1926

The influence of time and temperature on the swelling of gluten

Werner W. Duecker
Iowa State College

DP

14431

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

Iowa State College of Agriculture and

Mechanic Arts

THE INFLUENCE OF TIME AND TEMPERATURE ON THE SWELLING OF GLUTEN

A Dissertation

Submitted to the Graduate
Faculty in Candidacy for the
Degree of

Doctor of Philosophy

By

Werner W. Duecker

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Graduate Dean

1926

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

ACKNOWLEDGMENT

The author is indebted to Dr. E. I. Fulmer for the suggestion of the problem and to Mr. Leo M. Christensen for aid with a great deal of the experimental work.

TABLE OF CONTENTS

I. INTRODUCTION.

The problem under consideration in this thesis is an extension of certain principles which have been evolved in this laboratory, during a study of the swelling of gluten in the presence of ammonium chloride. Fulmer, Nelson, and Sherwood[4,5], have shown that the concentration of ammonium chloride optimum for the growth of yeast is the same as that in which wheat gluten is the least swollen. The higher the temperature, the greater the concentration of ammonium salt required. At all temperatures studied, 21°, 30°, 35°, 40°, 42°, 43° C., the concentration of ammonium salt, optimum for the growth of yeast, was found to coincide with the concentration of the salt in which the protein, wheat gluten, was the least swollen. Since wheat gluten is one of the most important proteins in wheat flour and investigators on the baking qualities of flour have tried to correlate the swelling of gluten with the strength of flour, it seemed worth while to make a study of the swelling of gluten in acids, making use of the principles previously developed in this laboratory.

A search of the literature on gluten revealed the fact that the effect of temperature on the swelling of gluten has not been adequately investigated. In fact in some of the investigations it is doubtful whether temperature had been controlled at all.

II. REVIEW OF THE LITERATURE.

A review of the literature on the swelling of gluten, shows that Wood[19,20] Wood and Hardy[21], were the first to apply the methods of physical chemistry to a study of the problem. They adopted the method used by Hofmeister[10], in his study on emulsoid colloids. Wood and Hardy suspended strings of gluten across V-shaped glass rods and immersed them in various solutions. They found that gluten in distilled water retained its coherence, but gluten in 0.001 N hydrochloric acid dispersed, the rate of dispersion increasing as the concentration of the acid increased up to about 0.003 N. Higher concentrations of acid caused the gluten to become more coherent. In phosphoric and oxalic acids, the gluten dispersed even more rapidly than it did in hydrochloric acid.

Upson and Calvin[16,17] used a more exact method in studying the effects of acids on gluten swelling. They cut disks from gluten and found that they obtained a maximum absorption, determined by weighing the gluten before and after swelling, with 0.005 N hydrochloric acid, 0.01-0.02 N lactic acid, and 0.02 N acetic acid. The swelling being greatest in acetic, less in lactic, and nearly as great in hydrochloric acid as in lactic acid.

Gortner and Doherty[7], using the method of Upson and Calvin, tried to determine the difference between strong and

weak flour through a study of the various glutens. Sharp and Gortner[15], continuing the work of Gortner and Doherty, found that in various concentrations of hydrochloric and lactic acid, as well as in potassium, sodium, barium, calcium, and ammonium hydroxides, gluten from strong flour had a much higher rate of imbibition than that of weak flour. The hydrogen ion concentration at which they obtained the maximum imbibition, pH 3.25-2.25, was practically the same for all of the acids investigated. They state, "Drying the gluten, washed from different flours, in a vacuum oven at 45-50° C. markedly altered the physical chemical properties of the gluten, the properties of the different glutens studied becoming more alike".

Balland[2], in this same connection, states that gluten dried in air recovers its weight and elasticity when placed in water, but moist gluten dried at 100° C. and then placed in water absorbs part of the water lost, but does not regain its elasticity.

Other investigators have studied the problem from different angles and in general their findings are in accord with those put forward by Gortner and his collaborators. Among the methods that have been used are: the study of changes in viscosity produced by addition of acids to flour and water suspensions[8,15], and the resistance to the stirring of doughs as influenced by various acids[18]. Whether

the changes in viscosity or the resistance to stirring are directly comparable to swelling, as determined by the gravimetric method, is a question. According to Leurs and Schneider[13], all the methods mentioned give the same result. Recently, however, Alsberg[1] has said, "Fuller understanding of the water capacities of flours can hardly come until accurate methods are used to determine dough texture. Dough is not viscous as this term is applied to liquids. It is more properly termed plastic. The laws of plastic flow are not the same as those of viscous flow." If this is true, it is altogether probable that different investigators are studying entirely different properties of gluten and flour, and it is remarkable that their findings should be in such close agreement.

There is nothing in the literature, on the effect of temperature on the rate of hydration of gluten with different acids. Hoffman and Gortner[10], in their studies on the acid binding qualities of various proteins, have varied temperature. They find a negative temperature coefficient was obtained when the experiments on the binding of hydrochloric acid and sodium hydroxide were carried out at 15°, 25°, and 35° C. and when the final pH was more than pH 2.5 and the OH ion concentration was more than pH 10.5. The ratio was approximately 1:2:3, when the amount bound at 35° is 1. They, however, give no data on hydration.

Freundlich[6] reports the work of Dimetrievics and Reinke in which they found no particular relation of the maximum swelling of peas to temperature.

Lichwitz and Renner[14] investigated the swelling of muscle and kidney tissue in Ringer's solution at various temperatures and found that the rate of swelling was markedly influenced by temperature. Swelling being most rapid at the higher temperature. With kidneys they found that different parts had different rates of swelling.

Haubeniesser and Schonfeld[9] in their work on the swelling of beef tissue, show that beef tissue has a lower swelling maximum with increase in temperature and also that the speed is less at higher temperatures.

Ilün[12] has reviewed the work of Haubenisser and Schonfeld on the swelling of cartilage in Ringer's solution and attempted to show the mathematical relationship between swelling and temperature.

Chick and Lubizynska[17] studied the effect of temperature on viscosity of pure egg albumin. They find that in dilute solutions temperature had little effect on viscosity and only when the albumin reached the high figure of 28% was temperature found to have a marked influence.

III. STATEMENT OF PROBLEM.

The object of the work presented by the author is to determine, if possible, what effect time, temperature, and concentration have on the swelling of wet and dry gluten in nitric, hydrochloric, sulfuric, phosphoric, oxalic, lactic, acetic, tartaric, and citric acid.

IV. MATERIALS AND METHODS.

The gluten used in this investigation was made from Kelly's Famous Flour, manufactured by the Wm. Kelly Milling Company of Hutchinson, Kansas.

The wet gluten was made after the directions given by Gortner[7]: 250 grams of flour were made into a stiff dough with 150 cc. of distilled water. The dough was immersed in distilled water at room temperature and allowed to remain there for thirty minutes, when it was washed with distilled water until the gluten was free from starch. The gluten was pressed between glass plates to a thickness of about 5 mm. and cut with a cork borer into disks one half inch in diameter. The disks so prepared were exceptionally uniform in size, shape, and weight. They were placed in conductivity water, at the temperature of the experiment, and allowed to remain for thirty minutes, removed, allowed to drain, weighed, and placed in the acid solution to be investigated.

The method used in determining the amount of water imbibed by the gluten is similar to that used by Gortner and Doherty[7]. To aid, however, in the manipulation, there was devised a small glass stirrup which supported the small perforated button of a Gooch crucible. The stirrup serves as a handle by means of which the gluten could be very neatly removed from the solution and weighed. This proved to be a great advantage. By the usual method it was necessary to "fish out" the gluten with tweezers. The blob of gluten would sometimes break and fall back into the solution, with the probable result that part of the gluten could not be recovered and weighed.

In detail the method was as follows: the stirrup, complete with button, was immersed in the acid solution to be used, it was then removed and allowed to drain for five minutes in an atmosphere saturated with water vapor, at the temperature of the acids. It was then weighed, the weighed gluten placed on the small perforated plate, and the whole placed in the acid under investigation. At the end of the desired time the stirrup and gluten were removed, allowed to drain for five minutes, as before, and the hydration determined by weighing. The hydration was then expressed as grams of water imbibed per gram of moist gluten.

The dry gluten was made from the same flour. Fifty pounds of flour were mixed with enough distilled water, to make a thin dough. This mixture was placed in a small knead-

ing machine and washed with distilled water until the gluten was entirely free from starch. The gluten pressed between glass plates to a thickness of 5 mm. and cut into small disks. The disks were placed on a glass plate and dried in a vacuum oven for 18 hours at 40° C. under a 21 inch vacuum. At the end of 18 hours the temperature was gradually raised so that after 24 hours the temperature was 60° C. The dried gluten was then ground and graded so that only gluten of 30-40 mesh was used in the experiments.

0.5 grams of dry ground gluten were placed in a weighed Gooch crucible, which had been previously moistened with the indicated acid, so that the asbestos contained the same amount of absorbed acid it would in the subsequent weighings. After weighing, the Gooch crucible was placed in a beaker containing 50 cc. of the indicated acid and the beaker covered with a watch glass to prevent evaporation. At the desired time the Gooch crucible was removed and the excess acid drained off, using slight suction until the presence of air bubbles on the bottom indicated that all the excess acid had been removed. The crucible was then wiped and weighed, each weighing being completed in approximately one minute in order to make the evaporation factor constant. The draining required less than one minute so that there was little evaporation and only a small change in temperature during the entire opera-

tion. Since the total amount of water absorbed was large, amounting to from six to seven times the weight of the gluten in some cases, the error introduced due to evaporation and change in temperature was considered negligible. The only large error was that encountered in some cases of enormous hydration, when the gluten became fluid and cohesion resulted, so that it was difficult to remove all of the surplus acid. Another error was that encountered when the gluten remained in the acid for long periods of time and the temperature was favorable for bacterial growth.

The temperature in all cases was maintained constant by means of a water bath.

The pH of all solutions was determined with a Leeds and Northrup Company Student potentiometer, using a saturated potassium chloride calomel half cell and a Bailey electrode. The Bailey electrode was used because only small quantities of liquid were required and because of the fact that it is more rapid in action than the Hildebrand electrode. Ten cc., of the acid whose pH was desired, were removed and an equal quantity of fresh acid was then supplied to the beaker containing the gluten so that the volume of the system remained constant.

V. EXPERIMENTAL RESULTS.

The acids studied may be divided into two classes, based upon their effect upon the swelling of dry gluten. Those which produce a more or less sharp optimum, that is, there is one concentration of acid which has a pronounced positive effect upon the swelling of gluten. And secondly those which have a broad optimum, in which various concentrations of acid produce similar swelling. Acids of the first type with a more or less sharp optimum are nitric, hydrochloric, oxalic, and phosphoric acids. Those which have a decidedly broad optimum are acetic, tartaric, citric, and lactic acids. Sulfuric acid is indefinite and will be discussed by itself.

A. Discussion of Acids of the First Group. (Those with a more or less sharp optimum).

(1) Nitric Acid.

In Tables I, II, III, IV, and V and VI, there is given the complete data for the swelling of both wet and dry gluten in nitric acid at 20°, 25°, 30°, 35°, and 40° and at various times.

The graphs 1, 2, 3, 4, 5, and 6 show the relationship of swelling to concentration. Normalities being plotted as abscissa and swelling as ordinates.

Table VII shows the concentration of acid required to produce maximum swelling, of wet and dry gluten, at different temperatures and times.

At 20°, at one hour, dry gluten swells the most in acid 0.012-0.02 N, pH 1.98-1.75. With time there is a decided shift to the lower concentrations, so that at 12 hours gluten swells most in acid 0.004-0.008 N, pH 2.82-2.36, which is practically the same concentration in which wet gluten swells the most in one hour.

At 25°, at one hour, dry gluten swells most in acid 0.01-0.016 N, pH 2.08-1.83. At 12 hours dry gluten swells most in 0.004-0.008 N, pH 2.62-2.27, which is practically the same as with wet gluten in one hour.

A glance at the graphs for the other temperatures shows that in all cases it is evident that wet gluten reaches equilibrium early, but with time dry gluten will approach this same equilibrium. With increase in temperature a lower concentration of acid is required to produce optimum swelling. With wet gluten, at 20° C., optimum swelling occurs in 0.004-0.006 N. At 40° C., altho the optimum is very broad, 0.002 N will produce practically the same degree of swelling as the higher concentrations studied.

With dry gluten the change from a higher to a lower concentration with temperature is not so evident. With increase in temperature, the optimum normality required becomes more pronounced and definite, but stays the same.

TABLE I.

SWELLING OF WET GLUTEN IN NITRIC ACID.

Hydration (Sw) is expressed as grams of water imbibed per gram of wet gluten.

pH_1 is the initial pH.

	20° C.		25° C.		30° C.		35° C.		40° C.	
N	Sw	pH_1	Sw	pH_1	Sw	pH_1	Sw	pH_1	Sw	pH_1
H_2O	0.43	4.25	0.42	4.05	0.31	4.6	0.02	5.57	0.09	5.1
0005	0.05	3.42	0.5	3.4	0.02	3.5	0.02	3.52	0.10	3.25
001	0.79	2.96	0.65	2.93	0.82	3.06	1.81	3.22	0.14	2.82
002	1.6	2.76	0.89	2.7	1.07	2.55	1.87	2.78	0.26	2.55
004	1.87	2.42	1.25	2.48	1.0	2.8	1.26	2.45	0.29	2.27
006	1.93	2.3	1.50	2.29	1.20	2.4	1.74	2.33	0.34	2.07
008	1.58	2.21	1.50	2.17	0.99	2.55	2.14	2.14	0.26	2.05
01	1.63	2.06	1.51	2.08	1.16	2.18	1.58	2.1	0.16	1.85
012	1.8	1.98	1.45	1.95	1.25	2.09	1.78	2.0	0.27	1.85
014	1.24	1.95	1.49	1.9	1.17	2.02	1.53	1.99	0.30	1.8
016	1.45	1.8	1.26	1.83	0.90	1.9	1.2	1.83	0.33	1.65
018	0.97	1.8	1.13	1.83	0.98	1.89	1.41	1.8	0.26	1.65
02	1.1	1.75	1.15	1.78	1.28	1.86	1.16	1.8	0.18	1.5
025	0.74	1.7	1.0	1.7	1.49	1.8	0.98	1.72	0.06	1.5
03	0.98	1.65	0.75	1.62	0.79	1.7	1.22	1.62	0.02	

TABLE II.

SWELLING OF DRY GLUTEN IN NITRIC ACID.

Hydration (Sw) expressed as grams of water imbibed per gram of dry gluten.

pH_1 is initial pH.
pH_2 is final pH.

20° C.

N	1 hr.			2 hr.		5 hr.		8 hr.		12 hr.	
	pH_1	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2
H_2O	4.25	1.48	4.96	1.46	5.0	1.41	5.06	1.49	5.16	1.33	5.2
0005	3.42	1.92	3.56	1.92	3.86	1.91	3.95	1.73	3.98	1.58	3.48
001	2.96	2.74	3.12	2.59	3.38	2.16	3.52	3.07	3.56	2.66	3.6
002	2.76	1.98	2.86	2.12	2.98	2.35	3.02	2.96	3.14	3.60	3.05
004	2.42	2.24	2.54	2.29	2.65	3.40	2.78	4.60	2.80	4.76	2.82
006	2.30	2.22	2.36	3.37	2.42	3.50	2.54	4.36	2.56	4.78	2.5
008	2.21	2.56	2.25	3.27	2.37	3.81	2.38	5.14	2.38	4.99	2.36
01	2.06	2.27	2.19	3.29	2.24	3.79	2.3	3.27	2.34	3.2	2.36
012	1.98	2.74	2.0	3.53	2.16	3.27	2.18	2.90	2.20	3.01	2.2
014	1.95	2.62	2.0	3.05	2.08	2.75	2.12	2.55	2.18	2.36	2.08
016	1.8	2.56	1.86	2.82	1.92	2.24	1.96	2.10	2.0	2.05	2.0
018	1.8	2.78	1.88	3.02	1.9	3.21	1.94	2.89	1.96	3.18	1.90
02	1.75	2.70	1.85	2.66	1.88	2.49	1.9	3.82	1.94	3.26	1.9
025	1.7	2.53	1.8	2.44	1.8	1.98	1.88	2.10	1.88	1.97	1.8
03	1.65	2.21	1.72	1.87	1.72	1.82	1.7	1.89	1.74	1.40	1.76

TABLE III.

SWELLING OF DRY GLUTEN IN NITRIC ACID.

Hydration (Sw) expressed as grams of water imbibed per gram of dry gluten.

pH_1 is initial pH.
pH_2 is final pH.

25° C.

N	1 hr.			2 hr.		5 hr.		8 hr.		12 hr.	
	pH_1	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2
H_2O	4.05	1.41	5.1	1.32	5.06	1.39	5.55	1.42	5.21	1.50	5.15
0005	3.4	1.20	3.57	1.	3.9	1.22	4.02	1.25	3.96	1.31	3.92
001	2.93	1.46	3.12	1.60	3.4	1.41	3.6	1.62	3.45	1.77	3.2
002	2.7	1.63	2.83	2.53	3.01	2.48	3.12	2.56	3.1	2.88	3.05
004	2.48	2.01	2.52	2.53	2.6	3.14	2.8	3.51	2.75	4.56	2.62
006	2.29	1.92	2.37	2.65	2.45	3.34	2.52	3.66	2.42	4.83	2.43
008	2.17	2.39	2.25	3.	2.35	3.73	2.37	4.23	2.30	2.35	2.27
01	2.08	2.43	2.17	3.31	2.24	3.69	2.3	3.74	2.25	3.98	2.1
012	1.95	2.76	2.06	3.43	2.15	3.56	2.2	3.63	2.2	3.86	2.21
014	1.9	2.64	2.	3.03	2.07	3.25	2.12	3.01	2.01	2.97	2.02
016	1.83	2.36	1.9	2.78	1.92	2.54	1.97	2.34	1.96	1.93	1.9
018	1.83	2.32	1.9	2.92	1.92	2.43	1.92	2.27	1.9	2.10	1.87
02	1.78	2.36	1.86	2.76	1.86	2.25	--	--	--	--	--
025	1.7	2.34	1.75	2.44	1.8	1.74	1.74	1.71	1.72	1.85	1.67
03	1.62	2.26	1.7	2.03	1.69	1.64	1.74	1.53	1.72	1.07	1.67

TABLE IV.

SWELLING OF DRY GLUTEN IN NITRIC ACID.

Hydration (Sw) expressed as grams of water imbibed per gram of dry gluten.

pH_1 is initial pH.
pH_2 is final pH.

30° C.

N	1 hr.			2 hr.		5 hr.		8 hr.		12 hr.	
	pH_1	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2
H_2O	4.6	1.37	5.06	1.44	5.41	1.28	5.67	1.1	5.4	1.18	5.52
0005	3.5	1.82	3.76	1.5	4.	1.75	3.9	1.15	4.05	.95	4.06
001	3.06	1.36	3.23	1.77	3.46	1.49	3.57	1.59	3.52	1.87	3.6
002	2.55	1.83	2.95	2.06	3.08	2.08	3.25	2.85	3.15	3.24	3.2
004	2.8	2.15	2.6	2.66	2.76	3.12	2.88	5.04	2.8	5.90	2.86
006	2.4	2.34	2.44	3.03	2.5	2.54	2.63	5.54	2.52	5.41	2.55
008	2.55	2.81	2.33	3.82	2.47	4.42	2.5	4.5	2.3	4.	2.48
01	2.18	3.	2.22	3.92	2.35	4.03	2.38	4.13	2.25	3.63	2.16
012	2.09	2.80	2.2	3.63	2.24	3.52	2.25	3.34	2.15	2.79	2.13
014	2.02	2.56	2.07	3.09	2.25	3.27	2.15	3.08	2.08	4.42	2.03
016	1.9	2.7	1.95	2.96	1.98	2.78	2.	2.53	1.95	2.46	1.95
018	1.89	3.02	1.95	2.89	2.1	2.66	2.	2.23	1.96	2.51	1.92
02	1.86	2.25	1.92	2.85	2.	2.23	1.98	1.98	1.9	2.16	1.95
025	1.8	2.68	1.76	2.54	1.89	2.15	1.8	1.94	1.82	1.67	1.8
03	1.7	2.46	1.75	1.9	1.8	1.92	1.7	1.66	1.72	1.51	1.68

TABLE V.

SWELLING OF DRY GLUTEN IN NITRIC ACID.

Hydration (Sw) expressed as grams of water imbibed per gram of dry gluten.

pH_1 is initial pH.
pH_2 is final pH.

35° C.

