

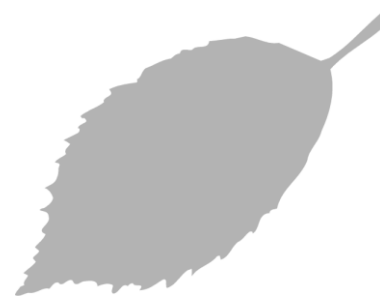
**Massachusetts
Tests for Educator Licensure[®] (MTEL[®])**



Chemistry (12)

**PRACTICE TEST
APPENDIX:**

**Multiple-Choice
Question Analyses**



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**MULTIPLE-CHOICE QUESTION
ANALYSES**

1. A chemist hypothesizes that a newly developed photodegradable plastic will degrade twice as fast as currently available photodegradable plastics. Which of the following investigations would best test this hypothesis?
- A. modeling the chemical reactions involved in the degradation of the new plastic and using this model to project degradation rates under different environmental conditions
 - B. subjecting the new plastic and the existing plastics to the same environmental conditions and measuring their degradation rates
 - C. comparing the degradation rate of the new plastic with the degradation rates provided by the manufacturers of the existing photodegradable plastics
 - D. exposing the new photodegradable plastic to conditions of constant UV radiation and no UV radiation and comparing the resulting degradation rates

Correct Response: B. The environmental conditions are controlled, and the comparison stated is correct and sufficient to answer the question as to which plastic degrades more quickly. **A** is incorrect because the two plastics are not compared and degradation rates are theoretical. **C** is incorrect because degradation rates provided by the manufacturer may be biased and also because the degradation rates of the two types of plastic were likely measured using different environmental conditions. **D** is incorrect because the experiment in this option only involves one type of plastic.

2. Several unknown solutions have been tested for the presence of Group 1 or Group 2 metals using a flame-test protocol. Which of the following methods would be the best way to represent the collected data?
- A. a table
 - B. a histogram
 - C. a scatter plot
 - D. a line graph

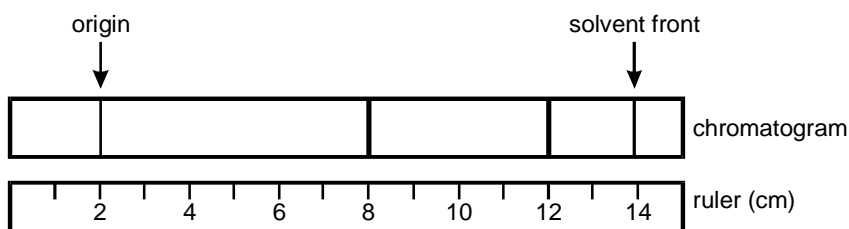
Correct Response: A. A flame-test protocol gives results that are qualitative in nature (e.g., the presence of sodium in Group 1 gives a yellow flame color). Qualitative results are conveyed with tables. All other options require numerical data (which is not obtained in this experiment). **B** is incorrect because a histogram requires a numerical value for frequency. **C** is incorrect because scatter plots are used to show the relationship between two numerical sets of data (e.g., a graph of students' heights versus weights). **D** is incorrect because line graphs are used to show the numerical relationship between two sets of data.

3. A chemist is attempting to identify an unknown solid substance by determining its density. The substance is found to have a volume of 70.3 cm^3 , and repeated weighing of the solid produced an average mass of 51.12 g . Given these data, which of the following correctly reports the density of the solid substance with the correct number of significant figures?
- A. $7 \times 10^{-1} \text{ g/cm}^3$
 - B. $7.2 \times 10^{-1} \text{ g/cm}^3$
 - C. $7.27 \times 10^{-1} \text{ g/cm}^3$
 - D. $7.272 \times 10^{-1} \text{ g/cm}^3$

Correct Response: C. The volume measurement has 3 significant figures, and the mass measurement has 4. The quotient of these two numbers (density = mass/volume) will therefore have 3 significant figures (the least number of significant figures of any number in the problem determines the number of significant figures in the answer). **A** is incorrect because this number has only 1 significant figure. **B** is incorrect because this number has only 2 significant figures. **D** is incorrect because this number has 4 significant figures.

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

Chromatography Reference Table	
Cation	R_f $\left(\frac{\text{distance of cation}}{\text{distance of solvent}}\right)$
Ni^{2+}	0.50
Cu^{2+}	0.58
Fe^{3+}	0.83

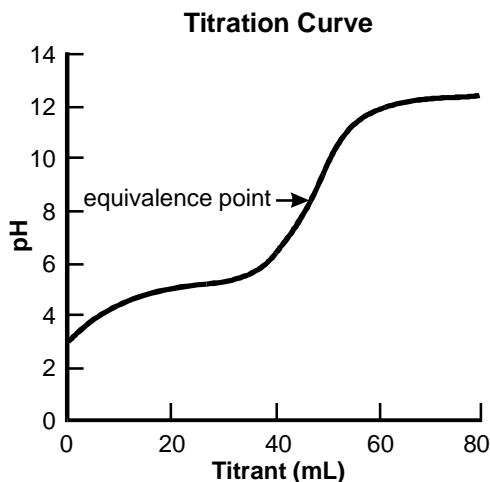


A chemist is using paper chromatography to identify the components of a sample known to contain at least one of the cations shown in the reference table. Given the chromatogram shown above, the unknown consists of:

- A. Cu^{2+} cations.
- B. Ni^{2+} and Fe^{3+} cations.
- C. Fe^{3+} and Cu^{2+} cations.
- D. Ni^{2+} , Cu^{2+} , and Fe^{3+} cations.

Correct Response: B. The rightmost line in the chromatogram has an R_f value of $\frac{(12-2)}{(14-2)}$, or $\frac{10}{12}$, which is 0.83. This corresponds to the R_f value of Fe^{3+} . The leftmost line in the chromatogram has an R_f value of $\frac{(8-2)}{(14-2)}$, or $\frac{6}{12}$, which is 0.5. This corresponds to the R_f value of Ni^{2+} . **A** is incorrect because Cu^{2+} would give a line at (0.58×12) , or approximately 7. The chromatogram does not have a line at 7. **C** is incorrect because while a line corresponding to Fe^{3+} is present, a line corresponding to Cu^{2+} is not present in the chromatogram (Cu^{2+} would give a line at (0.58×12) , or approximately 7). **D** is incorrect because a line corresponding to Cu^{2+} is not present in the chromatogram (Cu^{2+} would give a line at $0.58 \cdot 12$, or approximately 7).

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



The graph above depicts the results of a titration experiment. Which of the following conclusions about the titration experiment is best supported by these data?

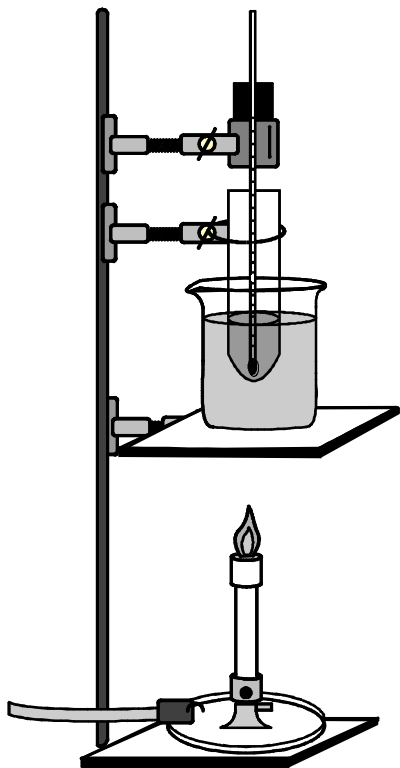
- A. The acid being titrated is a polyprotic acid.
- B. A strong base is being titrated with a weak acid.
- C. The titrant used in this experiment is a strong acid.
- D. A weak acid is being titrated with a strong base.

Correct Response: D. The combination of chemicals is that of a weak acid and a strong base. This conclusion can be drawn because the equivalence point on the graph corresponds to a pH greater than 7. It is clear that a weak acid is being titrated with a strong base (instead of a strong base being titrated with a weak acid) because the pH at the beginning of the titration is around 3. This pH value is characteristic of solutions of weak acids. **A** is incorrect because the graph shows only one equivalence point. If multiple protons were present, the graph would have an equivalence point for each one. **B** is incorrect because the starting pH value is that of a weak acid (3). **C** is incorrect because combining a weak acid, which is the substance being titrated, with a strong acid would not produce this type of titration curve.

6. A chemistry class is planning to use a fume exhaust hood to study the reaction between the elements copper and sulfur. Before beginning the experiment, the teacher will review with the class the proper use of the exhaust hood. Which of the following instructions should be included in this discussion?
- A. Avoid using Bunsen burners within the fume exhaust hood.
 - B. Turn off the fan while performing the experiment.
 - C. Keep the sash in its lowered position during the experiment.
 - D. Step away from the fume exhaust hood once the reaction has begun.

