ED 325 392 SE 051 732

AUTHOR	Phillips, Kenneth L.
TITLE	Relating the Mole Concept and Fundamental Mathematics.
PUB DATE	May 89
NOTE	57p.; M.S. Practicum, Nova University.
PUB TYPE	Dissertations/Theses - Practicum Papers (043) -- Tests/Evaluation Instruments (160)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Abstract Reasoning; *Chemistry; Computer Assisted Instruction; Computer Uses in Education; *Concept Formation; *Mathematical Applications; *Mathematical Models; *Problem Solving; Programed Instructional Materials; Reading Skills; Science Education; *Science Instruction; Scientific Literacy; Scientific Methodology

ABSTRACT

The high percentage of students who have difficulty in solving free-response problems related to the mole concept was addressed by implementation of reading skill strategies and computer assisted instruction. Frayer models, semantic mapping, and graphic organizers from Reading in the Content Area (RICA) were used to increase student understanding of the scientific principles involved. Computers and a variety of computer programs from COMPress and Knowledge Factory were used by the target group for review, drill, and practice in relating their math skills to solving problems. The results indicated a considerable increase in the ability to solve problems related to the mole concept. It was concluded that better understanding of scientific concepts coupled with computer use for drill and practice was very effective in helping students relate science and mathematics. Appendices include evaluation instruments, examples of RICA Skills, supplementary handouts used for computer instruction, and sample responses from student comments regarding computer aided instruction. (Author)

RELATING THE MOLE CONCEPT AND FUNDAMENTAL MATHEMATICS

by

Kenneth L. Phillips

A Practicum Report
Submitted to the Faculty of the Center for the Advancement of
Education at Nova University in partial fulfillment of the
requirements for the degree of Master of Science.

The abstract of this report may be placed in a National
Database System for reference.

May/1989

Authorship Statement

I hereby testify that this paper and the work it reports are entirely my own. Where it has been necessary to draw from the work of others, published or unpublished, I have acknowledged such work in accordance with accepted scholarly and editorial practice. I give this testimony freely, out of respect for the scholarship of other workers in the field and in the hope that my work, presented here, will earn similar respect.

Signed

Abstract

Relating the Mole Concept and Fundamental Mathematics Phillips, Kenneth L., 1989: Practicum Report, Nova University, The center for the Advancement of Education.
Descriptors: Mole Concept / Science Instruction / Chemistry / Scientific Literacy / Abstract Reasoning / Concept Formation / Scientific methodology / Computer Assisted Instruction / Mathematical Applications / Programmed Instructional Materials / Problem Solving / Mathematical Models.

The high percentage of students with difficulty in solving free-response problems related to the mole concept was addressed by implementation of reading skill strategies and computer aided instruction. Frayer models, semantic mapping, and graphic organizers from Reading in the Content Area (RICA) were employed to increase student understanding of the scientific principles involved. Computers and a variety of computer programs from COMPress and Knowledge Factory were used by the target group for review, drill, and practice in relating their math skills to solving problems. The results indicated a considerable increase in the ability to solve problems related to the mole concept. It was concluded that better understanding of scientific concepts coupled with computer use for drill and practice is very effective in helping students relate science and mathematics. Appendicies include evaluation instruments, examples of the RICA Skills, supplimentary handouts used for computer instruction, and sample responses from student comments regarding computer aided instruction.

Table of Contents

Page

Chapters

CHAPTER I
PURPOSE

This practicum was conducted at a high school located in a southeastern community of one of the most rapidly growing urban areas in the state of Florida. The county is approximately 635 square miles in size and ranks seventh in the state in population, almost 580,000. This translates into 910 persons per square mile (Clements, 1987).

The population increased 22 percent in the years between 1980 and 1986, from 473,000 to 578,000. Twenty-four thousand of that increase (22.4 percent) is considered natural growth while 83,000 (77.6 percent) is due to migration. This increase is primarily attributed to the availability of jobs created by a tremendous increase in the tourist industry. It is estimated that the area receives over 25 million tourists per year (Clements, 1987). Statistics show that 26 percent of Central Florida households relocate every year (Donnelley , 1985).

The city covers approximately 65 square miles and has a population of approximately 150,000. This is almost 2,300 persons per square mile. The main ancestry groups are English and Irish. The present population is approximately 83 percent

White, 13 percent African-American, and four percent Latin-American, Asian/Pacific islanders, and others. Approximately 28 percent of the population is under the age of eighteen (Clements, 1987).

Although the school is located near the center of such a rapidly growing area, the community it serves is one of the oldest and most established sections of the city and, therefore, experiences little growth. The predominate socio-economic categories of the community are middle and upper-middle class but include lower-upper and middle-upper class. The community attitude is one of pride and conservatism and there is much concern for the education and welfare of the children.

Two parent organizations, the Parent/Teacher Association (PTA) and the Boosters Club, actively support academic and sports programs of the school with their time and financial assistance. A large percentage of the parents of the students have attended college and approximately 40 percent have a college degree. This characteristic is passed from parents to children as evidenced by the fact that for the past several years over 60 percent of the graduating seniors have attended college. Students consistently score above county, state, and national averages on the State Student Assessment Test (SSAT) and college entrance exams, such as the American College Test (ACT) and the Scholastic Aptitude

Test (SAT). In 1988, 28 percent of the graduating seniors received honors diplomas (Annual Report, 1988).

The school population was 1,965 total enrollment with 564 ninth-grade students, 511 tenth-grade students, 476 eleventh-grade students, and 414 twelfth-grade students. Almost 88 percent of the enrollment was White, four percent African-American, six percent Latin-American, and the remainder Asian/Pacific islander or Native American (Enrollment Summary, 1989).

The author of this practicum is a teacher certified in the areas of chemistry and physics with 20 years experience in the classroom. Three levels of chemistry are offered at the school (Chemistry I, Chemistry I Honors, and Chemistry II Honors), and the author presently teaches classes at each level.

The target population for this practicum was a class of 19 Chemistry I students. There were three tenth-grade students, ten eleventh-grade students, and six twelfth-grade students. There were six female and 13 male students. All of the students had taken and successfully completed Biology I and Algebra I. All of the students had taken and passed the State Student Assessment Test part II, which is required of all students in order to receive a high school diploma.

A large segment of the physical sciences is described by, exemplified by, or employs fundamental mathematics to some extent. By fundamental mathematics, the author is referring to addition, subtraction, multiplication, division, and the ability to solve a simple algebraic equation with a single unknown, such as a direct proportion. In almost every major topic of a first-year chemistry course, there is some use of numbers, most often involving computations for the solution of a problem. For this reason, first year algebra is a pre-requisite before a student is permitted to enroll in a chemistry course.

It was the author's observation that most of the students in the target population could perform the necessary mathematical computations and were as scientifically literate as other first-year chemistry students of comparable background. Nonetheless, they experienced great difficulty relating their mathematics skills to scientific concepts. The following summary of information taken from the students' Cumulative Folders is offered as evidence of the capabilities of the students regarding their computational skills and science background.

With one exception, all of the students in the target population had completed Algebra I with a grade of C or better. One student took Algebra I in summer school and passed with a grade of D. The available results of the Comprehensive Test of Basic Skills (CTBS) related that 60 percent of the students had a stanine score in the 7 to 9 range (above average) and that 40 percent had a stanine score in the 4 to 6 range (average) in mathematics. In addition to the stanine scores, 86.7 percent were above the seventieth percentile, 6.7 percent were in the sixtieth percentile, and 6.7 percent were below the thirtieth percentile in mathematics.

The students' science grades and scores on the CTBS were not as impressive as their math grades and scores. Seventy-five percent of the students made a C or better in biology, and 25 percent made a D. Only 31.2 percent of the class had stanine scores from 7 to 9 in science, and the remainder of the class, 68.8 percent, fell into the four to six stanine category. Forty-two and nine-tenths percent were above the seventieth percentile, 42.9 percent were in the fortieth to sixtieth percentile, and 14.2 percent were in lower than the fortieth percentile in science (Cumulative Folders,1989).

After having been taught the mole concept, having practiced solving mole problems in class and at home, and having completed work sheets on the mole concept, 79 percent of the students in the target group scored less than 20 percent on the free-response section of the chapter test. The other 21 percent scored only 50 percent on the free-response portion of the test. The free-response section of the test consisted of six problems related to the mole concept. None of the problems involved math skills in addition to those previously mentioned on page four (Appendix A).

