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Title: The Effects of Advance Organizers on Student
Achievement in General Chemistry

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Thomas P. Evans

The purpose of this study was to investigate the
effectiveness of an expository advance organizer on the
achievement of students in a general chemistry course.

The subjects included 181 first year college students
enrolled in 12 sections of general chemistry at the
Chulachomklao Royal Military Academy, Thailand. The subjects
were randomly assigned by section into two treatment and
control groups. The treatment groups received an advance
organizer or an introductory passage prior to instruction.
The control group received no treatment prior to
instruction.

The equivalence of the control and two treatment groups
at the beginning of the study was determined by the
application of a teacher-made pretest. No significant
differences in chemistry achievement were found among the
three groups.

Prior to classroom instruction and laboratory
instruction, the advance organizer group received expository organizers, and the introductory passage group received introductory passages to read and study. The treatment period covered 21 days of instruction. Upon completion of all study material, a teacher-made achievement posttest covering the material taught during the study was administered to all groups. The posttest was administered again two weeks later as a retention test.

Achievement test scores were analyzed by use of a one-way analysis of variance. The results indicated that the advance organizer group performed significantly better than the control and introductory passage groups on the achievement posttest and retention test. Theses findings provided evidence that an expository organizer facilitated learning and retention of general chemistry more than an introductory passage and no treatment. These results supported Ausubel’s Advance Organizer Theory in the facilitating effects of advance organizers on student achievement.
The Effects of Advance Organizer on Student Achievement in General Chemistry

by

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THE EFFECTS OF ADVANCE ORGANIZERS ON STUDENT ACHIEVEMENT IN GENERAL CHEMISTRY

CHAPTER I

INTRODUCTION

Every experienced teacher and developer of instructional materials knows that the way instructional material is introduced to a student influences student motivation and learning. Such introductions provide a perspective of what lies ahead and serve as a framework on which subsequent learning can be based. In addition, such introductions suggest to the learner that which is important or essential within the material.

In designing instructional materials much thought and care should be given to choosing the best way of preparing students for, and introducing them to, new and different learning materials. These introductions have been termed advanced organizers (Ausubel, 1960). Ausubel (1963) stated that the purpose of advanced organizers is to relate the potentially meaningful materials to be learned to the already existing cognitive structure of the learner. He assumes that the full learning potential of materials can only be reached when the learner possesses a cognitive structure to which substantive aspects of the new knowledge
can be related. When the student already possesses adequate background knowledge for the new task, Ausubel suggests that advance organizers probably facilitate learning and retention by mobilizing whatever relevant anchoring concepts already exist. These concepts then take on the role of subsumers. The new material is made more meaningful as it is assimilated by relevant antecedent ideas. Advance organizers at the appropriate level of inclusiveness ensure that subsumers are specifically and explicitly relevant to new ideas (Ausubel, 1968).

When students lack adequate background knowledge, they do not have directly relevant subsumers already available. Advance organizers then provide the relevant subsumers. The need for rote memorization of unfamiliar material is lessened (Ausubel, 1968). Advance organizers, then, either activate knowledge already acquired which can be used to subsume new information or provide the subsumers for the new information.

In the 20 years since Ausubel (1962, 1963) proposed his theory of meaningful verbal learning, a large amount of empirical research based on that theory has accumulated. Much of this research has focused on the role of advance organizers in promoting learning and retention. Reviews of the advance organizer literature reveal, however, that support for such organizers is equivocal at best. Barnes and Clawson (1975) reviewed 32 advance organizer studies and
concluded that the efficacy of organizers was not supported. Luiten, Ames, and Akerson (1980), on the other hand, conducted a meta-analysis of 135 advance organizer studies and concluded that, overall, these studies indicated a small, but facilitative effects. In yet another meta-analysis, Stone (1983) reported findings that supported the facilitative effects of advance organizers. In addition, in a series of studies reviewed (see Chapter II) on the use of advance organizers to facilitate learning and retention in science subjects have shown conflicting results. These results suggest that there is a need to conduct more research on the use of advance organizers to facilitate learning in science.

Rationale and Theoretical Framework of the Study

The theoretical framework for the study was drawn from a review of literature and an analysis of the characteristic of teaching/learning at CRMA. The framework is organized into three areas as follows:

1. Advance organizers.
2. Findings of related research.
3. Background of the problem.

Each of these areas is discussed in the following paragraphs.
Advance Organizers

Theory of Meaningful Verbal Learning

The Theory of Meaningful Verbal Learning represents an information-processing approach to learning. Ausubel believes that the structural concepts of each discipline can be identified and taught to the student, which then become an information processing system for him/her: an intellectual map which can be used to analyze more particular aspects of the content to be learned.

According to Ausubel (1967) the information-processing system is a set of ideas which provide anchors for new information as it is received and which provide a storehouse when new meanings are acquired.

Ausubel (1967) states:

...new ideas and information can be usefully learned and retained only to the extent that they are related to already available concepts or propositions which provide ideational anchors.

The understanding of the assimilation process is essential for explaining the process of learning or acquiring new meanings.

When a new, potentially meaningful idea is related to an established idea in cognitive structure, the interactional product that results is the emergence of a new meaning. This is the type of meaning that results when a potentially meaningful concept or proposition can be
subsumed under a more inclusive established idea in
cognitive structure as for example, an extension,
elaboration, modification or qualification of the
established idea.

... the meaning A'a' that emerges when "a" is related
to and interacts with "A" in this fashion, is the
product of this interaction between them, and is itself
a differentiated cognitive content (Ausubel, 1968).

\[ A + a \rightarrow A'a' \]

Established idea in cognitive structure
New, potentially meaningful idea
New meaning

The assimilation process requires a progressive
differentiation of cognitive structure from regions of
greater to lesser inclusiveness. Each region of
differentiation is contiguously ordered in a hierarchical
arrangement with the apex of the hierarchy consisting of the
most inclusive, stable, general and abstract ideas. As new
material is received, it interacts with and is appropriately
subsumed under a relevant and stable subsumer already
existent in the learner's cognitive structure. Hence, the
subsumer provides "ideational scaffolding" for the
acquisition of new information.

Initially, the consequence of the assimilation of new
material into an already organized cognitive structure
facilitates both initial learning and retention. In
addition, anchorage for the new material is provided which
enhances its retention for future reproducibility. The
information remains dissociated from its subsuming concepts and is reproducible as individually identified entities for a variable period of time. However, the new subconcepts are susceptible to the erosive influences of the tendency toward conceptualization. Larger, more inclusive concepts are more economical to retain than are the concepts and the specific information. Ausubel calls this process the obliteratorative stage of assimilation. The specific ideas become progressively less dissociable as entities and finally are no longer reproducible. They are forgotten.

One of the most important factors affecting the learning and retention of new meaningful material is the availability in cognitive structure of specifically relevant anchoring ideas that are inclusive enough to provide optimal relatability and anchorage. If these specific relevant ideas are not available in cognitive structure for the learner attempting to acquire meanings, he/she will most likely attempt to utilize ideas that are only tangentially or vaguely relevant. Another possibility is that he/she may employ a rote learning process. In either case, the result is inefficient anchorage of the new material, which results in the acquisition of unstable and ambiguous meaning.

Therefore, in order to avoid these pitfalls, it is preferable to introduce suitable advance organizers whose relevance to the learning task is made explicit and which function as facilitators of assimilation rather than to rely
on the haphazard availability or use of inappropriate anchoring ideas in cognitive structure.

**Definition of Advance Organizers**

An organizer is an instructional procedure used at the beginning of a learning activity that will organize and anchor concepts for the facilitation of learning. The term organizer is used to describe more complex and deliberately prepared sets of ideas which are presented to the learner in advance of the body of meaningful material to be learned, in order to insure that relevantly anchoring ideas will be available (Ausubel, 1969, p. 145).

According to Ausubel (1969, p. 146), organizers may be of two kinds. If the new learning material is totally unfamiliar to the learner, an expository organizer would be used. Such an organizer would build on whatever established and relevant knowledge currently exists in the student's cognitive structure. This would serve to make the learning material more plausible or comprehensible. The organizer itself would thus bear a combinational relation to cognitive structure, and its content would make explicit both its relatedness to general relevant knowledge already present in cognitive structure and its own relevance for the more detailed aspects of the material to be learned. These latter detailed aspects would then be subsumed under the organizer.
If the new learning material is not completely novel, a comparative organizer would be used. This organizer is used to integrate new concepts with basically similar concepts in cognitive structure, as well as to increase discriminability between new and existing ideas (Ausubel, 1963, p.83). Thus, whether already established anchoring ideas are non-specifically or specifically relevant to the learning material, the organizer both makes this relevance more explicit and itself explicitly related to the more differentiated content of the learning task.

True organizers should not be confused with ordinary introductory overviews (Ausubel, 1969, p.315). The latter are typically written at the same level of abstraction, generality, and inclusiveness as the learning material. They achieve their effect largely through repetition, condensation, selective emphasis on central concepts and prefamiliarization of the learner with certain key words. Summaries are comparable to overviews in construction, but are probably less effective rather than proactive relative to the learners task.

Organizers also have certain inherent advantages both over various kinds of intra-material organization and over any existing subsumers within cognitive structure that could be used for organizational purposes. Unlike intra-material organization that provides necessary anchorage for and differentiation of new ideas at a particular level just
before each new idea is encountered, organizers perform the same functions in advance at a much more global level before the learner is confronted with any of the new material.

**Characteristics of Advance Organizers**

According to Mayer (1979), an advance organizer generally has each of the following characteristics:

1. Short set of verbal or visual information,
2. Presented prior to learning,
3. Containing no specific content from the to-be-learned information,
4. Providing a means of generating the logical relationship among the elements in to-be-learned information,
5. Influencing the learner’s encoding process. The manner in which an organizer influences encoding may serve either of two functions: to provide a new general organization as an assimilative context that would not have normally been present, or to activate a general organization from the learner’s existing knowledge that would not have normally been used to assimilate the new material.

**Functions of Advance Organizers**

Advance organizers represent the teacher’s attempt to
make the organization of material to be learned and remembered explicit for the students in advance of the presentation of the material. Advance organizers reduce, or even eliminate, the need for the student to organize the material.

According to Ausubel (1968), the function of the advance organizer is to "bridge the gap between what the learner already knows and what he/she needs to know before he/she can successfully learn the task at hand."

Advance organizers are probably most usefully thought of in terms of their function rather than in terms of their appearance. Three functions are clearly discernible:

1. To provide ideational scaffolding for the more differentiated learning task, or

2. To increase the discrimiability of the latter from related ideas in existing cognitive structuring, or

3. To effect integrative reconciliation at a level of abstraction, generality and inclusiveness which is much higher than that of the learning material itself (Ausubel & Robinson, 1969).

Unless one or more of these functions are fulfilled, directly or indirectly, more and more of the characteristics of rote learning can become apparent. Furthermore, learning becomes much more unstable or ambiguous, with a consequent memory loss. The ultimate goal of an advance organizer is to help a learner fit new, and increasingly more difficult
material, into his/her existing cognitive structures. Attitudinal or affective structures can be similarly served.

**Developing Advance Organizers**

Ausubel (1968) defines advance organizers as "appropriately relevant and inclusive introductory materials...introduced in advance of learning...and presented at a higher level of abstraction, generality, and inclusiveness (p. 148).

Much criticism has been leveled against the advance organizer strategy (Barnes & Clawson, 1975; Hartley & Davis, 1976; Rickards, 1980). The most common criticism is that the Ausubel’s definition of advance organizer is vague and ambiguous. In this connection, Hartley and Davis (1976) said:

> Most of the research seems confused. It is now recognized that there is currently no acceptable way of generating or recognizing advance organizers. This uncertainty has led at least one researcher to complain, "If it works, it’s an advance organizer; if it doesn’t work, it isn’t" (p. 256).

Ausubel (Ausubel, Novak, & Hanesian, 1978) has argued that this common criticism is unjustified. He claimed to have spent 23 pages discussing organizers in an earlier book (Ausubel, 1968) including a discussion of how to construct an organizer on the topic of biological evolution.

Still, Ausubel’s definition of the advance organizer is logical rather than operational. It explains conceptually
what advance organizer is but does not specify how it is to be constructed (Clarke & Bean, 1982).

However, Ausubel (1978) has suggested a simple procedure of constructing an advance organizer. He indicated that one can identify the organizer by simple comparison with its accompanying learning passage and from knowledge of the student's prior knowledge. At a more sophisticated level of methodology, one can obtain consensus among judges that the organizer actually fulfills its purported criteria in relation to the learning passage, and one can map existing concepts in cognitive structure either through pretests or by means of Piagetian clinical interviews. Unfortunately, this procedure has not completely solved the problem of operationalizing the advance organizers. For example, no specific step suggested in this procedure related to selecting the content included in the organizer.

Some other procedures have been proposed for operationalizing the organizers (Barron, 1969; Clawson & Barnes, 1974; Singleton, 1979). These procedures seem to have some limitations. For example, those procedures do not include the step of mapping the cognitive structure of the learners. For Ausubel, this mapping is a major step towards constructing the organizers (Ausubel, 1978).

Zeitoun (1983) proposed a new procedure that can be utilized by researchers to construct effective advance organizers. This procedure is called "The Procedure of
Operationalizing Advance Organizer" (POAO). The procedure is based mainly on the Ausubel propositions related to advance organizers. It is also based on the empirical findings of advance organizer research.

**Finding of Related Research**

Research in the use of advance organizers to facilitate learning in science area has taken place in the last two decades, but it appears that certain aspects of it have been nebulous and inconclusive. A critical review literature showed that there is a need for future study. Forty-seven studies concerning advance organizers have been reported. Of these, 20 concluded that advance organizers affect the ability of the learner to grasp concepts more efficiently and thereby retain knowledge longer (Adejumo & Ehindero, 1980; Chandler, 1985; Cliburn, 1985; Grimaldi, 1987; Hawk, 1986; Jones, 1977, 1979; Kahle & Rastovac, 1976; Kennedy, 1974; Krahn & Blancaer, 1986; Kuhn & Novak, 1970; Lewis, 1986; Morgan, 1985; Pella & Triezenberg, 1969; Pizzini & Gross, 1981; Ryder, 1970; Slock, 1980; Weisberg, 1970; West & Fensham, 1976; West & Kellet, 1981). Twenty-seven of the studies showed that no significant differences exist among groups using advance organizers and those not using them (Bricker, 1989; Carnes, Lindbeck & Griffin, 1987; Corbett, 1985; Dennis, 1984; Dvergsten, 1971; Feller, 1973; Forsythe,

A critical review of these 47 studies revealed that a majority were poorly designed. As a result, several of the reported findings are questionable. The conflicting results of previous research, coupled with the poor research designs used in many of the studies reveal a need to conduct additional research using a good design on the use of advance organizers to facilitate learning.

Five studies investigated the use of advance organizers to facilitate learning in chemistry (Graber, Mean & Johnsten, 1972; Hoffelder, 1973; West & Fensham, 1976; Petrich & Montague, 1981; West & Kellet, 1981). Though the literature revealed the use of advance organizers in chemistry, no reported studies could be found which related advance organizers to learning effectiveness in laboratory or classroom and laboratory settings. Since the laboratory is an important aspect of science instruction, there is a need to conduct research on the use of advance organizers to facilitate learning in the chemistry laboratory as well as the classroom using a design with good internal and external validity.
**Background of the Problem**

Chulachomklao Royal Military Academy (Hereafter referred to as CRMA) is the only army academy in Thailand which offers the Bachelor of Science Degree. No other university in Thailand requires five full years of exhaustive studies in the arts and sciences and 262 semester credit hours to obtain a degree. Only 20 percent of the credits are in military science courses. Every credit hour represents 16 hours of lectures or 32 hours of laboratory work and at least 14 hours of independent research and study. Excluding military science courses, a Chulachomklao Royal Military Academy Bachelor of Science Degree requires nearly 70 semester credit hours more than any other degree from any civilian university in the Kingdom.

General chemistry and organic chemistry are required courses for the first and the second year cadets. The higher level chemistry courses are offered for the fourth and the fifth year cadets. Generally, teachers of general chemistry in CRMA are confronted with problems in two fundamental areas—what chemistry content to teach, and how to teach chemistry. In terms of what to teach, the general chemistry teacher is faced with an expanding number of topics to consider for inclusion in the course. Some topics that used to be reserved for advanced courses in analytical or
physical chemistry is being introduced in general chemistry. The teacher is, therefore, confronted with the problem of trying to select from an expanding body of knowledge those topics which are most appropriate to student needs in subsequent chemistry courses and related fields.

Basically, the primary teaching methods the general chemistry teachers at CRMA use are lecture, discussion, demonstration and laboratory. All the chemistry teachers are allotted office hours and help sessions during the time they are not teaching. However, every year some cadets do not pass the general chemistry course. One main reason is the large number of science and military training courses in each semester for the first and second year, which limits the independent study of the cadets. The second reason is that most regular students in this course have little or no previous knowledge in general chemistry course and thus have lack of anchoring points in the cognitive structure to aggregate the new concepts.

Students cannot be expected to learn new concepts or fundamentals without first having a good basic knowledge of related material that was taught previously. A teacher cannot depend on the students's already possessing a relevant subsumer, it is best that a relevant subsumer be provided before presenting new information. This assumes that the subsumer provided can be related to the learner's cognitive structure.
Purpose

The primary purpose of this study is to investigate the effectiveness of advance organizers on the facilitation of learning in a general chemistry course. More specifically, this research is designed to investigate the effects of written expository organizers on the facilitation of learning and retention resulting from instruction in the chemistry classroom and laboratory at the university level.

Research Questions

1. Do students who receive an expository organizer prior to classroom instruction achieve significantly more in chemistry than those who do not receive an expository organizer prior to classroom instruction?

2. Do students who receive an expository organizer prior to laboratory instruction achieve significantly more in chemistry than those who do not receive an expository organizer prior to laboratory instruction?

Research Hypotheses

The null hypotheses are:

1. There is no significant difference in achievement of general chemistry classroom material between students who
are given an expository organizer prior to classroom instruction and those who are given an introductory passage prior to classroom instruction.

2. There is no significant difference in achievement of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are not given an expository organizer prior to classroom instruction.

3. There is no significant difference in achievement of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are given an introductory passage prior to laboratory instruction.

4. There is no significant difference in achievement of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are not given an expository organizer prior to laboratory instruction.

5. There is no significant difference in retention of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are given an introductory passage prior to classroom instruction.

6. There is no significant difference in retention of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction.
instruction and those who are not given an expository organizer prior to classroom instruction.

7. There is no significant difference in retention of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are given an introductory passage prior to laboratory instruction.

8. There is no significant difference in retention of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are not given an expository organizer prior to laboratory instruction.

Assumptions

1. Advanced organizers have the potential of helping a learner fit new and increasingly more different material into his/her existing cognitive structure.

2. The findings of the research on the use of advance organizers to facilitate learning in science are inconclusive and contradictive.

3. Every student at CRMA does not already possess a relevant subsumers for learning new materials in chemistry.
Limitations

1. The study is limited to the students at Chulachomklao Royal Military Academy (CRMA) who enrolled as the first year cadets in general chemistry.

Definition of Terms

The following definitions are used in this study:

**Advance Organizer:** A relevant all encompassing, subsuming concept introduced before a lesson for purposes of organizing learning (Ausubel, 1963).

**Anchorage:** The characteristic of assimilating new learning material by the more inclusive meaning of its subsumers. The base on which new knowledge is subsumed (Ausubel, 1963).

**Cognitive Structure:** The organized mass of previously acquired knowledge which serves as a guide for the comprehension and assimilation of new ideas and concepts (Good, 1973).

**Expository organizer:** An organizer used for completely unfamiliar learning material and consisting of more inclusive concepts that could subsume or provide anchorage for the new material in terms that are already familiar to the learner (Ausubel, 1967).

**Ideational Scaffolding:** Temporary framework to link
(anchor) the new material with the cognitive structure.

Meaningful Learning: This process of learning involves the act of relating in a nonarbitrary way symbolically expressed ideas to what the learner already knows. It presupposes two conditions. First, the learner has to manifest a learning set, that is, a disposition to relate the new material with his cognitive structure. Second, the material has to contain elements capable of being related with cognitive structure. When one of the conditions fails, a potentially meaningful subject is integrated as rote learning.

Subsuming Concept: Associative concepts in the learner’s cognitive structure that accept new knowledge for purposes of enlarging and strengthening a concept (Ausubel, 1962). For purposes of this study it is the all-inclusive concept found in the advance organizer.

Written Advance Organizer: Any passage or printed material that reflected an all-encompassing, subsuming concept introduced before a lesson to organize learning.

Classroom achievement is the test score a student obtains from a teacher-made achievement test constructed to measure the knowledge attained in classroom instruction.

Laboratory achievement is the test score a student obtains from a teacher-made achievement test constructed to measure the knowledge attained in laboratory instruction.

Classroom instruction refers to a process of
instruction in which the teaching methodology emphasized is lecture, group discussion, and demonstration.

**Laboratory instruction** refers to a process of instruction in which the teaching methodology emphasized is laboratory activities.

**Methodology**

The population of the study will be composed of 181 students (12 class sections) taking first-year chemistry at CRMA. Intact classes will be randomly assigned to three treatment groups. Students will be pretested and posttested in chemistry using teacher-made tests. One-way analysis of variance will be used to analyze the data.

**Outline of the Remainder of the Thesis**

Chapter II presents a critical review and analysis of research in which the effects of advance organizers on science achievement was examined. The methodology used in the study is included in Chapter III. The analysis and interpretation of the findings are reported in Chapter IV. Summary, conclusions and recommendations are presented in Chapter V.
CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this chapter was to review and analyze research reports in which the effect of an advance organizer on student achievement in science was examined. It includes forty-seven research reports.