Correct Response: C. Keeping the sash lowered is necessary in order to contain fumes produced by the reaction within the exhaust hood. **A** is incorrect because using Bunsen burners within the fume exhaust hood does not present a safety hazard and is a necessary part of performing the experiment. **B** is incorrect because turning off the fan would prevent the removal of undesired fumes by the exhaust hood (the exhaust hood cannot work when it is off). **D** is incorrect because stepping away from the fume exhaust hood would prevent the student from being able to manipulate the experiment within the exhaust hood and is not a necessary method for avoiding exposure to fumes.

7. Use the diagram below to answer the question that follows.



The apparatus shown above is most likely to be used in which of the following scientific experiments?

- A. separating a mixture of two unknown liquids
- B. determining the boiling point of an unknown liquid
- C. constructing a titration curve of an unknown liquid
- D. detecting the presence of cations in an unknown liquid

Correct Response: **B.** Boiling point is determined by heating a liquid substance and recording the temperature at which gas is formed. **A** is incorrect because a distillation apparatus is used to separate two liquids based on temperature. **C** is incorrect because a buret is used to add an acid dropwise to a solution of base of known concentration. **D** is incorrect because a flame test, in which a small amount of an unknown liquid is placed directly in a flame, is used to detect the presence of cations in the unknown liquid.

8. When a chemical is transferred from a stock bottle into another container for use in the laboratory, the label on the new container must include the name and formula of the chemical, its concentration, and the:
- A. room number of the laboratory.
 - B. date the stock reagent bottle was received.
 - C. hazard warnings for the chemical.
 - D. phone number of the chemical hygiene officer.

Correct Response: C. Hazard warnings are an important safety consideration that are commonly mandated by legislation. Hazard warnings include information such as toxicity, radioactivity, or flammability. This information is needed in the event of an accident, such as a spill, ingestion, etc. **A** is incorrect because the room number of the laboratory is not information that is needed in the event of an accident. **B** is incorrect because the date the stock reagent bottle was received is not information that is needed in the event of an accident. **D** is incorrect because while the phone number of the chemical hygiene officer is important to have available in the laboratory, it is not information that will help a teacher respond specifically to an accident involving the chemical.

9. Which of the following is an example of a chemistry protocol being carried out in a safe manner?
- A. heating a compound in a test tube over a flame with the test tube opening oriented away from people
 - B. evaporating acetone from a beaker using direct heat from a Bunsen burner
 - C. using a glass stirring rod to assist in pouring a solution of NaClO into a beaker containing HCl
 - D. transferring a beaker containing boiling water directly from a hot plate into an ice bath

Correct Response: A. The test tube is not in direct contact with a heating surface, and the test tube is oriented away from people. This precaution is important in case of splashing, glass breakage, etc. Having the test tube in the flame could lead to glass breakage. **B** is incorrect because acetone is flammable and the beaker is in direct contact with a Bunsen burner. This would result in uneven heating and possible glass breakage and is a potential fire hazard. **C** is incorrect because NaClO reacts with HCl to produce chlorine gas. **D** is incorrect because transferring a beaker of boiling water directly into an ice bath could cause the beaker to break (resulting in spillage of boiling water).

10. A student splashes a chemical into an eye during a lab experiment. Which of the following is the first thing the teacher should do when responding to this situation?
- A. drive the student to an emergency room at the closest area hospital
 - B. flush the student's eye with water at the eyewash after checking for the presence of a contact lens
 - C. alert the school administrators that an accident has occurred
 - D. call the local poison control center for guidance on how to treat the student

Correct Response: B. Flushing the student's eye with water would be the fastest way to remove the chemical from the surface of the eye. This action would minimize potential damage to the student's eye. **A** is incorrect because the chemical would remain in contact with the eye during the drive to the emergency room. **C** is incorrect because safety concerns should be appropriately addressed first; administrators can be notified later. **D** is incorrect because the student has splashed a chemical into an eye; no chemicals have been ingested in this situation.

11. The use of carbon-reinforced plastic auto parts which are strong and lightweight is growing in the automotive industry. The use of this type of plastic in the automobile manufacturing process has led to a reduction in the:
- A. amount of soil contaminated with toxic heavy metals.
 - B. amount of carbon dioxide emitted into the atmosphere.
 - C. rate of eutrophication occurring in freshwater systems.
 - D. rate of ozone depletion occurring in the atmosphere.

Correct Response: B. The use of lightweight plastic materials for automobile parts reduces the overall weight of a vehicle. Less overall weight leads to an increase in fuel efficiency which reduces the amount of carbon dioxide emitted into the atmosphere. **A** is incorrect because the metal parts that would be replaced by the carbon-reinforced plastic parts would most likely be made of steel and are not considered toxic heavy metals. **C** is incorrect because the combustion of fossil fuels is not directly related to the eutrophication of waterways, which occurs as a result of increased concentrations of nitrogen and phosphorus in water. **D** is incorrect because ozone depletion is affected by the presence of chlorofluorocarbons in the atmosphere, not by the products of fossil fuel combustion.

12. Which of the following correctly identifies both an advantage and a disadvantage of using nuclear fission as a method of generating electricity?
- A. advantage: produces only nonhazardous waste products
disadvantage: leads to thermal pollution of rivers
 - B. advantage: uses an unlimited inexpensive fuel source
disadvantage: accelerates the rate of ozone depletion
 - C. advantage: produces minimal greenhouse gases
disadvantage: requires long-term storage of radioactive waste
 - D. advantage: inhibits the formation of acid rain
disadvantage: presents problems in safely containing plasma

Correct Response: C. Nuclear fission results in radioactive waste products that need to be stored long-term. Nuclear power plants are extremely expensive to build and represent a variety of safety hazards. However, greenhouse gases such as carbon dioxide are not produced as a result of using nuclear fission. **A** is incorrect because the waste produced is significantly hazardous. **B** is incorrect because neither is nuclear fission inexpensive nor does it accelerate the rate of ozone depletion. **D** is incorrect because nuclear fission does not inhibit the formation of acid rain, nor does it involve the containment of plasma.

13. Research into the production of ethanol from corn has been promoted by society's need to:
- A. decrease the price of corn-based food products.
 - B. stimulate job growth in automobile manufacturing.
 - C. decrease dependence on fossil fuels.
 - D. increase the number of small family-owned farms.

Correct Response: C. Ethanol, which can be derived from corn and other plants, has the potential to become a widespread replacement for gasoline in automobile combustion engines. **A** is incorrect because the price of corn-based food products would possibly increase if corn is being used for ethanol production instead of as food. **B** is incorrect since the production of ethanol does not affect the number of automobiles produced; rather, the type of fuel used for automobiles would change. **D** is incorrect because the production of ethanol would be widespread and would likely be done on large-scale corporate farms.

14. The development of airbags has led to significant improvements in automobile safety. The functionality of airbags is based on the decomposition of sodium azide into sodium and nitrogen. Which of the following equations could be used to determine how much sodium azide should be used to inflate an airbag to a certain set of specifications?
- A. $k = Ae^{-E_a/RT}$
- B. $q = ms\Delta T$
- C. $PV = nRT$
- D. $\Delta G = \Delta H - T\Delta S$

Correct Response: C. The ideal gas equation can be used to calculate the number of moles of gas needed to achieve a specific gas volume (the desired volume of the airbag) at specific pressure and temperature conditions. **A** is the Arrhenius equation and can be used to calculate the rate constant or activation energy of a reaction. **B** is the equation for calculating the amount of heat gained or lost when a given mass of a substance is warmed or cooled. **D** is an equation used to determine the change in free energy of a system for a constant-temperature process.

15. Which of the following responses correctly matches a technological development with its corresponding area of chemistry research?
- A. computer chips: chemical analysis of DNA
 - B. pest-resistant corn species: chemical equilibrium
 - C. photovoltaic cells: electrochemistry
 - D. synthetic fertilizers: molecular modeling

Correct Response: C. Photovoltaic cells have arisen in part as a result of research in the area of electrochemistry, which studies chemical reactions involved in producing electricity. **A** is incorrect because computer chips do not correspond to research involving the chemical analysis of DNA. Rather, they would correspond to research involving electron transfer in silicon or other metals. **B** is incorrect because pest-resistant corn species do not correspond to research in the area of chemical equilibrium. Rather, they would correspond to research in the area of genetic engineering. **D** is incorrect because synthetic fertilizers do not correspond to chemistry research in the area of molecular modeling. Rather, they would correspond to organic chemistry research.

16. Potassium hydrogen carbonate is best classified as which of the following types of matter?
- A. heterogeneous mixture
 - B. element
 - C. homogeneous mixture
 - D. compound

Correct Response: D. Potassium hydrogen carbonate, KHCO_3 , is a single chemical substance, a compound composed of potassium, hydrogen, carbon, and oxygen. **A** is incorrect because samples of this compound are uniform in composition throughout. **B** is incorrect because the compound contains four distinct elements. **C** is incorrect because KHCO_3 is a pure substance rather than a mixture.

