



*Michigan*

TEST FOR TEACHER CERTIFICATION  
**STUDY GUIDE**

**18 Chemistry**



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## **PART 1: General Information About the MTTC Program and Test Preparation**

The first section of the study guide is available in a separate PDF file. Click the link below to view or print this section.

[General Information About the MTTC Program and Test Preparation](#)

## PART 2: Test Objectives and Sample Test Questions

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### INTRODUCTION

This section includes a list of the test objectives, immediately followed by sample test questions and an answer key for the field covered by this study guide.

#### Test Objectives

As noted, the test objectives are broad, conceptual statements that reflect the knowledge, skills, and understanding an entry-level teacher needs in order to teach effectively in a Michigan classroom. Each field's list of test objectives represents the **only** source of information about what a specific test will cover and, therefore, should be studied carefully.

The test objectives are organized into groups known as "subareas." These subareas define the major content areas of the test. You will find a list of subareas at the beginning of the test objective list. The percentages shown in the list of subareas indicate the approximate weighting of the subareas on the test.

#### Sample Multiple-Choice Test Questions

The sample multiple-choice test questions included in this section are designed to give the test-taker an introduction to the nature of the test questions included on the MTTC test for each field. The sample test questions represent the various types of test questions you may expect to see on an actual test; however, they are **not** designed to provide diagnostic information to help you identify specific areas of individual strengths and weaknesses or predict your performance on the test as a whole. Use the answer key that follows the sample test questions to check your answers.

To help you identify which test objective is being assessed, the objective statement to which the question corresponds is listed in the answer key. When you are finished with the sample test questions, you may wish to go back and review the entire list of test objectives and descriptive statements once again.

#### Chemistry (18) Field-Specific Information

For the Chemistry (18) test, you will be provided with one of the following models of scientific calculators at the test administration. You may not use your own calculator or calculator manual for this test. The models distributed are subject to change; directions for use will not be provided at the test site.

- Texas Instruments TI-30X
- Texas Instruments TI-30X Solar
- Texas Instruments TI-30Xa
- Texas Instruments TI-30Xs
- Texas Instruments TI-30XIIs

## TEST OBJECTIVES

All examinees taking the Chemistry test (Field 18) will be provided with a Texas Instruments scientific calculator with functions that include the following: addition, subtraction, multiplication, division, square root, percent, sine, cosine, tangent, exponents, and logarithms. **You may NOT bring your own calculator to the test.**

<b>Subarea</b>	<b>Approximate Percentage of Questions on Test</b>
Reflecting On and Constructing Scientific Knowledge	25%
Using Inorganic Chemistry	32%
Using Physical Chemistry	27%
Using Organic Chemistry and Biochemistry	16%

### REFLECTING ON AND CONSTRUCTING SCIENTIFIC KNOWLEDGE

#### **Understand the principles and procedures of scientific inquiry.**

Includes formulating research questions and investigations in chemistry; developing valid experimental designs for collecting and analyzing data and testing hypotheses; recognizing the need for control groups in experiments; understanding procedures for collecting and interpreting data to minimize bias; recognizing independent and dependent variables and analyzing the role of each in experimental design; identifying the most appropriate method (e.g., graph, table, formula) for presenting data for a given purpose; applying mathematics to investigations in chemistry and the analysis of data; interpreting results presented in different formats; evaluating the validity of conclusions; and assessing the reliability of sources of information.

#### **Apply knowledge of methods and equipment used in scientific investigations.**

Includes selecting and using appropriate data collection and measurement devices and methods; identifying uncertainties in measurement; evaluating the accuracy and precision of a measurement in a given situation; identifying procedures and sources of information related to the safe use, storage, and disposal of materials and equipment related to chemistry investigations; identifying hazards associated with laboratory practices and materials; and applying procedures for preventing accidents and dealing with emergencies.

#### **Understand the nature of scientific thought, inquiry, and history.**

Includes demonstrating knowledge of the reliance of scientific investigations on empirical data, verifiable evidence, and logical reasoning; recognizing the effect of researcher bias on scientific investigations and the interpretation of data; demonstrating an awareness of the contributions made to chemistry by individuals of diverse backgrounds and different time periods; and recognizing the dynamic nature of scientific knowledge, including ways in which scientific knowledge is acquired and modified.

