1948

The construction and evaluation of an objective achievement test in organic chemistry for pharmacy students

Tobin. L. 1948 Construction and evaluation of an objective achievement test...

BOSTON UNIVERSITY

SCHOOL OF EDUCATION

THESIS

THE CONSTRUCTION AND EVALUATION OF AN OBJECTIVE ACHIEVEMENT TEST IN INORGANIC CHEMISTRY FOR PHARMACY STUDENTS

Submitted by

Louis Tobin

(B.S., Massachusetts College of Pharmacy, 1941)

In partial fulfillment of the requirements for the

Degree of Master of Education

1948

First Reader: John G. Read, Associate Professor of Science Education

Second Reader: Charles E. Stratton, Professor of Science and Mathematics

Third Reader: Leslie W. Irwin, Professor of Health and Physical Education

ACKNOWLEDGMENT

Grateful acknowledgment and appreciation are expressed to Doctor John G. Read, Associate Professor of Science Education, School of Education, Boston University, for his assistance in the preparation of this thesis.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION AND PRESENT STATUS OF EVALUATION INSTRUMENTS IN INORGANIC CHEMISTRY	1
	Introduction	1
	Statement of the problem	1
	Justification of the study	1
	Scope and limitations of the study	2
	Present Status of Evaluation Instruments in Inorganic Chemistry	3
	The need for measurement in chemistry	3
	Other instruments of measurement of chemistry achievement	4
II.	THE CONSTRUCTION AND DESIGN OF THE TEST	7
	Selection of broad inorganic chemistry areas	7
	Procedure	7
	Specific objectives for the chemistry test	9
	Description of the parts	20
	Administration of the test	21
	The unrevised form of the test	22
III.	ANALYSIS OF DATA	29
	Introduction	29
	The Statistics on Central Tendency and Variability	29

CHAPTER PAGE

Summarization of the Results of the Statistics on Central Tendency and Variability..... 32

The Individual Item Analysis..... 33

Method employed in determining the critical ratio..... 33

The data of the individual item analysis..... 35

Reliability..... 42

IV. SUMMARY AND CONCLUSIONS..... 44

Summary..... 44

Conclusions..... 44

V. SUGGESTIONS FOR FURTHER STUDY..... 45

BIBLIOGRAPHY..... 46

LIST OF TABLES

TABLE		PAGE
I.	Results of the Total Scores of the Test.....	29
II.	Results of the Administration of Part I.....	30
III.	Results of the Administration of Part II.....	30
IV.	Results of the Administration of Part III.....	31
V.	Results of the Administration of Part IV.....	31
VI.	Individual Item Analysis - Part I.....	35
VII.	Individual Item Analysis - Part II.....	38
VIII.	Individual Item Analysis - Part III.....	40
IX.	Individual Item Analysis - Part IV.....	41

CHAPTER I

INTRODUCTION AND PRESENT STATUS OF EVALUATING INSTRUMENTS IN CHEMISTRY

INTRODUCTION

Statement of the problem. The purpose of this thesis is to construct and to analyze a test which purports to measure the achievement of pharmacy students in inorganic chemistry. It is hoped that this test will serve as a standardized instrument for the writer's classroom situation and also function as one of the devices for selecting students capable of continuing work in chemistry.

Justification of the study. The subject of standardized objective testing has long attracted the attention of educators in pharmacy. Yet, despite this apparent interest and despite the most recent technological advances of pharmacy, there exists today no standardized test for the various phases of this professional area. Other professions, medicine, dentistry and engineering have developed standardized testing programs.

Remmers and Gage[1/] have written:

> Notwithstanding the importance of the pharmacist - of his selection, training and professional functioning - the inadequacy of the present utilization by the profession of available scientific knowledge concerning personnel problems is generally recognized by those technically competent to pass judgment.

1/ Remmers, H.H., and Gage, L.L., "Achievement and Predictive Testing in The Pharmaceutical Survey," American Journal of Pharmaceutical Education, Vol. 11, No. 1, January 1947, p. 43.

Chemistry is an important and integral part of the pharmaceutical curriculum. Schools and colleges of pharmacy emphasize this science throughout their entire program. The pharmaceutical chemist should be given "broad and sound training in all the fundamentals of chemistry."[1/] Review of the chemistry and pharmacy periodicals of the past decade has failed to disclose an objective achievement test which purports to measure the achievement of pharmacy students in chemistry. While we do find specific textbooks oftentimes contain fragmentary tests, no evaluated instrument is obtainable.

Aware of the general deficiency of testing programs, pharmacy has recently created an office known as The Pharmaceutical Survey. A special committee is to establish a program of predictive and achievement testing. No published reports are available to date. Objective testing in pharmacy, therefore, is in its infancy.

The specialized applications of chemistry to pharmacy warrant the utilization of a specialized objective test in that area. Teachers of chemistry in schools and colleges of pharmacy have definite need for a valid and reliable instrument which will measure objectively student achievement.

Scope and limitations of the study. This test is designed, in general, to cover the freshmen chemistry curriculum followed by pharmacy schools

---

1/ Hartung, Walter H., "A Course in the Chemistry of Organic Medicinal Products," American Journal of Pharmaceutical Education, Vol. 6, No. 1, January 1942, p. 84.

and colleges which adhere to the requirements of The American Association of Colleges of Pharmacy, although not necessarily members. One hundred freshmen students enrolled in a school of pharmacy in Massachusetts were given the test at the end of the school year. The number of students taking the test represents approximately 33 per cent of the freshmen pharmacy students in Massachusetts and approximately 3 per cent of the freshmen pharmacy students in the United States.

THE PRESENT STATUS OF EVALUATION INSTRUMENTS IN CHEMISTRY

The need for measurement in chemistry. While pharmacy schools and colleges are highly selective and high standards are maintained for admission to them, freshmen chemistry appears to prevent many "good" high-school students from continuing their professional pursuit. "The excellence of preparation for college chemistry cannot be judged by the amount of ground covered or by the grades received in high-school chemistry."[1] Furthermore, pharmacy graduates are required by law to pass a state examination in order to practice. The chemistry area in these examinations accounts for considerable failures. It appears, then, that one function of a valid and reliable instrument in chemistry would be to predict in some measure success in pharmacy insofar as becoming registered is concerned.