17. Fog, which is composed of finely divided water droplets dispersed in air, is an example of which of the following types of mixtures?
- A. solution
 - B. aerosol
 - C. foam
 - D. emulsion

Correct Response: B. Water droplets dispersed in air meet the requirements of an aerosol. An aerosol is a suspension of particles dispersed in air or gas. **A** is incorrect because a solution is a mixture in which a minor component is uniformly distributed within a major component. In this case there is only one substance, water, so fog cannot correctly be termed a solution. **C** is incorrect because foam refers to a mass of small bubbles that are typically at the top of a liquid. These bubbles are formed by any of a number of processes, including agitation or fermentation. **D** is incorrect because an emulsion is a fine dispersion of minute droplets of one liquid in another in which it is not miscible. Since water is the only substance in fog, fog cannot correctly be termed an emulsion.

18. The products of a chemical reaction are solid zinc carbonate and aqueous sodium chloride. Which of the following procedures will achieve the best separation of the mixture into its three components?
- A. filtering the mixture and then distilling the filtrate
 - B. crystallizing the mixture and then decanting the aqueous portion
 - C. centrifuging the mixture and then crystallizing the supernatant
 - D. distilling the mixture and then centrifuging the distillate

Correct Response: A. Filtering the mixture will result in separation of the solid zinc carbonate from the aqueous sodium chloride. Distillation of the aqueous sodium chloride mixture will result in the water being boiled off and collected as the distillate, with the sodium chloride left behind because its boiling point is considerably higher than that of water. **B** is incorrect because crystallization separates one solid from one liquid in which it is dissolved. **C** is incorrect because centrifugation would simply cause the zinc carbonate to move to the bottom of a test tube. Crystallizing the supernatant is unlikely to work well because sodium chloride is extremely water soluble over a wide range of concentrations. **D** is incorrect because distillation would result in water being separated from the zinc carbonate and the sodium chloride. The distillate will contain only water, and centrifugation will not produce further separation.

19. Which of the following statements correctly identifies a difference between a physical change and a chemical change?
- A. New atoms are formed in a chemical change but not in a physical change.
 - B. Energy is conserved in a physical change but not in a chemical change.
 - C. New substances are formed in a chemical change but not in a physical change.
 - D. Mass is conserved in a physical change but not in a chemical change.

Correct Response: C. Chemical reactions result in the formation of new substances, but physical changes involve changes of state (such as solid to liquid, or liquid to gas). **A** is incorrect because new substances are formed in a chemical change, but new atoms are not. **B** is incorrect because the Law of Conservation of Energy applies in both instances. **D** is incorrect because the Law of Conservation of Mass applies in both instances.

20. Use the table below to answer the question that follows.

Properties of Selected Alcohols			
Alcohol	Melting Point (°C)	Boiling Point (°C)	Density (g/cm ³)
2-propanol	-90	82	0.786
Cyclopentanol	-19	141	0.948
Cyclohexanol	25	161	0.962
2-methyl-2-propanol	26	82	0.789

An unknown alcohol is a liquid at room temperature (20°C), and a 50.0 mL sample has a mass of 39.4 g. Based on these properties, the unknown alcohol can be identified as:

- A. 2-propanol.
- B. cyclopentanol.
- C. cyclohexanol.
- D. 2-methyl-2-propanol.

Correct Response: **A.** 2-propanol has a density very close to that of the unknown alcohol. The density of the alcohol is calculated as $\frac{39.4 \text{ g}}{50.0 \text{ cm}^3}$. Further, room temperature (20°C) falls between the melting and boiling points of 2-propanol, so 2-propanol is a liquid at room temperature. **B** is incorrect because the density of cyclopentanol is different from that calculated for the unknown alcohol. **C** is incorrect because the density of cyclohexanol is different from that of the unknown alcohol and because cyclohexanol is a solid at room temperature. **D** is incorrect because, though the density of 2-methyl-2-propanol is close to that of the unknown alcohol, 2-methyl-2-propanol is a solid at room temperature. It melts at 26°C.

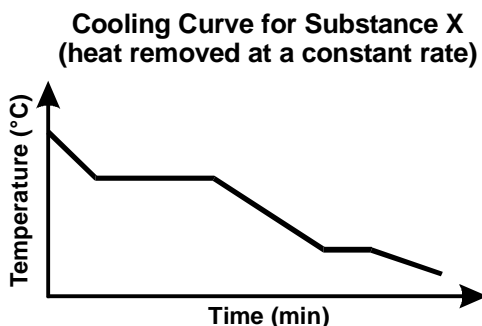
21. The constituent particles in a substance in its solid state tend to:
- A. remain motionless.
 - B. vibrate about fixed positions.
 - C. slide freely past one another.
 - D. move constantly in straight lines.

Correct Response: B. Vibration occurs in the solid state, and molecules in solids, such as crystal lattices, vibrate about fixed positions. **A** is incorrect; it is a common misconception that particles do not vibrate in the solid state. Particles in the solid state will vibrate less as temperatures of absolute zero are approached. **C** is incorrect because movement of particles in the solid state is restricted as a result of interactions with other particles (for example, NaCl in a crystal lattice). **D** is incorrect because particles in the solid state vibrate in such a way that interactions with neighboring particles are maintained.

22. According to the kinetic molecular theory, which of the following happens to the molecules of a gas when the gas is compressed?
- A. The average distance between the molecules decreases.
 - B. The electrostatic repulsion between molecules decreases.
 - C. The atomic radii of the atoms in the molecules decrease.
 - D. The lengths of the bonds within the molecules decrease.

Correct Response: A. As a gas is compressed, the pressure is increased and the molecules move closer together. This happens because the same number of molecules is forced to occupy a space of decreased volume. **B** is incorrect because electrostatic repulsion between molecules will increase as the distance between the molecules is decreased. The strength of intermolecular interactions decreases with the distance between molecules. **C** is incorrect because the size of the atoms in the molecules is not affected by the distance between the molecules. **D** is incorrect because the lengths of the bonds within the molecules are a function of the type of bond and the specific elements involved rather than the pressure of the gas in its container (i.e., the degree of compression).

23. Use the cooling curve below to answer the question that follows.

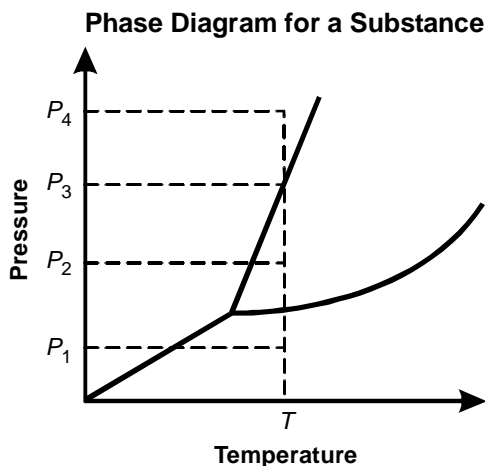


Which of the following statements is supported by the data presented in the cooling curve for substance X shown above?

- A. The heat of vaporization for substance X is greater than its heat of fusion.
- B. The specific heat of substance X is greater than its heat of formation.
- C. The boiling point of substance X is greater than its condensing point.
- D. The melting point of substance X is greater than its freezing point.

Correct Response: A. The cooling curve on the graph is divided into five distinct segments. The second segment from the left is horizontal with zero slope and corresponds to condensation of substance X. The heat change, Q , that corresponds to this section of the curve is calculated as $m\Delta H_{\text{vap}}$, where ΔH_{vap} represents the heat of vaporization. The second segment from the right (fourth one from the left) is also horizontal with zero slope and corresponds to solidification (fusion) of substance X. The heat change, Q , that corresponds to this section of the curve is calculated as $m\Delta H_{\text{fus}}$, where ΔH_{fus} represents the heat of fusion. Because the mass of the substance remains constant during cooling and because Q for the second segment from the left is greater than Q for the fourth segment from the left, it can be concluded that heat of vaporization of substance X is greater than its heat of fusion. **B** is incorrect because the specific heat cannot be compared to the heat of formation since the equations involving them are different. Q for the segments of the graph with a negative slope is calculated as $ms\Delta T$, where s is the heat capacity of whatever state is involved (the gas is involved in the first segment from the left, the liquid in the third segment from the left, and the solid in the fifth segment from the left). **C** is incorrect because boiling point and condensing point refer to the same physical property. **D** is incorrect because melting point and freezing point also refer to the same physical property.

24. Use the phase diagram below to answer the question that follows.



Based on the phase diagram above, which of the following pressures in combination with temperature T would result in the substance being present only as a gas?