According to county standards, 65 percent is a passing score and, although no teacher wants failure, seven percent is an acceptable failure rate. Even though the science scores and grades are generally lower than the math scores and grades, it was the contention of the author that at least 93 percent of the students should have been able to score a passing grade (i.e., 65 percent) on this material.

Generally all students in the target population were functioning below capability when applying their math skills to scientific concepts. After applying the techniques of concept modeling, semantic mapping, structural overviews, and after using computers for review, practice, and drill, the following objectives were assessed:

A. All of the students in the target group were to:
   1. calculate correctly the formula mass of a compound when given the formula and a table of atomic masses;
   2. calculate correctly the molar mass of a compound when when given the formula and a table of atomic masses.

B. Ninety percent of the students were to calculate correctly the percent of an element n a compound when given the formula and a table of the atomic masses.

C. Seventy-five percent of the students were to convert correctly a given amount of a substance to molecules, grams, or moles when given the formula and a table of atomic masses.

D. Fifty percent of the students were to calculate correctly the empirical formula and molecular formula for a compound from composition data.

E. All of the students were to solve correctly four of the six problems on the solution strategies evaluation.

These objectives were measured by assessing student performance on a free-response instrument designed to be analogous to the original free-response portion of the chapter test mentioned on page six (Appendix B).

CHAPTER II

RESEARCH AND SOLUTION STRATEGIES

"Chemistry is the science dealing with the structure and composition of substances, (and) the changes in composition..." (Metcalfe, Williams, and Castka, 1986). The individual pieces composing the matter (atoms and molecules) are so small that no one can see them or feel them. Since much of chemistry deals with quantities of matter, scientists have defined a unit for the measuring of an amount of a substance. This unit is the mole. By definition the mole is the amount of a substance that contains the Avogadro number of any kind of chemical unit (Metcalfe, Williams, and Castka, 1986). The mole is the most important concept in the first-year chemistry course because of its use in stoichiometry (Kolb, 1978). Stoichiometry is the branch of chemistry that deals with the calculations of quantities of substances involved in a chemical change (Herron, 1987).

For beginning chemistry students, there are many problems associated with understanding the mole and related concepts. According to the research to be cited by this author, these problems are not specific to the United States. Articles researched include materials from studies completed in Israel, England, Scotland, and Italy. Most of the problems cited are related to the students' abilities to understand scientific concepts, think abstractly, and relate their math skills to scientific concepts.

Language difficulties include, but are not limited to, the definitions of words and the method of statement of word problems. In a survey of chemistry textbooks used in secondary schools in Italy, some of the texts failed to define the mole as a unit of amount. Only three of thirteen texts gave a correct definition and related the mole to the Avogadro number (Cervellati, 1982).

Hudson (1976) stated that the mole should be defined as a quantity, not a number, and should be expressed as a mass or volume. Furthermore, students should be given the opportunity to use the term "mole" as often as possible in order to enhance understanding.

Because the mole is usually expressed in grams, some students tend to think of the mole as a certain mass rather than a definite number of particles. Other students limit the mole to gases, while still others apply the molar volume (the volume of one mole of gas at standard temperature and pressure) to all substances. Some students think that the mole is a property of a molecule. It is also plausible that the phonetic similarities of such terms as molecular mass, molar mass. molar volume, gram-molecular mass (weight), etc., add more difficulty to the understanding of the concept (Novick and Menis, 1976).

Henson and Stumbles (1979) stated that one of the difficulties in understanding problems associated with the mole, at least for students whose mathematical background is modern math, is the language in which the problems are stated. If the problems were stated in math terms these students understand, they would be as capable of solving problems as students having been taught traditional math.

Because of the minuteness of atoms and molecules, macroscopic observations must be explained in terms of microscopic concepts. Changes which the students can see are interpreted in terms of intangible particles. This necessity is difficult for many students to understand (Novick and Menis, 1976). Hudson (1976) pointed out that students are quite often required to relate inaccurate laboratory results to accurate expressions of formulas. This is especially a source of confusion for students that have been presented the mole concept via laboratory investigation.

Kolb (1978) viewed this aspect of understanding the mole concept from the reverse direction. When discussing chemical reactions, students were taught to use the terms atoms and molecules. However, when reactions were carried out in the laboratory, large numbers of molecules were required in order to see what was happening. In order to count out the molecules, the concept of moles of molecules was employed. Even more confusing to the students is the fact that the moles of molecules must be actually measured out on a balance, and the quantity is usually expressed in grams. The relationship between particles, moles, and grams is very difficult for students to grasp.

Schlenker and Perry (1983) cited that as many as half of the beginning chemistry students lack the ability to use abstract reasoning structures. This means that the thinking of this half of the students is still in the concrete mode. The results of the study by Novick and Menis (1976) indicated that many students do not function at the cognitive level necessary to understand the mole concept or to use it in problem solving. To understand the concepts related to the mole, students need to have developed intellectually to the stage of being able to use abstract symbols to solve problems and then translate the results back to reality (Duncan and Johnstone, 1973).

Students have difficulty coping with mathematical ideas, such as ratios and proportional reasoning, and scientific concepts, such as the mole concept, at the same time (Hudson, 1976). Students especially have difficulty solving mole problems that involve other than a 1:1 ratio (Duncan and Johnstone, 1973).

The distinction between numbers and quantities is a major problem for beginning chemistry students. Numbers in math classes and numbers in science classes are not used in the same manner and do not have the same meaning. Unlike the numbers used in math which are usually small and whole (i.e., integers), quantities in science often consist of very large or very small numbers and must include a unit of measure. The symbols used in math have no physical meaning. For example, in the expression X = 2, neither the X nor the 2 can be related to something physical. The symbols used in science do refer to specific entities. For example, the expression 2.0 g means two and zero-tenths grams of a substance, a quantity or amount of the substance measured in gram units (Herron, 1987). The meaning of the quantity must be retained when applying mathematical computations in a stoichiometric problem or when changing the quantity to a different unit of measure (Dierks, 1985).

There are many approaches to and possibilities for solution strategies that could lead to better understanding and use of the mole concept by beginning chemistry students. Some researchers recommended that the mole concept should be taught only when students have reached the cognitive level necessary to gain full understanding of the concept (Cervellati, 1982). Some indicate that simpler and less involved development in the early part of the course should be employed in order to reduce the conceptual demands placed on the students (Novick and Menis, 1976). Still others say that it is the responsibility of the teacher to use the language that students understand when asking questions and giving problems and not vice-versa (Henson and Stumbles, 1979). It must be stated that this author does not fully agree with any of these statements but realizes that they do hold some merit.

Instruction should be designed and given in such a manner as to facilitate learning at the concrete level (Schlenker and Perry, 1983). For students with a high level of mathematical anxiety, a more visual approach, i.e., the use of diagrams and/or concept mapping, and a less mathematical approach should be incorporated. For students that are lower level math-anxious, a less visual/more mathematical approach should be used, i.e., the factor label method, sometimes called unit cancellation (Gabel and Sherwood, 1983).

Thought processes (the use of "road maps") should be emphasized rather than the memorization of formulas for the solutions of problems (Festa, 1985). Problems should be presented with slight variations or modifications that would require the students to think about a particular problem's solution more carefully (Gabel and Sherwood, 1984). The use of a conversion matrix to simplify stoichiometric calculations from balanced equations was suggested by Berger as cited by Festa (1985). The matrix helps students understand the mole/gram relationships in a balanced equation. Analogies and analog tasks can be used not only to increase understanding of abstract concepts but also to determine which types of difficulties the students might have in understanding the concepts (Gabel and Sherwood, 1984).

In order to be successful in problem solving in chemistry, students need to practice. This is especially true in the areas involving the use of scientific notation (usually associated with the number of particles), multistage problems, and problems involving division (Gabel and Sherwood, 1984). Practice of this type can best be achieved via the use of computers. Some of the advantages computers have over teachers are that they:

1. are not judgmental, impatient, or critical;
2. provide instant feedback for the students;
3. allow the students to work at their own pace;
4. provide review information as often as needed;
5. are consistent in presentation of concepts and evaluation of responses (Brown, and Forrestall-Brown 1986).

This author implemented the use of techniques presented in the course Reading In The Content Area (RICA) and the use of computers to assist students in relating their math skills to solving problems associated with the mole concept. This approach served to clarify the meaning of the mole and related terms while allowing the students to drill and practice solving problems in a non-threatening atmosphere.