The present tendency of achievement tests in chemistry is to present an overall coverage of the field. While there are tests specializing in

---

[1] Ruch, G.M., and Stoddard, George D., Tests and Measurements in High School Instruction, World Book Company, Chicago, 1927, p. 147.

the various branches of chemistry such as the Cooperative Chemistry Test in Qualitative Analysis[1] and the Cooperative Objective Tests in Organic Chemistry,[2] there appears to be a great deal of overlapping insofar as inorganic chemistry is concerned. Few tests are clearly defined as inorganic chemistry instruments. This overlapping is especially apparent in high-school achievement tests. Here we find more organic chemistry involved than is generally conceded to fall within that scope. This may be due in part to the lack of clarity as to what is expected of chemistry teachers in both high schools and colleges. The wide divergence in the scope of the textbooks and manuals has been the subject of a great deal of critical study.[3]

Other instruments of measurement of chemistry achievement. As has already been disclosed, there has been published no instrument which deals exclusively with the achievement in inorganic chemistry of pharmacy students. The following tests, then, are presented as containing in part some items involving the general field of inorganic chemistry:

POWERS GENERAL CHEMISTRY TEST[4] appears in two equivalent forms, A and B. Each form contains thirty items covering a wide range of chemical information and thirty-seven items testing the pupil's ability to handle formulas and equations. This test is for high school students.

1/ Cooperative Test Service, New York, 1939-40.

2/ Ibid., 1939.

3/ Powers, S.R., "A Diagnostic Study of The Subject Matter of High School Chemistry," Teachers College Contributions to Education, No. 149, Columbia University, New York, 1924.

4/ World Book Company, Yonkers-on-Hudson, New York, 1924.

RICH CHEMISTRY TEST FOR HIGH SCHOOLS[1] is an unusually short test containing only twenty-five multiple choice items.

GLENN-WELTON CHEMISTRY ACHIEVEMENT TEST[2] contains eighty multiple choice questions, twelve true-false, and thirty equations to be completed. The questions deal with vocabulary, practical applications, range of information, and laboratory manipulation.

MALIN DIAGNOSTIC TEST IN THE MECHANICS OF HIGH SCHOOL CHEMISTRY[3] has two forms, each form containing forty-one general questions, seven mathematical problems, and nine reactions. This test deals with industrial chemical formulas and simple calculations.

THE UNITED STATES ARMED FORCES INSTITUTE CHEMISTRY TEST[4] contains ninety items of the multiple-choice type. The examination is intended for high-school level and appears to contain a great deal of organic chemistry.

COLUMBIA RESEARCH BUREAU CHEMISTRY TEST[5] for use by both high school and college students. It contains one hundred and fifty true-false questions and twenty-two equations to be completed.

1/ Public School Publishing Company, Bloomington, Illinois, 1925.

2/ World Book Company, Yonkers-on-Hudson, New York, 1924.

3/ Public School Publishing Company, Bloomington, Illinois, 1932.

4/ American Council on Education, New York, 1944.

5/ Teachers College, Columbia University, New York, 1939.

COOPERATIVE CHEMISTRY TEST[1] measures achievement on the high-school level. This test has undergone yearly revisions since it first appeared in 1933 and requires a knowledge of some organic formulas. No mathematical concepts are involved in this test.

COOPERATIVE CHEMISTRY TEST FOR COLLEGE STUDENTS[2] has been utilized by the American Chemical Society's Division of Chemical Education.[3]

The test to be constructed will deal almost exclusively with inorganic chemistry, will be of college level, and will be specialized.

1/ Cooperative Test Service, New York, 1933-40.

2/ Ibid., 1935-40.

3/ Phelan, E.W., "The 1936-1937 College Chemistry Testing Program," Journal of Chemical Education, Vol. 14, May, 1937, pp. 229-231.

CHAPTER II

CONSTRUCTION AND DESIGN OF THE TEST

Selection of broad inorganic chemistry areas. The general inorganic and pharmaceutical inorganic chemistry textbooks as well as the laboratory work sheets and manuals of The Boston School of Pharmacy, The Massachusetts College of Pharmacy, and The Western Massachusetts School of Pharmacy were searched for an inclusive listing of objectives from which to construct the test. Also examined were the scope and objectives as given in The Pharmaceutical Syllabus. 1/ While the program outlined by the Syllabus is at present not mandatory, many teachers in the field feel as does Professor Hugh C. Vincent, The State College of Washington, School of Pharmacy, that "The syllabus is necessary, and most of its provisions should be enforced." 2/ The Pharmaceutical Survey, 3/ presently being conducted, uses the Syllabus as one of the criteria for its achievement testing program.

Procedure. In the suggested outline for a course in general inorganic chemistry, the Syllabus lists specific topics to be discussed under the general outline. Lists were compiled of the terms, abbreviations, reactions, synonyms, laboratory requirements, laws, and mathematical concepts that appeared in the outline. Next, additions were made to the lists after

---

1/ The National Pharmaceutical Syllabus Committee: The Pharmaceutical Syllabus, Tentative Fifth Edition (revised), Chapel Hill, North Carolina, 1945.

2/ Vincent, Hugh C., "A Quantitative Survey of the 1945-1946 Pharmacy Curricula," American Journal of Pharmaceutical Education, Vol. 10, No. 1, January, 1946, p. 27.

3/ Remmers, H. H., and Gage L. L., op. cit., p. 47.

the standard textbooks, worksheets, etc. of the schools named in the previous paragraph, were examined. A review of the inorganic chemistry area of the Massachusetts Board of Registration in Pharmacy examinations of the past decade furnished additional material for the objectives. The lists were then given to two chemistry teachers in a school of pharmacy for comment and criticism. This review resulted in some minor changes.

SPECIFIC OBJECTIVES FOR THE CHEMISTRY TEST

A. The student should know the meaning of and be able to recognize the following terms:

absolute scale
acid
acid oxide
activity
adsorption
alkali
alkaline earth
alkaline
allotropic
alloy
alpha ray
amalgam
amorphous
anhydrous
anion
anode
aprotic
aromatic
association
atomic energy
atomic nucleus
atomic number
atomic weight
atom
Avogadro's number
base
basic oxide
basic salt
beta particle
binary compound
bivalent
boiling point
boiling point constant
bond
buffer
calcination
calibration
calorie
catalyst
cathode
cation
caustic
chemical change
chemical formula
chlorination
cleavage
colloid
combusion
complex ion
component
composition
compound
concentrated
concentration
condensation
conductivity
constituent
coordinate bond
couple
covalence
critical pressure
critical temperature
crystal

crystalloid
decomposition
deliquescence
density
depolarizer
destructive distillation
deuterium
deuteron
dialysis
diatomic
diffusion
dilute (official)
dipole
diprotic
disinfectant
disintegration
disperse
displacement
dissociation
dissolve
distillate
distillation
double bond
double salt
ductile
efflorescence
electrode
electrolyte
electro chemical series
electron
electrophoresis
electro valence
element
emanation
empirical formula
emulsifier
emulsion
emulsoid
endothermic
end point
energy
enzyme
equation, chemical
equilibrium
equivalent
eutectic
evaporation
exothermic
exsiccation
flammable
formula
fractional distillation
freezing point constant
gamma ray
gas
gel
Gram-Molecular Weight
Gram-Molecular Volume
graphic formula
halate
halide
halogen
hardness
heat
hydrate
hydrohalogen
hydrogenation
hydrogen - ion
hydrolysis

