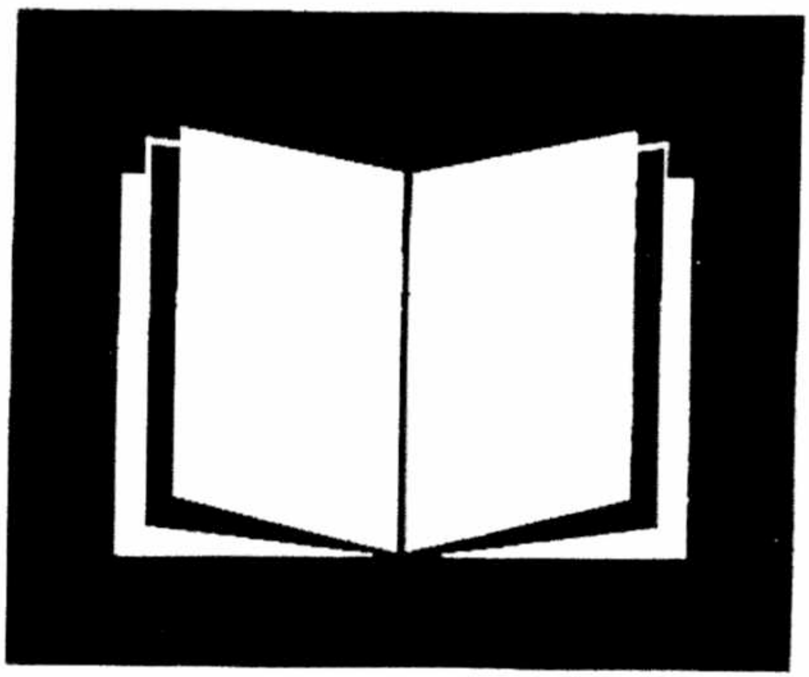
STATEMENT ON PREPARATION IN NATURAL SCIENCE EXPECTED OF ENTERING FRESHMEN



The Acadamic Senates of the California Community Colleges,
The California States University, and
The University of California

INTERSEGMENTAL COMMITTEE OF THE ACADEMIC SENATES
of the
California Community Colleges, The California State University and the
University of California

Dear Colleague:

The attached Statement on Preparation in Natural Science Expected of Entering Freshmen represents the third in a series produced jointly by the Academic Senates of the California State University, the California Community Colleges, and the University of California. Its primary intent is to provide guidance in science education so that students with college plans may benefit fully from their college experience.

The statement sets forth the position of postsecondary science faculty that stronger emphasis must be given to natural science in the junior and senior high schools. It recommends that all college-bound students receive instruction in physics, chemistry, and biology, regardless of their intended major, and that laboratory instruction be an integral part of science courses.

By 1988, both CSU and UC will require one year of a laboratory science for freshman admission; the State's 1985 model curriculum standards recommend two years of science for every high school student. Our faculty statement does not establish admission requirements but rather advises on the optimum preparation in science for entering freshmen.

The California Round Table on Educational Opportunity and the State Department of Education have encouraged the work of the faculties in preparing the statement; they have endorsed the statement in principle, and have assisted in its publication and dissemination. Many individual faculty and teachers have contributed to the development and review of the document.

As you read the document, bear in mind that it is an expression by the faculties of our colleges and universities as to the science education students should have prior to college entrance. Different expressions as to what is ideal or feasible are expected, and modifications to and refinement of the statement are anticipated in the future.

It is important that the statement be widely disseminated and discussed in the forum of seminars, conferences, and workshops. We seek your support of this activity, which, hopefully, will lead to curriculum development in science throughout the State. Your comments will be welcomed by the faculties and by the Round Table.

Bernard Goldstein
Chair, Academic Senate
CSU

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STATEMENT ON PREPARATION IN NATURAL SCIENCE EXPECTED OF ENTERING FRESHMEN

The Academic Senates of the California Community Colleges,
The California State University, and
The University of California

July 1986

Distributed by
The California Round Table on Educational Opportunity,
The Articulation Council of California, and
The California State Department of Education

PREFACE

The Academic Senates of the California Community Colleges, the California State University, and the University of California jointly have developed a *Statement on Preparation in Natural Science Expected of Entering College Freshmen.* The statement was prepared in response to the growing concern among educators, scientists, and business, community and political leaders regarding the decline in the number of scientifically literate college graduates. This trend, if allowed to continue, will result in serious shortages of trained scientists, technicians, and science teachers and will lead to a citizenry ill-equipped to participate fully and responsibly in an increasingly technical society.

This statement, like the previously developed *Statement on Competencies in English and Mathematics Expected of Entering Freshmen,** is intended to assist students in preparing for college, their parents and counselors in advising, and high school teachers and administrators in planning the curriculum. The statement considers high school science courses as complementary to, as well as preparatory for, a student's college experience. In contrast, the statement on English and mathematics addresses basic skills and competencies essential to all college-level work.

The Academic Senates urge that the statement on preparation in natural science be widely distributed so that the expectations of college and university faculty regarding science education at the high school level may become widely known and understood. Further, the Academic Senates urge that secondary and postsecondary educators take measures to implement the recommendations in this statement as educational policy in California.

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* *Statement on Competencies in English and Mathematics Expected of Entering Freshmen*, November 1982, by the Academic Senates of the California Community Colleges, the California State University, and the University of California, supported by the California Round Table on Educational Opportunity, and distributed by California State Department of Education, P. O. Box 271, Sacramento, California 95802.

TABLE OF CONTENTS

TABLE OF CONTENTS (contd.)

EXECUTIVE SUMMARY

The quality of California's public education system has been a matter of public debate for some time. The need for change and improvement in science education has been recognized by the state in the recent imposition of a state-mandated minimum high school graduation requirement of *two years of science for all students.*

The need to strengthen high school science requirements is evident from the increasing technical and scientific knowledge required of citizens in modern society. This is recognized to a limited extent by the freshmen admission requirements to the University of California, which currently include one year of a laboratory science, and to the California State University, which recently adopted a similar science requirement to become effective Fall 1988. These are, however, minimum rather than ideal requirements. The recommendations advanced in this statement go beyond UC and CSU requirements for admission and build on the state's model curriculum standards in science. The recommendations are *not* admissions policy but a faculty view of what every college-bound student should have in the way of science preparation. Thus, to aid in providing adequate science preparation for the college-bound student, we recommend the following:

1. *All high school students planning a baccalaureate education should take one year of biology, one year of chemistry, and one year of physics.*

Biology, chemistry and physics constitute the core of natural science. Core courses in these subjects normally are taken in a sequence that matches the maturing mathematical skills of the student, the most likely pattern being biology in the sophomore year, chemistry in the junior year, and physics in the senior year. If the student's mathematical development permits, an alternative pattern would be to start the sequence in the freshman year - leaving the senior year open for electives. A less traditional sequence would start with physics, then chemistry, then biology, and reflects the contributions of the physical sciences to modern biology and the logic of progressing from single particles to the complex structures of living organisms.

2. *The core science curriculum should be the same for all college-bound students, prospective science and nonscience majors alike. More specialized courses, or more simplified courses, should not be substituted for any of the core courses.*

High school science courses are an important component of a student's general education. Specialization is not appropriate at this level. This may be the only opportunity a student may have to study biology, chemistry, and physics if, as is often the case, he or she does not take courses in these subjects in college, or otherwise specializes in one to the exclusion of the other. Therefore we are opposed to the practice of segregating intended science from nonscience majors by creating special high school courses for each group.

3. *The content of the core science courses should be at a level that is accessible to, and can be mastered by, all college-bound students.*

The level of sophistication of the core science courses should be neither too high nor too low but should reach and serve students with a broad range of interests. Study of the historical development of science can be helpful in creating student interest and dispelling the notion that science is unrelated to human endeavor. Attention to the scientific background of public issues, as they arise, is highly desirable.

4. *A laboratory component in which students carry out experiments and projects, not just simulations, should be an integral part of the core science courses.*

The content and level expected in each course are specified in the text of the statement. Lists of topics to be covered and sample problems are included. Because experimentation is integral to the sciences, a strong laboratory component in the core courses is recommended, and a section on the laboratory portion of each is given.

5. *We call upon college, university, and secondary school science teachers to work closely together on the local level to review the content of the high school science curriculum and to guide instruction.*

Other recommendations which clarify those summarized in the preceding paragraphs, and which highlight ancillary matters, are contained in the body of the statement. We recognize that to implement our recommendations will require adjustments, some quite extensive, at both the high school and college levels. Our statement should be interpreted as a guideline which, we hope, will stimulate productive discussions that will lead to development and refinement of the school science curriculum for the benefit of all students in the state intending to pursue a college education. We hope that the statement will be distributed widely and teachers will be provided with ample opportunity to participate in forthcoming conferences and workshops that will address the subject of science education.

"The truth is, that those who have never entered upon scientific pursuits know not a tithe of the poetry by which they are surrounded." **Herbert Spencer,** *Education: Intellectual, Moral and Physical (1861).*

I INTRODUCTION

The state of science education has long been the subject of public debate, and in recent years the commentary has been increasingly negative. High school science courses have been criticized as being out-of-touch with the times and for being taught at too demanding a level. Attention has been drawn to the low percentage (25%) of American high school students who elect to take three years of science compared to about 98% in Japan, West Germany, and the Soviet Union. Recommendations as to how to ameliorate the situation have been forthcoming from leading educators, governmental agencies, and special groups, all of whom advocate increased emphasis on science in the high school curriculum. There is a consensus that substantial experience in science is needed by **every** college-bound student. The challenge is to establish a mechanism to provide this experience.

Although our recommendations address mainly high school preparation for college, we wish to stress the importance of science education prior to high school.

> *The teaching of science must not be postponed until high school. Substantial amounts of time need to be committed to science instruction prior to high school.*

And, in order to foster quality and continuous progress in the area of science instruction:

> *We call upon college, university, and K-12 science teachers to work closely together on the local level to review the content of the science curriculum and to guide instruction.*

To define competency in science, the **breadth** of a student's exposure and the **depth** of a student's comprehension need to be considered. We address **depth** by providing a statement of skills and attitudes toward science that high school students should acquire or develop in their high school experience. We address **breadth** in this statement through a recommended curriculum, course content lists, and sample laboratory exercises which we hope will provide guidance and stimulate further discussion and course development by high school and college faculties. Sample questions and problems are appended.

We wish to be clear that our recommendations of course content are meant to be guidelines only; they are not meant to represent course outlines. We anticipate that the suggested topics may be combined and sequenced in innovative ways, or ways suited to a particular teaching environment best determined by the teaching staff.

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II RECOMMENDATIONS

Skills, Attitudes, and Qualities That Should be Imparted in a High School Science Program

A broad background in science is necessary for every college-bound student. High school science courses can and should provide students with the intellectual attitudes, skills, and concepts that contribute to success in college curricula. Regardless of the fields of study students enter, literacy in science contributes in important ways to an understanding of our present culture, the prevailing philosophy of the Western world, and Western history for the past five hundred years, at least.

Skills and attitudes do not define a high school curriculum nor the content of a course. However, they are necessary for the student to develop in order to succeed in human endeavors that require intellectual effort. Therefore, it should be recognized that:

> *The teaching of science should foster the traits of inquisitiveness, objectivity, open-mindedness, skepticism and perseverance.*

Inquisitiveness: asking well-defined questions about nature.

Objectivity: viewing and describing events and phenomena without bias and preconceptions, insofar as possible; being aware of objective versus subjective choice; appreciation for the value of accuracy and honesty in making and reporting observations.