N	1 hr.			2 hr.		5 hr.		8 hr.		12 hr.	
	pH_1	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2
H_2O	5.57	1.28	4.32	1.30	4.16	1.31	3.72	.80	5.45	1.22	4.75
0005	3.52	1.53	3.85	1.41	3.88	1.74	3.77	1.73	5.46	1.52	4.
001	3.22	1.75	3.25	1.26	3.3	2.10	3.22	2.59	3.5	2.84	3.32
002	2.78	1.89	2.83	2.20	2.95	2.24	2.9	2.53	3.07	3.14	2.78
004	2.45	1.83	2.5	2.67	2.62	3.43	2.64	4.55	2.7	5.13	2.62
006	2.33	2.61	2.41	3.42	2.55	5.05	2.36	6.83	2.5	7.85	2.36
008	2.14	2.85	2.3	3.66	2.35	4.72	2.22	3.78	2.32	4.13	2.25
01	2.1	2.31	2.2	4.52	2.25	4.02	2.12	4.08	2.22	3.54	2.1
012	2.	2.40	2.05	2.32	2.1	3.66	2.	3.43	2.1	2.52	2.1
014	1.99	3.41	2.03	3.77	2.05	3.51	1.9	3.95	2.02	2.82	1.97
016	1.83	2.91	1.93	3.44	1.65	2.74	1.65	2.58	1.87	2.07	1.86
018	1.8	2.95	1.9	3.99	1.9	2.78	1.73	3.01	1.9	2.90	1.85
02	1.8	2.81	1.77	3.60	1.86	2.92	1.75	2.72	1.75	2.06	1.8
025	1.72	3.14	1.6	2.99	1.82	2.86	1.63	2.38	1.68	2.13	1.67
03	1.62	2.47	1.55	2.88	1.7	2.02	1.36	1.30	1.72	1.26	1.62

TABLE VI.

SWELLING OF DRY GLUTEN IN NITRIC ACID.

Hydration (Sw) expressed as grams of water imbibed per gram of dry gluten.

pH_1 is initial pH.
pH_2 is final pH.

40° C.

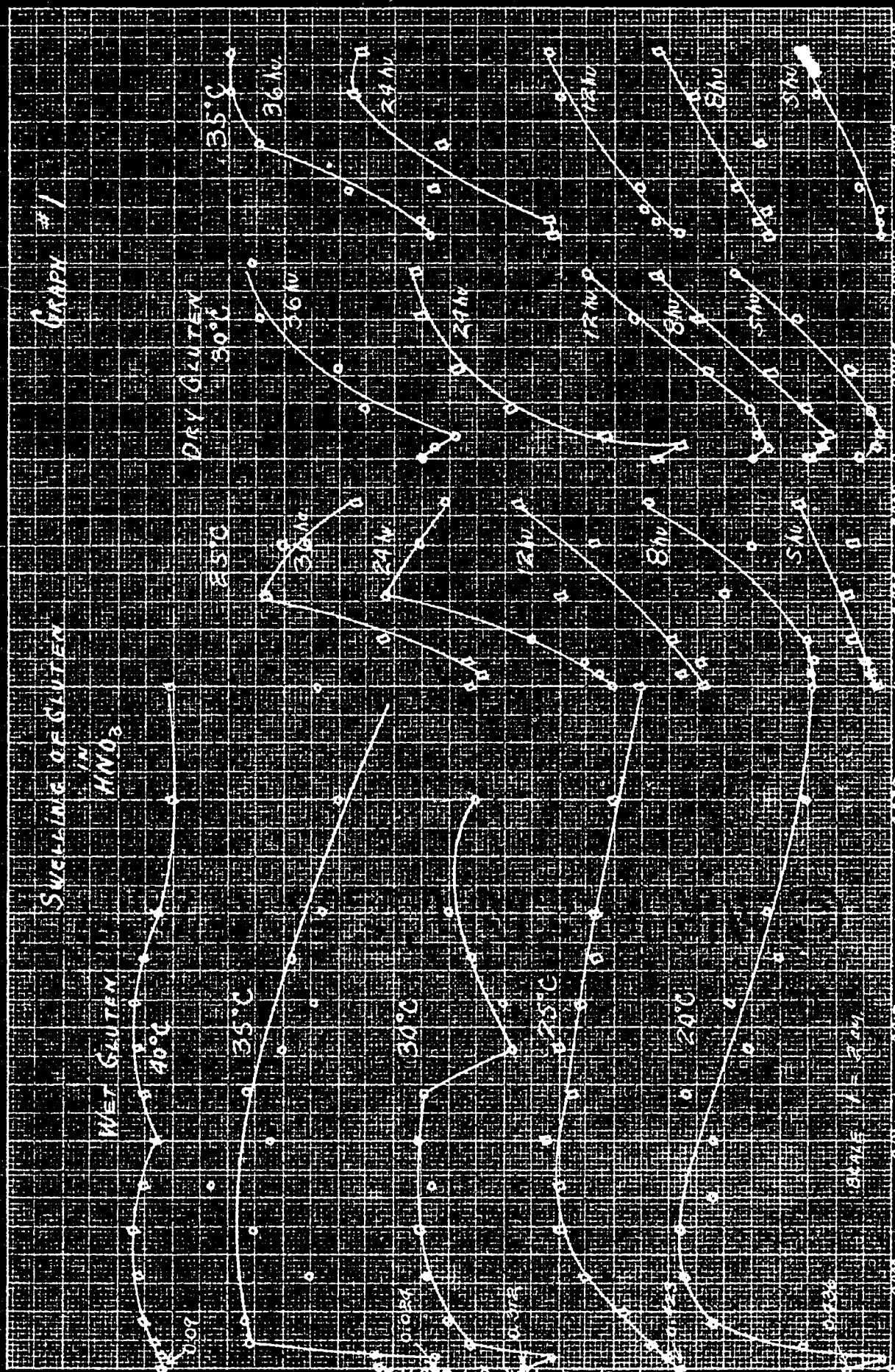
N	1 hr.			2 hr.		5 hr.		8 hr.		12 hr.	
	pH_1	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2	Sw	pH_2
H_2O	5.1	1.56	4.62	1.5	3.95	1.64	3.56	1.37	4.7	1.58	5.5
0005	3.25	1.62	3.35	1.42	3.32	1.67	3.75	1.22	4.02	1.59	3.95
001	2.82	1.68	3.22	3.48	3.7	1.78	3.37	1.56	3.92	1.35	4.07
002	2.55	1.84	2.67	2.63	2.9	3.48	3.	5.19	--	6.29	--
004	2.27	1.97	2.4	3.15	2.5	5.86	2.47	6.47	2.63	8.09	2.57
006	2.07	2.36	2.17	3.23	2.18	5.10	2.3	5.68	2.33	7.	2.35
008	2.05	2.78	2.07	3.88	2.1	4.89	2.12	5.49	2.1	5.88	2.05
01	1.85	2.41	1.95	3.99	2.15	4.18	2.07	4.06	2.06	4.50	1.95
012	1.85	2.66	1.9	3.90	1.97	3.92	1.95	3.56	1.95	4.69	1.86
014	1.8	3.05	1.8	3.27	1.87	3.09	1.9	3.23	1.9	3.24	1.85
016	1.65	3.29	1.64	2.94	1.75	2.73	1.7	2.89	1.75	2.57	1.85
018	1.65	2.41	1.67	2.94	1.75	2.42	1.7	2.60	1.75	2.23	1.72
02	1.5	2.55	1.65	2.86	1.67	2.48	1.7	2.39	1.68	2.11	1.68
025	1.5	2.57	1.55	2.3	1.6	2.12	1.5	2.13	1.62	2.11	1.68
03	--	2.48	1.4	2.02	1.47	1.79	1.5	1.39	1.45	1.50	1.47

TABLE VII.

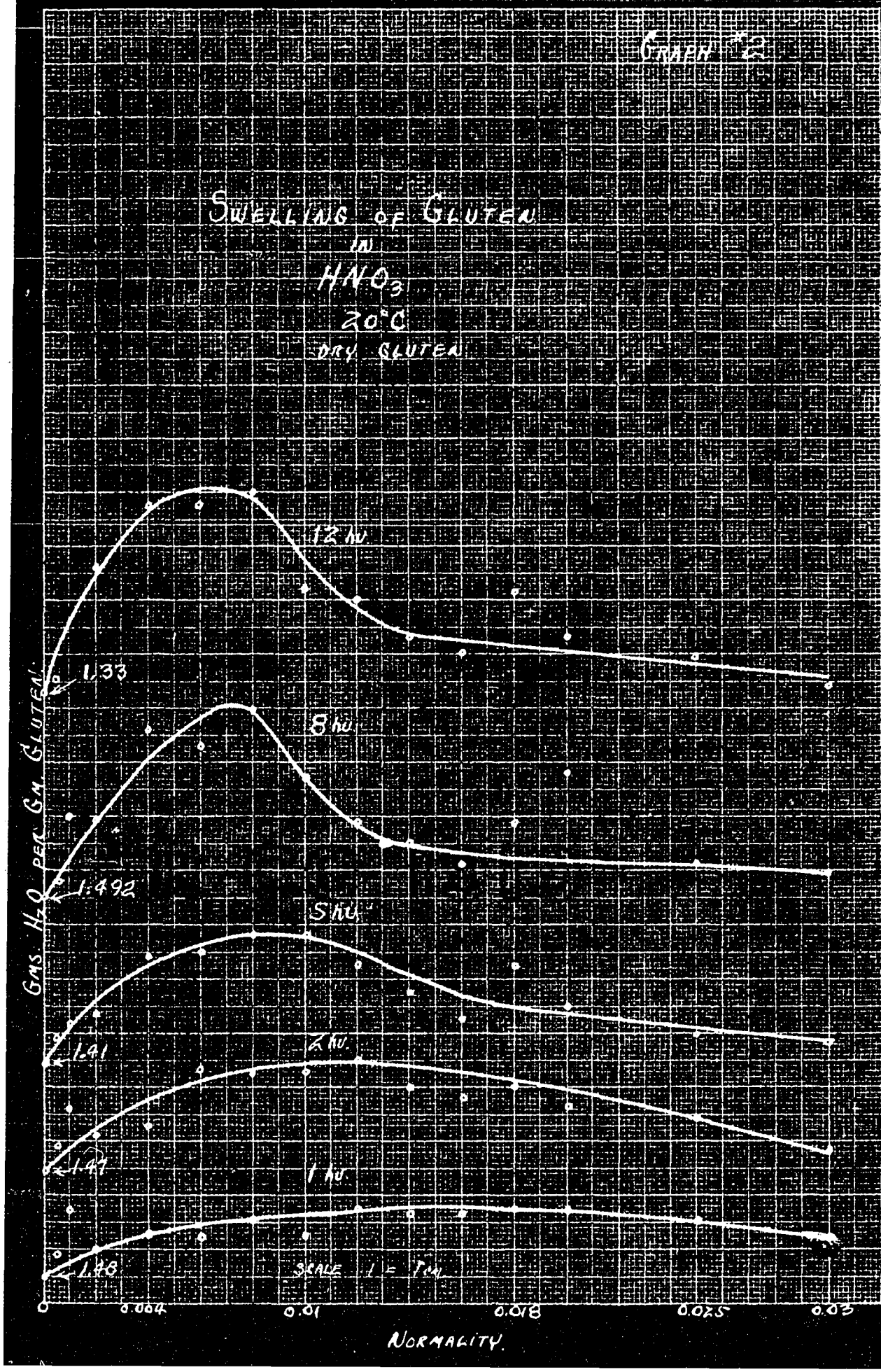
THE pH AND NORMALITIES OF NITRIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

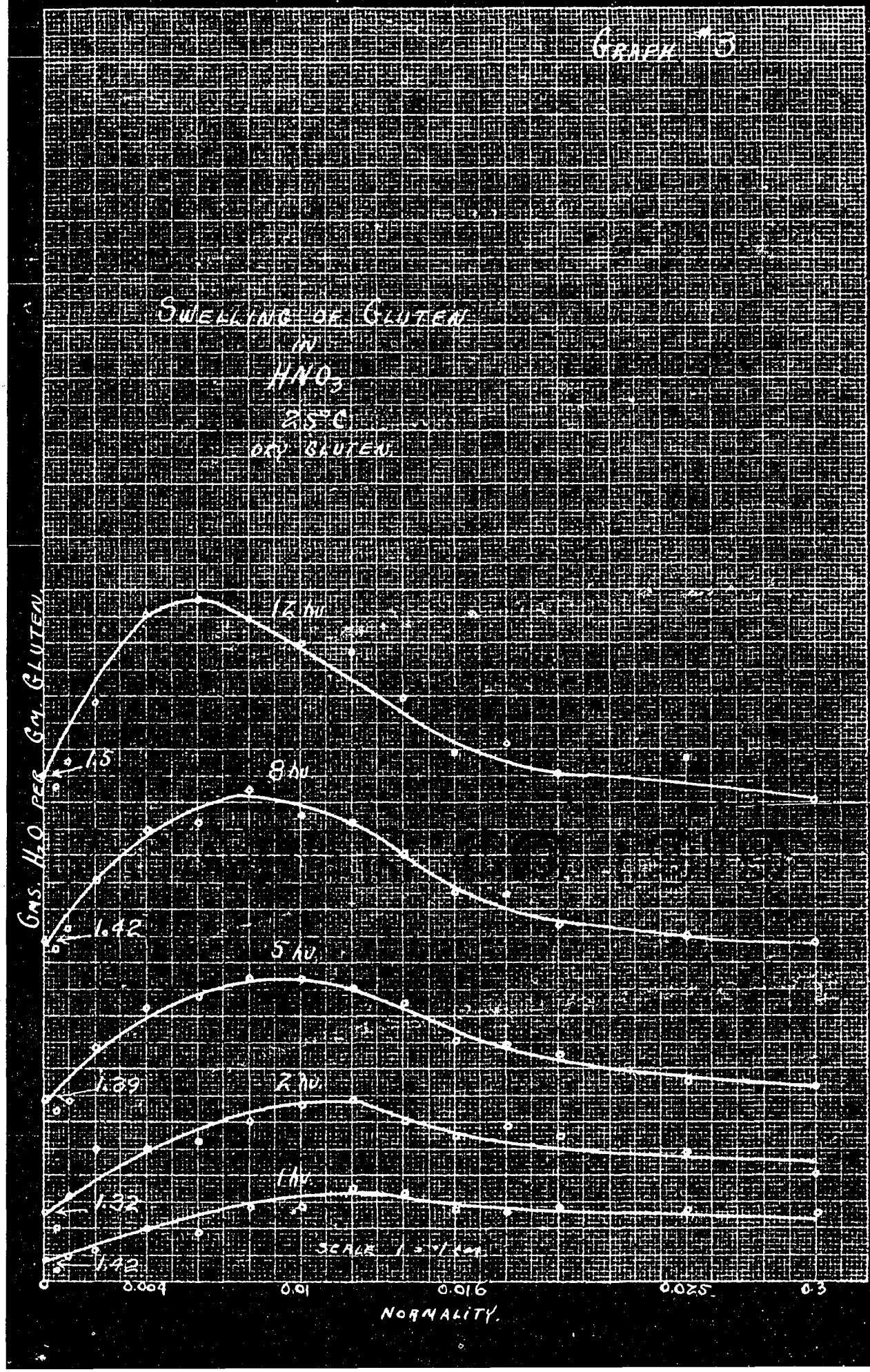
pH_1 is initial pH.
pH_2 is final pH.

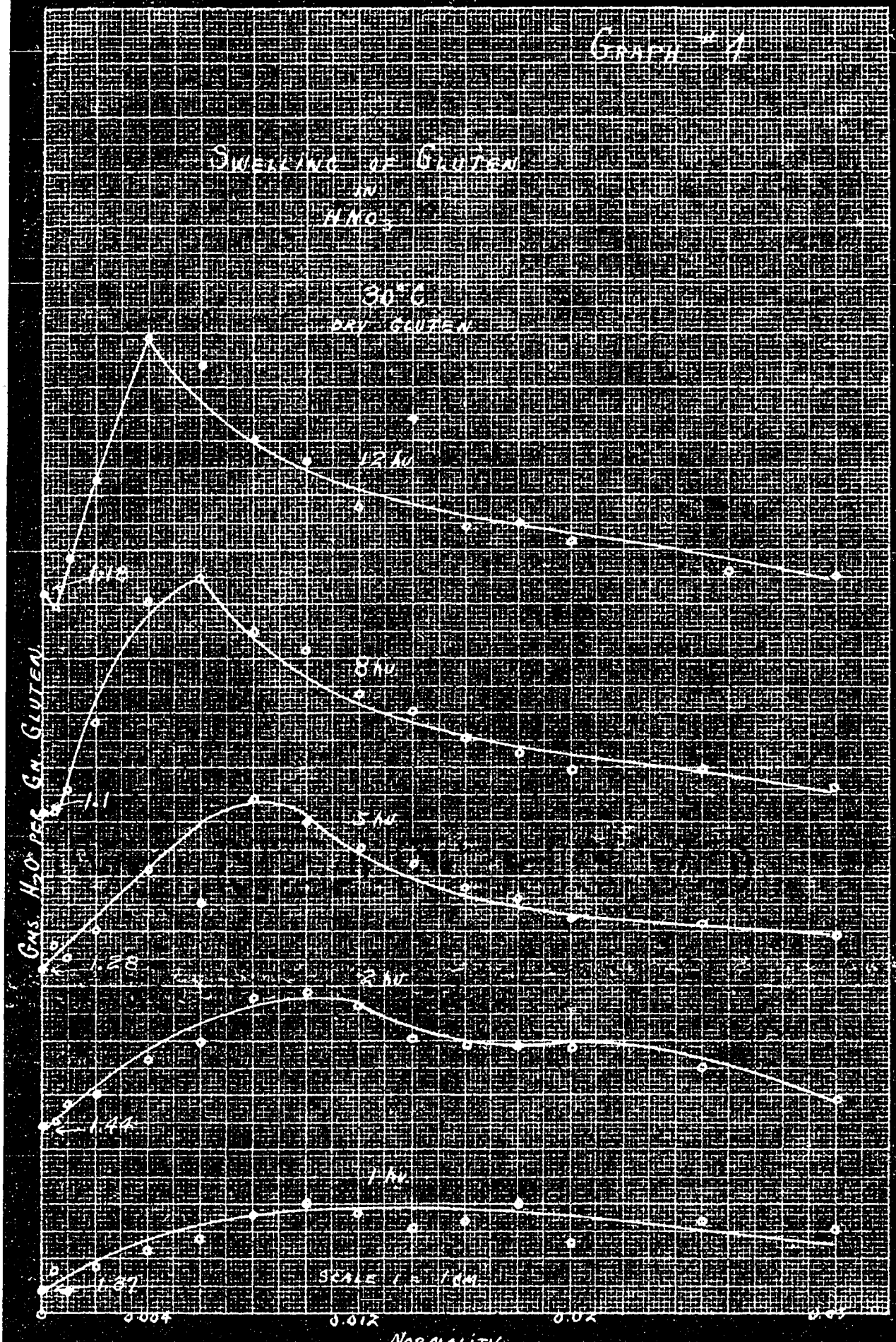
Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.004 to 0.006	2.42 to 2.3		0.006 to 0.014	2.29 to 1.9		0.004 to 0.012	2.8 to 2.09		0.002 to 0.012	2.78 to 2.0				0.002	2.55
							DRY GLUTEN								
1	0.012 to 0.02	1.98 to 1.75	2.0 to 1.85	0.01 to 0.016	2.08 to 1.83	2.37 to 1.9	0.01 to 0.018	2.18 to 1.89	2.23 to 1.95	0.014 to 0.018	1.99 to 1.8	2.03 to 1.9	0.014 to 0.016	1.8 to 1.85	1.8 to 1.64
2	0.006 to 0.012	2.3 to 1.98	2.42 to 2.16	0.01 to 0.012	2.08 to 1.95	2.24 to 2.15	0.008 to 0.012	2.55 to 2.09	2.45 to 2.24	0.01 to 0.014	2.1 to 1.99	2.25 to 2.05	0.008 to 0.012	2.05 to 1.85	2.1 to 1.97
5	0.006 to 0.01	2.3 to 2.06	2.54 to 2.3	0.008 to 0.01	2.17 to 2.08	2.37 to 2.3	0.008	2.55	2.5	0.006 to 0.008	2.33 to 2.14	2.36 to 2.23	0.004	2.22	2.48
8	0.004 to 0.008	2.42 to 2.21	2.8 to 2.38	0.008	2.17	2.3	0.004 to 0.006	2.8 to 2.4	2.8 to 2.53	0.006	2.33	2.5	0.004	2.27	2.63
12	0.004 to 0.008	2.42 to 2.21	2.82 to 2.36	0.004 to 0.008	2.48 to 2.17	2.62 to 2.27	0.004 to 0.006	2.8 to 2.4	2.86 to 2.55	0.006	2.33	2.36	0.004	2.27	2.58

