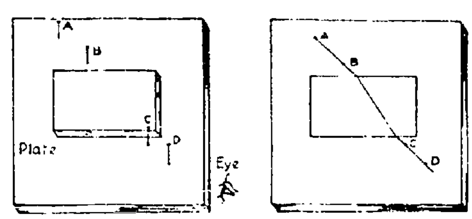
MATERIALS

ACTIVITIES

#REFRACTION OF LIGHT

a. Pupils can easily observe refraction of light if an optical disk is used. Allow a fine pencil of light to pass obliquely from air into glass. Observe the bending of light as it enters and leaves the glass.

b. Place a rectangular piece of glass about 1/2 inch thick on a tablet. With a pencil draw the outline of the glass. Place pins A and B in the tablet so that a line connecting the points would strike the glass obliquely. Place your eye close to the table and sight through the opposite side of the glass at pins A and B. Place two additional pins so that all four pins appear to be on the same line. Remove the plate. Extend lines AB and CD to the edge of the plate. Draw line BC. Construct perpendiculars at B and C. Note the bending of the light ray as it entered and left the glass.



KEY WORDS

refraction
color

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

REFLECTION OF LIGHT

Place several objects in the path of a beam of light. Objects suggested are paper of various colors, colored glass or cellophane, cardboard with surfaces of varying smoothness, and sheets of assorted metals. Note differences in the amount of light reflected, color reflected and whether your image can be seen when looking at the surface. Can you make any generalizations?

White Light is called polychromatic light because it is composed of many colors (different frequencies or wavelengths.) Light of each different color is slowed down differently as it moves from air into a more optically dense medium. When white light passes obliquely into a prism, each color is refracted differently and is separated.

The prism spectroscope, operating on the principle of the dispersion of light, is used to identify chemicals.

Probably the topics of the color of reflected and transmitted light have been presented in previous years. Only a brief review should be necessary here.

KEY WORDS

The wavelengths of light which are reflected from a surface depend upon the material of which the surface is composed. If the atoms in the surface are such that they will accept energy from incoming wavelengths of light, then those wavelengths will be absorbed. The other wavelengths will be reflected.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
IV. Sound	*Sound is a form of mechanical energy.
	Sound is a periodic disturbance in an elastic medium.
	*Sound requires a medium through which to travel.
A. Sources	Sound is produced by vibrating matter.
B. Characteristics of sound waves	The properties of sound depend upon the characteristics of its waves.
1. type	*Sound travels in longitudinal (compressional) waves.
	As longitudinal waves move through a medium, the molecules of the medium are alternately closer together (condensations) and farther apart (rarefactions) than when in the rest position.
2. frequency	The frequency of a sound wave is the number of vibrations of its particles each second.
	*The frequency of sound waves is less than that of light waves.
3. wavelength	The wavelength of a sound wave is the distance from one condensation to the next condensation.

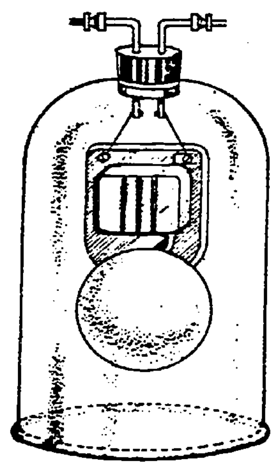
*optional

MATERIALS

ACTIVITIES

#TRANSMISSION OF SOUND THROUGH A MEDIUM

Place a bell jar with an opening on the top on a pump plate. Connect a bell in series with a switch and dry cell by means of wires passing through a rubber stopper. Place the stopper securely in the top of the bell jar. Close the switch. Note the loudness of the sound caused by the bell. Evacuate the air from the bell jar by means of a pump. How does the loudness of the sound change?



KEY WORDS

Sound
Longitudinal Wave

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

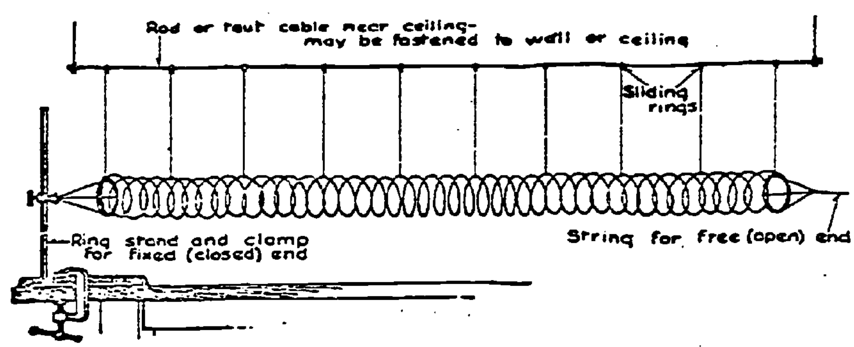
MATERIALS

ACTIVITIES

#LONGITUDINAL WAVES

Suspend a coiled screen door spring or a "slinky" between two upright supports so that the spring is slightly extended. Tie strings at regular intervals along the spring to give additional support.

Pinch together a few coils at one end of the spring and release. Note the motion of the pulse and its reflection from the end of the spring. Repeat by alternately compressing and releasing the spring. In what direction do the parts of the spring vibrate? Compare the direction of vibration with the direction of wave motion.



KEY WORDS

The pitch sound depends upon the frequency of the sound wave.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

The frequencies of sounds emitted by musical instruments may be changed by changing the lengths of air columns or strings.

Sound is often defined as a disturbance that can be detected by the human ear. Although there are individual variations, sound can be heard if the frequency of its wave is between approximately 20 cycles per second and 20,000 cycles per second. If the frequency is below 20 cycles per second, the sound is called infrasonic. Frequencies over 20,000 cycles per second produce sound that is known as ultrasonic.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. speed	*The speed of sound in air at 0°C. is approximately 331 meters per second (1090 feet per second.)
5. amplitude	The loudness of a sound depends upon the amplitude of a sound wave.
C. Reflection	*Sound waves may be reflected.
D. Resonance	A source of sound may cause an object to vibrate if the vibration rate of the object is the same as that of the source.

MATERIALS

ACTIVITIES

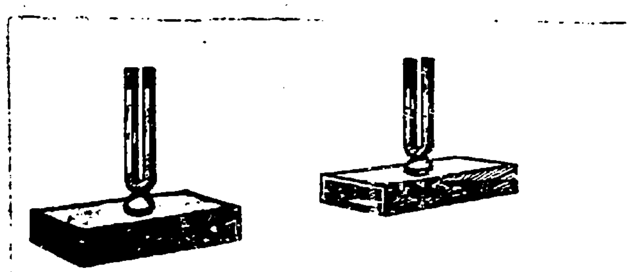
*The speed of sound in air increases about 0.6 meters per second (or 2 feet per second) for every Celsius degree increase in temperature.

*If a sound wave is reflected back to the ear in a time greater than 0.1 second, a separate sound is distinguished which is known as an echo.

Interesting applications of the reflection of sound involve whispering galleries, parabolic microphones to pick up crowd noises, and sonar.

RESONANCE

Obtain two tuning forks of the same frequency. Strike one fork and place both forks on a table several feet apart. After several seconds stop the vibrations of the first tuning fork. Can you determine if the second fork is vibrating? (If resonance boxes are attached to the two tuning forks, the results are more obvious. Place the boxes so that the open ends face each other.)



KEY WORDS

Amplitude
Resonance

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Actually resonance will occur if the natural vibration rate of the object is a multiple of the vibration rate of the source.

Resonance may be likened to pushing a child on a swing. A small force appl&ed at the proper times will increase the amplitude of the swing.

An outstanding example of resonance is the destruction of the Tacoma-Narrows Bridge in 1940 which began to oscillate due to the frequency of gusts of wind.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
V. Heat and Its Effect on Matter	
A. Heat	Heat is the total kinetic energy of all the molecules in a substance.
1. heat transfer	Adding heat to a substance increases the total kinetic energy of all the molecules in the substance.
	Removing heat from a substance decreases the total kinetic energy of all the molecules in the substance.
2. measurement of heat	Heat may be measured in MKS units call kilocalories.
	The kilocalorie is the heat required to raise the temperature of one kilogram of water one Celsius degree.
B. Temperature	Temperature is a property of bodies that determines in which direction heat will flow when the bodies are in contact.
	When two bodies are in contact, heat will flow from the body of higher temperature to the body of lower temperature.
1. measurement of temperature	The temperature of a body is stated in comparison to some standard temperature.

MATERIALS	ACTIVITIES

Substances such as a block of wood, a quart of water, or a cubic foot of gas, are composed of particles which are moving. The particles have kinetic energy due to their motion.

The Kilocalorie is equal to 1000 calories.

Food is often described as having a certain number of calories. This means the heat energy available when the food is oxidized. The Calorie (large calorie) is the kilocalorie.

*In the English system the unit of heat energy is the British Thermal Unit (B.t.u.). The B.t.u. is the heat required to raise one pound of water one Fahrenheit degree. The B.t.u. is often used to indicate heat energy available from fuels.

It is very difficult at this level to give a good definition of temperature. Temperature may be defined as being determined by the average kinetic energy of the molecules. Another definition of temperature is that property of a body that is measured by a thermometer.

KEY WORDS

Heat
Kilocalorie
Temperature

Since heat and temperature are so closely related, it is suggested that both be discussed at the same time. However, it should be made clear that temperature and heat are not the same.

A comparison that may help to distinguish heat and temperature is: Temperature is to heat as water pressure is to the amount of water.

*optional

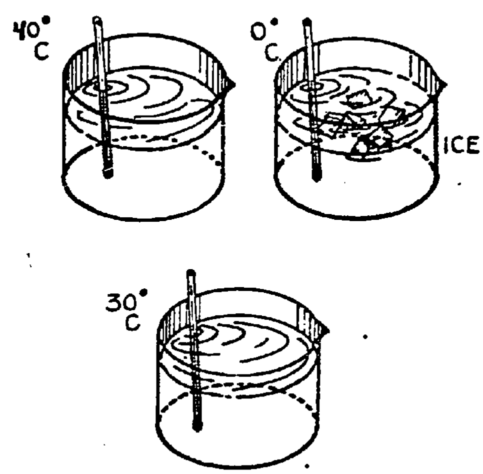
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	Two common standard temperatures are the boiling and freezing temperatures of water at one atmosphere of pressure.
	The boiling point and the freezing point of water are often referred to as the fixed points on a thermometer scale.
2. thermometer	A thermometer is a device to indicate temperature in relation to a certain standard temperature.
	Many thermometers operate on the principle of the expansion and contraction of solids, liquids or gases, with increases or decreases in temperature.
a. Celsius scale	The fixed points on the Celsius scale are 0 degrees and 100 degrees.
b. Fahrenheit scale	The fixed points on the Fahrenheit scale are 32 degrees and 212 degrees.

MATERIALS

ACTIVITIES

#TEMPERATURE IS RELATIVE

Three 500-ml. beakers can be used to demonstrate that temperatures are relative. One beaker is half-filled with water at room temperature, the second beaker is half-filled with water at 100-120°F., and the third beaker is half-filled with a mixture of ice and water. Have a student place one hand in hot water and the other in ice water for 1-2 minutes. Remove the hands and place them in the water at room temperature. Is the water at room temperature hot or cold? In which direction do you think heat is flowing in each case? Is the body a good thermometer?



KEY WORDS

thermometer
Celsius
Fahrenheit

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

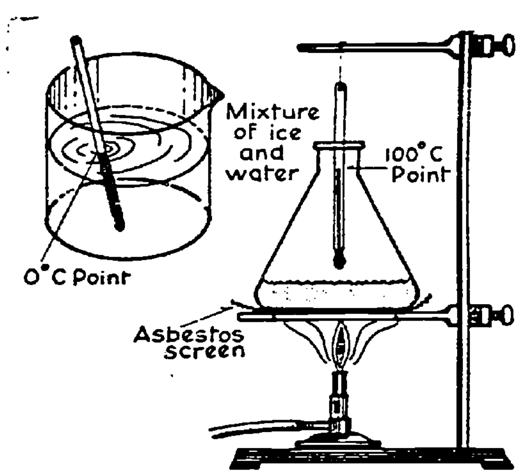
MATERIALS

ACTIVITIES

CALIBRATION OF A THERMOMETER

Place a mixture of ice and water in a beaker. Insert an unmarked mercury or alcohol thermometer. After the reading becomes constant, mark the location of the reading.

Place about 2 inches of water in an Erlenmeyer or Florence Flask. Suspend the thermometer so that its bulb is about 1 inch above the surface of the water. Heat the water to boiling. Mark the location of the liquid in the thermometer when the reading is constant.



KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

The type of thermometer used at a given time depends in part on the temperature to be measured. A mercury thermometer cannot be used at temperatures below -39° C., the approximate freezing point of mercury.

In some applications the temperature of a glowing object may be obtained from its color. An optical pyrometer is used for this purpose. In still other instances, temperature may be measured electrically. A thermocouple is a device to measure temperature in this way.

Thermometers are calibrated by determining two fixed points and dividing the distance between the points into a desired number of equal parts. Between the fixed points the Fahrenheit scale has 180 degrees while the Celsius (formerly Centigrade) scale has 100 degrees. The divisions may be extended beyond the fixed points in either direction.

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Sources of heat	Heat energy may be derived from other sources of energy, such as: mechanical energy electric energy chemical energy nuclear energy

MATERIALS

ACTIVITIES

TRANSFORMATION OF MECHANICAL ENERGY TO HEAT ENERGY

Place water in a 500-ml. beaker or other container until the container is about half full. Determine the temperature of the water. Remove the thermometer. Beat the water for one minute with a manually-operated egg beater (or an electric egg beater borrowed from the home economics department). Determine the temperature. Account for any change in temperature. Has the thermal energy of the water increased?

TRANSFORMATION OF ELECTRIC ENERGY TO HEAT ENERGY

KEY WORDS

Connect a 10-ohm, 5-watt resistor in series with a power pack. Place about 100 grams of water in a beaker. Determine the temperature of the water. Place the resistor in the water and connect the power pack to a voltage source. Set the output for about 6 volts. (If a power pack is not available, use four dry cells connected in series). After about one minute determine the temperature of the water. Has the temperature increased? Has the thermal energy of the water increased?