Open-mindedness: seeking and evaluating alternative models and hypotheses.

Skepticism: challenging dogmatic contentions and focusing on evidence.

Perseverance: continuing inquiry until a satisfactory level of understanding is reached.

Language skills, mathematical skills, and mental skills needed for scientific work or study should be sharpened and refined in secondary school science courses. A list of necessary skills follows:

Reading comprehension: read and comprehend scientific material; distinguish facts from hypotheses and opinions. (See the *Statement on Competencies in English...Expected of Entering Freshmen* referred to on page 1.)

Writing, listening, and speaking: communicate observations and ideas clearly. The importance of developing verbal skills cannot be overemphasized. (See the *Statement on Competencies in English ...Expected of Entering Freshmen* referred to on page 1.)

Memory: develop the ability to recall enough facts and scientific principles to progress to more complex problem-solving activities, such as generalization or application.

Mathematics: handle quantitative relationships, reason symbolically, translate symbolic statements into words, and *vice versa*; display and interpret data in tables and graphs, and prepare graphs from tables.

Analysis: identify the component parts of a theory or observation.

Reasoning: draw inferences from a set of statements or observations; marshal relevant arguments to defend or refute a proposition.

Generalization: find patterns in seemingly isolated facts and describe the patterns clearly and concisely.

Classification: organize concepts, observations, and objects in a way that promotes understanding of their relationships; recognize and use different levels of abstraction.

Application: use scientific principles and laws to explain familiar and unfamiliar observations; devise and apply analogies in a scientific setting.

Students should be exposed to the processes of scientific investigation. They include the following activities:

Defining a scientific problem: formulate questions about observable phenomena; recognize those questions for which answers are possible.

Proposing a scientific hypothesis: suggest solutions to problems, explanations of phenomena; distinguish relevant from irrelevant models.

Testing a scientific hypothesis: decide what measurements or observations will distinguish one hypothesis from another; recognize the necessary controls; make the measurements and other observations needed to confirm or refute hypothetical predictions.

Analyzing results: decide whether the evidence confirms or refutes a given prediction; apply simple statistics (error estimates) to make decisions.

Each high school student should receive practical instruction in laboratory procedures. Laboratory instruction provides essential perspective to understanding science. The following general skills should be taught in each laboratory course:

Planning: clarification of ideas and questions; development or modification of specific methods to yield answers to the questions.

Measurement: accuracy and precision; use of standard units; scientific notation; significant figures.

Use of statistics: calculation and meaning of "mean," "mode," and "median"; calculation and meaning of "variance"; estimation of errors, and interpretation of their significance.

Safety: awareness of common dangers; techniques for the safe operation and handling of instruments and materials; procedures in the event of dangerous situations; prevention of accidents.

Reporting: accuracy and completeness; selection, organization, and communication of cogent information.

"I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
and How and Where and Who."
Rudyard Kipling, *"The Elephant's Child,"*
Just So Stories (1902).

Curriculum Proposals

Development of appropriate science curricula for college-bound students requires answers to three questions:

- o Which courses should be taken by college-bound students and what should be the content of those courses?

- o Should students who are prospective majors in the sciences or engineering take the same number and level of courses as students who are not prospective science or engineering majors?

- o To what extent should the computer be utilized in secondary science instruction, and what form should such use take?

This section of the statement addresses these three questions and makes several specific recommendations. The recommendations build on those embodied in the 1985 *Model Curriculum Standards in Science* adopted by the California State Board of Education*, and in the 1985 *Academic Preparation in Science* adopted by The College Board**. While they go beyond the current CSU and UC freshman admission requirements in science they do not supplant the requirements and have no effect on freshman eligility.

> *All high school students planning a baccalaureate education should take one year of biology, one year of chemistry, and one year of physics.*

The three recommended courses, though complementary, present unique methodologies and viewpoints within the overall structure of scientific thought. Secondary school students who take these three courses will receive a broad exposure to scientific disciplines. Furthermore, a common curricular experience for pre-college students will provide them with more options for collegiate study and will assist colleges and universities in curriculum planning.

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* *Model Curriculum Standards. Grades Nine Through Twelve. Science.* First Ed., California State Department of Education, Sacramento, 1985

** *Academic Preparation in Science*. Educational Equality Project, The College Board, 45 Columbus Avenue, New York, New York 10023, 1985

The traditional sequence is: biology in the tenth grade, chemistry in the eleventh grade, and physics in the twelfth grade. This sequence is the basis on which the recommended contents of the three courses are described in Section III. However, many college faculty members have urged an alternative sequence based on the relative complexity of organization and structure in science which would progress from physics to chemistry to biology. Experimentation with such a plan is encouraged, including modifications in mathematical level to allow physics to be taught in the tenth grade. Such an ordering would encourage the presentation of physics on a more conceptual and less mathematical basis, thus making it accessible to many more students.

We presume that ninth grade instruction in science, where available, is a basic course of some substance that presents fundamentals needed to study science in general, particularly the physical sciences. In some four-year high schools, students can take biology in the ninth grade, chemistry in the tenth grade, and physics in the eleventh grade. We recommend such a program only when it is combined with appropriate mathematics courses so that a student's mathematics background supports the demands of the science courses.

The content of the core science courses should be at a level that is accessible to and can be mastered by all college-bound students.

These courses are not meant to be in-depth studies; nor are they meant to mimic introductory college courses. They should be sound introductions to the disciplines and, in addition, should address the scientific endeavor in general, the relationship between science and society, and the responsibilities of citizens in a technological society.

Science comes to life for many students when the historical development of understanding of a concept is presented. Whenever possible, students should be made aware of how a scientific concept developed, how the "pieces-of-the-puzzle" were found and pieced together, and how new ideas were born as a result.

A laboratory component in which students carry out experiments and projects, not just simulations, should be an integral part of the core science courses.

All three recommended disciplines are experimentally based. Without laboratory work, they cannot be taught well. Without laboratory work, the questions of "How do we know?" cannot be fully addressed. The importance of the experimental component of these disciplines cannot be overemphasized, yet it is frequently the least understood component of the science curriculum. Science is based on experiment, not on authority, yet many school systems deemphasize laboratory work in favor of course work, mainly because of cost and logistic problems associated with laboratory instruction. A greater commitment to provide laboratory instruction in secondary schools is needed.

The core science curriculum should be the same for all college-bound students, prospective science and nonscience majors alike. More specialized courses, or more simplified courses, should not be substituted for any of the core courses.

Instructional methods will certainly vary from one basic science course to another, even within the same discipline; but the rigor of these courses should not vary. Courses in applied areas of science, such as "Ecology" or "Human Anatomy," are inappropriate as basic science courses and, in fact, are better understood with a foundation of basic science. Students intending to pursue majors in nonscientific fields have the greatest need for an introduction to basic science offered in high school because they are less likely to take science courses in college. Prospective science and engineering majors would also be well served through a broad exposure to science in high school because their studies in college are likely to be more narrowly focused.

Advanced Placement (AP) courses are appropriate for properly prepared students; however, an advanced placement course in one discipline (biology, chemistry, or physics) should not be taken in place of a core course in a different discipline.

It is appropriate to provide honors or Advanced Placement (AP) courses for students who are greatly interested in science. Students entering high school in the ninth grade, and who have suitable preparation in English, mathematics, and introductory science, could take biology in the ninth grade, chemistry in the tenth, physics in the eleventh, and AP or honors courses in the twelfth grade. The alternative mode of providing AP or honors courses by combining the core courses with advanced course material in an accelerated format is less preferred. Omission of elementary material in one area to make room for more advanced material in another area is not recommended practice. Specifically, AP courses are intended to be equivalent to college-level courses and, as such, require content of the high school courses as prerequisites.

The foregoing recommendations have precedent. They describe a curriculum that was a common pattern for college-bound students a generation ago. Relaxation of this curricular pattern has *not* enhanced the preparation of students in California. Increasing numbers of remedial courses at the college level, and increasing enrollments in these courses, indicate quite the reverse. Other industrialized nations require secondary school course patterns similar to those proposed here. Japan, for example, requires prospective college students to take an average of three natural science courses and four mathematics courses in three years of high school.

Students should be enabled and encouraged to use computers in science courses. However, the teaching of computer literacy or computer programming should not displace any part of the regular science curriculum; rather, these skills should be developed in an integrative approach that emphasizes their applications to the sciences.

The role of computers in secondary science instruction is twofold, first in computer-assisted instruction (CAI), and second as a tool to facilitate computation, data analysis, and rapid graphic display of scientific results. The intent of science courses should be to teach scientific content and process, and when the use of a computer enhances that process, it should be used. We caution, however, that the use of a computer should be the means to the end and not the end in itself; its use should not detract from the scientific course content nor dilute the laboratory experience.

A description of the recommended content of the biology, chemistry, and physics courses at the high school level follows. There are surely improvements that can and should be made in our recommendations, but we forward them, imperfect though they may be, in the hope that they will stimulate careful evaluation of the science curriculum and its further development for the ultimate benefit of our students and society.

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III COURSE CONTENT - BIOLOGY

Introduction

The remarkable advances in the biological sciences in the past decade or so present a serious challenge: how can we ensure that the future citizens of California will be prepared to make responsible decisions involving biological principles that will affect their welfare and that of society in general? We have now and will continue to see a greatly augmented ability to manipulate the living world through genetic engineering - just as the chemist has learned to manipulate the world of chemistry through synthesis. In addition, there are major societal problems of biological origin, such as genetic diseases, viral diseases (AIDS), drug addiction, mental disease, malnutrition, environmental carcinogens, population control, effects of radiation, and so on, that have to be understood in order to be solved.

Effective solutions through intelligent decisions are unlikely to be forthcoming from a citizenry ignorant of the biological principles involved. Suspicion and fear would more likely result. However, in our opinion, students cannot acquire the necessary depth of understanding of the power and potential applications of modern biology if they lack an understanding of the fundamental principles of the subject. A modern view of biology, in fact, has the capacity and power to treat the "traditional" topics in biology. High school courses in biology are well positioned to cover fundamental principles in a way that students will find topical and current. Whenever possible, the subject matter in each topic area should be extended to include its personal, social, and economic relevance.

High school students who take biology in preparation for college should be presented with a wide range of topics, all of which should be treated in major textbooks. A list of principal topics follows this introduction and represents the proposed minimum content of a one-year general course in biology. Additional topics, such as plant physiology and animal behavior, are encouraged.

Principles of biological evolution should be introduced near the beginning of the course and developed as an experimentally verified framework within which other topics are studied. If this approach is found to be difficult with currently available textbooks, we urge authors and publishers of biology textbooks to adopt this framework in new and revised texts.

There are laboratory skills and experiences that are uniquely important to the biological sciences. Enrichment of the course topics with examples of laboratory demonstrations, field trips, and laboratory exercises is essential. Although the constraints of time, space, and supplies may require some schools to emphasize different topics, we feel that it is important for each student to have some exposure to each of the topics, skills, and experiences listed.

Defining the depth required of a high school biology course is more difficult. Depth cannot be determined from the list of topics given here, for the topics are much the same as those taught in introductory college courses and, in a less intensive fashion, in pre-high school science courses. However, each of the topics listed should be covered in sufficient depth for the student to master basic vocabulary and concepts. Perhaps the best way to illustrate depth is to consult a list of questions that an entering college student should be prepared to answer on the subject. Such a list is given in Appendix I.