The chapter is organized into six sections based on the area of science covered in the reports. The first section includes 23 reports in biology. The second section contains five reports in chemistry. The third section includes nine reports in general science. The fourth section contains three reports in physical science. The fifth section includes three reports in physics. The sixth section consists of four reports in other science areas. The chapter concludes with a summary and conclusion based on a critical review of the research reports.

Biology


Schulz (1966), using 376 sixth-grade students of above average ability, compared a group that received two advance organizers based on Ausubel's criteria with a group that did not receive organizers. The subject matter was science; the treatment period covered 20 weeks of instruction. The first advance organizer was provided to the experimental group at the beginning of the study, and the second one 12 weeks later. There were no significant differences on the posttest or on the delayed posttest among any subgroups in the sample. Schulz concluded that advance organizers did facilitate learning when students lack the processing skill necessary to reorganize information independently into suitably clear, inclusive, and stable cognitive structure although his statistical difference were not significant.

Pella (1969) determined the relative effectiveness of three levels of abstraction (verbal, pictorial, working model) in the use of the conceptual scheme of equilibrium as an advance organizer when applied to instruction with reference to ecological systems in grades seven and nine as indicated by a test at three cognitive process levels. The relative effectiveness of the three levels of stimuli was tested by comparing the results achieved by three treatment groups: (1) the conceptual scheme of equilibrium presented
verbally, (2) the conceptual scheme of equilibrium presented verbally supplemented by sketches of appropriate models, and (3) the conceptual scheme of equilibrium presented verbally supplemented by appropriate mechanical models. The concepts related to the conceptual scheme of equilibrium were produced in three forms corresponding to the three treatments and were presented to each treatment group in a series of nine videotape lessons. The ecological concepts were identical. An analysis of variance was used to determine significance among the variables of an ability x grade design for the pretest. For posttest data a treatment x ability x grade x test event "repeated measure" design was used with the repeated measures only on the test event. The findings indicated that at the comprehension level, the use of working models for reference to the organizer was superior to verbal reference or the use of sketches. The use of models was not significantly superior when the desired level was knowledge or application.

Malone (1970) conducted two separate studies to test the following hypotheses: (a) knowledge acquisition of students receiving a cybernetic model advance organizer will be higher than that of students receiving a historical introduction prior to a learning task on physiological regulation; and (b) knowledge retention of students receiving a cybernetic model advance organizer will be higher than that of students receiving a historical
introduction prior to a learning task physiological regulation. The sample populations consisted of community college students enrolled in an introductory biology course. The students were randomly assigned to either the advance organizer or historical introduction groups. The students were directed to read the introductory passage twice and then proceed to the learning passage which they read twice. When they finished reading their materials, they were given the teacher constructed test based on the four regulatory systems presented in the learning passage. In the first study the subjects were retested after three weeks, and in the second study, after one week. Two-way analysis of variance showed no significant difference between treatment groups, between males and females, and no interactive effects between treatment and sex.

Kuhn and Novak (1970) conducted a study to test the hypothesis that the acquisition and retention of unfamiliar, but meaningful, verbal material can be facilitated by the advance introduction of relevant subsuming concepts which Ausubel calls organizers. This study utilized two major concepts of modern biology as expository organizers. The unfamiliarity of the material was established by the administration of a test to a comparable group of subjects who had not studied the learning passage. There were two studies in this experiment. In Study I, a classic Ausubelian approach was used, but in Study II, an attempt was made to
combine the use of an organizer and the careful sequencing of subsequent material to be learned. In Study I the experimental group was exposed to the organizer on two occasions, before the actual learning experience and prior to the laboratory exercise. In study II, an expository organizer was presented to the experimental group immediately before a laboratory exercise, and students were allowed to refer to the organizer during the subsequent learning module. An analysis of variance was used to analyze the data from the posttest scores. The data indicated that there was a significant difference in favor of the organizer treatment groups in both studies. The results of the studies provided support for Ausubel’s model of learning.

Dvergsten (1971) compared the outcomes resulting from different methods of instruction. One method used advance organizers coupled with guided-discovery and the other used guided-discovery alone. Each subject in two groups consisting of 30 tenth graders enrolled in BSCS Green Version Biology was randomly selected and assigned to treatment groups. In the advance-organizer-guided discovery treatment, the students were presented with advance organizers (major idea) prior to encountering them in the reading assignments or laboratory exercises. Class discussions centered on the identification of concepts which supported the major ideas and on illustrations and applications of the major ideas or generalizations. In the
guided-discovery treatment, the students were given no advance information on major ideas which were of prime importance in reading or laboratory assignments. They were instructed to identify the concepts and their key attributes and attempt to combine concepts into meaningful generalization or major ideas. The finding, based on student posttest scores, showed that the advance-organizer-guided-discovery and the guided-discovery treatments were equally effective in teaching facts, concepts, and principles of biology, understandings of methods and processes of science, and critical thinking abilities. The treatment groups were equally effective in retaining acquired facts, concepts, and principles over a 56 day period.

Lucus (1972) studied the effects that three types of advance organizers had upon the learning of a biological concept in seventh-grade science as measured by a teacher-constructed achievement test. Assignment to treatment groups was random and stratified on the basis of I.Q. One hundred and twenty students were randomly selected to comprise the sample used in the analysis of the results. Treatment groups included an audio advance organizer group, a visual advance organizer group, a written advance organizer group, and a control (historical passage). Instruction included the presentation of an advance organizer or a historical passage prior to the reading of an instructional passage. Instruction was one hour in length during the school day,
and consisted of individualized teaching. A posttest was administered immediately after the reading of the learning passage. Scores of the achievement test were statistically analyzed by use of an analysis of variance. The results of the study indicated that the use of three types of advance organizers did not significantly affect the learning of a biological concept in seventh grade science, and that no interactive effects of I.Q. and sex were found.

Feller (1973) examined the effects of two types of introductions (advance organizer and historical organizer) and two types of spaced questions (factual recall questions and comprehension and application questions) on the reading comprehension of a selected group of tenth-grade students. The subjects consisted of 131 tenth-grade students in six biology classes. The six classes were randomly assigned to treatment groups. The organizer groups were given their respective introductions verbally immediately prior to reading the science passage. The spaced question groups read passages which had questions spaced at intervals throughout the reading passage. The questions were answered by the subjects as they were encountered in the text. All of these experimental treatment groups took the criterion test immediately after reading the science passage. Feller reported that there was no significant differences between the effects of the experimental treatments. The treatment method which utilized spaced "comprehension" questions
showed the most promise for facilitating the ability of students to understand and retained information from written science material.

Koran and Koran (1973) investigated individual differences in learning from written materials preceded by advance organizers. Eighty-nine fourth-grade subjects were randomly assigned to treatment conditions in which programmed material on insects was preceded by one of three introductory passages containing: (1) higher level generalizations and specific examples; (2) higher level generalizations without examples; or (3) a control passage. Membership in treatment groups was determined by random assignment. The posttest was administered immediately following the completion of the programmed material, and again one week later. Results of an analysis of variance of treatment effects showed that the three treatments were about equally effective in terms of promoting retention and program errors.

Shmurak (1974) determined if advance organizers designed to match student cognitive styles would produce greater learning and retention of expository science material than unmatched organizers. Students’ learning styles were determined by means of the Sigel Cognitive Styles Test. One hundred and twenty eighth-grade students participated in this study. Assignment to treatment condition was random and stratified by sex and reading
ability, as well as cognitive style. Each student was classified as having either a categorical-inferential, descriptive-part-whole, or relational style. Each experimental subject received one of four introductory passages which was either an advance organizer to match his/her style, an advance organizer designed to match one of the two other styles, or a non-organizer. After a five minute period of studying the introduction, each student was given 20 minutes to study an 1100-word learning passage on the action of insulin. A posttest was administered immediately after the reading of the learning passage and readministered one week later. Posttest and retest scores were analyzed in a 2x3x4 (readability by style by introduction) analysis of variance. The principal research hypothesis, that a match of student style and organizer style would produce greater learning and retention, was not supported by the data. The non-organizer was shown to be as effective as the advance organizers.

Toth (1975) investigated the effects of certain entering behaviors, more specifically, critical thinking and prior knowledge, on the interpretation of an advance organizer in the learning of a biology unit. The subjects for this study consisted of 136 ninth-grade students enrolled in BSCS Biology (Green Version). Prior to instruction, students were administered the Cornell Critical Thinking Test, to determine high and low levels of critical
thinking. All students were also given a test for prior knowledge. Treatment consisted of all students reading a 3000-word passage adapted from BSCS Biology. One half of students read a 425-word advance organizer prior to the treatment, and the other half read a comparable length historical passage prior to the treatment. The posttest scores were analyzed within a 2x2 factorial design which consisted of two levels of critical thinking (high and low) and two levels of instruction (advance organizer and historical passage). The results of analyses indicated that higher critical thinkers scored significantly higher than low critical thinkers on the achievement test. Interaction between critical thinking levels and the two levels of instruction was not significant. No significant difference between the advance organizer group and the historical passage group was observed. The result obtained in this study appear to dispute the necessity of advance organizers to make new material more meaningful.

Kahle and Nordland (1975) investigated the differential effect of an advanced organizer on the meaningful learning and retention of information presented to the learner in a sequential, structured program of individualized instruction. Two hundred and ninety three students enrolled in a biology course for elementary education majors participated in this study. The students were randomly divided into two treatment groups: one treatment group
received the advanced organizer, while the second group did not. Both groups received identical instructional materials, utilized in a mastery learning situation. The treatment period was 25 days. Several kinds of testing procedures were used to ascertain student progress: micro-learning tasks, self-administered tests, weekly oral quizzes, and weekly written unit tests. Part of the first hour exam in the course comprised the retention test which was administered four weeks after the study terminated. An analysis of variance was used to analyze the data. There was no significant difference found in means as a result of the treatment.

Kahle and Rastovac (1976) analyzed the effect of an organizer on meaningful learning when utilized with sequentially structured learning materials. One hundred sixteen students in grades nine and ten enrolled in an introductory high school biology course which was team-taught by two teachers were the subjects of the study. All subjects were assigned into six instructional periods by computer. For the three-week experimental period the subjects were assigned randomly within their predetermined class to one of the two treatment groups (experimental and control). Both treatment groups received identical self-instructional, audio-tutorial learning material. These materials had identified behavioral objectives and were carefully sequenced. Prior to receiving each of the three
learning units, each subject received either an advanced organizers (experimental) or an historical narrative (control) by means of audio-tape. Achievement in both groups was measured by a final examination. A one-way analysis of variance was used to analyze the data. There was a significant effect in favor of the experimental group. The study showed that advanced organizers increased meaningful learning of carefully sequenced materials.

Varano (1977) determined the effects of an advance organizer, behavioral objectives, a combination of advance organizer and behavioral objectives or a historical passage on the facilitation of learning and retention of a tenth-grade biology unit when the entering behaviors, prior knowledge and mental ability, were considered. Four classes of BSCS Yellow Version Biology consisting of 103 students participated in the investigation. Scores from a prior knowledge pretest and an IQ test were used to partition the students into high and low groups to analyze for any interaction between the treatments and the entering behaviors. The experimental data collected from the 103 tenth-grade biology students were analyzed for significant differences between the mean scores of the four treatments and also for interaction between the entering behaviors, prior knowledge and mental ability, using an analysis of variance technique. Results of the analysis revealed no significant differences between the four instructional
treatments on immediate learning or long-term retention. Varano concluded that the results obtained in her study indicated that learning was enhanced for those students receiving the advance organizer treatment even though the differences in mean scores were not significant.

Kahle (1978) conducted a study to determine the effects of advanced organizers and behavioral objectives on meaningful learning by disadvantaged students. All 105 subjects enrolled in an introductory biology course taught by two experienced biology teachers, were assigned randomly to either an experimental or control group. The two groups were established as equivalent by means of standardized tests and by a pretest which covered the instructional materials and was an equivalent form of the summative posttest. The instructional material was a series of three audio-tutorial units in genetics. During a six week experimental period, all subjects received audio tapes, study guides, visual aids, and tests. The control group received historical reviews for each unit, while the experimental group received advanced organizers or behavioral objectives or both. The reviews and treatments material were presented by audio tape as well as by printed format. After the completion of three learning units, all students took summative posttest. The delayed posttest was administered three weeks later. The t-test was used to analyzed the experimental data. The results indicated no
significant difference in achievement between treatment
groups.

Slock (1980) determined if an advance organizer would
cause both short term and long term increases in student
performance on an achievement test. The freshman medical
students taking the medical microbiology course were divided
into an experimental and control group. On two occasions
prior to the instructional unit both groups read a six-page
written passage. The experimental group read an advance
organizer while the control group read a non-conceptual
passage. The short term and long term effectiveness of the
advance organizer were determined by student scores on the
achievement test. The achievement test was administered
immediately after the instruction period to measure post-
instructional achievement (short term). It was also
administered six months later to measure retention (long
term). A three-factor analysis of variance was used to
analyze student scores on the achievement test. The results
showed that the experimental group performed significantly
better than the control group on the achievement test for
both post-instructional achievement and retention. It was
the recommendation of this study that advance organizers be
used in appropriate situations where large amounts of
factual information must be learned.

Adejumo and Ehindero (1980) investigated the use of
advance organizers in some modified form by involving
students in the preparation of organizers so as to enhance meaningful learning from textual material at a secondary (high) school level. The subjects for the study were 180 randomly selected students in classes two and five of a secondary (high) school in Nigeria. The students in class two were divided into three groups: (1) student participation organizer group, (2) experimental organizer group, and (3) control group. The same procedure was employed for class five groups. The students in the first group participated in the construction of advance organizers. The students in the second group used the advance organizers prepared by the experimenter. An analysis test was performed on the data for class-two groups and class-five groups. There were significant difference as a result of the strategy groups. The results of this study showed that the students in the lower class performed best when they participated in the construction of advance organizers. Students in class five scored higher when using organizers prepared by the experimenter as compared with that in which their colleagues participated.

Forsythe (1982) investigated the efficacy of advance organizers and behavioral objectives, when provided simultaneously, on the achievement of community college students. The treatments were distributed prior to instruction, in varying sequences, to 144 students. The students, who were divided into four sections, were told to
use the organizers and/or objectives in preparing for the lectures and examinations. The study included five separate treatment periods, with each period dealing with different biological concepts. The individual treatment periods were followed by a multiple choice examination and a final examination. An analysis of covariance was used to analyze the experimental data. No significant difference in achievement between treatment groups was observed. The researcher concluded that the efficacy of advance organizers and behavioral objectives when used as a combined treatment with science related material can not be determined with assurance.

Dennis (1984) investigated the effectiveness of advance organizers and repetition at the high school level with respect to: (a) measurement of lower level cognitive skills, and (b) measurement of higher level cognitive skills. Four groups of tenth-grade students enrolled in advanced biology classes were utilized. Students in all four groups were selected on past academic performance in previous science classes. Each group contained 18 students. Students were assigned to one of the three experimental groups or to a control group. Students in Experimental Group I received a pretest, an advance organizer, slide-tape presentation (two times), and a posttest. Students in Experimental Group II received a pretest, an advance organizer, slide-tape presentation (one time), and a posttest. Students in
Experimental Group III received a pretest, slide-tape presentation (two times), and a posttest. Students in Group IV (control) received a pretest, slide-tape presentation, and a posttest. The slide-tape presentation consisted of three genetic concepts that were presented over a three-day period. Results from a multivariate analysis of variance indicated no significant interaction between treatments on the lower and higher level cognitive skills. Student performance in the control group was as productive as student performance in the experimental groups.

Morgan (1985) investigated the effects of two types of prelaboratory exercise when used as advance organizers in an introductory biology laboratory course on student achievement and attitudes toward biology. The group of 19 college students randomly designated as the experimental group was provided advance organizer of two types (computerized lessons or journal articles) on an alternating basis for eight weeks, prior to the main instructional event. The main instructional event was a series of laboratory exercise found in a standard laboratory manual principally designed for nonscience majors. Twenty-one students enrolled in the other class constituted the control group. The control group was provided nonorganizing placebos that closely approximated the length and format of the advance organizers. Student mean scores on final examination as well as scores on seven weekly quizzes were analyzed by
treatment group. The results (statistically significant at .05 level) indicated facilitating effects of advance organizers on both student achievement and student attitudes as assessed in the study. The two types of prelaboratory exercise used as advance organizers were equally effective in enhancing student achievement. The results obtained support Ausubel’s Theory of Cognitive Subsumption, the theoretical basis of the study.

Cliburn (1985) compared two systems for organizing and presenting lecture material: the traditional method of sequencing in close accord with a textbook and an Ausubelian approach using concept maps for sequencing and as advance organizers for instruction. Subjects were students enrolled in anatomy and physiology classes at a Mississippi public junior college. Intact class sections were randomly assigned to control (traditional) and experimental (Ausubelian) treatments. The treatment encompassed a three-week unit covering the skeletal system, plus that time required for pretesting and posttesting. Demographic data were obtained using a questionnaire. A 30-item multiple choice test was administered three weeks prior to the experimental unit, immediately following the experimental unit, and six weeks following the experimental unit. Data were analyzed using a variety of statistical techniques. The experimental group exhibited marginally better performance on the immediate posttest than the control group. Experimental group scores
on the delayed posttest were significantly higher than those of the control group. Cliburn suggested that using concept mapping strategies during instructional planning and concept maps as advance organizers during implementation of that plan was a valid tactic for improving meaningful learning and retention of conceptual material. This study also stressed the importance of delayed posttesting in advance organizer research.

Corbett (1985) conducted an experiment to investigate either an expository alone, or in combination with behavioral objectives, would increase learning not only at a lower, but also at higher cognitive levels of Bloom's taxonomy. A sample of 106 baccalaureate nursing students were randomly assigned to four treatment groups and given different versions of preinstructional strategies before reading a study unit on the nursing implications of coagulation test. The four different versions contained behavioral objectives and/or an expository organizer which focused on the conceptual basis of the coagulation process. One version had the context of the expository organizer embedded in the text to extinguish its potency as a preinstructional strategy. After reading the study unit, subjects completed a unit posttest. A combination of behavioral objectives and an expository organizer produced an educationally significant increase in total scores when compared with the strategy of an expository organizer alone,
or with the strategy of behavioral objectives with the content of the expository organizer embedded in the text. Compared with the strategy of behavioral objectives alone, the combination strategy showed a slight increase in total scores, not quite educationally significant. The results indicated that behavioral objectives alone, were more effective than expository organizers alone. However, when the expository organizer was combined with behavioral objectives there was a small increase in scores. The potency of the expository organizer was lost when embedded in text.

Lewis (1986) compared the effectiveness of an Ausubelian Advance Organizer and simplified readability of science content when used together or separately in the biology laboratory. The criterion measure was a content examination. The population of this study included 239 ninth-grade students in eight academic biology classes, which were randomly assigned to treatments. In this study, the advance organizer groups received a written organizer at the beginning of class prior to receiving written laboratory procedures. Students then received either of the two types of written laboratory procedures. One types was written at a reading level close to the students own grade level, while the other type was rewritten at a lower grade level without changing content. The control group received no organizer or simplified written laboratory procedures. Upon completion of all study material, a posttest was administered to test
groups from the material taught during the study. The data analysis indicated that either the advance organizer or simplified reading material was significantly better than no treatment, but the two together are significantly better than either alone. The results of the study supported Ausubel's Advance Organizer Theory and use of the simplified readability method, as a facilitator to learning. When both treatments were given together, a greater facilitation of learning occurred, as compared to either alone.

Hawk (1986) determined the efficacy of graphic organizers in facilitating learning of above average students who were studying life science in the sixth and seventh grades. The subjects for this study were 213 seventh grader enrolled in seven classes of life science at four middle schools (control group); and 177 sixth graders enrolled in eight classes of life science at four other middle schools (experimental group). All students scored above the 60 percentile on the standardized achievement test. The classroom teachers administered the pretest during the second week of the school year. Instruction progressed throughout the first semester with all the teachers using their usual pedagogy and the selected activities. The teachers gave each student in the treatment group a graphic organizer at the beginning of each chapter and explained to the students that the graphic organizers were study guides. During the second week in January, the post-test was
administered to all 15 classes. The same instrument was used for the pre and posttest. The one-way analysis of covariance showed a statistically significant main effect in favor of the students who received instruction using graphic organizers. The result clearly supported the use of graphic organizers as a teaching strategy for improving student achievement.

Chemistry

Five studies investigating the effects of advance organizers on student achievement in chemistry were reviewed. These included Graber, Means and Johnsten (1972), Hoffelder (1973), West and Fensham (1976), West and Kellett (1981), and Petrich and Montague (1981).

Graber, Means and Johnsten (1972) studied the effect of subsuming concepts on student achievement on unfamiliar learning material in science. Students enrolled in an undergraduate chemistry class were rank ordered by their performance on a test of organizing ability. The median break was used to form two groups: good organizers (GO) and poor organizers (PO). Students within these groups were randomly assigned to treatments. Treatment I subjects received an advance organizer followed by a learning passage. Treatment II subjects received the same organizer
preceded by the learning passage. Treatment III subjects received an historical nonorganizer and the learning passage. A 3x2 ANOVA design was employed to analyze the results of learning passage test. No significant differences were observed on treatment or interaction, but students in GO group achieved significantly higher learning passage scores than students in the PO group.