**Understand the relationship of chemistry to contemporary, historical, technological, and societal issues.**

Includes recognizing the relationships between science and technology; analyzing historical, political, and social factors that affect developments in chemistry, including current issues related to chemistry research and technology (e.g., alternative fuels, polymers); and evaluating the credibility of scientific claims made in various forums (e.g., mass media, professional journals, advertising).

**Understand interrelationships among the physical, life, and earth/space sciences and their connections to mathematics and technology.**

Includes recognizing major unifying themes and concepts that are common to the various scientific disciplines (e.g., patterns, cause and effect, conservation of energy, entropy); and describing the integration and interdependence of the sciences, mathematics, and technology and their applications in real-world contexts.

**USING INORGANIC CHEMISTRY****Apply the rules of chemical nomenclature and notation.**

Includes applying basic rules of nomenclature to identify and name inorganic substances; and interpreting symbols and chemical notation for elements, isotopes, ions, molecules, and compounds.

**Understand atomic and molecular structure and bonding.**

Includes identifying the parts of an atom and their characteristics; comparing historic models of the atom; using the periodic table to predict the properties of a given element; representing atoms, ions, and compounds with electron-dot diagrams; analyzing the characteristics of different types of bonds (covalent, ionic, metallic), including the role of electrons in bonding; predicting physical and chemical properties based on the bonding in a substance; using VSEPR theory to explain molecular geometry and polarity; and identifying types of intermolecular forces and relating them to the physical properties of molecular substances.

**Apply the mole concept and the principles and methods of stoichiometry.**

Includes defining a mole and recognizing the significance of the mole concept; calculating the number of moles in a given mass or volume of a substance; solving problems involving molecular and formula masses and percent composition; determining empirical and molecular formulas; applying the law of conservation of mass to solve problems involving moles, mass, and volume and problems involving solution chemistry; balancing chemical equations; solving problems involving limiting reagents and percent yield; and recognizing net ionic equations.

**Apply knowledge of chemical equilibrium and reaction rates.**

Includes analyzing the effects of concentration, pressure, temperature, and catalysts on chemical equilibrium and applying Le Chatelier's principle to chemical systems; solving problems involving equilibrium constants and reaction quotients; solving problems involving solubility product constants of slightly soluble salts and the common-ion effect; analyzing everyday phenomena in terms of chemical equilibrium; describing how temperature, concentrations, and catalysts affect reaction rates; analyzing potential energy versus reaction coordinate diagrams; identifying first-order and second-order reactions from the rate law for a reaction; determining the rate law of a reaction from experimental data; and recognizing the relationship between a reaction mechanism and the rate law.

**Understand the principles and applications of acid-base chemistry.**

Includes analyzing acids and bases according to acid-base theories (i.e., Arrhenius, Brønsted-Lowry, Lewis); distinguishing between strong and weak acids and bases and identifying conjugate acid-base pairs; calculating the hydronium or hydroxide ion concentration and the pH or pOH of various acid and base solutions; predicting the acid-base properties of various salts; analyzing the composition and function of buffer solutions; applying the principles of acid-base titration, including the selection of indicators, and interpreting the results of acid-base titrations; and identifying applications of acid-base chemistry.

**Understand the principles and applications of electrochemistry.**

Includes interpreting the behavior of common substances in terms of oxidation-reduction reactions; determining oxidation numbers and balancing oxidation-reduction reactions (e.g., half-reaction method); analyzing the feasibility of given reactions based on electrode potentials at standard conditions and nonstandard conditions; analyzing the components, operating principles, and potentials of electrochemical and electrolytic cells; relating cell potentials to spontaneity and equilibrium constants; demonstrating knowledge of methods and applications of electrochemical analysis; and identifying applications of electrochemistry.

**Understand qualitative analysis.**

Includes demonstrating knowledge of various separation techniques (e.g., distillation, filtration, chromatography) and their basic principles; selecting an appropriate separation technique in a given situation; demonstrating knowledge of the methods and equipment used for determining the types of substances present in a sample; and identifying everyday applications of qualitative analysis.

**USING PHYSICAL CHEMISTRY****Understand chemical thermodynamics and thermochemistry.**

Includes differentiating among forms of energy (e.g., heat, chemical, nuclear); analyzing how the laws of thermodynamics apply to chemical systems; predicting the spontaneity of given reactions based on enthalpy changes, entropy changes, and temperatures of the systems; analyzing endothermic and exothermic reactions; distinguishing between heat and temperature; demonstrating knowledge of the principles of calorimetry; analyzing the results of calorimetry experiments; and solving enthalpy problems using Hess's law, standard enthalpies of formation, and bond energies.