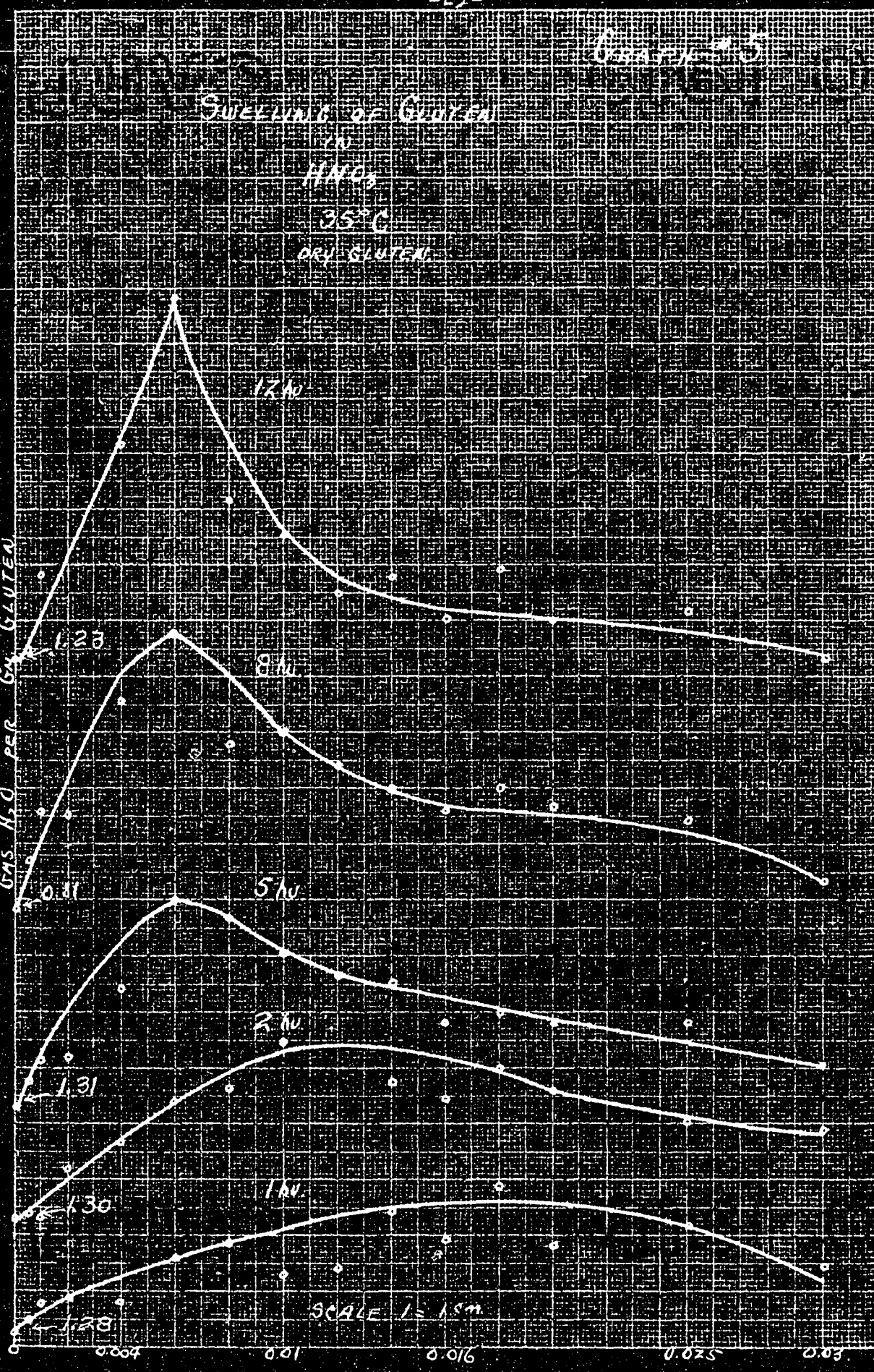

GRAPH #1
SWELLING OF GLUTEN IN HNO3
WET GLUTEN 40°C
DRY GLUTEN 30°C
35°C
30°C
25°C
20°C
36hr.
24hr.
12hr.
8hr.
5hr.
NORMALITY
CMS OF H2O PER GM GLUTEN

Form E-3


GRAPH #2
SWELLING OF GLUTEN
IN
HNO_3
20°C
DRY GLUTEN
12 hr
8 hr
5 hr
2 hr
1 hr
1.33
1.492
1.41
1.47
1.48
GMS. H_2O PER GM. GLUTEN
SCALE 1 = 1cm
0
0.004
0.01
0.018
0.025
0.03
NORMALITY


Gluten "B"
SWELLING OF GLUTEN
IN
HNO3
25° C
OF GLUTEN
GMS. H2O PER GM. GLUTEN
12 hr.
8 hr.
5 hr.
2 hr.
1 hr.
1.5
1.42
1.39
1.33
1.42
SCALE 1 = 1/2 cm.
0.004
0.01
0.016
0.025
0.3
NORMALITY.

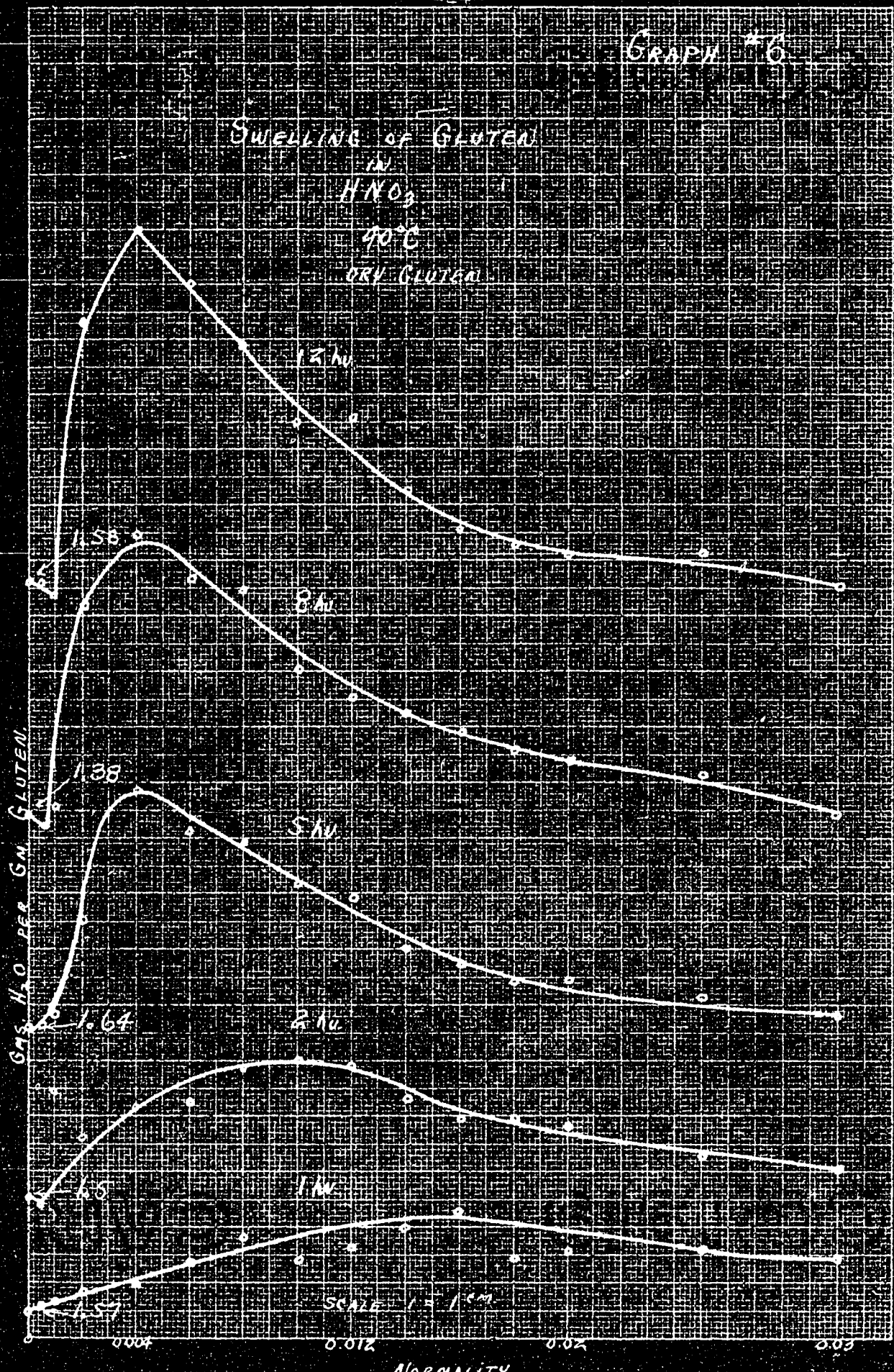

Gms. H2O per Gm. Gluten
Normality
0.004
0.012
0.02
0.03
12 Hr.
8 Hr.
3 Hr.
2 Hr.
1 Hr.
1.1
1.4
1.67


Swelling of Gluten
in
HNO3
35° C
Dry Gluten
Gms H2O per Gm Gluten
12 hr
8 hr
5 hr
2 hr
1 hr
1.28
1.31
1.30
1.28
0.004
0.01
0.016
0.025
0.03
Normality
Scale 1 = 1 cm.

GRAPH #6

SWELLING OF GLUTEN IN HNO_3 @ 90°C

DRY GLUTEN



(2) Swelling of Wet and Dry Gluten in Hydrochloric Acid.

At 20° C. wet gluten swells most in acid 0.002-0.01 N. Dry gluten, for one hour, swells most in acid 0.01-0.02 N, but at 12 hours dry gluten swells most in acid 0.004 N. It being evident that with time dry gluten will exhibit maximum swelling in the same concentration required for maximum swelling of wet gluten.

At 25° wet gluten swells most in acid 0.004-0.01 N. Dry gluten in one hour swells most in acid 0.008-0.03 N, while at the end of 12 hours it swells most in acid 0.015 N.

At 30° C., wet gluten swells most in acid 0.004 N. Dry gluten in one hour swells most in acid 0.015-0.02 N., while at the end of 36 hours as seen in graph 12, it swells most in acid 0.004 N, which is the same normality required to produce maximum swelling with wet gluten.

At 35° C. wet gluten swells most in acid 0.004-0.01 N. Dry gluten in one hour swells most in acid 0.02 N, and at the end of 12 hours in acid 0.004 N, which is the same as that for wet gluten.

At 40° C. wet gluten swells most in acid 0.004 N. Dry gluten in one hour swells most in acid 0.01 N and at the end of 12 hours it swells most in acid 0.004 N, which is the same as that required for wet gluten.

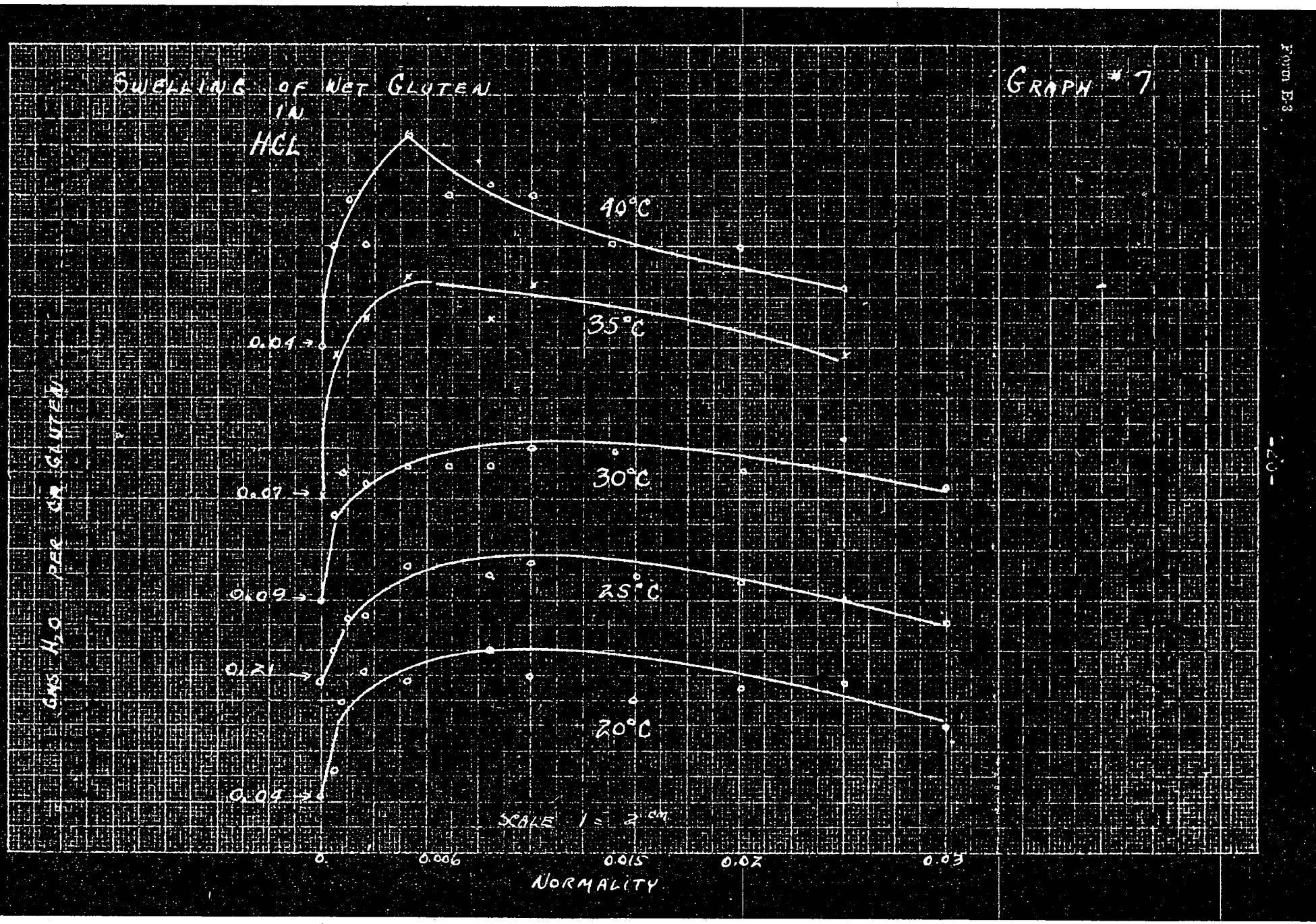
It is evident that, given time, the swelling of dry gluten is like the swelling of wet gluten. With increase in temperature the rate of swelling increases, the optimum becomes more pronounced, but the optimum is the same regardless of temperature.

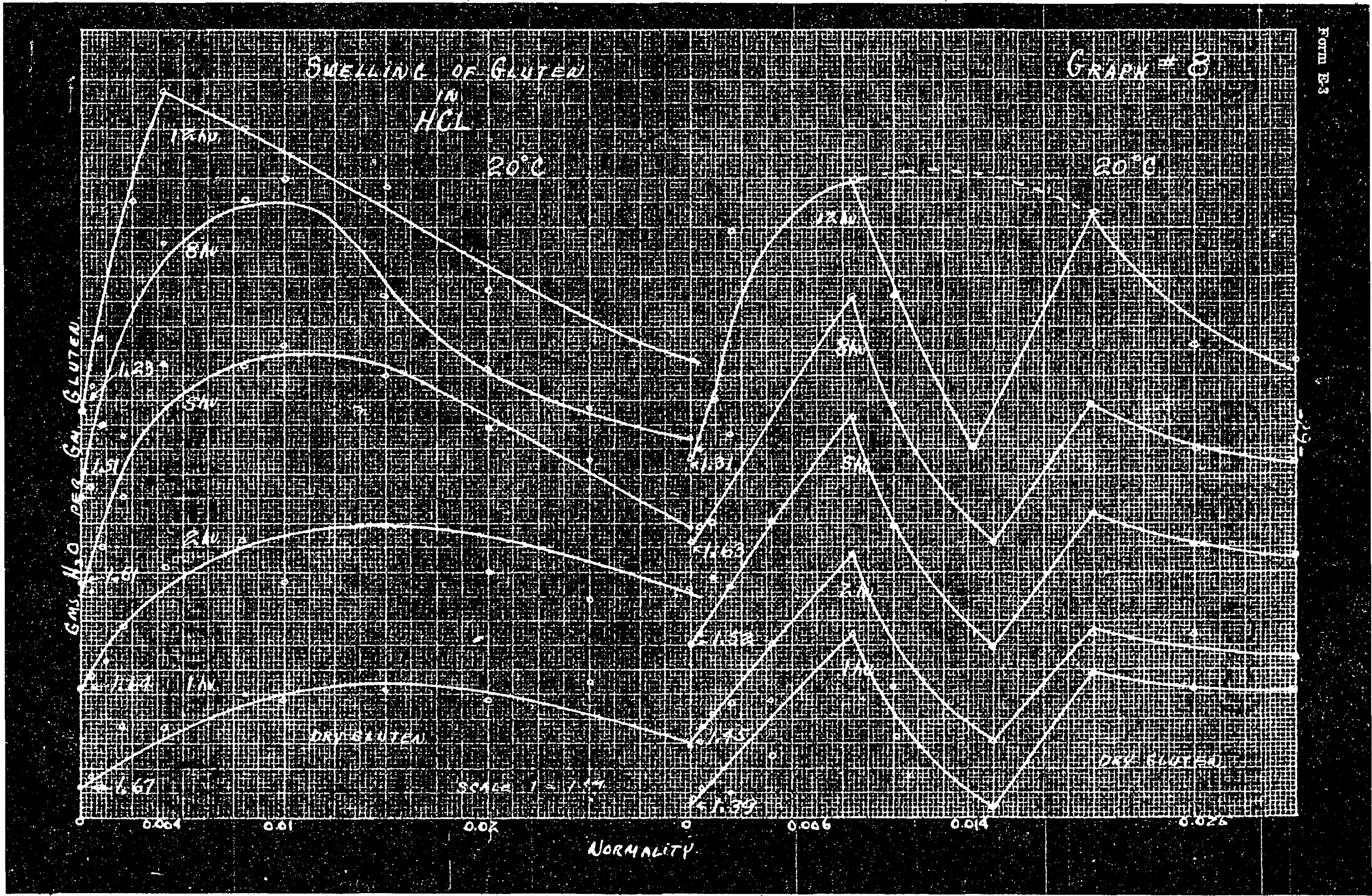
TABLE VIII.

THE pH AND NORMALITIES OF HYDROCHLORIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

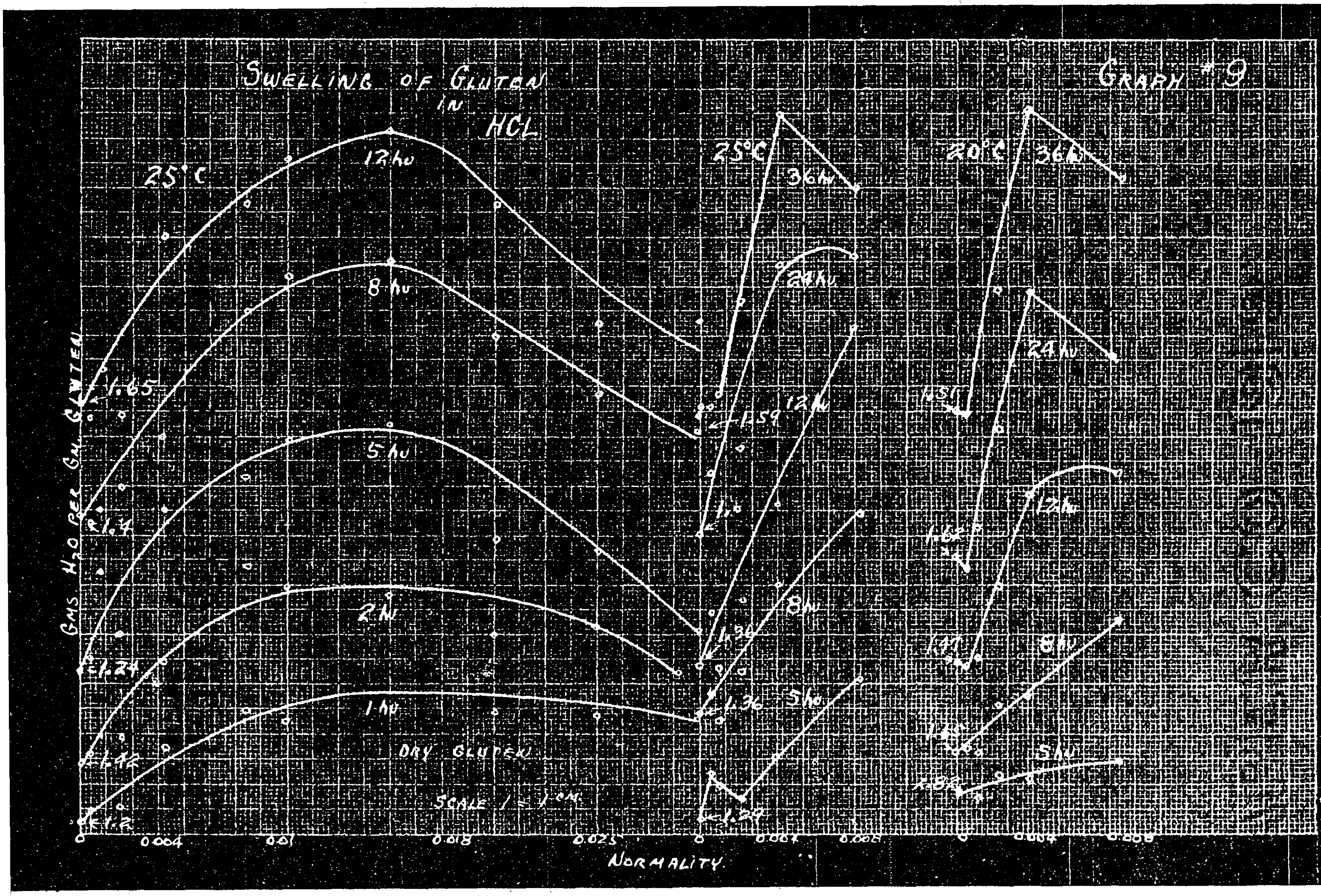
pH_1 is initial pH.
pH_2 is final pH.