- A. P_1
- B. P_2
- C. P_3
- D. P_4

Correct Response: A. In the bottom section of the curve, the substance is present only as a gas. This section of the graph corresponds to low pressure, where the particles occupy a larger volume. **B** is incorrect because the substance exists as a liquid in this section of the curve. This section of the curve represents an intermediate pressure and temperature range. **C** is incorrect because the substance will exist both as a solid and a liquid along this line. **D** is incorrect because at higher pressures the substance will exist as a solid. Under conditions represented by the leftmost region of the graph, the substance exists entirely as a solid.

25. A 20.0 L cylinder of oxygen gas is at a temperature of 27.0°C and a pressure of 5.00 atm. What is the density of the oxygen gas in the cylinder?
- A. 72.0 g/L
 - B. 6.50 g/L
 - C. 3.25 g/L
 - D. 0.203 g/L

Correct Response: B. The ideal gas law $PV = nRT$ is used to solve this problem. To find density, the number of moles, n , is replaced with $\frac{\text{g (grams)}}{\text{M (molar mass)}}$. This substitution is made and then the expression is rearranged to find $\frac{\text{g}}{\text{V (density)}}$. In this case, $\frac{\text{g}}{\text{V}} = \frac{(P \cdot M)}{(R \cdot T)}$. The temperature is in Kelvin and is 300 K. Pressure is 5.00 atm, as stated in the question, R is the ideal gas constant $\left(\frac{0.0821\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)$, and the molar mass of oxygen is $\frac{32.0\text{ g}}{\text{mol}}$. **A** is incorrect and is obtained if the temperature is not converted to Kelvin before being substituting into the expression. **C** is incorrect and is obtained if one fails to remember that oxygen is a diatomic molecule. A value of $\frac{16.0\text{ g}}{\text{mol}}$ for M is used to obtain the number given in this option. **D** is incorrect and is obtained by finding n using $PV = nRT$ and then dividing by 20.0 L.

26. An atom with 6 protons, 6 neutrons, and 6 electrons gains an additional electron. What is the resulting charge of the atom?
- A. -7
 - B. -1
 - C. $+1$
 - D. $+7$

Correct Response: B. In this atom (ion), the electrons outnumber the protons by 1, so the atom (ion) has a net charge of -1 . **A** is incorrect since this represents the total number of electrons and does not take into consideration the presence of the 6 protons. **C** is incorrect since it is the electrons that outnumber the protons, rather than the protons outnumbering the electrons. **D** is incorrect since 6 protons are present and the charge from all of these ($+6$) is offset as a result of the presence of 7 electrons.

27. Which of the following quantum numbers describes the shape of an orbital?
- A. the magnetic quantum number, m_l
 - B. the angular momentum quantum number, l
 - C. the electron spin quantum number, m_s
 - D. the principal quantum number, n

Correct Response: B. The angular momentum quantum number is the integer that defines the shape of the orbital. For example $l = 0$ is for s orbitals that are spherical, and $l = 1$ is for p orbitals that are shaped like dumbbells. **A** is incorrect because the magnetic quantum number specifies the z -component of the angular momentum for a particular orbital. **C** is incorrect because the electron spin quantum number is either $\pm \frac{1}{2}$ depending on the direction the electron is spinning. **D** is incorrect because the principal quantum number defines the location of the energy level. (This is also called the shell number.)

28. How much energy is emitted when an electron in a hydrogen atom transitions from the $n_i = 6$ state to the $n_f = 2$ state?
- A. 7.27×10^{-19} J
- B. 6.06×10^{-19} J
- C. 4.84×10^{-19} J
- D. 1.36×10^{-19} J

Correct Response: C. The energy emitted as a hydrogen atom transitions from the $n_i = 6$ state to the $n_f = 2$ state and can be calculated as follows:

$$\Delta E = E_{\text{final}} - E_{\text{initial}}$$

$$\Delta E = \left(-\frac{R_H hc}{2^2} \right) - \left(-\frac{R_H hc}{6^2} \right)$$

$$\Delta E = -R_H hc \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

In these equations, R_H , the Rydberg constant, is $1.097 \times 10^7 \text{ m}^{-1}$, h is Planck's constant ($6.63 \times 10^{-34} \text{ J}\cdot\text{s}$), c is the speed of light ($3.00 \times 10^8 \text{ m/s}$), 6 is the initial energy level (n_i), and 2 is the final energy level (n_f). The negative value of ΔE indicates that energy is emitted. For this reason, the negative sign

is not included in the responses. **A** is incorrect and is calculated as $(2.18 \times 10^{-18} \text{ J}) \left(\frac{2}{6} \right)$. **B** is incorrect

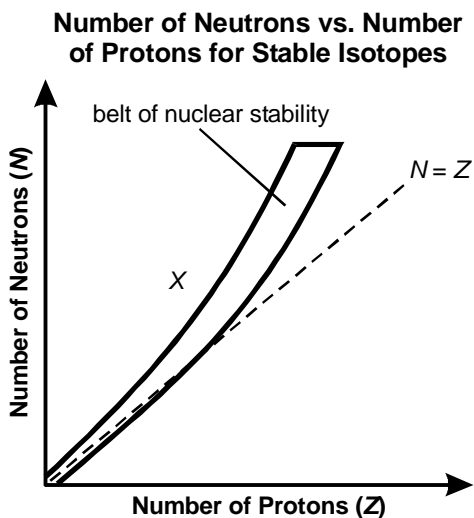
and is calculated as $(2.18 \times 10^{-18} \text{ J}) \left(\frac{10}{36} \right)$. **D** is incorrect and is calculated as $(2.18 \times 10^{-18} \text{ J}) \div ((2 \times 2) + (2 \times 6))$.

29. Which of the following is the correct electron configuration for a neutral iron atom?

- A. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4d^6$
- B. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
- C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^6$
- D. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3f^6$

Correct Response: B. Iron is a first-row transition element with 6 electrons in an outer $3d$ shell and 2 electrons in an outer $4s$ shell. The $1s^2 2s^2 2p^6 3s^2 3p^6$ is part of the electron configuration of the inner electrons that are not the valence electrons. **A** is incorrect because the iron's valence electrons are in the $3d$ shell (not the $4d$ shell, as indicated in $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4d^6$). **C** is incorrect because the $3d$ shell is filled before the $4p$ shell. **D** is incorrect because iron does not have f electrons and also because $3f$ electrons do not exist (only $5f$ and $6f$).

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

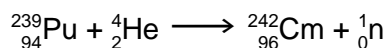


The isotope located in position X in the graph of nuclear stability shown above is most likely to undergo radioactive decay by emitting:

- A. alpha particles.
- B. gamma rays.
- C. positrons.
- D. beta particles.

Correct Response: D. Emission of a beta particle is the only option that would increase the atomic number of the isotope located in position X . Increasing the proton number would move the isotope located at position X closer to the belt of nuclear stability. **A** is incorrect since this would decrease the atomic number by 2, effectively moving the isotope located at position X farther from the belt of nuclear stability. **B** is incorrect since emission of gamma rays would not affect proton number. **C** is incorrect since positron emission would decrease atomic number by 1.

31. Use the equation below to answer the question that follows.



In order to overcome the electrostatic repulsion between alpha particles and the target nucleus, the reaction shown above is carried out using:

- A. high speeds.
- B. low temperatures.
- C. high pressure.
- D. low volumes.

Correct Response: A. High speeds are helpful for overcoming the electrostatic repulsion between alpha particles and the target nucleus because high speeds correspond with high particle velocity. With higher velocities, the alpha particles will be in close contact with the target nucleus for shorter periods of time. **B** is incorrect because lower temperatures will lead to lower particle velocities and increased interaction between the alpha particles and the target nucleus. **C** is incorrect because a high pressure of alpha particles would increase the interaction and repulsion between alpha particles and the target nucleus. **D** is incorrect because a low volume would also result in a high pressure and an increase in the interaction and repulsion between alpha particles and the target nucleus.

32. Given that the half-life of strontium-90 is 28.8 years, what mass of a 50.0 g sample of strontium-90 will remain after 144 years?
- A. 25.0 g
 - B. 6.25 g
 - C. 1.56 g
 - D. 0.391 g

Correct Response: C. The time interval of 144 years represents 5 half-lives for strontium-90, so the starting amount of 50.0 g will be halved 5 times. After 1 half-life, 25.0 g remain. After 2 half-lives, 12.5 g remain. After 3 half-lives, 6.25 g remain. After 4 half-lives, 3.125 g remain. After 5 half-lives, 1.56 g remain. **A** is incorrect because 25.0 g is the mass that remains after 1 half-life. **B** is incorrect because 6.25 g is the amount that remains after 3 half-lives. **D** is incorrect because 0.391 g is the amount that would remain after 7 half-lives.