The RICA concepts used were the Frayer model, the graphic organizer, and semantic mapping. The Frayer model (Frayer, Frederick, and Klausmeier, 1969) is a technique of word categorization which requires students to distinguish relevant features, identify characteristics from various perspectives, classify examples and non-examples, and cite reasons for the classifications based on the defining attributes. The graphic organizer (Readence, Bean, and Baldwin, 1981) was used by the author to identify and classify the vocabulary and relationships of the concepts. Graphic organizers include such items as pictures, flow charts, maps, etc. Semantic mapping (Heimlich and Pittelman, 1986) was used to relate words to other words. It differs from the graphic organizer in that it is student involvement that develops the relationships between the words.

The computer-assisted instruction was primarily for review of the concepts and drill and practice of problem solving. A variety of programs were used to present random problems related to the mole concept, including such types as percent composition, mass-mole problems, mass-mass problems, and the calculation of mole ratios to determine empirical and molecular formulas. In some programs the degree of difficulty could be regulated so that students weaker in math skills would not become intimidated and give up. The computers provided a continual source of review and problem-solving practice which allowed the students to proceed at their own pace and to the extent necessary for mastery of the subject.

CHAPTER III

METHOD

The solution strategies can be divided into two categories on the basis of purpose and expected outcome. The first of these involves the use of content reading strategies to improve understanding of the major concept, the mole, and the related vocabulary. These strategies were incorporated during the first three weeks of implementation. The second category of strategies involves the use of the computer for actual drill and practice to improve skills in solving problems related to the mole concept. This portion of the implementation occurred during weeks four through nine. The evaluation of the solution strategies was conducted in week ten.

In week one the students in the target group were presented the basic attributes of the Frayer model (Appendix C:1). The author defined a word related to the mole concept. The students were then divided into small groups for a period of 10 to 15 minutes. The purpose of the small groups was to develop a list of examples of the defined word. As the examples were supplied by the students, the author wrote them on the overhead projector and organized them into categories. Examples were distinguished from non-examples on the basis of relevant attributes. Similarities of the examples or common characteristics were grouped as essential characteristics and differences were grouped as non-essential characteristics. From these considerations the students were helped in understanding what the mole is, as well as what it is not (Appendix C:2).

In week two the semantic mapping strategy was introduced to the students (Appendix D:1). The term "mole" was the central concept. Students then constructed a class semantic map on the chalkboard and produced visual connections between associated words. Discussion of the relationships of the words accompanied this development. A more extensive semantic map than the author anticipated was developed (Appendix D:2).

In week three the students were presented with graphic organizers in an attempt to depict visually the conceptual scheme whereby conversions from one unit of measure to another unit of measure is accomplished. These organizers visually demonstrated the mathematical relationships between moles, grams, atoms, molecules, the molar volume of a gas, etc.

The first graphic organizer presented multiplication as the mathematical process used when converting moles of an element to grams, particles (atoms for monatomic or molecules for diatomic elements), or liters (gaseous elements only). The graphic organizer also gave the conversion factor to be used in the conversion (Appendix E:1). A second graphic organizer was given for the conversion of moles of a compound to grams, particles, or liters (Appendix E:2). The primary difference in the change of units for elements as compared to compounds is the fundamental particle of each (atoms or diatomic molecules for elements, molecules or formula units for compounds). Any time the unit changes from moles to some other unit of measure, multiplication is the mathematical skill to be used.

The third and fourth graphic organizers (Appendix E:3 and E:4) presented division as the mathematical process used when converting grams, particles, or liters of an element or compound to moles. Any time the unit changes to moles, division is used.

During week four the implementation of the use of computers began. Because the computers are not in the chemistry classrooms, a suitable schedule for their use had to be devised with the other instructor involved. This presented some problems because he did not wish to exchange rooms. For this reason, all of the instruction about the computer's use was conducted in the author's classroom and the students had to delay actual hands-on learning until moving into the physics classroom. To begin the instruction, the students were given a lecture/demonstration on how to start and run a computer program. They were introduced to and told the functions of the basic components of a microcomputer. They were also instructed in the use of proper terminology and the correct use of each part of the equipment. Handouts prepared from the Apple IIGS owner's manual were given to each student. These included a picture of the keyboard indicating its "special" key functions, a list of the essential terminology with definitions, and a list of rules for the proper handling of the program diskettes (Appendix F:1 - F:4).

During week five each of the students demonstrated to the author, the proper use of the equipment, i.e., handling of the diskettes, turning on the computer, booting and running a program, etc. Students initially worked in small groups (2 or 3 individuals) until they felt comfortable working with the computers. Many of the students had taken or were taking either basic computer programming or business education applications of computers and were relatively computer-literate at the start.

In weeks six through nine, the students worked individually or in small groups with the computers. The programs used were from <u>Introduction to General Chemistry</u> by COMPress and <u>Knowledgebase-General Chemistry 1a</u> by Knowledge Factory. The COMPress programs are tutorial in nature with no provision for record keeping or grading on the diskettes. There was a total of ten programs from COMPress, each of which contained from 2 to 5 lessons. The Knowledge Factory programs are primarily quiz type programs with timed and untimed modes as well as varying levels of performance expectation. There were five programs from Knowledge Factory, each containing from 10 to 25 questions. Students were expected to complete all of the programs, either individually or in small groups.

Since the number of computers available was limited to eight, most class-time use was in small groups. Individuals were allowed to rotate computer use; however, this limited actual computer time to approximately 20 minutes per student per day. To a limited extent students were able to work at their own pace in a non-threatening atmosphere and were able to review as necessary for mastery of the material. Students were encouraged to stay after school for individual work whenever possible but this was seldom utalized.

Week 10 was used for the final evaluation of the effect of the solution strategies on the ability of the target group to solve problems related to the mole concept. Students were given the evaluation instrument in Appendix B and the results are discussed in the following section.

CHAPTER IV

RESULTS

The evaluation of solution strategies took place during the tenth week of implementation. A six question free-response instrument was developed by the author to evaluate the ability of the target population to solve problems related to the mole concept. The instrument was analogous to the initial evaluation instrument that originally alerted the author to the problem. A comparison of the results from the post-implementation of strategies evaluation with the results from the initial instrument reveals the relative significance of the value of the improvement program as presented to and executed by the target population. It must be noted that not only the correct answer was graded, but the solution method had to be correct and logical for the students to receive credit for the problem. This was primarily because it is sometimes possible to derive a correct answer via an incorrect process because of mass similarities and differences among the elements.

The first problem required that the students calculate the formula mass of a compound. To solve this problem the mass of each element must be checked in a periodic table, the mass multiplied by the number of atoms of that element in the formula, and the sum of all of the masses of all of the atoms of each element be determined. The author had anticipated that 100 percent of the target population would solve this problem correctly. Eighteen of the 19 students (94.7 percent) solved this problem correctly. The one student that did not solve the problem correctly had the set-up for a proper solution but made a calculator error.

The second problem required that the students calculate the molar mass of a compound. The molar mass is the numerical portion of the formula mass but the unit of measure is the gram instead of the atomic mass unit (a.m.u.). The solution procedure is essentially identical with that of problem one. The author again had anticipated that 100 percent of the target population would solve this problem correctly. Once again 18 of 19 (94.7 percent) of the students solved this problem correctly. The student that did not solve the problem correctly determined the molar mass correctly and then multiplied by Avogadro's number.

Problem three involved finding the mass percent of an element in a compound. Any mass data that gives the ratio of the mass of the element to the total mass of the compound can be used. Because the formula is a mole ratio of the elements in one mole of the compound, the masses used in this problem were to be derived from the formula mass or molar mass as in the first and second problem. The mass percent equals the mass of the element in the formula divided by the total mass of the formula and then multiplied by 100 percent to change the decimal to a percent. Because of the previous background of the target population in working with percentages, the author had anticipated that 90 percent of the target population would solve this problem correctly. Twelve of the 19 students (63.2 percent) calculated the mass percent of nitrogen in the compound $(NH_4)_2CO_3$ correctly. Of the seven students who solved the problem incorrectly, four students (57.1 percent) failed to use the total amount of nitrogen for its mass, one student (14.3 percent) inverted the masses, one student (14.3 percent) did both, and one student (14.3 percent) used a procedure totally foreign to the correct solution method.

Problem four was to convert a given mass in grams of a compound to moles. The formula of the compound was also given. The process involves dividing the given mass by the molar mass of the compound. The author had anticipated that 75 percent of the target population would solve this problem correctly. Sixteen of the 19 students (84.2 percent) solved this problem correctly. Of the three that were incorrect, one made a calculator error, one multiplied instead of divided, and the other converted the mass to the number of particles instead of moles.

