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An Experimental Study to Determine the Effect of Frequent Testing on Mastery of Chemistry Content

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AN EXPERIMENTAL STUDY TO DETERMINE THE EFFECT OF FREQUENT TESTING ON MASTERY OF CHEMISTRY CONTENT

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by

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CHAPTER I

THE PROBLEM

The purpose of this study was to determine the effect upon a student's knowledge of chemistry resulting from participation in a program where quizzes were given regularly over all assigned work as an integral part of a course in beginning high school chemistry.

Importance of the study. The "daily quiz" is often employed as a means of insuring student coverage of assigned work, particularly reading assignments, the assumption apparently being that the desire for a competent test performance will serve to motivate the student to prepare himself. Particularly would this be so, and such was the case in those instances of which the writer has first-hand knowledge, where the results are recorded and serve as one evaluative tool for a term's work.

Some teachers state that these tests result in the students being better prepared for discussions. Remarks not infrequently heard were to the effect that "it is the only way I can get them to study," and "I give a daily quiz because others do, and, if I don't,

my students neglect this class to prepare for those who do quiz."

The general feeling, among those who employ this device, is that quizzes serve to "keep the students on their toes" by requiring them to make daily and more thorough preparations.

Studies have been made to evaluate programs and procedures where tests were used to aid students in studying for subsequent examinations. These studies involve a variety of applications of the quiz technique.

Although agreement was general that the quiz technique helped, there was found no experimental research work to validate an assumption that a positive correlation exists between the use of a frequent testing program and an understanding or retention of course content.

This study was then directed toward finding out whether such a correlation does exist.

CHAPTER II

REVIEW OF THE LITERATURE

Use of the quiz as a guide or instrument in subject matter preparation has not been extensively examined. Little research work has been published relative to the use of frequent testing as a tool for increasing understanding of a subject area.

The value of previous questions. Holmes equated one hundred and seventy college students into two groups, and presented them with reading material concerning science and the history of English literature. Both had specific instructions as to how to proceed with the study time made available. One group had a list of twenty questions, and their reading amounted to finding answers for each subsequent question. The other group was told to read carefully and re-read if sufficient time was available.

Testing for immediate recall occurred following the close of the study period, and for delayed recall the test was given two weeks later. In each case the same test, which included the twenty study questions given the one group plus twenty supplemental and different questions for a total of forty, was used.

Reading guided by questions was found to be significantly

superior to careful reading and re-reading in both immediate and delayed recall of those questions used in the study.[1] This holds true for questions dealing with both subject areas.

Reading guided by questions was found to be significantly superior to reading and re-reading for delayed recall of all material of both types.[2]

Holmes concluded that the superiority evidenced by the students given the questions was the result of the procedure making possible better organization of the work without the student having to first take time to ascertain the most important points.

Three types of pre-examination material. Jersild experimented with true-false questions, multiple-choice questions, and an essay form, which contained the essential points or facts, as learning aids. The aids were given in conjunction with assigned readings in psychology.

Results, from subsequent tests over the assigned material, established the usefulness of the multiple-choice and essay-type

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[1]Eleanor Holmes, "Reading Guided by Questions versus Careful Reading and Re-reading Without Questions," School Review, 39:370, May, 1931.

[2]Ibid., p. 365.

pre-examinations. Of these two, the multiple-choice type was superior, and resulted in the most effective learning during the period of pre-examination.[3]

The author questions the use of true-false questions as learning aids. There was an apparent reverse effect when the group, which had no questions, actually scored higher than the group which had them.[4]

In the opinion of the author, the categorical nature of the true-false question serves to emphasize the response, be it right or wrong. This type of question was also criticized on the grounds that it made little demand on the student to organize his knowledge.

Literature on the best time for questions. Another experiment relates indirectly to this study of frequent testing. The experiment, by Washburne, attempted to determine the best time for presentation of questions relative to assigned readings. One group had all the questions listed at the beginning of the entire article, another had the questions pertaining to each section at the beginning of that section of the article, and a third had the questions at the end

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[3]Arthur T. Jersild, "Examination As An Aid to Learning," Journal of Educational Psychology, 20:607, November, 1929.

[4]Ibid.

of each section. The fourth group had questions at the end of the entire article, and the fifth group had no questions at all.

The two most effective procedures were those where the questions appeared at the beginning of the article or at the beginning of the sections, and, of these two, placement at the beginning of the article was the better. This placement was reliably superior in the area of factual recall and the ability to generalize. Placement of the questions before the article didn't, as was true in the case of the procedures where questions followed the article, serve to inhibit incidental learning or those facts not specifically identified in the questions.[5]

The orientation provided for by the questions preceding the article or section seemingly enabled the students to fit facts not specifically referred to into a more meaningful picture.

A question this writer had concerning this experiment on frequent testing was what tendency would there be for a student to overlook facts not asked for directly by the questions.

True-false questions as study tools. The value of true-false questions as study tools was indicated in a 1938 experiment.

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[5]J. N. Washburne, "The Use of Questions in Social Science Material," Journal of Educational Psychology, 20:355, May, 1929.

Four hundred and fifty college freshmen in an introductory general psychology course were divided into two equated groups and given prior experience with true-false tests. After four such tests had been taken, two special true-false tests were then constructed over the same material and labeled "Test A" and "Test B." Test B was matched question for question as to material covered and difficulty with Test A, but the questions in Test B were worded differently.

All the students of both groups were handed copies of Test A to take home, study, and mark. At the beginning of the period on the following day these tests were collected for scoring, and the instructor commenced to lecture. Both groups were then surprised with subsequent tests. One group, henceforth referred to as Group I in this discussion, received an identical copy of Test A while Group II received Test B. The effect of the change in wording for Test B was shown by a lower Product-moment correlation coefficient for Group II, .290 - .047 as compared with .761 - .016 for Group I.[6] This apparent failure to generalize or really understand the material covered was evidenced by another statistical outcome of the study. Forty-six per cent of Group I scored lower on the surprise test as compared with

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[6]W. N. Kellogg and Bryan Payne, "The True-False Question as an Aid in Studying," Journal of Educational Psychology, 29:588, November, 1938.

89 per cent of Group II students who scored lower.

Using another test, Test C, taken as an average or typical test performance-wise from twelve weekly tests and comparing this test with Test B, there was found a relatively higher average score in Test B by 5.1 per cent of the control average.[7] This was interpreted by Kellogg and Payne as a measure of the benefit to be derived from the practice of using differently worded true-false questions on subsequent tests covering the same material.

Increasing pupil preparation through use of quizzes. A University of Illinois professor of chemistry, Dr. William E. Morrell, discussed an experiment performed by him using quizzes in an attempt to increase the amount of student preparation.

The experiment was a result of the observation that students, in a situation where lecture predominates, will often tend to rely on notes from the instructor and will not prepare themselves by reading material assigned them.

The course was for one hundred college students in chemistry who had had no high school chemistry, or, as determined by tests, remembered little or nothing about the subject. The lecturer supplemented the text but did not attempt to completely cover or

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[7] Ibid., p. 589.

abstract the material pertaining to each assigned reading. The students were informed that they could expect a quiz over the current assignment at the beginning of any lecture period. A total of eight quizzes were given during the course of the semester.

The questions were of a multiple choice variety and covered the material in the previously assigned reading. Some of the questions required very careful study and interpretation of facts. The students had an understanding that the quizzes did not take the place of examinations, but that they would constitute a part of the course evaluation.

In the opinion of Dr. Morrell and his assistants, the twelve to fifteen minutes spent taking and discussing the quizzes in class were well spent, and it was also felt that the quiz scores reflected an increased amount of time devoted to preparation.

The students were of the opinion that the quizzes helped because they had to prepare for them, and this gave them a better background for understanding the lecture to follow. Another suggestion by the students was that the quizzes be given every day to counter a tendency not to prepare in the hope that no quiz would be given.

A further consideration in the matter of time spent administering the quiz program, was a consensus that the instructor could cover material in less time, with adequate student preparation, than

would be given to the program.

The technique has since been adopted by other faculty members of the department who liked the results and have incorporated the procedure as an integral part of the general chemistry program.

CHAPTER III

MATERIALS USED AND GROUPS STUDIED

The daily tests or quizzes. The quizzes used were constructed by the writer and were largely of a multiple choice type in which there could be more than one correct answer. They were designed and constructed to cover what the author considered the essentials of the content in the assigned reading and experiments performed.

It was the intent to so construct the quizzes that more than just looking up the answers would be involved. The emphasis was toward formulating questions which would require the individual to search and reason on the basis of knowledges past and present. As an example using a question from the quizzes:*

II. Nuclear reactions occurring within atomic energy 'piles':

a--give us trans-uranium elements such as americium.
b--involve transmutations resulting in new elements being formed.
c--utilize graphite moderators to speed up neutrons.
d--can be speeded up or slowed down.
e--result in radioactive isotopes being formed which possess chemical properties not different from the properties of the non-radioactive isotopes of the same element.