33. As atomic number increases in a group of the periodic table, which of the following atomic properties decreases?
- A. electronegativity
 - B. metallic character
 - C. atomic mass
 - D. atomic radius

Correct Response: A. Electronegativity decreases going down a group (column) of the periodic table. For example, fluorine has a higher electronegativity than that of iodine. **B** is incorrect because metals are on the left of the periodic table and nonmetals are on the right. **C** is incorrect because atomic mass increases going down a periodic table group. **D** is incorrect because atomic radius increases going down a group as a result of the presence of electrons in orbitals that are farther from the nucleus.

34. Which of the following elements has an atomic radius closest to but smaller than that of sulfur?
- A. selenium
 - B. phosphorus
 - C. oxygen
 - D. chlorine

Correct Response: D. Chlorine is element 17, and sulfur is element 16. Chlorine has a slightly smaller radius than sulfur because of the extra proton in the nucleus; this extra proton causes the positively charged nucleus to hold the electrons more tightly, and the resulting atomic radius is smaller. **A** is incorrect because selenium is element 34 and so has an atomic radius considerably larger than that of sulfur. Selenium is larger and has 18 more protons and 18 more electrons than sulfur does. **B** is incorrect because phosphorus is element 15 and therefore has 1 less proton in the nucleus than sulfur does; because there is 1 less proton, the electrons are held less tightly to the positively charged nucleus and the resulting atomic radius is larger. **C** is incorrect because oxygen is element 8 and so is considerably smaller; oxygen has 8 fewer protons and 8 fewer electrons than sulfur does.

35. Which of the following series of halogens is arranged in order of increasing boiling point?
- A. I_2 , Br_2 , Cl_2 , F_2
 - B. Cl_2 , I_2 , F_2 , Br_2
 - C. F_2 , Cl_2 , Br_2 , I_2
 - D. Br_2 , F_2 , I_2 , Cl_2

Correct Response: C. The major factors affecting boiling point are molecular size and polarity, since both of these will increase the strength of intermolecular forces. All four halogen molecules in this question are non-polar, since there is a single bond between two atoms of the same element. Therefore, molecular size (mass) will be the predominant factor affecting boiling point. In the correct option, the molecules are arranged in order of increasing molecular mass: F_2 (38 g/mole), Cl_2 (70 g/mole), Br_2 (160 g/mole), and I_2 (254 g/mole). **A**, **B**, and **D** are all incorrect because the molecules are not arranged in order of increasing molecular size (mass).

36. The oxidation state of Mn in the permanganate ion (MnO_4^-) is:
- A. -8.
 - B. -1.
 - C. +2.
 - D. +7.

Correct Response: D. The oxidation state of oxygen in the permanganate ion is -2 , since -2 is generally the oxidation state of oxygen except in a fairly small number of cases, such as in peroxide compounds. If oxygen has an oxidation state of -2 , the oxidation state of Mn can be derived as follows, where -1 is the charge on the permanganate ion as a whole and x represents the oxidation state of Mn:

$$-1 = x + (-2)(4)$$

The 4 in this equation follows from the fact that 4 oxygen atoms are present in the permanganate ion. **A** is incorrect and can be calculated as $(-2)(4)$. **B** is incorrect and is the same as the charge on the permanganate ion. **C** is incorrect and is one of the common oxidation states of Mn.

37. Which of the following symbols represents the element silver?

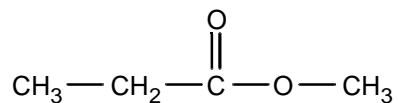
- A. Si
- B. Hg
- C. Sn
- D. Ag

Correct Response: D. Ag is the chemical symbol for silver. A is incorrect because Si is the chemical symbol for silicon. B is incorrect because Hg is the chemical symbol for mercury. C is incorrect because Sn is the chemical symbol for tin.

38. What is the IUPAC name for the molecule $\text{CH}_3\text{CH}_2\text{CHClCH}_3$?
- A. 2-chlorobutane
 - B. 3-chloropropane
 - C. 2-chloroethane
 - D. 3-chloropentane

Correct Response: A. The chain is 4 carbons in length, thus the name butane, and the chlorine is on the second carbon. As a result, this molecule is correctly named 2-chlorobutane. If the carbons were numbered in the other direction (left to right), the molecule would be 3-chlorobutane. This name is incorrect because IUPAC convention requires that the name with the lowest number be chosen. **B** is incorrect because the chain is four carbons in length, not three. Propane is used for chains that contain three carbons. **C** is incorrect because ethane is used for chains that contain two carbons. **D** is incorrect because pentane is used for chains that contain five carbons.

39. Use the diagram below to answer the question that follows.



Which of the following organic functional groups does the molecule shown above contain?

- A. hydroxyl
- B. ether
- C. carbonyl
- D. ester

Correct Response: D. The molecule shown above contains the $-\text{COOC}-$ linkage characteristic of esters. **A** is incorrect because hydroxyl groups are $-\text{OH}$ groups. These compounds are present in alcohols, for example. **B** is incorrect because ethers are defined by the presence of a $-\text{COC}-$ linkage. Dimethyl ether, CH_3OCH_3 , is an example of this type of compound. **C** is incorrect because a carbonyl group is simply a carbon double-bonded to an oxygen. These are present in aldehydes and ketones.

40. The complex ion $[\text{Pt}(\text{NH}_3)_4]^{2+}$ has a square planar structure. Which of the following substances, in which chloride ions replace ammonia as ligands, can exist as geometric isomers?
- A. $[\text{PtCl}(\text{NH}_3)_3]^{1+}$
 - B. $\text{PtCl}_2(\text{NH}_3)_2$
 - C. $[\text{PtCl}_3\text{NH}_3]^{1-}$
 - D. $[\text{PtCl}_4]^{2-}$

Correct Response: B. Isomers of $\text{PtCl}_2(\text{NH}_3)_2$ will exist because there are multiple possible arrangements of atoms with this same molecular formula. The isomers can be either "cis," in which both chloride ions and both ammonia ligands are on the same side of the molecule, or they can be "trans," in which one side of the molecule has both a chloride ion ligand and also an ammonia ligand. **A** is incorrect because the ammonia ligand is present three times. All possible locations for the chloride ion ligand are chemically indistinguishable. **C** is incorrect because the chloride ligand is present three times. All possible locations for the ammonia ligand are chemically indistinguishable. **D** is incorrect because the same chloride ion ligand occupies all four possible bonding positions, so no isomers exist for this structure.

41. What is the molar mass of the compound $\text{Zr}(\text{NO}_3)_4$?
- A. 259.2 g/mol
 - B. 297.2 g/mol
 - C. 339.2 g/mol
 - D. 612.8 g/mol

Correct Response: C. The molar mass of $\text{Zr}(\text{NO}_3)_4$ is 339.2 g/mol and is calculated as follows: $91.2 + 4(14.01) + 12(16.00) = 339.2$ g/mol, since 91.2 is the atomic mass of zirconium, 14.01 is the atomic mass of nitrogen, and 16.00 is the atomic mass of oxygen. **A** is incorrect because it was calculated as $91.2 + 4(14.01) + 7(16.00)$. **B** is incorrect because it was calculated as $91.2 + 14.01 + 12(16.00)$ —that is, it does not include a coefficient of 4 in front of the mass of nitrogen. **D** is incorrect because it was calculated as $[91.2 + 14.01 + 3(16.00)] \times 4$.

42. What is the percentage by mass of oxygen in $C_3H_5N_3O_9$?
- A. 7.045%
 - B. 37.18%
 - C. 63.41%
 - D. 84.20%

Correct Response: C. The percent by mass of oxygen in $C_3H_5N_3O_9$ is calculated by finding the mass of oxygen in 1 mole of $C_3H_5N_3O_9$, divided by the formula mass of $C_3H_5N_3O_9$, multiplied by 100%:

$$\frac{9(16.00)}{3(12.01) + 5(1.01) + 3(14.01) + 9(16.00)} \times 100\%$$

A is incorrect and is calculated by the omission of the 9 in the numerator of this expression. **B** is incorrect and is calculated by omission of the coefficients 9, 3, and 5 from the expression. **D** is incorrect and is approximated by replacing the 9 in the numerator of this expression with a 12.