The fifth problem was to convert the moles of a compound to the mass in grams. This problem was the reverse process of that in problem four, i.e., students had to multiply the number of moles given by the molar mass. The author had anticipated that 75 percent of the target population would solve this problem correctly. Fifteen students (78.9 percent) solved this problem correctly. Of the four students that were incorrect, two students (50 percent) divided instead of multiplied, one student (25 percent) converted moles to number of particles instead of grams, and one student (25 percent) used a process totally unrelated to the correct solution process.

The sixth and most difficult problem had two parts and credit was not given unless the students solved both parts correctly. The first part of the problem was to determine the empirical formula of a compound from mass data. The solution process involves converting the mass in grams of each element to moles as in problem four. After this has been done, determining the simplest whole number mole ratio produces the ratio of atoms in the formula. The second part of the problem involved the determination of a molecular formula (which is some multiple of the empirical formula) from the empirical formula and a given molar mass. The author had anticipated that 50 percent of the target population would solve this problem correctly. Only five students (26.3 percent) solved both parts correctly. Fourteen students (73.2 percent) solved one of the two parts correctly while two students (10.5 percent) solved neither part of problem six correctly. Of the 14 students solving at least one of the two parts correctly, only one student (7.1 percent) calculated the empirical formula correctly. Of the thirteen students who calculated the empirical formula incorrectly, only five (38.5 percent) calculated the mole ratio correctly even though 16 of 19 of the target population (84.2 percent) had solved problem four correctly. Two of the five students (40.0 percent) with a correct mole ratio rounded or cleared the decimal incorrectly. The other three students with a correct mole ratio (60.0 percent) used a process unrelated to determining the simplest whole number ratio. Of the eight students with incorrect mole ratios, four (50.0 percent) had used the mass ratio or percent to determine the empirical formula. The other four students (50.0 percent) did something unrelated to the correct solution of the problem.

Of the 14 students not receiving credit for problem six, 11 (78.6 percent) were able to solve the second part correctly even though they were incorrect on the first part. This was possible because of the similarity in molar mass of oxygen and nitrogen (16 and 14 respectively). This allowed an incorrect process to produce a correct answer for the empirical formula.

If elements with a greater difference in molar mass had been used, such as hydrogen and carbon (1 and 12 respectively), this would not have happened.

If problem six had been considered as two separate problems, 6 of 19 (31.6 percent) of the target population solved problem 6a correctly, and 16 of 19 (84.2 percent) solved problem 6b correctly. Table I summarizes these results.

Table I
Summary of correct responses
and objectives.

PROBLEM #	# CORRECT	% OF TARGET	% EXPECTED	OBJ. MET
1	18	94.7	100	NO
2	18	94.7	100	NO
3	12	63.2	90	NO
4	16	84.2	75	YES
5	15	78.9	75	YES
6	5	26.3	50	NO

It can be clearly seen that the multistage problems, percent calculation (problem three) and empirical/molecular formula calculations (problem six) present the greatest difficulty for students. With the exception of problem three, this outcome was expected as indicated by the author's outcome objectives; however, the percentages were not expected to be so low. In formulating and stating the outcome objectives the author did not make allowance for such things as calculator error, incorrect rounding, etc. This would have made a difference in attaining at least two of the objectives.

Table II presents a summary of the number and percentages of the target group solving a given number of problems corectly before and after implementation. It also lists the percentage increase or decrease in correct responses. A decrease in the lower range and an increase in the upper range indicate the relative success of the solution strategies.

Table II

Summary of the total correct responses
for the pre-test and post-test
and percentage change.

# CORRECT	PRE	%	POST	%	% + OR -
0	10	52.6	0	00.0	-52.6
1	6	31.6	0	00.0	-31.6
2	2	10.5	2	10.5	00.0
3	1	5.3	1	5.3	00.0
4	0	00.0	10	52.6	+52.6
5	0	00.0	3	15.8	+15.8
6	0	00.0	3	15.8	+15.8

It can be seen that on the pre-test, 100 percent of the target population scored less than 50 percent. One student (5.3 percent) solved three out of six problems correctly, two students (10.5 percent) solved two out of six problems correctly, six students (31.6 percent) solved one out of six problems correctly, and ten students (52.6 percent) solved zero out of six problems correctly.

On the post-test, only three students (15.8 percent) scored less than 50 percent. There was an 84.2 percent increase in the number of students scoring over 50 percent, an amount equaling that of all students solving zero or one problem correctly on the pre-test. Ten students (52.6 percent) solved four out of six problems correctly. This was a 52.6 percent increase over the pre-test. Three students (15.3 percent) solved five out of six problems correctly. This was a 15.3 percent increase over the pre-test. Three students (15.3 percent) solved six out of six problems correctly. This is also a 15.3 percent increase over the pre-test.

Two groups of "number of problems correct" remained the same: two students (10.5 percent) solving two out of six problems correctly and one student (5.3 percent) solving three out of six problems correctly. In view of the other increases in problem solving ability, the author believes that it is not very probable that they were the same students.

Although the author's objective of having a 93 percent increase in the number of students that solved at least four out of the six problems correctly was not achieved, the increase in student ability due to the solution strategies cannot be denied. The Frayer model, graphic organizers, and semantic maps aided the students in developing a better conceptual understanding of the mole concept. The use of the computers for review, drill, and practice was an outstanding success. Appendix G provides some typical responses received from the students after they were asked to comment on the value of the computers in their learning experience. It is reasonable to assume that if there had been a computer lab or computers in the author's room providing unlimited use by the students, even greater success could have been attained.

CHAPTER V

RECOMMENDATIONS

Because of the notable success of the solution strategies implemented to improve student ability to solve problems related to the mole concept, the author plans to apply these strategies to the concepts of stoichiometry, solution concentration, gas laws, kinetics, and equilibrium. Just as the mole concept is difficult for students, these areas of chemistry pose particular problems for beginning chemistry students. The author believes that this is because of the relationships between mathematics and scientific concepts. This practicum was designed to study and implement strategies for improvement of exactly these types of situations. The author will continue to use the RICA strategies and strive to develop new graphic organizers for the above mentioned intended areas of application. The author will also continue to use the computers for review, drill, and practice as scheduling permits.

Students of the target population have been encouraged to use the RICA strategies in each of the new areas of study because new concepts and new vocabulary necessary to the understanding of the subject will be presented. It is essential to learn the language of chemistry in order to develop the skills necessary for the mastery of the material.

Using the results of this practicum as evidence for successful achievement of enhanced learning, the author will submit a request for the acquisition of computers for the chemistry department. Supplying the chemistry department with computers will greatly lessen the confusion and problems related to sharing classrooms and scheduling computer use with the physics department.

The other chemistry teacher in the school is being encouraged by the author to implement these techniques in her first year chemistry classes and the author is extending use of the techniques to the first year honors classes and the second year honors class.

The results of the practicum will be presented to the entire science department of "Practicum High School" at the next regularly scheduled meeting. Since many of the teachers already practice the use of RICA techniques the emphasis will be toward stimulating interest in the use of computers as a supplemental technique for the improvement of learning in the field of science.

The author will also disseminate the results of this practicum to the county science supervisor and the other chemistry teachers in the county as evidence for the successful use of computers in the science classroom. This will be accomplished through the newly founded alliance of chemistry teachers which is scheduled to meet in the fall of 1989. It is expected that these results will stimulate interest among the chemistry teachers in becoming computer-literate. This should lead to in-service education programs which will enable the teachers to apply the latest technology for enhancing and stimulating the education of their students.

REFERENCE LIST

Annual Report from "Practicum" High School. 1988.

Brown, William F., Dorothy Z. Forrestall-Brown. "Assisted Effectiveness of Computer-Assisted Study Skills Improvement Program (CASSIP) as Reported by Program Directors." Paper presented at the (94th) Annual Convention of the American Psychological Association. Washington, D.C. 1986.

Cervellati, R., et al. "Investigation of Secondary School Students' Understanding of the Mole Concept in Italy." *Journal of Chemical Education*. Oct. 1982.

Clements, John. *Florida Facts*. Dallas: Clements Research Inc. 1987.

Dierks, Werner, Johann Weniger, J. Dudley Herron. "Mathematics in the Chemistry Classroom. Part 1. The Special Nature of Quantity Equations." *Journal of Chemical Education*. Oct. 1985.