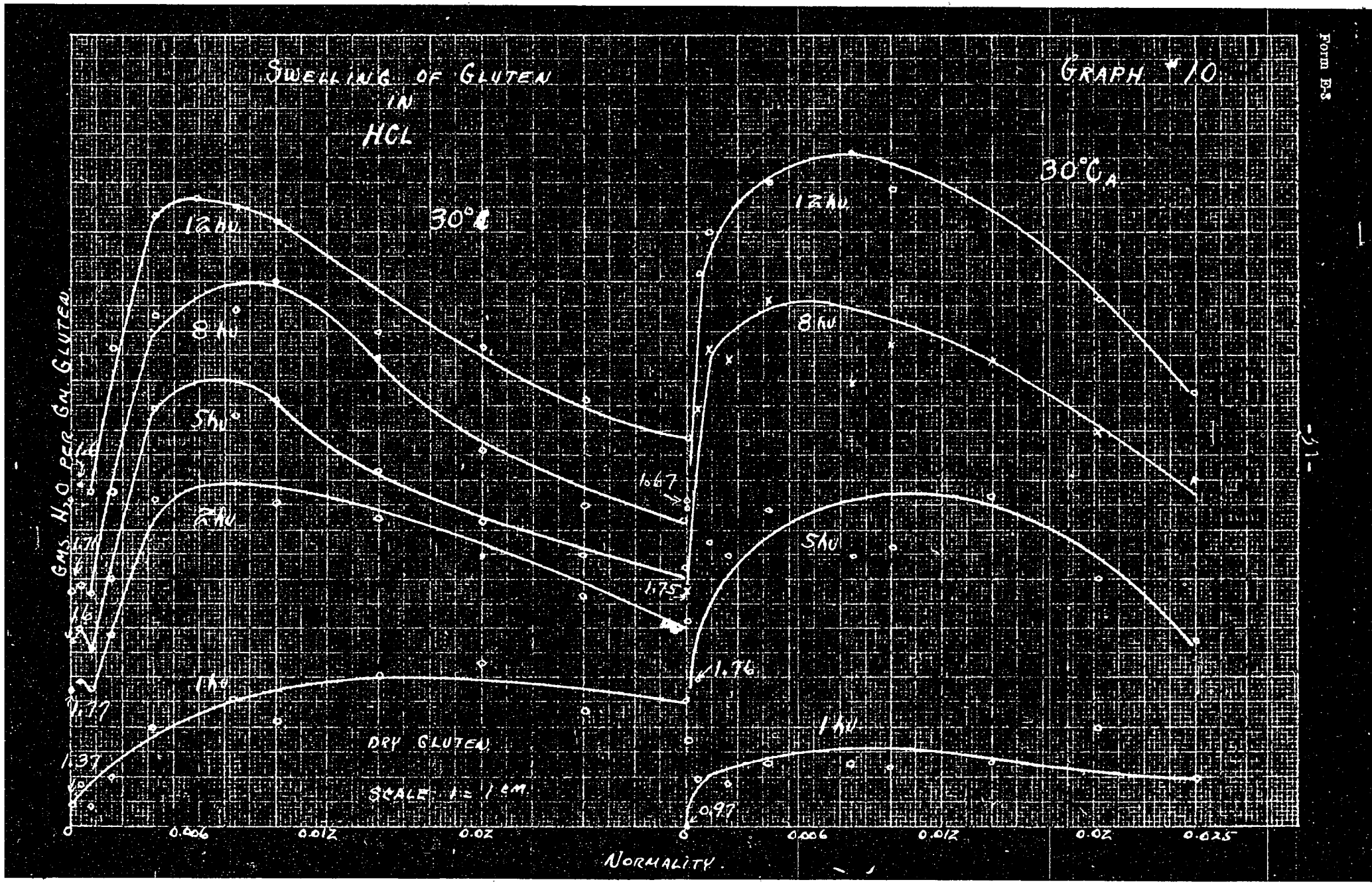
Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.002 to 0.01			0.004 to 0.01	2.39 to 2.08		0.004 to 0.01	2.27 to 2.0		0.004 to 0.01	2.27 to 2.0		0.004	2.45	
							DRY GLUTEN								
1	0.01 to 0.02	2.12 to 1.82	2.13 to 1.8	0.008 to 0.03	2.14 to 1.66	2.2 to 1.64	0.015 to 0.02	1.88 to 1.78	1.92 to 1.7	0.02	1.66	1.68	0.01	2	2.1
2	0.008 to 0.015	2.18 to 1.94	2.3 to 2.0	0.01	2.08	2.25	0.004 to 0.01	2.27 to 2.08	2.37 to 1.95	0.01 to 0.02	2.0 to 1.66	2.2 to 1.84	0.01	2	2.26
5	0.004 to 0.015	2.39 to 1.94	2.57 to 1.95	0.01 to 0.015	2.08 to 1.94	2.3 to 2.05	0.004 to 0.01	2.27 to 2.08	2.42 to 2.06	0.008	2.08	2.25	0.004 to 0.008	2.45 to 2.02	1.95
8	0.008	2.18	2.2	0.01 to 0.015	2.08 to 1.94	2.38 to 2.06	0.004 to 0.01	2.27 to 2.08	2.6 to 2.17	0.004	2.27	2.67	0.004	2.45	2.4
12	0.004	2.39	2.62	0.015	1.94	2.07	0.004 to 0.01	2.27 to 2.08	2.52 to 2.12	0.004	2.27	2.55	0.004	2.45	2.55


SWELLING OF WET GLUTEN IN HCL
GRAPH #7
40°C
35°C
30°C
25°C
20°C
0.04
0.07
0.09
0.12
0.09
GMS H2O PER GM GLUTEN
SCALE 1 = 2 cm
0.
0.006
0.015
0.02
0.03
NORMALITY

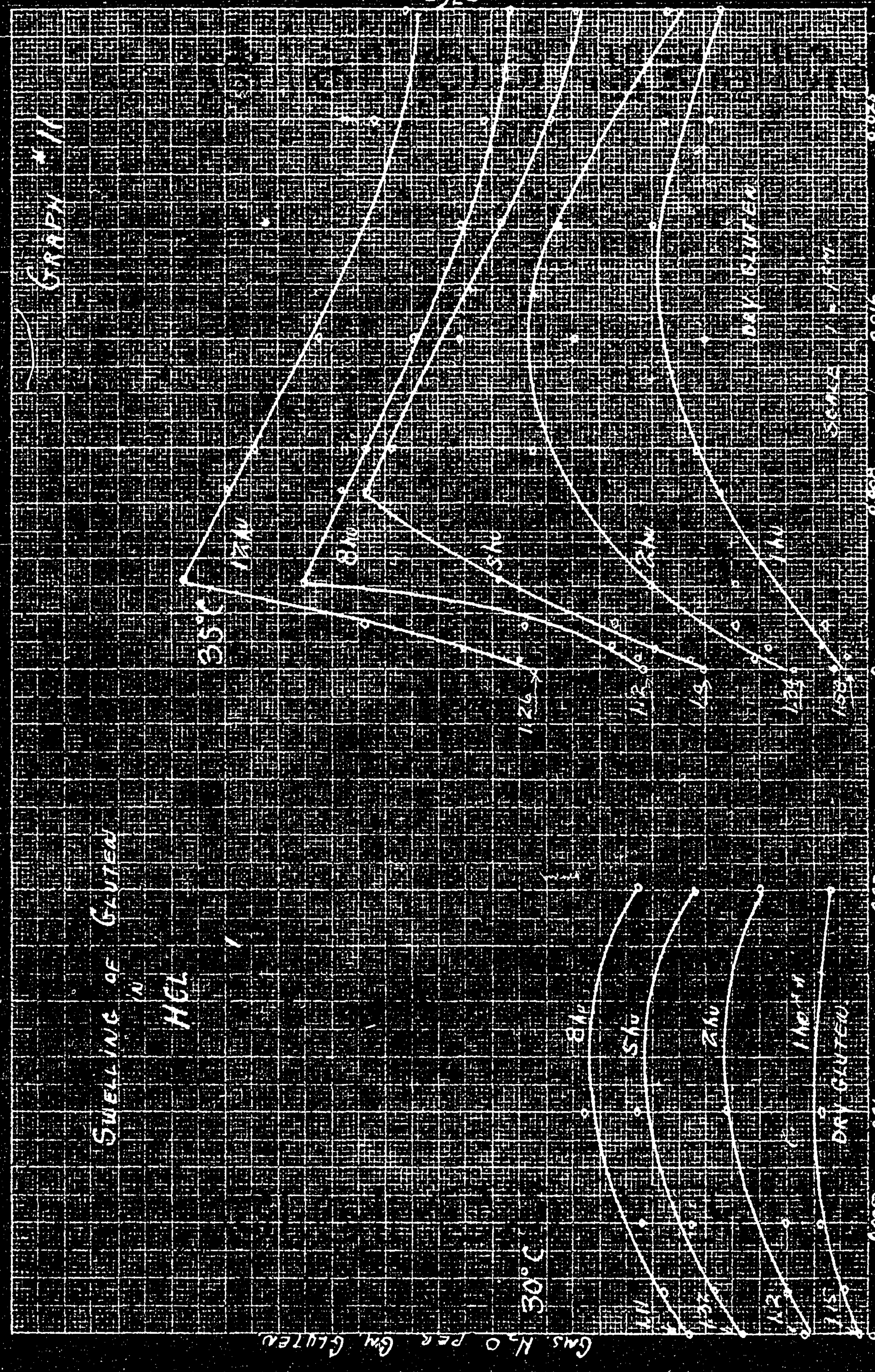


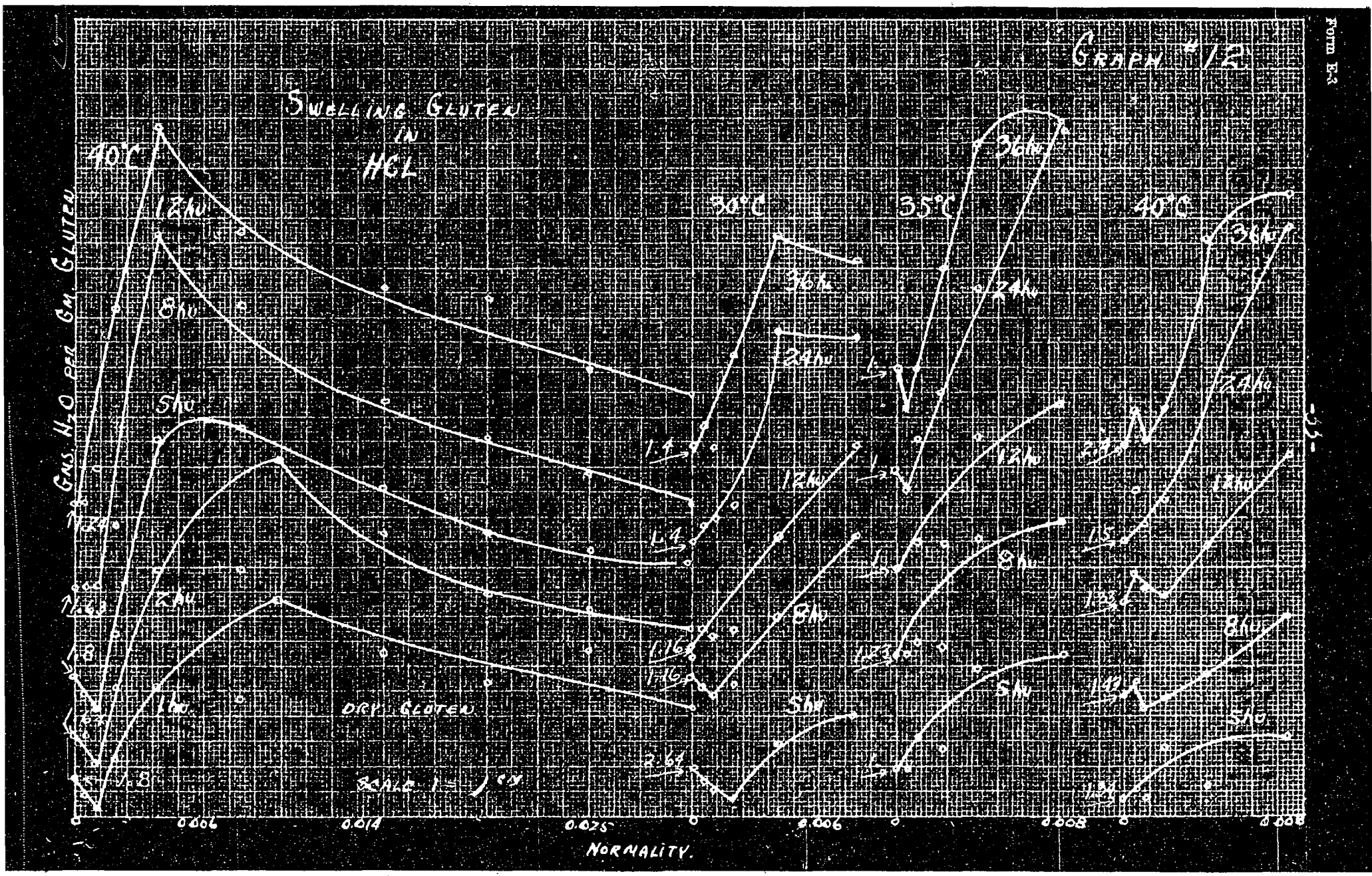
SWELLING OF GLUTEN IN HCL
GRAPH # 8
20°C
20°C
GMS. H_2O PER GM. GLUTEN
NORMALITY
DRY GLUTEN
DRY GLUTEN
0
0.004
0.01
0.02
0
0.006
0.014
0.026


SWELLING OF GLUTEN
IN
HCL
GRAPH #9
25°C
20°C
12 hr
8 hr
5 hr
2 hr
1 hr
36 hr
24 hr
DRY GLUTEN
SCALE 1 = 1 CM.
GMS H2O PER GM. GLUTEN
NORMALITY
0
0.004
0.01
0.018
0.025
0.008
1.65
1.4
1.24
1.42
1.2
1.59
1.36
1.29
1.51
1.47


SWELLING OF GLUTEN IN HCL
GRAPH 10
30°C
30°C
12 hr.
8 hr.
5 hr.
2 hr.
1 hr.
1.67
1.75
1.76
1.77
1.37
GMS. H2O PER GM. GLUTEN
DRY GLUTEN
SCALE 1 = 1 cm
0.006
0.012
0.02
0.025
NORMALITY
- 31 -

Form E-3


GRAPH # 11
SWELLING OF GLUTEN IN HCL
35°C
17hr
8hr
5hr
2hr
1hr
DRY GLUTEN
1.26
1.3
1.9
1.34
1.58
30°C
8hr
5hr
2hr
1hr
DRY GLUTEN
1.1
1.37
1.2
1.15
0
0.005
0.01
0.02
0.008
0.016
0.025
NORMALITY
GMS. H2O PER GM GLUTEN


GRAPH 1/52
SWELLING GLUTEN IN HCL
40°C
30°C
35°C
40°C
GMS. H2O PER GM. GLUTEN
DRY GLUTEN
SCALE 1 = 1 CM
NORMALITY.
0.006
0.014
0.025
0.006
0.008
0.008
Norm E3
-54-

(3) Swelling of Wet and Dry Gluten in Oxalic Acid.

At 20° wet gluten swells most in solutions having a normality greater than 0.02. Dry gluten in one hour swells most in solutions 0.04-0.07 N, while at the end of 12 hours dry gluten swells most in acid 0.02 N.

At 25° wet gluten has its maximum swelling in acid 0.02 N, while dry gluten for one hour swells most in acid 0.07-0.1 N and at the end of 12 hours in acid 0.04 N.

At 30° C. wet gluten swells most in acid 0.02 N. Dry gluten in one hour swells most in acid 0.02-0.1 N, while at the end of 12 hours it swells most in acid 0.02 N.

At 35° C. wet gluten swells most in acid having a normality slightly greater than 0.02. Dry gluten in one hour swells most in acid 0.07-0.1 N and in 12 hours in acid 0.04 N.

At 40° C. wet gluten swells most in acid 0.04 N. Dry gluten swells most in acid 0.07 N and in 12 hours most in acid 0.02 N.

It is evident that with oxalic as with hydrochloric acid, given enough time dry gluten will exhibit maximum swelling in the same solution required to produce maximum swelling with wet gluten.

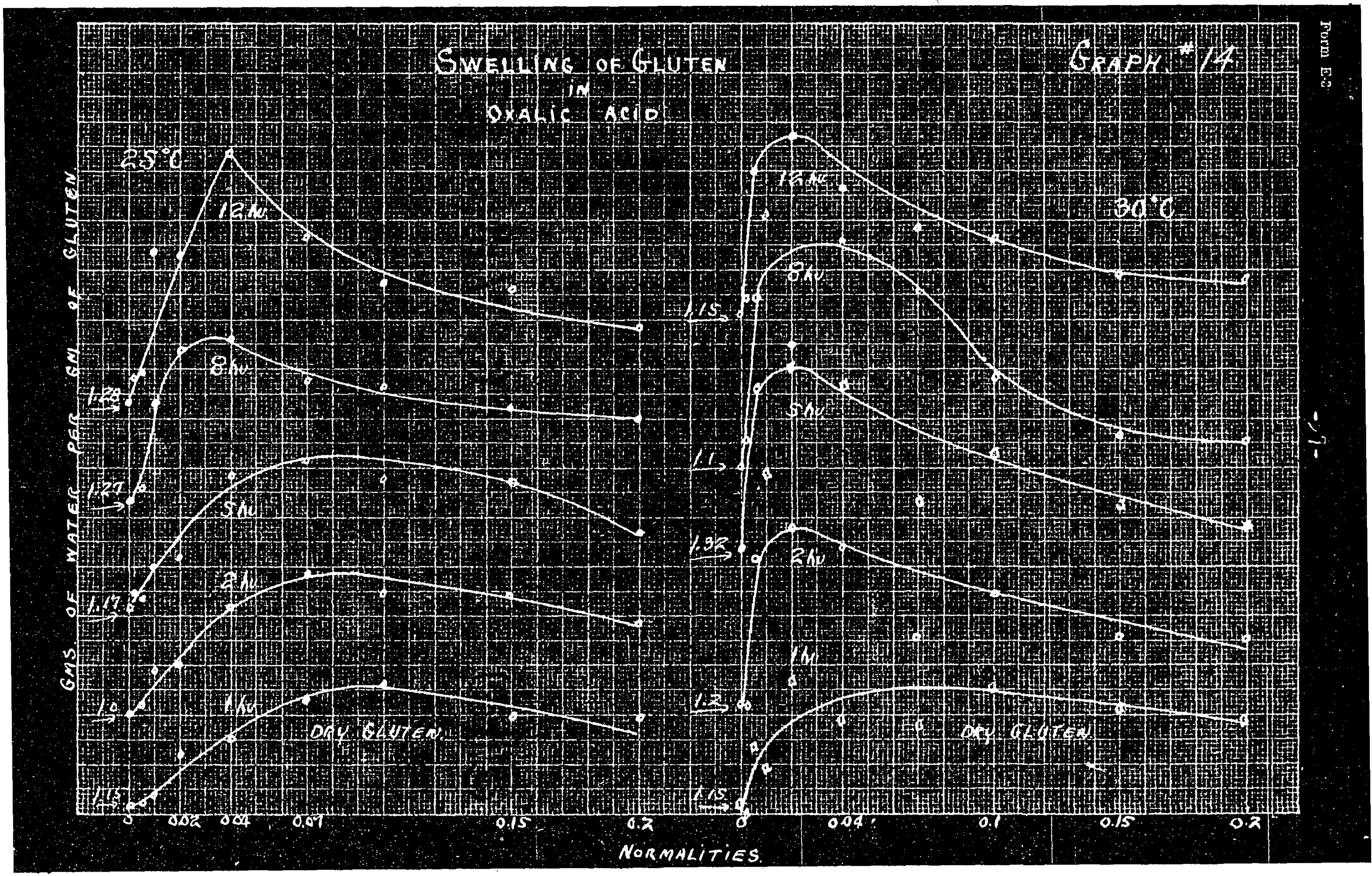
TABLE IX.