Hoffelder (1973) investigated three types of instructional organizing materials for each of four units of introductory college chemistry. These materials--performance objectives, sample tests and informational narratives--were developed and incorporated into the regular curricula of the introductory course. The study was conducted in a liberal arts college for one semester. The students who enrolled in introductory college chemistry assigned themselves to one of the four available laboratory sections, each of which was then assigned one of four treatment types. The instructional organizer (or no organizer) assigned to each laboratory section was studied during the laboratory period for a specified amount of time during each of the two weekly meeting. From the data analysis, it was concluded that the types of instructional organizing materials (or the absence of an instructional organizer) had no effect on the learning of introductory college chemistry as measured by performance on a test of immediate and review learning.

West and Fensham (1976) attempted to apply a critical
empirical test to the part of Ausubel’s theory which describes the role played by the learner’s prior knowledge structure in meaningful learning. A prediction was made from the theory concerning the relationship between prior knowledge, whether or not an advance organizer was incorporated in the learning materials, and meaningful learning. The prediction was based on Ausubel’s postulation of the role of cognitive structure and advance organizers in meaningful learning. The prediction was confirmed by the experiment. It was argued that the result only weakly supported the theory since there may be many alternative explanations of the effect. The second prediction was considered to be more critical. It was argued that if the role of cognitive structure and advance organizers were as Ausubel proposes, then the remedial teaching of relevant prior knowledge would tend to remove the facilitating effect of advance organizers for subjects initially low on relevant prior knowledge. This prediction was also confirmed, and it was argued that the prediction represented strong support for that aspect of Ausubel’s theory.

West and Kellett (1981) conducted an investigation to test the proposition that meaningful learning of intellectual skills proceeds by Ausubel’s subsumption process. The methodology adopted involved the use of materials that could be interpreted as "advance organizers," but the intention of the study was to test hypotheses
related to the role of the learner’s existing knowledge rather than to the efficacy or otherwise of the advance organizers. Three studies were undertaken in secondary school in Australia. The subject matter was chemical equilibrium. Eleventh grade students (the first year of formal chemistry) were chosen to participate in the study. In studies IA and IB (replications), the chemical equilibrium was taught via two learning programs which were identical except that one program (the organizer program) contained materials that were constructed as advance organizers. The control program contained extra materials that were placebos and were not written to have an organizer function. Study II replicated study I, except prior to beginning the program, the subjects were given a learning program in a content area closely related to, and normally considered as a prerequisite for, the concept taught in the organizer and control programs. The results of both studies showed that meaningful learning of intellectual skill was enhanced by the addition of advance organizers and that this effect was removed if prior teaching in relevant background knowledge was included. The results provided the support for the proposition that Ausubel’s theory can be applied to the meaningful learning of intellectual skills.

Petrich and Montague (1981) investigated the effect of organization and accuracy of detail in instructional aids on the achievement of students in a freshman college chemistry
lecture course. Treatments consisted of (1) no aid, which was assumed to be low in detail and low in instructor organization; (2) a script given prior to lectures, which was assumed to be moderate in instructor organization and high in detail; and (3) an outline provided prior to lectures, which was assumed to be high in instructor organization and moderate in detail. The treatments were randomly assigned to three intact classes of 54 students in freshman chemistry. All student were instructed on three different topics by means of videotaped lectures. Students were given a pretest, and following instruction on each of the three topics, they were given posttests. The results seemed to indicate that the more aid in organization provided by the instructor prior to the lecture, the lower the student achievement. That is, students provided no aids achieved higher than those given a script, and those given a script achieved higher than those given an outline. The effect of detail provided followed no clear pattern.

**General Science**

Nine studies investigating the effects of advance organizers on general science achievement were reviewed. These included Weisberg (1970), Thelen (1970), Ryder (1970), Jones (1977), Jones (1979), McAdargh (1981), Grimaldi (1987), Simmon, Griffin, and Kameenui (1988), and
Weisberg (1970) examined the application of the advanced organizers to a specific learning task to determine if a conceptual framework facilitating subsequent learning was developed by two types of visual advance organizers. The media chosen for the advance organizers were a map and graph versus a verbal form of advance organizer. Each of four groups of 24 eighth-grade students were exposed to one of the different organizers (graph, map, verbal, and no organizer) and a subsequent new learning task. All students received the pretest before being placed into one of the test groups. The students were divided by sex and by prior knowledge as reflected by categories of high, middle, or low. The posttest was administered immediately following the new learning task. The ANOVA treatments of the posttest scores and of the data contained in the prior knowledge categories showed a highly significant difference among the means. A post-hoc comparison was used to determine the pairs of means which were contributing to the over-all differences. It was reported that the visual advance organizer functioned at a highly significant level, whereas the verbal advance organizer did not function for any of the group in the study. There were definite differences in performance among the students in the various categories of prior knowledge. All the organizers functioned well for boys and girls in the middle category of prior knowledge.
Thelen (1970) investigated whether or not the exposure of students to advance organizers and guide material would have an effect on their recall of motion pictures content and/or their attitude toward motion pictures as instructional tools. One hundred and thirty-seven ninth-grade science students were randomly assigned to four treatment groups. Seven Earth Science films were used in this study. The treatment groups were administered a pre and post attitude scale, a content test after each film and a test in retention two weeks after the treatment was completed. One treatment group received advance organizers five minutes prior to viewing of a motion picture. Guides were assigned as independent classwork and were discussed in small groups for 10 minutes the following day. Another group was not given advance organizers but was assigned guides as independent classwork. Upon completion the guides were discussed in the same manner. The third group was given an advance organizers five minutes prior to the viewing of a motion picture but did not receive guides after the film. Discussion of the film conducted by the teacher lasted 15 minutes. The control group viewed the motion picture and discussed in the same manner as the third group. Overall, the results indicated that the use of advance organizers and guide materials when used alone or in combination did not result in statistically significant differences in learning. Students who did not use advance organizers demonstrated a
significant difference in attitude change towards motion pictures as instructional tools. This change was negative in general.

Ryder (1970) conducted a study to: (1) determine whether specific experiences in the students' background significantly influence the ability to understand two concepts on air pressure, and (2) investigate the effects of an advance organizer on the students' ability to understand the two concepts. On the basis of information obtained on the Experience Inventory, a sample of 80 third and fifth graders was selected, representing 40 with "good" experience background and 40 with "poor" experience background. A demonstration-interview was conducted, individually, with every child in the experimental and control group, at which time four demonstrations were performed. Prior to observing the demonstrations, students in the experimental group read a 260-word conceptual passage, called an "advance organizer." An achievement test designed to measure student understanding of the two concepts was administered on the third and fifth day following the demonstration-interview. The findings revealed that grade, sex, and treatment significantly affected student understanding of the two concepts, and that experience background had no statistically significant effect. The advance organizer approach is a potentially effective instructional tool for relating the content of "advanced" subject matter to
elementary school children. The advance organizer was most advantageous to students with rich experience backgrounds.

Jones (1977) proposed that advance organizers could be prepared on a given topic that would facilitate learning for learners from a wide spectrum of abilities. To test this proposition an attempt was made to determine if students with widely differing demonstrated scholastic abilities could have learning of the same general concepts facilitated by the use of advance organizers. High school science students enrolled in science courses were rigorously ability grouped into "college preparatory" courses or "basic" courses. Assignments to classes were made according to students' I.Q. scores, past academic records, and Iowa Test of Basic Skills scores. Jones used two treatment groups (college prep advance organizer, basic advance organizer) and two placebo groups (college prep advance non-organizer, basic advance non-organizer). The students in each class were randomly divided into experimental and control group. After four normal classroom periods, a performance test was administered. The results of performance test scores showed that each advance organizer containing relatively abstract and inclusive materials apparently promoted the process of cognitive subsumption more than the non-organizers containing no conceptual details. The findings suggested that learners from a wide range of academic abilities might benefit from the use of advance organizers that were
appropriately prepared.

Jones (1979) proposed that in order for learners to subsume an unfamiliar new concept, they must occupy a special position with respect to the learning material. The subjects chosen were tenth and eleventh grade non-science majors. Students were assigned to learning groups according to scores on the Iowa Test of Basic Skills and records of past academic performance. Class assignments in science were to one of three ability groups referred to as "tracks." For this study the highest ability students (A-track) and the lowest ability students (C-track) were included. For the four class periods of the experiment, both groups studied the concept of feed-back. Each class was randomly divided into three treatment groups. Each group was randomly assigned to receive one of three treatments. The organizer prepared for use with A-track students was referred to as the A-track organizer (ATO). The organizer prepared for use with C-track students was referred to as the C-track organizer (CTO). A placebo introduction (PI) was prepared for use with control group. One day after the experiment, an unannounced performance test was administered; 21 days later an identical unannounced retention test was administered. The results showed that the ATO group scored significantly higher than the PI group and significantly higher than CTO group of A-track subjects. For the C-track subjects, the CTO group failed to score significantly higher than the PI group.
but did score higher than the ATO group. Performance test results were reported to offer a considerable amount of support for the idea that appropriately prepared organizers may be discriminantly facilitative only for certain learning groups.

McAdargh (1981) examined the effects of an advance organizer and background experience in science on the attainment of science concepts. Ninety ninth-grade earth science students were given the Dubbins Earth Science Test (DEST) and a science Background Experience Inventory developed by the researcher. They when placed into high, medium, and low experience groups, each group subdivided into a treatment (receiving an advance organizer on the rock cycle) and a control (receiving a placebo on the rock cycle) group. A DEST posttest was given after two weeks; in addition, data on sex, Differential Aptitude Test (DAT) scores, socioeconomic status, and grade point average were collected. It was concluded that: (1) neither the advance organizer nor the background experience of the student made a significant difference in achievement; (2) there was no significant interaction between method and background experience of the student; (3) there was a strong covariance relationship between the DAT section on Abstract Reasoning and achievement on the DEST. Interpretations included, among others, the possibility that the unit of study may not have been broad enough to allow for a maximum advance organizer
effect and that the samples did not include the full spectrum of student abilities.

Grimaldi (1987) investigated whether instruction involving an emphasis on study skills could help seventh-grade students retain material encountered in science classes. Subjects were 32 students from two intact science classes. The experimental group received an advance organizer as an overall summary of a textbook chapter they were studying to help them in organizing the content. They were introduced to the chapter; were told to look at headings, pictures, and diagrams; pronounced and defined vocabulary terms; and noted names of people and places relevant to the chapter. Each day, a review of the previous lesson was conducted before the new lesson was begun. The control group was taught without the use of any learning aid. All students were tested at the end of each chapter. The results indicated a significant difference between the means of the samples in favor of the experimental treatments. The findings suggested that study skills could help students retain science material content.

Simmons, Griffin, and Kameenui (1988) compared the effectiveness of three instructional procedures for facilitating sixth graders' comprehension and retention of science content: (a) use of teacher-constructed graphic organizers (GO) before text reading (pre-GO), (b) use of teacher-constructed graphic organizers after text reading
(post-GO), and (c) use of a traditional form of instruction consisting of frequent questions and text-oriented discussion interjected before, during, and after text reading. The results indicated that all three groups were comparable on daily probe measures and an immediate posttest; however the pre-GO group outperformed the post-GO group on a delayed posttest measure. The overall results suggested that teacher-constructed graphic organizers, whether presented prior or following textual reading, appear no more effective than traditional instruction in increasing sixth-grade children’s comprehension and retention of science content-area information. The finding failed to corroborate previously documented advantages of postgraphic organizer treatment and suggested the need for further analysis of dimensions that coexist and potentially coact during graphic organizer instruction.

Bricker (1989) conducted the study to show that there would be no difference between students in two samples to complete a hands-on science project when one was provided with advance organizers and the other was not. The sample of students were second, third, and fourth-graders from the science program. The experimental sample and the control sample each consisted of 10 randomly selected, heterogeneously grouped students from a suburban community. The experimental sample was presented with an advance organizer providing information to complete a hands-on
science project. The control group was given oral directions to complete the same hands-on science project. Each group was evaluated with the use of a checklist. The results indicated that the use of an advance organizer resulted in no significant difference between the abilities of students in the control and experimental to complete a hand-on science project. In fact, the addition of the advance organizer hindered the completion of the science activities. The children left with an advance organizer were somewhat confused about its use and interrupted the examiner with questions.

**Physical Science**

Three investigations in physical science area were reviewed. These included Kennedy (1974), Valente (1976), and Chandler (1985).

Kennedy (1974) determined the effectiveness of a comparative advance organizer in the learning and retention of metric system concepts. The subjects used in this study were 60 undergraduate elementary education majors who enrolled in the course of physical science for elementary teachers. Each of the three classes was assigned by random selection to one of the three treatment groups (advance organizer, historical introduction, and control group). Following the pretest, the comparative advance organizer
group and the historical introduction group were given their respective passages to read and study. The subjects in the three treatment groups completed the metric system learning activities. Immediately after the completion of the learning activities, all three treatment groups were administered the posttest to determine the effectiveness of the experimental passage in learning metric system concepts. The delay posttest was administered to all treatment groups 30 days later to determine the effectiveness of the introductory passage in aiding the retention of metric system concepts. Resulting from the analysis of data showed that the comparative advance organizer and the historical introduction were effective in the achievement of metric system concepts as measured by the posttest scores. The comparative advance organizer was significantly more effective in retention than the historical introduction.

Valente (1976) attempted to evaluate the effects of using advance organizers in a laboratory inquiry oriented physical science course for nonscience majors. The sample, taken from among college students, was divided into eight different groups using two classification variables with two levels each (high and low academic ability and high and low degree of previous knowledge) and the treatment variable also with two levels (existence or nonexistence of advance organizers before the learning units). From the data analysis based on achievement test scores, the treatment of
use or nonuse of written advance organizers did not result in any statistically significant difference for any of the considered groups: (1) high academic ability and high previous science knowledge, (2) low academic ability and high previous science knowledge, (3) high academic ability and low previous science knowledge, (4) low academic ability and low previous science knowledge. The main conclusion reported was that the course, independent of the use of advance organizers, did not increase the performance of the students in those outcomes that were evaluated through the criterion instruments. A completely new approach was suggested for the evaluation of the use of advance organizers.

Chandler (1985) investigated the use of experimental training to induce combinatorial reasoning in adolescents. The training was Piagetian in nature but functioned simultaneously as an operationally defined Ausubelian advance organizer for novel learning material in chemistry. The sample consisted of 161 students. The study employed a pretest-posttest control group design. The pretest consisted of Piaget's first chemical experiment. Training presented the conceptual framework, embodying, a systematic approach, and three analogous problems. Students were trained individually. The experimental group obtained significantly higher scores than the control group on criterion tasks. A delayed test on the train evaluation task, three weeks after
reinforcement of training, showed no significant difference from the immediate test. Students received instruction on rates of chemical reactions. The experimental subjects performed significantly better in generating the subsumer consisting of the concept underlying the topic. They also tended to achieve better on the recall of factual knowledge pertaining this topic, reaching significance for Standard Nine boys. The older subjects with higher IQ tended to obtain higher scores (but not significant) for the sample in general. It was reported that IQ, rather than training, contributed to the higher performance on issues requiring insight into the subject-matter.

**Physics**

Three studies in physics area investigating the effects of advance organizers on student achievement were reviewed. These included Hershman (1971), Carnes, Lindbeck, and Griffin (1987), and Healy (1989).

Hershman (1971) conducted a study to investigate the utility of advance organizers and behavioral objectives in a traditional introductory physics class at the university level. The sample consisted of 140 students enrolled in Physics 205. The students were initially assigned to four divisions by regular registrar scheduling. The experimental treatments on which this experiment was based consisted of
the distribution of three types of materials designed to aid in the student’s study. The researcher prepared an advance organizer, behavioral objectives, and a personality sketch. The advance organizer was designed to compare and contrast the content to be learned with content that had been previously studied in the class or assumed to be common knowledge. The behavioral objectives listed the terminal performances that were expected to be demonstrated during examination. The personality sketch was intended to produce interest but did not help students organize their study or specify terminal performances. The students were told to use the instruments in their assignment and test preparations. After the appropriate instruction period, these students were tested by examinations based on the behavioral objectives. A one-way analysis of covariance with multiple covariates of the resulting treatment group scores was used to compare the effects of treatments. The first examination in the class was used as a covariate to equate the treatment groups on instructor effects. SAT scores were used as a covariate to equate groups on general ability. No significant differences were found that could be attributed to the treatment effects with assurance. Since the classes were composed of low motivated students, it was concluded that the motivation and level of aspiration of the students were decisive variables that masked the treatment effects.

Carnes, Lindbeck, and Griffin (1987) investigated how
the use of CAI tutorial programs, incorporating advance organizers and involving various sizes of groups of subjects, would affect students' achievement scores, retention scores, and rates of learning. Used as subjects were 100 suburban high school physics students using interactive tutorial physics programs. For 50 students in the experimental group an advance organizer program preceded each tutorial. The remaining 50 students in the control group had an advance non-organizer program preceding each tutorial. While pursuing the tutorials, the students worked individually or together in groups of two, three, or four. Five days were allocated for the students to repeat the four tutorials until 90% competency level was attained. Achievement and retention were measured by individually administered paper-pencil teacher-made tests which sampled the content of all four tutorials. Rate of learning was determined for groups by number of times the first three tutorial programs were executed in order to attain 90% competency. A two-way analysis of variance revealed that the only significant result at the .05 level pertained to group size. Student scores on the Tukey Test revealed that students working in groups of three and four on CAI tutorials had significantly better rates of learning than students working alone. No significant differences in achievement or retention were observed for the various groups.
Healy (1989) investigated the effects of advance organizers and prerequisite knowledge passages on the learning and retention of science concepts. Fifty-five ninth-grade science students participated in this study which compared the effects of two pretreatments, an advance organizer and a prerequisite knowledge passage, on learning and retention as measured at low (knowledge and comprehension) and high (application and analysis) levels of the cognitive domain. The effectiveness of the pretreatments was measured by a framework test and a prerequisite knowledge test prior to the beginning of instruction. An analysis of covariance, with IQ as the covariate, was performed on the framework test and the prerequisite knowledge test scores. It was reported that the advance organizer group performed significantly better than the prerequisite knowledge group on the first framework test; however, the prerequisite knowledge group performed significantly better than the advance organizer group on the prerequisite knowledge test. These results provided evidence that both passages were read and understood by the students and that the passages had their intended effects as preinstructional treatments. An analysis of covariance was performed on the low and high-level questions, and total score for the posttest and retention test. The group means for the two question levels and the total scores were not found to be significantly different for either the posttest
or retention test. It was reported that these findings did not provide evidence that an advance organizer facilitated learning and retention more than a preinstructional treatment that concentrated on developing prerequisite knowledge.

**Other Science Areas**

Four studies in other science areas investigating the effects of advance organizers on student achievement were reviewed. These included Lawrence (1970), Pizzini and Gross (1978), O'Connell (1984), and Krahn and Blanchaer (1986).

Lawrence (1970) conducted an experiment to determine whether or not mimeographed factual information material, a pretest, and mimeographed teacher determined behavioral objectives could serve as extrinsic organizing devices. The study population consisted of 216 subjects enrolled in the schools of nursing in Pennsylvania. The variables manipulated in this study were primarily the three organizers—the informational, the behavioral, and the pretest. The dependent variable was achievement, and a researcher developed test provided the criterion measure. This 50 item multiple-choice test served as both the pretest organizer and the posttest. The content area selected for the study was the Nursing Care of the Patient Experiencing Pain. The organizers were presented in advance of the
lecture. The subjects from each school were randomly assigned by systematic sampling from an alphabetical list to the treatment groups. The results of the statistical analysis showed no significant difference between the treatment groups.

Pizzini and Gross (1978) attempted to: (1) analyze the effects of advance organizers on an environmental education unit when advance organizers were utilized in conjunction with a one-day field experience, and (2) determine if there was a change in student perceptions of a wilderness community, a woodland. The organizer phases were conducted during class followed by the one-day ecology field trip. Activities, utilized during the advance organizer component were specifically designed to develop sensory and conceptual perceptions and "feelings" about the natural world. The results indicated that the program, consisting of advance organizers and a one-day field experience, was effective and beneficial in changing cognitive knowledge and perceptions of woodland. These findings indicated that significant gains in knowledge and attitudes could result from an instructional unit and field trip concerned with environmental education. Although the effectiveness of the advance organizer used was not tested in this study, previous research and their positive posttest and retention test results suggested that it may facilitate learning of both knowledge and attitudes.
O’Connell (1984) investigated the efficacy of two instructional treatments in a study involving 150 sixth-graders from a large suburban school system. One treatment used an Ausubelian advance organizer and the other a content overview. After these differential pretreatments, each group was given instruction which reflected the characteristics of that group’s pretreatment. The research was motivated by the conflicting reports of previous organizer studies. Three instruments were used to assess the learning and retention of the basic geology content which was presented in both treatments. Each group was exposed to the same content for the same length of time. The only difference in the two instructional treatments was the way in which the content was organized. The pretreatments and treatments were structured differently. The class mean scores were analyzed using analysis of covariance with IQ as the covariate. The results showed that the content overview treatment was statistically more effective than the expository advance organizer treatment when both were assessed by an achievement test. There were no interactive effects between treatment and prior knowledge of the content or knowledge of the concepts included in the pretreatment.