Donnelley Marketing Information Services. Pace Magazine, Jan. 1985.

Duncan, I. M., A. H. Johnstone. "The Mole Concept." *Education in Chemistry*. Nov. 1973

Enrollment Summary from "Practicum" County Public Schools. Jan. 1989.

Festa, Roger R. (Editor) "Insights." *Journal of Chemical Education*. May 1985.

Frayer, D. A., W. C. Frederick, and H. J. Klausmeier. A Schema for Testing the Level of Concept Mastery. Madison, WI: University of Wisconsin R & D Center for Cognitive Learning. 1969.

Gabel, Dorothy L., Robert D. Sherwood. "Facilitating Problem Solving in High School Chemistry." Journal of Research in Science Teaching. Feb. 1983.

Gabel, Dorothy L., Robert D. Sherwood. "Analyzing Difficulties with Mole-Concept Tasks by Using Familiar Analog Tasks." Journal of Research in Science Teaching. Nov. 1984.

Heimlich, Joan E., and Susan D. Pittelman. Semantic Mapping: ClassroomApplications.. Newark, DE: International Reading Association. 1986.

Henson, R., A. Stumbles. "Modern Mathematics and The Mole." Education in Chemistry. Jan. 1979.

Herron, Dudley J., et al. Heath Chemistry. Massachusettes: D. C. Heath and Co., 1987.

Hudson, M. J., "Introducing the Mole." Education in Chemistry. July 1976.

Kolb, Doris. "Chemistry Principles Revisited: The Mole." Journal of Chemical Education. Nov. 1978.

Metcalfe, H. Clark, John E. Williams, Joseph F. Castka. Modern Chemsitry. New York: Holt, Rinehart, Winston, 1986.

Novick, S., J. Menis. "A Study of Student Perceptions of the Mole Concept." Journal of Chemical Education. Nov. 1976.

Readence, J. E., T. W. Bean, and R. S. Baldwin. Content Area Reading: An Integrated Approach. Dubuke, IA: Kendall/Hunt Publishing Co. 1981.

Schlenker, Richard M., Constance M. Perry. "The Molar Concept: A Piagetian-Oriented Learning Cycle." Journal of College Science Teaching. May 1983.

APPENDIX

APPENDIX A

NAME________________________ DATE__________ PER.______

YOU MUST SHOW ALL WORK TO RECEIVE CREDIT!!!!!!!!!!!!!!!!!!!!!

PLEASE PUT YOUR ANSWER IN THE SPACE PROVIDED TO THE RIGHT

1. Calculate the formula mass of $NaHCO_3$.

1.____________________

2. Calculate the molar mass of $Ba(NO_3)_2$.

2.____________________

3. $(NH_4)_2SO_4$ is what % nitrogen by mass?

3.____________________

4. Calculate the number of moles of formula units in 154 g of CO_2.

4.____________________

5. Calculate the number of grams of $Mg(ClO_3)_2$ in 0.34 mole(s) of of this substance.

5.____________________

6. What is the empirical formula of an oxide of nitrogen if 25.0 grams of it contains 9.2 grams of nitrogen?

6.____________________

6b. If the molar mass of this compound is 152g, what is its molecular formula?

6b.____________________

APPENDIX B

NAME_______________________ DATE________ PER________

YOU MUST SHOW ALL WORK TO RECEIVE CREDIT!!!!!!!!!!!!!!!!!!!

PLEASE PUT YOUR ANSWER IN THE SPACE PROVIDED TO THE RIGHT

1. Calculate the formula mass of Na_2SO_4.

1.________________

2. Calculate the molar mass of $Ca(NO_3)_2$.

2.________________

3. $(NH_4)_2CO_3$ is what % nitrogen by mass?

3.________________

4. Calculate the number of moles of formula units in 224 g of SO_2.

4.________________

5. Calculate the number of grams of $KClO_3$ in 0.25 mole(s) of of this substance.

5.________________

6. What is the empirical formula of an oxide of nitrogen if 25.0 grams of it contains 15.9 grams of nitrogen?

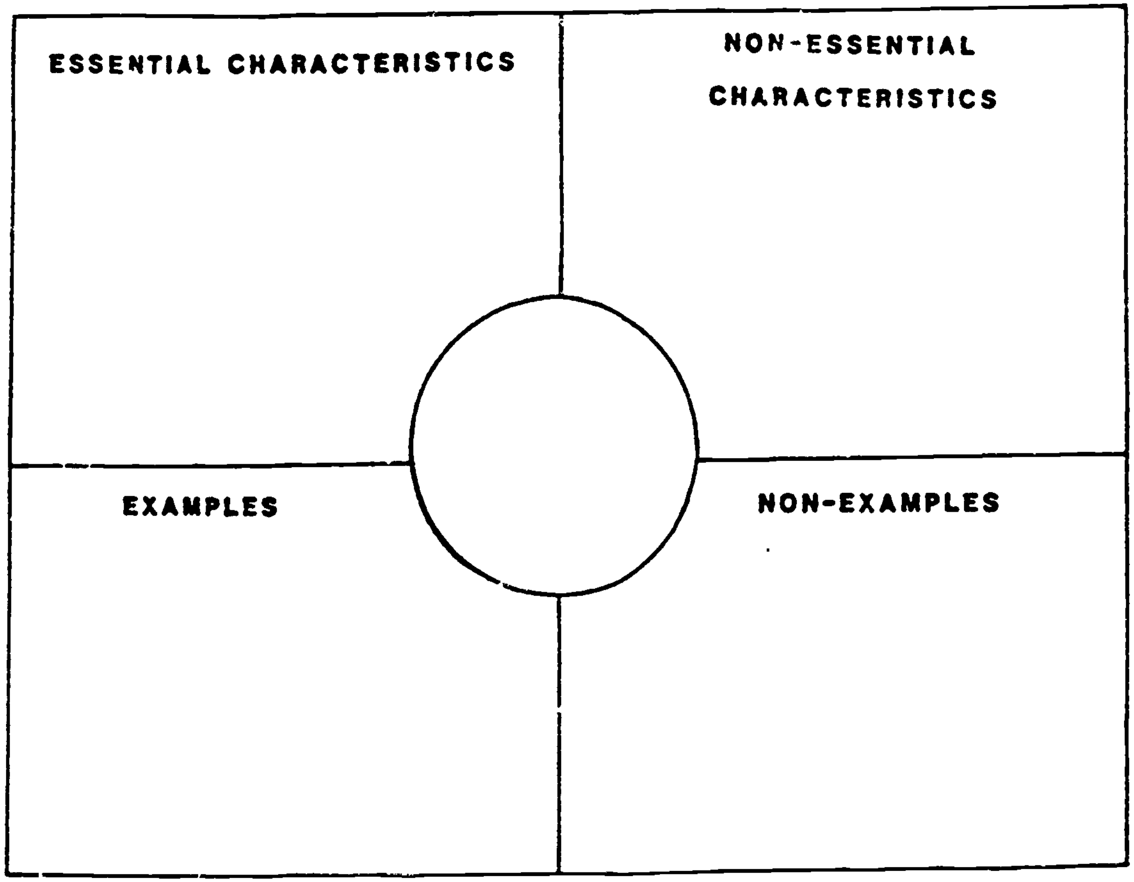
6.________________

6b. If the molar mass of this compound is 88.0g, what is its molecular formula?