Topics for a One-Year Course in Biology

The focus of the topics here listed is on the fundamentals of biology within the context of human needs and experience. There are sixteen general topic headings, each of which includes several subtopics considered as essential preparation in a precollege biology course. It is understood, however, that within this broad framework there should be allowance for flexibility in content, depth and breadth of coverage, and for variations in instructional strategy.

If the course is the students' first introduction to science, there should be discussion at the outset on the nature of science as "a way of knowing." The process of scientific inquiry - the accuracy, predictability and verification of scientific knowledge - is intuitively understood by some but not all students, and the opportunity to introduce them to the scientific method should be made early in the course and emphasized throughout.

1. The Cell - Building Blocks of All Life Forms

introductory section presenting an overview of course
cell structure
biological organization
utilization of energy by living systems
growth
responses to stimuli
cellular and organismic adaptation
cells, tissues and organs in human beings
introduction to the principles of evolution

2. The Chemical Basis and Requirements of Life

atoms, molecules, chemical bonds and reactions
molecules essential to the functioning of living systems
    their molecular structure and biological role -
    proteins, nucleic acids, lipids, and polysaccharides
energetics of chemical reactions - including role of
    enzymes and other catalysts
critical role of light in making life possible on Earth

3. **The Structural Basis of Life**

structure of plant and animal cells
the cellular environment
movement of materials across cell membranes
movement within the cell
levels of organization in multicellular structures
nature and role of anaerobiosis and fermentation - applications to humans and medicine

4. **Energetics of Life**

overview of energy processes within cells
cellular respiration
photosynthesis
uses and conversions of cellular energy
the balance of autotrophs and heterotrophs
preditor-prey relationships
the balance of chemical and energy cycles
energy flow within communities
impact of human society on the natural environment

5. **Growth and Reproduction**

comparison of roles of meiosis and mitosis in cellular and organismic reproduction
sexual and asexual reproduction - alternative means of species perpetuation
potentials of bioengineering
reproductive technology in agriculture and medicine

6. **Evolution**

history of life and organic diversity
survey of organic evolution and speciation
synthesis of genetic variation and natural selection in effecting morphological, physiological, and behavioral changes in populations over time
evidence and logic in defining the evolutionary process
evidence from fossils
interpretations of human evolution

7. **Principles of Heredity**

chromosome theory of heredity
Mendelian genetics and improvement of crops
gene-enzyme relationships
their applications to human inheritance

8. Taxonomy

classification (reasons for and concept of)
contributions of Linnaeus
modern taxonomic systems
scientific nomenclature
present-day classification systems
phenetic and phylogenetic trees

9. Animal Phyla, Physiology and Behavior

major classes of animal organisms
  invertebrates
  vertebrates
their structural and functional similarities - differences
their evolutionary relationships
major systems of vertebrates
  system-by-system analysis
  application of basic principles to humans
energy systems in animals
neurobiology systems
behavioral patterns

10. Plants and Protists

major classes of plant organisms
botanical principles
plant structures
protists in the web of life
structure, evolutionary relationships, functional
  differences, economic significance, organizational
  complexity of the following groups of organisms:
  viruses and bacteria
  protozoa
  fungi
  algae
  mosses, liverworts, and ferns
  gymnosperms
  angiosperms
role of plants and protists in nutrition and medicine
applications in modern agriculture and technology

11. Ecology

structure and function of ecosystems
  population biology
  community structure
  animal behavior patterns
demographics and the environment

wise use of renewable and non-renewable resources
the "agricultural revolution"
  its consequences for population growth etc.
control of pollution and toxic waste
conservation of natural resources

12. Human Biology

overview of anatomical structure and function
systems analyses
cell biology and metabolism
organ physiology
human reproduction and sexuality
human embryology and development
human brain and thought processes

13. Health and Major Diseases

nutrition and food processing
public health and modern medicine
principles of genetic counseling
potentials of bioengineering
concepts and controversies in human health and fitness

16. Biology and Human Affairs

public participation in scientific undertaking
using knowledge to reach informed decisions
careers and avocations in biology
ethical and moral considerations in biology

Laboratory Exercises for a One-Year Course in Biology

The goal of the laboratory portion of high school biology is to reinforce and enrich the topics introduced in textbooks and in classroom discussion. Each of the experiences listed below should be covered in the one-year course, although the emphasis and the materials used may vary from class to class. The general objectives of the laboratory are:

- **Sharpening observational skills. Training in accurate perception and communication:** A student should be able to describe a living system in sufficient detail to allow a fellow student to identify the organism and its salient characteristics. The training should stimulate curiosity and imagination, so that a student will ask questions and make hypotheses on the basis of his or her observations.

- **Connecting abstractions with real images:** There are many subjects that are outside the limits of normal experience which, when described in textbooks, are seen by students as abstractions. The laboratory is the place to give meaning to such topics as microorganisms, cellular and tissue organization of plants and animals, and reproductive stages. Some concepts are truly abstract and require illustration. These include the principles of heredity and the principles of classification.

- **Showing that living organisms are suitable for scientific study:** The laboratory is the proper place to show that biology rests on empirical observation. This can be accomplished through exercises demonstrating the chemical constituents and activities of cells and tissues, or through semiquantitative studies in physiology or behavior.

Suggested Laboratory Exercises

1. **Use of the microscope:** Training in basic techniques, including focusing, determining magnification, making microscopic measurements, preparing wet mounted slides, and caring for the microscope.

2. **Observations of a wide variety of organelles, cells, and tissues:** Suggested materials: wet mounts of cheek, onion, potato, tomato skin, and *Elodea* leaf cells; prepared slides and cultures of unicellular organisms such as *Amoeba*, *Paramecium*, and *Euglena*; prepared slides of epithelial, connective, muscular, and nervous tissue.

3. **Observations of characteristics of biological chemicals and chemical reactions:** Suggested projects: tests for starch, sugar, proteins, and lipids; assays for amylase, pectinase, and polyphenol oxidase.

4. **Observation of the total life cycle of an organism:** Suggested organisms: pea plants, *Drosophila*, and bread mold (asexual and sexual reproduction). Other useful materials: prepared slides showing stages of mitosis in animal (whitefish blastula) and plant (onion root tip) cells; prepared slides showing stages of meiosis in animals (grasshopper testis) and plants (lily anther and ovule). Principles of heredity may be illustrated with *Drosophila* or corn ears.

5. **Observation and description (with drawings) of the external morphology and behavior of a wide variety of living plants and animals, including representatives of all major taxa:** Plants to include: blue-green algae, mushrooms, green, red, and brown algae, mosses, ferns, gymnosperms, and angiosperms (from angiosperm forms with a variety of leaves, stems, roots, flowers, fruits, and seeds). Suggested invertebrates: sponges, *Hydra*, *Planaria*, *Ascaris*, snails, earthworms, crayfish, starfish, spiders, grasshoppers, and at least one real insect such as a beetle or cockroach. Suggested vertebrates: fish, frogs, turtles, snakes, birds, and mammals (study of mounted skeletons included). Field trips to zoos, natural history museums, botanical gardens, and aquaria are encouraged.

6. **Dissection of a representative preserved invertebrate and a representative preserved vertebrate. Description (with drawings) of anatomical features:** Suggested invertebrates: earthworms, crayfish, grasshoppers, and sea urchins. Suggested vertebrates: fish, frogs, and fetal pigs.

7. **Dissection and description of representative plant organs:** Suggested material: leaves, stems, roots from plants grown in classroom; fruits, seeds, specialized stems and roots from the grocery (peas, tomatoes, apples, onions, carrots).

8. **Work with classification systems (using keys):** Possible projects: identification of microscopic pond water denizens, or identification of wild flowers, using appropriate manuals.

9. **Demonstrations and experimentation with cellular and organismal physiology:** Possible phenomena: Brownian movement, diffusion ion, osmosis, blood cell lysis; patella reflex, tasting, color blindness, respiration, pulse rate, seed germination, greening of etiolated shoots, phototropism and gravitropism.

10. **Conceiving, planning, organizing, executing, and summarizing a research project. Include explicit hypotheses, data accumulation, and conclusions:** When available, computers may be used to simulate experiments, calculate results, perform statistical manipulations, and prepare reports.

* * *

IV COURSE CONTENT - CHEMISTRY

Introduction

We provide here a brief discussion of the context in which the high school chemistry course is taught, a list of topics to be covered (with recommended emphases), an annotated list of representative laboratory exercises, and a set of example problems with answers (Appendix II). The lists are not intended to prescribe course content in detail but rather to guide development of the course.

The chemistry course serves a dual purpose: (1) to provide a foundation for those who intend to continue the study of chemistry in college, and (2) to help *all* students (including those who do not plan to continue in the sciences) develop an understanding of chemistry and its role in society. Therefore, the course should be directed to the general college-bound student, not just the intended chemistry or science major. The course outline has been designed to provide flexibility in meeting the goals of the course. Some 60-80% of the course outline constitutes fundamental topics, and up to 40% of the course can encompass material of choice by the instructor.

Cultivating interest and curiosity in students while developing the basics of the subject is encouraged and can be done with the use of examples that expose students to the applications and practice of chemistry, especially as they affect everyday life. Additionally, chemistry is important to the study of fields such as biology, engineering, agriculture, pharmacy, and medicine. This connection should be stressed.

The chemical sciences also play a vital role in our economy and our culture. The chemical industry is one of the largest industries in the country and in the world. New compounds are discovered and created daily, and many have applications as pharmaceuticals, structural materials, coatings, adhesives, fabrics, fertilizers, herbicides, and a myriad other possible uses. Many societal benefits have accrued from these applications of chemistry. Conversely, hazards may be associated with the indiscriminate use of chemicals (pesticides, PCB's, toxic wastes, etc) and these hazards are of significant concern to society. It is more important than ever before that young people entering society as productive and responsible citizens have an adequate background in chemistry to deal intelligently with the benefits and problems associated with chemicals. The ramifications of chemistry for society should be examined in the high school chemistry course.

> *"Though many have tried, no one has ever yet explained away the decisive fact that science, which can do so much, cannot decide what it ought to do."* Joseph Wood Krutch, *The Measure of Man (1954)*

Mathematics, calculators, and computers: Chemistry requires reasonable mathematical prerequisites. These should correspond to the mathematics recommendations made in the 1982 *Statement on Competencies in English and Mathematics Expected of Entering Freshmen*. Hence, completion of Algebra I and concurrent enrollment in geometry are reasonable minimum requirements. Handheld calculators are recommended for everyday use because they greatly facilitate the numerous computations involved in chemistry. By using calculators, students can learn much about data entry, the significance of calculated digits, and the inherent limitations of such devices. Larger computers should be used only when students are adequately prepared to benefit from them. They should not be used for trivial calculations.

The Laboratory Program: Like other parts of the course, laboratory work needs to be oriented primarily to the general college-bound student. Chemistry is an experimental science and needs to be taught as such. The laboratory must involve the student's active participation and should not rely exclusively on passive demonstrations. The relationship between experimental evidence and scientific conclusions must be emphasized, and the laboratory experience should stress the concrete over the abstract. However, abstract thinking must not be eliminated, because many students at this stage are just beginning to learn to think abstractly, and it is important for their progress that they continue to do so.

Topics for a One-Year Course in Chemistry

The topics are divided into two groups: *Fundamental Concepts* and *Additional Concepts*. At least 60% of the time and effort in the course should be spent on the *Fundamental Concepts*, and none of them should be omitted or covered only superficially. College instructors in general chemistry will assume that a high school chemistry course will have covered each of the fundamental topics listed.