Krahn and Blanchaer (1986) investigated the efficacy of using an advance organizer as a device to improve medical students’ understanding of a clinical case simulation on the microcomputer and to enhance performance on a posttest.
Seventy-nine students in a first-year medical class voluntarily attempted an experimental computer-based patient simulation. Subjects were covertly assigned alternately to the advance organizer group and control group. After administering the pretest, the advance organizer group received the advance organizer passage on a computer screen. The control group did not. The students worked individually through the simulation at their leisure. The program was written in such a way that the student, when posed a question, was unable to continue the simulation without providing a response. When the response was inappropriate, the question was repeated until either the student was able to give the desired response or the computer provided the response. This was to insure that each student would have the same information before continuing in the program. The data analysis from the posttest scores gave the results that supported the effectiveness of an advance organizer in improving understanding and performance of medical students in computer-based clinical case simulations. Generally, the findings suggested that an advance organizer was helpful in computer-based learning materials that required users to apply their existing knowledge to solve a problem they had not encountered previously.
Summary

The variety of studies based on Ausubel’s theory is notable, but the results are conflicting. Of the 47 studies reviewed, 25 used prose advance organizer formats. Other types of formats were used in 22 studies. Other formats included graphic organizers, concept maps, trainings, etc. In some studies, the advance organizers were compared with introductory passages, behavioral objectives, questions, or many kinds of buffers. Some used nothing instead of the advance organizers for the control group. In some studies the interaction of the main effects with subjects’ ability is analyzed. However, ability is measured by means of many different instruments.

The reported findings of the 47 studies were found to be inconsistent and inconclusive. Significant increases in student achievement as a result of the use of advance organizer were reported in 20 studies, while 27 studies reported no significant facilitative effects. A critical review of the studies revealed additional problems which further confuse the understanding of the effects of advance organizers on science achievement. Those problems were: (1) lack of good research designs, (2) failure to establish validity and reliability of instruments, (3) short instruction time, and (4) no assurance that advance organizers were used.
CHAPTER III

METHODOLOGY

This chapter provides a description of the methodology used in this study. It consists of the following sections: (a) Experimental Design, (b) Selection of Sample, (c) Instruments, (d) Procedures, and (e) Statistical Analysis.

Experimental Design

The research design used in this study was a pretest-posttest control group design (Campbell & Stanley, 1963) in which the intact groups constitute naturally assembled classes. With subjects in pre-assembled classes it was necessary to randomly assign the treatments to the intact classes. The experimental design could be diagrammed as follows:

\[ R \ O_1 \ X_0 \ O_2 \]
\[ R \ O_1 \ X_1 \ O_2 \]

Where: 
- \( R \) = random assignment to treatments
- \( X_0 \) = control group
- \( X_1 \) = experimental group
- \( O_1 \) = observation (pretest)
- \( O_2 \) = observation (posttest)
Advance organizers served as an independent variable. The dependent variable was student achievement as measured by a teacher-made achievement test.

Selection of Sample

The population of this study was composed of 181 students in 12 sections who were taking the first year chemistry at CRMA in Thailand. There were random assignment of intact classes to three different treatment groups.

Instruments

The instruments used in the study were as follows: (1) four advance organizers for classroom instruction, (2) two advance organizers for laboratory instruction, (3) six introductory passages, (4) four framework tests for classroom instruction, (5) two framework tests for laboratory instruction, (6) achievement pretest, (7) achievement posttest. Each instrument was constructed by the researcher. The following paragraphs described the procedure for constructing the instruments.

The Advance Organizers

The advance organizers developed for this study were
designed to provide guidelines upon which the reading material for the chemistry course could be subsumed. The advance organizers were developed by a modified procedure suggested by Zeitoun (1983). The development of each advance organizer consisted of the following steps: (1) Analysis of Learning Materials, (2) Determining the Characteristics of Advance Organizers, (3) Valuing the Validity of the Advance Organizer, and (4) Checking the Understandability and Assessing the Study Time of the Advance Organizer.

**Step 1: Analysis of Learning Materials**

An analysis was made to identify the content in chemistry that was to be covered during the first semester. The topics included atoms and elements, mass relationships for the pure substance, mass relationships in chemical reaction, atomic structure and periodic table, and chemical bonding. The purpose for identifying the content was to develop advance organizers for each topic deemed appropriate for study. The procedure of the analysis of these materials proceeded in the following three substeps:

a). **Determining the organization of the materials.**

Content areas were disregarded if they contain built-in organizers and proceed deductively, i.e., proceed from regions of lower to greater differentiation (higher to lower inclusiveness). It seemed reasonable to assume that content areas with these characteristics would not be appropriate
b). **Assessing the familiarity of the materials.** Content areas in which the students were familiar were excluded from the study. A pretest was constructed covering all five content areas to assess the students' familiarity with the content areas. The method used to construct the test is provided later in this chapter. The pretest was administered 15 days before the beginning of the study. The purpose of the pretest was to determine previous knowledge and/or familiarity of the students with content areas that were to be taught during the first semester. The pretest consisted of five content areas, i.e., atoms and elements, mass relationships for the pure substance, mass relationships in chemical reactions, atomic structure and periodic table, and chemical bonding. It was determined from a statistical analysis that the content area in which students received the lowest mean scores was the content area of chemical bonding. The results indicated a lack of student knowledge of this concept. Therefore, chemical bonding was chosen as the content area for use in the study. The rationale was being that advance organizers seem to be less effective with content areas in which students already familiar.

c). **Extracting the major ideas contained in the materials.** Major ideas in the form of superordinate concepts, principles (generalizations) and conceptual
schemes were extracted from the content area of chemical bonding by a panel of chemistry teachers at CRMA. An outline of the content area included the topics as follow:

1. The formation of ionic compounds (ionic bonds, Lewis symbols, formation of ions by the representative elements, ionic compound properties),
2. The formation of covalent compounds (electron sharing, Lewis structures, the octet rule, covalent bond, covalent compound properties),
3. Theories of covalent bonding and shapes of molecules,
4. Resonance,
5. Coordinate covalent bond,
6. Hydrogen bond,
7. Metallic bond,
8. Polar bonds and polar molecules (dipole moment, polarity of molecules).

The teachers met as a group and discussed the outline and knowledge students should know prior to being instructed in the area of chemical bonding. As a result of this discussion, the concepts to be used as subsumers of chemical bonding topic were identified. A list of the concepts to be used as subsumers is as follows:

1. Ionization energy (IE),
2. Electron affinity (EA),
(3) The trends in properties within periodic table
   (atomic size, IE, EA, electronegativity),
(4) Quantum numbers,
(5) Orbital,
(6) Shape of orbital,
(7) Electron configuration (Pauli exclusion principle,
   Hund’s rule, orbital diagram, filling order of
   subshell),
(8) paired electrons and unpaired electron.
These concepts were used to prepare advance organizers for
classroom instruction.

**Step 2: Determining the Characteristics of Advance Organizers.** Four expository advance organizers were
developed in a written form containing the identified
subsumers that were extracted in Step 1. A copy of each
advance organizer is included in Appendix A.

**Step 3: Valuing the Validity of the Advance Organizer.**
According to Ausubel (1978) an advance organizer is
valid if it contains subsumers (major ideas) that match the
basic ideas of the learning material. Validity of the four
advance organizers developed in Step 2 was ensured by a
panel of judges composed of five chemistry teachers at CRMA.
Both the organizers and content areas were given to the
judges. There was unanimous agreement among judges that the
advance organizer contained subsumers that matched the basic ideas of the content areas. The panel of judges was also asked to determine if the reading and vocabulary levels of the advance organizers were at appropriate level for the students.

**Step 4: Checking the Understandability and Assessing the Study Time of the Advance Organizer.**

The procedure recommended to check the understandability of an organizer was to study the reactions of a random sample of subjects given that organizer. At a more sophisticated level of methodology, the researcher looked for differences in performance between two random samples of 20 students who were second-year cadets. One sample was given the advance organizer, the other did not receive the advance organizer. The students read the advance organizer. Then, the two groups were administered a framework test. A description of the development of the framework test is presented later in this chapter. The performance of the two groups was measured by the mean score on the framework test. This test included questions related to information contained in the advance organizer only. A t-test was used to determine the difference in performance of the two groups. The results of the t-test indicated that the group receiving advance organizers scored significantly better at the .05 level than the group that did not receive
advance organizers.

The method used to estimate study time was to present the organizer to a random sample of students. Then, the time taken by each subject to study the organizer was recorded. The average time was calculated to be ten minutes. This average was considered to be the "study time."

**Advance Organizers for Laboratory Instruction**

Two content areas chosen for laboratory instruction were the preparation of complex and double salts, and halogens. The unfamiliarity of the content areas for laboratory instruction was established the same way as the content area for classroom instruction. Two expository advance organizers were developed for laboratory instruction. Each advance organizer contained the subsumers of each content area. The procedure used to develop the advance organizers for laboratory was identical to the procedure used to develop classroom instruction advance organizer.

The advance organizers in this study were separately prepared for classroom instruction and laboratory instruction. A copy of the advance organizers used is included in Appendix A.
**Introductory Passage**

Students in treatment group II were given an introductory passage. The materials in the introductory passage were directly related to the content area presented in the classroom and laboratory instruction, but they did not provide a framework upon which the content areas could be subsumed. Four introductory passages were developed for classroom instruction and two were developed for laboratory instruction. A copy of the introductory passages used in this study can be found in Appendix B.

**Framework Tests**

Framework tests were developed to determine if the advance organizers were read and understood by the students. Each question was related to one of the concepts presented in the advance organizer. This was validated by a panel of chemistry teachers. One framework test was developed for each advance organizer. Thus, there were four framework tests for classroom instruction and two framework tests for laboratory instruction. A copy of each framework test can be found in Appendix C.
**Pretest**

A pretest was developed which included 50 multiple-choice test items. The purpose of this test was to determine whether students had any previous knowledge and/or familiarity with the content in chemistry that was to be covered during the first semester. The test items were selected from related published tests and past examinations. Content-related evidence was used to establish validity; a panel reviewed test items to assure questions reflect the objectives of course. A copy of the pretest can be found in Appendix C.

**Posttest**

A posttest was constructed which consist of 25 multiple-choice test items for classroom instruction and 15 multiple-choice test items for laboratory instruction. The posttest was developed to assess the achievement of the selected content areas. The test items were constructed from: content specified in the chemistry textbook, laboratory manual, and selected items from past examinations, and from the related published tests. Using the method described by Gronlund (1981) the test items were constructed, selected, and examined so as to weigh the content in accordance with the importance of each of the
objectives. This procedure made use of a matrix to relate test items to the objectives and subject matter content. The matrix (Table of specification) is shown in Appendix D. The numbers in the matrix were the test items that correspond to a particular objective and a certain area of subject matter. As can be noted in the matrix, it was not necessary that the various content topics received the same number of items. The numbers of items per topic depended on the emphasis in instruction. The extent to which content was divided into topics would be an arbitrary decision make by the teacher. A copy of posttest is included in Appendix C.

Reliability

Reliability of the test instruments was determined by using Kuder-Richardson formula 20 (Wiersma, 1985). Students scores on the chemistry achievement test were used to determine the reliability. The reliability of the classroom posttest was found to be 0.86. The reliability of the laboratory posttest was found to be 0.79. A value of 0.75 was set as the stated value of acceptance. This level of acceptance was recommended by Borg (1989).

Procedures

Ten days before the beginning of the study, the target
population was given the pool of 22 questions from the six framework tests to establish presence or absence of concepts contained in advance organizers. One hundred and eighty-one students who received scores below 50% on the test were selected for this study and for final data analysis. Twelve class sections were randomly assigned to three different treatments.

**Treatment Group I**

Students in treatment group I received an advance organizer before the actual learning experience. No other instructional materials were made available at this time. They were informed that they must carefully read this handout because information obtained from the sheet would help them to understand the instructional materials. Students were given ample time to read the advance organizer. Then, it was collected. Each student was then given the framework test.

**Treatment Group II**

Students in treatment group II received a chemistry introductory passage prior to instruction. Students were given ample time to read the introductory passage. Then, it was collected. Each student was then given the framework
test.

**Treatment Group III (Control)**

Students in treatment group III received no advance organizer prior to instruction. Students were given the framework test when they first entered the classroom. After completing the framework test, students received the regular instruction. The general chemistry course was taught by a team of teachers. Each teacher in the team took turn to teach each of the 12 sections. All treatments groups studied the same subject matter, received the same lecture-discussion examples, received the same problem assignments, and conducted the same experiments in the laboratory. After 21 days of instruction, students in all treatment groups were given the posttest covering the content taught during the instruction. Two weeks after completion of instruction, students were given the posttest used as a retention test.

**Statistical Analysis**

The primary purpose of this study was to investigate the effectiveness of advance organizers on the facilitation of learning in a general chemistry course. More specifically, this research was designed to investigated the effects of written expository organizer on the facilitation
of learning and retention in both chemistry classroom and laboratory instruction.

One-way analysis of variance was used to analyze the achievement test scores of students in three different treatments groups. Additional analysis based on Scheffe’s test for multiple comparisons for evaluating the differences between various pairs of treatment achievement test scores. The null hypothesis for the analysis was as follow:

There is no significant treatment effect.

\[ \sigma^2 T = 0 \]

The mathematical model for testing this hypothesis was:

\[ Y_{ij} = \mu + \alpha_i + \varepsilon_{ij} \]

\( \mu \) = a fixed constant representing the overall mean
\( \alpha_i \) = the effect of the treatment
\( \varepsilon_{ij} \) = a random variable

Table 1 shows the one-way analysis of variance for analyzing the first to eighth hypotheses.

Table 1
One-way analysis of variance

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>SSB</td>
<td>MS between</td>
<td>F statistic</td>
</tr>
<tr>
<td>Within groups</td>
<td>178</td>
<td>SSW</td>
<td>MS within</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>SST</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DF = degree of freedom
SS = sum of squares
SSW = sum of squares within
SSB = sum of squares between
SST = sum of squares total
MS = mean squares

The F statistic was calculated according to the following formula:

\[ F = \frac{MS \text{ between}}{MS \text{ within}} \]

A 0.05 level of significance was used as a basis for rejecting the hypotheses.

Post hoc analysis based on Scheffe's test for multiple comparisons for evaluating the differences between various pairs of achievement test scores. The formula is shown below.

\[ S_c = \frac{|x_a - x_b|}{\{MS(1/n_a + 1/n_b)\}^{1/2}} \]

\[ S_t = \{(k-1)F_{(k-1; n-k; \alpha)}\}^{1/2} \]

\[ x_a = \text{mean scores of group a} \]
\[ x_b = \text{mean scores of group b} \]
\[ n_a = \text{number of students in group a} \]
\[ n_b = \text{number of students in group b} \]
\[ n = \text{total number of students} \]
\[ k = \text{total number of groups} \]
\[ MS = \text{mean squares within.} \]
The null hypothesis is rejected when $S_c > S_\cdot$.

**Summary**

Chapter III presented the methodology of the study. It included a discussion of the experimental design, sample selection, development of instruments, procedure, and statistical analysis.
CHAPTER IV

THE FINDINGS

The purpose of this chapter is to report the findings of the study. It is divided into the following sections:

1. Analysis of Pretest Data.
4. Summary of the Findings.

Analysis of Pretest Data

An analysis of pretest score data was conducted to determine whether any significant differences in chemistry achievement existed among students in each group prior to the administration of advance organizers to the treatment groups. Analysis of all pretest data was performed using the Statistical Package for the Social Sciences (SPSS). Table 2 and Table 3 present the mean scores and standard deviations of student scores on the classroom instruction pretest and laboratory instruction pretest, respectively.
### Table 2
Mean scores and standard deviations of classroom instruction pretest scores for the three groups.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>2.31</td>
<td>.30</td>
</tr>
<tr>
<td>Group II</td>
<td>2.31</td>
<td>.36</td>
</tr>
<tr>
<td>Control</td>
<td>2.29</td>
<td>.41</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group II received introductory passages.

### Table 3
Mean scores and standard deviations of laboratory instruction pretest scores for the three groups.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>1.85</td>
<td>.33</td>
</tr>
<tr>
<td>Group II</td>
<td>1.85</td>
<td>.30</td>
</tr>
<tr>
<td>Control</td>
<td>1.86</td>
<td>.33</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, Group II received introductory passages, and Group III was the control.
Mean pretest scores of the three groups were tested for differences using a one-way analysis of variance. Table 4 and Table 5 present the results of the analysis of pretest data of classroom instruction and of laboratory instruction, respectively.

Table 4
One-way analysis of variance for classroom instruction pretest of the two treatment and control groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>.032</td>
<td>.016</td>
<td>.12</td>
</tr>
<tr>
<td>Within Groups</td>
<td>178</td>
<td>23.574</td>
<td>.132</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>23.607</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5
One-way analysis of variance for laboratory instruction pretest of the two treatment and control groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>.003</td>
<td>.001</td>
<td>.01</td>
</tr>
<tr>
<td>Within Groups</td>
<td>178</td>
<td>18.866</td>
<td>.105</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>18.868</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From an F table with 2 and 200 degree of freedom, a 3.04 critical F value at the .05 level of significance was obtained. Since 3.04 is larger than the .12 obtained in the one-way analysis of variance for the pretest data for classroom instruction and the .01 obtained for the pretest data for laboratory instruction, it can be seen that no significant differences existed at the .05 level of significance in the means of pretest scores of classroom instruction, and no significant difference existed in the means of pretest scores of laboratory instruction. Since there were no significant differences found, the groups were considered equal in chemistry achievement in the content area of chemical bonding, preparation of complex salts, and the halogens at the beginning of the study.

Analysis of Posttest Data and Testing the Research Hypotheses

The posttest data obtained by implementing procedures previously described in Chapter III were analyzed to determine the extent to which they either rejected or retained the statistical hypotheses advanced in Chapter I. That is, analyses were aimed at assessing the effect of expository advance organizers on the students' achievement in a general chemistry course and a general chemistry laboratory course.
Hypotheses one to four were tested using a one-way analysis of variance and the Scheffe's test of multiple comparisons. The results of the one-way analysis of variance for classroom instruction achievement in the general chemistry course of the two treatment and control groups are provided in Table 6, while the results of the Scheffe's test of multiple comparisons are presented in Table 7.

Table 6
One-way analysis of variance for classroom achievement of students in the three groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>748.315</td>
<td>374.157</td>
<td>33.004</td>
</tr>
<tr>
<td>Within Groups</td>
<td>178</td>
<td>2017.949</td>
<td>11.336</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>2766.265</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From an F table with 2 and 200 degree of freedom, a 3.04 critical F value at the .05 level of significance was obtained. Since 3.04 is less than the 33.004 obtained in the one-way analysis of variance for classroom achievement of students in the three groups, it can be stated that a significant difference existed at the .05 level of significance among the means achievement scores of the three
Table 7

Variance ratios from Scheffe's test between control and two treatment groups.

<table>
<thead>
<tr>
<th>Group comparison</th>
<th>$S_c$</th>
<th>F-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I and II</td>
<td>4.09/.617</td>
<td>6.62</td>
</tr>
<tr>
<td>Group I and III</td>
<td>4.70/.626</td>
<td>7.51</td>
</tr>
<tr>
<td>Group II and III</td>
<td>.618/.600</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, Group II received introductory passages, and Group III was the control.

The Scheffe's test was used to determine specifically which mean achievement scores were significantly different. The Scheffe's test of multiple comparisons between the means of achievement scores of the three groups produced the variance ratios (F-ratio) reported in Table 7.

The absolute values of the F-ratio between group comparisons shown in Table 7 were compared with the calculated test statistic of 2.46 ($S_c$). From Table 7, it can be seen that a significant difference existed at the .05 level of significance in the mean scores between groups I and II, and groups I and III.
Hypothesis 1

There is no significant difference in achievement of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are given an introductory passage prior to classroom instruction.

Hypothesis 1 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of student for groups I and II on the general chemistry achievement pretest and posttest are provided in Table 8.

Table 8
Mean scores and standard deviations of the classroom pretest and posttest for groups I and II.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest score</td>
<td>2.31</td>
<td>.30</td>
</tr>
<tr>
<td>Posttest score</td>
<td>17.91</td>
<td>3.31</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest score</td>
<td>2.31</td>
<td>.36</td>
</tr>
<tr>
<td>Posttest score</td>
<td>13.82</td>
<td>3.22</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group II received introductory passages.
Table 8 shows that the posttest mean scores in general chemistry of students in groups I and II were 17.91 and 13.82, respectively. The Scheffe's test results (Table 7) disclosed that the F-ratio (F=6.62) of groups I and II comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 1 was rejected at the .05 level of significance. Thus, students in the group who received advance organizers scored significantly higher in general chemistry than students in the group who received introductory passages.

**Hypothesis 2**

There is no significant difference in achievement of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are not given an expository organizer prior to classroom instruction.

Hypothesis 2 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of student scores in groups I and III on the general chemistry achievement pretest and posttest are provided in Table 9.
Table 9
Mean scores and standard deviations of the classroom pretest and posttest for groups I and III.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pretest score</td>
<td>2.31</td>
<td>.30</td>
</tr>
<tr>
<td>posttest score</td>
<td>17.91</td>
<td>3.31</td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pretest score</td>
<td>2.29</td>
<td>.41</td>
</tr>
<tr>
<td>posttest score</td>
<td>13.20</td>
<td>3.57</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group III was the control.

Table 9 reveals that the posttest means scores in general chemistry of students for groups I and III were 17.91 and 13.20, respectively. From Table 7, it can be seen that the F-ratio (F=7.51) of groups I and III comparisons was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 2 was rejected at the .05 level of significance. Thus, students in the group who received advance organizers scored significantly higher in general chemistry than students in the group who did not receive advance organizers.
Table 10 summarizes the results of the one-way analysis of variance for chemistry achievement in the general chemistry laboratory course of the control and the two treatment groups, while Table 11 shows the results of the Scheffe's test of multiple comparisons.