43. A compound is found to be composed of 30.9% sodium, 47.7% chlorine, and 21.5% oxygen. What is the empirical formula of this compound?
- A. NaClO
 - B. NaClO₂
 - C. NaClO₃
 - D. NaClO₄

Correct Response: A. The correct answer is calculated by first assuming 100 grams of the compound. The number of grams of each element is then divided by the atomic mass of that element: $\frac{30.9 \text{ g Na}}{23.0 \text{ g}}$, $\frac{47.7 \text{ g Cl}}{35.5 \text{ g}}$, $\frac{21.5 \text{ g O}}{16.00 \text{ g}}$. In every case, the ratio that results is 1.34. Dividing through by the lowest ratio (which is 1.34, since all are 1.34) results in 1 (Na), 1 (Cl), and 1 (O) for the subscripts of the elements in the chemical formula. **B** is incorrect because it is calculated as $\frac{2(21.5 \text{ g O})}{16.0 \text{ g}}$. Dividing through by 1.34 results in 1 (Na), 1 (Cl), 2 (O) for the subscripts in the chemical formula. NaClO₂ is a chemically reasonable formula (sodium chlorite). **C** is incorrect because it is calculated as $\frac{3(21.5 \text{ g O})}{16.0 \text{ g}}$. Dividing through by 1.34 results in values of 1 (Na), 1 (Cl), and 3 (O) for the subscripts in the chemical formula. NaClO₃ is a chemically reasonable formula (sodium chlorate). **D** is incorrect because it is calculated as $\frac{4(21.5 \text{ g O})}{16.0 \text{ g}}$. Dividing through by 1.34 results in values of 1 (Na), 1 (Cl), and 4 (O) for the subscripts in the chemical formula. NaClO₄ is a chemically reasonable formula (sodium perchlorate).

44. A substance with an empirical formula of CH_2 has a molecular weight of 28.05 amu. What is the molecular formula for this substance?
- A. CH
 - B. CH_2
 - C. C_2H_4
 - D. C_3H_6

Correct Response: C. C_2H_4 has a molecular weight of 28.05 amu. It is calculated as $2(12.01 \text{ amu}) + 4(1.01 \text{ amu})$. It also has an empirical formula of CH_2 , since 2 CH_2 units compose C_2H_4 . **A** is incorrect because the empirical formula of CH is CH (not CH_2) and the molecular weight is 13.02 amu. Further, this is not a reasonable molecular formula, since carbon could not have an octet of electrons. **B** is incorrect because the molecular weight of CH_2 is 14.03 amu. Additionally, this is not a reasonable molecular formula, since carbon could not have an octet of electrons. **D** is incorrect because C_3H_6 has a molecular weight of 42.09 amu. This formula is chemically reasonable, and this compound is called propene.

45. In which of the following substances is the bonding between atoms ionic?

- A. P_2S_5
- B. HBr
- C. Al_2O_3
- D. P_4

Correct Response: C. The bonding in Al_2O_3 is between a metal and a non-metal and is therefore ionic. **A** is incorrect because phosphorus and sulfur are both non-metals. **B** is incorrect because the bond between hydrogen and bromine in HBr is covalent. **D** is incorrect because electrons are shared equally between the phosphorus atoms of phosphorus–phosphorus nonpolar covalent bonds.

46. Which of the following molecules has the strongest O — H bond?
- A. HClO_4
 - B. HClO_3
 - C. HClO_2
 - D. HClO

Correct Response: D. All HClO_x compounds in the options contain both oxygen and chlorine. Oxygen is the central atom in these structures. Oxygen is a highly electronegative atom and will pull electron density in its direction. Chlorine is also highly electronegative. HClO has the fewest number of electronegative atoms, and its structure is better understood if written as HOCl to reflect the fact that oxygen is the central atom. Thus, in HClO there is only 1 highly electronegative atom pulling electron density out of the O — H bond. **A** is incorrect because HClO_4 has the highest number of electronegative atoms pulling electron density out of the O — H bond. Oxygen is the central atom, and the structure is more correctly represented as H-O-ClO_3 , with 3 oxygens attached to the chlorine. **B** is incorrect because HClO_3 has 2 more electronegative atoms than HClO . **C** is incorrect because HClO_2 has 1 more electronegative atom than is present in HClO .

47. Use the diagram below to answer the question that follows.

Lewis Structure for Element "X"



Which of the following elements could the Lewis structure shown above represent?

- A. helium
- B. beryllium
- C. titanium
- D. germanium

Correct Response: D. Lewis structures show the valence electrons of an element. Because germanium has 2 electrons in the 4s orbital and 2 electrons in 4p orbitals, there should be a total of 4 electrons in the Lewis structure. **A** is incorrect because helium has 2 valence electrons, not 4, as are shown in the Lewis structure for Element X. **B** is incorrect because beryllium has 2 valence electrons, not 4. **C** is incorrect because titanium also has 2 valence electrons. Titanium has $4s^2 3d^2$ as the last 4 electrons of its electron configuration. Only the electrons with $n = 4$ are considered valence shell electrons. Electrons in d orbitals are not included in Lewis structures.

48. Which of the following molecules has trigonal planar molecular geometry?

- A. BF_3
- B. PBr_3
- C. ClF_4
- D. AsH_3

Correct Response: **A.** Boron trifluoride, BF_3 , has a trigonal planar geometry. Boron is in Group 13 and so is often considered electron-deficient in chemical structures. In BF_3 , boron is the central atom with 3 substituent fluorine atoms attached. There are no lone pairs of electrons on the central B atom, making the structure trigonal planar. **B** is incorrect because this structure is tetrahedral. Phosphorus, the central atom, is bonded to 3 bromine atoms, and P also has 1 lone pair of electrons that give the molecule a tetrahedral geometry. **C** is incorrect because this structure is tetrahedral. The chlorine atom is the central atom, and there are 4 fluorine atoms attached. This bonding arrangement gives the structure a tetrahedral geometry. **D** is incorrect because this structure is also tetrahedral. Arsenic is the central atom, and there are 3 hydrogen atoms attached and 1 lone pair of electrons on arsenic. This bonding arrangement gives the structure a tetrahedral geometry.

49. Which of the following molecules can form a hydrogen bond with water?
- A. HCl
 - B. H₂S
 - C. CH₃F
 - D. NH₃

Correct Response: D. Hydrogen bonds can occur in cases where hydrogen is covalently attached to fluorine, oxygen, or nitrogen. Hydrogen is covalently bound to nitrogen in ammonia, NH₃. **A** is incorrect, since neither fluorine, oxygen, nor nitrogen is present. **B** is incorrect, since neither fluorine, oxygen, nor nitrogen is present. **C** is incorrect because hydrogen is covalently bound to carbon in CH₃F. While fluorine is present in this compound, there is no hydrogen–fluorine bond.

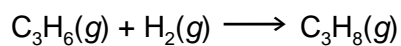
50. In which of the following substances are dipole-dipole forces the primary intermolecular force?
- A. PCl_5
 - B. CCl_4
 - C. BeCl_2
 - D. NCl_3

Correct Response: D. Nitrogen trichloride has a tetrahedral shape, and dipole-dipole forces are the primary intermolecular force. One of the 4 positions of the tetrahedron has a lone pair of electrons, and chlorine atoms occupy the other 3 positions. Because the molecule does not have a center of symmetry, it is polar, and dipole-dipole interactions are the predominant intermolecular force. **A** is incorrect because phosphorus pentachloride has a molecular geometry of trigonal bipyramidal, with no lone pairs. This molecule is therefore non-polar and so will have London dispersion forces as the primary intermolecular force. **B** is incorrect for the same reason, since carbon tetrachloride is tetrahedral, with no lone pairs of electrons. It is therefore non-polar with London dispersion forces as the primary intermolecular force. **C** is incorrect for the same reason, since beryllium chloride is a linear molecule, completely symmetrical with no lone pairs of electrons. It is therefore non-polar with London dispersion forces as the primary intermolecular force.

51. Methanol is considerably more soluble in water than 1-hexanol. Which of the following best explains this difference in solubility?
- A. Methanol contains fewer hydroxyl groups than 1-hexanol.
 - B. The alkyl group is longer in 1-hexanol than in methanol.
 - C. 1-hexanol is a significantly more polar molecule than methanol.
 - D. The greater number of hydrogen atoms in 1-hexanol increases the amount of hydrogen bonding.

Correct Response: B. The formula of methanol is CH_3OH . The formula of 1-hexanol is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$. As can be observed from the formulas, the alkyl group that is non-polar and contributes to insolubility is considerably longer in 1-hexanol than methanol. Because "like" dissolves "like" and because water is polar and the alkyl region is not, the alkyl region contributes to insolubility. **A** is incorrect because both formulas indicate the same number of hydroxyl groups. **C** is incorrect because 1-hexanol is considerably less polar due to the presence of the longer alkyl chain. **D** is incorrect because the only hydrogen atom that can interact via hydrogen bonding is on the hydroxyl group and both molecules have the same number (1) of hydroxyl groups.

52. Use the chemical equation below to answer the question that follows.

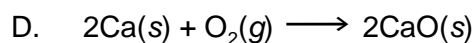
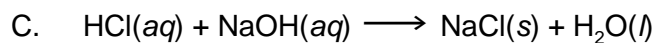
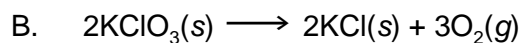
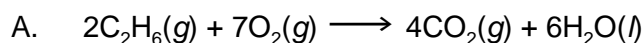


The reaction shown above is an example of which of the following types of chemical reaction?