Aside from an understanding of the terminology required

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*Taken from Appendix A, page 34.

before an intelligent appraisal of the question can be made by the student, there are a number of rather basic learnings therein. With the exception of response "c," all responses are correct, and should have been so marked by the students. Using a correct response, "e," for further example, one of the important functions or uses of atomic piles is the formation of a variety of isotopes which have a wide range of uses. This, of course, would relate to the first part of the response. The remainder of the response deals with a student's knowledge of what is implied in the word isotope. Radioactivity, being a nuclear phenomenon, does not, for all practical purposes, affect the chemical activity of that particular isotope--chemical activity being a function of the valence electrons. This latter point is not dealt with specifically in the immediate area the quiz was given to cover, but had been discussed in previous assignments.

This provides some idea of the nature and purpose of the quizzes, and their intended use. Eighteen quizzes were given during the course of the nine-week experimental period. The general frequency was two or three quizzes a week, although this would vary somewhat depending on the amount of reading assigned, and laboratory experiments performed.

Unit and nine-week tests. Three tests were used to evaluate the frequent testing program. Two of these were tests covering units on nitrogen and carbon chemistry, and the third was a nine-week examination covering the three major areas dealt with during the course of the nine-week period, nuclear, nitrogen, and carbon chemistry.

Some of the questions were taken as written or with slight changes in wording, from various book company test manuals. These questions were carefully selected in accordance with how well they correlated with material presented in class. Other questions were composed by the writer; particularly was this true with those questions having to do with formula writing and problem solving.

Each test contained a maximum of one hundred points. This is an arbitrary total designed to facilitate a comparison between the groups tested, and has no other special significance.

Groups used. The students participating in this study attended a senior high school which serves a city of some 8,000 population plus surrounding rural areas. The total enrollment of the high school is about 525. The school operates a six-period day, each period of fifty-five minutes duration.

Sixty-one students were taking chemistry at the time of the experiment. They were divided into three sections which met during

the second, fourth, and sixth periods.

Two days out of each five were usually set aside as laboratory days. The other three were for lecture, discussion, reports, films, and so forth. Demonstrations, either by the instructor or students, were considered part of the laboratory procedure. The quizzes were usually not given on the day the students had laboratory since the full time was needed.

Parallel-group technique. The parallel group technique was employed, the grouping accomplished on the basis of (1) the grade point average, and (2) the Inductive Reasoning scores. The grade point average was arrived at by assigning a numerical value to the grades received during the previous year's work as follows: A - 4, B - 3, C - 2, D - 1, X - 0.

Inductive reasoning scores, as evidence of one's ability to discover and relate underlying principles, was considered a significant factor in equating the two groups. The raw scores were converted to percentile rank scores for purpose of equating.

Selection of groups. The fourth section was selected as the experimental group. Their grade point averages and inductive reasoning scores were then totalled.

The control group was established by selecting, from the

other two sections, twenty students whose total grade point average and inductive reasoning scores were the same or nearly the same as was that of the experimental group. Equating, then, was not accomplished on the basis of an individual for individual comparison, but rather on a total basis.

The mean grade point average for the experimental group was 2.895 as compared with 2.885 for the control group. The mean inductive reasoning scores for the experimental and control groups were 84.54 and 84.51 respectively. The variance in either case was not significant.

The only considerations given in selection of the control group, other than arriving at two groups whose total scores were close to the same, were to have about the same number of seniors and girls as did the experimental section. When the groups were finally established, there were six seniors in both. Five members of the experimental group and three of the control group were girls. Each group finally contained fourteen juniors and six seniors.

There was no attempt to equate youngsters on the basis of past experiences relative to courses having been taken or being taken at the time the experiment was conducted. The final composition of the groups evidenced no apparent advantage to either group in this matter.

CHAPTER IV

EXPERIMENTAL PROCEDURES

Throughout the experiment every effort was made to employ the same teaching procedures with both groups, and thus to make the frequent testing program the only variable.

Administering the quizzes. The quizzes were handed to the students who were then able to take them home for study. On the following day, during the first part of the class period, a newly prepared and re-arranged copy of the test was distributed. The sequence of both the questions and the responses was altered from the take-home test to help forestall memorization, but there was no change in the context or wording of the questions.

Approximately three minutes were allowed, following distribution of the quizzes, for the answers to be marked. This was accomplished by simply encircling the correct response or responses. Following their collection the take-home copies were then used to review and discuss the principles involved. The take-home copies were then collected so that no copies of either quiz were left in the hands of the student. This precaution was taken to minimize, as much

as possible, the chance of control group students using the quizzes as study material.

Scoring and disposition of the quizzes. When the testing program was first presented to the students, they were given an opportunity to express themselves as to the disposition of their scores on the individual quizzes. Their choice was to have them count toward their course evaluation, but to what extent this should be so was not established. It was simply left that the quiz grades would be a factor in their final grade.

Correction was done by the writer, the score being figured by subtracting the number wrong (those not marked were also counted wrong) from the total possible points. The total possible points on any test was one hundred. Whenever requested, the scores were made available to the students although the review following each quiz was usually sufficient for one to determine his performance.

Administering the three tests used to evaluate the program of frequent testing. These tests were administered during the time of the regular class period and followed immediately the completion of the unit of chemistry involved. The entire class period of fifty-five minutes was available.

The largest section contained 24 students, and the room was of sufficient size to permit a distribution of students such that the

possibility of cheating was reduced to a minimum.

Scoring the three tests. No special scoring formula was employed; the total score represented the number of points received out of a possible one hundred. Any questions left out were counted as wrong and also resulted in a subtraction from the total points possible. The tests were corrected by the writer, and points were totalled on the basis as shown for the sample tests in the appendix.*

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*Appendix B, page 54.

CHAPTER V

RESULTS

Tests and examination statistics. The most significant results of this experimental study were to be interpreted on the basis of the comparative scores for the two groups from the three main evaluative instruments. These were the two unit tests over nitrogen and carbon chemistry and the nine-weeks examination over all work covered during the experimental period.

Comparative data for the three instruments can be noted in Table I; Table II, page 22; and Table III, page 23.

As can be noted in Table I, the experimental group scored higher on the Nitrogen test, but not significantly so. Table II shows a higher mean score for the control group--this, too, lacks significance.

The greatest difference, and one favoring the experimental group, occurred on the nine-weeks examination, and is shown in Table III. The difference was 7.19 per cent of the control average.

As shown in Table III, the critical ratio for the nine-week examination was found not to be significant at the 5 per cent level of confidence.

Further study of the formula used in deriving the critical ratio shows that if everything else remained constant, a sample size of 52 students would be required to give a critical ratio of 2.02 which would be significant at the 5 per cent level of confidence.

TABLE I

MEAN SCORES AND STANDARD DEVIATIONS
FROM THE NITROGEN TEST
FOR THE EXPERIMENTAL AND CONTROL GROUPS

Group	Number of Students	$\bar{x}$	s
Experimental	20	59.400	15.256
Control	20	57.950	16.004

TABLE II

MEAN SCORES AND STANDARD DEVIATIONS
FROM THE CARBON TEST
FOR THE EXPERIMENTAL AND CONTROL GROUPS

Group	Number of Students	$\bar{x}$	s
Experimental	20	71.950	14.665
Control	20	73.000	14.441

TABLE III

MEAN SCORES, STANDARD DEVIATIONS, DIFFERENCE, STANDARD ERROR OF THE DIFFERENCE, AND CRITICAL RATIO FROM THE NINE WEEKS EXAMINATION FOR THE EXPERIMENTAL AND CONTROL GROUPS

Group	N	$\bar{x}$	s	Difference	s Difference	C.R.
Experimental	20	68.60	10.58	4.60	3.73	1.23
Control	20	64.00	12.36			

CHAPTER VI

SUMMARY AND CONCLUSIONS

On the basis of the statistics. Statistically, the results do not support a conclusion that the frequent testing program was effective in terms of consistently and significantly better test performance.

There are several factors important to consider relative to the inconclusive nature of the results.

With the small size of the sample--twenty students comprising the experimental group--unexpectedly poor performances on the part of just a few or even one student could considerably affect the outcome. This was true in the case of several students who dropped sharply and for no apparent reason from their usual performance level.

Student use of the quizzes. It was rather obvious that the quizzes were not always utilized in the way intended. While some gave evidence of careful study in regard to them, others relied on the few minutes available prior to the class period to attempt getting the answers, thus losing one of the purposes of the question sheets--that of guiding the student to doing some reasoning on his own. Not having

benefited by searching out and understanding the main principles involved in the questions, the students may have had little or no carry-over when final tests were given. Those students that were generally "good" students were usually well prepared, and lesser degrees of preparation characterized the other students.