hydrophilic
ideal gas
impurity
indicator
inert
interstitial
insoluble (official)
ion
ionize
isotope
Kelvin scale
kinetic
latent heat
lattice
lyophilic
lyophobic
malleable
mass
matter
melting point
meta compound
metal
metathesis
miscible
molar solution
molal solution
mole
mole-fraction
molecule
monoprotic
nascent
neutralization
neutron
noble metal
normal solution
occlusion
official
optical activity
osmosis
osmotic pressure
oxidant
oxidation
oxidation-reduction
oxide
oxonium-ion
particle
perhalate
period
periodic table
phase
physical change
polar molecule
positron
precipitant
precipitate
pressure
property
protolysis
proton
pyro compound
qualitative
quantitative
radical
radioactive
reaction
redox equation
reduction
replacement
roasting
salt
saturated
semi-permeable

sol

solubility (official)

solute

solution

solvent

solvolysis

specific gravity

specific heat

spectrum

spontaneous combusion

stable

standard conditions

standard pressure

structural formula

sublimation

supersaturated

surface tension

suspension

suspensoid

temperature

tervalent

tertiary compound

thermal

titration

triatomic

triple bond

triprotic

tritium

valence

vapor

vapor density

vapor pressure

vaporize

viscosity

vitreous

volatile

yield

B. The student should be familiar with the following abbreviations:

1. T.S.
2. U.S.P.
3. N.F.
4. E.M.F.
5. cc.
6. Gm.
7. mg.
8. cc^3
9. $in.^2$
10. $ft.^2$
11. α
12. β
13. γ
14. /
15. Δ
16. $\rightarrow$
17. $\rightleftarrows$
18. $\uparrow$
19. $\downarrow$
20. (O)
21. C.
22. K.
23. F.
24. Sp. Gr.
25. ss.
26. pH
27. RX
28. HX
29. X
30. e
31. $_1H^1$
32. $_0n^1$
33. $_2He^4$
34. $-_1e^0$
35. +
36. -
37. cal.
38. D_2O
39. Kg.
40. ml.
41. G.M.W.
42. G.M.V.
43. Gm-Eq Wgt.

C. The student should be able to relate the following information on these items studied in the laboratory:

Method of preparation, properties of, and tests for

oxygen	sulfuric acid	phosphorus
hydrogen	hydrochloric acid	zinc
nitrogen	nitrous acid	magnesium
nitric acid	sulfur	aluminum

The following laboratory tests should be known:

sulfates	lime water	thiosulfates
peroxides	nitrates	carbonates
metals	nitrites	bicarbonates
chlorides	bromides	ammonia compounds
phosphates	iodides	sulfur
Hepar test		

Flame tests for the following should be known:

sodium	potassium	boric acid
copper	barium	lithium
calcium	strontium	

D. The student should know and be able to interpret the following laws:

1. Equal volumes of different gases, under the same conditions of temperature and pressure, contain the same number of molecules. (Avogadro)

2. The volume of a gas, provided the temperature is constant, is inversely proportional to the pressure. (Boyle)

3. The volume of a gas, provided the pressure is constant, is directly proportional to the absolute temperature. (Charles)

4. The rate of diffusion of a gas is inversely proportional to the square root of the density of the gas. (Graham)

5. Chemical reactions merely transform matter, never create or destroy it. (Law of Conservation of Mass or Matter)

6. Every compound has a definite chemical composition. (Law of Constant Composition)

7. Any chemical change transforms invariable relative weights of the reactants and produces invariable relative weights of the reaction products. (Law of Definite Proportions)

8. The weight of a gas that dissolves in any given liquid is directly proportional to the pressure, provided the temperature remains constant. (Henry)

9. The speed of a reaction is proportional to the molecular concentration of each of the reacting substances. (Law of Mass Action)

10. When a stress is placed upon a solution which is in equilibrium, the reaction displaces in that direction which tends to undo the stress. (Le Chatlier)

E. The symbols and valence of the following elements and their radicals should be known and formulas should be able to be written:

aluminum	calcium	fluorine	lithium	phosphorus	sulfur
antimony	carbon	gold	magnesium	potassium	tin
arsenic	cerium	helium	manganese	radium	zinc
bismuth	chlorine	hydrogen	mercury	silicon	
boron	chromium	iodine	nickel	silver	
bromine	cobalt	iron	nitrogen	sodium	
cadmium	copper	lead	oxygen	strontium	

F. The following men should be identified by the student with their contribution to the field of chemistry.

1. Fothergill invented a process for making hydriodic acid.
2. Arrhenius propounded a theory of ionization.
3. Debuye and Huckel are credited with the theory of ionization for substances in solid state.
4. Gudberg and Waage are credited with the law of mass action.
5. Cavendish is credited with the discovery of hydrogen.
6. Roentgen was discoverer of X-rays.
7. LeBlanc devised method for making baking soda.
8. Solvay is credited with process for making sodium bicarbonate.
9. Courtois first to discover iodine.
10. Becquerel discovered the phenomenon of radioactivity.
11. Lavosier is associated with the discovery of oxygen.
12. Priestley is associated with the discovery of oxygen.
13. Scheele is credited with the discovery of chlorine.
14. Curies discovered radium.
15. Guy-Lussac gave chemistry the law of combining volumes.
16. Mendeleeff introduced the periodic table.
17. Hall discovered method of obtaining aluminum.
18. Baumé introduced a specialized hydrometer.

G. The following applications of pharmacy to inorganic chemistry should be known:

SYNONYMS

$HgNH_2Cl$ (white precipitate)	NH_4OH (ammonia water)
$FeSO_4$; $7H_2O$ (green vitriol, copperas)	S (brimstone, sublimed sulfur)
As_2O_3 (white arsenic, ratsbane)	HgI_2 (red precipitate)
H_3BO_3 (orthoboric acid, boracic acid)	HgO (red oxide of mercury)
$CuSO_4$ (blue vitriol, blue stone)	$Na_2S_2O_3$ (hypo)
$ZnSO_4$ (white vitriol)	Na_2SO_4 (Glauber's salt, horse salt)
H_2SO_4 (oil of vitriol, vitriolic acid)	$NaHCO_3$ (baking soda, slaeratus)
$K_2Cr_2O_7$ (red vitriol)	NH_4Cl (sal ammoniac, battery salt)
CaO (quicklime)	HCl (battery acid, marine acid)
$Ca(OH)_2$ (slaked lime)	HNO_3 (azotic acid)
K_2S_x (livers of sulfur)	$(NH)_2CO_3$ (Baker's ammonia, sal volatile)
HgCl (calomel)	Chlorides (muriates) (butters)
$HgCl_2$ (corrosive sublimate)	Sulfides (glances)
H_3PO_4 (syrupy phosphoric acid)	$Na_2B_4O_7$ (borax, sodium tetraborate)
N_2O (laughing gas)	Na_2SiO_3 (water glass)
	PbO (litharge)

1. The solubility of iodine in water and how to enhance it.
2. The solubility of $Ca(OH)_2$ in water (hot and cold).
3. The solubility of potassium chlorate in water.
4. The solubility of $BaSO_4$ and BaS in water.
5. "3%, 10 volume hydrogen peroxide."
6. Decolorization of iodine by hypo and ammonia water.