Table 10

One-way analysis of variance for laboratory achievement of students in the three groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>363.950</td>
<td>181.975</td>
<td>32.45</td>
</tr>
<tr>
<td>Within Groups</td>
<td>178</td>
<td>1003.698</td>
<td>5.607</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>1367.648</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From an F table with 2 and 200 degree of freedom, a 3.04 critical F at the .05 level of significance was obtained. Since 3.04 is less than the 32.45 obtained in the one-way analysis of variance, it can be concluded that there was a significant difference at the .05 level of significance among the means of the achievement scores of the three groups.

The Scheffe's test was used to determine specifically when mean achievement scores differed significantly. The
Scheffe’s test of multiple comparisons between the means of achievement scores of the two treatment and control groups produced the variance ratios (F-ratio) reported in Table 11.

Table 11

Variance ratios from Scheffe’s test between two treatment and control groups.

<table>
<thead>
<tr>
<th>Group comparison</th>
<th>$S_c$</th>
<th>F-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I and II</td>
<td>2.90/.430</td>
<td>6.74</td>
</tr>
<tr>
<td>Group I and III</td>
<td>3.10/.440</td>
<td>7.05</td>
</tr>
<tr>
<td>Group II and III</td>
<td>.197/.422</td>
<td>.466</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, Group II received introductory passages, and Group III was the control.

The absolute values of the F-ratio between group comparisons shown in Table 11 were compared with the calculated test statistic of 2.46 ($S_c$). Table 11, shows that a significant difference existed at the .05 level of significance between groups I and II mean scores, and between groups I and III mean scores.
Hypothesis 3

There is no significant difference in achievement of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are given an introductory passage prior to laboratory instruction.

Hypothesis 3 was tested using a one-way analysis of variance and the Scheffe’s test. The mean scores and standard deviations of student scores for groups I and II on laboratory achievement pretest and posttest are provided in Table 12.

Table 12

Mean scores and standard deviations of the laboratory pretest and posttest for groups I and II.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest score</td>
<td>1.85</td>
<td>.33</td>
</tr>
<tr>
<td>Posttest score</td>
<td>10.20</td>
<td>1.96</td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest score</td>
<td>1.85</td>
<td>.30</td>
</tr>
<tr>
<td>Posttest score</td>
<td>7.29</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group II
received introductory passages.

Table 12 shows that the posttest mean scores in general chemistry laboratory of student in groups I and II were 10.20 and 7.29, respectively. From Table 11, it can be seen that the F-ratio (F=6.74) of groups I and II comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 3 was rejected at the .05 level of significance. Thus, students in the group who received advance organizers scored significantly higher in general chemistry laboratory than students in the group who received introductory passages.

**Hypothesis 4**

There is no significant difference in achievement of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are not given an expository organizer.

Hypothesis 4 was tested using a one-way analysis of variance and the Scheffe’s test. The mean scores and standard deviations of student scores for groups I and III on the general chemistry laboratory achievement pretest and posttest are provided in Table 13.
Table 13
Mean scores and standard deviations of the laboratory pretest and posttest for group I and III.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pretest score</td>
<td>1.85</td>
<td>.33</td>
</tr>
<tr>
<td>posttest score</td>
<td>10.20</td>
<td>1.96</td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pretest score</td>
<td>1.86</td>
<td>.33</td>
</tr>
<tr>
<td>posttest score</td>
<td>7.10</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group III was the control.

Table 13 reveals that the posttest mean scores in general chemistry laboratory of students in groups I and III were 10.20 and 7.10, respectively. From Table 11, it can be seen that the F-ratio (F=7.05) of groups I and III comparisons was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 4 was rejected at the .05 level of significance. Thus students in the group who received advance organizers scored significantly higher in general chemistry laboratory than students in the group who did not receive advance organizers.
Analysis of Retention Test Data and Testing the Research Hypotheses

The retention test data obtained by implementing the procedures previously presented in Chapter III were analyzed to test Hypothesis 5, 6, 7, and 8. That is, the analyses were aimed at assessing the effect of expository advance organizers on the retention in the content area of chemical bonding in classroom instruction and the content area of halogens and the preparation of complex salts in laboratory instruction.

The Hypotheses were tested using a one-way analysis of variance and the Scheffe's test of multiple comparisons. The results of the one-way analysis of variance for the chemistry classroom retention are provided in Table 14, while the results of the Scheffe's test of multiple comparisons are presented in Table 15.

Table 14
One-way analysis of variance for classroom retention of students in control and two treatment groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>669.553</td>
<td>334.776</td>
<td>39.74</td>
</tr>
<tr>
<td>Within groups</td>
<td>178</td>
<td>1499.430</td>
<td>8.423</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>2168.983</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From an F table with 2 and 200 degree of freedom, a 3.04 critical F value at the .05 level of significance was obtained. Since this 3.04 is less than 39.74 obtained in one-way analysis of variance, it can be stated that a significant difference existed at the .05 level of significance in the mean retention test scores of the three groups.

The Scheffe’s test was used to determine specifically which mean retention scores differed significantly. The Scheffe’s test of multiple comparisons between the means of retention test scores of the three groups produced the variance ratios (F-ratio) reported in Table 15.

Table 15
Variance ratios from Scheffe’s test between three groups.

<table>
<thead>
<tr>
<th>Group comparison</th>
<th>$S_c$</th>
<th>F-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I and II</td>
<td>3.76/.532</td>
<td>7.07</td>
</tr>
<tr>
<td>Group I and III</td>
<td>4.51/.539</td>
<td>8.36</td>
</tr>
<tr>
<td>Group II and III</td>
<td>.751/.517</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, Group II received introductory passages, and Group III was the control.

The absolute values of the F-ratio between group comparisons shown in Table 15 were compared with the calculated test statistic of 2.46 ($S_t$). The Table reveals a
significant difference existed at the .05 level of significance in mean scores between groups I and II and groups I and III.

**Hypothesis 5**

There is no significant difference in retention of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are given introductory passage prior to classroom instruction.

Hypothesis 5 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of student scores for groups I and II on the classroom posttest and retention test are provided in Table 16.

**Table 16**

Mean scores and standard deviations of the classroom posttest and retention test for groups I and II.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>17.91</td>
<td>3.31</td>
</tr>
<tr>
<td>retention test score</td>
<td>15.05</td>
<td>3.15</td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>13.82</td>
<td>3.22</td>
</tr>
<tr>
<td>retention test score</td>
<td>11.29</td>
<td>2.63</td>
</tr>
</tbody>
</table>
Note. Group I received advance organizers, and Group II received introductory passages.

The data in Table 16 show that the retention test mean scores in general chemistry of students in groups I and II were 15.05 and 11.29, respectively. The Scheffe's test (Table 15) disclosed that the F-ratio (F=7.07) of groups I and II comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 5 was rejected at the .05 level of significance. Thus, the retention of achievement in chemistry classroom instruction of students in the group who received advance organizers was significantly higher than the retention of achievement in chemistry classroom instruction of those in the group who received introductory passages.

Hypothesis 6

There is no significant difference in retention of general chemistry classroom material between students who are given an expository organizer prior to classroom instruction and those who are not given an expository organizer prior to classroom instruction.

Hypothesis 6 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of student scores for groups I and III on the general chemistry retention test and posttest are provided in Table 17.
Table 17

Mean scores and standard deviations of classroom posttest and retention test for groups I and III.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>17.91</td>
<td>3.31</td>
</tr>
<tr>
<td>retention test score</td>
<td>15.05</td>
<td>3.15</td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>13.20</td>
<td>3.57</td>
</tr>
<tr>
<td>retention test score</td>
<td>10.54</td>
<td>2.94</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group III was the control.

From Table 17 it can be seen that the retention test mean scores in general chemistry of student in group I and III were 15.05 and 10.54, respectively. From Table 15, it can be seen that the F-ratio (F=8.36) of groups I and III comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 6 was rejected at the .05 level of significance. Thus, the retention of achievement in chemistry classroom instruction of students in the group who received advance organizers was significantly higher than the retention of achievement in
chemistry classroom instruction of those in the group who did not receive advance organizers.

Table 18 summarizes the results of the one-way analysis of variance for retention in the general chemistry laboratory instruction of the control and two treatment groups, while Table 19 shows the results of the Scheffe's test of multiple comparisons.

Table 18
One-way analysis of variance for laboratory retention of students in control and two treatment groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>232.902</td>
<td>116.451</td>
<td>38.76</td>
</tr>
<tr>
<td>Within groups</td>
<td>178</td>
<td>534 744</td>
<td>3.004</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>767.646</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From an F table with 2 and 200 degree of freedom a 3.04 critical F value at the .05 level of significance was obtained. Since 3.04 is less than the 38.76 obtained in the one-way analysis of variance, it can be stated that a significant difference existed at the .05 level of significance among the mean scores on the retention test of the three groups.
The scheffe’s test was used to determine specifically which mean retention scores differed significantly. The Scheffe’s test of multiple comparisons between the mean scores of retention test scores of the three groups produced the variance ratios (F-ratio) reported in Table 19.

Table 19
Variance ratios from Scheffe’s test between three groups

<table>
<thead>
<tr>
<th>Grouping comparison</th>
<th>$S_c$</th>
<th>F-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I and II</td>
<td>2.41/.317</td>
<td>7.60</td>
</tr>
<tr>
<td>Group I and III</td>
<td>2.40/.322</td>
<td>7.45</td>
</tr>
<tr>
<td>Group II and III</td>
<td>.0139/.310</td>
<td>.045</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, Group II received introductory passages, and Group III was the control.

The absolute values of the F-ratio between group comparisons shown in Table 19 were compared with the calculated test statistic of 2.46 ($S_c$). The data from Table 19 reveal that a significant difference existed at the .05 level of significance in the mean scores between groups I and II and groups I and III.
Hypothesis 7

There is no significant difference in retention of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are given introductory passage prior to laboratory instruction.

Hypothesis 7 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of students scores for groups I and II on the laboratory posttest and retention test are provided in Table 20.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>10.20</td>
<td>1.96</td>
</tr>
<tr>
<td>retention test score</td>
<td>8.57</td>
<td>1.51</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest score</td>
<td>7.29</td>
<td>2.54</td>
</tr>
<tr>
<td>retention test score</td>
<td>6.15</td>
<td>1.89</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group II
received introductory passages.

Table 20 reveals that the retention mean scores of students in general chemistry laboratory in groups I and II were 8.57 and 6.15, respectively. From Table 19, it can be seen that the F-ratio (F=7.60) of groups I and II comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 7 was rejected at the .05 level of significance. Thus, the retention of achievement in chemistry laboratory of students in the group who received advance organizers was significantly higher than the retention of achievement in chemistry laboratory of those in the group who received introductory passages.

**Hypothesis 8**

There is no significant difference in retention of general chemistry laboratory material between students who are given an expository organizer prior to laboratory instruction and those who are not given an expository organizer prior to laboratory instruction.

Hypothesis 8 was tested using a one-way analysis of variance and the Scheffe's test. The mean scores and standard deviations of students scores for groups I and III on the laboratory posttest and retention test are provided in Table 21.
Table 21
Mean scores and standard deviations of the laboratory posttest and retention test for groups I and III.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest scores</td>
<td>10.20</td>
<td>1.96</td>
</tr>
<tr>
<td>retention test scores</td>
<td>8.57</td>
<td>1.51</td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posttest scores</td>
<td>7.10</td>
<td>2.54</td>
</tr>
<tr>
<td>retention test scores</td>
<td>6.16</td>
<td>1.78</td>
</tr>
</tbody>
</table>

Note. Group I received advance organizers, and Group III was the control.

Table 21 reveals that the retention means scores of students in general chemistry laboratory in groups I and III were 8.57 and 6.16, respectively. From Table 19, it can be seen that the F-ratio (F=7.45) of groups I and III comparison was found to exceed the calculated test statistic of 2.46. Based on these findings, Hypothesis 8 was rejected at the .05 level of significance. Thus, the retention of achievement in chemistry laboratory of students in the group who received advance organizers was significantly higher than the retention of achievement in chemistry laboratory of those in the group who did not receive advance organizers.
Summary of the Findings

In summary, the findings directly related to the hypotheses were as follows:

1. There was a significant difference in achievement of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were given introductory passage prior to classroom instruction.

2. There was a significant difference in achievement of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were not given an expository organizer prior to classroom instruction.

3. There was a significant difference in achievement of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were given introductory passage prior to laboratory instruction.

4. There was a significant difference in achievement of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were not given an expository organizer prior to laboratory instruction.

5. There was a significant difference in retention of general chemistry classroom material between students who
were given an expository organizer prior to classroom instruction and those who were given an introductory passage prior to classroom instruction.

6. There was a significant difference in retention of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were not given an expository organizer prior to classroom instruction.

7. There was a significant difference in retention of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were given an introductory passage prior to laboratory instruction.

8. There was a significant difference in retention of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were not given an expository organizer prior to laboratory instruction.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter is organized into three sections. The first summarizes design, methodology, and results of the study. The second presents conclusions and discussion. The final section is divided into recommendations and suggestions for future practice and research.

Summary of the Study

The primary purpose of this study was to investigate the effectiveness of advance organizers on the facilitation of learning in a general chemistry course. More specifically, this research was designed to investigate the effects of written expository organizers on the facilitation of learning and retention resulting from chemistry classroom and laboratory instruction at the university level.

The population of the study was composed of 181 college students from 12 sections taking general chemistry. Because selection of students into sections by the university, over which the researcher had no control, sections were randomly assigned as the unit of analysis, rather than the individual student.

All of the first year students were given a pretest to
assess student familiarity with the content knowledge that would be taught at the time this study was conducted. The topics of chemical bonding, preparation of complex salt and double salt, and halogens which students were less familiar were selected to be the learning material for classroom instruction and laboratory instruction in this study. The rationale being that advance organizers seem to be less effective with content areas in which students already familiar.

The advance organizers used in this study were developed according to the modified procedure suggested by Zeitoun (1982).

Ten days before the beginning of the study, all first year students were given a framework test to establish presence or absence of concepts contained in the advance organizer. One hundred and eighty-one students, who scored below 50% on this test, were selected for this study and for final data analysis. They were randomly assigned to one of treatment groups. One group received advance organizers at the beginning of classroom and laboratory instruction. This group which consisted of 55 students was identified as Treatment Group I. Students were given adequate time to read an advance organizer which was followed by a framework test. This procedure was used to insured that students would read the advance organizer prior to instruction.

A second group, Treatment Group II, which consisted of
65 students received introductory passages prior to classroom and laboratory instruction. The third group, Treatment Group III, which consisted of 61 students was identified as the control. Students in this group received neither advance organizers nor introductory passage prior to instruction.

All students in the control and treatment groups were given the teacher-made achievement test in chemistry at the end of the study. The study covered 21 days of instruction. A total of 25 multiple-choice test items were constructed for measuring achievement resulting from classroom instruction and 15 test items were constructed for measuring achievement resulting from laboratory instruction. Reliability of the teacher made achievement test was determined using Kuder-Richardson formula 20. The students were administered a test to measure retention of achievement two weeks following the instruction.

The statistical methods used to analyze the data consisted of two techniques. A one-way analysis of variance was used to analyze student achievement test scores in two different treatments and one control group. Scheffe's test for multiple comparisons was used for evaluating the differences between various pairs of treatment achievement test scores.

In summary the findings directly related to the hypotheses were as follows:
1. There was a significant difference in achievement of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were given an introductory passage prior to classroom instruction.

2. There was a significant difference in achievement of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were not given an expository organizer prior to classroom instruction.

3. There was a significant difference in achievement of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were given an introductory passage prior laboratory instruction.

4. There was a significant difference in achievement of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were not given an expository organizer prior to laboratory instruction.

5. There was a significant difference in retention of general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were given an introductory passage prior to classroom instruction.

6. There was a significant difference in retention of
general chemistry classroom material between students who were given an expository organizer prior to classroom instruction and those who were not given an expository organizer prior to classroom instruction.

7. There was a significant difference in retention of general chemistry laboratory material between students who were given an expository organizer prior to laboratory instruction and those who were given an introductory passage prior to laboratory instruction.

8. There was a significant difference in retention of general chemistry laboratory material between students who were given the expository organizer prior to laboratory instruction and those who were not given an expository organizer prior to laboratory instruction.

Conclusions and Discussion

From the findings it was concluded that providing students with advance organizers prior to classroom and laboratory instruction did significantly enhance achievement in selected chemistry topics which with the students were unfamiliar, as compared with providing students with introductory passages or providing students with no organizer prior to instruction in classroom and laboratory. This conclusion is limited to the Chulachomklao Royal Military Academy, Thailand and any similar situation and
groups that may exist. It is further limited to the specific content areas of chemical bonding, preparation of complex and double salts, and halogens.

The findings of the current study provided some evidence that supported the work of Ausubel. Posttest achievement scores for students in the treatment group who received an advance organizer were significantly higher than students in those groups which did not receive the advance organizer. Retention test scores for the group receiving the advance organizer were significantly higher than those groups who did not received the advance organizer. These results provide support for Ausubel's Advance Organizer Theory.

There has been a considerable amount of research done on advance organizers, with varying results. The results of this study regarding the effects of advance organizers on student achievement in chemistry differ from results of the earlier studies of Graber, Means and Johnsten (1972), Hoffelder (1973), and Petrich and Montague (1981), where the strategy of providing students with advance organizers did not enhance achievement in chemistry.

The difference between the results of this study and the three previous studies in chemistry might have been the results of differences in the procedure used to develop advance organizers and the methodology used to conduct the research. Graber, Means and Johnsten (1972) used the
identical advance organizer Ausubel developed for his study in 1968. However, the researchers found that the advance organizers was not suitable for their students. Petrich and Montague (1981) used scripts and outlines of lecture material as their advance organizers and they concluded that the scripts and outlines did not operate as advance organizers. As previously indicated, Jones (1977) suggested that advance organizers specifically designed for student ability level and background facilitated student learning. Hawk (1986) suggested that it was important for the teacher to be involved in the process of advance organizer construction because the involvement assisted the teacher in understanding what is most important for the student to learn and the relationship each concept has with the rest of the material. The researchers in these three studies did not provide any information on validity and understandability of their advance organizers. Graber, Mean, and Johnsten (1972) and Hoffelder (1973) did not provide any information on validity and reliability of the achievement test used in their studies. Therefore the advance organizers and/or testing instruments used in these investigations might not have been sensitive enough to cause or detect differences in achievement between groups.

Regardless of findings in other classroom settings, this researcher feels that the advance organizer technique was effective for the situation in which it was used.
Statistical evidence clearly indicates that the group receiving the advance organizers did significantly better on the posttest scores and retention test scores than those groups that did not receive an advance organizer prior to classroom and laboratory instruction. These findings indicated that students in the group which received an advance organizer were able to comprehend and interpret material significantly better than those groups which did not receive the advance organizer. It appeared that the advance organizer provided a global anchorage of major concepts and ideas at the beginning of the learning activities. These concepts and ideas were essential in the development of much more complex concepts and ideas which were later covered during the classroom and laboratory instruction. The students who received advance organizers appeared to have a greater ability to interpret and learn the new material more effectively as a result of having established a strong anchorage for the major concepts.

The results of the retention test support Ausubel's argument that advance organizers enhance retention by providing integrating framework for the learning material. It has been proposed by Novak (1977) that advance organizers provide a conceptual framework for factual information and that meaningful learning is the formation of concepts, not the memorization of isolated facts. In this study, the advance organizers seemed to provide an anchoring network
for the new facts and to establish cognitive bridge between apparently dissimilar facts. The new material, therefore, was integrated more easily into generalizability concepts by the students who received advance organizers. As a result, students who received advance organizers were able to retain significantly more of the chemistry content than those students who did not receive advance organizers.

Even though statistically significant differences were found between the advance organizer and control groups, the question arises as to how important these differences are from a pedagogical point of view. Are the differences substantial enough to justify the time and effort required to develop the advance organizer and provide them to students?

A review of Table 9 (page 93) reveals that the mean classroom achievement score of students in the control group was 13.20 (52.80 %) out of a maximum of 25 and that of the advance organizer group was 17.91 (71.64 %). This means that by providing advance organizers prior to classroom instruction, the mean score on classroom achievement was improved by 4.71 points, an increase of approximately 19 %. Similarly, a review of the mean scores of the advance organizer and control groups on laboratory achievement (Table 13, page 98) reveals that the mean scores for the control group and advance organizer group are 7.10 (47.33 %) and 10.20 (68.00 %), respectively. In this case the increase
in the mean score of the advance organizer group as a result of providing advance organizers prior to laboratory instruction was 3.10 points, an increase of approximately 20%.

An improvement of 19% in achievement resulting from classroom instruction and 20% in achievement resulting from laboratory instruction of students in a general chemistry by providing students with advance organizers prior to instruction represent substantial improvement in student achievement. It was a large increase for the amount of time and effort required to develop and introduce advance organizers. The strategy of providing students with advance organizers prior to instruction did have substantial practical significance for the chemistry teachers at CRMA.

Based upon the results of this study, it would appear that chemistry teachers could facilitate their students achievement by using advance organizers. The preparation of advance organizer is not immediately an easy task but becomes so with a minimum amount of experience. The process of advance organizer development further assists chemistry teachers in understanding what was most important for the student to learn and the relationship each concept has with the rest of the material.

Out of all information presented in chemistry textbooks and lectures at university level, it seems necessary for the teachers to know and to inform the student what information
he/she will be required to learn and for what information the student will be held accountable. In structuring this information, the teacher can also structure and organize his/her plan for instruction. The use of advance organizers may best be considered as only one of several methods or tools by which teachers use to increase student achievement in chemistry.