**Apply methods for measuring the physical properties of solids, liquids, and gases.**

Includes comparing physical properties (e.g., melting point, density, solubility) of solids, liquids, and gases; demonstrating knowledge of methods and equipment used for measuring the physical properties of substances; and using the physical properties of a substance to identify it.

**Apply knowledge of the kinetic molecular theory to the states of matter, phase changes, and the gas laws.**

Includes identifying the basic tenets of the kinetic molecular theory; using the kinetic theory to describe and explain characteristics of the states of matter, including changes of state; explaining the dynamic equilibrium between phases; analyzing heating and cooling curves; analyzing vapor pressure curves and phase diagrams; analyzing the relationships among pressure, temperature, and volume of a gas or mixture of gases; distinguishing between ideal and real gas behavior; and setting up and solving problems involving gas law relationships.

**Understand characteristics and properties of solutions.**

Includes analyzing the colligative properties of solutions; recognizing factors that affect solubility, including intermolecular forces; interpreting solubility curves; solving problems involving concentrations of solutions (e.g., molarity, molality, percent by mass percentage); analyzing the process of dissociation in solution; identifying properties of strong and weak electrolyte solutions; and applying solubility rules of inorganic salts to predict the occurrence of precipitation reactions.

**Understand quantum mechanics.**

Includes identifying basic features of the quantum mechanical model of the atom; recognizing the experimental evidence for the quantum mechanical model of the atom; analyzing the relationships among electron energy levels, photons, and atomic spectra; demonstrating a basic understanding of quantum numbers; describing atomic orbitals; predicting the electron configurations of neutral atoms and ions of given elements; and relating photon energy to the wavelength and frequency of light.

**Understand the basic principles and methods of spectroscopy.**

Includes demonstrating knowledge of the basic principles used in spectroscopy, limited to UV, visible, infrared, and mass spectroscopy; recognizing the kind of information that can be determined using spectroscopic analysis; and identifying everyday applications of spectroscopy.

**USING ORGANIC CHEMISTRY AND BIOCHEMISTRY****Understand the structure and nomenclature of organic compounds.**

Includes classifying hydrocarbons (e.g., alkane, aromatic) based on the type of carbon-carbon bonds; identifying the main families of organic compounds by means of their functional groups; using IUPAC rules to name simple organic compounds; identifying heterocyclic compounds; and recognizing isomers of organic compounds, including stereoisomers.

**Understand organic reactions of major functional groups.**

Includes demonstrating knowledge of the reactions of the major functional groups (addition, condensation, elimination, substitution); identifying the processes by which organic polymers are formed; and identifying everyday applications of organic reactions.

**Understand the structure and function of biomolecules.**

Includes recognizing and distinguishing the structures of the major classes of biomolecules (proteins, lipids, carbohydrates, nucleic acids); identifying the primary functions of the various types of biomolecules and relating these functions to molecular structure; recognizing the role of enzymes in biological systems; recognizing factors that affect enzyme kinetics; and recognizing the importance and role of buffers in biological systems.

**Understand biochemical reactions and processes.**

Includes using chemical principles (including thermodynamics) to analyze important biochemical processes (e.g., synthesis, degradation, electron transport, oxidative phosphorylation); and identifying the overall chemical equations for the metabolic reactions of photosynthesis and respiration.

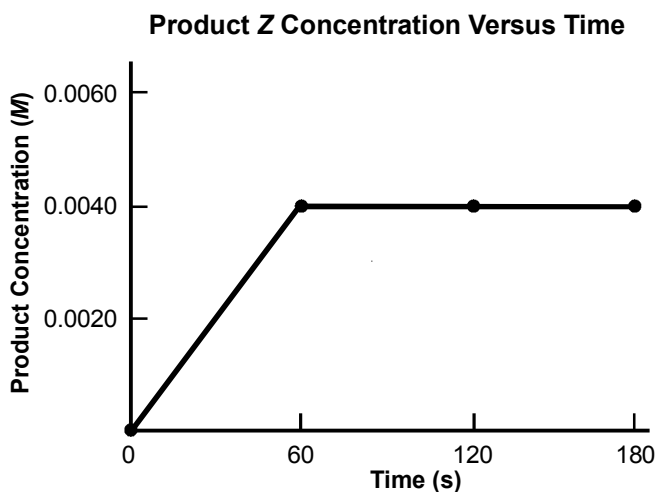


## SAMPLE MULTIPLE-CHOICE TEST QUESTIONS

All examinees taking the Chemistry test (Field 18) will be provided with a Texas Instruments scientific calculator with functions that include the following: addition, subtraction, multiplication, division, square root, percent, sine, cosine, tangent, exponents, and logarithms. **You may NOT bring your own calculator to the test.**