- A. addition
- B. neutralization
- C. double displacement
- D. combustion

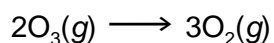
Correct Response: A. The hydrogens are "added" across the double bond present in propene, C_3H_6 , and the compound that is formed is propane, which is totally saturated. **B** is incorrect because neutralization reactions occur between acids and bases. **C** is incorrect because displacement is not occurring. Displacement occurs when two elements exchange positions (e.g., $\text{AB} + \text{CD}$ reacts to form $\text{AD} + \text{CB}$). **D** is incorrect because combustion reactions involve a reaction between hydrocarbons and oxygen to produce carbon dioxide and water.

53. Which of the following chemical equations is an example of a neutralization reaction?



Correct Response: C. The equation written in option C is an acid-base reaction. HCl, hydrochloric acid, is a strong acid with complete dissociation in water, and NaOH is a strong base with complete dissociation in water. The products, a salt and water, are characteristic of acid-base reactions. **A** is incorrect because the equation presented is a combustion reaction. **B** is incorrect because the equation presented is a decomposition reaction. **D** is incorrect because the equation presented is a synthesis or composition reaction.

54. Use the chemical equation below to answer the question that follows.



Which of the following compounds is a catalyst for the chemical reaction shown above?

- A. CH_4
- B. H_2SO_4
- C. CO_2
- D. CF_2Cl_2

Correct Response: D. Dichlorodifluoromethane is a coolant that belongs to the class of hydrocarbons known as chlorofluorocarbons, which are known for their role in depletion of the ozone layer. The reaction given corresponds to the conversion of ozone to molecular oxygen. **A** is incorrect because methane, a greenhouse gas, is not the catalyst for this reaction. **B** is incorrect because sulfuric acid, a component of acid rain, is not the catalyst for this reaction. **C** is incorrect because carbon dioxide, a greenhouse gas, is not the catalyst for this reaction.

55. Which of the following is one cause of eutrophication in aquatic ecosystems?
- A. an increase in the amount of acid precipitation
 - B. an increase in the concentration of heavy metals
 - C. an overabundance of nitrogen-containing compounds
 - D. an overabundance of dissolved oxygen

Correct Response: C. Eutrophication is a process in which the introduction of excessive nutrients into an aquatic system leads to excessive plant and algae growth. Agricultural fertilizers or other nitrogen-rich chemicals are often a source of the excess nutrients. When the plants and algae die, they are decomposed by aerobic organisms that reduce the oxygen levels in the aquatic system. **A** is incorrect because acid rain is not involved in eutrophication. In fact, acid rain would hinder plant and algae growth rather than promote it. **B** is incorrect because heavy metals can be detrimental to plants and algae. **D** is incorrect because eutrophication results in a shortage in the supply of oxygen in the aquatic system.

56. In a reaction between KBr and $\text{Pb}(\text{NO}_3)_2$, which of the following substances will precipitate out of solution?
- A. PbBr_2
 - B. K_2Pb
 - C. KNO_3
 - D. NO_3Br

Correct Response: A. The reaction between KBr and $\text{Pb}(\text{NO}_3)_2$ is a double replacement reaction, so the metals swap anion partners to form the products. The products of this reaction are KNO_3 and PbBr_2 . Further, lead bromide is insoluble based on solubility rules. **B** is incorrect because it is extremely rare for compounds to form between two metals. **C** is incorrect because, although KNO_3 is a product of this reaction, all compounds containing nitrates are soluble according to solubility rules. **D** is incorrect since this compound would result from combination of two anions of like charge.

57. Which of the following products is formed when benzene (C_6H_6) undergoes a substitution reaction with nitric acid (HNO_3)?
- A. $C_6H_5NO_2$
 - B. CNO_3
 - C. $C_6H_7NO_3$
 - D. HCO_3

Correct Response: **A.** Nitrobenzene ($C_6H_5NO_2$) is correct because one of the hydrogens of benzene is replaced with the NO_2 group as benzene undergoes a substitution reaction with nitric acid. **B** is incorrect because the benzene ring remains intact during the substitution reaction. **C** is incorrect because benzene loses the hydrogen that is substituted with the NO_2 group. The compound in this option has 1 extra hydrogen and 1 extra oxygen as compared to the correct answer. **D** is incorrect because the hydrogen of benzene is substituted with the NO_2 group. This option shows the nitrogen of nitric acid being swapped for carbon.

58. What is the pH of a buffer made from 0.25 M NH_3 and 0.50 M NH_4Cl at 25°C? (K_b for $\text{NH}_3 = 1.8 \times 10^{-5}$)
- A. 4.7
- B. 7.5
- C. 9.0
- D. 13

Correct Response: C. The relevant chemical equation is

$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \longrightarrow \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$, and the expression for K_b is given as follows.

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

If 1.8×10^{-5} is substituted as the value of K_b and if 0.25 M is used as the concentration of NH_3 and 0.5 M is used as the concentration of NH_4^+ , $[\text{OH}^-]$ can be calculated. Solving for $[\text{OH}^-]$ gives a value of 9.0×10^{-6} M. Using $\text{pOH} = -\log[\text{OH}^-]$ gives a value of 5.0 for the pOH. Using $\text{pOH} + \text{pH} = 14$, pH ($5 + \text{pH} = 14$) can be calculated. This gives $\text{pH} = 9$. **A** is incorrect and is calculated as the negative logarithm of 1.8×10^{-5} . **B** is incorrect since a value this close to 7 (neutral) is unlikely even for a weak base—like ammonia at this concentration. **D** is incorrect and is calculated using $\text{pOH} = -\log 0.25$ (the concentration of ammonia). This pH is then calculated using the equation $\text{pH} = 14 - 0.6$.

59. A chemist uses 22.0 mL of 0.10 M H_2SO_4 to neutralize 10.0 mL of NaOH. What is the concentration of the NaOH solution?
- A. 0.055 M
 - B. 0.11 M
 - C. 0.22 M
 - D. 0.44 M

Correct Response: D. To calculate the concentration of the NaOH solution, in units of molarity, the number of moles of NaOH and the volume of NaOH are both required. The volume of NaOH is given in the problem. At the equivalence point, the number of moles of acid is equal to the number of moles of base. The number of moles of acid is equal to $(0.10 \text{ mole H}_2\text{SO}_4 \text{ per liter})(0.022 \text{ liter})(2)$ because there are 2 moles of H^+ ion produced with dissociation of 1 mole of H_2SO_4 . The number of moles of acid, 4.4×10^{-3} , is then equivalent to the number of moles of base. The final step is to divide 4.4×10^{-3} moles by 0.010 liters (the volume of NaOH). **A** is incorrect. This number is obtained by calculating the number of moles of acid as $[(0.10 \text{ mole H}_2\text{SO}_4 \text{ per liter})(0.022 \text{ liter})/4]$ and then dividing the result by 0.0100 L (the volume of NaOH). **B** is incorrect and is obtained by calculating the number of moles of acid as $[(0.10 \text{ mole H}_2\text{SO}_4 \text{ per liter})(0.022 \text{ liter})/2]$ (dividing by 2 instead of multiplying by 2 as is needed) and then dividing the result by 0.0100 L (the volume of NaOH). **C** is incorrect and is obtained by calculating the number of moles of acid as $(0.10 \text{ mole H}_2\text{SO}_4 \text{ per liter})(0.022 \text{ liter})$, thereby omitting the coefficient of 2 that is needed. This value (0.0022 mole) is then divided by 0.0100 L NaOH (the volume of NaOH).

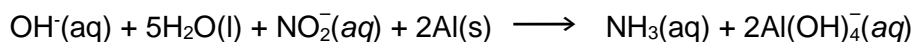
60. Use the incomplete unbalanced chemical equation below to answer the question that follows.



Nitrite ions (NO_2^-) and aluminum (Al) react in a basic environment as shown in the incomplete unbalanced equation above. When this oxidation-reduction reaction is balanced with the lowest set of whole-number coefficients, what is the coefficient for the hydroxide ion (OH^-) and on which side of the equation will it appear?

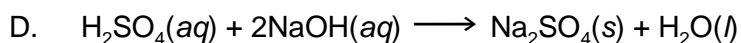
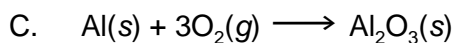
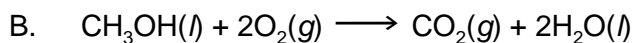
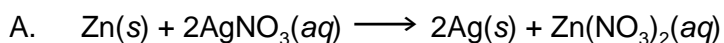
- A. 2, on the product side
- B. 1, on the product side
- C. 2, on the reactant side
- D. 1, on the reactant side

Correct Response: D. The coefficient for the hydroxide ion is 1, and it is on the reactant side, as shown by the complete balanced chemical equation below.



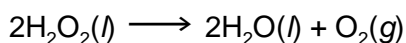
A is incorrect because the hydroxide ion appears on the left (reactant) side and has a coefficient of 1. **B** is incorrect because the hydroxide ion appears on the left (reactant) side of the equation, not on the product side of the equation. **C** is incorrect because the coefficient is 1 instead of 2.