Recommendations and Suggestions for Future Practice and Research

Practice

1. Instructors as well as professional designers of instructional materials (textbooks, audio-visual programs and CAI) should more frequently and more conscientiously consider advance organizer theory and research findings when developing and/or implementing an instructional plan.

2. Teachers can substitute advance organizers for prelaboratory component to maximize the students understanding of the objective, and data obtained, and the process involved in laboratory activities.

3. The results of this study indicate beneficial effects in learning. It appears that teachers can facilitate their students' achievement by using advance organizers. Teacher training for advance organizer development should be
undertaken to assist teachers in preparing advance organizers for their classroom and laboratory instruction.

Research

1. This study was conducted at CRMA which is a unique university. The study should be replicated in different as well as similar environments in an attempt to confirm the findings.

2. Investigations should be conducted on those students who possess most of the concepts contained in the advance organizers to determine how they organize for learning. Possibly this could be done using a qualification research design. Additional investigation should include whether the advance organizers helped them to organize for learning when they were provided to them, and whether they developed their own organizer.

3. Investigations should be conducted under conditions that would generate data needed to more conclusively address questions related to the differential effects of using advance organizers of various formats, i.e., using visual organizer, audio organizer, etc.

4. Studies that specifically examine that interactions between or among organizer format, learner characteristic, and/or the nature of the material to be learned should be undertaken.
5. Studies should be conducted to investigate the effects of previous science experience upon the effective use of advance organizers.


APPENDICES
Appendix A

Advance organizers for classroom and laboratory instruction

1. Advance organizers for classroom on page 132
2. Advance organizers for laboratory on page 139
In a periodic table the elements are arranged in rows called periods, in order of increasing atomic number. The rows are stacked so that elements in the columns, called groups or families, have the same number of valence electrons. Therefore the elements in the same group have similar chemical and physical properties.

We will see frequently that as we move from position to position across a period or down a group, chemical and physical properties change in a more or less regular fashion. Some examples of trends in properties within the periodic table are size of atom, ionization energy, electron affinity and electronegativity.

In the periodic table, atomic size varies in a more or less systematic way. Atoms become larger from top to bottom in a group; they become smaller from left to right in a period. Negative ions are larger than the atom from which they are formed; positive ions are smaller than the atoms from which they are formed.

Ionization energy (IE) is the energy needed to remove an electron from an isolated, gaseous atom. For an element X, it is the energy associated with the change

\[ X_{(g)} \rightarrow X^{+}_{(g)} + e^- \]

Usually IE is expressed in units of kilojoules per mole, which is really the energy needed to remove one electron from one mole of atoms. Atoms with more than one electron have more than one ionization energy. These correspond to the stepwise removal of electron one after the other. In general, successive ionization energies always increase because each subsequent electron is being pulled away from an increasingly more positive ion. In the periodic table ionization energy increases from bottom to top within a group and increases from left to right within a period.

Electron affinity (EA) is energy released when an electrons added to an atom to create a negative ion.

\[ X_{(g)} + e^- \rightarrow X^-_{(g)} \]

For nearly all the elements, the addition of one electron is exothermic, and therefore the EA is given as a negative value. However when a second electron must be added, work must be done to force the electron into an already negative ion. This change is therefore endothermic and the EA is given as a positive value. EA generally increase from left to right in a period and increases from bottom to top in a group.

The term that we use to describe the relative attraction of an atom for the electrons in a bond is called the electronegativity of the atom. The electron pair of the
covalent bond spends more of its time around the more electronegative atom. Within the periodic table, electronegativity varies in a more or less systematic way. Electronegativity increase from bottom to top in a group, and from left to right in a period.
According to the quantum theory developed by Schrödinger, there is a region of space around the nucleus in which electrons are most likely to be found. We call this region an orbital. Each orbital is characterized by a set of three integer quantum numbers, \( n \), \( l \), and \( m_l \).

1. The principal quantum number, \( n \). The energy levels in an atom are arranged into main levels, or shells, as determined by the principal quantum number, \( n \). The larger the value of \( n \), the greater the average energy of the levels belonging to the shell. \( n \) may have values of 1, 2, 3, ..., and so on. Letters are also associated with these shells as shown below.

<table>
<thead>
<tr>
<th>Principal quantum number</th>
<th>Letter designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
</tr>
<tr>
<td>4</td>
<td>N</td>
</tr>
</tbody>
</table>

For example, the shell with \( n=1 \) is referred to as the K shell.

2. The azimuthal quantum number, \( l \). Each main shell is composed of one or more subshells, or sublevels, each of which is specified by a secondary quantum number, \( l \), called the azimuthal quantum number. This quantum number determines the shape of an orbital. For any given shell, \( l \) may have values of 0, 1, 2, and so on, up to a maximum of \( n-1 \) for that shell. Thus, when \( n=1 \), the largest (and only) value of \( l \) that is allowed is 0. Therefore, the K shell consists of only one subshell. When \( n=2 \), two values of \( l \) occur, \( l=0 \) and \( l=1 \). Notice that the number of subshell in any given shell is simply equal to the value of \( n \) of that shell. It is common practice to associate letters with the various values of \( l \): 0, 1, 2, 3, ..., s, p, d, f.

To specify a subshell within a given shell, we write the value of \( n \) for the shell followed by the letter designation of the subshell. For example, 2p denotes a subshell with quantum number \( n=2 \) and \( l=1 \).

3. The magnetic quantum number, \( m_l \). Each subshell is composed of one or more orbitals. An orbital within a particular subshell is distinguished by its value of \( m_l \), which serves to determine its orientation in space relative to the other orbitals. The magnetic quantum number has integer values that range between -1 and +1. When \( l=0 \), only one value of \( m_l \) is permitted, \( m_l=0 \); therefore an s subshell consists of only one orbital, the s orbital. A p subshell (\( l=1 \)) contains three orbitals corresponding to \( m_l \) equal to -1, 0, and +1. There are always \( 2l+1 \) orbitals in each subshell of quantum number \( l \). A d subshell (\( l=2 \)) is composed of five orbitals and an f subshell (\( l=3 \)), seven.

In addition to the three quantum numbers, \( n \), \( l \), and \( m_l \), there is another, called the spin quantum number, \( m_s \). This quantum number arises because the electron behaves as if it
was spinning. Since the electron can only spin in either of two directions, \( m_s \) may have only two values. These turn out to be +1/2 and -1/2. Therefore, each electron in an atom can be assigned a set of values for its four quantum numbers, \( n \), \( l \), \( m_l \) and \( m_s \), which determine the orbital in which the electron will be found and the direction in which the electron will be spinning.
ELECTRON CONFIGURATION

An electron configuration describes the particular arrangement of electrons in the subshell of an atom. Electron configuration of an element is obtained by placing electron into the lowest available orbitals, while heeding the Pauli exclusion principle and Hund’s rule. This lead to the electron arrangement with the lowest energy.

Pauli exclusion principle states that no two electrons in the same atom may have identical values for all four quantum numbers. This principle is really telling us that the maximum number of electrons in any orbital is two, and that when two electrons are in the same orbital, they must have opposite spins.

Hund’s rule states that when electrons are placed in a set of orbitals equal energy, they are spread out as much as possible to give as few paired electron as possible.

In order to write electron configuration of an element, we must know atomic number of that element which is equal to the number of electrons. In its ground state these electrons will occupy the lowest energy orbital that available. To indicate the population of a subshell, we use a superscript with the designation. Thus the electron configuration of 11Na is written as 1s^22s^22p^63s^1. Another way to expressing electron configurations that we will sometimes find useful is the orbital diagram. In it, each orbital is represented by a circle or square or line and arrows are used to indicate the individual electrons, heads up for spin in one direction and head down for spin in the other. The orbital diagram for 6C is written as

```
C 1s^22s^22p^2

C □ □ ▲ ▲
1s 2s 2p
```

We have known that two electrons occupying the same orbital must have opposite spins. When this occurs, we say that the spins of the electrons are paired. We called them paired electrons. If there is one electron in the orbital, we called it unpaired electron.

```
□
paired electron

▲
unpaired electron
```

Knowing how to predict electron configuration is important because the arrangement of electrons controls an atom’s chemical properties.

A way to remember the filling order of subshells is shown on the next page.
Starting at the bottom and following the diagonal arrows.
SHAPE OF ORBITALS

An electron behaves as if it were spread out around the nucleus in a sort of electron cloud. The electron spends most of its time in region where the probability of finding it is high and there is the concentration of charge, which we call electron density, is large. In looking at the way of electron density distributes itself in atomic orbitals, we are interested in the shape of the orbital and its orientation in space.

All s orbitals have a spherical shape. If we go out a given distance from the nucleus in any direction, the probability of observing the electron would be the same. The size of the orbital increases with increasing n.

The p orbitals are quite different from s orbitals. For a p orbital, the electron density is equally distributed in two regions on opposite side of the nucleus. We represent all p orbitals as a pair of dumbbell-shape lobes pointing in the opposite directions from the nucleus. A p subshell consists of three orbitals whose directions lie at 90 degree to each other along the areas of an xyz coordinate system. They have the same shape. The orbitals are often labeled according to the axis along which they lie as p_xy, p_yz and p_z.

The d orbital are a bit more complicated than p orbitals. There are five orbitals in a d subshell. Four of them, labeled d_xy, d_yz, d_zz and d_x2-y2, have the same shape and consist of four lobes of electron density. These orbitals differ only in their orientations around the nucleus. The fifth d orbital, labeled d_z2, has two lobes that point in opposite directions along the z axis plus a doughnut-shaped ring of electron density around the center that lies in the xy plane.

A f subshell is composed of seven f orbitals. The shape of the f orbitals are even more complex than the d orbitals, but we will have no need to discuss their shapes.
CRYSTALLIZATION

Crystallization is one of the purification process for solid. Crystallization from saturated solution is a useful process. In this process, we need to prepare saturated solution of substance we want to crystallize at the boiling point of solvent. Impurities in the solution are removed by filtration when solution is hot. As the solution is cooled, our substance will crystallize out.

It is necessary to choose the appropriate solvent for crystallization. The good solvent for crystallization must completely dissolve the substance when the solution is hot but rarely dissolve when the solution is cool. It must not dissolve any impurities when the solution is hot.

Sometimes the substance does not crystallize out as the solution is cooled. In this circumstance, we need to add the second solvent which dissolve in the first solvent but does not dissolve our substance. This method is called crystallization from the mixture of solvent.

The size of our crystal depends on how fast we allow the solution to be cooled. If the solution is rapidly cooled and it is disturbed, the result will be small size crystals. If the solution is slowly cooled and it is not disturbed, the result will be large size crystals. A good crystal should not be too large or too small. If the crystal is too large, it will occlude large amount of solution. Thus there will be impurities inside the crystal. On the other hand, impurities will adsorbed on the surface of the crystal if the crystal is too small.

CuSO₄·5H₂O (COPPER SULFATE PENTAHYDRATE)

Copper sulfate forms blue crystal with the formula CuSO₄·5H₂O in which there are five water molecules for each CuSO₄. When these blue crystals are heated strongly, the water is driven off and the solid that remains, now nearly pure CuSO₄, is almost white. If left exposed to the air, the CuSO₄ will absorb moisture and form blue CuSO₄·5H₂O again.

In water solution of copper (II) salts, such as CuSO₄ or Cu(NO₃)₂, the copper is not present as simple Cu²⁺ ions. Instead, each Cu²⁺ ion becomes bonded to four water molecule, which gives a pale blue ion with the formula Cu(H₂O)₄²⁺. If ammonia is added to an aqueous solution containing the Cu(H₂O)₄²⁺ ion, for example the color deepens dramatically as ammonia molecules displace water molecules.

\[
\text{Cu(H₂O)₄²⁺(aq) + 4NH₃(aq) \rightarrow Cu(NH₃)₄²⁺(aq) + 4H₂O (pale blue) → Cu(NH₃)₄²⁺(aq) + 4H₂O (deep blue)}
\]
HALOGENS

When chlorine is bubbled into water, some of what dissolves reacts to give a mixture of hydrochloric acid and hypochlorous acid in the following equilibrium.

\[ \text{Cl}_2(aq) + H_2O \rightleftharpoons HCl(aq) + HOCl \]

Bromine is produced from its most common sources, naturally occurring brines. The reaction in which chlorine oxidizes bromide ion goes by the following equation.

\[ \text{Cl}_2(aq) + 2\text{Br}^-\text{(aq)} \rightarrow 2\text{Cl}^-(aq) + \text{Br}_2(aq) \]

The bromine is removed by passing either air or steam into the solution, which carries bromine vapors out where they can be condensed and further purified. Bromine resembles chlorine in chemical properties, except for reactivity. It is more soluble in water than chlorine but, unlike chlorine.

\[ \text{Br}_2(aq) + H_2O \rightleftharpoons HBr(aq) + HOBr(aq) \]

Many natural brines contain iodide ion, so when chlorine is bubbled through them, I\(^-\) is oxidized to I\(_2\). This is just like the recovery of bromine from brines, only iodide ion is more easily oxidized than bromide ion. Bromine, of course, also oxidizes iodide ion.

\[ 2\text{I}^-(aq) + \text{Cl}_2(aq) \rightarrow \text{I}_2(s) + 2\text{Cl}^-(aq) \]

\[ 2\text{I}^-(aq) + \text{Br}_2(aq) \rightarrow \text{I}_2(s) + 2\text{Cl}^-(aq) \]

The order of ease of oxidation of halide ions to halogens, X\(_2\), is as follow.

In Ease of Oxidation  \( I^- > \text{Br}^- > \text{Cl}^- > F^- \)

Chlorine or bromine can readily add to the double bond. Iodine generally is not reactive enough to add to double bond and fluorine reacts explosively.
Appendix B

Introductory passages for classroom and laboratory instruction

1. Introductory passages for classroom on page 142
2. Introductory passages for laboratory on page 147
CHEMICAL BONDING

The properties of a substance are determined in part by the chemical bonds that hold the atoms together. A chemical bond is a strong attractive force that exists between certain atoms in a substance.

Ionic Bonding

The forces of attraction between positive and negative ions in an ionic compound are called ionic bonds. The formation of ionic compounds by electron transfer is favored when atoms of low ionization energy react with atoms of high electron affinity, that is, when metal combine with nonmetals. The chief stabilizing influence in the formation of ionic compounds is the lattice energy, the energy needed to separate the ions completely, or the energy lowering that occurs when gaseous ions are brought together to form the crystal of the ionic compound. When atoms of the representative elements form ions, they usually gain or less enough electrons to achieve a noble gas electron configuration.

Covalent Bonding

Electron sharing between atoms occurs when electron transfer is energetically too "expensive." Shared electrons attract the positive nuclei and this leads to a lowering of the energy of the atoms as a covalent bond forms. Electrons generally become paired when they are shared. An atom tends to share enough electrons to complete its valence shell. Except for hydrogen, the valence shell usually holds eight electrons, which forms the basis of the octet rule. The octet rule states that atoms, particularly those of the representative elements, tend to acquire eight electrons in their outer shells when they form bonds. Single, double, and triple bonds involve atomic nuclei sharing one, two, and three pairs of electrons, respectively. Some molecules don't obey the octet rule. Compounds of B and Be often have less than an octet around the central atom. Atoms of the elements of period 2 cannot have more than an octet because their outer shell can hold only eight electrons. Elements in period 3 and below can exceed an octet if they form more than four bonds.

Lewis Symbols and Lewis Structures

Lewis symbols are a bookkeeping device used to keep track of valence electrons during bond formation. The Lewis symbol of an element consists of the element's chemical symbol surrounded by a number of dots equal to the number of valence electrons. The Lewis structure for a molecule or
polyatomic ion uses pairs of dots between chemical symbols to represent shared pairs of electrons. Electron pairs in covalent bonds usually are represented by dashes, one dash equals two electrons.
The shapes of molecules are very important because many of their physical and chemical properties depend upon the three dimension arrangement of their atoms. For example; the functioning of enzymes, which are substance that control how fast biochemical reactions occur, require that there be a very precise fit between one molecule and another. Even slight alternations in molecular geometry can destroy this fit and deactivate the enzyme, which in turn prevents the biochemical reaction involved from occurring.

We know from various experiments that molecules have definite shapes or geometries. By definite shape, we mean that the atoms of a molecule occupy definite positions relative to one another in three-dimensional space. We know that the shape of a molecule controls some of its chemical and physical properties. We will be concerned with aspects of geometrical and electronic structure of molecules that can be understood by using simple models for the distribution of electrons in molecules.

When first encountering a molecule, how can one predict its shape? For example, consider the molecules BF₃ and PF₃ which both contain three fluorine atoms attached to a central atom. The BF₃ molecule has a trigonal planar structure, where all four atoms are in a plane with the F atoms oriented in a regular array about the B atom. The PF₃ molecule has a trigonal pyramidal structure, with the P atom above a plane defined by the three F atoms. We will see how to predict such structural differences.

There are three fundamental theories involving covalent bonding that we will study. They are called valence bond (VB) theory, molecular orbital (MO) theory, and valence shell electron pair repulsion (VSEPR) theory.

According to VB theory, a covalent bond is formed between two atoms when an atomic orbital on one atom overlaps with an atomic orbital on the other and a pair of electrons with paired spins is shared between the overlapping orbitals.

The MO theory views a molecule as a collection of positively charged nuclei surrounded in some way by electrons that occupy a set of molecular orbitals.

The VSEPR theory is based on the idea that valence shell electron pairs, being negatively charged, stay as far apart from each other as possible so that the repulsions between them are at a minimum.

The VSEPR theory is helpful and accurate for predicting molecular geometry but it does not tell us about why covalent bonds are formed or how electron manage to be shared between atoms. The VB theory and MO theory are helpful if we wish to understand more fully the covalent bond and the factors that determining molecular geometry.
BOND ENERGY AND BOND LENGTH

Bond energy which is the energy needed to separate the bonded atoms and bond length which is the distance between the nuclei of the atoms connected by the bond are two experimentally measurable quantities that can be related to the number of pairs of electrons in the bond. For bonds between the same atoms, bond energy increases and bond length decreases as we go from single to double to triple bonds.

RESONANCE

Two or more atoms in a molecule or polyatomic ion are chemically equivalent if they are attached to the same kinds of atoms or groups of atoms. Bonds to chemically equivalent atoms must be the same, they must have the same bond length and the same bond energy, which means they must involve the sharing of the same number of electron pairs. Sometimes the Lewis structures we draw suggest that the bonds to chemically equivalent atoms are not the same. Typically, this occurs when it is necessary to form multiple bonds during the construction of a Lewis structure. When alternatives exist for the location of this multiple bond among two or more equivalent atoms, then each possible Lewis structure is actually a resonance structure or contributing structure, and we draw them all. In drawing resonance structures, the relative locations of the nuclei must be identical in all. Remember that none of the resonance structures corresponds to a real molecule, but their composite -- the resonance hybrid -- does approximate the actual structure of the molecule or ion.

COORDINATE COVALENT BOND

We sometimes single out a covalent bond whose electron pair originated from one of the two bonded atoms. An arrow is sometimes used to indicate the donated pair of electrons. Once formed, a coordinate covalent bond is no different than any other covalent bond.

HYDROGEN BOND

A hydrogen atom bonded to N, O, or F is simultaneously attracted to an unshared pair of electrons on an unshared pair of electrons on an N, O, or F atom of a neighboring molecule. This hydrogen bridge between the two molecules is called a hydrogen bond.
Electronegativity is the attraction an atom has for electrons in a bond. When two atoms of different electronegativity form a covalent bond, the electrons in the bond are shared unequally and the bond is polar; it has opposite partial charges on opposite ends. A nonpolar bond is formed when the two atoms have the same electronegativity, and ionic bonds is formed when the difference in electronegativity is very large. A covalent bond is more than 50 % ionic if the electronegativity difference is larger than 1.7. A diatomic molecule is polar if its bond is polar. The extent of polarity is determined by the dipole moment of the molecule -- the magnitude of the partial charge on either end multiplied by the distance between the partial charges. In polyatomic molecules, bond dipoles can cancel to give nonpolar molecules if all the atoms attached to the central atom are alike. When lone pairs are in the valence shell of the central atom, the molecule is usually polar.
HYDRATES

Certain compounds form crystals that contain water molecules. An example is ordinary plaster, the material often used to coat the interior walls of buildings. Plaster consists of crystals of calcium sulfate, CaSO₄, that contain two molecules of water for each CaSO₄. These water molecules are not held very tightly and can be driven off by heating the crystals. The dried crystals absorb water again if exposed to moisture, and the amount of water absorbed always gives crystals in which the H₂O to CaSO₄ ratio is 2 to 1. Compounds such as this, whose crystals contain water molecules in fixed ratios, are quite common and are called hydrates. The formula for this hydrate of calcium sulfate is written CaSO₄·2H₂O to show that there are two molecules of water per CaSO₄. The raised dot is intended to suggest that there are two molecules of water per CaSO₄. The raised dot is intended to suggest that the water molecules are not bound too tightly in the crystal and can be removed.

DOUBLE SALTS

When a solution that contains equal numbers of moles of aluminum sulfate and sodium sulfate is evaporated, crystals are formed that have the composition NaAl(SO₄)₂·12H₂O. Similar crystals are formed from solutions that contain both aluminum sulfate and either ammonium sulfate or potassium sulfate. Their formulas are NH₄Al(SO₄)₂·12H₂O and KAl(SO₄)₂·12H₂O. These are examples of double salts compounds that contain the components of two salts in a definite ratio. A double salt that has the general formula M⁺M³⁺(SO₄)₂·12H₂O is called an alum, and salts of this type include double salts formed not only by aluminum, but also by Cr³⁺ and Fe³⁺. Under carefully controlled conditions, large well-formed crystals of the alums can be grown that are quite beautiful.
HALOGENS

The hydrides, metal salts, and a few oxoacids are the most commonly used compounds of the halogen family. The halogen family consists of fluorine, chlorine, bromine, iodine, and astatine. As a name, halogen comes from Greek roots meaning "sea-salt producer," after the ability of halogens to combine directly with metals to make salts.