A measure of the depth of coverage can be gained by comparing the sections on *Fundamental Concepts* and *Additional Concepts*, and by examining the sample questions and answers contained in Appendix II. The latter deal mostly with *Fundamental Concepts* and range from the qualitative to the quantitative.

The time spent on topics will vary. Those topics which are more quantitative, such as **Measurement, Calculations and Chemical Formulas, Chemical Equations and Calculations, Gases, Solutions,** and **Chemical Reactivity**, probably will require more time to treat than other less quantitative topics, such as **Geometry of Simple Molecules and Polyatomic Ions**, and **Introduction to the Periodic Table**. High school chemistry texts usually emphasize the time distribution for the fundamental topics in an appropriate manner.

The material in the *Additional Concepts* section is either new or an extension of that in the fundamental category. No more than 40% of the course should consist of this material, and the choice of the material is at the discretion of the instructor. The material included could illustrate chemical principles applied to contemporary society or provide a more in-depth understanding of the principles. It may be treated separately or incorporated into the *Fundamental Concepts*. Neither breadth nor depth of coverage in the *Additional Concepts* section will be assumed by college instructors.

A. Fundamental Concepts

1. Introductory Concepts - Definitions and examples

states of matter
chemical and physical properties
pure substances and mixtures
heterogeneous and homogeneous substances
physical change
chemical change

2. Measurement - Definitions and quantitative application

measurement systems - the metric system and SI units
scientific notation - its relationship to metric prefixes
significant figures - the uncertainty of measurement
the qualitative concept of precision and error
dimensional analysis and unit conversion - emphasis on mass, volume, and density

3. The Atomic Nature of Matter - Atoms and elements

the atomic theory
the nuclear atom
subatomic particles - protons, electrons, neutrons
qualitative introduction to atomic structure
elements - atomic number
chemical symbols and names of the elements
isotopes - mass number
atomic mass unit - relative weights of the atoms
ion formation through electron gain or loss
the charges and nomenclature of common monoatomic cations and anions

4. **Introduction to the Periodic Table** - to be discussed in a qualitative and descriptive fashion with the emphasis on periodicity.

atomic number and the periodic table
classification of the elements - metals, metalloids, and nonmetals
classification of elements according to the periodic table - main group elements, transition elements,
physical properties of the common elements - common physical states, densities, etc.
chemical formulas of the elements - allotropes
chemical families - names of the families and some simple illustrations of the chemical and physical properties of families

5. **Compounds and Chemical Formulas**

elements and compounds
chemical formulas of compounds
binary compounds: molecular and ionic
nomenclature of binary compounds
molecules and ions containing three or more elements
formulas and names of common polyatomic ions
nomenclature of salts

6. **Calculations and Chemical Formulas**

the mole
molecular weight (formula weight)
Avogadro's number
mass-to-mole and mole-to-number interconversions
elemental composition (percent composition)
empirical formula determination

7. **Chemical Equations and Calculations**

writing and balancing equations
conservation of atoms and charge, and the meaning of a balanced equation
conservation of mass and reaction stoichiometry - including mole-to-mole, mole-to-mass, and mass-to-mass calculations
the yield of a reaction and percent yield
limiting reagent calculations

8. **Gases** - this section should be used to introduce graphical representation of mathematical relationships

the kinetic molecular theory of gases (qualitative)
pressure and its measurement - units of pressure
temperature and temperature scales - Kelvin scale
Boyle's law
Charles' law
Avogadro's law - law of combining volumes
the ideal gas law
standard temperature and pressure and molar volume
stoichiometry problems involving gases

9. **Solids and Liquids**

comparison of the properties and characteristics of gases, liquids, and solids

phase changes: evaporation and condensation; melting and solidification; sublimation
heat energy changes accompanying phase changes
qualitative introduction to the concept of dynamic equilibrium
vapor pressure - boiling point
qualitative structural picture of the nature of crystalline solids and of liquids

10. **Geometry of Simple Molecules and Polyatomic Ions**

classification of common molecules and ions based on a central atom and pendant (ligand) atom
geometric structure of simple molecules and ions
linear and bent triatomic molecules (2 ligands)
pyramidal trigonal planar geometries (3 ligands)
tetrahedral and square planar geometries (4 ligands)

11. **Chemical Bonding**

the concept of valence electrons in atoms
Lewis dot representation of atoms
Lewis dot representation of monoatomic ions
relative sizes of monoatomic cations and anions compared to atoms
the Lewis concept of covalent and ionic bonds
the concept of electronegativity - polarity of bonds in diatomic molecules
Lewis structures of simple molecules - the use of the octet rule

12. **Solutions**

water and its properties
solutes and solvents
electrolytes and nonelectrolytes in aqueous solution
concentration
concentration units - percent by weight, molarity
calculations involving interconversions among moles, mass, volume, and molarity, including dilution

13. **Chemical Reactivity**

a. *Precipitation Reactions in Aqueous Solutions:*

qualitative aqueous solubility of common salts
strong electrolyte character of most common soluble salts

deduction of a chemical equation for a precipitation reaction using the solubility data for common salts

b. *Acid-Base Reactions in Aqueous Solution*

Arrhenius and Bronsted-Lowry definitions of acids and bases
nomenclature of common inorganic acids and bases
strong electrolyte character of many common acids and bases
the neutralization reaction
deduction of a chemical equation for an acid-base reaction using the neutralization reaction - emphasis on common strong acids and bases
definition of pH - qualitative applications
acid and base precursors - oxides of nonmetals and oxides of metals

c. *Oxidation and Reduction Reactions*

descriptive chemistry of oxygen and the halides, including the preparation of simple oxides and halides of common main group elements as examples of oxidation and reduction
descriptive chemistry of the Group I and Group II representative metals, including the action of other active metals on aqueous solutions - generation of hydrogen gas
combustion of simple hydrocarbons
definition of oxidation and reduction
concept of oxidation numbers
balancing simple equations by inspection, and checking the gain and loss of electrons by oxidation state changes
practical applications - combustion and batteries

14. Energetics and Dynamics

energy changes during chemical reactions
dynamic equilibria in chemical systems
Le Chatelier's principle

B. Additional Concepts

1. Measurement

quantitative treatment of error and precision
statistical treatment of data
error analysis

2. Atomic Structure

nature of energy
conversions of energy
the Bohr atom and its shortcomings
qualitative view of the modern picture of the atom
quantization of energy and quantum numbers
electromagnetic spectrum
s and p orbitals - shapes
atomic spectra

3. Periodic Trends

electron configuration of atoms; the periodic table and trends in: ionization potentials, electron affinity, atomic size

4. Gases

partial pressure and Dalton's law
kinetic molecular picture of gases - ideal gases, real gases
preparation of common gases (oxygen, hydrogen, carbon dioxide)

5. Solids and Liquids

molecular picture of liquids and crystalline solids, including ionic solids
phase diagrams - qualitative discussion
metals and semiconductors

6. Chemical Bonding

the covalent bond (post-Lewis)
the ionic bond (post-Lewis)

electronegativity trends
Lewis structures of more complex molecules and ions
resonance
orbital hybridization
valence-shell electron-pair repulsion (VSEPR)
polarity of bonds
polarity of molecules

7. **Interatomic, Intermolecular and Interionic Forces**

Van der Waals' forces
dipolar forces
the hydrogen bond
covalent solids
ionic solids

8. **Solutions**

Raoult's law
colligative properties - boiling point elevation, freezing point depression, osmotic pressure

9. **Reactivity and Solution Stoichiometry**

a. *Precipitation Reactions* - solution stoichiometry including molarity to mole-to-mass interconversions and the concept of the limiting reagent

b. *Acids and Bases* - reactions of strong bases and weak acids, weak acids and strong bases, as well as strong acids and strong bases; titration - the concept of an endpoint and an indicator; definition of pH - calculation of pH of strong acid solutions; K_w and the inverse relationship of $[H^+]$ and $[OH^-]$; calculation of pH in strong base solutions

c. *Oxidation and Reduction* - balancing more complex equations using the half-reaction method or oxidation state method; relative strengths of oxidizing and reducing agents

10. **Dynamics**

a. *Equilibrium* - equilibrium constants and calculations

b. *Rates of Reactions* - concept of reaction rate, effects of variations in concentration; rate laws, temperature effects, catalyst effects, medium effects, activation energy, potential energy diagrams

11. Special Topics

a. *Descriptive Chemistry of Common Metals and Nonmetals* - chemistry of nitrogen, phosphorus and sulfur, emphasizing their compounds with oxygen, halogens, and hydrogen; chemistry of carbon and silicon; chemistry of iron

b. *Simple Organic Molecules* - composition, structure, and bonding of simple hydrocarbons - alkanes, alkenes, alkynes, and aromatic hydrocarbons; concept of isomers; functional group definitions - alcohols, ethers, aldehydes, ketones, carboxylic acids, amines, amino acids; simple organic molecules

c. *Nuclear Chemistry* - types of nuclear radiation, mass-energy relationship, nuclear decay of radioisotopes, nuclear fission and fusion, isotopic tracers

Laboratory Exercises for a One-Year Course in Chemistry

Incorporation of a substantial laboratory component into the secondary school course is strongly recommended. Much effort has gone into developing experiments useful for teaching secondary school chemistry and, as a result, a number of effective laboratory manuals are available with a wide range of experiments to accommodate a range of student abilities and classroom facilities.

Six general objectives for the laboratory program are given. These objectives are not unique to chemistry and are by no means mutually independent:

- **Relate concepts in the abstract to actual experience:** There is a need to make a connection between classroom lectures, which often deal with material in the abstract, and real-life situations. For example, the element copper, symbolized as Cu, must be associated by students as the common metal encountered in everyday life.

- **Development of experimental strategies:** Students should learn the process of posing a question and devising an experiment to provide an answer. Conceptual and mathematical analysis must be addressed in the process.

- **Development of laboratory skills:** Students need to be taught laboratory techniques and observational skills. They should become familiar with laboratory apparatus and its use in experimentation. Careful observation and recording of experimental phenomena should be stressed.

- **Verification of physical laws:** It is necessary to verify some of the laws of chemistry in the laboratory because hearsay extends only so far. Scientific belief is always subject to test and verification and should be so presented.

- **Discovery of physical behavior:** The laboratory is a place of discovery. Hence some of the exercises should allow for discovery by the students. This means that some exercises must precede discussion of the results to be expected. Students can learn to interpret a specific natural observation and generalize therefrom.

- **Laboratory reports:** It is essential that students learn the importance of reporting their experimental observations accurately, objectively, clearly, and in sufficient detail that their work could be repeated by others following their reports.

The proper use of computers as data analyzing tools must be addressed carefully. Laboratory exercises must not degenerate into computer programming sessions or computer simulation of exercises the students can perform for themselves. Simulations are best employed for situations that cannot be duplicated in the laboratory.

An annotated list of experiments follows that is representative of the types available. It is by no means a complete list or necessarily a preferred list. However, one aspect of the laboratory is mandatory and must be emphasized: *Safety*. Proper procedures must be taught and used throughout the course. The simplest and most effective of these is wearing safety goggles or glasses at all times in the laboratory when experiments are in progress. Instructors must set the example for the students.

Suggested Laboratory Exercises

Combustion of a Candle: This classic experiment can be both qualitative and quantitative. It encourages observation and deduction and can be studied at several levels with relatively simple apparatus.