7. Addition of KI to enhance the solubility of mercuric iodide.
8. Chemical reactions involved in white lotion, yellow lotion, black lotion, glycerite of boroglycerin, Blaud pills, Basham's mixture, etc., and all official preparations involving inorganic reactions.
9. Solubility of the powdered and crystalline form of boric acid.

APPLICATION OF CONCEPTS

The student should be able to calculate the following:

1. the percentage composition of a compound.
2. percentage of water of crystallization.
3. centigrade scale from Fahrenheit, etc.
4. absolute scale from centigrade.
5. temperature, volume and pressure as applied to gases.
6. density and diffusion as applied to gases.
7. specific gravity.
8. molecular weights from specific heat.
9. molecular weights from boiling point elevations.
10. molecular weights from freezing point determinations.
11. concentration of a reaction.
12. write and balance redox equations.
13. the derivation of formulas from percentage composition.

With the objectives in view, a test was constructed; and examined by the same teachers who reviewed the objectives. Here again, some slight changes resulted. Next, a sophomore pharmacy student was asked to take the test and indicate the questions that possibly might lack clarity. This student level criticism resulted in more changes than by the teacher readings.

The test is divided into four parts, each part consisting of a different objective testing technique to mitigate the weakness of a single type. Since the subject matter was broad and the time required for the examination limited, a representative sampling of the material covered was included in all the parts. An almost equal number of questions appear for the various phases of the school year.

To facilitate correction and also to reduce the number of tests to be mimeographed, an answer sheet was made up. The ideal time allocated for this test is two hours, which is the usual time given for final examinations in most schools and colleges of pharmacy. The average student should finish the test in approximately one hour.

Description of the parts. Part I consists of fifty questions of the true-false variety. There is no arrangement as to difficulty and the items are woven together in random fashion by the coin method. The number of true-false answers are about even. As in the case with the other sections, the items cover a broad scope, including some mathematical concepts.

Part II contains twenty-five multiple choice questions, offering four choices under each question. Here again the choice of subject matter is comprehensive, the questions being selected from each special listing

of the objectives.

Part III is composed of fifteen completion questions. They are of the single word variety, and all the omissions are uniform in appearing at the end of the sentence. The answers called for are short ones, and the correction key makes allowances for more than one answer.

Part IV consists of eleven items to be evaluated and nine items to be matched. The evaluated items bring into play the unconscious use of the scientific method. The area on evaluation is placed near the end of the instrument as these questions are usually the most difficult and require considerable thought on the part of the student. In the matching questions allowances are made for the re-use of an item, and the student is told that he may do so. There is a greater number of choices as compared to the main headings to be matched.

Administration of the test. The test was given to a large freshman class in a school of pharmacy in Massachusetts. Two experienced teachers administered the test, which was given during the second week of May 1948.

ANSWER SHEET

Do not write on the test paper. Record all your answers in the appropriate blanks provided on this sheet. Write clearly.

PART I

1.___
2.___
3.___
4.___
5.___
6.___
7.___
8.___
9.___
10.___
11.___
12.___
13.___
14.___
15.___
16.___
17.___
18.___
19.___
20.___
21.___
22.___
23.___
24.___
25.___
26.___
27.___
28.___
29.___
30.___
31.___
32.___
33.___
34.___
35.___
36.___
37.___
38.___
39.___
40.___
41.___
42.___
43.___
44.___
45.___
46.___
47.___
48.___
49.___
50.___

PART II

1.___
2.___
3.___
4.___
5.___
6.___
7.___
8.___
9.___
10.___
11.___
12.___
13.___
14.___
15.___
16.___
17.___
18.___
19.___
20.___
21.___
22.___
23.___
24.___
25.___

PART III

1._____
2._____
3._____
4._____
5._____
6._____
7._____
8._____
9._____
10._____
11._____
12._____
13._____
14._____
15._____

PART IV

1.___
2.___
3.___
4.___
5.___
6.___
7.___
8.___
9.___
10.___
11.___
12.___
13.___
14.___
15.___
16.___
17.___
18.___
19.___
20.___

ACHIEVEMENT TEST IN INORGANIC CHEMISTRY
PART I FOR STUDENTS OF PHARMACY

In the proper spaces below, write (+) if true and (-) if false.

( ) 1.The end product in heating the alkali salt of an organic acid is a carbonate.

( ) 2.Barium sulfide is insoluble in water.

( ) 3.Oxides of non-metalswhen dissolved in water form bases.

( ) 4.The commercial name for mercuric chloride is calomel.

( ) 5.The solubility of iodine in water can be greatly enhanced by the addition of potassium iodide.

( ) 6.Red phosphorus is more poisonous than white.

( ) 7.The ideal gas, if it remained in that state, would have its zero volume at - 273 degrees centigrade.

( ) 8.Water will boil below 100 when the atmospheric pressure is less than 760 mm.

( ) 9.Normal and molal solutions are identical.

( ) 10.Molar and molal solutions are identical.

( ) 11.When a system is in a state of equilibrium, reaction has ceased.

( ) 12.Anhydrous copper sulfate is white.

( ) 13.The valence of aluminum in the sulfate and aluminate is the same.

( ) 14.The freezing point constant per liter of molar concentration of electrolytes is - 1.86.

( ) 15.The word "Hartshorn " is commonly associated with nitrogen compounds.

( ) 16.An aqueous solution of the sodium ion is yellow.

( ) 17.A reduction in temperature results in the increase in the rate of reaction.

( ) 18.In commercial hydrogen peroxide, acetanilid is a negative catalyst.

( ) 19.The word, " Azotic " is usually associated with mercury compounds.

( ) 20.According to Arrhenius,dissociation occurs to a greater extent as the solution of an electrolyte is diluted more.

( ) 21.Valence can be determined by dividing the Gm. Equivalent Weight by the atomic weight.

( ) 22.The iron and sulfur in iron sulfide are constituents.

( ) 23.The solubility of calcium hydroxide increases with temperature increase.

( ) 24.An element of atomic number 37 and atomic mass 85, has 37 protons in each nucleus.