This experiment may be conducted quantitatively by a few pupils using more elaborate apparatus. The container of water should be insulated. The voltage and current across the resistor should be determined by appropriate meters. The method for calculating the heat gained by the container is found in most physics textbooks. Pupils should be able to determine a relationship between electric energy and heat energy.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Transmission of heat energy	Heat may be transferred from a body of higher temperature to a body of lower temperature by conduction, convection, and radiation.
1. Conduction	Conduction is the transfer of heat from particle to particle within a body.
	Metals are usually the best conductors of heat.
	Substances which conduct heat slowly are known as heat insulators.
2. convection	Convection is the transfer of heat through liquids and gases by means of currents.
	Convection currents transfer heat through the waters and atmosphere of the earth.
3. radiation	Radiation transfers heat by infra-red electromagnetic waves.
	Radiant heat travels at a speed of $3x10^8$ meters per second (186,300 miles per second).
	The heat which the earth receives from the sun is transmitted through space by radiation.

MATERIALS

ACTIVITEES

HEAT TRANSFER BY CONDUCTION
(Do not repeat unnecessarily)

Place one end of a metal bar or wire in the flame of a bunsen burner or near another heat source. Place your fingersat the other end of the metal. Is a temperature rise noted?

The investigation can be made more quantitative by heating various solids (including metals) of equal demensions (length and cross-sectional area) and noting the time for a given increase in temperature at the other ends. Bits of wax are often placed at the opposite ends. How does wax serve as a temperature indicator. Which substances conduct heat most rapidly? Least rapidly?

KEY WORDS

conduction

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

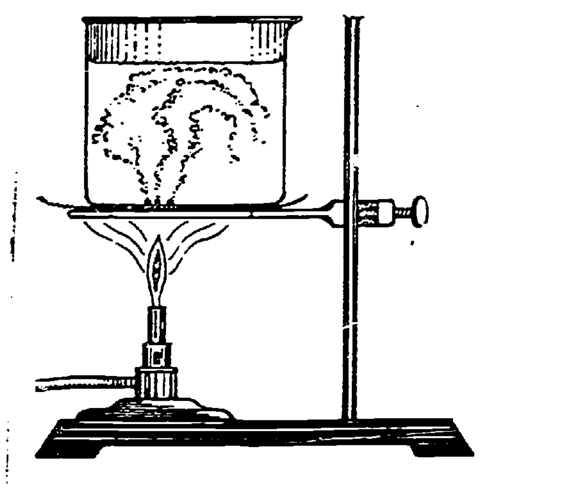
MATERIALS

ACTIVITIES

HEAT TRANSFER BY CONVECTION
(Do not repeat unnecessarily)

Place approximately 400-ml of water in a 500-ml. beaker. Set the beaker on a tripod. Apply heat to the center of the bottom of the beaker. Add two or three crystals of potassium permanganate or two or three drops of ink to the water. Note the direction of the currents as shown by the movement of the coloring material.

Open a refrigerator door. Check the motion of currents using smoke or by threads held in the hand. Have pupils hold thermometers above and below the open door to note any change in temperature.



KEY WORDS

convection

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

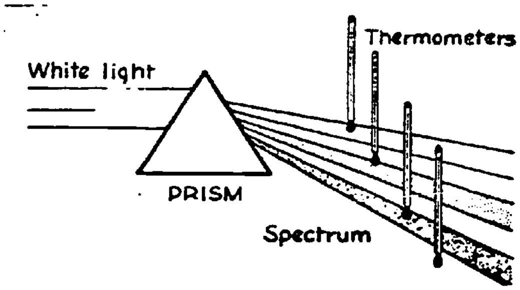
MATERIALS

ACTIVITIES

TRANSFER OF HEAT BY RADIATION

Have pupils hold their hands about 6 inches above, below and to the side of an operating electric iron. Can convection account for any transfer of heat below and to the side of the iron?

Use a triangular prism to disperse light from the sun or some other intense source of heat and light. Hold a thermometer for a minute in the blue, yellow, and red portions of the spectrum. Is there any temperature rise? Hold the thermometer in the dark area beyond the red. What effect, if any is noted?



An interesting "recent" application of the use of infrared rays is infrared photography. Photographs taken with special film reveal differences in ground cover anddthe location of cities by differences in heat radiated from various objects. This technique has important military and civilian uses.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

TEMPERATURE AND CHANGES OF PHASE

Have pupils place crushed ice into a 150-ml. beaker. Support a thermometer so that its bulb is buried in the crushed ice. At one-minute intervals, have the pupils read and record the temperature and note the state(s) of matter seen in the beaker at the time of each reading. Continue to take the temperature after the ice has changed to water.

The data should be graphed with temperature on the x-axis. The graph will be a horizontal line during the change of phase since any heat absorbed by the ice is used to rearrange the molecules for the liquid phase. After all the ice has melted, the temperature will rise at a fairly uniform rate. Details of the latent heat of fusion can be found in physics textbooks.

The time required for this activity can be decreased by setting the beaker of ice in a dish of hot water.

Have pupils account for the change in the slope of the graph.

KEY WORDS

solid
liquid
gas
melting point
freezing point
boiling point
condensation point
expansion
contraction

The energy being absorbed or liberated during a change of phase is involved with the particles adjusting themselves to the new conditions necessary for the new phase. Primarily, it is a shift of potential energy since the constant temperature indicates that the average kinetic energy of the particles is remaining constant.

It is not necessary for pupils to learn the boiling and freezing points of any substance except those for water.

As the pressure on a liquid increases, the boiling point increases.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
E. Phases of matter	Matter may exist in the solid phase, liquid phase, and gaseous phase. The phase in which matter exists depends on how close together its particles are and how fast they move. When a change of phase occurs, energy is either absorbed or liberated.
1. melting point and freezing point	A pure solid has a definite temperature called the melting point, at which it turns into a liquid. A liquid changes into a solid at a temperature called its freezing point. The melting and freezing points of a substance are the same under the same pressure. It is possible for a substance to exist as a solid and liquid at the same temperature.
2. boiling point and condensing point	A pure liquid becomes a gas at a definite temperature called the boiling point. The boiling point is usually recorded at one atmosphere of pressure. A gas condenses into a liquid at the condensation point. The condensation and boiling points of a given substance are the same temperature under the same pressure.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
F. Expansion and contraction	Matter generally expands as it absorbs heat and generally contracts when heat is removed from it. (A notable exception to these effects takes place in water between 0° C. and 4° C.
G. Conservation of heat energy	When heat flows from one body to another, the heat lost by the warmer body is equal to the heat gained by the cooler body.

K-121

MATERIALS

ACTIVITIES

KEY WORDS

BLOCK L

LIVING WITH THE ATOM

BLOCK L - LIVING WITH THE ATOM

INTRODUCTION

Radioactivity

nuclear reactions
nature of radiations
detection of radioactivity
rate if deca' - half life

Induced Radioactivity

Nuclear Fission

chain reactions
uncontrolled reactions
controlled reactions

Nuclear Fusion

Uses of Radioactive Isotopes

chemistry
biology
medicine
agriculture
archeology
industry

Radiation Safety

effects of radiation
effects of nuclear explosions
physiological effects of radiation
protection against effects of nuclear explosions

Important concepts are indicated by a dagger (+). Materials considered of an enrichment nature are indicated by an asterisk (*).

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
I. Radioactivity	Radioactivity is an atomic property and is independent of the state of chemical combination.
A. Particles	Radioactivity is an effect of transmutation with emission of alpha and beta particles.
	Alpha particles are positively charged helium nuclei. Beta particles are negatively charged electrons.
	When an atom is bombarded by alpha particles, scattering occurs giving evidence of the presence of an extremely small, positively charged nucleus and much empty space.
	It was proposed that when radioactivity is occuring, heavier atoms are breaking down into lighter atoms and are giving off some energy in the form of radiations.
	Information obtained from x-rays made it possible to arrange elements in a table according to their atomic numbers.

K-3

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Some symbols commonly used to represent nuclear particles are:

proton $^{1}_{1}H$

electron $^{0}_{-1}e$

neutron $^{1}_{0}n$

alpha particle $^{4}_{2}He$

gamma ray $^{0}_{0}\gamma$

deuteron $^{2}_{1}H$

The lower number (subscript) represents the charge or the atomic number. The upper number (superscript) represents the mass.

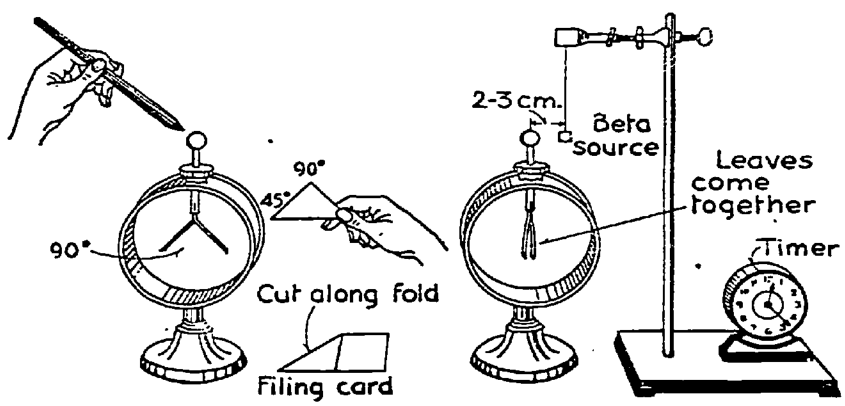
MATERIALS

filing card
electroscope
timer
beta source
rubber rod

ACTIVITIES

Charge an electroscope so that its leaves diverge 90° and measure the time that elapses until the divergence is reduced to 45°. Now charge the electroscope again so that its leaves diverge 90° and suspend a radioactive beta source near the ball at a distance of 2 or 3 cm. Measure the time required to discharge the electroscope to the same point as before.

To measure divergences of 45° and 90° with reasonable accuracy, fold over the corner of a filing card as shown in the diagram and cut along the fold with a scissors. A small right triangle remains. Sight across the right angle corner of the triangle and adjust the charge of the electroscope until the diverged leaves are in line with it. Sight across one of the 45° angles of the triangle until the electroscope is discharged to that point.



KEY WORDS

alpha particle
atomic
beta
deuteron
elements
emission
nucleus
nuclear
property
radioactivity
symbols
transmutation

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. Isotopes	+Atoms of the same element always have the same number of protons in the nucleus.

+Atoms of the same element may have different numbers of neutrons in the nucleus. These atoms of the same element with different masses are called isotopes.

Isotopes of a given element occupy the same place in the periodic table.

Many isotopes are unstable and break down spontaneously emitting atomic radiations These unstable isotopes are called "radioisotopes".

Isotopes of an element have the same chemical properties but different masses. The chemical properties are the same number of electrons outside the nucleus. These electrons are involved in chemical reactions.

Although there are only about 103 different elements, about 280 stable isotopes exist in nature. Man has been able to make an additional 800 or more isotopes -- most of which are unstable and radioactive.

+The location of unstable isotopes may be determined by detecting the radiations they produce.

All isotopes with atomic numbers greater than 83 are radioactive.

L-7

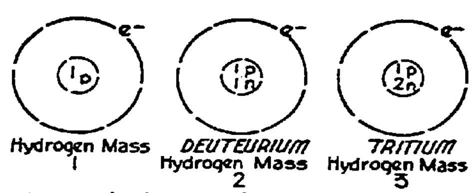
MATERIALS

ACTIVITIES

Atoms of the same element may vary in mass because of different numbers of neutrons within the nucleus. These different atoms of the same element are called <u>isotopes</u>. Isotopes of an element contain the same number of protons but a different number of neutrons. Isotopes of the same element have similar chemical properties.

The chemical properties of the isotopes are the same since the number of orbital electrons is identical for isotopes of the same element. (In the case of the isotopes of hydrogen, distinctive names have been given to each isotope. This is a unique situation. In other cases the isotopes are identified by their mass number such as U-235 and U-238).

Use the isotopes of hydrogen to illustrate the nuclear structure of a series of isotopes as shown on the following diagram:



Isotopes of Hydrogen

KEY WORDS

detecting
isotope

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Listed are some common isotopes, some of which are radioactive. Have pupils determine the difference in nuclear structure of the following series of isotopes and identify the more stable isotope in each series. What determines which one of the isotopes is considered the "more" stable? (Its mass is usually closest to the average mass of the isotope given in the periodic table.)

$^{39}_{19}K$	$^{40}_{19}K$	$^{41}_{19}K$	$^{31}_{15}P$	$^{32}_{15}P$	$^{34}_{15}P$
$^{16}_{8}O$	$^{17}_{8}O$	$^{18}_{8}O$	$^{273}_{88}Ra$	$^{224}_{88}Ra$	$^{226}_{88}Ra$
$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$	$^{233}_{92}U$	$^{235}_{92}U$	$^{238}_{92}U$
$^{59}_{27}Co$	$^{60}_{27}Co$				

Establish specific lists of isotopes and their applications in medicine, industry, agriculture, food preparation and preservation, etc.

KEY WORDS

masses
periodic table
spontaneously
unstable

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Nuclear Reactions	
1. Radioactive atoms	+The nucleus of an atom may be stable and therefore give off no radiations. The nucleus of an atom may be unstable and give off radiations. This type of nucleus is said to be radioactive.
	+Some atoms are naturally radioactive.
	+Some atoms can be made radioactive by bombarding them with particles.
	Some particles which are used to bombard atoms are neutrons, protons, and alpha particles.
	+Radioactive atoms emit particles and/or other forms of radiation.
	The emissions of radioactive atoms include protons, neutrons, beta particles, alpha particles, and energy in the form of gamma rays.

MATERIALS

ACTIVITIES

THE NATURAL RADIOACTIVE SERIES

Three series of naturally radioactive isotopes are known: the uranium-238; the thorium series; and the actinium or uranium-235 series. Another series, the neptunium-237, has been produced in the laboratory. The Np-237 series with a half-life of 2.2 million years is too short to enable this series to sustain itself over the age of the universe, 4×10^9 years.

CHARACTERISTICS OF NATURAL RADIOACTIVE ISOTOPES

Name	Parent Nuclide	Stable end product	Half-life of parent nuclide
Thorium	Th-232	Pb-208	13.9×10^9 yrs.
Uranium	U-238	Pb-206	4.5×10^9 yrs.
Actinium	U-235	Pb-207	0.71×10^9 yrs.

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

L-13

MATERIALS

ACTIVITIES

DECAY OF ISOTOPES

Many isotopes are unstable and break down spontaneously emitting atomic radiations. Many of these radioactive isotopes are useful to man in industry, agriculture, and medicine.