1. Use the information below to answer the question that follows.

A researcher carried out a reaction between  $0.010\text{ M}$  reactant  $X$  and excess reactant  $Y$ . The researcher measured the concentration of product  $Z$  at 60-second intervals. The researcher's results are shown in the graph below.



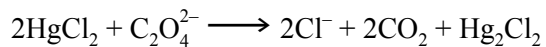
The researcher concludes from these data that the reaction rate was  $6.7 \times 10^{-5}\text{ M/s}$ . Which of the following is the best evaluation of the validity of the researcher's conclusion?

- A. It is invalid because the chosen time interval of 60 seconds was not short enough to allow for an accurate measurement of the rate of this reaction.
- B. It is valid because the leveling off of the product concentration curve indicates the reaction was complete at 60 seconds.
- C. It is invalid because the rate should have been calculated by dividing the final product concentration by the full 180-second duration of the experiment.
- D. It is valid because reaction rate is an intensive property of the reactants and products involved in the reaction.

2. A student has to measure out 9.40 mL of a liquid and selects a 100 mL graduated cylinder. To improve the accuracy of the measurement, it would be most effective to:
- A. take the average of multiple measurements using the graduated cylinder.
  - B. measure the liquid using a 25 mL graduated cylinder instead.
  - C. estimate the measurement obtained from the graduated cylinder to an additional significant figure.
  - D. measure the liquid using a 10 mL graduated pipette instead.
3. Which of the following is an illustration of the use of verifiable evidence in the practice of science?
- A. Thinkers in ancient India proposed that atoms came in two forms, soft or rough, which caused them to combine in pairs, forming the basis for all matter.
  - B. Ernest Rutherford hypothesized that atoms must have dense cores, since some alpha particles, when shot at gold foil, passed through and others were greatly deflected.
  - C. Niels Bohr reasoned that an atom's electrons orbiting the nucleus would have to radiate energy in a manner consistent with the law of conservation of energy.
  - D. Democritus proposed the idea of the atom when the smell of baking bread caused him to question how the smell traveled to one's nose from a distance.

4. Scientific claims published in professional journals are generally considered more credible than those posed through the mass media. This is true primarily because professional journals:
- A. ensure that every investigation is repeated and the results independently verified before a paper is published.
  - B. direct their content to a more narrow readership with highly specialized interests.
  - C. maintain their editorial objectivity by refusing to accept paid advertising.
  - D. subject researchers' methodologies and conclusions to peer review prior to publication.
5. The most important similarity between the mole in chemistry and the light year in astronomy is that these units:
- A. provide accurate physical models of natural phenomena.
  - B. have been refined since first being introduced as more data were collected.
  - C. represent combined laws worked out by numerous researchers.
  - D. convert extremely large- or small-scale phenomena into values that are easier to work with.
6. Which of the following is the correct notation for the calcium-44 isotope existing as a 2+ ion?
- A.  ${}^{2+}_{44}\text{Ca}-20$
  - B.  ${}^{20}_{44}\text{Ca}^{2+}$
  - C.  ${}^{44}_{20}\text{Ca}^{2+}$
  - D.  ${}^{46}_{20}\text{Ca}$
7. Which of the following substances is likely to exhibit the highest boiling point due to intermolecular forces?
- A.  $\text{CH}_3\text{OH}$
  - B.  $\text{CH}_3\text{SH}$
  - C.  $\text{CH}_3\text{F}$
  - D.  $\text{CH}_2\text{O}$
8. Which of the following quantities contains the greatest number of moles?
- A. 30 g of  $\text{N}_2$
  - B. 35 g of  $\text{NH}_3$
  - C. 60 g of  $\text{NaCl}$
  - D. 75 g of  $\text{CaO}$

9. Use the information below to answer the question that follows.



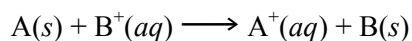
The reaction above was carried out with various starting concentrations of the two reactants, and the initial reaction rate was determined. The experimental results are recorded in the table below.