6b.________________

APPENDIX C:1

FRAYER MODEL



APPENDIX C:2

FRAYER MODEL

Mole

ESSENTIAL CHARACTERISTICS

Definite Quantity
Atomic mass of element
Formula mass of compound
6.02×10^{23} particles

NON-ESSENTIAL CHARACTERISTICS

Physical State
Size (Volume)
What it is

EXAMPLES

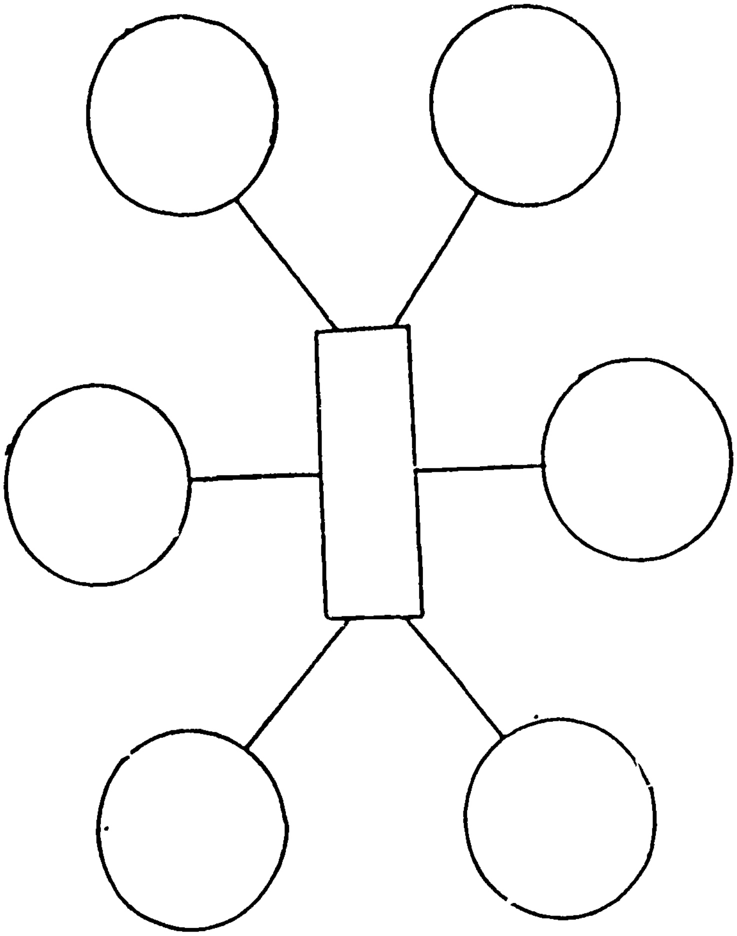
12g of C atoms
1g of H atoms
2g of H_2 Molecules
44 g of CO_2