Warming and Cooling Behavior of a Pure Substance: The melting point and heating curve of a substance can be obtained with simple apparatus. The experiment utilizes graphing skills and introduces students to phase changes.

Measurement Exercises: Weighing samples or measuring lengths can be used to introduce the concepts pf precision and accuracy. These are recurring concepts in science with many levels of sophistication. They can be introduced at a simple level.

Determination of Avogadro's Number from a Monomolecular Film: This experiment allows the calculation of an important and commonly used number with a simple apparatus. Moreover, students gain an appreciation of molecular size in the process.

Determination of the Formula of a Compound by Direct Combination of the Elements: Chemical formulas are central to our understanding of compounds. This experiment shows how a molecular formula can be determined. There are numerous variations on this experiment. All reinforce the importance of accurate measurement, especially weighing.

Determination of the Solubility of a Salt: This experiment reinforces the relative nature of solubility and its dependence on temperature. Crystallization of a salt is also demonstrated.

Determination of Acidity and Basicity with Indicators: Students are exposed to acid-base concepts and relate these to common solutions. A more advanced experiment is **Acid-base Titration: Titration of Vinegar** which reinforces the neutralization reaction and its quantitative nature.

Investigations into the Corrosion of Iron: The use of chemistry to explain everyday observations highlights this experiment. The reactivity of the element is emphasized.

Packing of Atoms or Ions in Crystals: This experiment uses models to understand crystalline structures. It shows how models can be used to visualize structures built up from atoms and ions.

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V COURSE CONTENT - PHYSICS

Introduction

The study of physics provides a systematic understanding of the fundamental laws that govern physical, chemical, biological, terrestrial and astronomical processes. Physics is the root science. The basic principles of physics are the foundation of most other sciences and of technological applications of science. Physics is also part of our culture and has had enormous impact on technological developments. Many issues of public concern, such as energy, nuclear power, national defense, pollution, and space exploration involve physical principles that require some understanding for informed discussion of the issues. Thus comprehending physics is important for a rational, enlightened citizenry to participate responsibly in decisions on public policy regarding complex technological issues.

Physics is not just for physicists. In fact, few people who study the fundamentals of physics actually become physicists. Many enter related fields, such as engineering or other sciences, and many pursue nonscientific careers. For this reason, pre-college physics should be taught at a general level and should demonstrate the general principles of the science.

Physics is an experimental science in that every statement of physical law is subject to verification and should be taught with this in mind. The relevance of physics to present and future technology should be made apparent.

The course content list that follows is offered as a best estimate of what should be included in the high school physics course for college-bound students. It is hoped the list will serve as a starting point for continuous discussion regarding the nature and scope of the course.

Mathematics: The physics course can be taught well with various levels of mathematical preparation. In fact, physics lends itself well to introducing students to the mathematical aspects of science. Physics is easy to describe mathematically, but it should not be inferred that physics can be easily learned mathematically. An overemphasis on mathematical analysis will disenfranchise many capable students from studying physics at the high school level. Ideally, a balance must be struck between the conceptual and mathematical aspects of physics - with neither predominating. Physics teachers should make reasonable adjustments in their presentations to ensure this balance and to keep the scientific level compatible with the mathematical preparation of their students. Prerequisites consistent with the *Statement on Competencies in Mathematics Expected of Entering Freshmen* are Algebra I and geometry with a corequisite of Algebra II. A closer idea of the mathematical depth of high school physics can be gained from the sample exercises given in Appendix III.

Topics for a One-Year Course in Physics

The topics are grouped under five main classifications: *Mechanics, Heat and Thermodynamics, Electricity and Magnetism, Light and Optics,* and *Modern Physics*. Specific concepts are grouped in relation to the topics within which they may best be covered. It is assumed that basic concepts of the nature of science have been covered at an earlier stage either in other science courses or, preferably, at a pre-secondary level. Basic to an understanding of science would be an appreciation of:

- the nature of scientific evidence
- strengths and limitations of science as a way of "knowing"
- the objective process of scientific inquiry
- accuracy and predictability of scientific knowledge

There are other topics that should be covered in introductory science courses, such as *climate, weather, and weather predictions; plate tectonics; descriptive astronomy.* Additional coverage of weather behavior (not just prediction!) and plate tectonics (and the consequences of plate motion), while based in physics, is the domain of earth science.

The topics marked with a single asterisk (*) are also listed under the chemistry curriculum. The topics marked with a double asterisk (**) are considered to be special or advanced topics.

A. Mechanics

1. The Metric System of Units for Length, Time, and Mass*

- estimates and approximations
- metric units: their relation to units commonly used in everyday life
- dimensions
- measurement and error
- scientific notation

2. Concepts of Velocity and Acceleration

falling bodies:
 in vacuum (constant acceleration)
 in air
 in viscous fluids (terminal velocity)

3. Projectile Motion in a Vertical Plane

trajectories

4. Newton's Three Laws of Motion

law of inertia
Newton's second law:
gravity of Earth
springs
viscosity
friction

5. Gravity (Newtonian)

universal gravitation:
 on Earth (law of falling bodies)
 beyond (orbits)

6. Concepts of Torque, Center of Mass, Equilibrium

levers
tension
center of mass and torque
machines (mechanical advantage)

Comment: The fundamentals of simple machines (lever, wheel, pulley, and suchlike) and mechanical advantage should be addressed in this segment as these discussions have been largely displaced from the college curriculum.

"Give me somewhere to stand, and I will move the earth." Archimedes, in reference to the lever.

7. Concepts of Work, Energy, and Power; Conditions for the Conservation of Energy

work
kinetic energy
gravitational potential energy
other potential energy

8. **Linear Momentum; Conditions for Conservation of Linear Momentum**

   conservation of momentum
   collisions and other applications

9. **Circular Motion**

   centripetal force
   centrifugal force
   speed, acceleration

10. **Rotational Motion and Angular Momentum**

    conservation of angular momentum
    gyroscopes
    Kepler's second law**

11. **Fluids; Statics and Dynamics**

    fluid statics (Archimedes' principle)
    energy in fluid flow (Bernoulli's principle)**

12. **Harmonic Motion**

    springs
    pendulums (time-keeping)

13. **Waves in Linear Media; Principle of Superposition; Sound**

    waves (water waves, sound waves)
    wave properties (speed, frequency, wavelength, standing waves, propagating waves)
    resonance**

B. **Heat and Thermodynamics**

1. **Temperature and Heat**

   heat
   heat and temperature
   thermometers; F, C, K scales
   heat as a kinetic phenomenon

2. **Thermal Equilibrium and Heat Transfer**

   spread of heat
   conduction
   convection
   radiation

3. **Mechanical Equivalent of Heat**

4. **Change of State***

   state of matter
   phase transitions

5. **Thermal Expansion of Matter**

   thermal coefficient of expansion

6. **The Ideal Gas Law***

7. **Kinetic Theory of Matter**

   ideal gas law as a kinetic phenomenon*

8. **First and Second Laws of Thermodynamics**

   Carnot engine**
   absolute temperature*
   cryogenics**

C. **Electricity, Magnetism, and Electromagnetism**

1. **Coulomb's Law**

   charge
   charge conservation
   Coulomb's law

2. **Electric Field and Electric Potential**

   potential energy and voltage
   electric field

3. **Ohm's Law**

   electricity in matter
   conductors and insulators
   current
   batteries
   Ohm's law
   simple circuits
   power and heat

4. **Capacitance**

   capacitors
   typical values of voltage, charge, and energy
   electrostatics machines and devices

5. **The Magnetic Field; Magnetic Forces**

   force on a moving charge
   atomic magnetism (magnetic materials)**
   permanent magnets
   planetary magnetism**

6. **Electromagnetic Induction**

   principle of electromagnetic induction
   transformers

7. **Energy of Electric and Magnetic Fields**

8. **Alternating Current**

   AC generators; motors
   AC transmission lines (reason for)

9. **Electromagnetic Waves**

D. **Light and Optics**

1. **Light and Color**

2. **Reflection and Refraction**

   prism spectrometer (observation and discussion of)
   refraction; Snell's law
   colors

3. **Mirrors and Lenses**

   lenses and images
   telescopes and microscopes
   fiber optics**

4. **Diffraction and Polarization**

   grating spectrometer (observation and discussion of)
   wave nature of light; diffraction
   the electromagnetic spectrum
   polarization

5. **Coherent Light**

   lasers (holograms)**

E. Modern Physics

1. Special Relativity**

the Michelson-Morley experiment
time dilation and space contraction
relativistic mass:
$E = mc^2$
gravitational and inertial mass
principle of equivalence
curved space and black holes

2. The Heisenberg (Indeterminacy) Principle**

quantum physics
the photoelectric effect; waves are particles
electron diffraction; particles are waves
Heisenberg principle of uncertainty (indeterminacy)

3. Atomic Theory and Structure (introductory)

electricity: nature of atoms, solids and liquids
x-ray diffraction**
transistors**
integrated circuits and computers**

4. Nuclear Structure (introductory)**

elementary particles, quarks, etc.

5. Radioactivity; Fission; Fusion**

stability of nuclei
fission, fusion
nuclear decay, lifetimes
nuclear reactors; health-physics concerns

F. Science and Human Affairs

public participation in scientific undertaking
using knowledge to reach informed decisions
careers and avocations in science

Laboratory Exercises for a One-Year Course in Physics

The laboratory program, like the lecture program, should be oriented to the general college-bound student. Enrichment activities, when provided in the context of the course for students with special interests in the sciences, are most desirable but should not detract from the general nature of the course.

The general objectives of the physics laboratory program are described below, and overlap substantially with those of other laboratory sciences. There follows a list of specific laboratory exercises that are considered useful and feasible. The list is not exhaustive and in no way represents a "best" list.

1. **Relate concepts in the abstract to actual experience:** There is a need to make a connection between classroom lectures, which often deal with material in the abstract, and real-life situations. By way of illustration, the word "torque" should be connected to a "twisting feeling" that students have sensed and can recall.

2. **Development of experimental strategies:** If at all possible, students should be involved in the design of an experiment; they should be required to make the decision as to *what* to measure and *how* to measure it. Conceptual and mathematical analysis must be addressed in the process.

3. **Development of laboratory skills:** Students need to be taught laboratory techniques and observational skills. They should become familiar with laboratory apparatus and its use in experimentation. Careful observation and recording of experimental phenomenon should be observed.

4. **Verification of physical laws:** It is necessary to verify some of the laws of physics in the laboratory because hearsay extends only so far. Scientific belief is always subject to test and verification (if not proof) and should be so presented.

5. Discovery of physical behavior: The laboratory is a place of discovery. Hence some of the exercises should allow for discovery by the students. This means that some experiments must precede discussion of the results to be expected. Students can learn to interpret a specific natural observation and generalize therefrom.

6. Laboratory reports: It is essential that students learn the importance of communicating their observations accurately, objectively, clearly, and in sufficient detail that their work could be repeated by others following their reports.

Computers are useful as data-analyzing tools, but their use must not overshadow the objectives of the experiment. Laboratory exercises ought not to become computer programming sessions or computer simulation exercises. Simulations are best employed for behavior that cannot be duplicated in the laboratory.