Trial	$[\text{HgCl}_2](M)$	$[\text{C}_2\text{O}_4^{2-}](M)$	Initial Rate (M/s)
1	0.05	0.15	$8.75 \times 10^{-6}$
2	0.05	0.30	$3.50 \times 10^{-5}$
3	0.10	0.15	$1.75 \times 10^{-5}$
4	0.10	0.30	$7.00 \times 10^{-5}$

Which of the following rate laws is consistent with the experimental data?

- A.  $\text{rate} = k[\text{HgCl}_2][\text{C}_2\text{O}_4^{2-}]$
- B.  $\text{rate} = k[\text{HgCl}_2]^2[\text{C}_2\text{O}_4^{2-}]^2$
- C.  $\text{rate} = k[\text{HgCl}_2][\text{C}_2\text{O}_4^{2-}]^2$
- D.  $\text{rate} = k[\text{HgCl}_2][\text{C}_2\text{O}_4^{2-}]^4$

10. Which of the following is a characteristic of methanoic acid (HCOOH) that makes it a suitable component of a buffer?
- A. It changes color when it undergoes ionization.
  - B. Its ionization is incomplete.
  - C. It has two ionizable hydrogens.
  - D. It can ionize to produce both hydrogen and hydroxide ions.
11. Use the reaction below to answer the question that follows.

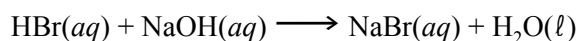


The overall reaction of an electrochemical cell is shown above. The cell potential is 1.0 V when the cell is at 25°C and the solution concentrations are 1.0 M. Which of the following changes would result in an increase in cell potential?

- A. increasing the concentration of  $B^+(aq)$
- B. increasing the concentration of  $A^+(aq)$
- C. increasing the surface area of the  $B(s)$  electrode
- D. increasing the surface area of the  $A(s)$  electrode

12. A soluble ionic compound is thought to contain either sodium or calcium as the cation. Which of the following solutions could be added to an aqueous sample of the compound to determine the identity of the cation?
- A. hydrochloric acid
  - B. nitric acid
  - C. potassium bromide
  - D. potassium carbonate

13. Use the information below to answer the question that follows.



The reaction shown above is studied in a constant-pressure calorimeter with a heat capacity of  $500 \text{ J/}^\circ\text{C}$ . In the experiment,  $100 \text{ mL}$  of  $0.10 \text{ M}$  HBr and  $100 \text{ mL}$  of  $0.10 \text{ M}$  NaOH are mixed.

The entire system, including both solutions, started at  $20.00^\circ\text{C}$ , and the final temperature was  $20.42^\circ\text{C}$ .

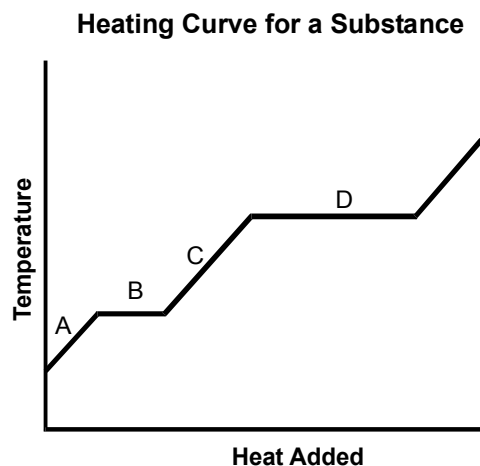
Assuming additive volumes, no heat loss to the surroundings, solution densities of  $1.00 \text{ g/mL}$ , and solution specific heats of  $4.184 \text{ J/g}\cdot^\circ\text{C}$ , what is the approximate value of  $\Delta H$  for the reaction?

- A.  $-35 \text{ kJ/mol}$
- B.  $-40 \text{ kJ/mol}$
- C.  $-56 \text{ kJ/mol}$
- D.  $-123 \text{ kJ/mol}$

14. An unknown substance is a solid at room temperature. The substance is soluble in water, but the aqueous solution does not conduct electricity. Attempts to measure the melting point of the substance are unsuccessful, as a chemical reaction occurs prior to melting. Which of the following substances is most consistent with this description of physical properties?