( ) 25.If the specific gravity of a liquid is .9, 18 Gms. of it will occupy 20 cubic centimeters.

( ) 26.When 10 ft^3 of air at 60 lbs/in^2 expands to 30 ft^3 at constant temperature, its pressure changes to 180 lbs/in^2.

( ) 27.The reaction $_1H^2$ plus $_{11}Na^{23}$ ——→ $_{11}Na^{24}$ plus $_1H^1$, represents a radioactive change.

( ) 28.If a solution was colored, then the salt which formed that solution was colored.

( ) 29.In the electrolysis of water,hydrogen is liberated at the cathode.

( ) 30.In the chemical abbreviation,RX, the X represents a halogen.

( ) 31.Boron and silicon occur in the same periodic group.

( ) 32.By lowering the temperature,a greater yield of ammonia from nitrogen and hydrogen results.

( ) 33.Chromium trioxide is the anhydride of $HCrO_2$.

( ) 34. Vitriols are sulfides generally.

( ) 35.Thorium is the final element of natural radioactive disintegration.

( ) 36.The magnetization of iron is a physical change.

( ) 37.Sulfur dioxide dissolved in water produces sulfuric acid.

( ) 38.Iodine can be used to detect the presence of dextrins.

( ) 39.The T.S. acid solutions of the pharmacopoeia are generally 10%.

( ) 40.A substance which has lost its water of crystalization is effloresced.

( ) 41.A solution containing 9.8 Gms. of H_2SO_4 (100%) per 100 cc. is $\frac{N}{2}$.

( ) 42.The hydrogen ion concentration in a solution of pH 2 is twice as great as one of pH 4 .

( ) 43.In general, metals tend to gain electrons.

( ) 44.A molar and normal solutions of potassium hydroxide have the same concentration of potassium hydroxide.

( ) 45.The concentration of the solution depends upon the quantity of solution.

( ) 46.Meta-phosphoric acid is solid at room temperature.

( ) 47.If ether is mixed with water,the supernatant liquid is the water.

(,) 48.Ammonia water will decolorize iodine.

( ) 49.The hepar test is used to detectbthe presence of salt in the liver.

( ) 50.If a Gm. molecular weight of glycerin is dissolved in 1000 Gms. of water,the boiling point of the solution is 100.52 degrees centigrade.

PART II

Select the number which gives the correct or nearly correct answer and place it in the blank provided at the left of the question.

___(1)A group of atoms which cling together in a chemical change and behave as one atom is called,

1. a radical ; 2. an element; 3. a compound; 4. a molecule

___(2)A pH of 4 denotes the solution is

1.acid; 2. basic; 3.neutral; 4.negative

___(3) The " Fothergill " method is employed in making

1. iodine 2.hydriodic acid; 3.craem of tartar; 4. saleratus

___(4) Nitric anhydride

1. NO_2 2. N_2O 3. NO 4.N_2O_5

___(5) Hypophosphorous acid has

1. one 2. two 3. three 4. four replaceable hydrogens

___(6) The official sodium phosphate is the

1. primary 2. secondary 3. tertiary 4. mono-sodium

___(7) The complex copper ammonio ion is

1. colorless 2. pale blue 3. deep blue 4. violet

___(8) The weight of crystalized oxalic acid needed to prepare one liter of a normal solution ($H_2C_2O_4 \cdot 2H_2O$)

1. 90 2. 126 3. 63 4.199 Gms.

___(9) The temperature at which Centigrade and Farenheit scales are equal is

1. -4 2. 24 3. -40 4. 46

___(10) Nitrohydrochloric acid is a mixture by volume of

1.one part HCl : 4 HNO_3; 2. one HNO_3 : 4HCl; 3. HNO_3: 3HCl 4.HCl:3HNO_3

___ (11)The oxidation number of chlorine in sodium chlorate is

1. plus one 2. minus one 3. plus five 4. minus five

___(12) Magnesium hydroxide will not be precipitated by the addition of ammonium hydroxide to a solution of a magnesium salt,when salts of

1. magnesium 2. ammonium 3. chlorine 4. zinc are present

___(13) Gold has an equivalent weight of 65.7 and a specific heat of .032, its Gm. Atomic Weight is

1. 65.7 2. 131.4 3. 262.8 4. 197.1

___(14) The complex ammonic ion is represented by

1. $CuNH_3$ 2. $CuNH_4$ 3. $Cu(NH_3)_4$ 4. $Cu(NH_3)_2$

___(15) A carbon tetrachloride solution of iodine is

1. colorless 2. violet 3. brown 4. crimson

___(16) Nitrigen compounds are used medicinally for

1.Hypertension 2. diuretics 3. disinfectants 4.hypotension

___(17) Avogadro's number is

1. 96,500 2. 60×10^6 3. 6.06×10^{23} 4. 22.4

___ (18) Alums are formed by

1. Rh 2. Pd 3. Pt 4. Ru

___(19) Of the following,the most difficult to liquify is

1.Hydrogen 2. Oxygen 3. Helium 4. Carbon Dioxide

___(20) Hydrogen having a mass of 2 is referred to as

1.protium 2. tritium 3. deuterium 4. zwitter

___(21) In solid NaCl, the individual particles of the Na and Cl consist of

1.atoms 2. molecules 3. ions 4. isotopes

___(22) The above question involves the theory of

1. Debuye Huckel 2. Arrhenius 3. Guldberg Waage 4. Lavosier

___(23)In the laboratory,oxygen is most commonly prepared from

1.Potassium chlorate 2. sodium peroxide 3. HgO 4. MnO_2

___(24) A mixture of sulfur and iron can be separated by means of

1. steam 2. carbon bisulfide 3. zinc chloride 4. water

___(25) In the periodic table, which of the following has its order reversed.

1. sodium 2. iodine 3. calcium 4. magnesium

PART III

Fill in the blanks at the end of each statement with what you consider the most correct answer; then bring your answer to the left of the number in the space provided. PRINT ANSWERS.

_____(1) The color of the sulfur flame is _____ .

_____(2) The approximate nitrogen content of air is _____ .

_____(3) Like elements grouped together in the periodic table constitute a chemical _____ .

_____(4) The name given to an alloy of another metal with mercury is an _____ .

_____(5) The formation of perchromic acid with sulfuric acid and potassium dichromate indicates the presence of a _____ .

_____(6) Reactions which liberate heat are called _____ .

_____(7) In the preparation of oxygen using potassium chlorate, the manganese dioxide serves as a _____ .

_____ (8)Ammonia water belongs to the class of compounds known as _____ .

_____(9) An acid which donates two protons is called _____ .

_____(10)Name another test paper besides litmus _____ .

_____(11)Name a halogen which will liberate chlorine from a chloride _____ .

_____(12)Name a gas that connot be collected over water _____ .

_____(13)The color of a freshly prepared solution of nitrous acid is _____ .

_____(14)The color of a boric acid flame is _____ .

_____(15) Another substance which gives the same color flame as in question (14) is _____.

Part IV

Place the appropriate figure as indicated in the blank provided.