Acceptance of the procedure by the students as a factor in the outcome. The time consumed by the student in preparing himself for the quiz posed a problem. Most of the students had rather heavy obligations to other classes. Their concern that the quizzes would be in addition to their regular assignments was lessened when it was pointed out that anyone really interested in getting the essential facts could use the quiz as a guide with the possibility that time required for preparation would actually be shortened. The students expressed general acceptance since they would be able to take the quiz home for study on the day prior to taking a copy of the quiz under test conditions which would count toward their nine-weeks grade.

Values incidental or indirectly accrued. An average of two hours was needed to construct each quiz. The search for the last of the possible responses in a given question can become quite a profitable project in itself. The result was that the writer, who was teaching his first chemistry classes, may well have been better

prepared than he would have been otherwise.

There were occasions where quiz questions proved deficient for one reason or another. An interesting result of this was the enthusiasm evidenced by students well enough versed to discuss or challenge the correctness of the question.

A further aspect of this experiment with frequent testing could have contributed to the inconclusive nature of the results obtained. In working so closely with the material and noting the degree to which it was understood, as indicated by performance on the quizzes, one could not help but recognize areas needing more emphasis or clarification. A result could have been more thorough coverage with resultant benefit to members of both groups.

A consideration for future work. Even after the present research, it still is not known whether frequent testing increases the students' efficiency in learning chemistry. If everything else remained equal, calculations show minimum samples of 52 students, or 104 students altogether, would have been required for the results to be significant. This would have been 43 more students than the combined enrollment of all three classes.

It is probable that such an investigation in a larger school with more students enrolled in chemistry might answer the question of whether frequent testing aids in the mastery of high school chemistry.

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APPENDIX A

Quizzes

I. PERIODIC CHART AND RADIOACTIVITY

Directions: Encircle the letter of the correct response or responses.

1. The Periodic Chart
   a. is a very valuable and useful chemical tool.
   b. is an orderly arrangement of elements according to atomic weights.
   c. exists today largely through the effort and genius of Mendeleef.
   d. agrees in detail with the displacement series.
   e. is completed.

2. Some generalizations that can be drawn from the position of the elements in the periodic chart are:
   a. chemical activity determines the position of the element on the chart.
   b. acid formers are at the left of the table or chart.
   c. the "rare earth" elements are chemically similar.
   d. hydrogen acts like a metal.
   e. periodicity is a function of the nucleus.

3. The Periodic Chart can be used to:
   a. write formulas.
   b. predict physical and chemical properties of elements suspected to exist but not yet discovered.
   c. lessen the need for memorization.
   d. figure the number of isotopes each element has.

4. The study of radioactivity:
   a. involves particles, all of which exhibit an electrical charge either plus or minus.
   b. was facilitated by such men as Crookes, Thompson, and Roentgen.
   c. has been aided by accidents.
   d. really began in earnest when American scientists began working on the production of an atom bomb.
   e. received an enormous contribution from the work of Madame Curie in the isolation of radium.

5. Radioactivity:
   a. can discharge an electroscope.
   b. of an element consists largely of electron exchange.
   c. can result from the bombardment of the nuclei of certain elements or atoms with such "bullets" as neutrons, deuterons, and protons.
   d. is not a "natural process."
   e. indicates stability.

II. THE PERIODIC CHART

Directions: Encircle the letter of the correct response or responses.

1. An atom with a mass number of 24 and an atomic number of 12:
   a. would be found in group I.
   b. would possess an electron configuration of 2 - 8 - 2.
   c. would possess more protons than neutrons.
   d. would unite atom for atom with a member of group VI.
   e. would be an acid former.

2. An atom with an atomic number of 17 and a mass number of 35:
   a. would most likely exhibit a + 7 valence.
   b. would likely be highly electronegative.
   c. would be an isotope of any element with a mass number of 35.
   d. would likely be an acid former.
   e. would unite eagerly with an electron donor.

*3. An atom (X) with a mass number of 27 and an atomic number of 14:
   a. would likely form the compound X_2O_3.
   b. is less likely to be amphoteric than a member of Group II.
   c. could theoretically have an isotope with a mass number of 30 and possess 16 electrons.
   d. could not exist since we don't find it on the chart.
   e. forms compounds by electrovalence.

4. Some generalizations to be drawn from the periodic chart would be that:
   a. the number of non-metals far exceeds the number of metals.
   b. chemical activity increases with increasing mass.
   c. all elements have been found.
   d. as you proceed to the right from sodium, the acid forming capacity of the elements increases.
   e. the formula of a compound containing Sn, C, and O could be $Sn(CO_3)_2$.

*There are no correct responses for 3.

III. RADIOACTIVITY

Directions: Encircle the letter of the correct response or responses.

1. Electrons emitted as a result of transmutation:
   a. serve to decrease the mass of an atom.
   b. cause the atomic number to decrease.
   c. probably come from decomposed protons.
   d. are called alpha particles.
   e. are apparently the result of neutron disintegration.

2. Alpha particles:
   a. have an atomic weight of four and have a + 4 charge.
   b. when spontaneously emitted during natural transmutation decrease the mass of an atom by four units and the atomic number by 2.
   c. possess tremendous penetrating powers.
   d. are helium nuclei.
   e. travel at a speed approximately one tenth the speed of light.

3. During transmutation:
   a. there appears to be a general movement toward stability.
   b. that is artificial, the speed of the "bullet" is of considerable importance.
   c. particles emitted can themselves cause further transmutations.
   d. the weight of the subsequent isotope is less.
   e. that is artificial, deuterons are usually emitted.

4. Nuclear energy:
   a. results from activity within the planetary electrons.
   b. seems to be the result of mass being converted to energy.
   c. available can be predicted from the formula $E = mc^2$.
   d. is available to us largely through the mathematical genius of Albert Einstein.
   e. derived from an exploding A-bomb is a result of the conversion of the total mass of the bomb to energy.

5. During nuclear fission:
   a. two new atoms, whose combined mass exactly equals the mass of the "parent" atom, are formed.
   b. the old version of the "Law of Conservation of Matter" holds true.
   c. various isotopes of lead result.
   d. chain reactions always occur.
   e. radioactive isotopes sometimes result or nearly always result.

IV. RADIOACTIVITY AND TRANSMUTATION

Directions: Encircle the letter of the correct response or responses.

1. In the atomic pile:
   a. control rods serve to absorb neutrons thus reducing the number of neutrons which could cause fission.
   b. $_{92}U^{238}$ is transmuted to the fissionable $_{92}U^{235}$.
   c. only fission occurs.
   d. two isotopes of uranium cannot be used simultaneously.
   e. an uncontrolled fission reaction occurs.

2. Nuclear reactions occurring within atomic energy "piles":
   a. give us trans-uranium elements such as americium.
   b. involve transmutations resulting in new elements being formed.
   c. utilize graphite moderators to speed up neutrons.
   d. can be speeded up or slowed down.
   e. result in radioactive isotopes being formed which possess chemical properties not different from the properties of the non-radioactive isotopes of the same element.

3. The nuclear reaction, $_{7}N^{14} + {}_{2}He^{4} \dashrightarrow {}_{8}O^{17} + {}_{1}H^{1}$:
   a. is an example of fission.
   b. produces a molecule of hydrogen.
   c. involves an alpha particle whose mass is 4.
   d. produces a common isotope of oxygen.
   e. shows nitrogen with an atomic number of 14.

4. The equation for the transmutation of nitrogen by cosmic ray neutrons, $_{7}N^{14} + {}_{0}n^{1} \dashrightarrow {}_{6}C^{14} + {}_{1}H^{1}$:
   a. shows the close relationship between the mass of an atom and its chemical nature or name.
   b. produces a useful type of "clock."
   c. is entirely man-caused.
   d. accounts for all the material.
   e. would indicate that a beta particle is emitted.

V. NITROGEN

Directions: Encircle the letter of the correct response or responses.

1. Free nitrogen:
   a. would be found as N_2.
   b. is found in Chile saltpeter.
   c. comprises nearly half the air we breathe.
   d. can be obtained by burning phosphorus in an inverted jar placed over water.
   e. is used by plants as a food.

2. The production of nitrogen:
   a. is facilitated by its boiling point being lower than that of oxygen.
   b. is made difficult by its extreme activity.
   c. by fractional distillation results in chemically pure nitrogen.
   d. compounds by bacteria is known as fixation.
   e. compounds is usually highly exothermic.