Suggested Laboratory Exercises

- **Laboratory Basics**

  Safety in the laboratory

  Measurement basics

- **Mechanics of Solids**

  Measurement of the force constant of a spring (Hooke's law)

Determination of the gravitational constant by pendulum

Measurement of speed, velocity, and acceleration in an automobile: a time-motion home study assignment

- Mechanics of Fluids

  Determination of the velocity of sound in air by resonance tube

  Wave tank (ripple tank) exercises

  Measurement of surface tension

  Verification of Boyle's law

- Heat and Kinetic Theory

  Measurement of the specific heat capacity of a metal

  Measurement of the heat of fusion of ice

  Verification of Charles' law

- Electricity and Magnetism

  Investigation of electromagnetic phenomena

  Investigation of charge interactions (Coulomb's law)

  Mapping of electric and magnetic fields

  Verification of Ohm's law

- Light and Optics

  Basic geometrical optics

  Observation of light polarization, diffraction, interference, refraction

Observation of solar and line emission spectra

Determination of the magnification of a telescope

- **Radioactivity**

  Determination of half-life

  Demonstration of a cloud chamber

- **Kinetic Theory of Matter**

  Determination of the size of a molecule by monomolecular film

  Demonstration of Brownian motion

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Sample Problems in Biology

Biological science questions appropriate for high school students in a college preparatory program appear below. These questions are taken, with permission, from a New York State Regents High School Examination. A multiple-choice format is used in this examination undoubtedly because it facilitates grading. An alternative format in which the questions provide no prompting by a set of responses is more difficult to grade and may be less familiar to the high school student. However, both examination formats are used in college and university courses, and it is important, therefore, that the college-bound student be familiar with both. A second most important reason for encouraging increased use of non-multiple choice questions is that it gives the student the opportunity to write about and rephrase concepts introduced in the course. Communicating knowledge and ideas in writing is an essential skill and one which can be developed more through subjective questions than through a multiple-choice format.

The sample questions provided are considered appropriate, but they are not endorsed as ideal. They are fair questions, given the current content of biology courses and currently available biology textbooks at the pre-college level. The answers are listed at the end of the exam.

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1. To collect mitochondria from cells and study their structure in fine detail, which instruments would a scientist most likely use?

1 microdissection apparatus and compound light microscope

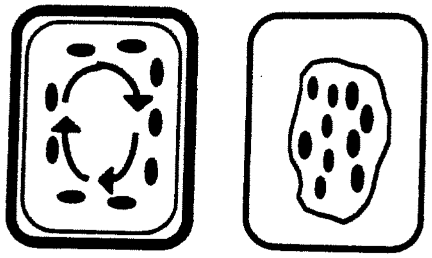
2 ultracentrifuge and electron microscope

3 microdissection apparatus and dissecting microscope

4 ultracentrifuge and compound light microscope

Base your answers to questions 2 through 4 on the information below and on your knowledge of biology.

A student observed a green plant cell under the low power objective of her microscope and noted the movement of organelles as shown in diagram A. She then added three drops of a salt solution to the slide, waited a few minutes, and observed the cell as shown in diagram B.



2. The organelles observed were most likely

1 centrosomes 3 mitochondria

2 chloroplasts 4 ribosomes

3. The movement of these organelles as shown in diagram A is known as

1 ingestion 3 pinocytosis

2 transpiration 4 cyclosis

4. The appearance of the clumped material as shown in diagram B is due to

1 loss of water from the cell

2 loss of salt from the cell

3 addition of water into the cell

4 addition of salt into the cell

5. A characteristic of all known living things is that they

1 use atmospheric oxygen

2 use carbon dioxide

3 carry on metabolic activities

4 are capable of locomotion

6. Blue-green algae lack a membrane separating their nuclear material from their cytoplasm. On this basis these organisms are classified as

1 fungi 3 monerans

2 protists 4 plants

7. Which word equation represents the process of photosynthesis?

1 carbon dioxide + water ⟶ glucose + oxygen

2 glucose ⟶ alcohol + carbon dioxide

3 maltose + water ⟶ glucose + glucose

4 glucose + oxygen ⟶ carbon dioxide + water

8. Which is a polysaccharide associated with the cells of a tomato plant, but not with the cells of a grasshopper?

1 hemoglobin 3 protease

2 glycogen 4 cellulose

9. A common characteristic of animals and fungi is their ability to carry on

1 heterotrophic nutrition

2 alcoholic fermentation

3 auxin production

4 transport through vascular tissue

10. The site of aerobic cellular respiration is the

1 nucleus 3 chromosome

2 ribosome 4 mitochondrion

11. Which organism carries on gas exchange in a terrestrial environment?

1 amoeba 3 hydra

2 shark 4 grasshopper

12. A chemical injected into a tadpole caused the tadpole to undergo rapid metamorphosis into a frog. This chemical was most probably an

1 enzyme 3 hormone

2 neurohumor 4 blood protein

13. According to the fluid mosaic model, a cell membrane is described as a structure composed of a

1 protein layer in which large lipids are found

2 carbohydrate structure in a "sea of lipids"

3 double lipid layer in which proteins float

4 phospholipid layer divided by carbohydrates

14. Which compounds are produced in human muscle cells as a result of the oxidation of glucose in the absence of oxygen?

1 lipase and water

2 sucrase and carbon dioxide

3 ethyl alcohol and ATP

4 lactic acid and ATP

15. Nitrogenous wastes may be produced as a result of the metabolism of

1 glucose 3 fatty acids

2 glycogen 4 amino acids

16. Compared to blood entering the human kidney, blood leaving the kidney normally contains a lower concentration of

1 red cells 3 white cells

2 proteins 4 urea

17. Each of the two daughter cells that result from the normal mitotic division of the original parent cell contains

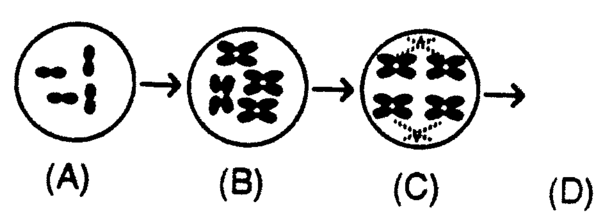
1 the same number of chromosomes, but has genes different from those of the parent cell

2 the same number of chromosomes and has genes identical to those of the parent cell

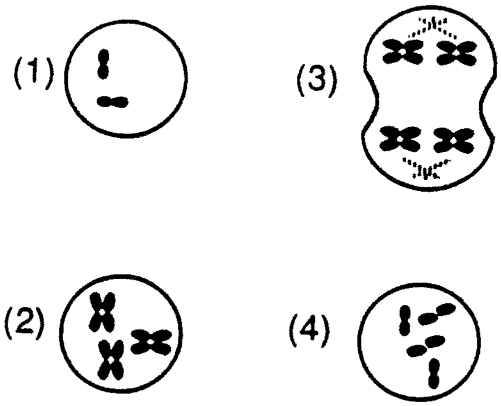
3 one-half of the number of chromosomes, but has genes different from those of the parent cell

4 one-half of the number of chromosomes and has genes identical to those of the parent cell

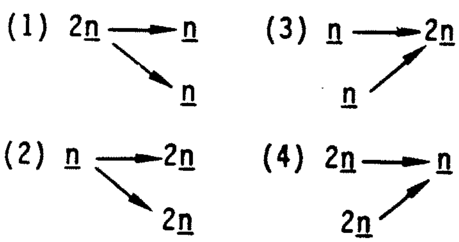
18. The diagrams below represent the sequence of events in a cell undergoing normal meiotic cell division.



Which diagram most likely represents stage D of this sequence?



19. In the diagrams below, 2n represents the diploid number of chromosomes in a cell of an organism, and n represents the monoploid number. Which diagram represents fertilization?



20. In most species of fish, a female produces large numbers of eggs during a reproductive cycle. This would indicate that reproduction in fish is most probably characterized by

1 internal fertilization and internal embryonic development

2 internal fertilization and external embryonic development

3 external fertilization and internal embryonic development

4 external fertilization and external embryonic development

21. Curly hair in humans, white fur in guinea pigs, and needle-like spines in cacti all partly describe each organism's

1 alleles 3 chromosomes

2 autosomes 4 phenotype

22. The appearance of a recessive trait in offspring of animals most probably indicates that

1 both parents carried at least one recessive gene for that trait

2 one parent was homozygous dominant and the other parent was homozygous recessive for that trait

3 neither parent carried a recessive gene for that trait

4 one parent was homozygous dominant and the other parent was hybrid for that trait

23. Which series is arranged in correct order according to <u>decreasing</u> size of structures?

1 DNA, nucleus, chromosome, nucleotide, nitrogenous base

2 nucleotide, chromosome, nitrogenous base, nucleus, DNA

3 nucleus, chromosome, DNA, nucleotide, nitrogenous base

4 chromosome, nucleus, nitrogenous base, nucleotide, DNA

24. One weakness in Darwin's theory of evolution was that he was <u>not</u> able to

1 explain selection of favorable traits

2 account for an increase in population

3 explain the genetic basis for variation in populations

4 understand competition among individuals of a species

25. A supporter of the evolutionary theory set forth by Lamarck would probably theorize that the giraffe evolved a long neck due to

1 need and inheritance of acquired traits

2 mutations and genetic recombination

3 variations and survival of the fittest

4 overproduction and struggle for survival

26. A change in the frequency of any mutant allele in a population most likely depends on the

1 size of the organisms possessing the mutant allele

2 adaptive value of the trait associated with the mutant allele

3 degree of dominance of the mutant allele

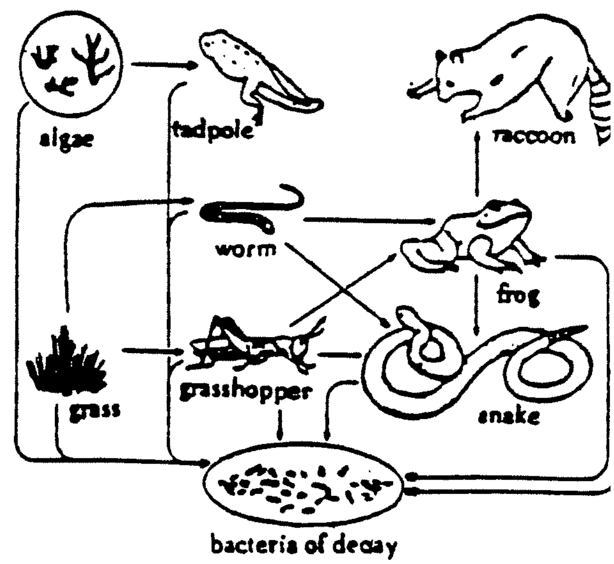
4 degree of recessiveness of the mutant allele

27. Which would be considered a biotic factor in a pond ecosystem?

1 snails 3 oxygen

2 water 4 sunlight

Base your answers to questions 28 through 31 on the diagram that follows and on your knowledge of biology. The diagram represents different species of organisms interacting with each other in and around a pond environment.