Decay of Isotopes	Use
$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$	Carbon dating Photosynthesis research
$^{59}_{26}Fe \rightarrow ^{59}_{27}Co + ^{0}_{-1}e + ^{0}_{0}\gamma$	Friction and lubrication studies
$^{131}_{53}I \rightarrow ^{131}_{54}Xe + ^{0}_{-1}e + ^{0}_{0}\gamma$	Thyroid gland physiology
$^{60}_{27}Co \rightarrow ^{60}_{28}Ni + ^{0}_{-1}e + ^{0}_{0}\gamma$	Cancer treatment Measuring liquid heights
$^{198}_{79}Au \rightarrow ^{198}_{80}Hg + ^{0}_{-1}e + ^{0}_{0}\gamma$	Cancer treatment
$^{32}_{15}P \rightarrow ^{32}_{16}S + ^{0}_{-1}e + ^{0}_{0}\gamma$	Agriculture research

KEY WORDS

bombard
emit
gamma rays

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Mass-charge relationships	+If a particle is added to a nucleus, the mass of the nucleus increases. +If a nucleus emits a particle, the mass of the nucleus decreases. +A new kind of atom is made when a nucleus gains or loses a particle. *The changing of one element into another element or isotope is known as transmutation. Transmutation may be represented by nuclear equations. *In nuclear equations the sum of the atomic numbers (or changes) is the same on each side of the equation. *In nuclear equations the sum of the mass numbers is the same on each side of the equation.

MATERIALS

ACTIVITIES

MASS-CHARGE RELATIONSHIPS IN NUCLEAR EQUATIONS

Nuclear equations indicate the particles, masses and charges involved but normally do not indicate energy changes. In writing nuclear equations, the subscripts indicate the charges while the superscripts indicate the masses of the particles. In the case of atoms, the superscript indicates the charge which is equal numerically to the atomic number.

The sum of the superscripts on one side of the equation equals the sumeof the superscripts on the other side. Similarly, the sum of the charges on one side of the equation is equal to the sum of the charges on the other.

Pupils should be given the opportunity to write nuclear equations. One example of a nuclear equation deals with neutron bombardment. Normal nitrogen is bombarded by a neutron to produce radioactive carbon-14 and the emission of a proton. The complete equation is:

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$$

7 0

KEY WORDS

atomic number
equation

(nitrogen) + (neutron) → (carbon-14) + (proton)
Note that the sums of the superscripts are equal, that 14 + 1 = 14 + 1. Also note the sums of subscripts are equal, that 7 + 0 = 6 + 1.

A good teaching technique is to write imcomplete equations and have the pupils determine one particle that has been omitted. An example is:

Complete the equation $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{1}_{1}H +$ _____

The pupils determine from the sums of the superscripts that the mass of the unknown particle is 14. Similarly, the charge (or atomic number) must be 6. The periodic table indicates that the atom with an atomic number of 6 is carbon. Therefore, the missing term is $^{14}_{6}C$.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

NATURAL RADIOACTIVITY

There are two general types of nuclear disintegration: induced radioactivity and natural radioactivity. Induced radioactivity results when stable nuclei are subjected to bombardment by other particles. Natural radioactivity refers to the decay of naturally occuring unstable isotopes.

* One series of natural radioactivity is the decay of U-234 to stable lead. The equations given below do not show the rate at which the disintegration proceeds nor the emission of energy...only the end products are given:

$${}^{234}_{92}U \rightarrow {}^{230}_{90}Th + {}^{4}_{2}He$$

$${}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$$

$${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

$${}^{222}_{86}Rn \rightarrow {}^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$$

$${}^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}e$$

$${}^{214}_{83}Bi \rightarrow {}^{210}_{81}Tl + {}^{4}_{2}He$$

$${}^{210}_{81}Tl \rightarrow {}^{210}_{82}Pb + {}^{0}_{-1}e$$

$${}^{210}_{82}Pb \rightarrow {}^{210}_{83}Bi + {}^{0}_{-1}e$$

$${}^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e$$

$${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$$

KEY WORDS

mass-charge
mass-number
relationship

Note that when an alpha particle is emitted the mass of the original atom is decreased by 4 and its atomic number decreased by 2. When a negative beta particle is emitted, the mass remains (essentially) constant and the atomic number is increased by 1.

*optional

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

THE DISINTEGRATION OF URANIUM-238 SERIES

Radioactive disintegrations are entirely different from ordinary chemical reactions and are independent of external conditions. The rate of disintegration does not change whether at the temperature of white heat or of liquid air. Moreover, the disintegration goes on at the same rate whether the radioactive element is in a free or a combined form.

Note in the table below that some of the disintegration products are stable for millions of years while others disintegrate in a few seconds.

KEY WORDS

DISINTEGRATION PRODUCTS OF THE U-238 SERIES

Isotope	Symbol	Half-Life period	Particle emitted
Uranium	U-238	4.5×10^9 years	alpha
Thorium	Th-234	24.10 days	beta
Protactinium	Pa-234	1.1175 minutes	beta
Uranium	U-234	2.48×10^5 years	alpha
Thorium	Th-230	8.0×10^4 years	alpha
Radium	Ra-226	1622 years	alpha
Radon	Rn-222	3.825 days	alpha
Polonium	Po-218	3.05 minutes	alpha
Lead	Pb-214	26.8 minutes	beta
Bismuth	Bi-214	19.7 minutes	beta
Polonium	Po-214	1.64×10^{-4} seconds	alpha
Lead	Pb-210	19.4 years	beta
Bismuth	Bi-210	5.0 days	beta
Polonium	Po-210	138.4 days	alpha
Lead	Pb-206	Stable form	none

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

ARTIFICIAL TRANSMUTATION OF ELEMENTS

The equations below are primarily for the information of teachers and represent transmutation by bombardment with high energy particles.

1. Bombardment by protons

$${}^{9}_{4}Be + {}^{1}_{1}H \rightarrow {}^{6}_{3}Li + {}^{4}_{2}He$$

$${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$$

2. Bombardment by heavy hydrogen (deuterium)

$${}^{209}_{83}Bi + {}^{2}_{1}H \rightarrow {}^{210}_{83}Bi + {}^{1}_{1}H$$

3. Bombardment by alpha particles

$${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$$ (Rutherford's work in 1919)

$${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

$${}^{45}_{21}Sc + {}^{4}_{2}He \rightarrow {}^{48}_{22}Ti + {}^{1}_{1}H$$

4. Formation of plutonium from uranium

$${}^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{92}U + {}^{0}_{0}\gamma$$

$${}^{239}_{92}U \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}e$$

KEY WORDS

$${}^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e + {}^{0}_{0}\gamma$$

Pupils frequently ask whether other metals may not be transmuted into gold. This transmutation is possible but impractible from an economic point of view.

EFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

D. Nature of Radiations

1. Particles

a. alpha particles

+Alpha particles are helium nuclei with a mass of approximately 4 a.m.u. and a positive charge of +2.

Each alpha particle contains two protons and two neutrons.

Alpha particles travel at a speed less than 1/10th the velocity of light.

+Alpha particles lose their energy very rapidly as a result of ionization of the substances through which they pass.

Alpha particles darken photographic film and produce fluorescence in certain substances.

Due to their double positive charge, they easily ionize a gas and will activate a Geiger counter tube if the window is very thin.

+Alpha particles have slight penetration. A thin sheet of paper or an air space of several inches is sufficient to absorb them.

*When an alpha particle is emitted by an atom, a new atom is produced with a mass reduction of 4 a.m.u.

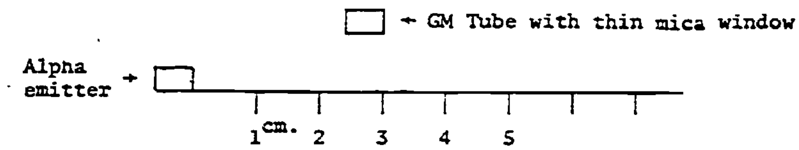
*Alpha particles are charged and will be deflected when passed through a magnetic field.

MATERIALS

geiger-muller tube
alpha source
metric measure
paper

ACTIVITIES

The range of alpha particles is limited in air. This range can be demonstrated in an empirical manner by using a thin mica window Geiger-Muller tube and a point source of alpha particles such as PO-210.



Take the background count for five minutes. Place the GM tube at a distance of 1cm. from the alpha emitter and record the count for a 5-minute period. Correct for the background count. Repeat at the 2 cm., 3 cm.,...6 cm.-distances until the count equals the background count. If desired, plot the counts/minute against distance. Repeat using a thin sheet of paper as an absorber in front of the alpha emitter.

KEY WORDS

a.m.u.
charge
deflected
fluorescence
geiger counter
ionization
ionize
magnetic field
mass reduction
penetration
velocity

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
B. beta particles	+Naturally occurring beta radiation consists of high speed negatively charged electrons.
	+Since beta particles are charged, they ionize molecules of a gas.
	The speed of beta particles range from 25 to 99 per cent of the velocity of light.
	+Because of their high velocity, beta particles are more penetrating than the heavier alpha particles.
	Since beta particles are charged, they are deflected by a magnetic field.
	*The emission of a beta particle produces a new element with an atomic number increased by one and with (practically) no change in mass.
	Beta particles darken photographic film and produce fluorescence in certain substances.
	Thin sheets of metal such as aluminum can be used to absorb beta radiation.
	Beta particles are deflected to a more marked extent in a magnetic field because of their smaller mass.
	When the gas contained in a Geiger-Muller tube is ionized by a charged particle a pulsation is produced which can be ampflified and counted.

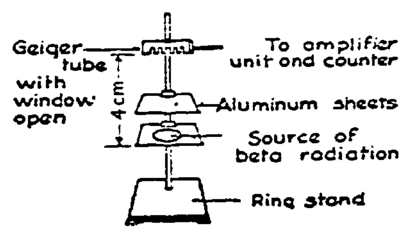
MATERIALS

G.M. tube
aluminum sheets
ring stand
beta source
ring
clamp

ACTIVITIES

THE RANGE AND ABSORPTION OF BETA RADIATION

Beta particles are usually stopped by passage through approximately 10 feet of air or by varying thicknesses of metal sheet. A simple experiment to demonstrate the effectiveness of an absorber for beta radiation is to set up a ring stand as illustrated in the figure with a source of beta radiation on the lower support, 4 cm. from a GM tube with the window exposed. (P-32, I-131, uranyl nitrate or other radiation sources may be used.) Take a 5-minute count of beta radiations with no absorber in place and record the average "activity" in counts per minute.



Repeat using various types of shielding materials.

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

lead foil
beta source
alnico magnet

ACTIVITIES

DEFLECTION OF BETA PARTICLES IN A MAGNETIC FIELD

Since beta particles are negatively charged, they are deflected when passing through a magnetic field. The degree of deflection depends on the kinetic energy of the particles and the strength of the magnetic field.

Set up a linear arrangement as shown in Fig. 1 using slits in two sheets of lead foil to collimate the beam of beta particles. A source of beta particles may be P-32, I-131, a radium button, or some uranium salt. Take a number of readings of radioactive counts with a Geiger counter before using magnets.

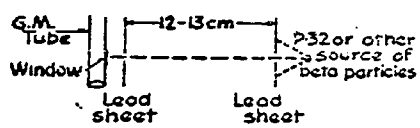


Fig. 1

KEY WORDS

Insert an Alnico magnet around the beam as shown in Fig. 2 so that the beam passes between the poles of the magnet perpendicular to the direction of the field. If more than one magnet is used (recommended), place the poles alternately N-S-N-S to increase the strength of the magnetic field. Note the variation in beta counts with the magnets in place and without.

The degree of deflection can be measured by moving the GM tube up or down relative to the slit in the lead shield. The direction of the deflection can be determined by the use of the left-hand rule, if desired.

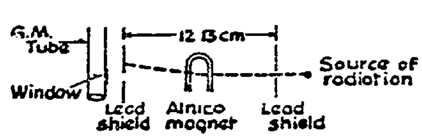


Fig. 2

REFERENCE OUTLINE	UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
c. neutrons	+Free neutrons are emitted during nuclear reactions.
	+Released neutrons can traverse considerable distances through air and penetrate appreciable thicknesses of solid substances.
	+Neutrons can produce harmful effects on living organisms.
	Neutron emission results from such nuclear reactions as fission, and some fusion reactions.
	The atoms of elements bombarded by neutrons become a source of radiation for doing useful work in science, industry, medicine, and agriculture. Many of these activated nuclei are used as process tracers.
2. Gamma rays	+Gamma rays consist of very high frequency electromagnetic waves similar to X-rays but of shorter wavelength.
	Gamma rays have no mass or charge and travel at the speed of light.
	+Gamma rays have a high degree of penetration. Materials such as lead or dense concrete can reduce the distance that they travel.
	The high penetrating ability of gamma rays makes them the most useful and the most dangerous of all nuclear radiations.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

S1

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

Since gamma rays carry no charge, they are not deflected in a magnetic field.

It is generally not possible to absorb gamma radiation completely. However, if a sufficient thickness of matter is placed between the radiation source and an individual, the exposure dose can be greatly reduced.

+Gamma rays travel hundreds of feet in air and are stopped by thick lead or dense concrete.

MATERIALS

ACTIVITIES

PRODUCTION OF NEUTRONS

Free neutrons are produced when light elements are bombarded with alpha particles. Since neutrons have no charge, they are difficult to detect. The production of free neutrons occurs in high energy accelerators. Some examples are:

$$^{4}_{2}He + ^{9}_{4}Be \rightarrow ^{12}_{6}C + ^{1}_{0}n$$

$$^{4}_{2}He + ^{24}_{12}Mg \rightarrow ^{27}_{14}Si + ^{1}_{0}n$$

$$^{40}_{18}Ar + ^{4}_{2}He \rightarrow \text{[illegible]}$$

$$^{12}_{6}C + ^{2}_{1}H \rightarrow ^{13}_{7}N + ^{1}_{0}n$$

An example of neutron formation through natural radioactive decay is:

$$^{87}_{36}Kr \rightarrow ^{86}_{36}Kr + ^{1}_{0}n$$

KEY WORDS

electro-magnetic waves
exposure dose
free neutrons
speed of light
traverse

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

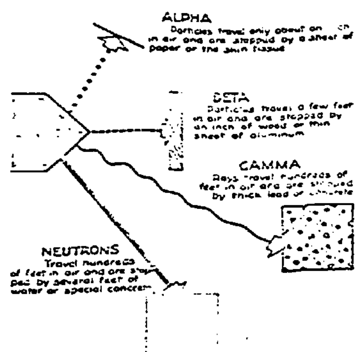
KEY WORDS

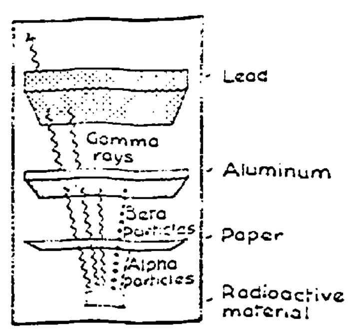
ACTIVITIES

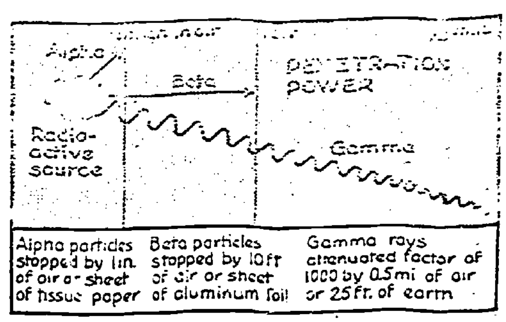
PENETRATING POWER OF NUCLEAR EMISSIONS

Heavy alpha particles will travel only an inch or so in air and are stopped by a thin sheet of paper. Beta particles travel as much as 10 feet through air and may be stopped by several thicknesses of aluminum. Gamma rays penetrate to considerable distances, even through several inches of lead.