THE pH AND NORMALITIES OF OXALIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.04	2.1		0.02	2.4		0.02	2.45		0.02	1.48		0.04	2.05	
							DRY GLUTEN								
1	0.04 to 0.07	2.1 to 1.75	2.22 to 1.97	0.07 to 0.1	1.9 to 1.6	1.94 to 1.54	0.02 to 0.1	2.4 to 2.6	2.44 to 2.74	0.07 to 0.1	1.82 to 1.65	1.78 to 1.73	0.07	1.72	1.78
2	0.04 to 0.07	2.1 to 1.75	2.2 to 1.86	0.07	1.9	1.62	0.02	2.4	2.2	0.04 to 0.07	2.0 to 1.82	2.08 to 1.88	0.07	1.72	1.88
5	0.04 to 0.07	2.1 to 1.75	2.2 to 1.91	0.07	1.9	1.75	0.02	2.4	2.51	0.04	2.0	2.14	0.04	2.05	2.14
8	0.02	2.4	2.5	0.04 to 0.02	2 to 2.4	1.75 to 2.5	0.02	2.4	2.45	0.02 to 0.04	2.45 to 2.0	2.12 to 2.15	0.04	2.05	2.15
12	0.02	2.4	2.28	0.04	2.0	2.18	0.02	2.4	2.69	0.04	2.0	1.61	0.02 to 0.04	2.5 to 2.05	2.63 to 2.08

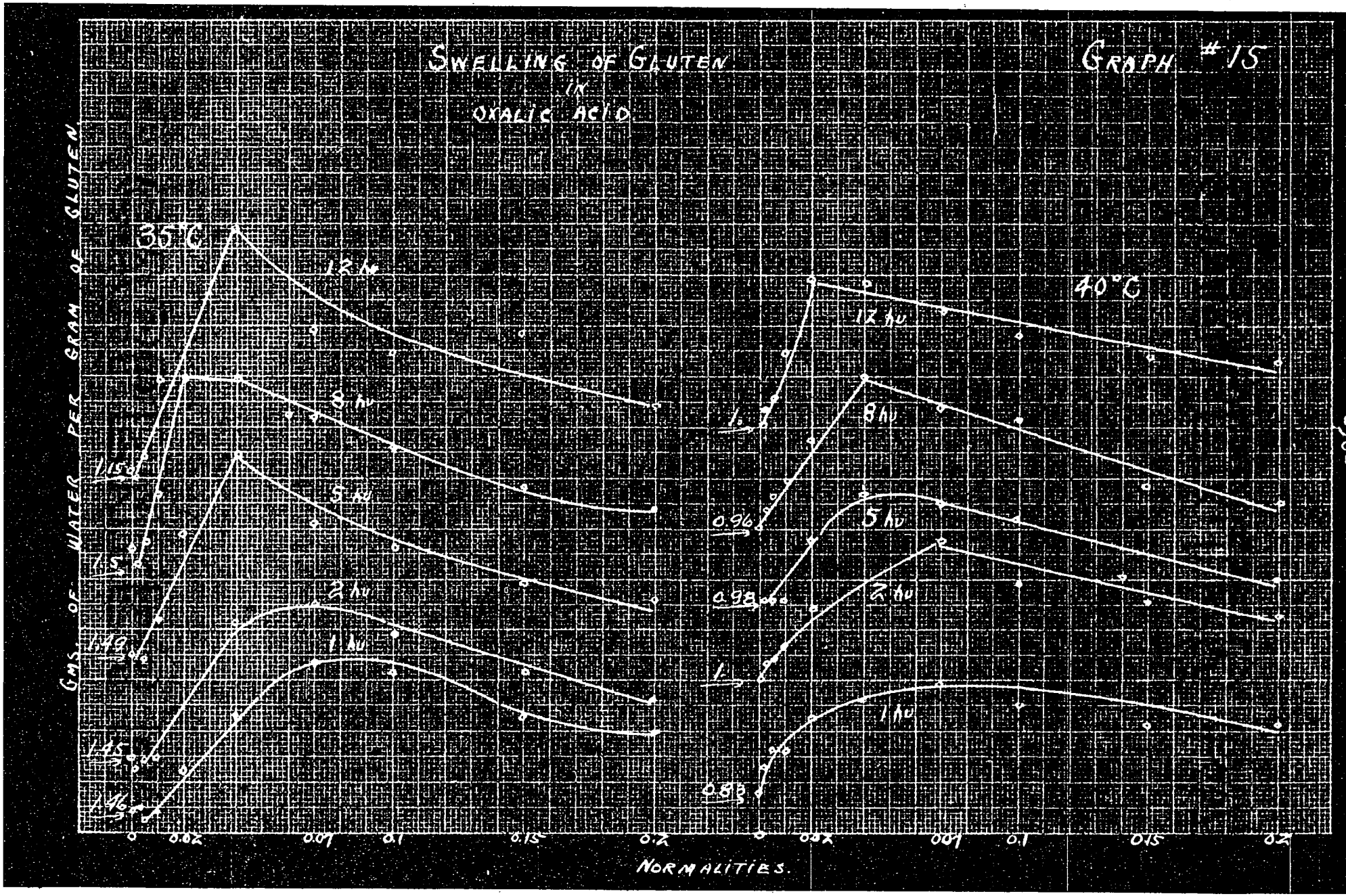
GRAPH #13
SWELLING OF GLUTEN IN OXALIC ACID
GMS. OF WATER PER GRAM OF GLUTEN
NORMALITIES
WET GLUTEN
DRY GLUTEN
SCALE 1 CM.
40°C
35°C
30°C
25°C
20°C
20°C
12 Hr.
8 Hr.
5 Hr.
2 Hr.
1 Hr.
0.94
0.98
0.97
0.94
0.93
1.21
1.28
1.24
0.95
1.45
0.2
0.15
0.1
0.02
0.01
0.2
0.15
0.1
0.04
0.02
0.01



SWELLING OF GLUTEN
IN
OXALIC ACID
GRAPH #14
25°C
30°C
12 hr
8 hr
5 hr
2 hr
1 hr
DRY GLUTEN
1.28
1.27
1.17
1.0
1.15
1.1
1.32
1.2
0
0.02
0.04
0.07
0.1
0.15
0.2
NORMALITIES
GMS OF WATER PER GM OF GLUTEN

Form E-2

-7-


SWELLING OF GLUTEN
IN
OXALIC ACID.
GRAPH #15
GMS. OF WATER PER GRAM OF GLUTEN.
35°C
40°C
12 hr
8 hr
5 hr
2 hr
1 hr
1.
0.96
0.98
0.83
0.02
0.07
0.1
0.15
0.2
NORMALITIES.

(4) Swelling of Wet and Dry Gluten in Phosphoric Acid.

Wet gluten at 20° C. swells most in phosphoric acid 0.07-0.1 N, with increase in temperature there is a shift to a lower normality, the gluten swelling most in acid 0.04 N.

Dry gluten at 20° C. in one hour swells most in acid 0.07-0.1 N, at the end of 12 hours it swells most in acid 0.04 N.

At 25° C. dry gluten swells most in acid 0.07 N regardless of time.

At 30° C. dry gluten swells most in acid 0.1 N, but at the end of 12 hours it swells most in acid 0.04 N.

At 35° C. dry gluten in one hour exhibits maximum swelling in acid 0.07 N, while in 12 hours the maximum is in acid 0.02 N.

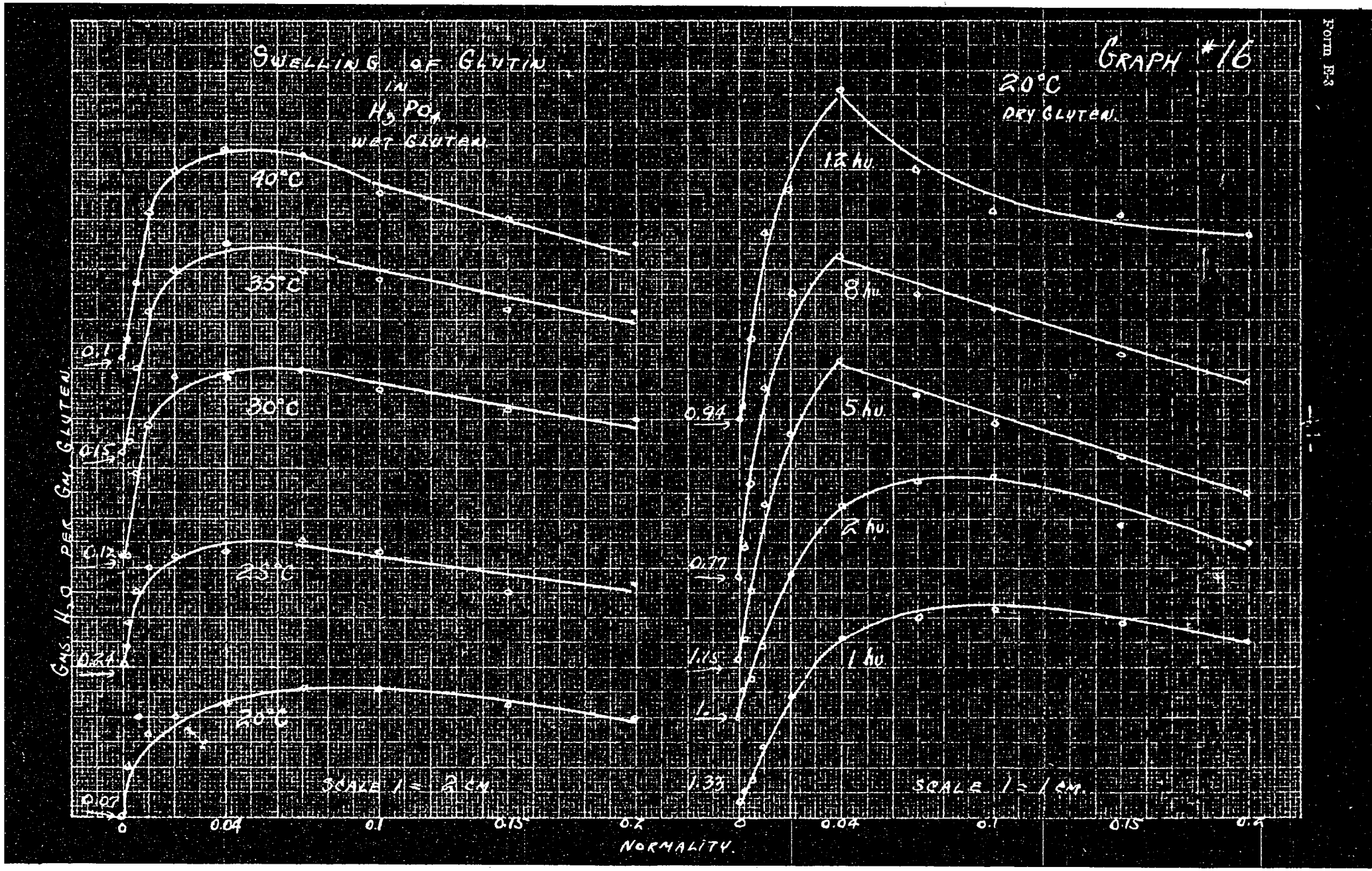
At 40° C. regardless of time maximum swelling occurs in acid approximately 0.1 N.

TABLE X.

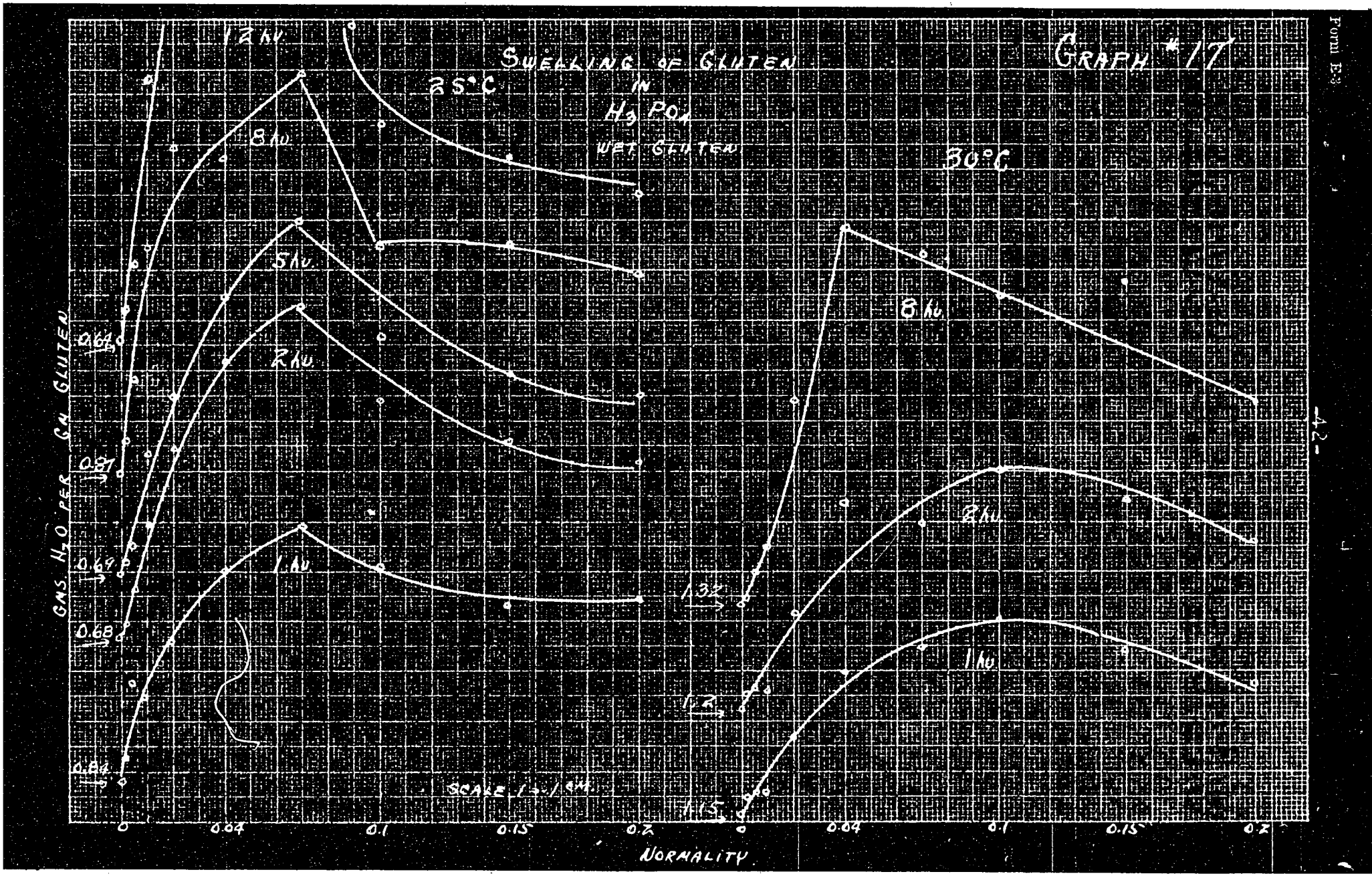
THE pH AND NORMALITIES OF PHOSPHORIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

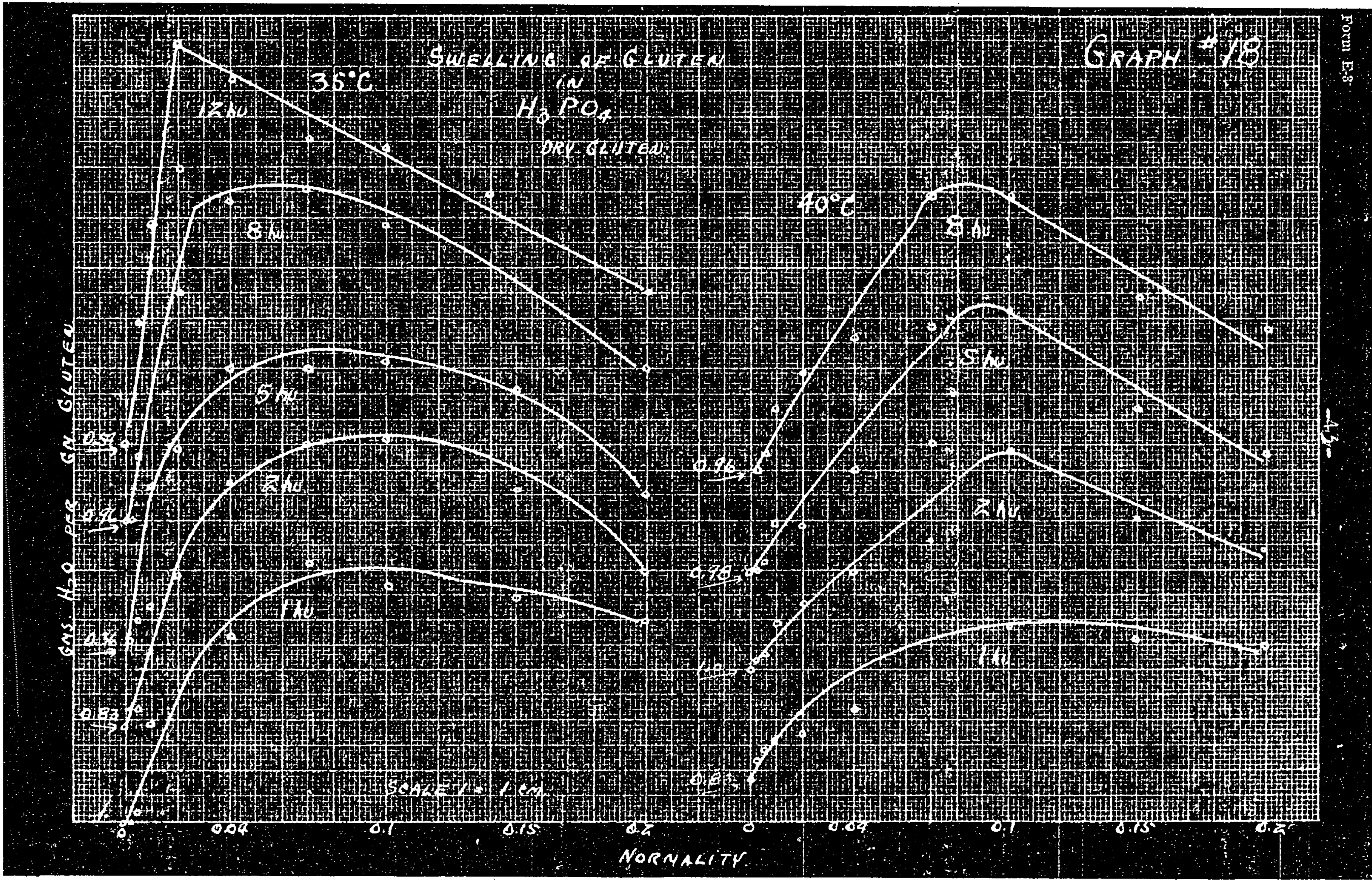
pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.07 to 0.1	2.22 to 1.87		0.04 to 0.1	2.15 to 1.87		0.02 to 0.07	2.37 to 2.1		0.04	2.15		0.04	2.15	
							DRY GLUTEN								
1	0.07 to 0.1	2.02 to 1.87	2.2 to 2.03	0.07	2.05	1.8	0.1	1.9	1.96	0.07	2.1	2.05	0.1	1.85	1.9
2	0.07 to 0.1	2.22 to 1.87	2.2 to 2.05	0.07	2.05	2.3	0.1	1.96	1.96	0.07 to 0.1	2.1 to 1.87	2.1 to 1.95	0.1	1.85	1.96
5	0.04	2.15	2.29	0.07	2.05	2.07	0.04	2.18	2.31	0.04 to 0.1	2.15 to 1.87	2.35 to 1.95	0.07 to 0.1	2.1 to 1.85	2.13 to 1.98
8	0.04	2.15	2.31	0.07	2.05	1.9				0.04 to 0.07	2.15 to 2.1	2.25 to 2.0	0.07 to 0.1	2.1 to 1.85	2.13 to 1.96
12	0.04	2.15	2.10	0.07	2.05	2.1				0.02	2.35	2.42			


SWELLING OF GLUTIN IN H_3PO_4
WET GLUTEN
GRAPH #16
20°C
DRY GLUTEN.
40°C
35°C
30°C
25°C
20°C
12 hr.
8 hr.
5 hr.
2 hr.
1 hr.
0.94
0.77
1.15
1.33
0.1
0.15
0.12
0.24
0.07
GMS. H_2O PER GM. GLUTEN.
SCALE 1 = 2 CM.
SCALE 1 = 1 CM.
0
0.04
0.1
0.15
0.2
NORMALITY.