NON-EXAMPLES

20 ml
Pair
Dozen
1g of H_2 molecules
2g of H atoms
small animal

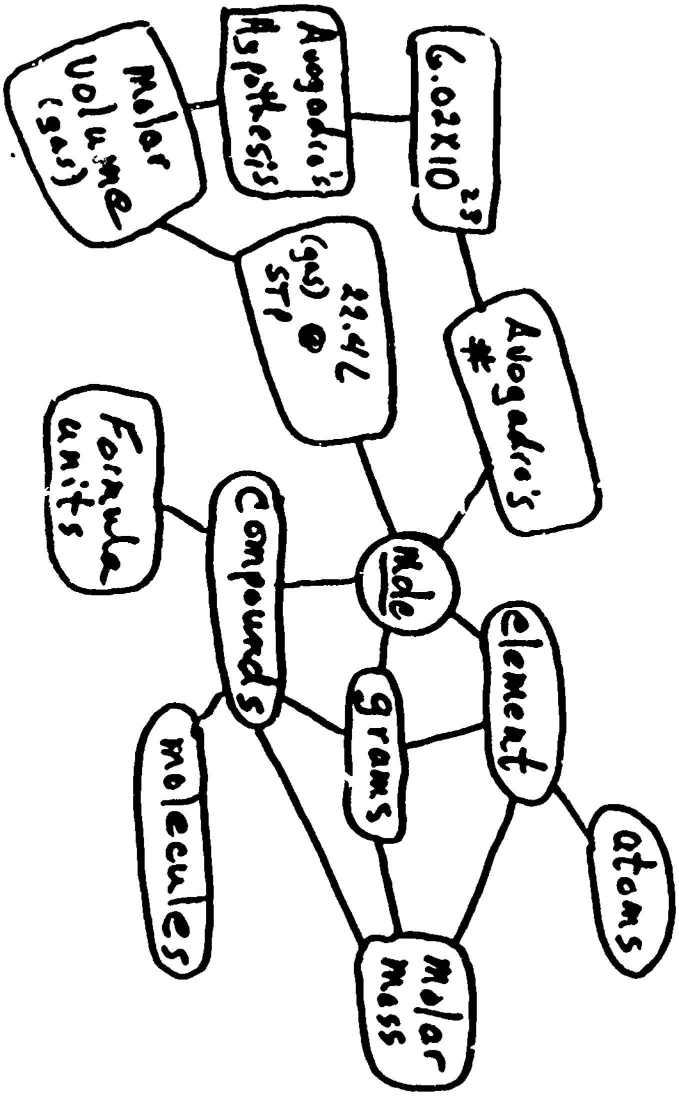
APPENDIX D:1

SEMANTIC MAP



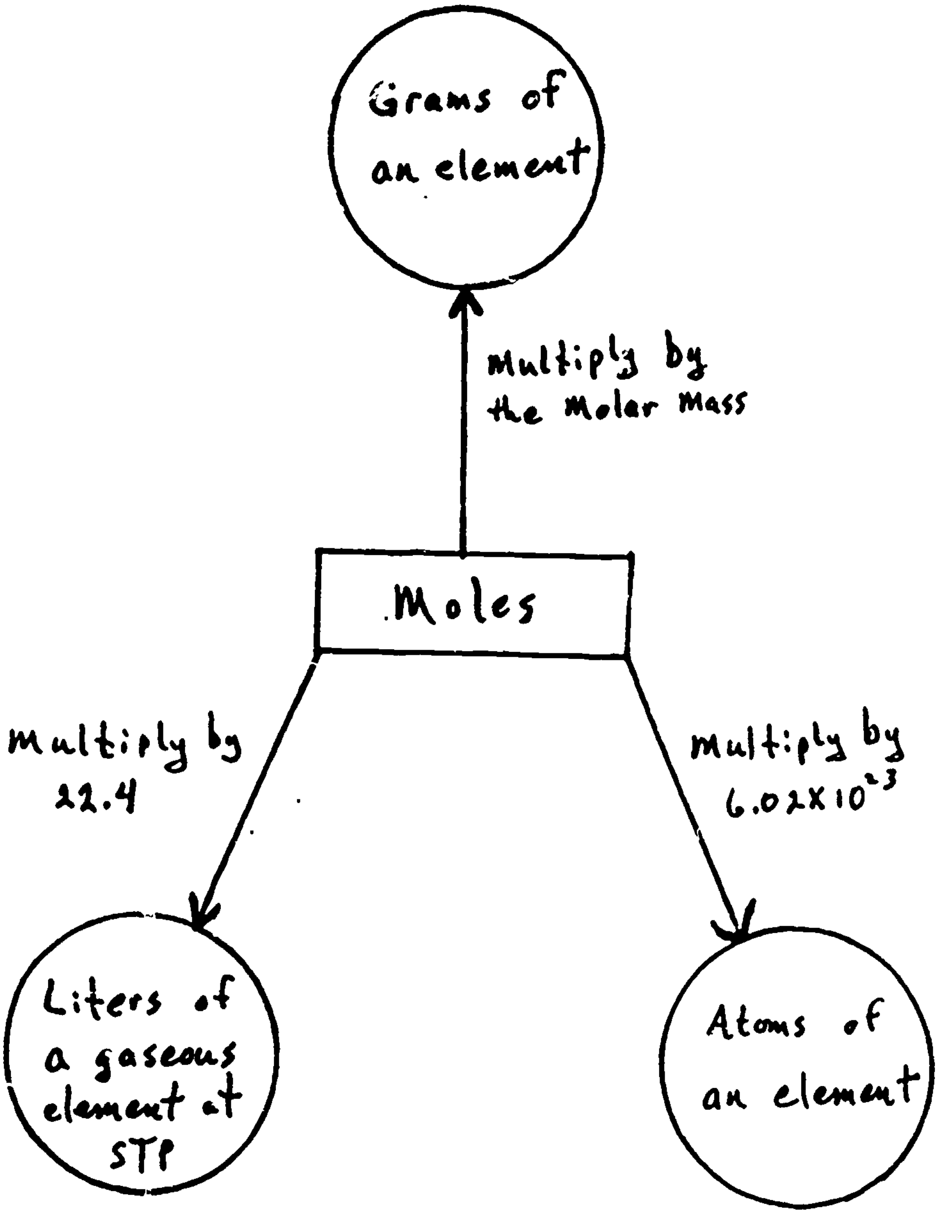
APPENDIX D:2

SEMANTIC MAP



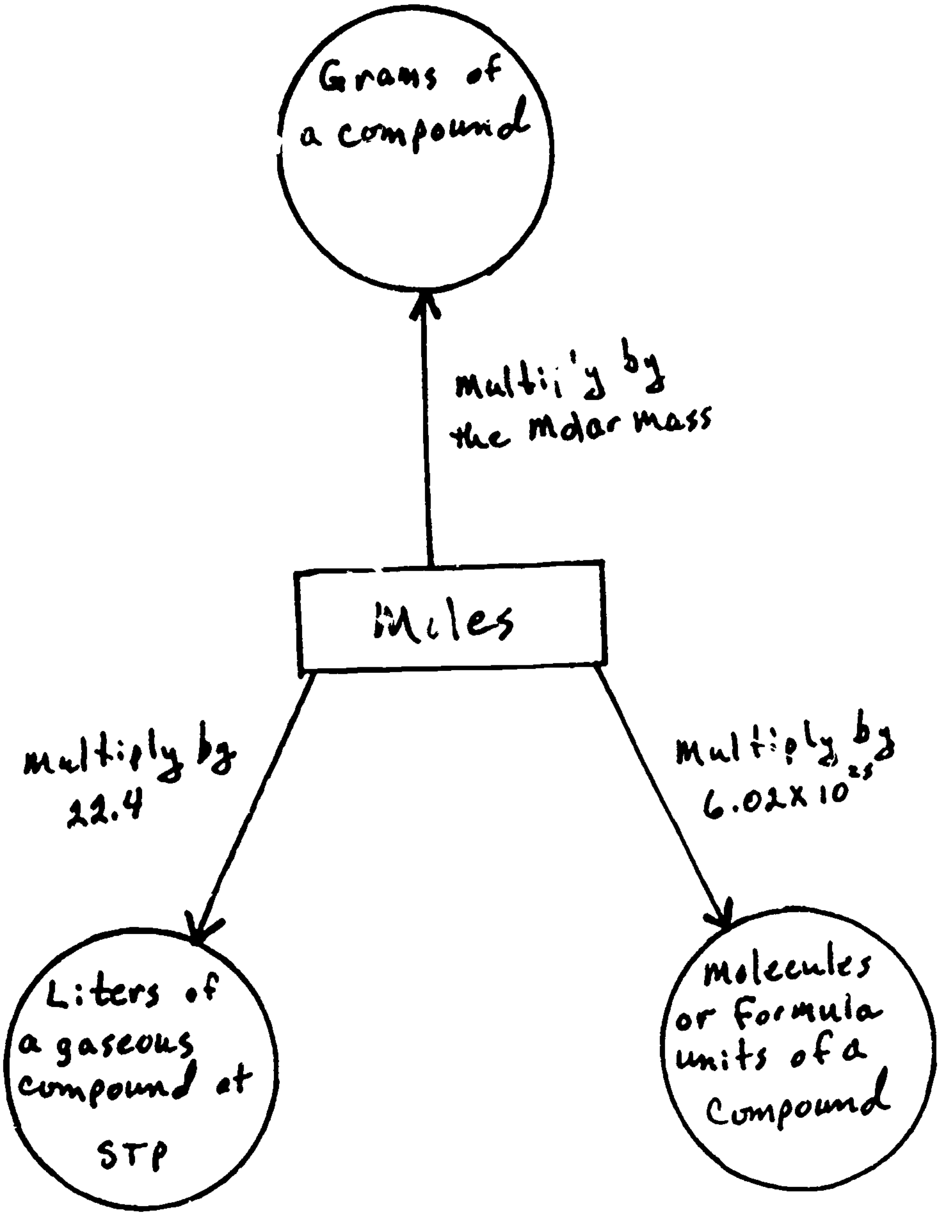
APPENDIX E:1

GRAPHIC ORGANIZER



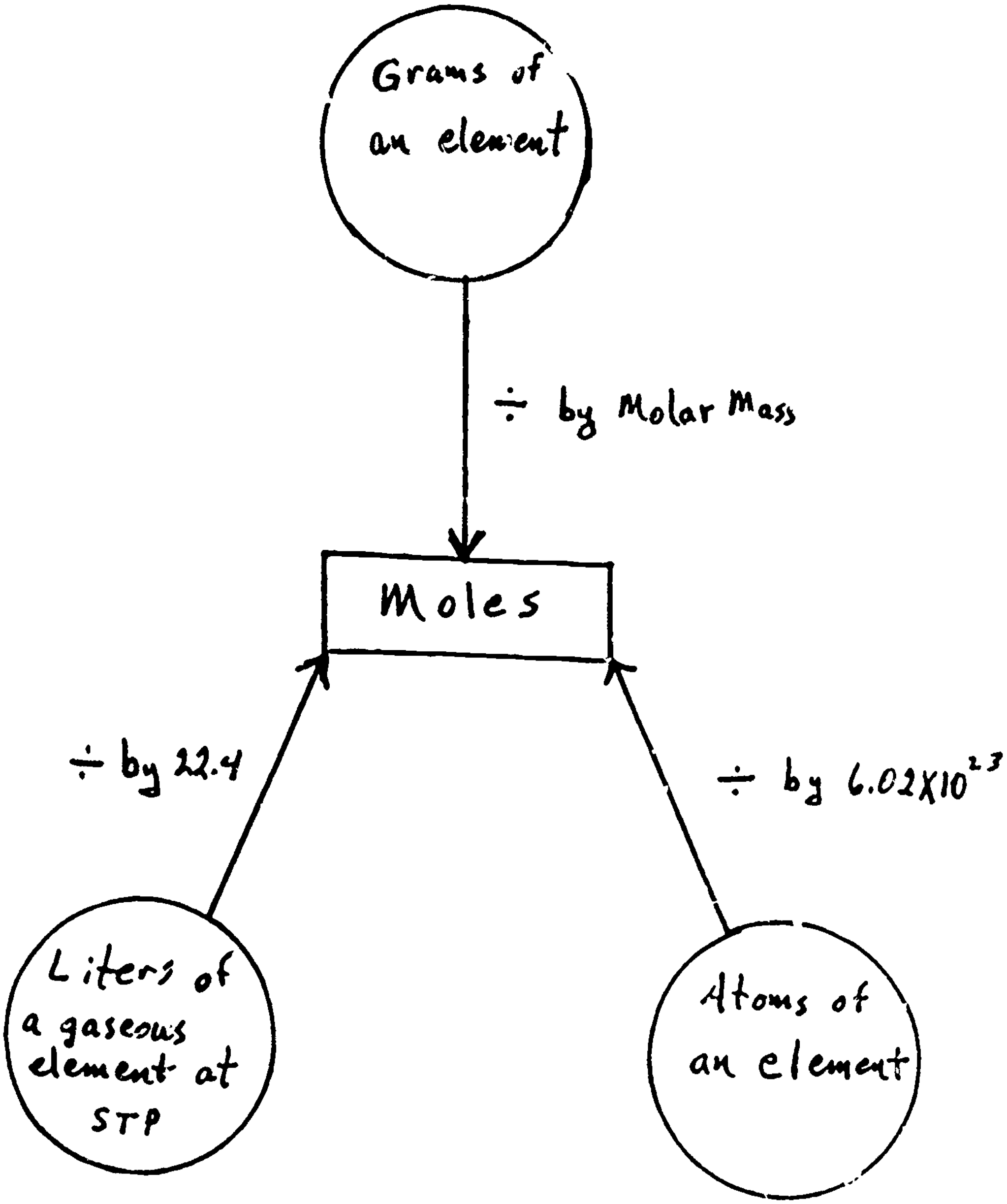
APPENDIX E:2

GRAPHIC ORGANIZER



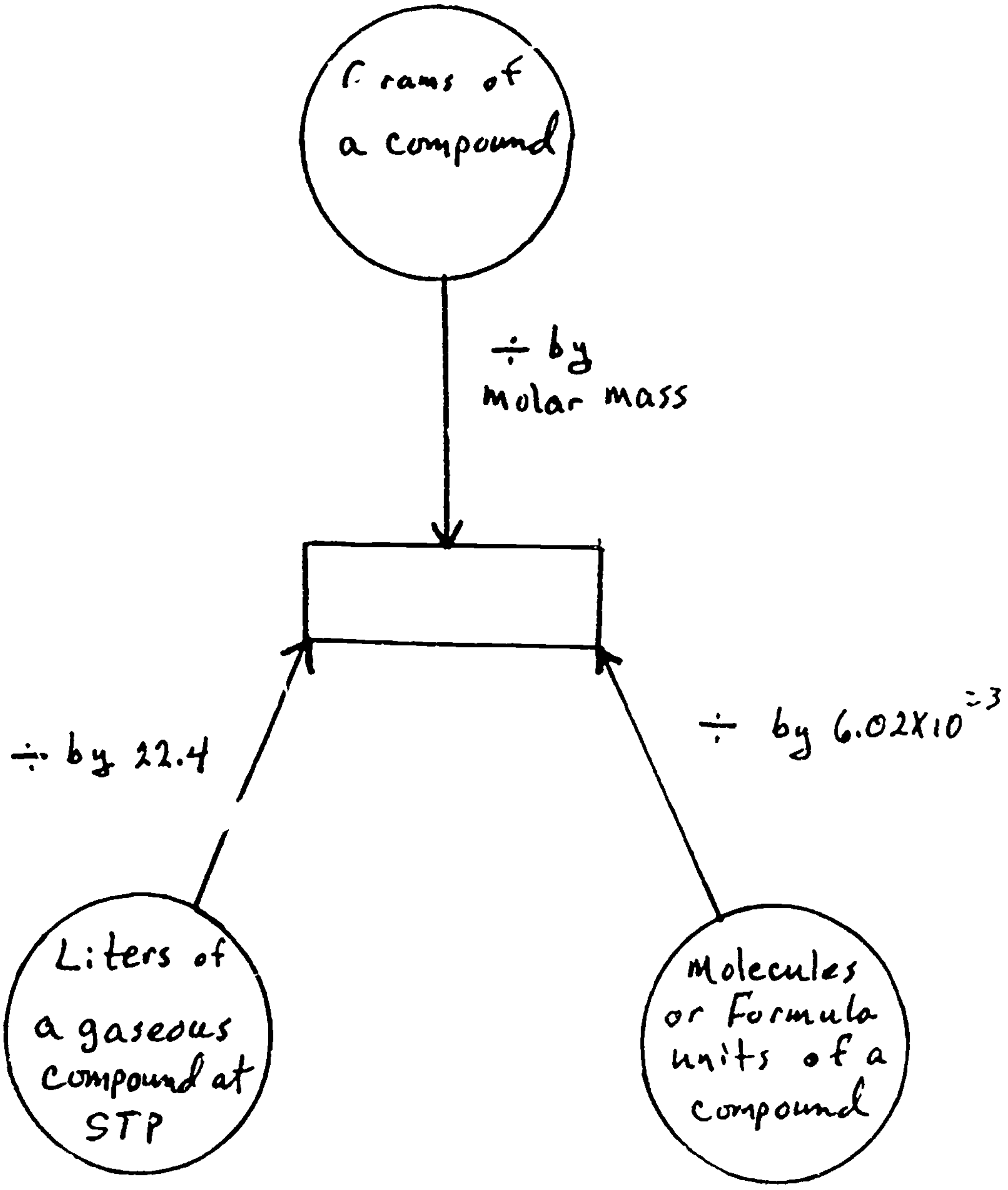
APPENDIX E.3

GRAPHIC ORGANIZER

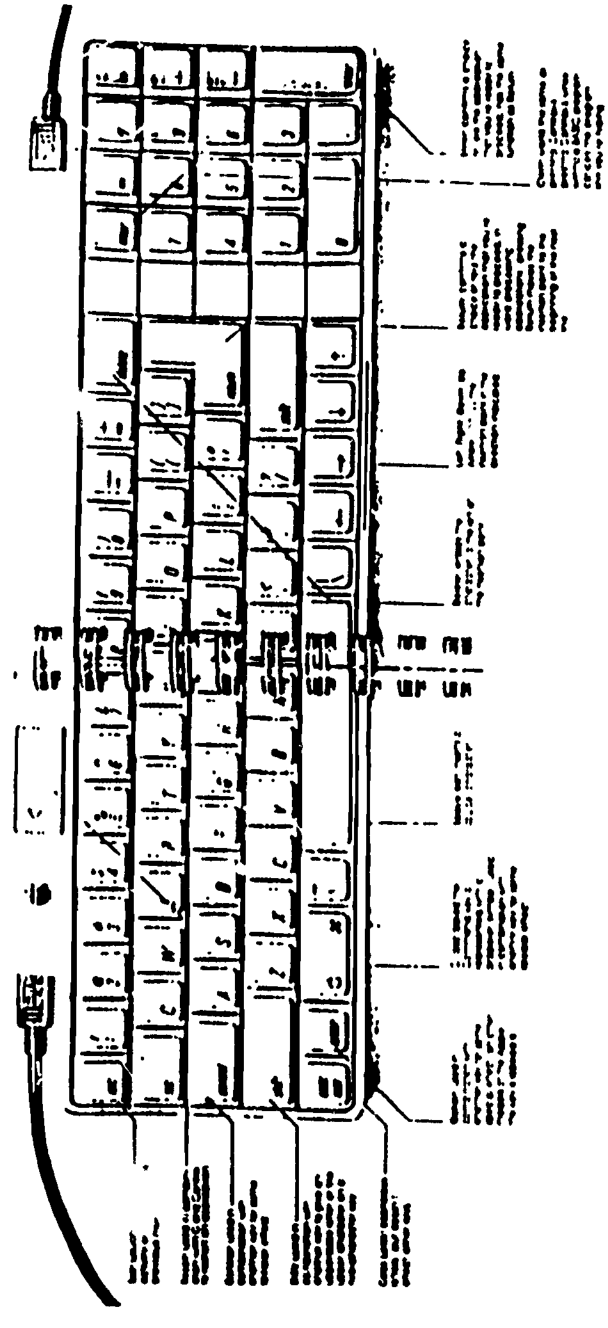


APPENDIX E:4

GRAPHIC ORGANIZER



APPENDIX F:1



APPENDIX F:2

VOCABULARY FOR "HOW TO RUN A COMPUTER PROGRAM"

APPLICATION software designed for a particular purpose.

BOOT to load an application from a disk into the memory of the computer.

CPU (CENTRAL PROCESSING UNIT) controls all computer functions (arithmetic and logic functions, sends commands to the peripheral devices, and controls access to memory).

CRT (CATHODE RAY TUBE) a peripheral device resembling a television set that displays input and output: also called a monitor.

DISKETTE (FLOPPY DISK) a circular plastic object coated with a magnetic material and covered with plastic for protection: used in conjunction with a disk drive for storing information.

DISK DRIVE a peripheral device that spins a floppy or hard disk and reads information from and writes information to the disk.

EXECUTE run a program.

EXTERNAL MEMORY devices that store information such as cassettess, floppy and hard disks.

HARDWARE the equipment or electrical components of a microcomputer.

INTERNAL MEMORY the electrical circuts within the computer that allow the micrompter to retain information.

KEYBOARD a typewriter-type device used to enter information into the computer.

APPENDIX F:3

LOAD to transfer information from peripheral storage into memory or transfer from the memory to a secondary storage.

MEMORY the circuts or devices that can store information for the computer to use.