Copy the diagrams below on the chalkboard to give pupils a visual overview of the penetrating power of the types of ionizing radiation.







REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
E. Detection of Radioactivity	Radioactivity may be detected by several devices.
1. Photographic film	+The chemicals in photographic emulsions react to nuclear radiations.
	+The degree of fogging or darkening of film in a unit of time is a quantitative measure of the amount of radiation received.
	Photographic films are sensitive to electromagnetic wave lengths including those of visible light and nuclear radiations.
	An ionizing particle passing through a photographic emulsion leaves a chemical trail which is visible upon development.
2. Spinthariscope	Some invisible radiations cause a phosphorescent material to light up and thus indicate their presence.
	This is a relatively simple instrument used to detect alpha particles.
3. Electroscope	+Nuclear radiations cause air to become charged (ionized). Charged air particles discharge an electroscope.
	+The rate at which an electroscope discharges is a measure of the intensity of radiation.
	Air, ionized by radiations from a radioactive source, is attracted to a charged electroscope and neutralizes its charge.

L-35

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	One of the first instruments to be used in the study of radioactivity was the gold-leaf electroscope.
	The self-reading dosimeter operates on the same principle as the electroscope. Dosimeters obtained from civil defense are designed to measure gamma radiation only.

MATERIALS

photograhic film
radioactive source
tape
developer

ACTIVITIES

DETECTING RADIATION WITH PHOTOGRAPHIC FILM

Students can duplicate Becquerel's discovery by placing a radioactive source in close proximity to one or several sheets of photographic film wrapped in opaque paper.

Uranite, pitchblende, carnotite, and gummite are minerals often found in school mineral collections which emanate enough radioactivity to satisfactorily darken photographic emulsions. A radioactive watch dial may also be used.

Tape the radiation source to the film and place it and a control film packet in a cupboard or closet where it will not be disturbed. [Once the film packages have been prepared, darkness is not essential].

The exposure time will vary with the sensitivity of the film and the type and amount of radiation produced by the sample. If a number of packets are exposed to similar radioactive sources, each film might be developed after a varied number of days of contact.

At the completion of the exposure time, processing should be completed in a contrast-type developer such as D-19 or X-ray film developer. (Any commonly used film developer may be used but the negative will show less contrast.) Prints may be made from the negative following ordinary photographic procedures.

It is suggested that this demonstration is best done as a student activity. The preparation, processing, and printing are familiar processes to many pupils.

Discuss the use of various detection devices in prospecting for radioactive minerals.

KEY WORDS

development
dosimeter
electroscope
emulsion
film
fogging
intensity
neutralizes
phosphorescent
quantitative
visible light

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

electroscope
rubber rod
radioactive source

ACTIVITIES

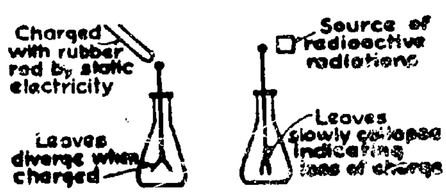
USING AN ELECTROSCOPE TO DETECT IONIZING RADIATIONS

A simple method to show the ionization of air by a radioactive source is through the use of a simple electroscope. Either a goldleaf or aluminum foil electroscope may be used to illustrate this phenomenon.

An electroscope consists of a metal rod with two small sheets of metal foil ached at one end, and a container which ser to protect the delicate leaves from air currents. When the metal rod is charged, the leaves diverge and remain separated until the charge is dissipated.

A qualitative test to show the ionization effect of a radiation source is to charge the electroscope with a rubber rod. The leaves of the electroscope will diverge indicating a charge.

Place a source of radiation near (2-3cm. distance) the knob of the electroscope. Note that the charge on the electroscope decreases. The rate at which the leaves are discharged is proportional to the ionization of the air and proportional to the intensity of the radioactive source.



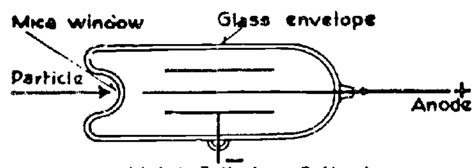
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
4. Geiger-Muller tube (Geiger counter)	Radiations passing through a gas causes the gas to become charged (ionized). When the gas is sufficiently ionized a discharge occurs between two electrodes. +The number of discharges in a given time is a measure of the intensity of radiation.

MATERIALS

ACTIVITIES

THE PRINCIPAL OF OPERATION OF A GEIGER MULLER TUBE

Geiger-Muller counters are widely used in radioactive detection and measurement. An electric discharge takes place between two charged bodies when a gas which surrounds the charged body is ionized by a fast moving particle. The essential part of this counter is the Geiger-Muller tube. See the illustration below for its construction.



Geiger-Müller Tube

KEY WORDS
disc
discharge
electrodes

A tungsten wire is stretched inside a metal cylinder. The wire is the positive electrode (anode), and the metal cylinder is the negative electrode (cathode). Both of these electrodes are insulated from each other and may be sealed in a glass envelope. The glass envelope is filled with a dry gas usually argon or a mixture of argon and a polyatomic gas such as chlorine, bromine, or an organic gaseous compound.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

A voltage of 800 to 1,000 volts is placed across the electrodes. Radiation from the radioactive substance enters the tube through a mica window. After entrance, the radiation causes ionization to take place. This is accomplished by ripping off electrons from the atoms of gas. Ions are produced having positive charges and others having negative charges. The ions are attracted to the electrode of opposite charge so fast that they in turn ionize other atoms of gas. The formation of ions builds up the conductivity of the gas until a discharge occurs in the tube. This discharge is a momentary pulse of current passing between the electrodes. The strength of the current depends upon the voltage applied to the electrodes. This current can be amplified through suitable electronic circuits and be made to actuate a counting device or can be heard as a click in a loud-speaker. Instruments of this kind can be used to measure beta.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

GM counter
radiation
source(s)

KEY WORDS

ACTIVITIES

OPERATING A GEIGER COUNTER

Most schools can obtain a Geiger counter for the detection of radioactivity. Contact the Civil Defense office in your area for loan of an instrument. Science teachers should become familiar with the operation of a Geiger counter.

A Geiger-Muller counter or "GM" counter consists of a probe equipped with a beta shield, a high voltage circuit, and a meter or earphone to register the rate of intensity of radiation.

The GM counter should be checked to see that it is operating properly. First, turn the selector switch to the X-100 or X-10 range and allow at least 30 seconds for warmup. Second, rotate the shield on the probe to the fully open position. Three, place the open area of the probe as close as possible to a known source of radiation. If no clicks are heard or recorded on the meter, the batteries may be dead. Check the batteries and replace if necessary.

If a Civil Defense instrument is being used, a source of radioactivity will be found on the side of the case. The meter at the X-10 range should read between 1.5 and 2.5 mr/hr. With the window open, the instrument reads both beta and gamma radiation. Gamma radiation is read with the window closed.

Most GM tubes will not detect alpha radiation since the thickness of the window is sufficient to absorb this type of radiation.

A Geiger counter is a sensitive, scientific instrument and cannot take physical abuse. After use, be certain to TURN OFF CIRCUIT; otherwise the batteries may corrode the case.

Hide a source of radioactivity. Have pupils locate it by use of the detecting instrument.

REFERENCE OUTLINE

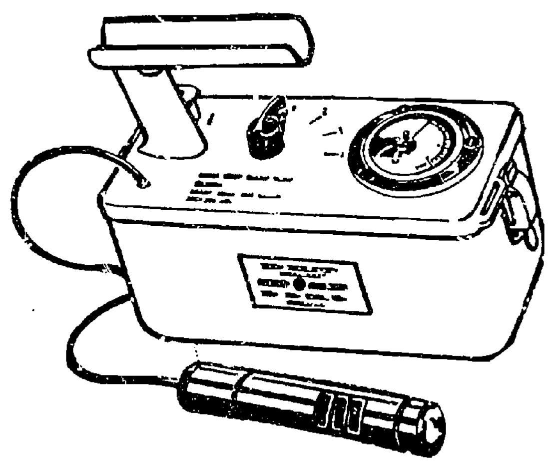
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

Measure the counts/minute caused by a source at some distance (example, 10 centimeters) from the meter. Double, triple and quadruple the distance and repeat the readings. What is the approximate relationship between counts/minute and distance? (The inverse square law is not strictly applicable since the source is not a point.)

A Geiger counter adapted for Civil Defense use, the CD V-700, is illustrated below. This is a low range instrument that detects the presence of beta particles and measures gamma dose rates. This instrument is designed for low level measurements (0-50 mr/hr) and has limited usefulness in areas of high contamination.

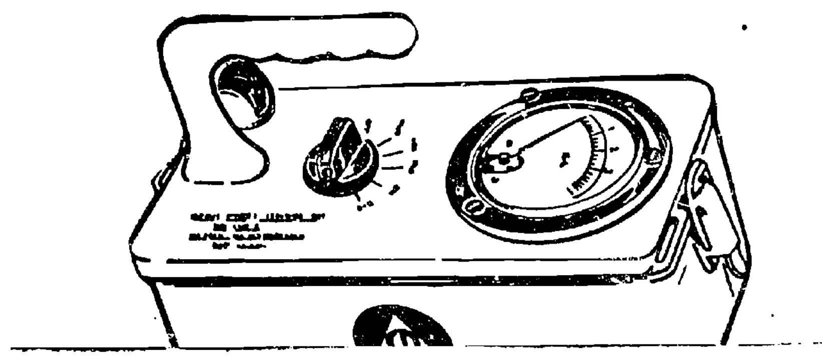


KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS	ACTIVITIES
	A detection instrument used for the major survey of nuclear radiations is the CD V-715 meter. This instrument measures gamma dose rates only (no beta capability) and has 0-500 r/hr. range.



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
5. Cloud chamber	+Water vapor may condense and become visible along the trail of ions produced by an ionizing particle. Dust free air that is saturated with vapor becomes supersaturated on sudden expansion in the cloud chamber. Excess vapor condenses and becomes visible along the tracks produced by the charged particle as it moves through the chamber. The tracks of alpha particles appear as straight lines of dense fog droplets. Beta particles produce tracks much less dense. The tracks of gamma rays are very faint and scattered.
6. Scintillation counters	Scintillations can activate a counting device. Modern scintillation detectors use phosphors in combination with a photo-multiplier tube. Scintillation counters are superior to Geiger-Muller counters for general survey purposes especially where gamma ray detection is concerned.

ACTIVITIES

OBSERVING TRACKS OF NUCLEAR RADIATION IN IN A CLOUD CHAMBER

MATERIALS

- screw-cap fruit jar
- black felt
- light source (parallel beam)
- ethyl alcohol
- dry ice
- gamma source

The cloud chamber is the device that probably comes closest to allowing the pupil to "see" radiation. In a cloud chamber, liquid droplets condense on the ions produced by a charged particle moving rapidly through the chamber. The tracks produced by gamma rays are faint and scattered. These tracks are due to the secondary electrons ejected by the gamma rays on collision with the atoms of the gas in the chamber.

A Wilson-type cloud chamber may be borrowed from the physics laboratory to show the ionizing effects of nuclear radiations. If none is available, a simple cloud chamber can be made using a fruit jar, pieces of black felt, and dry ice.

The glass container from which this cloud chamber is made will not permit alpha and beta particles to penetrate into the chamber. Gamma rays, however, penetrate the chamber and ionize the gas within the bottle producing tracks which can be seen.

KEY WORDS

- chamber
- expansion

The materials needed are an ordinary screw-cap fruit jar, black felt, a source of light capable of providing a bright parallel beam, ethyl alcohol, a block of dry ice about 5 pounds or larger, and a gamma source.

To prepare the cloud chamber, carefully cut a circle of felt to fit the inside of the cover, and another circle of felt to fit the bottom of the jar. The bottom piece of felt is kept in place by iron bailing wire or made oversize to provide a snug fit.

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

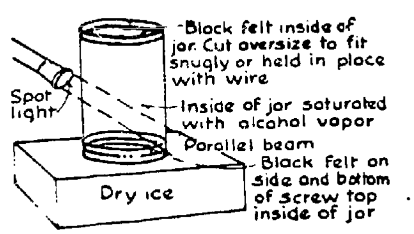
Pour just enough alcohol into the jar to saturate both the top bottom pieces of felt. Tighten the cap and set the jar, cap down, on the cake of dry ice. Adjust the spot light at an angle as shown in the sketch and look down into the side of the jar through the beam of light.

After approximately 5-10 minutes, when conditions have stabilized, a supersaturated layer will form above the cold surface of the jar lid. When high energy particles from cosmic rays enter this zone, they form trails of ions on which condensation takes place, forming visible cloud traces. The cloud tracks should appear against the black background at unequal intervals of time. When a gamma source is brought near the jar, the size of the droplets will increase, there will be more precipitation, and many tracks will be observed inside the jar.

It is possible to increase the display by placing a weak source of alpha particles in the chamber at the time it is assembled. This source should be supported just above the cooling surface.