In the laboratory determination of the equivalent weight of magnesium using HCl and measuring the volume of hydrogen obtained from a given weight of magnesium, (1)too high a change (2) too low a change (3) no change in the value would be obtained,

1.___ if the gas had a temperature slightly higher than the air in the room.

2.___ if a bubble of hydrogen were lost.

3.___ if a particle of magnesium failed to dissolve.

4.___ if the magnesium contained iron as an impurity.

5.___ if through error in weighing,the Mg actually weighed more than your figure.

6.___ if the water over which the gas was collected actually was cooler than the temperature you used.

The specific gravity of a viscous liquid is to be determined; from point of speed and reasonable accuracy, evaluate the following instruments. Mark the best with the figure(1), the next best (2) etc.

7.___ Mohr Westphal balance

8.___ Lovi beads

9.___ hydrometer

10.___ pycnometer

11.___ Sprengel tube

Place in the blank before each element or compound, the number of the color which most nearly describes it. One color may be used more than once if necessary.

12.___ malachite

13.___ cupric oxide

14.___ cobalt chloride

15.___ magnesium oxide

16.___ manganese chloride

17.___ manganous chloride

18.___iodine T.S.

19.___ferrous sulfate

20.___nickelous nitrate

1. black
2. white
3. colorless
4. green
5. pink
6. gray
7. blue
8. tan
9. orange
10. reddish brown

CHAPTER III

ANALYSIS OF DATA

Introduction. The evaluation of this instrument includes some general measures of central tendency and variability, an individual item analysis, and a determination of reliability. The test has curricula validity.

The statistics on central tendency and variability. In this preliminary test administration, the summarized results of the total test scores will be presented and interpreted first. A breakdown of the individual parts of the test will follow.

TABLE I

RESULTS OF THE TOTAL SCORES OF THE TEST

Mean	S.D.	Range	No. of Items	N
57.99	7.50	36 - 84	110	100

Table I indicates that the scores were spread over a total of forty-eight points. The highest raw score obtained was eighty-four out of a possible one hundred and ten.

TABLE II

RESULTS OF THE ADMINISTRATION OF PART I

Mean	S.D.	Range	No. of Items	N
31.65	4.71	20 - 41	50	100

Table II shows the range to be twenty-one points. No pupil got the possible fifty points on this area. The highest raw score was forty.

TABLE III

RESULTS OF THE ADMINISTRATION OF PART II

Mean	S.D.	Range	No. of Items	N
12.22	3.21	5 - 21	25	100

Table III gives the range as being sixteen. No student obtained the possible twenty-five points. The general achievement of the students on this part of the test was not as good as on Part I. The highest raw score was twenty-one.

TABLE IV

RESULTS OF THE ADMINISTRATION OF PART III

Mean	S.D.	Range	No. of Items	N
8.69	1.94	4 - 12	15	100

Here we see that the highest raw score in this section of the test is twelve and the lowest, four. The scores are spread over eight points.

TABLE V

RESULTS OF THE ADMINISTRATION OF PART IV

Mean	S.D.	Range	No. of Items	N
5.50	2.12	1 - 13	20	100

Out of a possible twenty in this section, the highest raw score obtained was thirteen. The scores were spread over twelve points. This part of the test appears to have been the most difficult as is evidenced by the low mean of the scores.

Summarization of the results of the statistics on central tendency and variability. No student achieved the highest possible score on any one of the parts of the test. Part I, the true-false area appears to have been the least difficult while Part IV, the evaluation and matching area, was the most difficult.

THE INDIVIDUAL ITEM ANALYSIS

The discriminatory power and difficulty of each test item was ascertained by an individual item analysis. The difference between the percentage of correct responses for the upper twenty-five per cent of the cases and the percentage of correct responses for the lower twenty-five per cent of students taking the test divided by the standard error of the difference gave the critical ratio. The following formulas were employed:

$$\text{Critical ratio} = \frac{\text{diff. } P_1 P_2}{\text{S.E. diff. } P_1 P_2}$$

$$\text{S.E. diff.} = \sqrt{\text{S.E. of } P_1^2 + \text{S.E. of } P_2^2}$$

Calculations were facilitated by the use of The Edgerton Tables[1] which provided the standard errors of the percentages squared. In this study, a critical ratio of 2.576 or better was deemed statistically significant. Lindquist[2] maintains the following concerning the choice of levels:

> The "critical value" which the significance ratio must exceed in order that we may declare the difference "significant" depends upon the level of confidence that we choose to employ, and this in turn depends upon our temperment and other considerations. Educational and psychological research workers have in the past frequently followed the practice of requiring that the significance ratio exceed 3 before declaring a difference significant, that is, they have insisted on a very high degree of confidence (0.26 per cent level) that the null hypothesis is false. More recent practice is to utilize the 1 per cent or 2 per cent levels, with 2.58 and 2.33 as the corresponding "critical values" of the significance ratio.

1/ Edgerton, Harold A., and Patterson, Donald G., "Table of Standard Errors and Probable Errors of Percentages for Varying Numbers of Cases," Photostat from Journal of Applied Psychology, Vol. 10, September, 1926, pp. 378-391.

2/ Lindquist, F.E., "A First Course in Statistics," Houghton Mifflin Company, Boston, 1942, p. 132.

Correction for guessing. Part I and Part II of this instrument contain respectively the true-false and multiple choice types of questions. Chances of success due to guessing must be taken into consideration. Guilford[1] gives the following formula for the correction for chance success:

$$ {}_{c}p = \frac{n\,p - 1}{n - 1} $$

where ${}_{c}p$ = proportion of passes corrected for chance success.

n = number of alternative responses.

p = obtained, uncorrected, proportion of passes.

A table based upon the above derivation was referred to and the corrections for chance success in Part I and Part II were made.[2]

1/ Guilford, J. P., "Fundamental Statistics in Psychology and Education," McGraw-Hill Book Company, Inc., New York, 1942, p. 118.

2/ Ibid., p. 117.