3. Nitrogen:
   a. has chemical properties very similar to those of oxygen.
   b. is "fixed" by legumes.
   c. compounds are present in all rich soils.
   d. combines readily with hot copper.
   e. has the same general physical properties as "air."

4. The formula equation $NH_4Cl + NaNO_2 \dashrightarrow NaCl + 2H_2O + N_2$:
   a. is one of an endothermic decomposition reaction.
   b. indicates that 107 grams of NH_4Cl would produce 28 liters of nitrogen.
   c. indicates that 44.8 moles of water vapor are formed.
   d. uses Chile saltpeter.
   e. is one for a laboratory preparation of nitrogen.

5. Chemical properties of nitrogen:
   a. include its slightly greater density as compared to air.
   b. could be predicted from its position in group V.
   c. compounds are sometimes evidenced in extreme instability.
   d. are evidenced by: $_7N^{14} + {}_2He^4 \dashrightarrow {}_8O^{17} + {}_1H^1$.
   e. relating to its combining capacity are shown by the equation: $Ne + Cl \dashrightarrow NeCl_5$.

VI. AMMONIA

Directions: Encircle the letter of the correct response or responses.

1. The preparation of ammonia:
   a. was successfully accomplished by alchemists who named it "Spirits of Hartshorn."
   b. is accomplished by bacterial decomposition of proteins.
   c. involves water displacement as a means of collection.
   d. is evident near manure piles.
   e. is closely associated with the German chemist, Haber.

2. The reactions, $2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_4OH \downarrow 2NH_3 + 2H_2O$

   and

   $(NH_4)_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2NH_4OH \downarrow 2NH_3 + 2H_2O$:
   a. both produce 22.4 liters of NH_3 when 2 moles of the ammonium salt are used.
   b. point out the stability of ammonium hydroxide.
   c. are "redox" (reduction-oxidation) type reactions.
   d. are double displacement reactions.
   e. are examples of a chemical principle that any ammonium salt $(NH_4)^+$ will react with any active base $(OH)^-$ to form ammonium hydroxide which by decomposition forms ammonia.

3. The Haber process:
   a. obtains ammonia by destructive distillation of coal.
   b. was an enormous contribution to Germany's plans for military conquest.
   c. combines "free" N with hydrogen.
   d. is an American contribution to the field of chemistry.
   e. has undergone some modificationssince its discovery.

4. The reaction, $N_2 + 3H_2 \rightarrow 2NH_3 +$ heat:
   a. indicates the attainment of a state of equilibrium.
   b. Would be shifted to the left upon application of pressure according to Le Chatelier's principle.
   c. is somewhat exothermic.
   d. requires a catalyst.
   e. tells us that 22.4 liters of nitrogen is used to provide 22.4 liters of ammonia.

5. Ammonia:
    a. upon changing from a liquid to a gas absorbs heat (the amount required to bring this about is its heat of vaporization) in sufficient quantities to make it usable as a refrigerant.
    b. is very highly soluble in water.
    c. evolution with its subsequent solution in H_2O is the test for any ammonium salt.
    d. forms NH_4Cl in the presence of HCl.
    e. is a base.

VII. EXPERIMENT OVER PREPARATION AND STUDY OF AMMONIA

Directions: Encircle the letter of the correct response or responses.

1. The reaction occurring when NH_4Cl is added to $Ca(OH)_2$, and the reactants heated:
   a. is a typical one for NH_3 preparation.
   b. would be best represented by the formula equation:
      $2NH_4Cl + Ca(OH)_2 \xrightarrow{heat} 2NH_4OH + CaCl_2$.
   c. would be best represented by the formula equation:
      $2NH_4Cl + Ca(OH)_2 \xrightarrow{heat} CaCl_2 + 2NH_4OH \downarrow NH_3 + HOH$
   d. would operate best upon application of pressure.
   e. violates the law of conservation of mass.

2. Conditions which make for success in experiment #42 include:
   a. a knowledge of the relative weight of NH_3 to air.
   b. a source of considerable heat out-put so as to increase the speed of the reaction.
   c. water troughs with the bridges removed.
   d. the solubility of ammonia.
   e. the knowledge of definite procedures to be followed in "sniffing" a gas.

3. The red color obtained upon addition of phenolphthalein to a water solution of the gas obtained:
   a. indicates the presence of the H_3O^+ ion.
   b. is a reaction unique to and confirms the presence of bases.
   c. disappears upon heating because of the instability of NH_4OH.
   d. depends upon the removal of ions.
   e. disappears because water is formed.

4. The basic nature of a water solution of ammonia is indicated by:
   a. $NH_4OH \rightleftharpoons NH_4^+ + OH^-$.
   b. its ability to clean.
   c. its uses as a solvent for certain salts.
   d. the strong odor it possesses.
   e. the fact that it decomposes so readily.

VIII. NITRIC ACID

Directions: Encircle the letter of the correct response or responses.

1. Nitric Acid:
   a. is of considerable importance in the fertilizer industry.
   b. has earned the name "aqua fortis."
   c. has relatively few uses, but those it does have are, of course, very important.
   d. exhibits its relative inactivity by the scarcity of the salts of this acid.
   e. has a boiling point considerable distance above that of H_2SO_4 making for relatively easy separation of the two acids.

2. The reaction: $NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + HNO_3$:
   a. owes at least part of its success to the boiling point differential of the two acids involved.
   b. would produce 63 grams of nitric acid if a mole of H_2SO_4 were used (assuming perfect conditions and no loss of material)
   c. would produce 63 grams of nitric acid if 2N H_2SO_4 (in the same quantities as in "b") were used.
   d. is presently the greatest source of nitric acid.
   e. will go with greatly increased efficiency if carried out at great heat.

3. The Oswalt process:
   a. produces nitric acid in pure but somewhat limited quantities.
   b. includes the reaction $NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$.
   c. includes the reaction $2NO + O_2 \longrightarrow 2NO_2$.
   d. includes the reaction $2HNO_3 + \text{heat} \longrightarrow 2NO_2 + H_2O$.
   e. includes the reaction $3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$.

4. When itric cid enters into chemical activity:
   a. it is very much like other acids when diluted.
   b. it tends toward stability.
   c. it undergoes reduction to form products exhibiting a variety of valences for the element N.
   d. it acts as a very powerful oxidizer--it releases oxygen from itself.
   e. in a dilute form with copper, nitric oxide can be formed.

5. Nitric acid reacts:
    a. with HCL to form aqua regia whose great activity seems to result from the formation of the chloride ion.
    b. with flesh to break down the protein molecules.
    c. with 184 grams of glycerine to form 654 grams of glyceryl trinitrate.
    d. with cellulose to form cellulose nitrate by removing the OH radicals.
    e. (three moles react) with an excess of Ag to form 214 gm of $Ag\ NO_3$ according to the reaction showing how nitric acid behaves in concentrated form.

IX. EXPERIMENT OVER PREPARATION AND STUDY OF NITRIC ACID

Directions: Encircle the letter of any correct response or responses.

1. Precautions to be observed in the execution of this experiment include:
   a. the need for a precise control of temperature so as to avoid having the H_2SO_4 "come over."
   b. the prevention of your contacting the distillate.
   c. the use of a rubber cork in the collection flask to prevent evaporation of the product.
   d. caution as to the manner in which a test tube and contents are heated.
   e. exercising care in testing for a gas upon addition of Cu to HCl.

2. The reaction resulting from the addition of $NaNO_3$ to H_2SO_4:
   a. using the quantities suggested, should give each student (or pair) just slightly over 11 grams of HNO_3.
   b. typifies acid production through use of a cheap NO_3^- source and a source or H^+ ions.
   c. could best be shown by: $2NaNO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + 2HNO_3$
   d. could best be shown by: $NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + HNO_3$.
   e. is a commercial source of HNO_3.

3. Reactions resulting from adding metals to concentrated HNO_3:
   a. include: $Zn + HNO_3 \longrightarrow Zn(NO_3)_2 + H_2$.
   b. are what we might term "typical acid reactions."
   c. are examples of oxidation occurring without reduction.
   d. show the oxidizing properties of HNO_3.
   e. are totally different from reactions of any of the other common mineral acids with metals.

4. Nitrates:
   a. can be tested for by the "brown ring test"--a test which depends upon the solubility of all salts of HNO_3.
   b. are "ate" salts of an "ic" acid.
   c. are present in saltpeter.
   d. of Cu are blue because of the characteristic color of the NO_3^- ion.
   e. contain N possessing a valence of -5.

X. NITRIC ACID

Directions: Answer each problem as asked.

1. Write the series of formula equations (three steps) involved in the Oswalt Process for production of nitric acid via oxidation of ammonia. Show your knowledge of the question relating to full utilization of materials by pointing out the place in the process where this occurs.