KEY WORDS

fog droplets
Geiger-Muller counter
ions
phosphor
photo-multiplier tube
scintillation
super saturated
track
vapor



REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
7. Bubble chamber	Ionizing particles can produce a trail of bubbles when they pass through a superheated liquid. If the pressure is reduced in a liquid already near its boiling point, bubbles will form along the path of ionized particles. Much can be learned about nuclear particles by studying the bubble paths.
F. Rate of Decay Half-Life	During a given period of time, a certain fraction of a radioactive isotope will spontaneously decompose. The time required for half the nuclei in a sample to decay is known as the half-life of the isotope. Each radioactive isotope has a definite half-life which is independent of the amount of material present. Determination of half-life is a statistical process. Although it can be determined fairly accurately when half the number of radioactive nuclei will have decayed, it is impossible to determine which ones will decay during this time. Some radioisotopes have very long half-lives, others decompose in a fraction of a second. An isotope is considered stable if its half-life is longer than the age of the earth (4-6 billion years). There are no stable nuclei with atomic numbers higher than 83.

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

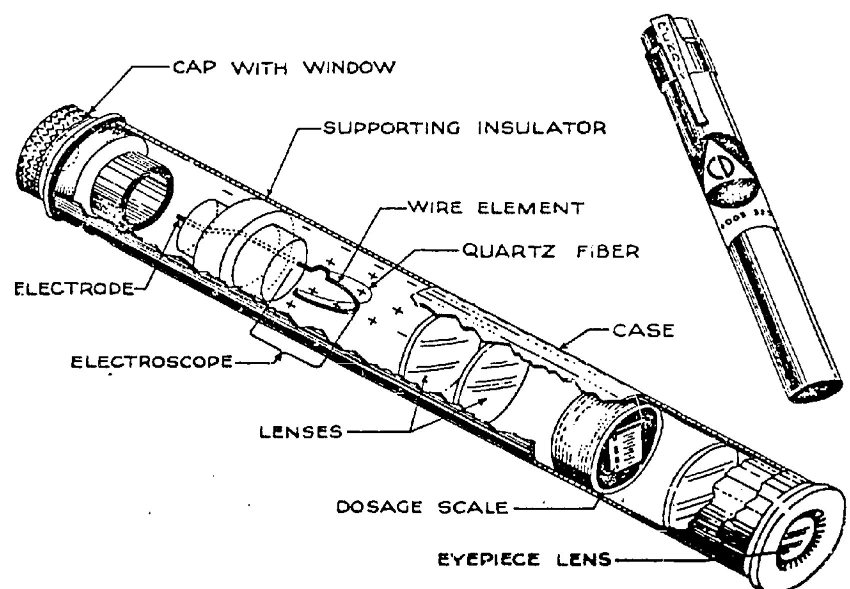
The half-lives of isotopes range from a fraction of a second to billions of years. As an example the half-life of polonium-214 is 160 milliseconds whereas that of uranium-238 is 4.5 billion years.

MATERIALS

ACTIVITIES

DOSIMETER DETECTION OF NUCLEAR RADIATIONS

The self-reading dosimeter operates upon the same principle as an electroscope. An electrical charge is placed on a quartz fiber and its parallel supporting rod causing the fiber to be repelled. These are both insulated from the outside container wall. Radiation entering the chamber, encasing the fiber and metal frame, causes the formation of ions which are collected on the quartz fiber or outside wall. A reduction of the charge on the quartz fiber is reflected in the movement of the fiber. If a scale is inserted in the eyepiece and the charge on the fiber is adjusted to zero on the scale, then the movement of the fiber along the scale can be calibrated to indicate the total accumulated ionizing radiation exposure or, as it is more commonly called, the total dose. Dosimeters that are obtained from and used in civil defense are designed to measure gamma radiation only.



SELF-READING POCKET DOSIMETER

KEY WORDS

boiling point
bubble chamber
decompose
half-life
millisecond
pressure
statistical
superheated

Discuss half-life in relation to:

geology
paleontology
archaeology
astronomy, and other fields of science,

e.g.; effect on present information, dating, use in making new finds, etc.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
II. Induced Radioactivity	Bombardment of nuclei by accelerated particles cause nuclei to become unstable and may result in the formation of isotopes or new elements.
	Unstable nuclei decay into other nuclei with the emission of radioactive particles and usually with a release of energy.
	Transmutations involve high energy particles such as protons, deuterons, and alpha particles.
	Many radioactive isotopes produced artificially serve useful purposes as "tracers" in industry and medicine.
	Nuclear reactions involve energies much greater than ordinary chemical reactions. The energy changes may be a million or more times larger.
*1. Man-made elements	*Elements with atomic numbers greater than 92 have been made by bombardment of atoms by neutrons.

MATERIALS

ACTIVITIES

THE TRANSURANIUM ELEMENTS

The capture of free neutrons by uranium during neutron bombardment has produced elements of atomic number greater than 92.

Most stable isotope	At.No.	Estimated half-life
Neptunium-237	93	2.20×10^6 years
Plutonium-244	94	3.73×10^5 years
Americium-243	95	7950 years
Curium-247	96	4×10^7 years
Berkelium-247	97	7×10^3 years
Californium-251	98	660 years
Einsteinium-254	99	280 days
Fermium-255	100	22 hours
Mendelevium-256	101	0.5 hours
Nobilium	102	*Existence of stable
Lawrencium	103	isotopes is doubtful.

KEY WORDS

acceleration
artificially
atomic piles
betatron
cyclotron
electron
energy
tracers
van de Graff generator

1. Make a van de Graff generator
2. Discuss the historical development induced radioactivity.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Accelerators	Accelerators or "atom smashers" are devices used to increase the velocity of atomic particles.
	Scientists use accelerators to explore the forces that hold together the nucleons, the nature of the particles inside the nucleus, and the processes that go on among nuclear particles.
	The principle behind each accelerator or "atom smasher" is to provide particles with sufficient kinetic energy so that they might penetrate the nucleus of the element being bombarded.
	Particles and the devices with which they are generally associated include respectively; electrons (betatron); protons (proton synchroton); alpha particles (cyclotron); deuterium (synchrocyclotron); neutrons (nuclear reactor).
III. Nuclear Fission	In the fission process the nucleus of a heavy element is caused to split into two or more parts releasing large quatities of energy.
	Fission of heavy elements is started when a neutron is absorbed by the nucleus.
	In addition to the release of energy, the fission process releases products such as beta particles, neutrons, and gamma rays.

MATERIALS

ACTIVITIES

KEY WORDS

atom smasher
fission
heavy element
kinetic energy
nucleons
proton synchrotron
synchrocyclotron

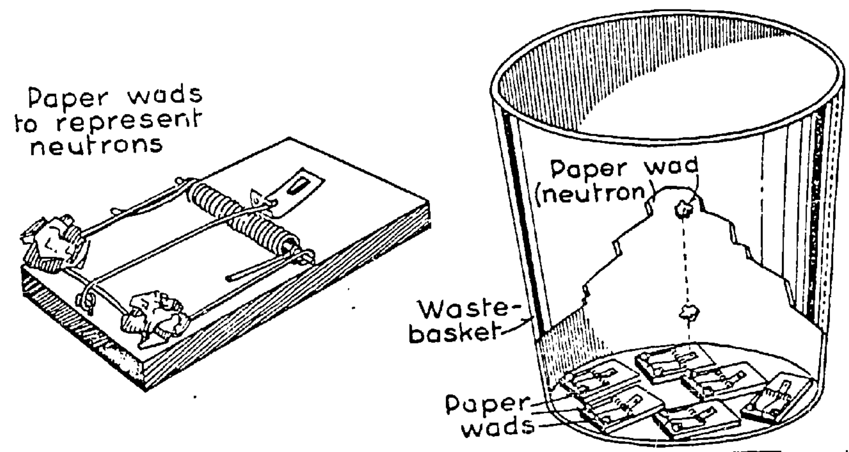
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND
	A few pounds of fissionable material can liberate as much energy as the explosion of thousands (or millions) of tons of T.N.T. This is the energy source for the nuclear bomb (atomic bomb).
	The equation for the fission of uranium-235 is: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n + energy$
	The mass of the products is less than the mass of the fissionable nuclei and the neutrons which strike them. The mass which has apparently been lost has been converted into energy in accordance with the Einstein equation. $E=mc^2$ where c is the velocity of light.
A, Chain Reactions	When the nucleus of some heavy elements is hit by a slow moving neutron, the nucleus splits and also yields one or more neutrons. If conditions are right, these neutrons may cause other nuclei to fission. This reaction is self-sustaining and is called a chain reaction.
B. Uncontrolled Reactions	An uncontrolled reaction continues until there are no more available neutrons striking fissionable nuclei.

MATERIALS

waste paper basket
mouse traps
paper

ACTIVITIES

The principle of U-235 chain reaction can be demonstrated very dramatically by means of several mousetraps and a large waste-basket. Each mousetrap will represent an atom of U-235. When the mousetrap is set, it has energy just as an atom of U-235 has.



Make a dozen paper wads each about one inch in diameter. These will represent neutrons. Set six mousetraps and place them very carefully in the bottom of the wastebasket. Opposite the trigger of each, place two paper wads as shown in the diagram.

With everything in readiness, drop a paper wad neutron on the trigger of one of the mousetraps. If a direct hit is not scored on the first try, call attention to the fact that this often happens and that many neutrons are left over in a real chain reaction. As soon as a direct hit is scored, the paper neutrons will be set in motion and all the mousetrap atoms will give up their energy accompanied by considerable clatter within the wastebasket.

KEY WORDS

atomic bomb
chain reaction
$E=mc^2$
Einstein
explosion
fissionable
liberate
self-sustaining
uncontrolled reaction

1. Make various devices to show chain reaction.
2. Discuss various ramifications of $E=mc^2$, especially its abstractions.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Controlled Reactions	Fission reactions are controlled by regulating the speed of neutrons or the number available for further fission reactions.
	Fission reactions are controlled in a nuclear reactor (atomic pile).
	Neutrons are slowed down by moderators such as graphite. Control rods made of such materials as boron steel will absorb neutrons.
	Nuclear reactors provide a controlled source of heat energy which can be converted to electrical energy.
	Many useful radioactive elements are produced in the nuclear reactor. These radioisotopes are used effectively in medicine and in industry.
	A single pound of U-235 yields about 3 million times more energy than can be yielded by burning a pound of coal.
IV. Nuclear Fusion	In nuclear fusion, a pair of light nuclei unite (or fuse) together to form a nucleus of a heavier atom. In the process of fusion, mass is converted into energy.
	The principal of the fusion process is derived from the theory of relativity of Albert Einstein (1877-1955).

MATERIALS

ACTIVITIES

KEY WORDS

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

The mass-energy equation $E=mc^2$, indicates the tremendous energy evolved when mass is converted to energy.

An example of a fusion reaction involves two atoms of deuterium (hydrogen-2) which produce helium and energy:

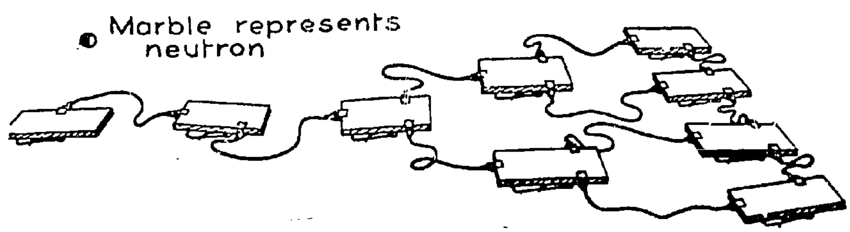
$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + \text{energy}.$$

MATERIALS

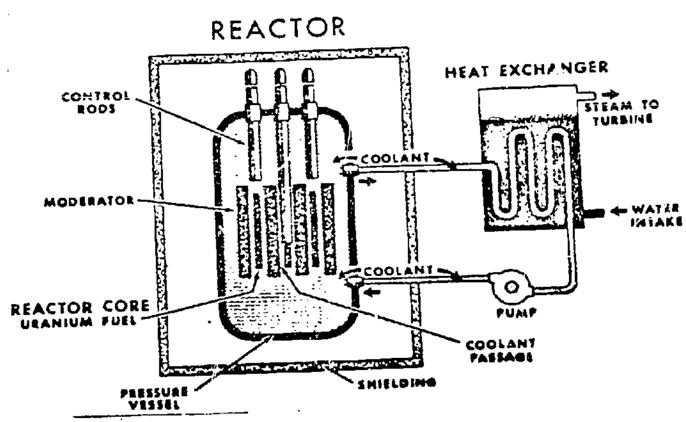
Mouse traps
cord/string
marble
radiometer
cardboard

ACTIVITIES

The multiplying nature of the U-235 chain reaction can be further clarified by arranging set mousetraps as shown in the diagram. When a small object representing a neutron is dropped on the first trap, it springs and starts a chain reaction which passes on to the rest of the traps.



THE NUCLEAR REACTOR IS AN ATOMIC FURNACE



KEY WORDS

controlled reaction
deuterium
electrical energy
fossil fuels
fuse
fusion
mass-energy equation
moderator
nuclear reactor
radioisotopes

Place a radiometer in the sunlight near the window and develop the idea that it runs by atomic energy. Shield it from the direct solar radiations with a piece of cardboard and notice that it immediately slows down.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	High temperature is required to activate the fusion process. Fusion reactions are called thermonuclear reactions.
	The thermonuclear or H-bomb is activated by the heat of a fission reaction.
V. Uses of Radioactive Isotopes	Radioisotopes are used in a wide variety of quality control techniques.
A. Chemistry	Tagged atoms allow the chemist to follow chemical reactions even where no observable chemical changes take place.
	The chemist uses radioisotopes to identify the purity of chemicals, to develop separation schemes, and to carry out kinetic studies.
	A great deal of inorganic chemistry involves separating ions or compounds.
	In organic chemistry, the tagging of elements permits an analysis of the molecular structure and the detection of reaction intermediates.
B. Biology	Biologists use radioisotopes as an aid in tracing chemical interactions in organisms.
	Carbon-14 has been useful in studying the mechanisms of photosynthesis.