28. The adult frog represents a type of consumer known as a

1 producer 3 saprophyte

2 carnivore 4 parasite

29. Which organisms are classified as herbivores?

1 algae, tadpole, raccoon

2 worm, snake, bacteria

3 tadpole, worm, grasshopper

4 grasshopper, bacteria, frog

30. Which statement about algae and grass is true?

1 they are classified as omnivores

2 they parasitize the animals that consume them

3 they contain the greatest amount of stored energy

4 they decompose nutrients from dead organisms

31. The interactions among organisms shown in the diagram illustrate

1 a food web

2 geographic isolation

3 abiotic factors

4 organic evolution

32. In humans, anaerobic respiration of glucose is a less efficient energy-releasing system than aerobic respiration of glucose. One of the reasons for this is that in anaerobic respiration

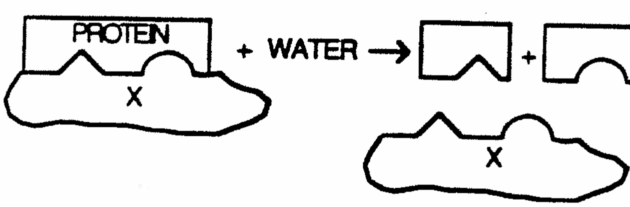
1 lactic acid contains much unreleased potential energy

2 water contains much released potential energy

3 oxygen serves as the final hydrogen acceptor

4 chlorophyll is hydrolyzed into PGAL molecules

33. The diagram below represents an enzyme-catalyzed reaction. Which substance is represented by letter X?



1 maltase

2 sucrase

3 lipase

4 protease

Directions 34-36: For each phrase in questions 34 through 36 select the food nutrient, chosen from the list below, that is described by that phrase.

Food Nutrients

(1) Carbohydrates
(2) Saturated fat
(3) Unsaturated fat
(4) Protein
(5) Water molecules

34. Serve as major sources of energy and also provide roughage

35. Provide a transport medium and help to regulate body temperature

36. Composed of amino acids and needed to maintain and repair body tissues

37. The right ventricle is the chamber of the heart which contains

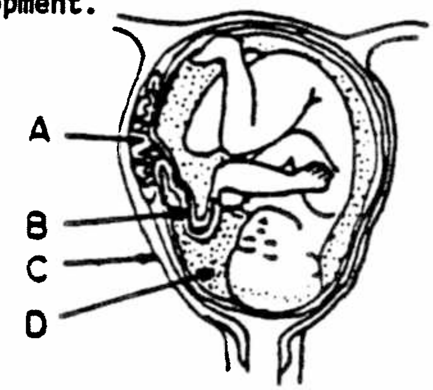
1 deoxygenated blood and pumps this blood to the lungs

2 deoxygenated blood and pumps this blood to the brain

3 oxygenated blood and pumps this blood to the lungs

4 oxygenated blood and pumps this blood to the brain

Base your answers to questions 38 through 40 on the diagram below which represents a stage in human development.



38. The exchange of oxygen, food, and wastes between mother and fetus occurs at

1 A 3 C

2 B 4 D

39. What is the function of the fluid labeled D?

1 nourishment 3 excretion

2 protection 4 respiration

40. The structure labeled C, within which development occurs, is known as the

1 oviduct 3 uterus

2 birth canal 4 placenta

41. In the early development of a zygote, the number of cells increases without an increase in mass by a process known as

1 ovulation 3 germination

2 cleavage 4 metamorphosis

42. The hollow-ball stage in the development of an invertebrate embryo is known as the

1 blastula 3 gastrula

2 ectoderm 4 endoderm

43. Which principal actions of genes insure homeostatic control of life processes and continuity of hereditary material?

1 oxidation and hydrolysis

2 enzyme synthesis and replication

3 oxygen transport and cyclosis

4 pinocytosis and dehydration synthesis

44. Human disorders such as PKU and sickle-cell anemia, which are defects in the synthesis of individual proteins, are most likely the result of

1 gene mutations 3 crossing-over

2 nondisjunction 4 polyploidy

45. The gene pool in a population of **Rana pipiens** in a pond remained constant for many generations. The most probable reason for this stable gene pool is that

1 it was a small population with nonrandom mating and many mutations

2 random mating occurred in a small population with many mutations

3 no mutations occurred in a large, migrating population

4 no migration occurred in a large population with random mating

46. Following a major forest fire, an area that was once wooded is converted to barren soil. Which of the following schemes describes the most likely sequence of changes in vegetation in the area following the fire?

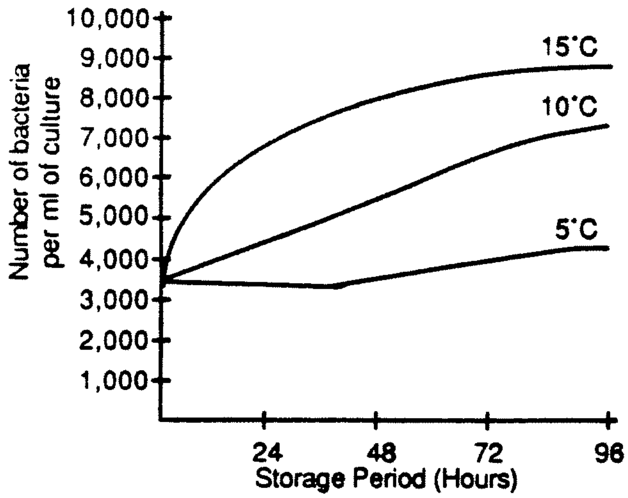
1 shrubs→maples→pines→grasses

2 maples→pines→grasses→shrubs

3 pines→shrubs→maples→grasses

4 grasses→shrubs→pines→maples

47. The graph that follows was developed as a result of an investigation of bacterial counts of three identical cultures grown at different temperatures. Which conclusion might be correctly drawn from this graph?



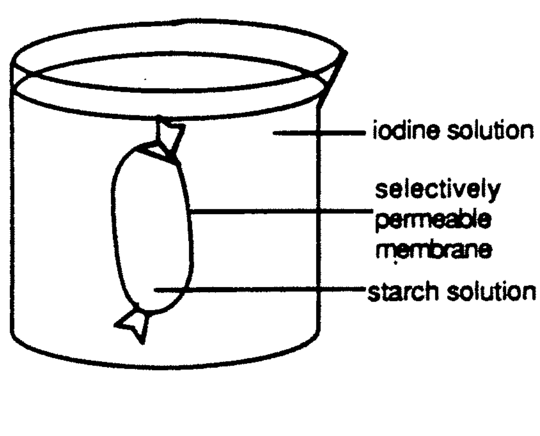
1 the culture contains no bacteria

2 refrigeration retards bacterial reproduction

3 temperature is unrelated to the bacterial reproduction rate

4 bacteria cannot grow at a temperature of 5°C

Base your answers to questions 48 and 49 on the diagram below and on your knowledge of biology.



48. If iodine molecules passed through the membrane into the starch suspension, the

1 starch suspension would turn blue-black

2 starch suspension would turn brick-red

3 membrane would dissolve

4 membrane would become impermeable

49. What process accounts for the movement of the iodine?

1 diffusion 3 phagocytosis

2 osmosis 4 pinocytosis

50. Dissection of an earthworm is normally begun with a cut along the dorsal surface. What is an advantage of beginning the cut here?

1 the four-chambered heart will remain in place

2 the kidneys will be clearly exposed

3 the backbone would be damaged by any other incision

4 the ventral nerve cord will not be damaged

Answers:

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

Appendix II

Sample Problems in Chemistry

The problems included here are examples of the level of accomplishment expected of students who have completed a high school course in chemistry. Two types of questions are presented: multiple-choice questions *and* questions for which *no* prompting by a set of responses is provided. As with the biology questions, multiple-choice test questions are convenient to grade but they should not be used exclusively. Both types of questions are used in college and university courses, and it is important that the college-bound student be familiar with both. A second most important reason for encouraging increased use of descriptive questions is the opportunity they give the student to write and rephrase concepts introduced in the course. Communicating knowledge and ideas in writing is an essential skill and one which can be developed more through subjective questions than through a multiple-choice format.

The sample questions are to be worked accompanied by a periodic table that includes atomic weights. The answers are given at the end.

****

1. One of the isotopes of potassium has mass number 42. The singly-charged positive ion of this atom contains

	protons	electrons	neutrons
a.	19	18	5
b.	19	18	23
c.	19	19	23
d.	18	19	24
e.	39	38	42

2. The atomic number of an atom or monatomic ion is the

a. number of neutrons

b. number of protons

c. number of electrons

d. sum of number of protons and neutrons

e. the difference between the number of neutrons and protons

3. When a halogen molecule reacts with an alkaline earth metal, the halogen molecule usually forms

a. ions of charge 2+

b. ions of charge 1+

c. neutral atoms

d. ions of charge 1-

e. ions of charge 2-

4. The chemical properties of an atom depend principally upon its

a. atomic weight

b. nuclear configuration

c. electron configuration

d. number of isotopes

e. net charge

5. Chromium forms an oxide of formula Cr_2O_3. The formula of the nitrate of chromium, with chromium in the same oxidation state, is

a. $Cr(NO_3)_3$ c. $Cr_3(NO_3)_2$

b. $Cr_2(NO_3)_3$ d. $Cr(NO_3)_6$

e. $Cr(NO_2)_3$

6. The total number of atoms in one mole of $CuSO_4.5H_2O$ is

a. 9 c. 6×10^{23}

b. 21 d. 5.4×10^{24}

e. 1.26×10^{25}

7. The percentage by weight of sulfur in SO_3 is

a. 25 c. 40 e. 50

b. 32 d. 46

8. A compound containing only carbon and oxygen has 53.0 percent carbon.
What is its empirical formula?

a. C_2O c. C_9O_8 e. CO_2

b. C_3O_2 d. CO

9. How many moles of sulfuric acid, H_2SO_4, are needed to convert two moles of magnesium oxide completely to magnesium sulfate? Assume that no other product containing magnesium is formed.

a. 1/2 c. 3/2 e. 4

b. 1 d. 2

Questions 10 and 11 refer to the reaction of CuO with NH_3:

$$CuO + NH_3 \longrightarrow Cu + N_2 + H_2O$$

10. When the equation is balanced with the smallest integer coefficient, the coefficient of Cu is

a. 1 c. 3 e. 6

b. 2 d. 4

11. In the reaction of CuO with NH_3

a. CuO is the oxidizing agent and NH_3 is reduced

b. CuO is reduced and NH_3 is oxidized

c. CuO is oxidized and NH_3 is reduced

d. CuO is reduced and NH_3 is the oxidizing agent

e. there is no oxidation or reduction

12. If 100g of Mg and 100g of O_2 are allowed to react, the only product formed being MgO, what is the maximum weight of MgO that might be formed?

a. 40g c. 126g e. 200g

b. 100g d. 166g

13. Which of the following has the same total electron configuration as a neon atom?

a. F c. Ne^+ e. Ar

b. Na d. Na^+

14. As atomic number increases, which of the following atomic properties also necessarily increases?

a. electronegativity

b. first ionization energy

c. number of outer-shell electrons

d. nuclear charge

e. charge on the most stable ion formed from the atom

15. Which of the following terms best describes the bond between the atoms in a single molecule of hydrogen chloride, which is a gas under ordinary conditions?

a. hydrogen bond

b. gaseous bond

c. pure covalent bond

d. pure ionic bond

e. polar bond

16. Which of the following materials is an ionic solid?

a. MgO c. graphite e. ice

b. CO_2 d. I_2

17. A sample of an ideal gas at a certain temperature and pressure has a volume $\underline{V}$. If the pressure on the gas is increased by a factor of three and the absolute temperature of the gas is increased by a factor of 2, what will be the new volume of the gas?