2. Write the formula equation for the laboratory process in production of nitric acid.

3. a. Write the formula equation for the reaction of dilute nitric acid on copper.

   b. Write the formula equation for the reaction of concentrated nitric acid on Cu.

XI. NITROGEN FAMILY

Directions: Encircle the letter of the correct response or responses.

1. Members of the nitrogen family:
   a. include antimony, bismuth, arsenic, and phosphorus.
   b. are in group Va
   c. are non-metals.
   d. have the same number of electrons in the valence ring.
   e. in the periodic chart form a series in which the degree of activity decreases as you go downward.

2. Phosphorus:
   a. is never found in the uncombined state.
   b. in the combined state can be a valuable source of fertilizer.
   c. due to the ease with which it combusts is used in match manufacturing.
   d. exhibits allotropy in the forms of red and white phosphorus --the white variety being so extremely active that it cannot be handled in the air.
   e. when oxidized becomes an acid anhydride for meta phosphoric acid which upon being added to hot water becomes ortho-phosphoric acid.

3. Uses of members of the nitrogen family include:
   a. production of an alloy-type metal.
   b. wide application of As in the dye industry.
   c. the making of metal alloys for fuses and automatic fire-fighting devices.
   d. food preservation through discriminate application of arsenic.
   e. their application in the medicine and cosmetic industry.

4. The following pair or pairs of words or terms are well-matched:
   a. glyceryl nitrate - nitroglycerine
   b. dynamite - unsafe to handle
   c. nitrated cellulose dissolved in acetone-- black gunpowder
   d. TNT - propellant
   e. rapid explosion - detonation

XII. EXPERIMENT OVER OXIDES OF NITROGEN

Directions: Encircle the letter of the correct response or responses.

1. The formation and collection of NO:
   a. by the method followed is indicative of its low solubility.
   b. could involve air displacement if it weren't for the relative weights of air and NO being so close.
   c. is best facilitated using concentrated HNO_3.
   d. involves the redox equation: $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$.
   e. as indicated in the equation (d) would, theoretically, result in a yield of about 1.2 liters.

2. Properties of NO_2 determined from tests taken in the experiment include:
   a. that it is very easily oxidized.
   b. that NO_2 is less soluble than NO.
   c. that NO_2 is an acid anhydride.
   d. that NO_2 supports combustion.
   e. that NO_2 is pleasant smelling, but dangerous.

3. The reaction indicated by the equation: $NH_4NO_3 \xrightarrow{heat} N_2O + 2H_2O$:
   a. would probably proceed best at a pressure somewhat above standard.
   b. is one which, according to the amount of heat required, indicates NH_4NO_3. has a high heat of formation.
   c. would result in the formation of 2 G. M. V. of N_2O from 2 G. M. W. of NH_4NO_3.
   d. forms a gas, used as an anesthetic, and which is similar in at least one respect to oxygen.
   e. is a reaction acquainted with no real hazard.

4. The valences assumed by nitrogen:
   a. could be and are sometimes called oxidation numbers.
   b. number 5.
   c. make N a good choice to illustrate the law of multiple proportions.
   d. are all positive.
   e. in the reaction, $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$, include a +5, a -2, and a +4.

XIII. FORMS OF CARBON

Directions: Encircle the letter of the correct response or responses.

1. Coal:
   a. is our chief source of energy.
   b. in all forms is chiefly carbon.
   c. is being formed as fast as it ever was, but we are using it so much faster.
   d. becomes coke during fractional distillation of coal.
   e. is used as the power source for the generation of nearly 3/4 of our electrical supply.

2. An appropriate word or phrase-function relationship exists in the following:
   a. carat . . . . . .0002 kg.
   b. high index of refraction . . .ability to bend and break white light into its components.
   c. carbon black . . . . . .printers ink
   d. high cost of diamonds . . .totally attributable to scarcity
   e. pure crystaline form of C . .drilling

3. Charcoal:
   a. was used in the manufacture of iron and steel, but fell into disuse because coke made a superior steel.
   b. is used to make a unique and relatively safe explosive which de-activates itself after a time.
   c. can be "activated" -- a term used to describe a process not fully known, but which causes the charcoal to become an excellent absorbing agent.
   d. can be made when wood is destructively distilled in somewhat the same manner as coal.
   e. helps make white sugar out of brown.

4. Associated with coke production:
   a. ammonia
   b. benzene
   c. dyes
   d. aspirin
   e. medicines

5. The production of coke:
    a. is closely related to the iron and steel industry.
    b. involves the baking of coal in the absence of air to a temperature between 700 and 1000 degrees C.
    c. is a process which makes somewhat questionable the advisability or economy of burning coal in our homes.
    d. separates the volatile components of coal.
    e. is associated with both destructive and fractional distillation.

XIV. CARBON COMPOUNDS

Directions: If the statement is a true one, fill in the circle at the left; if false, fill in the circle at the right.

O O 1. "Quick freezing" is superior to "slow freezing."

O O 2. CO_2 can be solidified by the application of pressure and heat.

O O 3. $COCl_2$ is a product containing carbon monoxide used as anesthetic.

O O 4. The fraction 44/29 is an indication of a physical property useful in fire fighting.

O O 5. The equation: $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO$ shows the oxidizing properties of CO.

O O 6. In the above equation, hematite is reduced.

O O 7. Carbon monoxide has a high heat of formation and is, therefore, an excellent fuel.

O O 8. All commercial baking powders produce CO.

O O 9. One fire extinguisher depends upon hydrolysis for its success.

O O 10. An application of Henry's Law makes possible the soft-drink industry.

XV. CARBON COMPOUNDS

Directions: Directions are given or implied for each question.

1. What happens to limewater when left exposed to the air, and why does it happen?

2. Write a balanced equation for the heating of a carbonate.

3. Write a balanced equation for the laboratory preparation of CO_2.

4. Referring to equation #3, what volume of CO_2 could you have produced assuming standard conditions with the ten grams of marble chips used.

5. Write a balanced equation showing what happened when the red color disappeared as the result of the addition of CO_2 solution.

XVI. EXPERIMENT OVER PRODUCING AND USING CARBON DIOXIDE

Directions: Encircle the letter of the correct response or responses.

1. Chemical and (or) physical properties of CO_2:
   a. include a density somewhat less than air.
   b. enable one to identify it by odor and color.
   c. make for its use as a reducing agent.
   d. are quite similar to those of CO.
   e. cause $CaCO_3$ to be formed when CO_2 is passed through a $Ca(OH)_2$ solution resulting in a milky coloration.

2. The reaction which occurs when HCl is added to $CaCO_3$:
   a. is correctly shown by $CaCO_3 + 2HCl \dashrightarrow CaCl_2 + H_2O + CO_2$.
   b. would result in the formation of 44 liters of CO_2 per mole of $CaCO_3$ used.
   c. using the 20 grams of limestone suggested by the author could yield about 4 liters of CO_2.
   d. should be operated in an open system (no outside pressure applied).
   e. forms a very unstable acid.

3. CO_2 has practical uses:
   a. related to its specific weight.
   b. as an anhydride.
   c. related to its low freezing point.
   d. as a constituent of "soda water."
   e. related to cooking.

4. Reactions which produce CO_2 include:
   a. any strong acid plus a carbonate.
   b. photosynthesis.
   c. the action of yeast enzymes on glucose.
   d. the heating of a bicarbonate.
   e. burning methane in a limited supply of air.

5. A student undertook to test a sample of an unknown colorless, odorless gas (or mixture of gases). He did the following things and made the following observations in this order:

   a. He passed the gas through limewater and noted that it remained clear. (He then dried the gas.)
   b. He burned the gas and noted that no liquid condensed on a cold inverted beaker held over the flame.
   c. He passed the product(s) of combustion through limewater and noted that it turned cloudy.

The student then proposed the following conclusions based on the above procedure and observations. In each case if the evidence shows that a conclusion is true or false, encircle the T or F. If a statement is not supported by evidence, encircle the ID (insufficient data). Then for each conclusion that you marked T or F, write the letter(s) of the observations that support your choice.

1. The original gas contained carbon dioxide. F T ID ____
2. The original gas contained hydrogen. F T ID ____
3. The original gas contained water vapor. F T ID ____
4. The product(s) of combustion contained CO_2. F T ID ____
5. The original gas contained combined carbon. F T ID ____

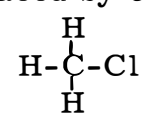
XVII. CARBON CHEMISTRY

Directions: Encircle the letter of the correct response or responses.

1. CO_2 is formed:
   a. whenever any carbonate or bicarbonate is acted upon by any common acid.
   b. when water is added to any baking powder.
   c. when NH_4HCO_3 is heated.
   d. during photosynthesis.
   e. as a result of the complete oxidation of fuels.