Like the first members of the oxygen and nitrogen families, fluorine is more different from chlorine, the second member, than chlorine differs from the rest of the family. Astatine is intensely radioactive and found only rarely in some uranium deposits. Chlorine is a poisonous, yellowish-green gas. It was isolated in 1774 by Carl Wilhelm Scheele, a Swedish scientist. Its name is form the Greek chloros meaning "yellow-green," the same association with color as found in the word "chlorophyll."

Bromine was first isolated in 1826 by young French chemist, Antone Balard (1802-1876) who found that the addition of aqueous chlorine (called "chlorine water") to water from the Montpellier salt marshes in France turned the water deeply yellow. After isolation and purification, the cause of the color was found to be a liquid element with a terrible smell. The French Academy named it bromine, from bromos, which is Greek for "stench."

Iodine was first prepared in 1811 by Bernard Courtois (1777-1838), who observed purple vapors rising from an extract of kelp ashes that he had acidified with sulfuric acid and heated. In his time, kelp was commonly collected, dried, and burned to give ashes from which sodium and potassium salts were obtained. The purple vapor condensed on a cold surface, forming nearly black crystals. It was named after the Greek iodes, meaning "violet."
Appendix C
Test items

1. Framework test on page 150
2. Classroom pretest on page 156
3. Laboratory pretest on page 164
4. Classroom posttest on page 169
5. Laboratory posttest on page 174
FRAMEWORK TEST

1. The elements in the same group have the number of valence electron equal to ....................

2. Elements in group IIA place the last electron in ...........orbital

3. Elements in the same period have their atomic size decrease from ........ to ........ of the periodic table. Element in the same group have their atomic size increase from ........ to ........ of the periodic table.

4. Ionization energy is .................

5. Ionization energy of elements in the same period increase as .................

6. Electronegativity increases from ........ to ........ of the periodic table.

7. 4Be, 5B, 7N, and 12Mg.
   Which one has largest atomic size? .................
   Which one has smallest atomic size? .................
   Which one has greatest first ionization energy? ........
1. Which sets of quantum numbers are not correct?
   a) \( n=1, \, l=2, \, m_l=0, \, s=1/2 \).
   b) \( n=3, \, l=1, \, m_l=-2, \, s=0 \).
   c) \( n=2, \, l=1, \, m_l=0, \, s=1/2 \).

2. If \( n=4 \), \( l \) can be equal to ..........................

3. The set of quantum numbers for an electron in 2p orbital
   \( n=....., \, l=........., \, m_l=........., \, s=........... \).
FRAMEWORK TEST

1. Write the electron arrangement of \( _{12} \text{Mg} \).

2. Which ones have the incorrect electron arrangement?

   a. \( 1s^12s^32p^5 \)
   b. \( 1s^22s^22p^63s^23p^73d^9 \)
   c. \( 1s^22s^22p^6 \)
   d. \( 1s^22s^22d^{11} \)

   correct electron arrangement.
FRAMEWORK TEST

1. The region of space in which an electron is most likely to be found is called ......................

2. There are .......... orbitals in the d-subshell.

3. Draw pₓ orbital.
1. The process for purification of solid substance using the effect of solubility change with the change in temperature is called

2. Good solvent used in the purification process in 1. must dissolve the substance well when .................
but poorly dissolve the substance when ................

3. In order to purify the substance by using mixture of solvent, the second solvent that add into the solution of the first solvent must dissolve........................
but must not dissolve............................

4. From the process in 1., the size of a crystal depends on

5. \( \text{Cu(H}_2\text{O)}_{4}^{2+} \text{(aq) + NH}_3\text{(aq)} \rightarrow \text{pale blue} + \text{deep blue} \)
1. \( \text{Br}_2(g) + \text{H}_2\text{O} \rightarrow \text{......} + \text{......} \)

2. Write the order of the ability to lose electron of \( \text{F}^- \), \( \text{Cl}^- \), \( \text{Br}^- \), and \( \text{I}^- \).
CLASSROOM PRETEST

Directions. Unless indicated otherwise, this is a multiple choice test. All questions have only one correct answer. In each question, circle the letter you choose.

1. Which of the following contains the most atoms? (Al=27, Ca=40, Hg=200, He=4)
   a. 0.1 mole of aluminum
   b. 8 g of calcium
   c. 20 g of mercury
   d. 2 g of helium

2. One gallon of octane (C₈H₁₈), a compound of gasoline, weighs about 2850 g. How many molecules are there in one gallon of octane? (C=12.0, H=1.0)
   a. 25.0
   b. 1.50x10²⁵
   c. 1.20x10²⁶
   d. 4.15x10⁻²³

3. What is the mass of 10 molecules of ozone?
   a. 7.9x10⁻²²
   b. 2.6x10⁻²²
   c. 7.9x10⁻²³
   d. 2.6x10⁻²³

4. A sample of gold weighs 1.97g. What is the mass of one atom of gold? (Au=197.0)
   a. .0602x10⁻²³
   b. 3.27x10⁻²²
   c. 32.7x10⁻²¹
   d. 197.0

5. How many neutrons are there in $^{27}{\text{Al}}^{3+}^{13}$?
   a. 14
   b. 13
   c. 11
   d. 10

6. How many electrons are there in $^{27}{\text{Al}}^{3+}^{13}$?
   a. 14
   b. 13
   c. 11
   d. 10

7. Laughing gas is a composition formed from nitrogen and oxygen in which there are 1.75 g of nitrogen to 1.00 g of oxygen. Below are given the composition of several nitrogen and oxygen compound. Which of these is laughing gas?
   a. 6.35 g nitrogen, 7.26 g oxygen
   b. 4.63 g nitrogen, 10.58 g oxygen
   c. 8.84 g nitrogen, 5.05 g oxygen
   d. 9.62 g nitrogen, 16.5 g oxygen

8. The number of copper atom in a 3.0 g lump of copper is 2.8x10²². How many electrons are present in the sample? (Atomic number of Cu=29)
9. How many atoms does a mole of oxygen molecules contain?
   a. 2   b. 3.01x10^{23}   c. 6.02x10^{23}   d. 12.04x10^{23}

10. Which of the following statements is not true?
   a. A mole of magnesium atoms (24.3 g) contains the same
      number of atoms as a mole of sodium atoms (23.0 g).
   b. An element with an atomic number of 29 has 29
      protons, 29 electrons, and 29 neutrons.
   c. Two atoms each have mass number 40. They are not
      necessarily atoms of the same element.
   d. An atom of the isotope $^{60}$Fe has 34 neutrons in its
      nucleus.

11. The empirical formula for a compound is $\text{C}_2\text{H}_3\text{S}$ and its
    molecular weight is about 60. What is the coefficient of
    S in its molecular formula? (C=12, H=1, S=32)
   a. 1   b. 2   c. 4   d. 6

12. What is the empirical formula for sodium oxalate,
    $\text{Na}_2\text{C}_2\text{O}_4$?
   a. $\text{C}_2\text{O}_4$
   b. $\text{NaCO}_2$
   c. $\text{NaO(CO)}_2\text{ONa}$
   d. $\text{Na}_2\text{C}_2\text{O}_4$

13. A 987.4 mg sample of cupric sulfate is decomposed and
    produces 393.1 mg of copper. The % of copper in
    cupric sulfate is:
   a. 0.398   b. 0.285   c. 39.8   d. 28.5

14. Which of the following compounds of nitrogen contains
    the greatest percentage of nitrogen by weight? (N=14.01,
    H=1.008, O=16.00, Cl=35.45, C=12.01, F=19.00)
   a. Ammonium nitrate $\text{NH}_4\text{NO}_3$
   b. Ammonium chloride $\text{NH}_4\text{Cl}$
   c. Urea $\text{N}_2\text{H}_4\text{CO}$
   d. Ammonium fluoride $\text{NH}_4\text{F}$

15. An analysis of a compound gave 54.1 % carbon, 36.1 %
    oxygen and 9.86 % hydrogen. If the empirical formula
    of the compound is $\text{C}_x\text{H}_2\text{O}_2$, what is $x$, the coefficient of
    C? (C=12.0, H=1.01, O=16.0)
   a. 4   b. 6   c. 7   d. 8
16. A crystal of a compound is found to contain 4.83 mg of Na, 1.89 mg of Al, and 3.36 mg of O. What is the empirical formula of the compound (assuming there are no other elements present)? Na=22.9898, Al=26.9815, O=15.9994

17. Is the number of atoms in the empirical formula for a compound:
   a. often greater than the number in its molecular formula?
   b. always equal to the number in its molecular formula?
   c. often less than the number in its molecular formula?
   d. always less than the number in its molecular formula?

18. How many atoms are there in 12 mg of helium, He? He=4.00
   a. 1.8x10²⁷  b. 2.9x10²²  c. 2.9x10¹⁹  d. 1.8x10¹⁸

19. Which of the following compounds of boron contains the greatest percentage of boron by weight? (B=10.81, Ca=40.08, O=16.00, Na=22.99, F=19.00, Cl=35.45)
   a. Calcium borate CaB₄O₇
   b. Borax Na₂B₄O₇
   c. Boron trifluoride BF₃
   d. Boron trichloride BCl₃

20. The empirical formula for datiscetin is C₉₁H₁₄O₅ and its molecular weight is about 600. What is the coefficient of O in its molecular formula? (C=12, H=1, O=16)
   a. 5   b. 10   c. 15   d. 20

21. How many moles of Mg(OH)₂ can be made from the Mg in 18 moles of Mg₃N₂?
   a. 18   b. 6   c. 54   d. 9

22. How many moles of Fe₂O₄ will supply the Fe to produce 6 moles of Fe₂O₃?
   a. 3   b. 6   c. 4   d. 9

23. Consider the equation:
   2Fe₂S₃ + 6H₂O + 3O₂ ---→ 4Fe(OH)₃ + 6S
   What mass of S is produced from 0.16 g of O₂? S=32.064, O=15.9994
24. How many gram of Carbon, C are required to make 162.0 g of C\textsubscript{3}H\textsubscript{4}? (C=12.011, H=1.00797)
   a. 16.2   b. 180.1   c. 145.7   d. 1621.1

25. How many liters of hydrogen gas at STP are required to prepare 45.0 g of ammonia?
\[ \text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g) \]
   a. 39.5   b. 30.0   c. 59.3   d. 88.9

26. A hydrocarbon undergoes complete combustion to give 0.44 g of CO\textsubscript{2} and 0.27 g of H\textsubscript{2}O. What is the simplest (empirical) formula of the hydrocarbon?
   a. C\textsubscript{4}H\textsubscript{27}   b. CH\textsubscript{4}   c. C\textsubscript{2}H\textsubscript{3}   d. CH\textsubscript{3}

27. If 7.30 g of HCl and 4.00 g of NH\textsubscript{3} are mixed,
\[ \text{HCl}(g) + \text{NH}_3(g) \rightarrow \text{NH}_4\text{Cl}(s) \]
How many grams of NH\textsubscript{4}Cl can be formed?
   a. 10.7   b. 11.3   c. 12.6   d. 13.3

28. What mass of KC\textsubscript{10} will produce 48.0 g of oxygen if the decomposition is complete?
   a. 61.3 g   b. 74.5 g   c. 122.5 g   d. 245.0 g

29. The density of a liquid sulfur compound is 1.14 g/ml. This compound contains 23.7 % sulfur. How many milliliters of the compound must be burned to obtain 6.40 g of SO\textsubscript{2}?
   a. 1.52   b. 4.22   c. 11.9   d. 23.7

30. Using the lowest possible whole integer numbers as the coefficients preceding each chemical formula, write and balance the equation for the reaction of coke, C with steam to produce carbon monoxide, CO and hydrogen, H\textsubscript{2}. What is the coefficient of CO?
   a. 1   b. 2   c. 3   d. 4

31. Which of the following elements are paramagnetic?
\begin{tabular}{|c|c|}
\hline
Element & Atomic number \\
\hline
A & 4 \\
B & 10 \\
C & 17 \\
D & 36 \\
\hline
\end{tabular}

   a. Element A, B, D   b. Element A, C, D
   c. Element A, B, C, D   d. Element C
32. The ground state electronic configuration of the manganese (Mn) atom is:
   a. $1s^22s^22p^63s^23p^64s^24d^5$
   b. $1s^22s^22p^63s^23p^63d^7$
   c. $1s^22s^22p^63s^23p^64s^24p^5$
   d. $1s^22s^22p^63s^23p^63d^54s^2$

33. Which of the following group has the element in the correct order of more to less metallic in character?
   a. D > B > C > A
   b. B > A > D > C
   c. A > B > C > D
   d. C > A > D > B

34. Consider this section of a periodic table.

$$\begin{array}{c|c}
A & E \\
Q & R \\
\end{array}$$

If atoms of R have one "d" type electron, what is the formula for a nitride of element A?

   a. $A_3N$
   b. $A_3N_2$
   c. $AN$
   d. $AN_2$

35. Which set of quantum numbers is correct and consistent with $n=4$?
   a. $l=3, m_l=-3, m_s=-1/2$
   b. $l=4, m_l=2, m_s=-1/2$
   c. $l=2, m_l=3, m_s=+1/2$
   d. $l=3, m_l=-2, m_s=+1$

36. Which of the following is true?
   a. Elements with similar chemistry tend to appear in the same period (row) of the periodic table and to have the same electron structure in their outermost shells.
   b. If two elements X and Z form chlorides $XCl_2$ and $ZCl_3$, then they can be expected to be in adjacent columns in the periodic table and to have electronic structures in their outermost shell that differ by only one electron.
c. Elements with similar chemistry tend to appear in the same group of the periodic table and to have electron structures that differ by only one electron that is in the outermost shell of one of them.

d. An atom of the element with large atomic number has less ionization energy than an atom of the element which is in the same group but has small atomic number because electrons in its outermost shell is closer to its nucleus.

37. Which of the following is true?
   
a. Ionization energy is the energy released when an electron in the outermost shell is removed.
   
b. The more easily an electron in the outermost shell is removed, the greater the ionization energy is.
   
c. The more an electron in the outermost shell is attracted to its nucleus, the greater the ionization energy is.
   
d. The ionization energy of Na is greater than Na+.

38. Which characteristic of an electron can be indicated by quantum number?
   
a. Energy level, shape of orbital, attraction force between an electron and its nucleus, and electron spinning.
   
b. Energy level, angular momentum, magnetize, and electron spinning.
   
c. Energy level, shape of orbital, magnetize, and electron spinning.
   
d. Energy level, angular momentum, attraction force between an electron and its nucleus, and movement around nucleus.

39. Which of the following is true about the shape and direction of orbital?
   
a. s-orbital is spherical and is larger as increasing n.
   
b. s-orbital is circular and is larger as increasing n.
   
c. p-orbital is dumb-bell shape and consists of three orbitals which are pₓ², pᵧ², and pₜ².
   
d. d-orbital is dumb-bell shape and consists of five orbitals which are dₓ², dᵧ², d₁, dₓᵧ, and dₓ²ᵧ².

40. Which of the following elements have half filled (p-orbital) configuration?
   
a. N, P, and As
   
b. C, N, and O
   
c. Cr, Mn, and Mo
   
d. F, Cl, and Br
41. PCl₃, NH₃, BCl₃, SO₂, SF₄, CHCl₃
   (1) (2) (3)
Which sets of compound are polar molecules?
   a. 1    b. 1 and 2   c. 1 and 3   d. 1, 2, and 3

42. Consider the following compounds.
   H₂S, NH₃, BF₃, PBr₅, HF
   (I) (II) (III) (IV) (V)
Which is true about these compounds?
   a. Compound I, III, and IV are covalent compounds, the rest are not.
   b. Compound I, III, IV, and V are covalent compound, the rest is not.
   c. Compound I and II have electron arrangement obey the octet rule.
   d. Compound III and IV do not have the electrons arrangement obey the octet rule.

43. A covalent compound, AH₃, has trigonal planar structure. Atom A in this compound has no lone paired electron. Which of the following are the chemical properties of AH₃?
   a. Polar molecule, water soluble, and low boiling point.
   b. Hydrogen bonding formation, high boiling point, and water soluble.
   c. Nonpolar molecule which have Van-der-waals attraction between molecules.
   d. Nonpolar molecule which have hydrogen bonding between molecules.

44. Which of the following group has the compound in the order of more to less ionic in character?
   a. Ca₃P₂ > CaS > CaCl₂   b. Mg₃N₂ > MgO > MgF₂
   c. LiF > NaF > KF       d. LiCl > BeCl₂ > CCl₄

45. Ba and Se from ionic compound. Which one is the Lewis structure of both ions?
   a. :Ba⁻ and Se⁻   b. :Ba⁻²⁻ and Se⁻²⁻
   c. Ba⁻ and :Se⁻⁻   d. Ba⁻²⁻ and :Se⁻⁻²⁻

46. Which one is most nearly the bond angle of SiF₄?
   a. 90°    b. 109°    c. 120°    d. 180°

47. Which one is true?
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a. GeCl₂ is bent, BCl₃ is trigonal planar, and SbCl₃ is trigonal planar.
b. GeCl₂ is bent, BCl₃ is trigonal planar, and SbCl₃ is trigonal pyramid.
c. GeCl₂ is linear, BCl₃ is trigonal pyramid, and SbCl₃ is trigonal pyramid.

48. A molecule XY is formed from two atoms with electronegativities: X=0.8, Y=1.3.
1) Is the bond "significantly" polar?
2) Which atom is negatively charge?
3) Which atom has the greater share in the bonding electrons?
   a. 1) yes  2) X  3) Y
   b. 1) yes  2) Y  3) Y
   c. 1) no   2) Y  3) X
   d. 1) no   2) X  3) X

49. Which of the following is the effect of chemical bonding on physical property?
   a. Metal has low ionization energy
   b. Heat is absorbed when NH₄Cl dissolves in water.
   c. Graphite is a conductor but diamond is not.
   d. Water molecule in ice form hydrogen bonding.

50. Electrnegativity of H, O, and S are 2.1, 3.5, and 2.5 respectively. Why H₂O has higher boiling point than H₂S?
   a. H₂O has greater Van der Waals force than H₂S.
   b. H₂O has stronger hydrogen bonding than H₂S.
   c. Hydrogen bonding in H₂O is stronger than Van der Waals force in H₂S.
   d. Hydrogen bonding in H₂O is stronger than ionic attraction in H₂S.
LABORATORY PRETEST

Directions. Unless indicated otherwise, this is a multiple choice test. All questions have only one correct answer. In each question, circle the letter you choose.

According to the Law of Conservation of Matter, Cadet. Ron measured 10 ml of 1 M Na₂CO₃ solution, 3 ml of 1 M CaCl₂ solution, and 3 ml of 1 M H₂SO₄. He poured each solution separately into three flasks and weighed each flask. Then he mix the three solution together and weigh the mixture. He found that the weight of the mixture was much more than the weight of the reactants before mixing. Answer question 1.

\[ \text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{CaCO}_3 + 2\text{NaCl} \]
\[ \text{CaCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{H}_2\text{O} + \text{CO}_2 \]

1. How might this experiment be improved to bring its results more in line with that law?
   a. Use Na₂SO₄ instead of Na₂CO₃ to prevent generating CO₂.
   b. Use the container that can prevent the escape of some CO₂.
   c. Use the balance that can weigh substances more accurately.
   d. Evaporate water before the final weighing.

Cadet. Wang did an experiment by mixing Cu(NO₃)₂ solution with saturated solution of Na₂CO₃. After some precipitate formed, Cadet. Wang separated the precipitate and used it to react with diluted H₂SO₄. He warmed the resulting solution until it became saturate and allowed it to cool. Some crystals appeared in the solution. Answer question 2.

2. What should be the color of the crystals?
   a. white  b. blue  c. light green  d. light gray

CuSO₄, CaCl₂, MgSO₄, and MgCl₂ usually contaminate with NaCl from sea water. To purify NaCl from sea water, Ba(OH)₂ is added to salt solution and shake well. Then white precipitate form. Answer question 3.

3. Which of the following reacts with Ba(OH)₂ to form white precipitate?
   a. CaSO₄  b. MgSO₄  c. CaSO₄, CaCl₂  d. MgSO₄, MgCl₂

To determine the percent of water in CuSO₄·5H₂O, this hydrate is finely ground and placed in the evaporating dish whose weight is already known. Weigh the dish containing the hydrate inside and gently heat them until the blue color
disappear. Allow the dish to cool for about a minute. Immediately find the weight of dish and anhydrous salt, and record the data. Then heat them, weigh, and record the data again. Answer question 4 and 5.

4. What may be the result if CuSO₄ · 5H₂O is not finely ground before heating?

a. There will be no effect because CuSO₄ · 5H₂O is fine enough to be used.
b. There might be an error in the finding of percent of water because large crystals absorb water from air better than small crystals.
c. Large crystal of CuSO₄ · 5H₂O might break into the black powder of CuO.
d. It will take longer time to change the color from blue to white.

5. If the student did not heat and weigh the salt the second time, what would be his result?

a. The percent of water in the hydrate is higher than it actually should be because anhydrous salt absorbs water from air when it is cool.
b. The percent of water in the hydrate is higher than it actually should be because the weight of hot anhydrous salt is less than cool anhydrous salt.
c. The percent of water in the hydrate is higher than it actually should be because there might be some water remain in the anhydrous salt.
d. The second heating will not have any effect on the percent of water in the hydrate if all water evaporate completely in the first heating.