- A.  $\text{CH}_3\text{OH}$
- B.  $(\text{NH}_4)_2\text{SO}_4$
- C.  $\text{MgCO}_3$
- D.  $\text{C}_6\text{H}_{12}\text{O}_6$

15. Use the graph below to answer the question that follows.



The graph above is the heating curve for a substance covering its solid, liquid, and gaseous phases. Which segment of the graph gives information about this substance's molar heat of fusion?

- A. segment A
- B. segment B
- C. segment C
- D. segment D

16. According to quantum theory, an atomic orbital represents:
- A. a region of space around the nucleus where the probability of finding an electron is high.
  - B. the three-dimensional path that a given electron follows around the nucleus.
  - C. the particular distance from the nucleus that a given electron must maintain.
  - D. a particular point around the nucleus where a given electron must be located.
17. A food scientist has a sample of a plant oil and wants to determine if the oil contains saturated or unsaturated fatty acids. Which of the following spectroscopic techniques would be most useful for this purpose?
- A. ultraviolet spectroscopy
  - B. visible spectroscopy
  - C. infrared spectroscopy
  - D. mass spectroscopy
18. Which of the following molecules can have both *cis* and *trans* geometrical isomers?
- A.  $\text{CH}_3(\text{CH}_2)_2\text{CH}_3$
  - B.  $\text{CH}_2\text{CHCH}_2\text{CH}_3$
  - C.  $\text{CH}_3\text{CCCH}_3$
  - D.  $\text{CH}_3\text{CHCHCH}_3$
19. Use the chemical equation below to answer the question that follows.
- $$\text{CH}_3\text{CHO} + \text{H}_2\text{O} \longrightarrow \text{CH}_3\text{CH}(\text{OH})_2$$
- Which of the following kinds of chemical reaction is represented by the equation above?
- A. addition
  - B. condensation
  - C. elimination
  - D. substitution

20. In living cells, nonspontaneous metabolic reactions are made thermodynamically possible primarily through:
- A. direct interaction of the bonds in carbohydrates with those in the molecules involved in the metabolic reaction.
  - B. coupling with the energy-releasing reaction of adenosine triphosphate (ATP) to adenosine diphosphate (ADP).
  - C. the compartmentalization of the various steps of the metabolic pathway within membranes.
  - D. heating of the immediate environment through the breaking of carbon-carbon bonds in large organic molecules.

**ANSWER KEY FOR THE SAMPLE MULTIPLE-CHOICE TEST QUESTIONS**

<b>Item Number</b>	<b>Correct Response</b>	<b>Objective</b>
1.	<b>A</b>	Understand the principles and procedures of scientific inquiry.
2.	<b>D</b>	Apply knowledge of methods and equipment used in scientific investigations.
3.	<b>B</b>	Understand the nature of scientific thought, inquiry, and history.
4.	<b>D</b>	Understand the relationship of chemistry to contemporary, historical, technological, and societal issues.
5.	<b>D</b>	Understand interrelationships among the physical, life, and earth/space sciences and their connections to mathematics and technology
6.	<b>C</b>	Apply the rules of chemical nomenclature and notation.
7.	<b>A</b>	Understand atomic and molecular structure and bonding.
8.	<b>B</b>	Apply the mole concept and the principles and methods of stoichiometry.
9.	<b>C</b>	Apply knowledge of chemical equilibrium and reaction rates.
10.	<b>B</b>	Understand the principles and applications of acid-base chemistry.
11.	<b>A</b>	Understand the principles and applications of electrochemistry.
12.	<b>D</b>	Understand qualitative analysis.
13.	<b>C</b>	Understand chemical thermodynamics and thermochemistry.
14.	<b>D</b>	Apply methods for measuring the physical properties of solids, liquids, and gases.
15.	<b>B</b>	Apply knowledge of the kinetic molecular theory to the states of matter, phase changes, and the gas laws.
16.	<b>A</b>	Understand quantum mechanics.
17.	<b>C</b>	Understand the basic principles and methods of spectroscopy.
18.	<b>D</b>	Understand the structure and nomenclature of organic compounds.
19.	<b>A</b>	Understand organic reactions of major functional groups.
20.	<b>B</b>	Understand biochemical reactions and processes.