Form E-3


GRAPH #17
SWELLING OF GLUTEN IN H_3PO_4
WET GLUTEN
25°C
30°C
12 hr
8 hr
5 hr
2 hr
1 hr
GMS. H_2O PER GM GLUTEN
0.64
0.87
0.69
0.68
0.84
1.32
1.15
SCALE 1 = 1 GM.
0
0.04
0.1
0.15
0.2
NORMALITY
Form E-3
-42-


GRAPH #18
SWELLING OF GLUTEN
IN
H_3PO_4
DRY GLUTEN
35°C
40°C
12 N
8 N
5 N
2 N
1 N
GMS. H_2O PER GM. GLUTEN
NORMALITY
SCALE 1 = 1 cm.
0
0.04
0.1
0.15
0.2
0.96
0.98
0.83

B. The Second Class of Acids Those Which Exhibit a Broad Optimum.

(1) Swelling of wet and dry gluten in Tartaric Acid.

At 20° C. wet gluten swells most in 0.07 N tartaric acid. Dry gluten at this temperature, at one hour, swells most in 0.1 N acid, after 12 hours it swells most in acid whose normality varies from 0.07-0.1.

At 25° C. optimum swelling of wet gluten occurs in 0.01-0.2 N acid. Dry gluten in one hour swells most in 0.04-0.2 N acid, while at the end of 12 hours maximum swelling occurs in 0.04 N acid.

At 30° C. optimum swelling of wet gluten occurs in 0.04-0.2 N acid. Dry gluten in one hour exhibits maximum swelling in 0.04 N acid, while at the end of 12 hours maximum swelling occurs in 0.04 N acid.

At 35° C. 0.005-0.2 N acid will produce maximum swelling of wet gluten. In one hour 0.1-0.2 N acid will produce maximum swelling with dry gluten. In 12 hours 0.02 N acid will produce maximum swelling.

At 40° C. maximum swelling with wet gluten occurs in 0.01-0.2 N acid. For dry gluten 0.2 N acid will produce maximum swelling in one hour, while in 12 hours 0.07-0.15 N acid will produce maximum swelling.

With dry gluten it is evident that with increase

in time a lower normality is required to produce maximum swelling and this normality tends to become similar to that required to produce maximum swelling with wet gluten.

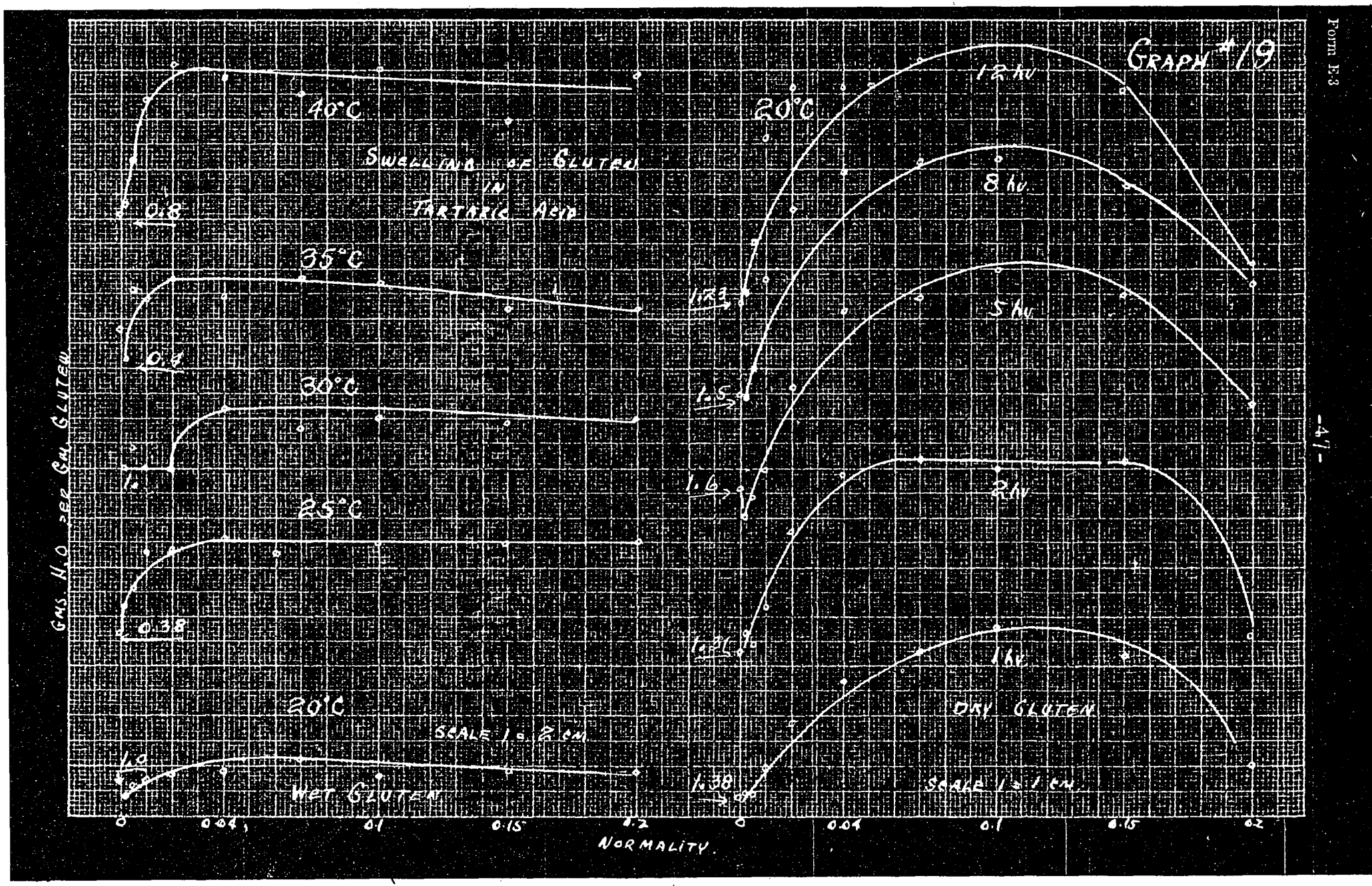
Altho the effect of temperature is not very evident, one may say that with increase in temperature a lower normality is required to produce maximum swelling. This effect is, however, not very regular. The reason for this may be that the solutions when compared as regards their normalities are different. When compared from the standpoint of pH it is evident that there is only a slight difference between the several solutions.

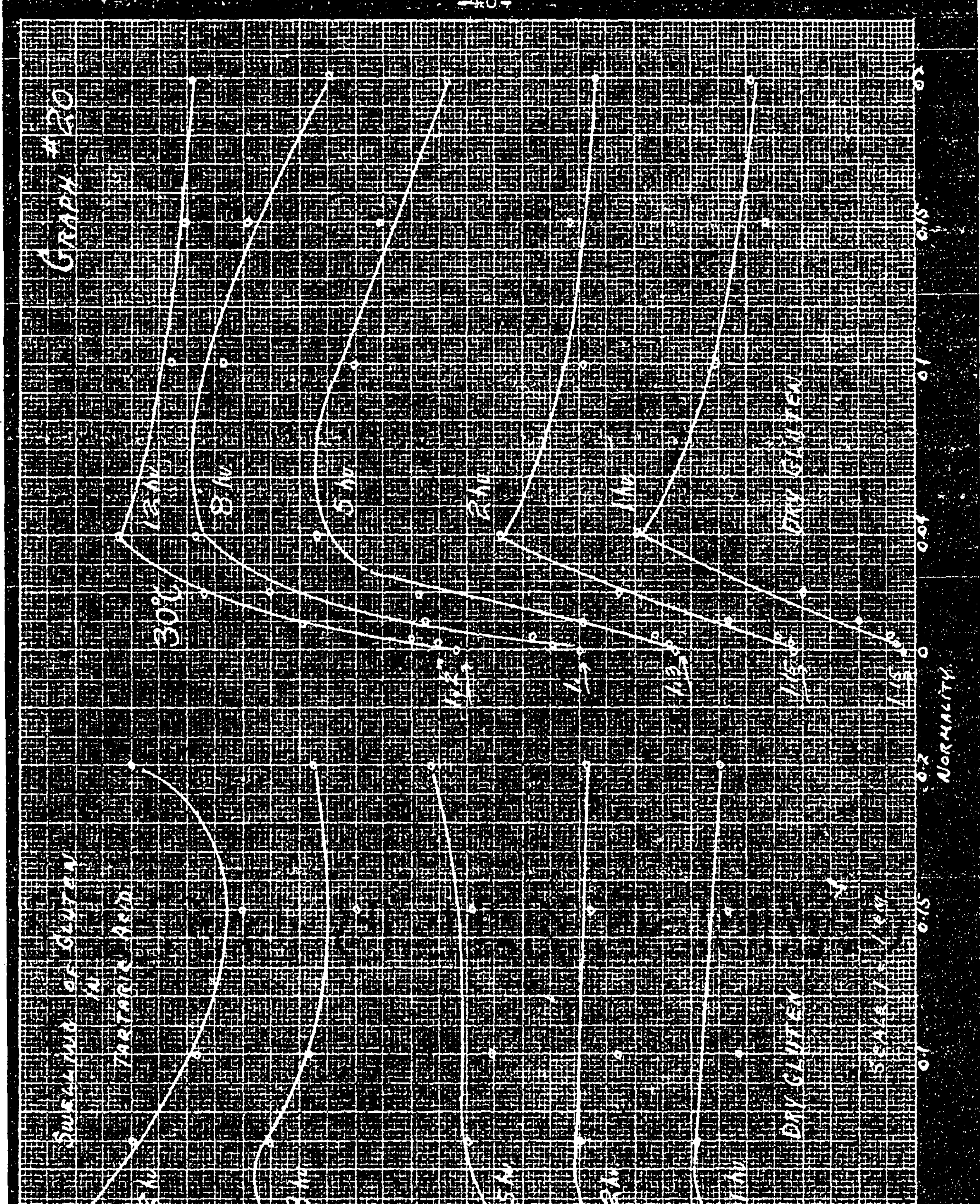
TABLE XI.

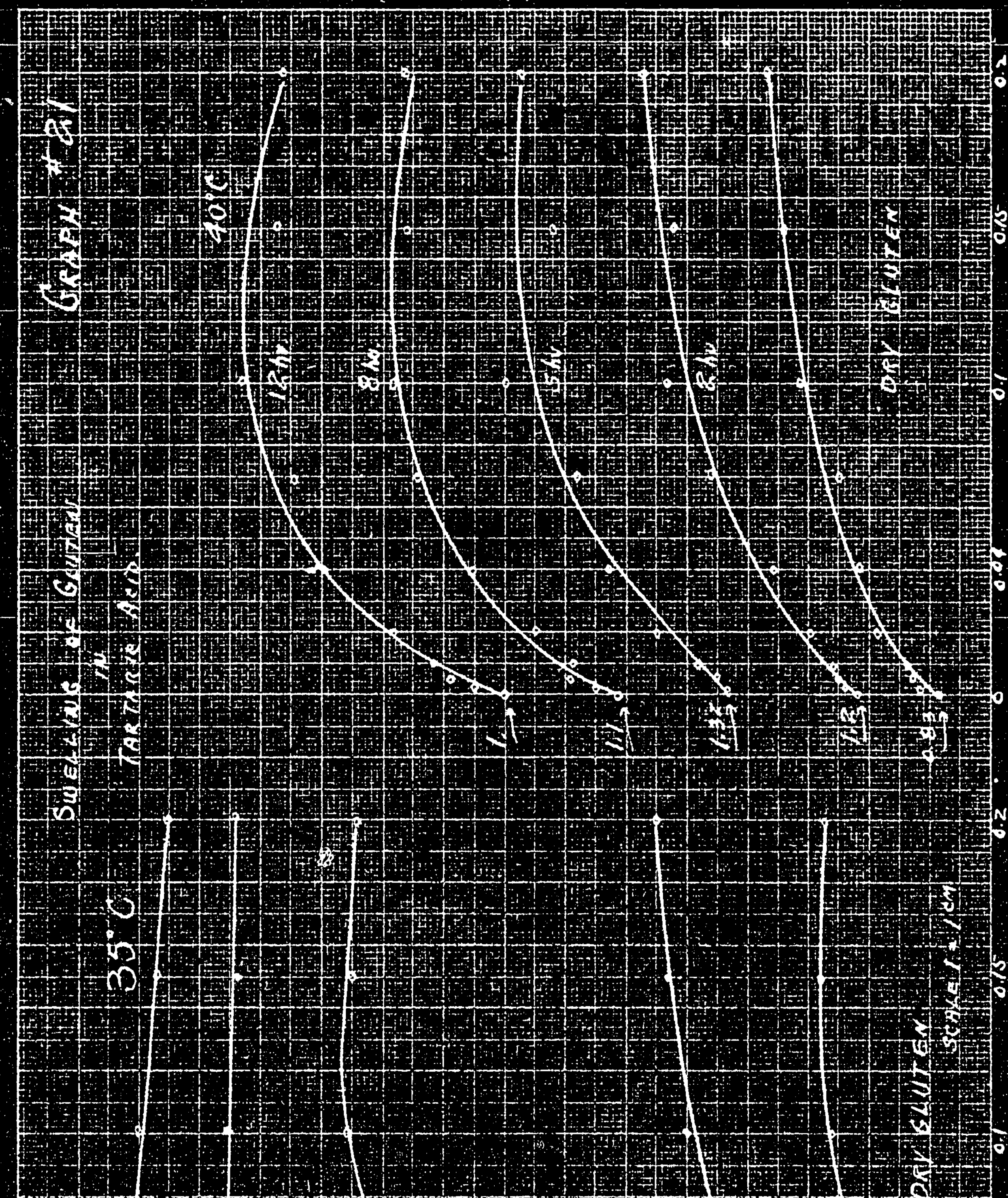
THE pH AND NORMALITIES OF TARTARIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.07 to 0.2	2.4 to 2.35		0.01 to 0.2	2.86 to 2.8		0.04 to 0.2	2.81 to 2.2		0.005 to 0.2	3.16 to 2.20		0.01 to 0.2	3.08 to 2.29	
							DRY GLUTEN								
1	0.1	2.35	2.81	0.04 to 0.2	2.65 to 2.25	2.01 to 1.88	0.04	2.81	2.25	0.1 to 0.2	3 to 2.20	2.07 to 2	0.2	2.29	
2	0.04 to 0.15	2.58 to 2.25	2.54 to 1.76	0.04 to 0.2	2.65 to 2.25	2.42 to 2.76	0.04	2.81	2.50	0.2	2.2	1.94	0.2	2.29	
5	0.1	2.35	2.3	0.07 to 0.2	2.46 to 2.25	2.05 to 2.05	0.04	2.81	2.33	0.1 to 0.2	2.44 to 2.2	2.26 to 2.02	0.1 to 0.2	2.46 to 2.29	2.36 to 2.01
8	0.04 to 0.10	2.58 to 2.25	1.95 to 1.78	0.04 to 0.07	2.65 to 2.46	2.52 to 2.24	0.04 to 0.1	2.81 to 2.32	2.23 to 2.06	0.02 to 0.2	2.84 to 2.2	2.2 to 2.04	0.1 to 0.2	2.46 to 2.29	2.13 to 1.99
12	0.07 to 0.1	2.4 to 2.35	2.3 to 2.13	0.04	2.65	2.25	0.04	2.81	2.3	0.02	2.84		0.07 to 0.15		


GRAPH #19
SWELLING OF GLUTEN IN TARTARIC ACID
40°C
35°C
30°C
25°C
20°C
0.8
0.6
0.4
0.2
GMS. H2O PER GM. GLUTEN
SCALE 1 = 2 CM.
WET GLUTEN
12 hr
8 hr
5 hr
2 hr
1 hr
1.52
1.42
1.6
1.38
DRY GLUTEN
SCALE 1 = 1 CM.
0
0.04
0.1
0.15
0.2
NORMALITY


GRAPH #20
SWELLING OF GLUTEN
IN
TARTARIC ACID
25°C
30°C
12 hr
8 hr
5 hr
2 hr
1 hr
DRY GLUTEN
NORMALITY


GRAPH #21
SWELLING OF GLUTEN IN TARTARIC ACID
40°C
35°C
12 hr
8 hr
5 hr
2 hr
1 hr
DRY GLUTEN
SCALE 1 = 1 CM
GMS H2O PER GM. GLUTEN
0
0.1
0.15
0.2

(2) The Swelling of Wet and Dry Gluten in Citric Acid.

The optimum concentration of acid required to produce maximum swelling of gluten with citric acid, at various times and temperatures is Broad. With increasing time all except the very dilute concentrations produce or try to produce the same amount of swelling.

With wet gluten maximum swelling is produced by a concentration of acid greater than 0.02 N. That is citric acid of a pH. 3.24-2.5 will produce maximum swelling.

Altho there is no definite decided optimum, the per cent increase at 0.02 is slightly greater with increase in temperature than at other concentrations, Altho this is not enough to bring about a decided maximum, we may conclude that temperature has a greater effect upon the swelling of wet gluten in 0.02 N citric acid than it does upon the swelling in greater concentrations.

With dry gluten and citric acid for all the times and temperatures studied, the curve is definitely upwards. There is no optimum, the gluten swelling most in the greatest normal solution.

However, if we note the points of inflection on all the curves. It is apparent that there is a decided shift from the greater to the smaller normalities. With the lower concentrations there is a lag, so that in one hour

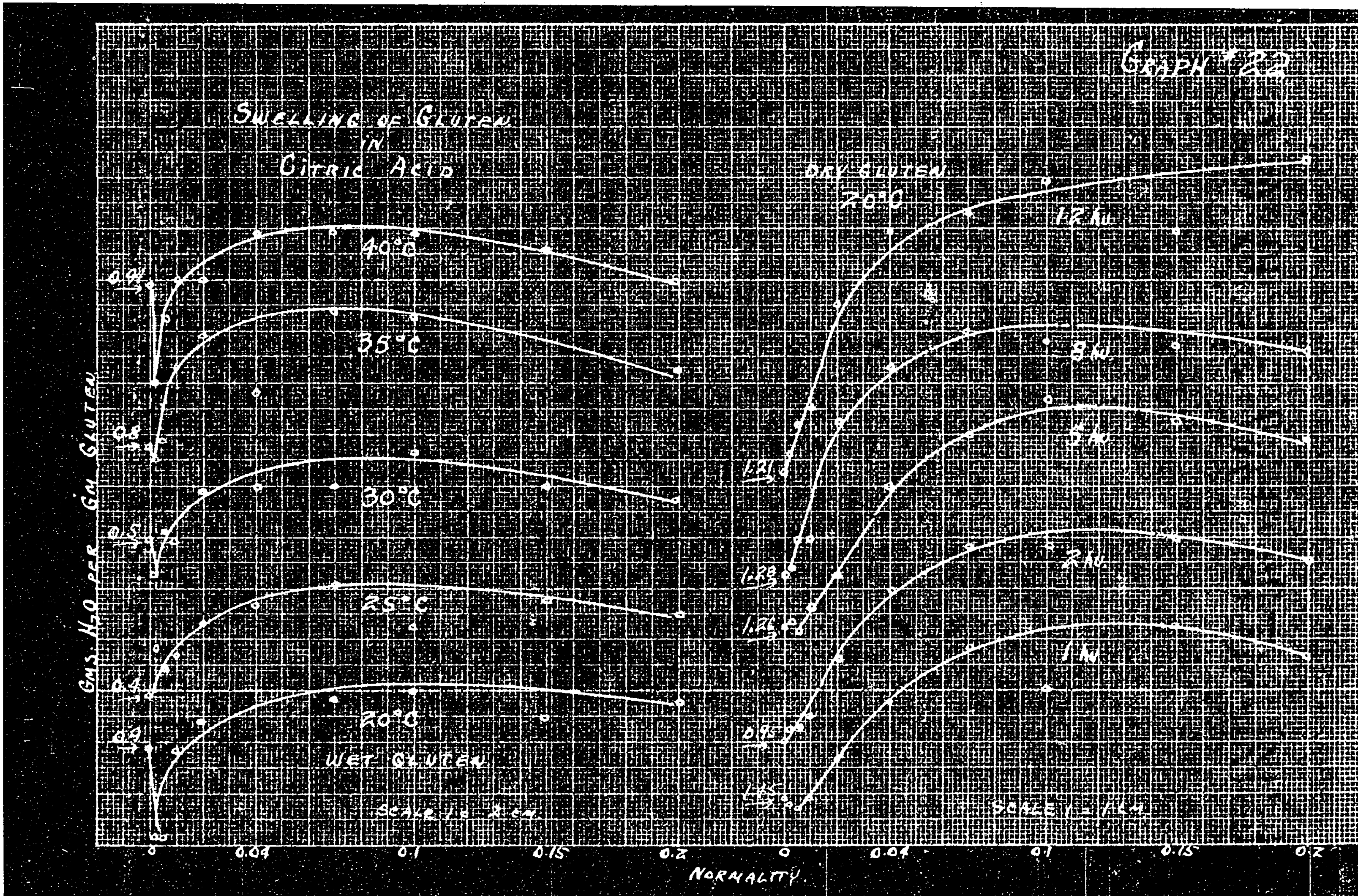
the greatest swelling occurs in the greatest concentration of acid. With time, however, the rate increases so that at the end of 12 hours the amount of swelling in acid 0.04 N is nearly as great as that with 0.2 N. We may conclude then that given enough time citric acid 0.04 N will produce as much swelling as 0.2 N acid. Or we may say that in time the swelling of dry gluten will be like the swelling of wet gluten in one hour. Drying under the conditions specified has not particularly altered the gluten, but as one would naturally suppose the rate at which the two swell is not entirely the same.