The following observation data are used for answering question 6 and 7.

weight of evaporating dish 30.00 g
weight of evaporating dish + CuSO₄ · 5H₂O 37.49 g
weight after the first heating 34.90 g
weight after the second heating 34.85 g

6. Compare the quantity of water in CuSO₄ · 5H₂O from the experiment with the theoretical value.

a. 2.59, 5.40  
   b. 2.64, 2.70
   c. 2.59, 2.64  
   d. 2.64, 5.00

7. Find the experimental error.

a. 1.93 %  
   b. 2.22 %  
   c. 47.20 %  
   d. 52.04 %
According to the preparation of complex salt Cu(NH₃)₄SO₄·H₂O, Cadet. Dang dissolved CuSO₄·5H₂O with ammonia solution in a beaker. He slowly add ethyl alcohol (CH₃CH₂OH) to the mixture without shaking or disturbing them. Then he covered the beaker with a watch glass and leave it on his bench. On the next day, he stirred the mixture slowly and allowed the crystals to settle down. Then he discarded the liquid and filtered the crystals. He washed the crystals with the mixture solution of ammonia and ethyl alcohol.

Answer questions 8 and 9.

8. What is the purpose of adding ethyl alcohol to the mixture?
   a. Ethyl alcohol is a starting material for generating H₂O.
   b. Ethyl alcohol makes CuSO₄·5H₂O dissolve much better in ammonia solution.
   c. Ethyl alcohol decrease the lost of ammonia.
   d. Ethyl alcohol is one of the solvent used in the preparation of this complex salt.

9. Cadet. Dang used water instead of ethyl alcohol by mistake. Which one should be the result of this mistake?
   a. Cu(NH₃)₄SO₄·H₂O cannot be prepared.
   b. The quantity of his resulting Cu(NH₃)₄SO₄·H₂O is less than the quantity of result from using ethyl alcohol.
   c. Cu(NH₃)₄SO₄·H₂O occurs faster because the amount of water is increased.
   d. There is no effect on the preparation of this complex salt because ethyl alcohol is not the reactant in this reaction.

Cadet. Rama prepared CuSO₄·(NH₄)₂SO₄·5H₂O by dissolving 4.99 g of CuSO₄·5H₂O and 2.64 g of (NH₄)₂SO₄ in 20 ml of H₂O. He heated the mixture until both salts dissolved completely. He allowed the solution cool slowly at room temperature until some crystals occurred. Answer questions 10, 11, and 12.

10. If Cadet. Rama wants large crystals, what should he do?
    a. After CuSO₄·5H₂O and (NH₄)₂SO₄ dissolved completely, he should cool the solution in ice immediately.
    b. After CuSO₄·5H₂O and (NH₄)₂SO₄ dissolved completely, he should leave the solution on his bench overnight without disturbing it.
    c. The crystals will occur more rapidly if he add a crystal of CuSO₄·(NH₄)₂SO₄·5H₂O to the solution
    d. Warm the solution of CuSO₄·5H₂O and (NH₄)SO₄ until it become concentrated solution. Then cool the solution immediately.
11. If Cadet. Rama misread the name of the substance, he used CuSO$_4$ in stead of CuSO$_4$.5H$_2$O. What his result should be?

a. CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O cannot be prepared.
b. CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O can occur.
c. CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O can occur but its weight is much more than theoretical weight.
d. Use much more water to dissolve CuSO$_4$ and ($\text{NH}_4$)$_2$SO$_4$ than to dissolve CuSO$_4$.5H$_2$O and ($\text{NH}_4$)$_2$SO$_4$.

12. If Cadet. Rama misread scale of the balance, the actual weight of CuSO$_4$.5H$_2$O he used was 7.00 g rather than 4.99 g. What his result should be?

a. He will receive the same quantity of CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O.
b. ($\text{NH}_4$)$_2$SO$_4$ will be used up completely.
c. The color of his resulting CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O is more intense than it should be.
d. CuSO$_4$.($\text{NH}_4$)$_2$SO$_4$.5H$_2$O should occur more rapidly and in much more quantity than it should be.

13. Which ones are the starting materials for preparation of bromine?

a. NaBr + MnO$_2$ + H$_2$SO$_4$
b. Na$_2$SO$_4$ + MnO$_2$ + HBr
c. KBr + H$_2$SO$_4$ + C
d. NaBr + CCl$_4$ + I$_2$

Into each of the three six-inch test tubes, place 3 ml of distilled water and 3 ml of CCl$_4$. Add three drops of bromine water to the first tube, shake them thoroughly. Add three crystal of iodine to the second test tube and shake them thoroughly. Add small quantity of KBr, and three crystals of iodine to the third test tube and shake them thoroughly. Set these test tubes aside to observe the results. Answer questions 14 and 15.

14. Which of the following results is true?

a. Water layer in the first tube is yellow. CCl$_4$ layer in the second tube is purple.
b. CCl$_4$ layer in the first tube is purple. CCl$_4$ layer in the second tube is yellow.
c. CCl$_4$ layer in the first tube is yellow. CCl$_4$ layer in the second tube is purple.
d. Water layer in the first tube is purple. Water layer in the second tube is yellow.

15. Which of the following results is true?
a. In the third tube water layer is colorless and CCl₄ layer is yellow.
b. In the third tube water layer is colorless and CCl₄ layer is purple.
c. In the third tube water layer is yellow and CCl₄ layer is purple.
d. In the third tube water layer is purple and CCl₄ layer is yellow.
CLASSROOM POSTTEST

Directions. Unless indicated otherwise, this is a multiple choice test. All questions have only one correct answer. In each question, circle the letter you choose.

1. Which of the following pairs of compounds have no lone pair electrons at central atom?
   a. C₂H₄, PCl₃
   b. C₂H₂, PCl₅
   c. CO₂, SO₂
   d. BCl₃, AsH₃

2. Which sets of compound are polar molecules?
   a. 1
   b. 1 and 2
   c. 1 and 3
   d. 1, 2, and 3

3. Substance | Electric conductor | Electric conductor (molten) | mp. | bp.
            |                  |                              |     |     
P          | no               | yes                          | 890 | 900 |
Q          | no               | no                           | 89  | 210 |
R          | yes              | no test                      | 1400| 2850|

Which is true about P, Q, and R?
   a. P should be ionic. Q should be covalent compound. R should be metal.
   b. P and R should be metal. Q should be covalent compound.
   c. P and R should be metal. Q should be non-metal.
   d. P and Q should be non-metal. R should be metal.

4. Consider the following compounds.
   H₂S  NH₃  BF₃  PBr₅  HF
   (I) (II) (III) (IV) (V)
Which is true about these compounds?
   a. Compound I, III, and IV are covalent compounds, the rest are not.
   b. Compound I, III, IV, and V are covalent compound, the rest is not.
   c. Compound I and II have electron arrangement obey the octet rule.
   d. Compound III and IV do not have the electrons arrangement obey the octet rule.

5. Element A has electron rearrangement as 2, 8, 5. Which of the following pair of compound have largest value of
the combination of all bond angles?

a. $\text{H}_2\text{O}$, $\text{ACL}_3$

b. $\text{NH}_3$, $\text{AF}_3$

c. $\text{SiCl}_4$, $\text{ABr}_3$

d. $\text{CH}_4$, $\text{ACl}_4$

6. Which of the following are nonpolar molecule?

a. $\text{CO}_2$, $\text{CCl}_4$, and $\text{CH}_3\text{Cl}$

b. $\text{CO}_2$, $\text{SF}_6$, and $\text{BCl}_3$

c. $\text{BCl}_3$, $\text{NCl}_3$, and $\text{CCl}_4$

d. $\text{HCN}$, $\text{NCl}_3$, and $\text{CO}_2$

7. Which of the following pair of substances are the best conductors?

a. $\text{SiO}_2(\text{s})$, $\text{Ge}(\text{s})$

b. $\text{Si}(\text{s})$, $\text{KNO}_3(\text{l})$

c. $\text{NaCl}(\text{s})$, graphite

d. $\text{Br}_2(\text{l})$, $\text{NH}_4\text{Cl}(\text{l})$

8. A covalent compound, $\text{AH}_3$ has trigonal planar structure. Atom A in this compound has no lone paired electron. Which of the following are the chemical properties of $\text{AH}_3$?

a. Polar molecule, water soluble, and low boiling point.

b. Hydrogen bonding formation, high boiling point, and water soluble.

c. Nonpolar molecule which have Van-der-waals attraction between molecules.

d. Nonpolar molecule which have hydrogen bonding between molecules.

9. Which of the following group has the compound in the order of more to less ionic in character?

a. $\text{Ca}_3\text{P}_2 > \text{CaS} > \text{CaCl}_2$

b. $\text{Mg}_3\text{N}_2 > \text{MgO} > \text{MgF}_2$

c. $\text{LiF} > \text{NaF} > \text{KF}$

d. $\text{LiCl} > \text{BeCl}_2 > \text{CCl}_4$

10. Which of the following is the correct order of boiling point from highest to lowest for $\text{CO}_2$, $\text{Ar}$, $\text{SCl}_2$, and $\text{SiC}$?

a. $\text{CO}_2 > \text{Ar} > \text{SiC} > \text{SCl}_2$

b. $\text{SiC} > \text{CO}_2 > \text{SCl}_2 > \text{Ar}$

c. $\text{SiC} > \text{SCl}_2 > \text{CO}_2 > \text{Ar}$

d. $\text{SCl}_2 > \text{SiC} > \text{CO}_2 > \text{Ar}$

11. $\text{Ba}$ and $\text{Se}$ from ionic compound. Which one is the Lewis structure of both ions?

a. $:\text{Ba}^{2+}$ and $:\text{Se}^-$

b. $:\text{Ba}^{2+}$ and $:\text{Se}^2-$

c. $\text{Ba}^+$ and $:\text{Se}^-$

d. $\text{Ba}^{2+}$ and $:\text{Se}^{2-}$

12. Which is the formula for the compound between $\text{Po}$ and $\text{Cl}$ that conforms to the octet rule?
13. Which ones are reasonable resonance of TeO_3?
   a. II and III  b. I and II  c. IV and III  d. III and V

14. Which is the molecular shape of AlBr_4⁻?
   a. linear  b. trigonal planar  c. tetrahedron  d. square planar

15. Which one is most nearly the bond angle of SiF_4?
   a. 90°  b. 109°  c. 120°  d. 180°

16. Which one is true?
   a. GeCl_2 is bent, BCl_3 is trigonal planar, and SbCl_3 is trigonal planar.
   b. GeCl_2 is bent, BCl_3 is trigonal planar, and SbCl_3 is trigonal pyramid.
   c. GeCl_2 is linear, BCl_3 is trigonal pyramid, and SbCl_3 is trigonal pyramid.

17. A molecule XY is formed from two atoms with electronegativities: X=0.8, Y=1.3.
   1) Is the bond "significantly" polar?
   2) Which atom is negatively charge?
   3) Which atom has the greater share in the bonding electrons?
   a. 1) yes  2) X  3) Y
   b. 1) yes  2) Y  3) Y
   c. 1) no  2) Y  3) X
   d. 1) no  2) X  3) X

18. When AlCl_3 combines with NF_3, which one is the correct resulting coordinate covalent bond?

   a. Cl-Al-N→F  b. Cl-Al→N-F
   c. Cl←Al-N-F  d. Cl-Al←N-F
19. Which of the following shows the hydrogen bonding in methanol (CH₃OH)?

\[ \text{a. } \text{H-C-O-H} \cdots \text{H-O-C-H} \quad \text{b. } \text{H-C-O-H} \]
\[ \text{c. } \text{H-C-O} \cdots \text{H-O-C-H} \quad \text{d. } \text{H-C-O} \cdots \text{H-C-O-H} \]

20. Which compound follows the octet rule?

\[ \text{a. } \text{BCl}_3 \quad \text{b. } \text{CO}_2 \quad \text{c. } \text{SF}_6 \quad \text{d. } \text{PCl}_5 \]

21. Which of the following is false?

a. Ionic compounds have high boiling points.
b. Ionic compounds are neutral because of the attraction between ions of different charge.
c. Ionic compounds usually form from metal with less 1st IE and nonmetal which great 1st IE
d. The structure of ionic compound is net work crystal. Ions are surrounded by each other with definite number.

22. Which of the following is the effect of chemical bonding on physical property?

a. Metal has low ionization energy
b. Heat is absorbed when NH₄Cl dissolves in water.
c. Graphite is a conductor but diamond is not.
d. Water molecule in ice form hydrogen bonding.

23. Electrongativity of H, O, and S are 2.1, 3.5, and 2.5 respectively. Why H₂O has higher boiling point than H₂S?

a. H₂O has greater Van der Waals force than H₂S.
b. H₂O has stronger hydrogen bonding than H₂S.
c. Hydrogen bonding in H₂O is stronger than Van der Waals force in H₂S.
d. Hydrogen bonding in H₂O is stronger than ionic attraction in H₂S.

24. \( \text{Cl}^\circ /\text{Cl}^\circ \quad \text{Cl}^5 /\text{Cl}^5 \)

Which of the following is not the reason why Cl-O-Cl has larger bond angle than Cl-S-Cl?
a. S has atomic size larger than O.
b. Cl has larger electronegativity than O and S.
c. The difference between electronegativity of O and Cl is larger than the difference between S and Cl.
d. Shared pair electron in the bond of OCl₂ is closer than the central atom than in the bond of SCl₂.

25. Molecular shape of H₂O is bent. If H⁺ binds to the lone pair of O in H₂O, what will be the shape of H₃O⁺?

a. trigonal planar  b. trigonal pyramid  
c. tetrahedron  d. octahedron
LABORATORY POSTTEST

Directions. Unless indicated otherwise, this is a multiple choice test. All questions have only one correct answer. In each question, circle the letter you choose.

1. What is the difference between complex salt and double salts?
   a. Complex salt is the result from the combination of two simple salts in the simple mole ratios.
   b. The structure of both salts are different from each other.
   c. The color of complex salt is deeper than double salt because of the stronger bond between ligand and the central atom.
   d. The ionic species obtained when CuSO₄·(NH₄)₂SO₄ dissolves in water are the same as those obtained when Cu(NH₃)₄SO₄ dissolves in water.

According to the preparation of complex salt Cu(NH₃)₄SO₄·H₂O, Cadet. Dang dissolved CuSO₄·5H₂O with ammonia solution in a beaker. He slowly add ethyl alcohol (CH₃CH₂OH) to the mixture without shaking or disturbing them. Then he covered the beaker with a watch glass and leave it on his bench. On the next day, he stirred the mixture slowly and allowed the crystals to settle down. Then he discarded the liquid and filtered the crystals. He washed the crystals with the mixture solution of ammonia and ethyl alcohol. Answer questions 2, 3 and 4.

2. What is the purpose of adding ethyl alcohol to the mixture?
   a. Ethyl alcohol is a starting material for generating H₂O.
   b. Ethyl alcohol makes CuSO₄·5H₂O dissolve much better in ammonia solution.
   c. Ethyl alcohol decrease the lost of ammonia.
   d. Ethyl alcohol is one of the solvent used in the preparation of this complex salt.

3. Cadet. Dang used water instead of ethyl alcohol by mistake. Which one should be the result of this mistake?
   a. Cu(NH₃)₄SO₄·H₂O cannot be prepared.
   b. The quantity of his resulting Cu(NH₃)₄SO₄·H₂O is less than the quantity of result from using ethyl alcohol.
   c. Cu(NH₃)₄SO₄·H₂O occurs faster because the amount of water is increased.
   d. There is no effect on the preparation of this complex salt because ethyl alcohol is not the reactant in
this reaction.

4. Why Cadet. Dang used the mixture solution of ammonia and ethyl alcohol to wash the crystal?

a. The resulting complex salt dissolves well in this mixture solution.
b. This mixture solution can dissolve CuSO₄ which contaminates with the complex salt.
c. Washing the complex salt with this mixture reduce the size of the crystals and make the crystal dry rapidly.
d. This mixture is the same as the solvent used at the beginning.

Cadet. Rama prepared CuSO₄·(NH₄)₂SO₄·5H₂O by dissolving 4.99 g of CuSO₄·5H₂O and 2.64 g of (NH₄)₂SO₄ in 20 ml of H₂O. He heated the mixture until both salts dissolved completely. He allowed the solution cool slowly at room temperature until some crystals occurred. Answer questions 5, 6, and 7.

5. If Cadet. Rama wants large crystals, what should he do?

a. After CuSO₄·5H₂O and (NH₄)₂SO₄ dissolved completely, he should cool the solution in ice immediately.
b. After CuSO₄·5H₂O and (NH₄)₂SO₄ dissolved completely, he should leave the solution on his bench overnight without disturbing it.
c. The crystals will occur more rapidly if he add a crystal of CuSO₄·(NH₄)₂SO₄·5H₂O to the solution
d. Warm the solution of CuSO₄·5H₂O and (NH₄)SO₄ until it become concentrated solution. Then cool the solution immediately.

6. If Cadet. Rama misread the name of the substance, He used CuSO₄ in stead of CuSO₄·5H₂O. What his result should be?

a. CuSO₄·(NH₄)₂SO₄·5H₂O cannot be prepared.
b. CuSO₄·(NH₄)₂SO₄·5H₂O can occur.
c. CuSO₄·(NH₄)₂SO₄·5H₂O can occur but its weight is much more than theoretical weight.
d. Use much more water to dissolve CuSO₄ and (NH₄)₂SO₄ than to dissolve CuSO₄·5H₂O and (NH₄)₂SO₄.

7. If Cadet. Rama misread scale of the balance, the actual weight of CuSO₄·5H₂O he used was 7.00 g rather than 4.99 g. What his result should be?

a. He will receive the same quantity of CuSO₄·(NH₄)₂SO₄·5H₂O.
b. (NH₄)₂SO₄ will be used up completely.
c. The color of his resulting CuSO₄·(NH₄)₂SO₄·5H₂O is more intense than it should be.
d. CuSO₄·(NH₄)₂SO₄·5H₂O should occur more rapidly and in much more quantity than it should be.

8. Which ones are the starting materials for preparation of bromine?

a. NaBr + MnO₂ + H₂SO₄
b. Na₂SO₄ + MnO₂ + HBr
c. KBr + H₂SO₄ + C
d. NaBr + CCl₄ + I₂

9. In the preparation of bromine, bromine gas is collected by dissolving in water. If we want to use another substance instead of water, what will that substance be?

a. Potassium iodide solution.
b. Potassium bromide solution.
c. Carbon tetrachloride.
d. Alcohol.

10. From the experiment, we mixed 2 ml of potassium iodide solution with chlorine water and shook them well. Then we added starch solution to the mixture. What is the purpose of adding starch solution?

a. According to the light yellowish green color of chlorine water which is difficult to see, adding starch solution help us see the color of chlorine more obviously.
b. Potassium iodide reacts with starch which turn the color of solution into purple. When the reaction is complete, the purple color disappears.
c. Iodine resulting from the reaction forms purple complex compound with starch.
d. Starch solution reduces acidity of chlorine water.

Into each of the three six-inch test tubes, place 3 ml of distilled water and 3 ml of CCl₄. Add three drops of bromine water to the first tube, shake them thoroughly. Add three crystal of iodine to the second test tube and shake them thoroughly. Add small quantity of KBr, and three crystals of iodine to the third test tube and shake them thoroughly. Set these test tube aside to observe the results. Answer questions 11 and 12.

11. Which of the following results is true?

a. Water layer in the first tube is yellow. CCl₄ layer in the second tube is purple.
b. CCl₄ layer in the first tube is purple. CCl₄ layer in
the second tube is yellow.
c. CC\textsubscript{4}, layer in the first tube is yellow. CC\textsubscript{4}, layer in
the second tube is purple.
d. Water layer in the first tube is purple. Water layer
in the second tube is yellow.

12. Which of the following results is true?

a. In the third tube water layer is colorless and CC\textsubscript{4},
layer is yellow.
b. In the third tube water layer is colorless and CC\textsubscript{4},
layer is purple.
c. In the third tube water layer is yellow and CC\textsubscript{4},
layer is purple.
d. In the third tube water layer is purple and CC\textsubscript{4},
layer is yellow.

13. If ethyl alcohol is used instead of CC\textsubscript{4}, What will be
the result?

a. The result will be the same.
b. The color in ethyl alcohol layer will be more intense
than the color in CC\textsubscript{4}, layer.
c. There will be no reaction.
d. The reaction occurs but the result is not clear.

Mix 0.2 g of potassium iodide with 0.2 g of manganese
dioxide in 250 ml beaker. Add 6 M sulfuric acid to the
mixture. The acid must cover the mixture. Then cover the
beaker with the evaporating dish which is filled with water.
Heat the mixture. Answer question 14 and 15.

14. If hydrochloric acid is used instead of sulfuric acid,
what will be the result?

a. Manganese cannot be prepared.
b. Chlorine gas is produced instead of iodine.
c. Manganese dioxide will be used up completely.
d. There will be no reaction.

15. What is the purpose of covering the beaker with the
evaporating dish filled with water?

a. To reduce the temperature of the beaker preventing
the beaker from broken by hot flame.
b. To prevent the fume of sulfuric acid evaporating
from the beaker which is dangerous to an experimenter
c. To condense the resulting iodine into solid.
d. To facilitate the reaction.
Appendix D

Table of specification
TABLE OF SPECIFICATION

Chemical Bonding

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