TABLE VI

INDIVIDUAL ITEM ANALYSIS PART I

Test Items	Percentage of Correct Responses		Adjusted % 2 Alternatives		Diff. %	S.E. diff.	C.R.
	High	Low	High	Low			
1	64	52	28	4	24	.098	* 2.449
2	80	20	60	0	60	.098	6.122
3	68	24	36	0	36	.096	3.750
4	92	44	84	0	84	.073	11.506
5	96	80	92	60	32	.112	2.857
6	92	44	84	0	84	.073	11.506
7	92	52	84	4	80	.082	9.756
8	76	48	52	0	52	.100	5.200
9	68	76					*
10	88	60	76	20	56	.113	4.955
11	76	60	52	20	32	.128	* 2.500
12	100	76	100	52	48	.100	4.800
13	72	44	44	0	44	.099	4.444
14	52	12	4	0	4	.039	* 1.026
15	48	32	0	0			*
16	100	60	100	20	80	.080	10.000
17	100	96	100	92	8	.054	* 1.481
18	76	68	52	36	16	.138	* 1.116
19	96	56	92	12	80	.027	2.962
20	76	28	52	0	52	.100	5.200

INDIVIDUAL ITEM ANALYSIS — PART I CONT'D

Test Items	Percentage of Correct Responses		Adjusted % 2 Alternatives		Diff. %	S.E. diff.	C.R.
	High	Low	High	Low			
21	52	24	4	0	4	.039	* 1.026
22	72	76					*
23	100	76	100	52	48	.100	4.800
24	60	32	20	0	20	.080	* 2.500
25	72	44	44	0	44	.099	4.444
26	60	40	20	0	20	.080	* 2.500
27	40	20	0	0			*
28	88	68	76	36	40	.127	3.228
29	76	52	52	4	48	.107	4.485
30	88	44	76	0	76	.085	8.941
31	64	40	28	0	28	.090	3.111
32	32	44	0	0			*
33	68	48	36	0	36	.096	3.750
34	84	52	68	4	64	.101	6.336
35	92	76	84	52	32	.124	2.580
36	96	72	92	44	48	.103	4.757
37	88	48	76	0	76	.085	8.941
38	68	24	36	0	36	.096	3.750
39	100	32	100	0	100		[1] ∞
40	96	76	92	52	40	.114	3.508

[1] The ideal situation where all of the cases in the upper group answer the question correctly and all of the cases in the lower group fail the question. This situation rarely occurs.

INDIVIDUAL ITEM ANALYSIS PART I CONT'D

Test Items	% Correct Responses		Adjusted % 2 Alternatives		Diff. %	S.E. Diff.	C.R.
	High	Low	High	Low			
41	96	64	92	28	64	.105	6.095
42	76	56	52	12	40	.119	3.362
43	76	52	52	4	48	.107	4.486
44	56	36	12	0	12	.065	*1.846
45	80	64	62	28	34	.132	*2.575
46	60	20	20	0	20	.080	*2.500
47	80	60	62	20	42	.125	3.360
48	80	44	62	0	62	.097	6.391
49	80	68	62	36	26	.136	*1.911
50	100	68	100	36	64	.096	6.666

Items 1, 9, 11, 14, 15, 17, 18, 21, 22, 24, 26, 27, 32, 44, 45, 46, and 49 are statistically insignificant as determined by the critical ratio of each item.

TABLE VII

INDIVIDUAL ITEM ANALYSIS PART II

Test Items	%Correct Responses High	Low	Adjusted % 4 Alternatives High	Low	Diff. %	S.E. Diff.	C.R.
1	92	60	89	47	42	.117	3.581
2	88	48	84	31	53	.117	4.529
3	36	20	15	0	15	.071	* 2.112
4	72	56	63	41	21	.137	* 1.532
5	60	40	47	20	27	.128	* 2.109
6	72	40	63	20	43	.125	3.440
7	88	44	84	25	59	.113	5.221
8	8	8	0				*
9	48	30	31	7	24	.104	* 2.307
10	88	48	84	31	53	.112	4.732
11	36	26	15	1	14	.073	* 1.917
12	84	8	68	0	68	.093	7.312
13	40	36	20	15	5	.106	4.732
14	96	48	95	31	64	.101	6.336
15	52	20	36	0	36	.096	3.750
16	64	24	52	0	52	.100	5.200
17	64	0	52	0	52	.100	5.200
18	48	20	31	0	31	.092	3.370
19	84	68	79	57	22	.127	* 1.733
20	92	80	89	73	16	.108	* 1.481

INDIVIDUAL ITEM ANALYSIS PART II CONT'D

Test Item	% Correct Responses High	Low	Adjusted % 4 Alternatives High	Low	Diff. %	S.E. Diff.	C.R.
21	92	56	89	41	48	.116	4.137
22	96	36	95	15	80	.083	9.638
23	96	44	95	25	70	.030	23.333
24	80	48	73	31	42	.127	* 2.383
25	96	44	95	25	70	.030	23.333

Items 3, 4, 5, 8, 9, 11, 19, 20 and 24 are below the one per cent level.

TABLE VIII

INDIVIDUAL ITEM ANALYSIS PART III

Test Items	Percent Correct Responses High	Low	%Diff.	S.E. Diff.	C.R.
1	92	60	32	.112	2.857
2	64	24	40	.127	3.150
3	72	60	12	.133	* 0.902
4	88	48	40	.119	3.360
5	0	0	0		*
6	100	88	12	.065	* 1.846
7	100	96	4	.039	* 1.025
8	92	40	52	.112	4.643
9	24	0	24	.085	2.823
10	92	88	4	.022	* 1.904
11	80	32	48	.122	3.934
12	88	52	36	.119	3.025
13	52	20	30	.128	* 2.343
14	80	40	40	.126	3.174
15	80	40	40	.126	3.174

Here it is observed that items 3, 5, 6, 7, and 10 show a high percentage of correct responses by both proportional groups resulting in a low C.R. Items 5 and 13 are also statistically insignificant as a result of the difficulty of the item to both groups.

TABLE IX

INDIVIDUAL ITEM ANALYSIS — PART IV

Test Item	Percent Correct Responses High	Low	% Diff.	S.E. Diff.	C.R.
1	44	16	28	.122	* 2.300
2	72	12	60	.111	5.405
3	12	4	8	.024	3.333
4	32	28	4	.129	* 0.310
5	36	20	16	.124	* 1.290
6	36	12	24	.115	* 2.086
7	72	12	60	.111	5.405
8	52	24	28	.131	* 2.137
9	4	0	4	.039	* 1.026
10	28	16	12	.115	* 1.043
11	32	0	32	.093	3.440
12	28	4	24	.031	7.742
13	32	8	24	.090	2.667
14	40	12	28	.117	* 2.400
15	88	32	56	.113	4.956
16	32	0	32	.093	3.440
17	36	0	36	.096	3.750
18	76	16	60	.111	5.415
19	76	28	48	.123	3.902
20	24	0	24	.085	2.824

The statistical standard set for this study is not met by items 1, 3, 4, 5, 6, 8, 9, 10, and 14 of this part of the test.

RELIABILITY

Concerning reliability, Greene, Jorgenson, and Geberich[1] have stated:

> A test is said to be reliable when it functions consistently. The reliability of an examination depends upon the efficiency with which a test measures what it does measure.