a. $\underline{V}/6$ c. $\underline{V}$ e. $6\underline{V}$

b. $2\underline{V}/3$ d. $3\underline{V}/2$

18. What is the approximate volume occupied by 0.0200g of gaseous H_2 at 0^oC and 1.00 atm?

a. 22.4 mL c. 224 mL e. 2.24L

b. 44.8 mL d. 448 mL

19. The unusually low volatility and high heat of vaporization and heat capacity of water can be attributed to the fact that water molecules

a. have a molecular weight of 18

b. form strong hydrogen bonds

c. have amphoteric character

d. are highly ionized

e. contain 10 electrons

20. Which one of the following pairs of terms are the reverse (antithesis) of one another?

a. ionization and dissociation

b. sublimation and evaporation

c. condensation and evaporation

d. melting and sublimation

e. melting and dissolving

21. The weight of Na_2CO_3 needed to prepare 0.50 liter of 0.20 $\underline{M}$ solution is

a. 10.6g c. 53g e. 5.3g

b. 21.2g d. 106g

22. Suppose that a sample of ocean water is filtered so that suspended sand and other solid particles are removed but is not otherwise purified. Compared to pure water, this sample of ocean water, at a given pressure, will have

a. a higher freezing point and higher boiling point

b. a lower freezing point and lower boiling point

c. a higher freezing point and lower boiling point

d. a lower freezing point and higher boiling point

e. the same freezing and boiling points

23. When solid magnesium nitrate dissolves in water, the reaction may properly be represented as

a. $Mg(NO_3)_2(\underline{s}) \longrightarrow Mg^{2+}(\underline{aq}) + 2NO_3^-(\underline{aq})$

b. $Mg(NO_3)_2(\underline{s}) \longrightarrow Mg^{4+}(\underline{aq}) + 2NO_3^{2-}(\underline{aq})$

c. $Mg(NO_3)_2(\underline{s}) \longrightarrow Mg^{2+}(\underline{aq}) + NO_3^{2-}(\underline{aq}) + NO_3(\underline{aq})$

d. $MgNO_3(\underline{s}) \longrightarrow Mg^+(\underline{aq}) + NO_3^-(\underline{aq})$

e. $Mg(NO_3)_2(\underline{s}) \longrightarrow Mg(\underline{aq}) + 2NO_3(\underline{aq})$

24. The term "base" is commonly used in chemistry to refer to any compound that

a. contains the OH group

b. forms a salt when neutralized

c. gives a pH below 7 when dissolved in water

d. is a donor of protons

e. is an acceptor of protons

25. What volume of 0.12 M KOH will be neutralized by 40 mL of 0.030 M HBr?

a. 2.5 mL c. 16 mL e. 160 mL

b. 10 mL d. 40 mL

26. Which of the following substances does not give an acidic solution when dissolved in water?

a. CO_2 c. H_2 e. HNO_2

b. HI d. SO_3

27. Assume that each of the following reactions is initially at equilibrium. For which of them will a decrease in pressure favor increased formation of products? Assume the temperature remains constant.

a. $H_2(\underline{g})+I_2(\underline{g}) = 2HI(\underline{g})$

b. $2NOBr(\underline{g}) = 2NO(\underline{g})+Br_2(\underline{g})$

c. $H_2O(\underline{g})+CuSO_4(\underline{s}) = CuSO_4.H_2O(\underline{s})$

d. $CH_3OH(\underline{g}) = CH_3OH(\underline{l})$

e. $2NO_2(\underline{g}) = N_2O_4(\underline{g})$

28. Which of the following statements does not apply to the alkali metal elements?

a. they are found naturally in the uncombined state

b. they readily form ions of charge 1+

c. they are relatively soft and low-melting

d. most of their common salts are soluble in water

e. their oxides are basic

29. Cobalt-60 is radioactive, with a half-life of 5.3 years. It emits gamma rays and is used in radiation therapy. Suppose a hospital director orders a supply of this material for use in therapy. What fraction of the original supply would have decayed radioactively after 10.6 years?

a. none   c. 0.50   e. all

b. 0.25   d. 0.75

30. The term "isomer"

a. refers to a compound that has the same properties as another compound

b. is a synonym for isotope

c. refers to the class of protein catalysts known as enzymes

d. refers to a compound that has the same structure as another compound but differs from it in composition and properties

e. refers to a compound that has the same chemical composition as another compound but differs from it in structure and properties.

31. The number of ml of 2.00 M HCl required to prepare 0.250 liter of 0.050 M HCl is

a. 12.50   c. 5.00   e. 25.00

b. 6.25   d. 2.50

32. If an aqueous solution contains 3.00 percent by weight of sugar, $C_6H_{12}O_6$, and has a density of 0.993 $g.ml^{-1}$, how many grams of sugar are present in 500 ml of the solution?

a. 12.0   c. 14.9   e. 37.5

b. 15.1   d. 50.0

Answers

1. b	12. d	23. a
2. b	13. d	24. e
3. d	14. d	25. b
4. c	15. e	26. c
5. a	16. a	27. b
6. e	17. b	28. a
7. c	18. c	29. d
8. b	19. b	30. e
9. d	20. c	31. b
10. c	21. a	32. c
11. b	22. d	

Non-Multiple Choice Questions

1. Calculate the molarity of sodium when 7.1g Na_2SO_4 is dissolved in 400 mL of water.

2. Draw Lewis structures for:

a. NH_3 c. O^{2-} e. H_2O

b. CCl_4 d. PF_3

3. How many grams of HF are required to react with 30.0g of SiO_2 if the reaction proceeds according to the balanced equation

$$SiO_2 + 4HF \rightarrow SiF_4 + 2H_2O$$

4. Name the following compounds:

a. NH_4NO_3 c. NaOH   e. $CaBr_2$

b. K_2SO_4 d. PCl_3

5. Give formulas for the following substances:

a. ozone

b. sodium carbonate

c. sulfur dioxide

d. ammonia

e. sulfurous acid

f. hydrochloric acid

6. Complete and balance the following equations:

a. $H_2SO_4 + NaOH \xrightarrow{H_2O}$

b. $Na_3PO_4 + CaCl_2 \xrightarrow{H_2O}$

7. Select those molecules that have a dipole moment and explain why the dipole moment exists.

a. CO_2 c. H_2O

b. HF   d. BF_3

8. If 30 mL of 0.50 M Na_2SO_4 solution reacts with 45 mL of 0.40 M $CaCl_2$ solution, calculate the grams of $CaSO_4$ that precipitate if the reaction proceeds according to the balanced equation shown below. Also calculate the molarity of the excess reagent ion.

$$Ca^{2+} + SO_4^{2-} \longrightarrow CaSO_4$$

9. If 25 mL of 0.40 M $MgCl_2$ and 50 mL of 0.60 M NaCl are added to 25 mL of water, calculate the molarity of chloride ion in the resulting solution. Assume the volumes are additive.

Answers

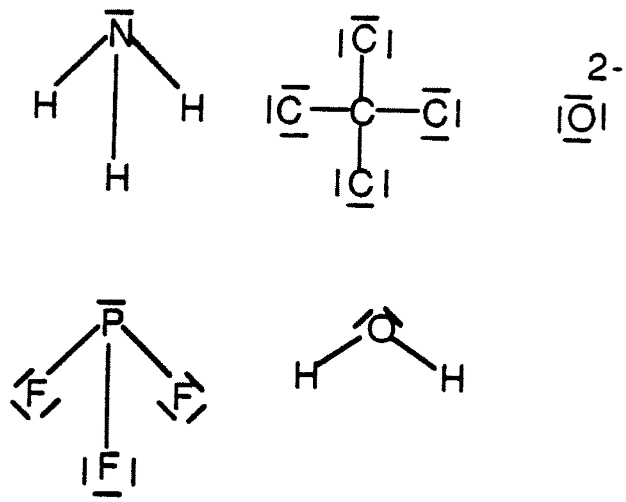
1. Number of moles in 7.1g of sodium sulfate (MW 142)

= 7.1/142 = 0.050

Since Na_2SO_4 is a strong electrolyte in water, there are 2 moles of Na^+ for every mole of Na_2SO_4. Hence, number of moles of Na^+ in 7.1g of sodium sulfate = 0.100

Recall molarity is mol/L; hence 0.100 moles in 400 mL corresponds to 0.250 moles in 1000 mL, or 0.250 M.

2.



3. Number of moles of SiO_2 (MW 60.1) in 30.0g

= 30.0/60.1 = 0.50

Number of moles of HF (MW 20) equivalent to 0.50 moles of SiO_2

= 4 x 0.50 = 2.0

Number of grams of HF = 2.0x20

= 40

4. a. ammonium nitrate
   b. potassium sulfate
   c. sodium hydroxide
   d. phosphorus trichloride
   e. calcium bromide

5. a. O_3 c. SO_2 e. H_2SO_3

   b. Na_2CO_3 d. NH_3 f. HCl

6a.

$$H_2SO_4 + 2NaOH \longrightarrow 2H_2O + Na_2SO_4$$

Since H_2SO_4 and NaOH are strong electrolytes, Na^+ and SO_4^{2-} are spectator ions and the net reaction is the neutralization reaction:

$$H^+ + HO^- \longrightarrow H_2O$$

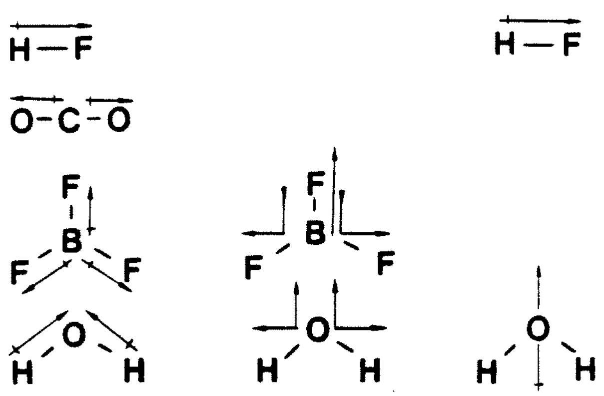
6b. $2Na_3PO_4$ + $3CaCl_2 \longrightarrow$
$Ca_3(PO_4)_2$ + 6NaCl

Recognizing the reactants as strong electrolytes, the precipitation of calcium phosphate is the driving force for the reaction. If the spectator ions are removed from the equation, the net reaction is:

$3Ca^{2+}$ + $2PO_4{}^{3-}$ $Ca_3(PO_4)_2$

7. All of the molecules have bond dipoles because of the electronegativity differences between the bonded atoms. However, CO_2 and BF_3 have a molecular geometry that generates opposing bond dipoles that results in a net dipole of zero for the molecule. HF and H_2O have bond dipoles that do not cancel, and a molecular dipole results.

bond dipoles	bond dipole components	molecular dipoles



8. Number of moles in 30 mL of 0.50<u>M</u> Na_2SO_4 = (30/1000)x0.50 = 0.015

Number of moles in 45 mL of 0.40<u>M</u> $CaCl_2$ = (45/1000)x0.40 = 0.018

Hence $CaCl_2$ or Ca^{2+} is in excess and $SO_4{}^{2-}$ is the limiting reagent.

Number of moles of $CaSO_4$ (MW 136)
=0.015

Number of grams = 0.015 x 136
= 2.0

Excess Ca^{2+} = 0.018-0.015 moles
= 0.003 moles
in 75 mL
= (1000/75)x0.003<u>M</u>
= 0.040 <u>M</u>

9. Recognizing the reagents as strong electrolytes in water:

Number of moles of Cl^- in 25 mL of 0.40 <u>M</u> $MgCl_2$
= 0.40(mol/L)x2x0.025(L)
= 0.020 moles Cl^-

Number of moles of Cl^- in 50 mL of 0.60 <u>M</u> NaCl
= 0.60(mol/L)x1x0.050(L)
= 0.030 moles of Cl^-
Total = 0.050 in a total volume of 25 + 50 + 25 = 100 mL

Molarity of chloride =0.50 <u>M</u>