TABLE XII.

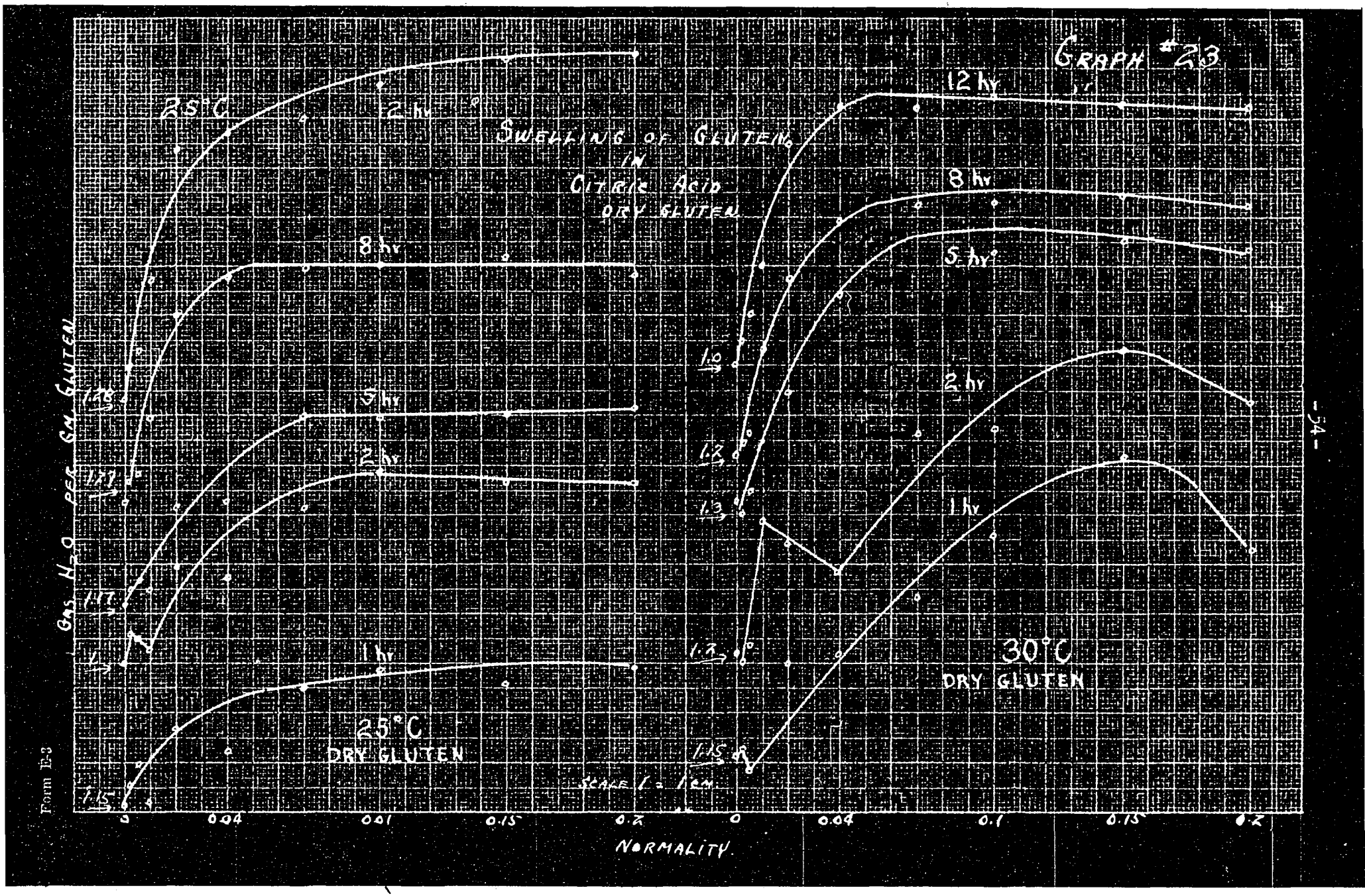
THE pH AND NORMALITIES OF CITRIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

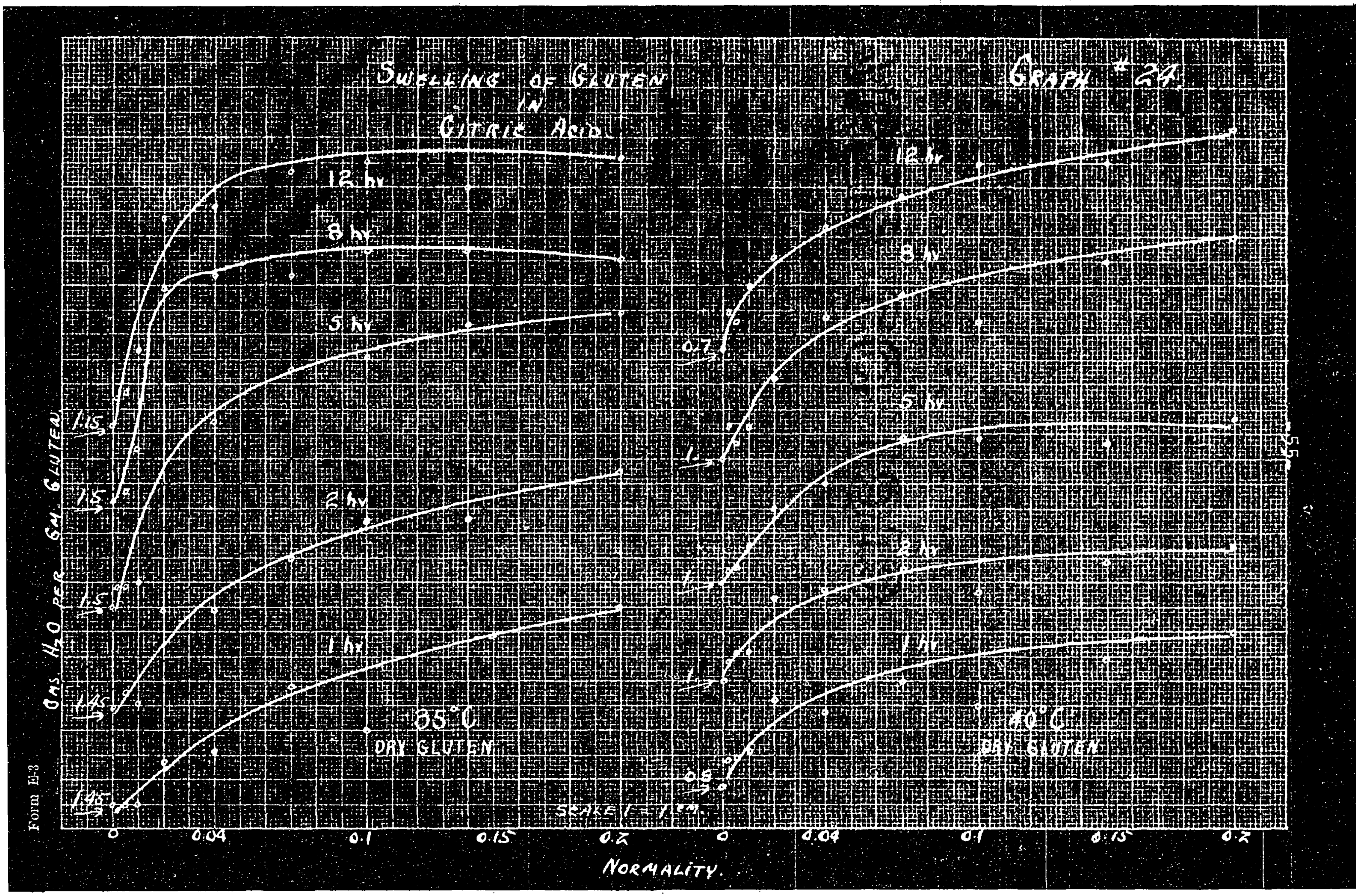
Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.07 to 0.02	2.54 to 2.42		0.04 to 0.2	2.96 to 2.50		0.02 to 0.2	3.24 to 2.50		0.02 to 0.1	3.24 to 2.54		0.04 to 0.15	3.18 to 2.54	
							DRY GLUTEN								
1	0.07 to 0.02	2.54 to 2.42		0.07 to 0.2	2.64 to 2.50	2.48 to 2.75	0.15	2.56	2.01	0.2	2.43	2.03	0.2	2.48	
2	0.07 to 0.15	2.54 to 2.46	2.39 to 2.25	0.1 to 0.2	2.58 to 2.5		0.15	2.56	2	0.2	2.43	1.86	0.07 to 0.2	2.72 to 2.48	2.49 to 2
5	0.1	2.52	2.46	0.07 to 0.2	2.64 to 2.5	2.68 to 1.40	0.07 to 0.2	2.81 to 2.50	2.03 to 2	0.2	2.43	2.15	0.07 to 0.2	2.72 to 2.48	2.53 to 2.14
8	0.07 to 0.2	2.54 to 2.42	2.28 to 1.27	0.04 to 0.2	2.96 to 2.5	2.66 to 1.39	0.04 to 0.2	3.11 to 2.5	2.18 to 1.96	0.04 to 0.02	3 to 2.43	2.68 to 2.12	0.2	2.72	1.98
12	0.1 to 0.2	2.52 to 2.42	2.29 to 2.14	0.15 to 0.2	2.52 to 2.5	2.37 to 2.25	0.04 to 0.2	3.11 to 2.5	2.2 to 2	0.07 to 0.2	2.70 to 2.43	1.35 to 2.17	0.2	2.72	2.04



Graph # 22
Swelling of Gluten in Citric Acid
Dry Gluten 20°C
1.2 N
8 N
5 N
2 N
1 N
40°C
35°C
30°C
25°C
20°C
Wet Gluten
Scale 1 = 2 cm
Scale 1 = 1 cm
Gms. H2O per Gm. Gluten
Normality
0.94
0.8
0.5
0.4
0.9
1.21
1.28
1.26
0.95
1.45
0
0.04
0.1
0.15
0.2


GRAPH #23
SWELLING OF GLUTEIN
IN
CITRIC ACID
DRY GLUTEN
25°C
DRY GLUTEN
30°C
DRY GLUTEN
12 hr
8 hr
5 hr
2 hr
1 hr
GMS. H2O PER GM GLUTEN
NORMALITY
SCALE 1" = 1 cm.
0
0.04
0.1
0.15
0.2

Form B-3


Swelling of Gluten in Citric Acid
Graph # 24.
12 hr
8 hr
5 hr
2 hr
1 hr
85° C
Dry Gluten
40° C
Dry Gluten
Gms. H_2O per Gm. Gluten
Normality.
Scale 1 = 1 cm.
0
0.04
0.1
0.15
0.2
1.45
1.5
1.15
0.7
1.
0.8
Form E3

(3) The Swelling of Wet and Dry Gluten in Lactic Acid.

With wet gluten and lactic acid, as with the other organic acids the optimum concentration required to produce maximum swelling at any temperature is broad and maybe said to be about 0.01 N.

With dry gluten and lactic acid, at 20° C. the concentration required to produce maximum swelling is likewise broad. Becoming more so as time increases. But here again on studying the curves it is noticable that there is a decided shift in the points of inflection. At one hour the concentration required to produce maximum swelling is around 0.1 N at 12 hours the optimum is above 0.02 N.

At 25° C. at 1, 2, and 5 hours the optimum concentration is broad 0.04-0.2 N. At eight and twelve hours however, there is a slight change, the optimum concentration becoming more defined 0.07-0.1 N.

At 35° C. the optimum is well defined being 0.1 N at all times. Here as at 25° C., at one and two hours the optimum is broader being above 0.2 N.

At 40° C. although the curves indicate a sharp optimum this is not actually the case. At 1, 2, and 5 hours the optimum is above 0.07 N, while at 8 hours there is a decided shift to the lower concentration.

Here as with the other acids it is apparent that the swelling of dry gluten will be like the swelling of wet gluten.

TABLE XIII.

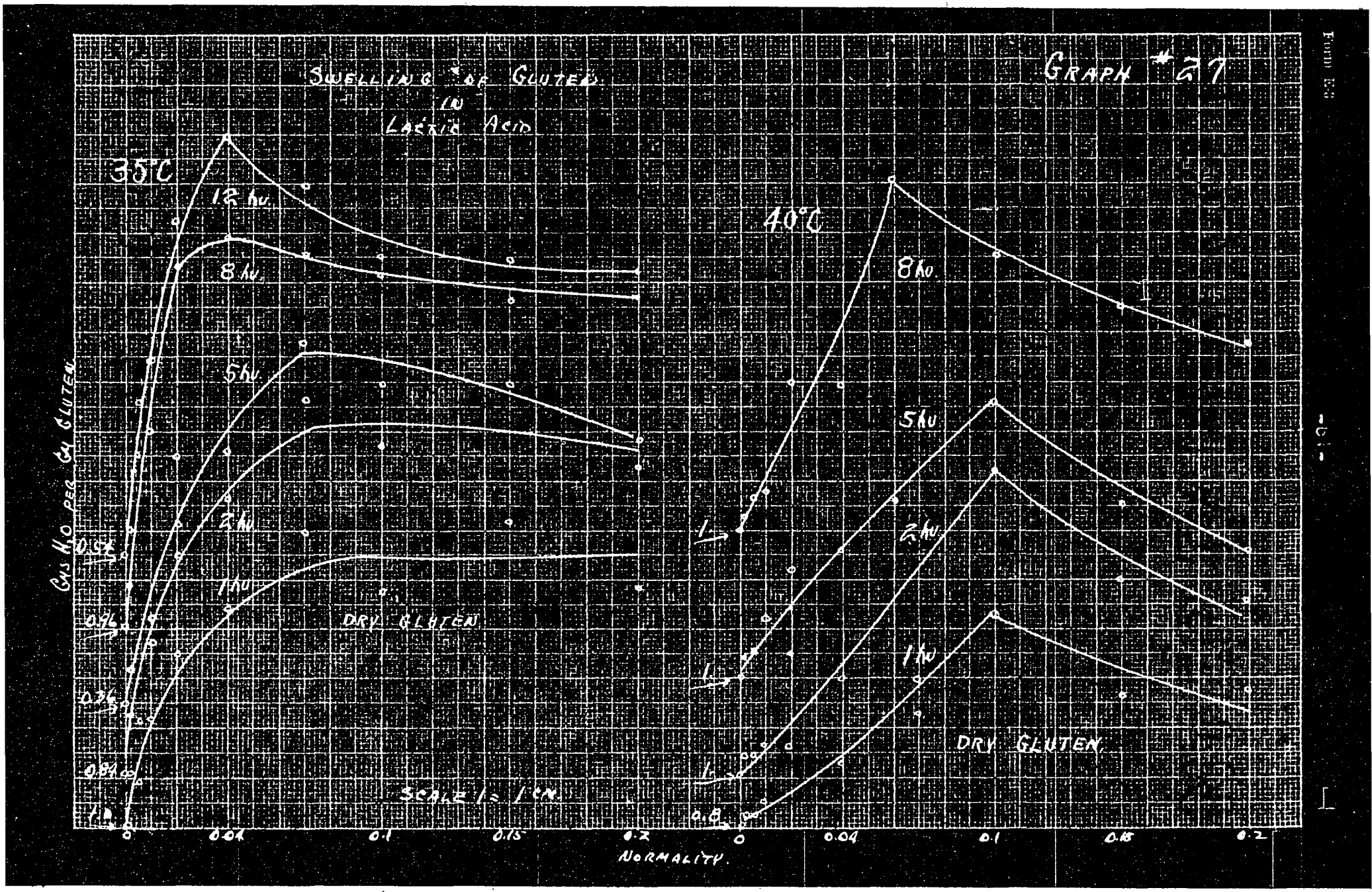
THE pH AND NORMALITIES OF LACTIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.02 to 0.2	2.86 to 2.34		0.02 to 0.2	2.96 to 2.36		0.02 to 0.2	2.76 to 2.32		0.02 to 0.2	2.86 to 2.48		0.2	2.4	
							DRY GLUTEN								
1	0.1	2.45	2.5	0.04 to 0.2	2.74 to 2.36	2.63 to 2.45	0.1	2.48	2.6	0.07 to 0.2	2.7 to 2.48	2.62 to 2.37	0.1	2.51	2.62
2	0.1 to 0.2	2.45 to 2.34	2.63 to 2.2	0.04 to 0.2	2.74 to 2.36	2.82 to 2.4	0.1	2.48	2.63	0.07 to 0.2	2.7 to 2.48	2.62 to 2.35	0.1	2.51	2.55
5	0.1	2.45	2.46	0.04 to 0.2	2.74 to 2.36	2.86 to 2.42	0.1	2.48	2.55	0.07	2.7	2.60	0.1	2.51	2.60
8	0.1 to 0.15	2.45 to 2.34	2.45 to 2.33	0.1	2.48	2.62				0.02 to 0.2	2.86 to 2.48	2.62 to 2.25	0.07	2.62	2.69
12	0.07 to 0.15	2.5 to 2.34	2.63 to 2.34	0.07 to 0.1	2.54 to 2.48	2.55				0.4	2.98	2.8			

GRAPH #25
SWELLING OF GLUTEN IN ACID
NORMALITY
GMS H2O PER GM. GLUTEN
20°C
35°C
30°C
25°C
20°C
12hr
8hr
5hr
2hr
1hr
30 min
15 min
10 min
5 min
0 min

GRAPH #26
Gas H2O per Gm Gluten
Dry Gluten
Scale
Normality


SWELLING OF GLUTEN
IN
LACTIC ACID
GRAPH #37
35°C
12 hr.
8 hr.
5 hr.
2 hr.
1 hr.
40°C
8 hr.
5 hr.
2 hr.
1 hr.
DRY GLUTEN
DRY GLUTEN
CMS H2O PER GM GLUTEN
0.4 cc
0.3 cc
0.2 cc
0.1 cc
0.0 cc
Scale 1 = 1 cm
0
0.05
0.1
0.15
0.2
0.04
0.1
0.15
0.2
NORMALITY

(4) Swelling of Wet and Dry Gluten in Acetic Acid.

Acetic acid is like the rest of the organic acids of this class. The optimum is very broad and in some cases the maximum has not been reached in the concentrations studied. But a comparison of the points of inflection of the curves shows that as with the other acids, the dry gluten tends to approach its maximum swelling in the same strength of solution required by the wet gluten.

TABLE XIV.