Of the several methods available for the determination of the coefficient of reliability, the writer chose the split-half method because of its feasibility in this type of examination which offers no alternate form.

Procedure. Those items eliminated by the individual item analysis were discarded, and the test items were renumbered and then rescored on the basis of dividing the test into odd and even numbered items. The two halves were correlated by use of the Pearson product-moment formula, which is explained below.

$$r_{xy} = \frac{\frac{\Sigma XY}{N} - (C_x C_y)}{(\sigma x)(\sigma y)}$$

where: X and Y are deviations from the guessed mean in terms of the class interval as the unit.

C_x and C_y are corrections in X and Y.

σx and σy are standard deviations in X and Y in terms of the class interval as the unit.

The coefficient of correlation thus obtained was 0.70. Next, by use of the Spearman-Brown formula, the reliability of the total test and not the half, was determined, and found to be 0.82.

1/ Greene, Harry A., Jorgenson, Albert N., and Geberich, Raymond J., MEASUREMENT AND EVALUATION IN THE SECONDARY SCHOOL, Longmans, Green and Company, New York, 1946, p. 61.

The Spearman-Brown formula is:

$$r_t = \frac{2r_{1/2}}{(1 + r_{1/2})}$$

where: r_t is the self-correlation of a test in its full length.

$r_{1/2}$ is the self-correlation of one-half of the test.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to construct and evaluate a test designed to measure the achievement of pharmacy students in inorganic chemistry. This test was given in May 1948 to exactly one hundred freshman pharmacy students enrolled in a school of pharmacy in Massachusetts. Measures of central tendency and variability as well as a coefficient of reliability and an individual item analysis were derived from the results.

Conclusions. The following conclusive statements are made:

1. Of the 110 items employed in this test,
   63 have a critical ratio of 3.0 or more,
   70 have a critical ratio of 2.576 or more,
   82 have a critical ratio of 1.960 or more.
2. Seventy test items meet the statistical standard set for this study.
3. The items of this test were based in part upon an established program of study and may be considered as possessing curricula validity, insofar as the program of study is valid.
4. The reliability coefficient of this instrument after revision as determined by the Pearson r and subsequent use of the Spearman-Brown formula is 0.82. This is as high as could be expected with a small number of items.

CHAPTER V

SUGGESTIONS FOR FURTHER STUDY

1. With those items that meet the statistical standard as the nucleus, the test could be lengthened to increase its reliability further. It should be borne in mind that approximately one-third of the items in the original test were eliminated.
2. The test should be administered to other freshman pharmacy students to compare the results with the statistical data of this study.
3. This test should be given to the sophomore pharmacy class to determine the grade difference and the results of taking advanced chemistry courses.
4. The use of this instrument with follow-up remedial measures should be studied.
5. This test might be given to candidates for registration as pharmacists in Massachusetts to set standards for the passing grades in the inorganic chemistry area.

BIBLIOGRAPHY

Babor, Joseph A., Basic College Chemistry, New York: Thomas Y. Crowell Company, 1946. 701 p.

Deming, Horace G., Fundamental Chemistry, New York: John Wiley and Sons, Incorporated, 1940. 749 p.

_____, A Laboratory Manual of College Chemistry, New York: John Wiley and Sons, Incorporated, 1937. 268 p.

Edgerton, Harold A., and Paterson, Donald G., "Table of Standard Errors and Probable Errors of Percentages for Varying Number of Cases," Journal of Applied Psychology, 10:378-391, September, 1926

Elder, Albert L., Textbook of Chemistry, New York: Harper and Brothers, 1941. 751 p.

Greene, Harry A., Jorgenson, Albert N., and Geberich, Raymond J., Measurement and Evaluation in the Secondary School, New York: Longmans, Greene and Company, 1946. 670 p.

Guilford, J. P., Fundamental Statistics in Psychology and Education, New York: McGraw-Hill Book Company, Incorporated, 1942. 333 p.

Hartung, Walter H., "A Course in the Chemistry of Organic Medicinal Products," American Journal of Pharmaceutical Education, 6:78-84, January, 1942

Jones, Norton W., Inorganic Chemistry, Philadelphia: The Blakiston Company, 1947. 817 p.

Lindquist, E. F., Statistical Analysis in Educational Research, Boston: Houghton Mifflin Company, 1940. 266 p.

_____, A First Course in Statistics, (Revised Edition), Boston: Houghton Mifflin Company, 1942. 284 p.

Mannion, M. H., "The Construction and Evaluation of a Test to Measure the Sentence Sense Development of Seventh Grade Pupils," Unpublished Master's Thesis, Boston University, School of Education, Boston, 1947. 70 p.

McPherson, William, Henderson, William Edwards, Fernelius, Conrad W., and Quill, Laurence Larkin, Introduction to College Chemistry, Boston: Ginn and Company, 1946. 608 p.

Mursell, James L., Psychological Testing, New York: Longmans, Greene and Company, 1947. 449 p.

National Pharmaceutical Syllabus Committee, The: The Pharmaceutical Syllabus, Tentative Fifth Edition (revised), Chapel Hill, North Carolina, 1945. 189 p.

Phelan, E. W., "The 1936-1937 College Chemistry Testing Program," Journal of Chemical Education, 14:229-31, May 1937

Powers, S. R., "Objective Measurement in General Science," Teachers College Record, Vol. 29, 1925, pp. 345-349

_____, "A Diagnostic Study of the Subject Matter of High School Chemistry, Teachers College Contributions to Education, No. 149, New York: Columbia University, 1924

Ray, Francis Earl, General Chemistry, New York: J. B. Lippincott Company, 1947. 592 p.

Remmers, H. H., and Gage L.L., "Achievement and Predictive Testing in the Pharmaceutical Survey," American Journal of Pharmaceutical Education, 11:43-62, January, 1947

Rogers, Charles H., Soine Taito O., and Wilson Charles O., Inorganic Pharmaceutical Chemistry, Philadelphia: Lea and Febiger, 1948. 704 p.

Ruch, G. M., and Stoddard, George D., Tests and Measurements in High School Instruction, Yonkers-on-Hudson, New York: World Book Company, 1927. 381 p.

Sorenson, H., Statistics for Students of Psychology and Education, New York: McGraw-Hill Book Company, Incorporated, 1936. 373 p.

Timm, John Arrend, An Introduction to Chemistry, New York: McGraw-Hill Book Company, Incorporated, 1938. 568 p.

Vincent, Hugh C., "A Quantitative Survey of the 1945-1946 Pharmacy Curricula," American Journal of Pharmaceutical Education, 10:11-34, January, 1946

Whiteford, G. H., Coffin R. G., and Wing Elizabeth M., An Outline of Laboratory Work in Inorganic Chemistry, St. Louis: The C. V. Mosby Company, 1940. 220 p.