2. The structure of carbon:
   a. in the allotrope, diamond, is such that each carbon atom is surrounded by four other carbon atoms at the corners of a regular tetrahedron.
   b. in graphite is such that the carbon atoms are in layers.
   c. is macromolecular in all cases.
   d. enables it to be a good conductor regardless of the form.
   e. where definite form seems lacking is referred to as being amorphous.

3. The methane series of hydrocarbons:
   a. includes CH_4.
   b. is expressed by a general formula C_nH_{2n+2}
   c. are saturated-chain hydrocarbons.
   d. can be called hydrocarbon derivatives when one or more hydrogen atoms are replaced by other kinds of atoms or groups of atoms, i. e.:



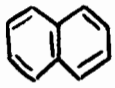
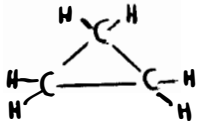
   e. are held together largely by covalent bonding.

4. The unsaturated-chain hydrocarbons and/or their derivatives:
   a. exhibit double bonding.
   b. include the ethylene series with the general formula C_nH_{2n}.
   c. still find carbon with a valence of four.
   d. with the general formula C_nH_{2n} are called olefins.
   e. the double bond is the weakest point, and the point where substitution of other atoms or groups of atoms is made.

XVIII. HYDROCARBONS

Directions: Encircle the letter of the correct response or responses.

1. The aromatic, benzene:
   a. possesses a "ring" structure whose covalent bonds appear to "shift"--at least the double bond is not always found between the same pair of carbon atoms.
   b. is represented by a picture 
   c. is a cyclo-paraffin.
   d. is a "saturated" hydrocarbon.
   e. can form derivatives by "addition."

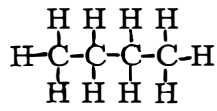
2. Members of the benzene series.
   a. include toluene or methyl benzene in which a hydrogen atom has been replaced by a methyl group.
   b. include 
   c. include 
   d. include 
   e. include moth-balls

*3. The cyclo-paraffin hydrocarbons:
   a. contain multiple bonds.
   b. are limited to cyclic hydrocarbons containing fewer than 6 C atoms.
   c. are found in all petroleums.
   d. are usually converted to "straight-chain" hydrocarbons during gasoline manufacture, particularly if there are 8 or less carbon atoms in their molecule.
   e. have the same general formulas the olefins, so they should be classed as unsaturated.

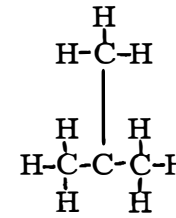
*No correct responses.

4. These two structural pictures:

(1)

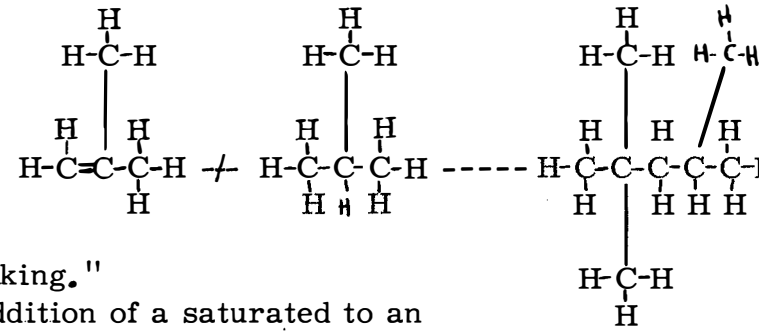


(2)



a. are isotopes.
b. are paraffins or saturated hydrocarbons.
c. show butane and an isomer of butane.
d. are of hydrocarbons, a kind which forms derivatives by substitution.
e. represent isomers important in the synthesis of gasoline.

5. The following equation:



a. represents "cracking."
b. represents the addition of a saturated to an unsaturated hydrocarbon--a process called isomerization.
c. results in the formation of 100 octane gasoline.
d. requires hydrogenation to convert the product to a workable gasoline.
e. could be represented by $C_4H_8 + C_4H_{10} \longrightarrow C_8H_{18}$.

APPENDIX B

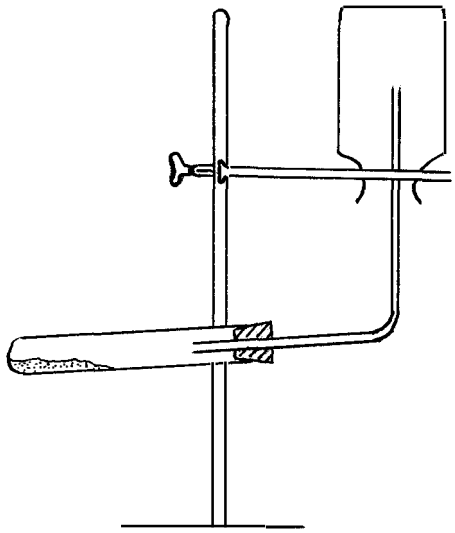
Unit Tests and Nine-Week Examination

CHEMISTRY UNIT TEST ON THE NITROGEN FAMILY

(Multiple Choice)

Directions: Write on the line at the right of each statement the number preceding the word or expression that best completes the statement.

Questions 1-8 refer to the drawing.



1. The gas which is prepared and collected in this apparatus is (1) nitrogen; (2) nitric oxide; (3) nitrogen dioxide; (4) ammonia. _____1

2. The generator contents should be (1) ammonium nitrate; (2) sodium nitrite and ammonium chloride; (3) copper and nitric acid; (4) sodium hydroxide and ammonium sulfate. _____2

3. The unstable compound first formed in the generator when it is producing the proper gas is (1) H_3N; (2) HNO_2; (3) HNO; (4) NH_4OH. _____3

4. The reaction in the generator is generally speeded up by (1) heating it; (2) adding the catalyst, MnO_2; (3) adding water; (4) changing the position of the generator. _____4

5. When the generator is operating, a piece of moist neutral litmus paper, placed near the open end of the collecting bottle will turn (1) red; (2) colorless; (3) yellow; (4) blue. _____5

6. The method of collection indicates that the gas is (1) colorless; (2) lighter than hydrogen; (3) heavier than oxygen; (4) much less dense than air. _____6

7. Another property of the gas, upon which the method of collection is based, is its (1) flammability; (2) noxious odor; (3) solubility; (4) ease of liquefaction. _____7

8. A white cloud would form in the collecting bottle if, before being put into position, it had been filled with the gas (1) HCl; (2) H_2; (3) CO_2; (4) O_2. _____8

9. Commercial nitrogen is generally obtained from (1) ammonia; (2) liquid air; (3) sodium nitrate; (4) nitrogen-fixing bacteria. _____9

10. The ion which is identified by the "brown ring" test is the (1) ammonium; (2) carbonate; (3) chloride; (4) nitrate. _____10

11. Nitric oxide has the formula (1) NO; (2) N_2O; (3) NO_2; (4) NO_3. _____11

12. One liter of dry air is slightly less dense at S. T. P. than one liter of (1) oxygen; (2) nitrous oxide; (3) nitrogen; (4) carbon dioxide. _____12

13. Since all the constituents of liquid air do not boil off at the same temperature, air is (1) an element; (2) a compound; (3) a mixture; (4) an allotrope. _____13

14. Nitrogen-fixing bacteria grow readily on the roots of (1) wheat; (2) peas; (3) oats; (4) corn. _____14

15. Ammonia is a (1) radical; (2) compound; (3) ion; (4) mixture. _____15

16. The generator used in the laboratory preparation of nitric acid should be (1) a round bottom flask; (2) a test tube; (3) a collection bottle containing a thistle tube; (4) a retort. _____16

17. The reaction between the products of heated nitric acid and excelsior, loosely plugged in the upper portion of the heated test tube, indicate that nitric acid is (1) a reducing agent; (2) a catalytic agent; (3) an oxidizing agent; (4) a dehydrating agent. _____17

18. To test for ammonium compound, react the compound with (1) an acid; (2) water; (3) a salt; (4) a base. _____18

19. Aqua regia is a mixture of nitric acid and (1) ammonia; (2) hydrochloric acid; (3) sulfuric acid; (4) platinum. _____19

20. A nitrogen compound used as an anesthetic has the formula (1) N_2O; (2) NO; (3) NO_2; (4) N_2O_3. _____20

21. In the manufacture of nitroglycerine, the sulfuric acid acts as (1) an oxidizing agent; (2) a catalytic agent; (3) a reducing agent; (4) a dehydrating agent. _____21