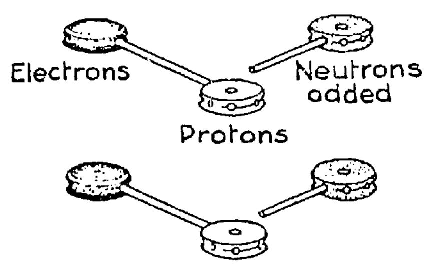
MATERIALS

tinker-toy set

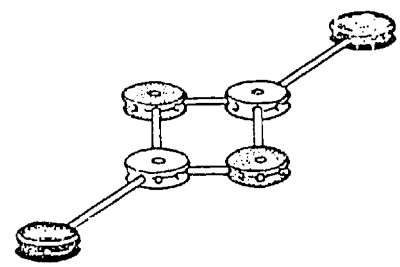
ACTIVITIES

One way in which the fusion of hydrogen atoms to form helium atoms may occur can be illustrated by means of wooden construction sets. Start with two hydrogen atoms, each consisting of an electron and a proton. Now add a neutron to each atom to form two atoms of deuterium. Bring the two deuterium atoms together and connect them to form a helium atom. This, of course, is an oversimplification of the process and does not explain where the energy comes from. Some inkling of this can be gained from the following facts.

Two deuterium atoms weigh more than a helium atom. Since a proton weighs 1.00758 and a neutron weighs 1.00893, two protons and two neutrons should weigh 4.03302. The observed mass of the helium nucleus is only 4.0028. The fusion of two deuterium atoms thus results in a loss of weight equal to .03022. This loss of weight, resulting from the fusion of the two atoms, can be accounted for by assuming that this "lost" weight is converted into energy.



2 hydrogen atoms + 2 neutrons = 2 deuterium atoms



2 deuterium atoms fused together = 1 helium atom + energy

KEY WORDS

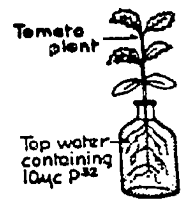
carbohydrate formation
carbon-14
chemical interactions
chromatographic technique
diagnosis
dilutions
distillations
filtrations
impurity
kinetic studies
photosynthesis
precipitation
quality control
reaction intermediates
separation schemes
synthesis
tagged atom
technique
therapeutic
thermonuclear

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	The utilization of radioisotopes in medical research and treatment has produced a new era of medical progress.
	Radioisotopes used as tracers and as therapeutic agents in medicine include: S-35 - to measure the volume of extracellular fluid Cr-51 - to label red blood cells I-131 - to treat tumors in the thyroid gland and to measure the rate of metabolism Co-60 - to treat cancer and tumors Au-198- to control excessive fluid formation in abdominal cancer
D. Agriculture	Research utilizing radioisotopes has increased the efficiency of agricultural production. Such research includes:
	By mixing a radioisotope P-32 into phosphate fertilizers, the actual uptake of fertilizer material by the plant can be followed.

MATERIALS

plants
P-32
water
bottles/flasks

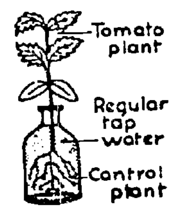
ACTIVITIES



PLANT UPTAKE OF P-32

Young tomato plants easily absorb P-32 from solution. The P-32 uptake can be detected with a GM counter or the leaves may be placed in contact with X-ray film producing radioautographs of the leaves when the film is developed.

Control plants should be used and several plants might be placed in lesser dilutions of the P-32 solution so that charts of varying absorptions can be made.



KEY WORDS

cancer
excretions
extracellular
fertilizer
injected
irrigation
mulches
nutrient
physiology
radioiodine
thyroid gland
thyroxine
tumor

RENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	In North Carolina, a new variety of peanut has been developed through radiation mutation. It has a much stronger hull and can be handled with less breakage than the original type.
	A variety of peach tree has been developed which bears fruit two weeks later than normal, thus lengthening the processing and marketing period.
	Control of insect pests by sterilization of male insects.
	Studying the action of fungicides, insecticides, and weed killers.
	The eradication of the screwworm fly from the entire Southeastern United States was accomplished by exposing flies' larvae to a dose of radiation sufficient to cause sexual sterility.
	Preservation of foods.
E. Archeology	The age of archeological discoveries can be estimated through an analysis of the abundance of C-14 in a relic. This technique is known as carbon dating.
	The Dead Sea Scrolls, charcoal around pre-historic campsites, rush matting from an old Nevada cave, rope sandals in an Oregon cave, and wood from an Egyptian funeral boat are examples of items dated by the C-14 technique.

MATERIALS

ACTIVITIES

KEY WORDS

archaeology
decay
fungicide
insecticide
larvae
marketing
mutation
preservation
relic
screwworm
speciman
sterilization

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
F. Industry	Radioisotopes permit testing without mutilating the product. Radioisotopes are used in many industrial processes for quality control, product testing, and detection of wear characteristics. There are many applications of radioisotopes in industry. Some of these include use in: thickness gauges level indicators control of coating thickness measuring viscosity in opaque liquids wear in piston rings abrasion of rubber effectiveness of soaps determination of separation efficiencies detection of leaks in buried pipes detection of flaws in castings and many more

MATERIALS

ACTIVITIES

INDUSTRIAL USES OF RADIOISOTOPES

Have pupils explore reports in industrial journals, magazines, newspapers, et al, to find uses of radioactive isotopes in industry. A number of select uses include:

- Process Control:
  - Thickness gauges
  - Level indicators
  - Specific gravity measures
  - Control of coating thickness
- Product Testing:
  - Wear of distributor points in auto engines
  - Wear of piston rings
  - Abrasion of rubber
  - Wear of shoes
  - Effectiveness of soaps and detergents
  - Wear of bearings
  - Effectiveness of fertilizers
  - Effectiveness of dry cleaners
- Service to Industry and to the Public:
  - Detect leaks in buried pipes
  - Locate manhole covers under snow
  - Trace pollution and sewage
  - Detect scrapers in pipe lines
  - Indicate replacement of brake linings

RADIOISOTOPES IN QUALITY CONTROL

The sketch below shows how radioisotopes are used to control thickness of an industrial process.

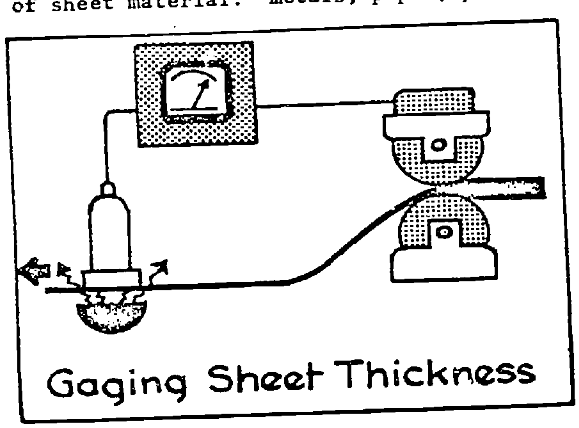
For example, in an aluminum rolling mill, the thickness gauge using a radioisotope can continually measure the thickness of aluminum over a range of 0.0002" to 0.075". The thickness gauge automatically adjusts the rollers so that the aluminum sheet is of uniform thickness.

In operation, a source of beta radiation is placed beneath the thin moving strip and a radiation detector unit is mounted above the strip. The thin sheeting will absorb part of the radiation; the amount absorbed being roughly proportional to the thickness of the aluminum sheet. Thus the radiation detector can be calibrated to read in terms of sheet thickness.

Radioisotope thickness gauges are used to control many different types of sheet material: metals, paper, plastics, rubber, textiles...

KEY WORDS

application
product testing
technological
viscosity
wear



REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

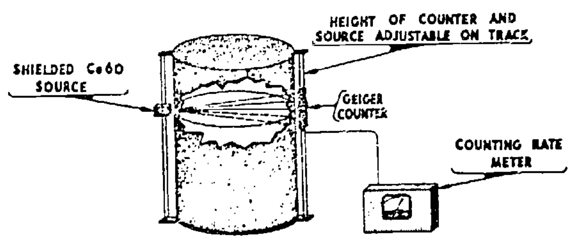
RADIOISOTOPES MEASURE LIQUID LEVELS

Cans of liquids of all types - beverages, detergents, etc. may have the level of their liquid measured by a sensitive radioisotope level gauge during the filling operation so that improperly-filled cans may be detected and corrected.

Similarly, the level of liquids in large storage tanks can be measured and adjusted by the use of radioisotope level gauges.

RADIOACTIVE COBALT – Co60

FOR INDICATING LIQUID HEIGHT



ADVANTAGES:

1- GAGE NOT AFFECTED BY CORROSION AND TEMPERATURE
2- CAN BE OPERATED BY NON-TECHNICAL PERSONNEL
3- ADAPTABLE TO AUTOMATIC RECORDING AND CONTROL OF LIQUID LEVEL

With tracers, it is possible to keep an extremely accurate control over the proportion of ingredients in fuel mixtures. In addition, radioactive atoms can be used to signal the arrival of various liquids flowing through pipe lines.

KEY WORDS

RADIOACTIVE ATOMS MEASURE WEAR

The wear characteristics of many materials can be determined long before the amount of wear is visible to the eye.

This idea is illustrated by tests made on the wearability of shoe leather. A radioisotope was incorporated into the leather sole of a shoe placed on a special machine which simulated a walking action. As minute amounts of the leather wore off, they carried tiny particles of the radioisotope with them. A radiation detector measured the radiation. Thus it was possible to measure the rate of wear in a very short period of time.

Rubber manufacturers, similarly, measure the rate of wear of automobile tires. Wear tests have also been made on floor waxes and polishes.

Oil firms use radioactive piston rings to improve the quality of their lubricating oils. As the friction between the piston ring and the cylinder wall increases, radioactive particles from the piston ring enter the oil and are measured by a detector. The radioisotope technique is so sensitive that accurate wear rates can be determined even though the amount worn is too small to be weighed or seen.

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
VI. **Radiation Safety**	**Nuclear radiations are harmful to living organisms.**
	Protection against radioactive particles and radiations is essential to man's existence.
	Nuclear radiations cannot be seen, heard, smelled, tasted, or felt. Instruments must be used to detect and measure radiation.
	Neutrons and gamma radiation are more penetrating than alpha and beta particles and are more dangerous (all other factors being the same).
A. Effects of Radiation	
1. Biological effects	The effects of radiation vary among individuals.
	Most people show symptoms of radiation sickness if they receive an acute dose of 100 to 550 or more roentgens in a four day period or less.
	The effects of nuclear radiation on humans depend on the amount absorbed, the rate of absorption, and the region and extent of the body exposed.
	Primary symptoms of radiation sickness include nausea, vomiting, or diarrhea. These symptoms may appear during the first or second day after exposure.

MATERIALS

ACTIVITIES

KEY WORDS

lassitude
nausea
radiation sickness
roentgens

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
a. exposure to external sources	Alpha particles present no hazard beyond a few inches from an external source. Beta radiation presents no hazard over a few yards from an external source.
b. exposure to internal sources	The general biological effects of nuclear radiations from an internal source are the same as from an external source. However, a very small amount of radioactive material present in the body can produce considerable injury.
c. effects of delayed fallout	With an [illegible]nal [illegible], the The long half-lives of some fission products and their decay products make them dangerous for a long period of time. The human body has no instinctive defense against radiation. Severe damage can result from exposure to radiation without the subject's being aware of the extent of radiation received. There may be a delay of weeks, months, or years before the total effects of exposure to radiation become apparent. Since the effects of exposure to radiation are cumulative, the permissible exposures to radiation depend upon the age of the individual.
2. Effects on agriculture	Crops that have not been harvested can absorb harmful radioactive material and incorporate them into their tissues.

MATERIALS

ACTIVITIES

KEY WORDS

calcifying
cataracts
concentration
convalescence
genetic
inhaling
ingesting
leukemia
marrow
prostration
succumbs

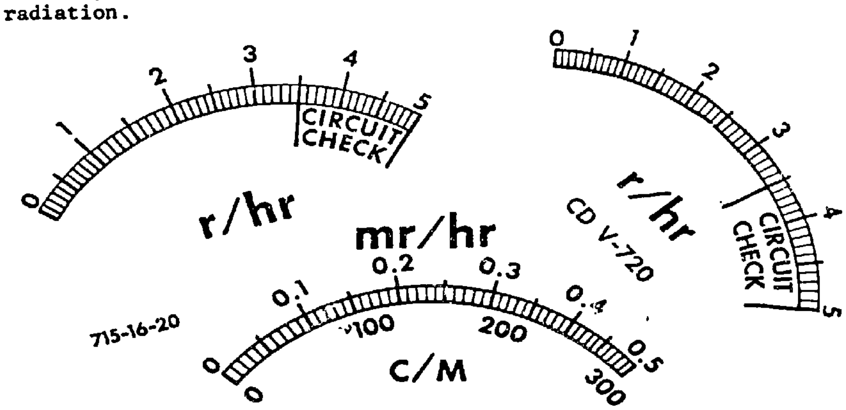
REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	Crops that have not been harvested will be subject to contamination on the outside. If fallout particles are removed, the food may be considered essentially "uncontaminated".

MATERIALS

ACTIVITIES

DETECTING NUCLEAR RADIATIONS

Radiation from fallout cannot be seen, heard, smelled, tasted, or felt; instruments must be relied upon to detect and measure radiation.



CD V-700

Several types of instruments are used to detect radiations. The dosimeter (or a photographic badge) measure accumulated exposure. Survey instruments measure current radiation intensity. Samples of **these instruments are available from Civil Defense. Pupils should become familiar with the operation of these instruments.**

KEY WORDS

affinity
anemia
contamination
harvested
instinctive
lethal
metabolism
tolerance

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
	Food and water which are exposed to radiation, but not contaminated, are not harmful and are fit for human consumption.
	Crops from soils rich in Sr-90 should be considered unsafe. Other isotopes have either short half-lives or low uptake by plants making decontamination unnecessary.
3. Effects on industry	Foods in the process of preparation generally have no cover protection and may be rendered unsafe by radioactive isotopes.
	Photographic materials are sensitive to radioactive isotopes. Although precautions are taken to minimize the effects of natural radiations, any general increase in radiation, particularly gamma radiation, will ruin the products even if these have already been packaged.
	In general, unless wholesale destruction occurs, most industrial plants are not seriously affected by radioactive fallout unless the area is rendered a radiation hazard for the workers.

MATERIALS

ACTIVITIES

FOOD FROM LAND CONTAMINATED BY FALLOUT

DANGER FROM STRONTIUM-90

Crops grown on land contaminated with fallout take up from the soil some of the long half-life radioactive materials, along with other minerals needed for their growth. The most hazardous of these is radioactive strontium (strontium-90). Chemically, it is similar to calcium which is needed by plants, animals and man. The roots of plants cannot differentiate between the two, and take up some strontium 90 along with the calcium. Some plants build much higher concentrations of calcium, and strontium, into their tissues than others. They also store more of it in some parts of the plant than in others. Small amounts of strontium-90 can be taken up from contaminated soil by successive crops for years. If man continues to eat plant food containing considerable amounts of strontium-90, enough of it can be concentrated in his bones to materially increase the chance of his developing delayed disease such as bone cancer or leukemia. That is a hazard that should be reduced to the lowest possible level.