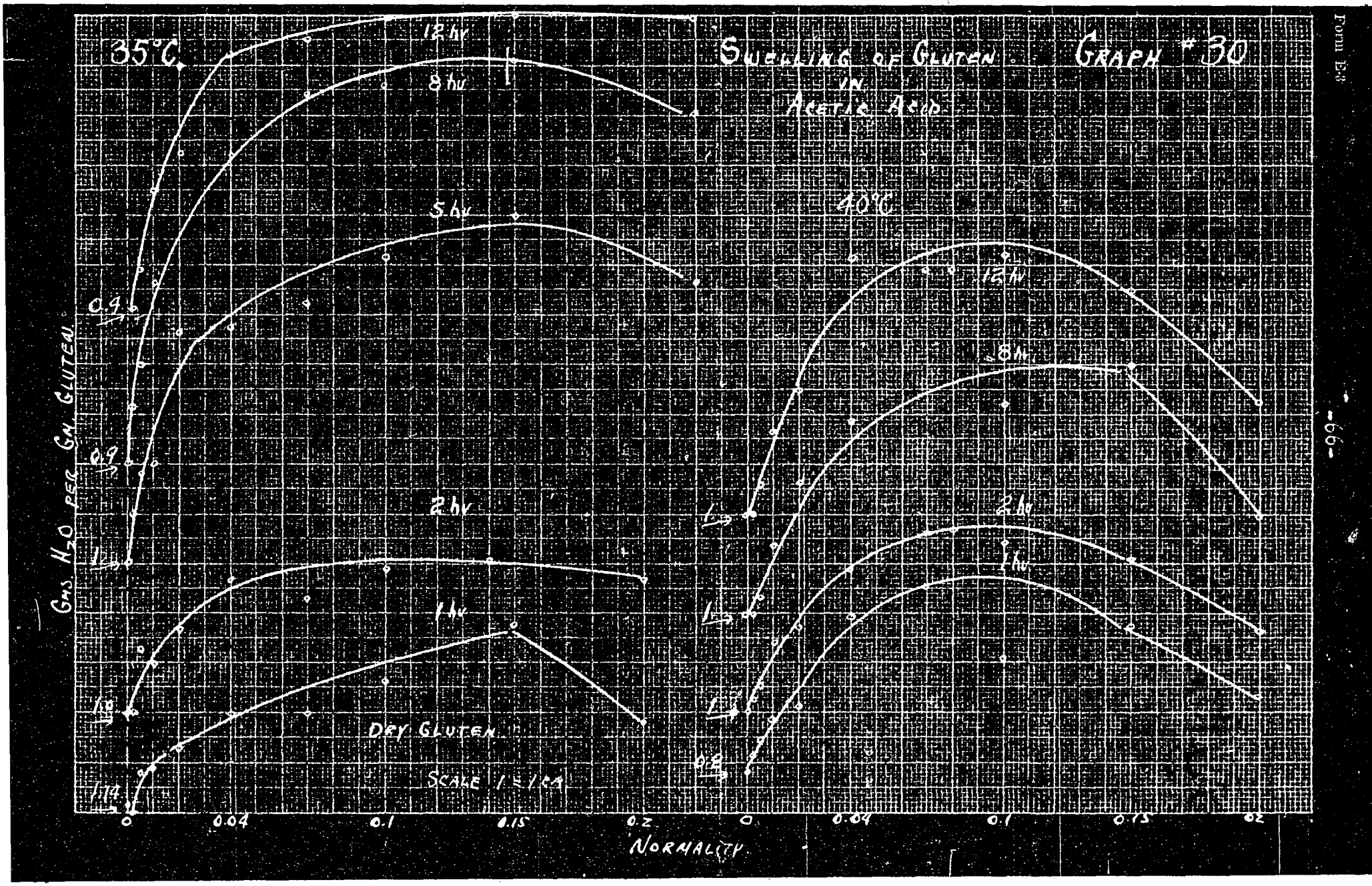
THE pH AND NORMALITIES OF ACETIC ACID REQUIRED TO PRODUCE MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.01			0.02 to 0.15	3.16 to 2.74		0.02 to 0.1	3.10 to 2.81		0.02 to 0.2	3.20 to 2.64		0.07 to 0.2	2.88 to 2.0	
							DRY GLUTEN								
1	No Optimum			0.15 to 0.2	2.72 to 2.64	2.96 to 2.76	0.1 to 0.2	2.81 to 2.67	3.0 to 2.87	0.15	2.78	2.86	0.07 to 0.1	2.88 to 2.87	2.98 to 3.06
2	"	"		0.07 to 0.2	2.88 to 2.64	3.3 to 2.84	0.1 to 0.2	2.81 to 2.67	3.16 to 2.88	0.04 to 0.02	3.0 to 2.64	3.10 to 2.76	0.07 to 0.1	2.88 to 2.87	3.0 to 3.02
5	"	"		0.07 to 0.2	2.88 to 2.64	2.9 to 2.62	0.1 to 0.2	2.81 to 2.67	3.16 to 2.52	0.15	2.78	2.88			
8	"	"		0.1 to 0.15	2.84 to 2.72	1.34 to 2.68	0.1	2.81	3.0	0.15	2.78	2.65	0.1 to 0.15	2.87 to 2.76	3.15 to 2.88
12	"	"		0.07	2.88	2.88	0.1	2.81	2.88	0.1 to 0.2	2.87 to 2.64	2.90 to 2.76	0.04 to 0.1	3.09 to 2.84	3.24 to 2.57

GRAM # 28
SWELLING OF GLUTEN IN ACETIC ACID
NORMALITY
WET GLUTEN
GMS. H2O PER GM GLUTEN
40°C
35°C
30°C
25°C
20°C
0.2
0.15
0.1
0.04
0
0.2
0.15
0.04
0.04
0

GRAPH 229
SWELLING OF GLUTEN IN Acetic Acid
25°C
30°C
12 hr
8 hr
6 hr
4 hr
2 hr
1 hr
DRY GLUTEN
SCALE 1/24
NORMALITY.
Gms H2O per Gm GLUTEN


Swelling of Gluten in Acetic Acid
Graph # 30
35°C
40°C
12 hr
8 hr
5 hr
2 hr
1 hr
½ hr
Gms H2O per Gm Gluten
Dry Gluten
Scale 1 = 1 cm
Normality
0
0.04
0.1
0.15
0.2
0.9
1.0
1.1

Form B-3

C. Swelling of Wet and Dry Gluten in Sulfuric Acid.

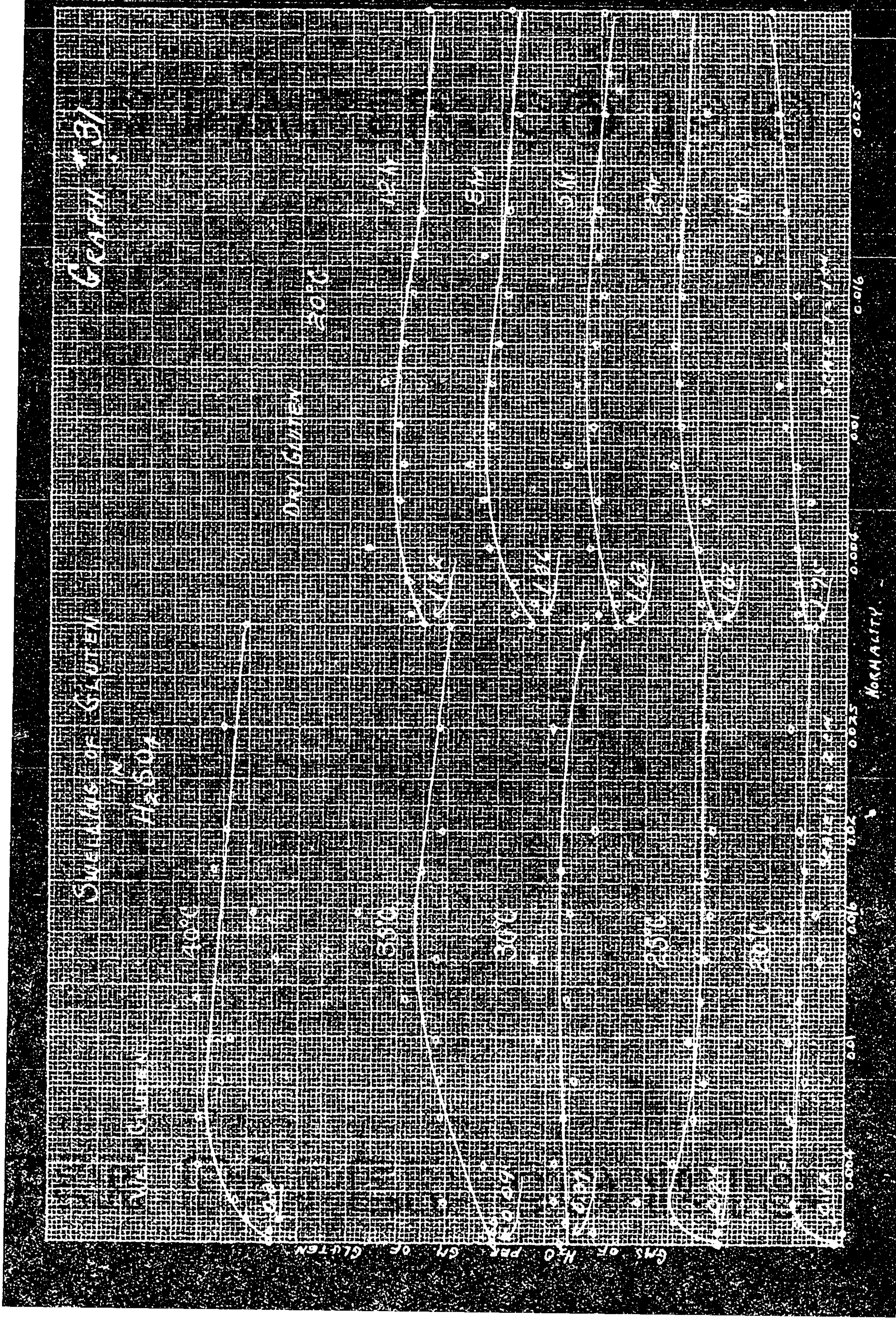
The results on the swelling of wet and dry gluten in sulfuric , as shown in table 14 and graphs 28, 29, and 30 are very irregular. The gluten imbibed so little water that the errors have became so large as to make it difficult to draw any definite conclusions. From the data given however, one is fairly safe in saying that dry gluten will exhibit the same kind of swelling as wet gluten provided it is allowed enough time.

TABLE XV.

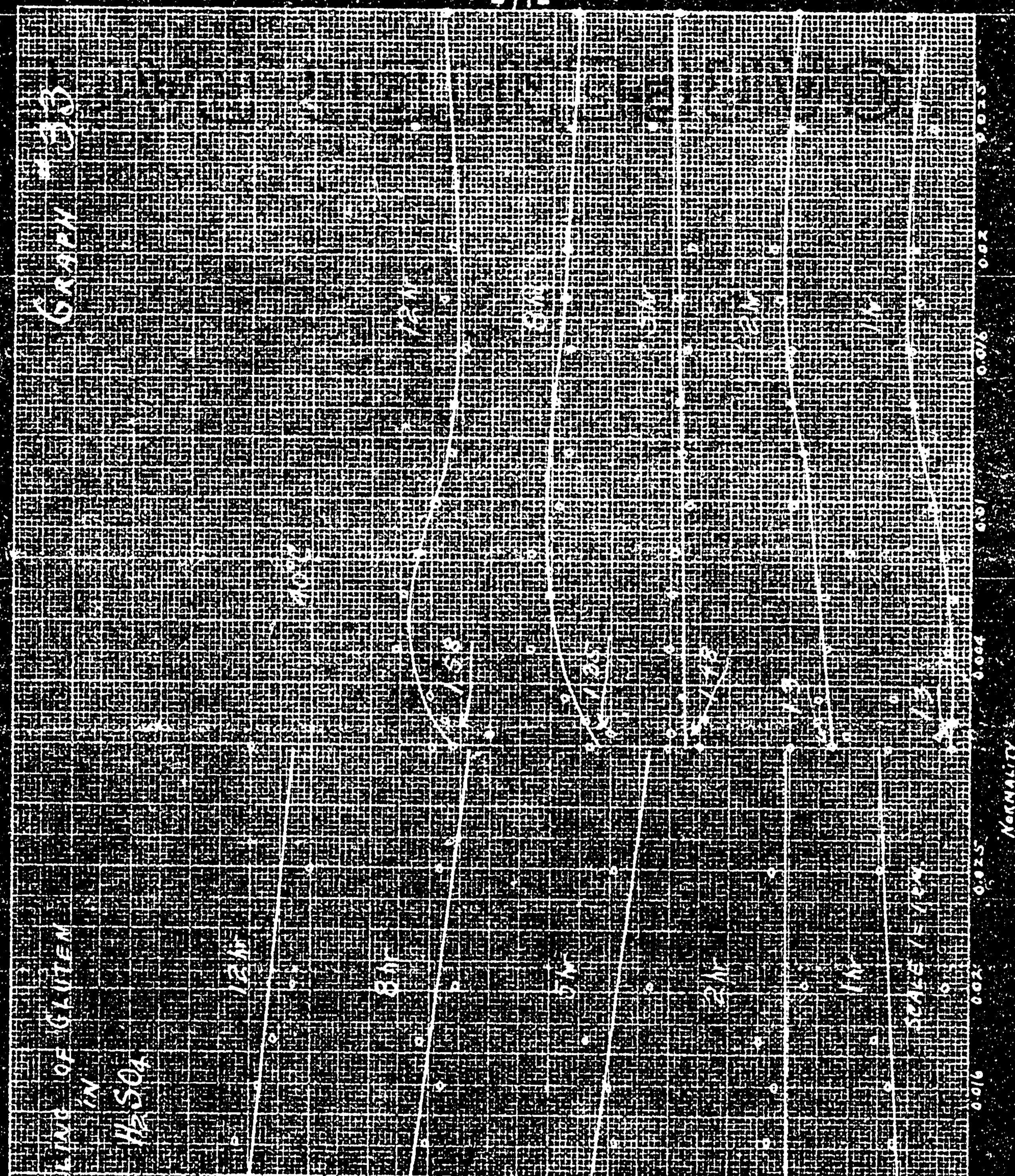
THE pH AND NORMALITIES OF SULFURIC ACID REQUIRED FOR MAXIMUM SWELLING OF GLUTEN AT VARIOUS TIMES AND TEMPERATURES.

pH_1 is initial pH.
pH_2 is final pH.

Time Hrs.	20° C. N	20° C. pH_1	20° C. pH_2	25° C. N	25° C. pH_1	25° C. pH_2	30° C. N	30° C. pH_1	30° C. pH_2	35° C. N	35° C. pH_1	35° C. pH_2	40° C. N	40° C. pH_1	40° C. pH_2
							WET GLUTEN								
1	0.002	3.47		0.001 to 0.002	3.12 to 2.81		0.002	2.83		0.012 to 0.018	2.3 to 2.12		0.004 to 0.006	2.45 to 2.35	
							DRY GLUTEN								
1	No Optimum			No Optimum			No Optimum			No Optimum			0.014	2.04	2.71
2	"	"		0.006 to 0.016	2.37 to 2.0	2.5 to 2.12	0.002	2.83	3.22	0.006	2.42	3.22	0.01	2.17	2.2
5	0.008	2.85	3.0	0.006 to 0.02	2.37 to 1.94	2.62 to 2.06	0.002	2.83	3.32	0.006 to 0.008	2.42 to 2.36	2.72 to 2.52	No Optimum		
8	0.008	2.85	2.45	0.004 to 0.01	2.55 to 2.16	2.85 to 2.3	0.004 to 0.01	2.53 to 2.16	2.83 to 2.3	0.004 to 0.008	2.65 to 2.36	2.79 to 2.62	0.004 to 0.008	2.45 to 2.15	2.93 to 2.54
12				0.004 to 0.006	2.55 to 2.37	2.95 to 2.63	0.004 to 0.006	2.53 to 2.35	3.0 to 2.63	0.004	2.65	2.61	0.004 to 0.008	2.45 to 2.15	2.87 to 2.35
24	0.004 to 0.006	3.1 to 2.96	3.31 to 3.03	0.004 to 0.006	2.55 to 2.37	2.3 to 2.25	0.004 to 0.006	2.53 to 2.35	3.4	0.006	2.42	3.94			
36	0.004 to 0.006	3.1 to 2.96	3.4 to 3.92	0.004 to 0.006	2.55 to 2.37	3.57 to 3.57	0.004 to 0.006	2.53 to 2.35	3.0	0.006	2.42	2.42	0.004 to 0.006	2.45	2.63


Swelling of Gluten
in
H_2SO_4
Graph #31
Wet Gluten
40°C
35°C
30°C
25°C
20°C
Dry Gluten
20°C
12N
8N
5N
2N
1N
Gms of H_2O per gm. of gluten
Normality
0.004
0.01
0.016
0.02
0.025
0.004
0.01
0.016
0.025

GRAPH PAPER
Form E-3
GMS OF H_2O PER GM OF GLUTEN
NORMALITY
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050


GRAPH #33
SWELLING OF GLUTEN IN H2SO4
35°C
40°C
NORMALITY
GMS. H2O PER GM OF GLUTEN
SCALE 1-1CM

VI SUMMARY.

1. A study has been made of the effect of nine acids upon the swelling of wet and dry gluten at several temperatures.

2. The acids studied may be divided into two groups, those which exhibit a broad, and those which exhibit a rather sharp optimum in the swelling of gluten.

3. Wet gluten swells very rapidly, while dry gluten swells rather slowly. Dry gluten, given enough time, will swell most in the concentration of acid causing maximum swelling of wet gluten.

4. With increase in time smaller concentrations of acid have the same effect on the swelling of dry gluten, that higher concentrations have in shorter periods of time, until an equilibrium is reached.

5. The temperature effect varies with the acid. Temperature, except in the case of phosphoric acid, does not change the concentration of acid required to produce maximum swelling after a given time. With phosphoric acid a greater concentration of acid is required to produce maximum swelling at 40° C than at 20° C.

6. With increase in temperature there is a pronounced increase in the rate of swelling.

7. The pH required to produce maximum swelling varies

with the acids.

For HNO_3	it varies from	2.0--2.8
" HCL	" " " " "	1.7--2.45
" Oxalic Acid	" " " " "	1.9--2.45
" H_3PO_4	" " " " "	1.9--2.37
" Tartaric	" " " "	2.35-3.16
" Citric	" " " "	2.43-3.24
" Lactic	" " " "	2.4--2.96
" Acetic	" " " "	2.72-3.20

VII. CONCLUSIONS.

Rise in temperature increases the rate of swelling of the gluten in acid, altho it does not have an appreciable effect upon the pH of the acid required to produce maximum swelling.

The swelling of wet gluten is very rapid.

The swelling of dry gluten is slow, but in time the swelling of dry gluten is like the swelling of wet gluten. The dry gluten has not been changed in the process of drying. Altho, as other investigations have shown, it does not have the same consistency of wet gluten, the swelling curve of wet and dry gluten with time are identical.

VIII. BIBLIOGRAPHY.

1. Alsberg, Colloidal Chemistry of the Cereals.

Bogue's, Theory and Application of Colloidal Behavior, Vol. II. Application of Colloidal Behavior, 1st Edition. McGraw-Hill Book Company, 1924.

2. Balland.

J. Pharm. Chem. Series S; 8, 501, 1883.

3. Chick and Lubizynska.

Bio. Chem. Jour. 8; 59-69.

4. Fulmer, Nelson and Sherwood.

Jour. Am. Chem. Soc. 43; 191, 1921.

5. Fulmer, Nelson and Sherwood.

Jour. Ind. & Eng. Chem. 16; 921, 1924.

6. Freundlich.

Kopillarchemie, page 504. Leipzig, Akademische Verlags-Gesellschaft, m. b. H., 1909.

7. Gortner and Doherty.

Jour. Agr. Res. 13; 389-418.

8. Gortner and Sharp.

Jour. Physical Chem. 27; 567-576, 1923.

9. Haubeniesser and Schonfeld.

Arch. exp. Path. u Pharm. 71; 102, 1913.

10. Hoffman and Gortner.

Physico Chemical Studies on Proteins, page 209-368; Colloid Symposium Monograph, Vol. II. Chemical Catalog Company, 1925.

11. Hofmeister.

Arch. exp. Path. Pharm. 27; 295-413, 1890.

12. Ilün.

Pflüger's Arch. 197; 257, 1922.

13. Leurs and Schneider.

Kolloid Z. 1-4, 1921.

14. Lichwitz and Renner.

Z. Physiologische Chemie 92; 104.

15. Sharp and Gortner.

Jour. Phys. Chem. 26; 101, 1922.

16. Upson and Calvin.

Jour. Am. Chem. Soc. 37; 1295-1304, 1915.

17. Upson and Calvin.

Nebr. Agr. Exp. Sta. Research Bul. No. 8.

18. Wachman, Henderson, Cohn, Cathcart, and Fenn.

Jour. Gen. Physiology 1; 459-72, 1919.

19. Wood.

Jour. Agr. Sci. 2; 139-160, 1907.

20. Wood.

Jour. Agr. Sci. 2; 267-277, 1907.

21. Wood and Hardy.

Proc. Roy. Soc. London (B) 81; 38-43, 1908.