22. A colorless gas, which turns brown in the presence of air, is (1) N_2O; (2) NO; (3) NO_2; (4) N_2O_3. _____22

23. The valence number of nitrogen in nitric acid is (1) 1; (2) 2; (3) 3; (4) 5. _____23

24. Reacting concentrated nitric acid with copper produces (1) NH_3; (2) H_2; (3) NO_2; (4) NO. _____24

25. The process by which certain plant organisms convert the elementary nitrogen of the air into nitrogen compounds is (1) photosynthesis; (2) denitrification; (3) decay; (4) nitrogen-fixation. _____25

26. The white deposit frequently found on the outside of laboratory bottles of ammonium hydroxide is (1) nitrate; (2) carbonate; (3) sulfate; (4) chloride. _____26

27. The heat of formation of nitrogen compounds is usually low or negative. This means that nitrogen is (1) active; (2) inert; (3) relatively inactive; (4) very active. _____27

28. Ammonia dissolved in water produces (1) an acid; (2) a base; (3) a nitrate; (4) a salt. _____28

29. Lightning supplies the energy for the formation of considerable quantities of compounds of nitrogen and (1) hydrogen; (2) argon; (3) oxygen; (4) carbon. _____29

30. Nitrous acid has the formula (1) H_3N; (2) HNO; (3) HNO_2; (4) HNO_3. _____30

31. In the reaction resulting from the addition of HNO_3 to Cu, the beautiful blue color results from the formation of the (1) cupric (Cu^{++} ion; (2) NO_3-ion; (3) H_3O ion (4) NO_2 dissolved in water _____31

32. Phosphorus occurs extensively in nature, mostly in the form of (1) chlorides; (2) oxides; (3) fluorides; (4) phosphates. _____32

33. The waxy type of phosphorus must be cut under water because of its (1) low density; (2) noxious odor; (3) low kindling temperature; (4) low solubility. _____33

34. Compounds of arsenic are used extensively in (1) alloys; (2) medicines; (3) insecticides; (4) detergents. _____34

35. The metal which is used in type metal is (1) arsenic; (2) antimony; (3) bismuth; (4) tin. _____35

(II. Writing and Balancing Equations)

Write balanced formula equations for the following. (Questions 1-10 each worth 3 points.)

1. Laboratory preparation of nitric acid.

2. The Haber process.

3. The Oswalt process for production of nitric acid.

4. The reason for the discoloration of HNO_3 if left exposed to sunlight.

5. The commercial production of phosphorus where sand and carbon are added to the most common mineral of phosphorus.

6. Making "laughing gas"

7. A typical reaction between a metal and dilute HNO_3.

8. Heating $Cu(NO_3)_2$.

9. Starting with elemental phosphorus, show in two steps how to make H_3PO_4.

10. Obtaining pure arsenic from its oxide, As_2O_3.

The test was scored as follows:

a. Each correct answer for Part I was worth two points.

b. Each correct answer for Part II was worth three points.

CHEMISTRY UNIT TEST ON CARBON

(I. Multiple Choice: Directions: Select the number of the answer which best completes the sentence, and place the number of that response in the space at the right.

1. Which of the following is used as a lubricant? (1) activated charcoal, (2) powdered graphite, (3) carborundum, (4) diamond dust, (5) granulated anthracite. _____1

2. In the reaction $SnO_2 + C \longrightarrow CO_2 + Sn$, the carbon acts as (1) a dehydrating agent, (2) a catalyst, (3) a reducing agent, (4) an oxidizing agent, (4) a refractory substance. _____2

3. In the soda-acid type of fire extinguisher, the acid used is (1) acetic acid, (2) hydrochloric acid, (3) nitric acid, (4) sulfuric acid, (5) phosphoric acid. _____3

4. Which one of the following reactions is not an oxidation and reduction reaction? (1) $CuO + H_2 \longrightarrow H_2O$, (2) $SnO_2 + C \longrightarrow CO_2 + Sn$, (3) $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$, (4) $CuO + CO \longrightarrow Cu + CO_2$, (5) $Fe_2O_3 + 3CO \longrightarrow 3CO_2 + 2Fe$. _____4

5. In which of the following is an incorrect chemical name given for a common substance? (1) dry ice--solid carbon dioxide, (2) limewater--calcium hydroxide solution, (3) marble chips--calcium carbonate, (4) cream of tartar--potassium acid tartrate, (5) "soda water"--sodium carbonate solution. _____5

6. One liter of carbon dioxide weighs (1) 0.8 grams, (2) 1.25 grams, (3) 1.96 grams, (4) 22.4 grams, (5) 885.6 grams. _____6

7. The percentage of carbon in $NaHCO_3$ is: (1) 12.0, (2) 14.3, (3) 27.2, (4) 57.2, (5) 70.0. _____7

8. A student was asked to list five contrasting properties of carbon dioxide and carbon monoxide. Which one of the following statements, while correct in itself, is technically not a correct answer to the above question? (1) carbon dioxide is heavier than air; carbon monoxide is lighter than air, (2) carbon dioxide is noncombustible; carbon monoxide

will burn, (3) carbon dioxide is suffocating; carbon monoxide is poisonous, (4) carbon dioxide is colorless, (5) carbon dioxide reacts with limewater forming a white precipitate of calcium carbonate while carbon monoxide does not. _____8

9. When three grams of carbon are completely burned, how many liters of carbon dioxide are formed? (1) 11.2, (2) 22.4, (3) 44.8, (4) 67.2, (5) 5.6. _____9

10. Carbon dioxide and water in plants unite to form glucose in the presence of light and chlorophyll. This reaction is called (1) analysis, (2) photosynthesis, (3) metathesis, (4) hydrogenation, (5) hydrolysis. _____10

11. Elements, like carbon, that have their outer rings half complete are said to be (1) inert, (2) metals, (3) non-metals, (4) electrolytes, (5) amphoteric. _____11

12. Silicon carbide has the formula (1) SiO_2, (2) SiC, (3) Si_2O, (4) Si_3O_6, (5) SnC. _____12

13. Because coal, coke, charcoal, boneblack, gas carbon, lampblack, and soot were thought to be noncrystalline, they were said to be (1) amorphous, (2) anydrous, (3) activated, (4) amphoteric, (5) friable. _____13

14. In the limewater test for carbon dioxide the precipitate formed is (1) $Ca(OH)_2$, (2) $CaCO_3$, (3) Na_2CO_3, (4) $NaHCO_3$, (5) $Ca(HCO_3)_2$. _____14

15. Carbon dioxide is usually prepared in the laboratory by the reaction of marble chips and (1) water, (2) hydrochloric acid, (3) limewater, (4) a base, (5) soda. _____15

16. Destructive distillation of soft coal produces (1) coke, (2) boneblack, (3) lampblack, (4) carbon black, (5) graphite. _____16

17. The gas whose density is closest to that of air is (1) CO_2, (2) CO, (3) CH_4, (4) C_2H_2, (5) COCl. _____17

18. The solid fuel that contains the highest percentage of carbon is (1) anthracite coal; (2) bituminous coal; (3) lignite; (4) peat; (5) coke. _____18

19. The form of carbon which is used widely as a reducing agent in metallurgy is (1) graphite, (2) bone black, (3) charcoal, (4) coke, (5) diamond. _____19

20. Carbon dioxide could be effectively collected by (1) displacement of limewater; (2) displacement of air, bottle mouth upward, (3) displacement of air, bottle mouth downward, (4) displacement of air, bottle mouth sideward, (5) collecting over water at a pressure of ten atmospheres. _____20

(II. Write responses as indicated.)

21. Calculate the weight of pure CO_2 obtainable from the dehydration of 38 grams of formic acid.

22. Write the formula equation for the reduction of Fe_3O_4 with CO.

23. How many liters of CO_2 are prepared when 100 grams of marble (80% pure $CaCO_3$) react with an acid? (at. wt. Ca - 40)

24. How much sulfuric acid is required to react with 1 kg of baking soda in a soda-acid fire extinguisher, according to the following equation:

$$2NaHCO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O + 2CO_2$$

25. Calculate the volume of carbon dioxide at S. T. P. liberated during the discharge of the fire extinguisher of Problem 24.

The test was scored as follows:

Each correct answer throughout the test was worth four points.

NINE-WEEKS EXAMINATION OVER NUCLEAR, NITROGEN, AND CARBON CHEMISTRY

I. Directions: Encircle the number preceding the response which best completes the sentence, and, then, above the duplicate of that number in the spaces at the right, fill in the proper circle.