MILK FROM CONTAMINATED ANIMALS

KEY WORDS

consumption
decontamination
fallout
minimize
natural radiations
reconnaisance

Milk produced by cows grazing on contaminated grass is likely to contain sufficient amounts of radioactive substances to be hazardous for consumption.

MEAT FROM CONTAMINATED ANIMALS

Some radioactive material is absorbed by the body and concentrated in bones or glands. The internal organs of exposed animals such as the intestine, liver, and spleen should be discarded. The muscle meat may not contain high concentrations of radioactive substances likely to be dangerous to humans.

B. Effects of Nuclear Explosions

Nuclear explosions of any type can be disastrous and may cause serious damage to life and property.

It is the personal responsibility of each individual to be aware of the precautions to take when a nuclear device explodes.

Nuclear explosions are accompanied by four destructive phenomena:

blast
heat
initial radiation
fallout

Blast, heat, and radiation are almost instantaneous at the moment of detonation, but fallout produces its effects later, longer, and over a wider area.

Most of the immediate damage of the explosion of a nuclear device is due to the effect of the blast wave and the energy released in the form of heat.

To gain personal protection from the thermal radiation, it is necessary to get out of the direct path of the rays from the fireball.

The thermal radiation travels at the speed of light; the blast wave travels at the speed of sound.

MATERIALS

ACTIVITIES

BLAST AND THERMAL DAMAGE FROM NUCLEAR EXPLOSIONS

A 5-MT burst at ground level would leave a crater one-half mile wide. The blast, heat, and fire caused by the explosion would cause widespread destruction, but radioactive fallout would be a much greater hazard. It could spread over thousands of square miles and sicken or kill unprotected people many miles from the point of detonation.

RANGE OF DAMAGE FROM A 5-MT BURST

Radii	Area (sq. miles)	Effect
0-3 mi.	28.3	All buildings almost completely destroyed by blast. Total death from blast and heat within this range.
3-6 mi.	84.7	Most buildings damaged beyond repair. Nearly 100% deaths within this area.
6-9 mi.	113.0	Moderately damaged buildings that must be vacated during repairs. Danger of 1st degree burns, blast, and early fallout.
9-12 mi.	226.4	Partially damaged buildings. Danger from both early and late fallout. Danger of 2nd degree burns.
Beyond 12 mi.		Danger of both early and late fallout if protection is not provided.

KEY WORDS

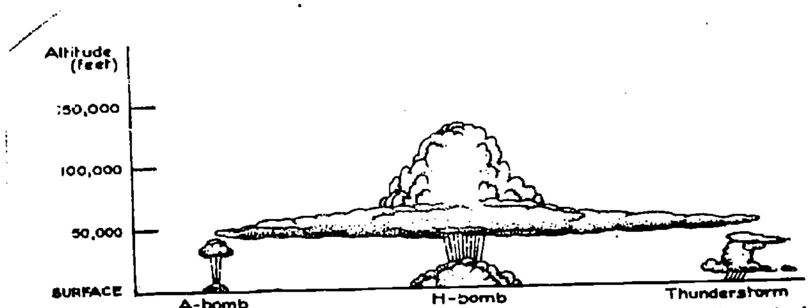
blast
detonation
fireball
nuclear device
phenomena
precautions
rendered
thermal

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
1. Air burst	The air burst explosion occurs in the air above land and water and no part of the fireball strikes the surface

MATERIALS

ACTIVITIES

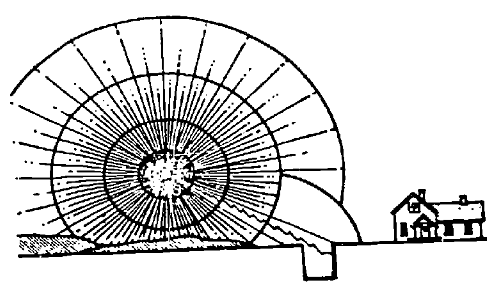
COMPARATIVE SIZES OF NUCLEAR EXPLOSIONS



Comparative size of A-bomb mushroom, H-bomb mushroom, and Thunderstorm cloud

NUCLEAR EXPLOSIONS — AIR BURST

An airburst occurs at sufficient height above the surface of the earth to prevent the fireball from coming in contact with the surface. The quantitative effects of an airburst will depend upon the actual height of the explosion as well as the energy yield.


Air Burst

KEY WORDS

air burst
blast wave
debris
dispersed
fission products
maximum brilliance
megaton
micron
precipitation

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Surface burst	The surface burst explosion occurs on the surface (or when a part of the fireball strikes the surface).
	A surface burst causes much more radioactive fallout than an air burst.
	Radioactive fallout from a surface burst may be carried many miles by prevailing winds.
3. Subsurface bursts	Subsurface bursts occur beneath the surface of land or water.

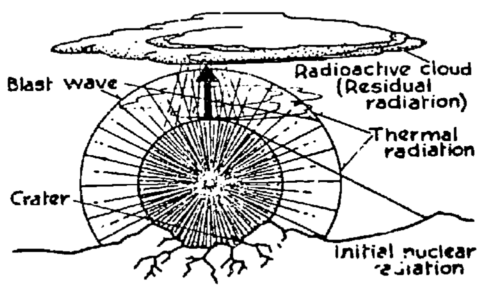
MATERIALS

ACTIVITIES

NUCLEAR EXPLOSIONS — SURFACE BURST

When a nuclear weapon is exploded close to the ground, thousands of tons of earth, rock and debris will be melted and vaporized. This gaseous material mingles with the fission products in the rapidly rising fireball. The majority of this material serves as a carrier for the fine particles of radioactive material that result from the cooling of these gases. These particles fall back to earth within a short period of time as radioactive fallout. Very fine and less dense debris may remain aloft for longer periods of time, carried and dispersed by winds, and thus present a hazard for greater distances and for a longer period of time.

A surface burst causes much more radioactive fallout than an air burst.



Surface Burst

KEY WORDS

compression wave
disturbances
incorporated
prevailing
stratosphere
subside
surface burst
transmitted
troposphere
vaporized

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
C. Physiological Effects of Radiation	Exposure to radiations can produce harmful body effects. Nuclear radiation causes injury by damaging living tissue and cells. When large amounts of radiation are absorbed by the body in short periods of time, sickness and death may result.

MATERIALS

ACTIVITIES

PHYSIOLOGICAL EFFECTS OF RADIATION

The harmful effects of radiation appear to result from the ionization produced in cells composed of living tissue. As a result of this ionization some constituents which are essential to the normal functioning of the cells are damaged or destroyed. In other cases, by-products formed from ionization reactions may act as cell poisons. Among the observed actions of nuclear radiation in cells are: breaking of chromosomes, swelling of nuclei and of the entire cell, destruction of cells, increase in viscosity of cell fluid and increased permeability of the cell membrane. The process of cell division (mitosis) is delayed by exposure to radiation. In many cases cells are unable to undergo mitosis, thereby inhibiting normal cell replacement.

Possible E[illegible]y Effects of Acute Gamma Radiation Dosages over Who[illegible] Body During Exposure of One Day or Less

Acute Dose in Roentgens	Possible Effects
0- 25r.....	No obvious injury.
25- 50r.....	Possible blood changes but no serious injury.
50-100r.....	Blood-cell changes, some injury, no disability.
100-200r.....	Injury, possible disability, generally not fatal
200-400r.....	Injury and disability certain, death possible.
400-450r.....	Median lethal dose fatal to 50% within 2 to 12 weeks.
600-700r.....	Lethal dose fatal to 95% or more within 2 weeks.

Somewhat larger doses may be accepted, with an equivalent likelihood of injury if exposure is protracted over several days or weeks.

KEY WORDS

critical
demarcation
residual
subsurface

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
D. Protection Against Effects of Nuclear Explosions	The danger from radiation depends upon the degree of exposure (the intensity and time of exposure). Protection from exposure to external radiation depends upon: time since the blast distance from the blast amount of shielding
1. Effect of time	The amount of radiation from a source decreases with time. It must be emphasized that the nuclear radiation in fallout cannot be destroyed. Neither boiling nor burning, treatment with chemicals, nor any other action will destroy or neutralize radioactivity. Because of radioactive decay, fallout will become less harmful with the passage of time, but there is no known way to speed up the decay process. Fallout cannot be made harmless quickly. However, fallout can be removed from many contaminated surfaces.

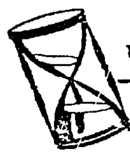
MATERIALS

ACTIVITIES

TIME—A FACTOR IN NUCLEAR DECAY

A close approximation of decay of fallout radiation can be obtained by assuming that the dose rate will decrease by a factor of 10 for every 7-fold increase in time. This is an operational assumption for the protection of individuals during fallout. Many isotopes have extremely short half-lives whereas others are radioactive for years.

Time - Decay



TIME (hr.)	DECAY	RADIATION INTENSITY
1	—	1,000 r/hr
7	1/10	100 r/hr
7X7 = 49 (2 days)	1/100	10 r/hr
7X7X7 = 343 (2 wks)	1/1,000	1 r/hr

Decay—7:10 Rule

HALF LIVES OF SOME FISSION PRODUCTS

About 200 different isotopes of nearly 40 elements have been identified among fission products created by nuclear explosions. The radioactivity of each isotope diminishes or "decays" at a specific rate, different for each isotope. Usually the rate of decay is expressed in terms of the "half-life" of the isotope. Some isotopes lose half their radioactivity within seconds after the explosion. Others take days or months or years to lose half their radioactivity. For example, iodine 131 has a half-life of 8 days. Thus, iodine 131 has decayed to half its original activity in 8 days, half the remainder is gone in another 8 days, and so on. After 64 days, only 1 percent of the radioactivity will remain. Strontium-90 has a half-life of 28 years and 1 percent of the radioactivity of strontium will still remain after 180 years.

Half-Lives of some radioactive isotopes significant in fallout are:

Isotope	*Half-life*
Silicon 31	2.62 hours
Sodium 24	15.06 hours
Iodine 131	8.14 days
Phosphorous 32	14.3 days
Cobalt 60	5.27 years
Strontium 90	28 years
Cesium 137	33 years
Carbon 14	5568 years

The total radiation hazard of newly formed, or fresh fallout, decreases rapidly at first because it contains many radioisotopes with short half-lives. The radiation hazard decreases more slowly after the shorter half-life elements have lost most of their radioactivity.

KEY WORDS

approximation
factor
primary decay
secondary decay
seven-fold
shielding
time period

REFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
2. Effect of distance	As the distance from the point of impact increases, the probability of survival increases and the damage to buildings decreases. The intensity of radiation varies indirectly as the square of the distance from the (point) source of radiation. Winds may carry radioactive material away from the point of the explosion. It is important to point out that the intensity of radiation decreases as the distance from the source increases. If a nuclear explosion occurred in Buffalo and if all of the radioactive products remained at Buffalo, the only danger from radiation would be close to Buffalo. However, when winds carry radioactive material which later falls on the surface elsewhere, the location of the source of radiation has moved.

MATERIALS

ACTIVITIES

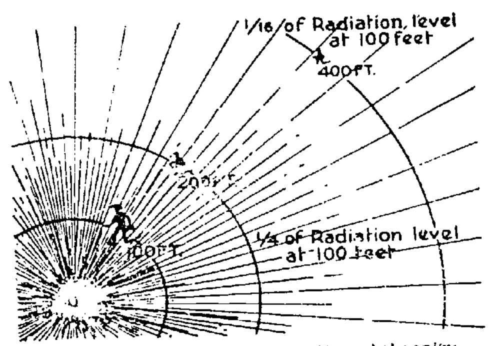
DISTANCE OFFERS PROTECTION AGAINST NUCLEAR RADIATIONS

A 5-megaton burst at ground level would leave a crater about one-half mile wide in the area of the explosion; it would destroy nearly everything within the radius of a mile from ground zero.

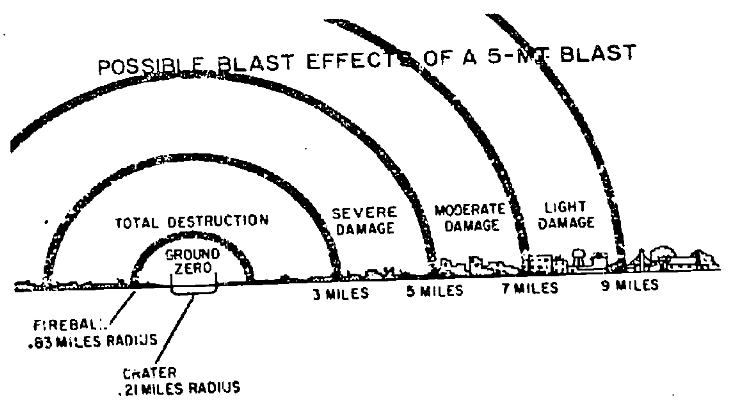
The destruction at 5 miles away would be less severe, but fire and fallout could be significant hazards.

Ten miles away, most buildings would remain intact but fires would be started indirectly by the blast wave which follows a burst.

Somewhat further away, buildings would remain standing. The most acute danger of these greater distances downwind from the explosion would be from early fallout.



Effect of Distance on Radiation Intensity



Possible range of damage—surface burst.