PERIPHERAL an imput or output device connected by wires to the CPU to send or receive electrical signals.

PROGRAM a list of specified instructions that tells a computer to perform a specific task.

RAM (RANDOM ACCESS MEMORY) chips in the computer that can store and transfer information to and from the CPU; can be altered and is erased when the computer is turned off.

ROM (READ-ONLY MEMORY) chips in the computer that are preprogrammed with the basic repetitive instructions to operate the computer; is permanent and cannot be changed.

RUN what applications do when the computer is carrying out their instructions.

SECONDARY STORAGE the information storage devices external to the computer.

SOFTWARE instructions, usually stored on disks, that tell the computer what to do.

APPENDIX F:4

USE OF FLOPPY DISKETTES

It is important to take good care of diskettes, therefore:

1. Use care and common sense when handling diskettes.
2. NEVER insert or remove a diskette while the disk drive is running (red light is on).
3. Do not touch the precision surface (exposed read/write area).
4. Keep the diskette away from magnetic fields.
5. Do not fold, bend, staple, or mutilate.
6. Do not force a diskette into or out of a disk drive.
7. Keep the diskette stored at moderate temperatures.
8. When not in use, keep the diskette in its protective jacket.
9. Keep diskettes dry. (No matter how good the program do NOT drool over them.)

APPENDIX G

The computer was helpful
because it showed me several
conversions that helped me work out
certain problems. I liked it.

I think it really does help,
it make you understand quicker.

Using the computer gave me
a greater understanding of the
subject matter. I liked it alot

I feel that reviewing with
the computer, helps me get a
better understanding of the
information.

The computers helped greatly w/
the understanding of chemistry
I'm glad to have the
opportunity to use them.

Appendix 16