1. The fissionable material produced in an atomic pile is (1) uranium-235; (2) plutonium; (3) neptunium; (4) thorium.	O 1	O 2	O 3	O 4
2. The purpose of the moderator is to (1) slow down neutrons; (2) absorb protons; (3) speed up electrons; (4) remove radiations.	O 1	O 2	O 3	O 4
3. The beta rays given off by radium are identical with (1) electrons; (2) positively charged helium nuclei; (3) protons; (4) X-rays.	O 1	O 2	O 3	O 4
4. The most effective atomic "bullets" are (1) alpha rays; (2) protons; (3) electrons; (4) neutrons.	O 1	O 2	O 3	O 4
5. The break-up of an atomic nucleus into two almost equal parts is called (1) fission; (2) fusion; (3) a chain reaction; (4) instability.	O 1	O 2	O 3	O 4
6. In the hydrogen bomb, hydrogen is converted into (1) deuterium; (2) uranium; (3) helium; (4) plutonium.	O 1	O 2	O 3	O 4
7. Two particles which have approximately the same weight are (1) proton and neutron; (2) neutron and electron; (3) electron and proton; (4) proton and positron.	O 1	O 2	O 3	O 4
8. An element which usually transfers electrons would have an outer orbit which contains (1) 3; (2) 5; (3) 7; (4) 8 electrons.	O 1	O 2	O 3	O 4
9. The element with atomic number 11 most closely resembles the element with atomic number (1) 19; (2) 17; (3) 15; (4) 13.	O 1	O 2	O 3	O 4

10. Ordinary chemical changes involve only the sharing or transfer of (1) neutrons; (2) protons; (3) electrons; (4) mesons.

O 1 O 2 O 3 O 4

11. Atoms with the same chemical properties, but different atomic weights are (1) amphotoeric, (2) isobars, (3) isomers; (4) isotopes.

O 1 O 2 O 3 O 4

12. The element whose atomic number is 20 will combine with the element whose atomic number is (1) 10; (2) 12; (3) 16; (4) 18.

O 1 O 2 O 3 O 4

13. An atom-smashing machine is called á(n) (1) cyclotron; (2) cation; (3) electrolyte; (4) cloud chamber.

O 1 O 2 O 3 O 4

14. The atmosphere contains about (1) 20; (2) 50; (3) 68; (4) 78 per cent nitrogen.

O 1 O 2 O 3 O 4

15. Pure nitrogen (1) will explode readily; (2) burns; (3) supports combustion; (4) is relatively inactive.

O 1 O 2 O 3 O 4

16. Bacteria which grow on the roots of leguminous plants (1) kill the host; (2) fix nitrogen; (3) make soil less fertile; (4) are a nuisance to man.

O 1 O 2 O 3 O 4

17. A common method for preparation of ammonia gas in the laboratory is by heating (1) NH_4Cl; (2) $NaNO_3$ H_2SO_4; (3) $NaNO_3$; (4) NH_4Cl $Ca(OH)_2$.

O 1 O 2 O 3 O 4

18. To test for nitric oxide (NO) you add (1) H_2O); (2) O_2; (3) H_2; (4) Cl_2.

O 1 O 2 O 3 O 4

19. The yellow color frequently observed in laboratory bottles of nitric acid is due to (1) dirty bottles; (2) decomposition of HNO_3; (3) poor methods of manufacture; (4) dissolved sulfur.

O 1 O 2 O 3 O 4

20. Nitric acid is a strong acid and also a(n) (1) reducing agent, (2) oxidizing agent; (3) chlorinating agent; (4) electron-losing agent. O 1 O 2 O 3 O 4

21. The presence of nitrates is tested for by (1) litmus paper; (2) Benedict's solution; (3) phenolphthalein; (4) the brown ring. O 1 O 2 O 3 O 4

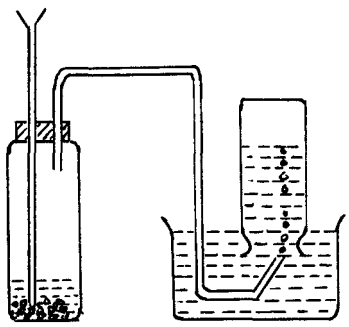
22. Laughing gas can be made by carefully heating (1) $Cu + HNO_3$; (2) NH_4Cl; (3) NH_4NO_3; (4) NO_2. O 1 O 2 O 3 O 4

23. The valence of nitrogen in nitric acid (HNO_3) is (1) one; (2) five; (3) three; (4) four. O 1 O 2 O 3 O 4

24. Nitric acid is often used in testing for the presence of (1) water; (2) carbohydrates; (3) fats; (4) proteins. O 1 O 2 O 3 O 4

25. Commercial nitrogen is generally obtained from (1) ammonia; (2) liquid air; (3) sodium nitrate; (4) nitrogen-fixing bacteria. O 1 O 2 O 3 O 4

Questions 26-32 refer to the drawing.



26. Two materials placed in this generator which would not produce CO_2 are (1) marble and HCl; (2) baking soda and vinegar; (3) baking powder and H_2O; (4) lime water and sodium carbonate.

27. The process which is generally used for producing CO_2 in the generator is (1) fermentation of dextrose; (2) thermal decomposition of a carbonate; (3) decomposition of a carbonate by acid; (4) decomposition of a bicarbonate.

(26) O 1 O 2 O 3 O 4

(27) O 1 O 2 O 3 O 4

28.	The unstable compound formed in the generator is (1) H_2CO_3; (2) $Ca(OH)_2$; (3) $Ca(HCO_3)_2$; (4) $NaHCO_3$.	O 1	O 2	O 3	O 4
29.	The gas may readily be identified by its action with (1) HCl; (2) $CaCO_3$; (3) $Ca(OH)_2$; (4) NH_4OH.	O 1	O 2	O 3	O 4
30.	A soluble compound formed, which remains in the generator in solution, may be (1) $Ca(OH)_2$; (2) $CaCl_2$; (3) $CaCO_3$; (4) Na_2CO_3.	O 1	O 2	O 3	O 4
31.	The reaction in the generator may be stopped almost completely by (1) stoppering the open end of the thistle tube; (2) removing the stopper from the generator; (3) removing the end of the delivery tube from the collecting basin; (4) pinching the rubber connection between the two glass portions of the delivery tube.	O 1	O 2	O 3	O 4
32.	The chemical reaction going on inside the generator most closely resembles the reaction going on in the (1) foam type fire extinguisher; (2) dry power type extinguisher; (3) liquid CO_2 extinguisher; (4) soda-acid extinguisher.	O 1	O 2	O 3	O 4
33.	A poisonous gas which combines permanently with the blood hemoglobin is (1) CO; (2) CO_2; (3) CH_4; (4) C_2H_2.	O 1	O 2	O 3	O 4
34.	Dry ice is solid (1) CO; (2) CO_2; (3) H_2O; (4) CO_2.	O 1	O 2	O 3	O 4
35.	Carbon monoxide is an important (1) oxidizing agent; (2) reducing agent; (3) dehydrating agent; (4) catalytic agent.	O 1	O 2	O 3	O 4
36.	Destructive distillation of soft coal produces (1) coke; (2) boneblack; (3) lampblack; (4) carbon black.	O 1	O 2	O 3	O 4

37. The gas present in largest per cent in natural gas is (1) hydrogen; (2) methane; (3) acetylene; (4) carbon monoxide. O 1 O 2 O 3 O 4

38. Acetylene may be prepared by adding water to calcium (1) carbide; (2) carbonate; (3) bicarbonate; (4) hydroxide. O 1 O 2 O 3 O 4

39. The process of changing large molecules in fuel oil into simpler molecules is known as (1) destructive distillation; (2) hydrogenation; (3) synthesis; (4) cracking. O 1 O 2 O 3 O 4

40. Octane has the formula (1) C_3H_8; (2) C_4H_8; (3) C_8H_{18}; (4) C_8H_{10}. O 1 O 2 O 3 O 4

41. Unsaturated hydrocarbons readily react with bromine by the process of (1) substitution; (2) double replacement; (3) addition; (4) single replacement. O 1 O 2 O 3 O 4

42. Compounds that have the same molecular composition, but a different arrangement of atoms in the molecule are called (1) polymers; (2) dimers; (3) isomers; (4) isotherms. O 1 O 2 O 3 O 4

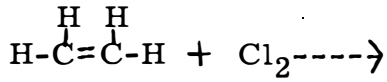
II. Directions: Answer the following as directed.

43. How many liters of oxygen are required to burn completely 50 liters of acetylene, volumes being measured under the same conditions?

44. Write the formula equation for the most abundant commercial source of NH_3.

45. Write the formula equation for a laboratory preparation of phosphoric acid.

46. Write a nuclear equation showing carbon 14 being formed by the bombardment of atmospheric nitrogen by cosmic-ray neutrons.

47. Complete this equation 

48. Write a formula equation for the reaction of nitric acid (concentrated) upon a metal.

49. Calculate the volume, in liters, of air necessary for the complete combustion of 672 liters of methane.

50. Determine the number of moles of CO_2 formed when 25 liters of ethane are burned.

The test was scored as follows:

Each correct answer throughout was worth two points.