KEY WORDS

approximation
indirectly
inverse square law
point source
probability

REFERENCE OUTLINE

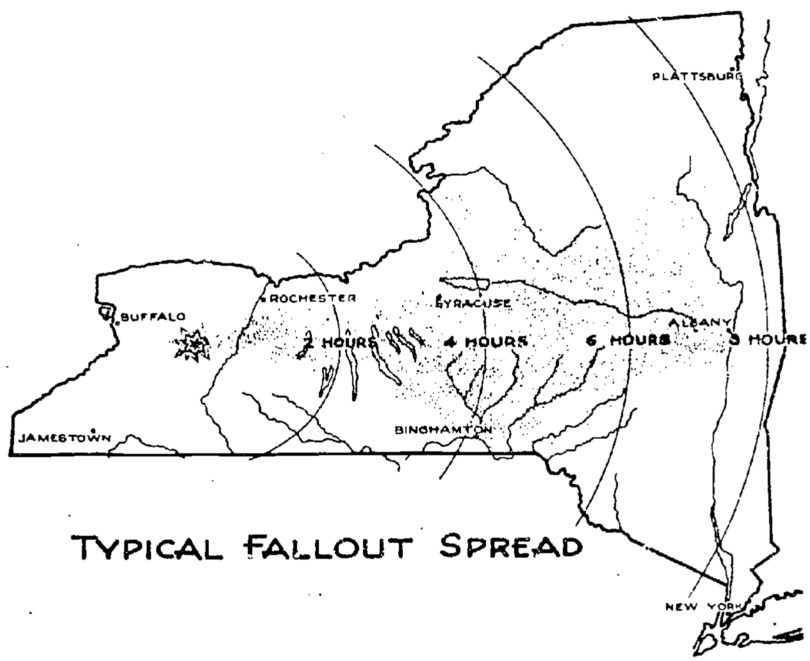
MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

MATERIALS

ACTIVITIES

DISPERSION OF FALLOUT IN NEW YORK STATE

Winds play an important part in the dispersion of fallout. Winds in the northern part of the United States are prevailing westerlies for the greatest portion of time. Therefore, winds are a factor in the dispersion of fallout throughout New York State. Note also the effect of time and distance on fallout.



KEY WORDS

EFERENCE OUTLINE	MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS
3. Effect of shielding	Protection from local fallout is accomplished by shielding. In general, protection increases with an increase in the thickness and/or density of the shielding material.
E. Shelters	A shelter places a mass of material between individuals and the source of radiation. Many parts of existing buildings provide good protection against fallout radiation and some measure of protection against blast and heat. Basements and central areas of high rise buildings offer satisfactory fallout protection. Every citizen has a responsibility in case of a nuclear attack--first and foremost, the responsibility for his own protection. Every individual must become capable of caring for himself in an emergency and be ready to contribute to the organized community survival effort. Each family must train and prepare to meet its own emergency problems. Each family must also prepare itself to assist others in need.

ATERIALS

ACTIVITIES

SHIELDING PROVIDES PROTECTION AGAINST NUCLEAR RADIATION

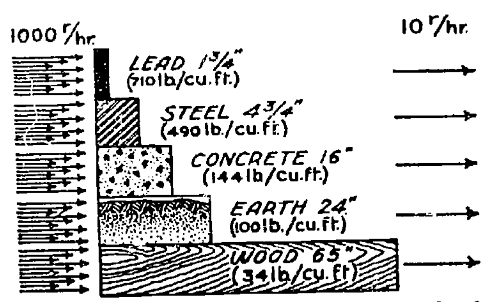
In planning for protection against nuclear radiation, time, distance, and shielding must be considered. Shielding is the placing of a mass of material between the individual and the source of radiation.

Different materials provide varying degrees of protection. The degree of protection is measured by a protection factor which is the amount by which shielding reduces radiation in the shielded area as compared to that in the surrounding exposed area. Thus a protection factor of 10 would mean that the intensity level with protection is one-tenth the level without protection.

A minimum protection factor of 100 has been selected by Civil Defense as a compromise between the maximum intensity level to which an individual can be continuously exposed without harm and the cost of providing such shielding.

A comparison of the mass of material which provides a protection factor of 100 follows:

SHIELDING WITH A PROTECTION FACTOR OF 100



Material Thickness for Protection Factor of 100

KEY WORDS

community
local fallout
population
shelters

REFERENCE OUTLINE

MAJOR UNDERSTANDINGS AND FUNDAMENTAL CONCEPTS

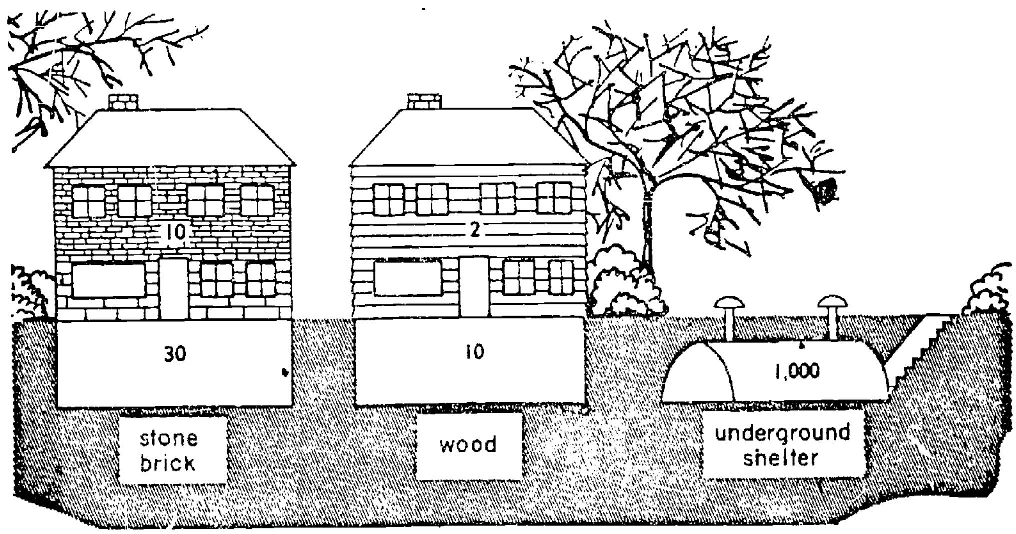
MATERIALS

ACTIVITIES

SHELTERS PROVIDE SHIELDING

Adequate protection against nuclear detonations involves a place for shelter. The shielding can vary from a minimum compact type of shelter to a suitably protected normal living space with all the necessities and conveniences. In large cities, community shelters are provided and stocked by Civil Defense. Pupils should be aware of the need for shielding and be familiar with where to go and what to do in an emergency.

A protective shelter should have a protective factor of 100. Discuss the protective factors offered in the homes shown below.



KEY WORDS

protection factor

Basements, as normally constructed, usually have a protection factor of 10 to 20 or more in small residences and 100 or more in multi-story structures, depending upon whether the basement is completely underground or partially exposed.

Much investigation and study has led to the conclusion that a protection factor of 100, if generally available, would afford an acceptable and realistic degree of protection against fallout for the people of New York. This standard would prevent fatalities and serious illness under almost any conditions of attack which can reasonably be anticipated.

Appendix

KEY WORDS

BLOCK O: ORIENTATION

acceleration
analyze
angles
application
area

balance
biased

capacity
Celsius
circle
circumference
communication
conclusion
constant
control
correlate

data
decimal system
define
degree
derived
dimension

equivalent
energy
event
expression
extensions

Fahrenheit
force
frequency
fundamental

generalization
gravity

hypothesis

illusion
independent
inertia
instruments
interval
investigation
irregular

netic

length
limitations

mass
matter
measure
molecules

observations

pressure
primary
procedure
protractor
pure number

qualitative
quantitative

rate
ratio
regular
relationship

sextant
scale
solution
speed
standard
substantiate
summarize
synonymous

temperature
tentative
thermocouple
thermometer
time

universal
unknown

variable
velocity
vibration
volume

waves
weight

KEY WORDS

BLOCK I: FORCES AT WORK

acceleration
acceleration of gravity
action
Archimede's Principle

balanced force
Bernoulli's Principle
bouyancy

compound machines
conservation of energy
conservation of momentum

density
direction
displacement (distance & direction)
displacement (fluid volume)

effort
effort arm
energy
equilibrium

force

fluid

fulcrum

gravitation
gravity

inclined plane
inertia

joule

kinetic energy

lever

machine
magnitude
mass
mechanical advantage
momentum

newton
Newton's First Law of Motion
Newton's Second Law of Motion
Newton's Third Law of Motion

Pascal's Law
potential energy
power
pressure
pulley

reaction
resistance
resistance arm

screw
simple machines
speed

velocity

watt
wedge
weight
wheel and axle
work
work input
work output

unbalanced force

KEY WORDS

BLOCK J: THE CHEMISTRY OF MATTER

absorbed
accelerate
accumulate
acid
activity
activity series
agitating
alkali
alloy
arbitrary
asbestos
atom
atomic number
atomic weight
attraction
axis
average

base
Bernoulli's Principle
Bohr
borrow
brackets
brittleness
burn
burning
business-like

catalyst
cathartic
charge
chemical action
chemical balance
chemical change
chemical combination
chemical decomposition
chemical replacement
chemically
chemically united
classification
classify
coagulation
coefficients
color
colloidal dispersion
colloids
combining gases
combining ratio
commercial
comparison
complex
composition
compounds
concentrated
concentration
converted
cool
counteract
crystal lattice
crystalize
curve

decelerate
decompose
deficiency
definite
detected
digestion
directions
dissolving
distribution
double replacement
drugs
ductility

elasticity
electrical balance
electricity
electrochemical series
electron
electrostatic
elements
endothermic
energy
energy level
energy shell
equation
etching
evaporating
exchange
exothermic
expands
explosion
explosives
expressing
extinguisher

families
fertilizer
filter
filter paper

filtrate
force
form
formation
formula
fundamental

gas
generator
graph
groups

halogens
hardness
heat
heterogeneous
homogeneous

identified
illustrate
impenetrability
incandescence
indicator
inert
inert gases
inertia
industrial processes
insoluble
internally
ion
irritate
isolated
isotope

key
kinetic
kindling temperature

law of mass action
lend
liberated
light
liquid
liquifies
litmus
lubricant
luminous

magnet
magnetic
malleability
mass
mass number

matter
membranes
metal
metallic
metalloids
minerals
mixtures
molecular
moles
motion
multiplier

nature
neutralize
noble gases
non-metals
non-metallic
non-metallic oxide
non-polar
neutral
neutron
nuclear
nuclei
nucleon
nucleus
numerical

odor
opaque
orbit
organize
original
oxidation
oxidizing

parenthesis
periodic table
periods
phase
phenopthalein
physical
polar
positive
potential
precipitate
prediction
preserving
pressure
properties
proportion
proton
pulverizing
Pyrex

rare gases
rate
react
reactants
reaction temperature
reagent
reduced
reducing
reflected
resistant
respiratory tract
revolve
rings
rounding-off

salt
saturated
seasoning
series
shatter
shear
simple replacement
solid
soluble
solubility curve
solubility graph
solubility table
solute
solution
solvent
space
spatula
specific
spud
standard
stirring
stopper
strain
stress
structure
subscript
substance
sufficient
supersaturated
suspension
symbol

temperature
tenacity

uniform
unsaturated
unstable

velocity
visible

water softener
weight
whole number
wing top

KEY WORDS

BLOCK K: ENERGY AT WORK

ampere
amplitude
angle of incidence
angle of reflection
atom
attract

boiling point

capacitor
Celsius
charged objects
charging by contact
charging by induction
color
condensation
conduction
conductor
conservation of charges
contraction
convection
current electricity

dry cell

electric circuit
electric coil
electric current
electric energy
electric motor
electric power
electrolytes
electron
electromagnetic radiation
electromagnetic spectrum
electrophorus
electroscope
electrostatic forces
expansion

Fahrenheit
fixed points (thermometer)
freezing point
frequency
fuel cell

galvanometer
gas
generator

heat
Hertz

insulator
ionized gases

joule

kilocalorie
kilowatt-hour

Leydon jar
light
liquid
longitudinal wave

magnetic fields
magnetism
melting point

neutron
nucleus

ohm

parallel circuit
permanent magnet
photoelectric cell
proton

radiator
reflection
refraction
repel
resistance
resonance

series circuit
solid
sound
static electricity
storage battery

temperature
temporary magnet
thermocouple
thermometer
transfer of charges

uncharged objects

volt
voltage
voltaic cell

watt
wavelength

KEY WORDS

BLOCK L: LIVING WITH THE ATOM

absorbed
acceleration
affinity
air burst
alpha particle
amplified
A.M.U.
anemia
application
approximation
archaeology
artificially
atom smasher
atomic
atomic bomb
atomic number
atomic pile

beta
betatron
blast
blast wave
boiling point
bombard
bubble chamber

calcifying
cancer
carbohydrate formation
Carbon-14
cataracts
chain reaction
charge
chamber
chemical interactions
chromatographic technique
community
compression wave
concentration
constant-frequency cyclotron
consumption
contamination
controlled reaction
convalescence
critical
cyclotron

debris
decay
decompose
decontamination
deflected
demarcation
detecting
detonation
deuteron
deuterium
development
diagnose
dilutions
discharge
dispersed
distillations
disturbances
dosimeter

electrical energy
elements
Einstein
electrodes
electromagnetic waves
electron
electroscope
$E=mc^2$
emission
emit
emulsion
energy
equations
excretions
expansion
explore
explosion
exposure dose
extracellular

factor
fallout
fertilizer
film
filtrations
fireball
fission
fissionable
fission products
fluorescence

fog droplet
fogging
fossil fuels
free neutrons
fungicide
fuse
fusion

gamma rays
Geiger-Muller counter
genetic

half-life
harvested
heavy element

impurity
incorporated
indirectly
ingesting
inhaling
injected
insecticide
intensity
instinctive
inverse-square law
ions
ionization
ionize
irrigation
isotope

kinetic energy
kinetic studies

larvae
lassitude
lethal
leukemia
liberate
local fallout

magnetic field
marketing
marrow
mass-charge
mass-energy equation
mass-number
mass-reduction
masses
maximum brilliance
megaton
metabolism

micron
millisecond
minimize
moderator
mulches
mutation

natural radiations
nausea
neutralizes
nuclear
nuclear device
nuclear reactor
nucleons
nucleus
nutrient

penetration
periodic table
phenomena
phosphor
phosphorescent
photo-multiplier tube
photosynthesis
physiology
point source
population
precautions
precipitations
preservation
pressure
prevailing
primary decay
probability
product testing
property
prostration
protection factor
proton synchroton
pulsation

quality control
quantitative

radiation sickness
radioactivity
radioiodine
radioisotopes
reaction intermediates
reconnaisance
relationship
relativistic effect
relic

rendered
residual
roentgens

scientists
scintillation
screwworm
secondary decay
self-sustaining
separation schemes
seven-fold
shelters
shielding
specimen
speed
speed of light
spontaneously
statistical
steel
sterilization
stratosphere
subside
subsurface
succumbs
supersaturated
surface burst
super-heated
symbols
synchrocyclotron
synthesis

tagged atom
technique
technological
Theory of Relativity
therapeutic
thermal
thermonuclear
thyroid gland
thyroxine
time period
tolerance
tracers
track
transmitted
transmutation
traverse
troposphere
tumor

uncontrolled reaction
unstable

Van De Graff generator
vapor
vaporized
velocity
viscosity
visible light