61. Which of the following chemical equations is balanced correctly?



Correct Response: **A.** Both sides of the chemical equation have 1 zinc atom, 2 silver atoms, 2 nitrogen atoms, and 6 oxygen atoms. **B** is incorrect because there are 5 oxygen atoms on the left and 4 oxygen atoms on the right. **C** is incorrect because there are 2 aluminum atoms on the right and 1 on the left, and 6 oxygen atoms on the left and 3 on the right. **D** is incorrect because there are 4 hydrogen atoms on the left and 2 on the right, and 6 oxygen atoms on the left and 5 on the right.

62. Use the chemical equation below to answer the question that follows.



Hydrogen peroxide decomposes according to the equation shown above. What volume of oxygen gas, measured at standard temperature and pressure, will be produced from the decomposition of 50.0 g of hydrogen peroxide?

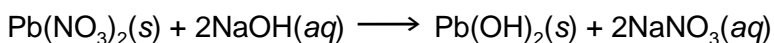
- A. 16.5 L
- B. 23.5 L
- C. 33.0 L
- D. 65.9 L

Correct Response: A. The correct answer is calculated by finding the number of moles of oxygen that will result from the decomposition of 50.0 g of hydrogen peroxide and then remembering that at standard temperature and pressure, 1 mole occupies 22.4 liters. The calculation is as follows.

$$50.0 \text{ g H}_2\text{O}_2 \times \frac{1 \text{ mol H}_2\text{O}_2}{34.01 \text{ g H}_2\text{O}_2} \times \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}_2} \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2}$$

B is incorrect and is calculated by using 32.0 L as the volume of 1 mole of oxygen gas. **C** is incorrect and is calculated by omitting the third factor in the expression (1 mole of oxygen divided by 2 moles hydrogen peroxide). **D** is incorrect and is calculated by using 2 moles of oxygen divided by 1 mole of hydrogen peroxide in the third factor of the expression.

63. Use the chemical equation below to answer the question that follows.



According to the reaction shown above, approximately how many grams of $\text{Pb}(\text{OH})_2$ will be formed when 100.0 g of $\text{Pb}(\text{NO}_3)_2$ is reacted with 250.0 mL of 2.00 M NaOH?

- A. 60.3 g
- B. 72.8 g
- C. 121 g
- D. 241 g

Correct Response: A. One hundred grams of lead nitrate ($\text{Pb}(\text{NO}_3)_2$) corresponds to 0.302 moles of $\text{Pb}(\text{NO}_3)_2$. Two hundred fifty milliliters of 2.00 M sodium hydroxide (NaOH) corresponds to 0.500 moles of NaOH. On the basis of the balanced chemical equation, 2 moles of NaOH react with 1 mole of $\text{Pb}(\text{NO}_3)_2$. This means that for 0.302 moles of $\text{Pb}(\text{NO}_3)_2$ to react completely, 0.604 moles of NaOH would be needed. Since there are only 0.500 moles of NaOH available, NaOH is the limiting reactant. Therefore, the number of grams of $\text{Pb}(\text{OH})_2$ is determined by the number of moles of NaOH and is calculated as follows.

$$0.500 \text{ mol NaOH} \times \frac{1 \text{ mol Pb}(\text{OH})_2}{2 \text{ mol NaOH}} \times \frac{241.22 \text{ g Pb}(\text{OH})_2}{1 \text{ mol Pb}(\text{OH})_2}$$

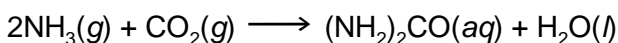
B is incorrect and is calculated based on an incorrect assumption that $\text{Pb}(\text{NO}_3)_2$ is the limiting reactant:

$$0.302 \text{ mol Pb}(\text{NO}_3)_2 \times \frac{1 \text{ mol Pb}(\text{OH})_2}{1 \text{ mol Pb}(\text{NO}_3)_2} \times \frac{241.22 \text{ g Pb}(\text{OH})_2}{1 \text{ mol Pb}(\text{OH})_2}$$

C is incorrect and is calculated without considering the reaction stoichiometry: $0.500 \text{ mol Pb}(\text{NO}_3)_2 \times 241.22 \text{ g Pb}(\text{OH})_2$. **D** is incorrect and is obtained through a mistake in dimensional analysis:

$$0.500 \text{ mol Pb}(\text{NO}_3)_2 \times \frac{2 \text{ mol NaOH}}{1 \text{ mol Pb}(\text{OH})_2} \times \frac{241.22 \text{ g Pb}(\text{OH})_2}{1 \text{ mol Pb}(\text{OH})_2}$$

64. Use the chemical equation below to answer the question that follows.



A chemist reacts 258 g of NH_3 with 425 g of CO_2 and produces 298 g $(\text{NH}_2)_2\text{CO}$ according to the reaction shown above. What is the percent yield for this reaction?

- A. 16.4%
- B. 32.8%
- C. 51.4%
- D. 65.5%

Correct Response: D. Two hundred fifty-eight grams of NH_3 equals 15.1 moles of NH_3 , and 425 g of CO_2 equals 9.66 moles of CO_2 . On the basis of the balanced chemical equation shown, 2 moles of NH_3 are required to react with 1 mole of CO_2 . This means that for 9.66 moles of CO_2 to react completely, 19.3 moles of NH_3 would be needed. Since there are only 15.1 moles of NH_3 available, it is the limiting reactant. As the limiting reactant, the amount of NH_3 will determine how much product can be theoretically formed:

$$258 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{1 \text{ mol } (\text{NH}_2)_2\text{CO}}{2 \text{ mol NH}_3} \times \frac{60.07 \text{ g } (\text{NH}_2)_2\text{CO}}{1 \text{ mol } (\text{NH}_2)_2\text{CO}} = 455 \text{ g } (\text{NH}_2)_2\text{CO}$$

The value of 455 g $(\text{NH}_2)_2\text{CO}$ represents the theoretical yield of the product. In actuality, 298 g of $(\text{NH}_2)_2\text{CO}$ were formed, so the percent yield is $\frac{298 \text{ g } (\text{NH}_2)_2\text{CO}}{455 \text{ g } (\text{NH}_2)_2\text{CO}} \times 100\%$, or 65.5%. **A** is incorrect

because the theoretical yield of product was calculated by using the inverse of this factor:

$$\frac{1 \text{ mol } (\text{NH}_2)_2\text{CO}}{2 \text{ mol NH}_3} \text{ (an error in which the 2 moles of NH}_3 \text{ are in the numerator instead of the}$$

denominator). **B** is incorrect and was calculated mostly in the same way as in the correct answer,

except that the $\frac{1 \text{ mol } (\text{NH}_2)_2\text{CO}}{2 \text{ mol NH}_3}$ factor was not included in calculation of the theoretical yield of

product. **C** is incorrect and was calculated based on the erroneous assumption that CO_2 is the limiting reagent:

$$425 \text{ g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.0 \text{ g CO}_2} \times \frac{1 \text{ mol } (\text{NH}_2)_2\text{CO}}{1 \text{ mol CO}_2} \times \frac{60.07 \text{ g } (\text{NH}_2)_2\text{CO}}{1 \text{ mol } (\text{NH}_2)_2\text{CO}} = 580 \text{ g } (\text{NH}_2)_2\text{CO}$$

Thus, in this case, $\frac{298 \text{ g } (\text{NH}_2)_2\text{CO}}{580 \text{ g } (\text{NH}_2)_2\text{CO}} \times 100\%$ is 51.4%.

65. How many grams of NaCl are contained in 50.0 mL of a 1.75 M NaCl solution?

- A. 35.0 g
- B. 28.6 g
- C. 5.12 g
- D. 0.875 g

Correct Response: C. The number of grams NaCl can be calculated as

$\frac{1.75 \text{ mol NaCl}}{\text{L}} \times 0.050 \text{ L} \times \frac{58.5 \text{ g NaCl}}{1 \text{ mol NaCl}}$. Molarity is moles of solute per liter of solution. Multiplying molarity by the volume gives the number of moles of NaCl, and then multiplying by the molar mass gives the number of grams of NaCl. **A** is incorrect and is calculated as $\frac{1.75 \text{ mol NaCl}}{\text{L}} \div 0.050 \text{ L}$. **B** is incorrect and is calculated by dividing 50.0 ml NaCl by 1.75. **D** is incorrect and is calculated as $\frac{1.75 \text{ mol NaCl}}{\text{L}} \times 0.050 \text{ L}$.

66. Which of the following pairs of gas samples would have closest to the same number of particles?
- A. 4.0 g of O_2 and 4.0 g of N_2
 - B. 73.1 g of SF_6 and 1.0 g of H_2
 - C. 8.8 g of CO_2 and 10.4 g of C_3H_8
 - D. 10.8 g of Ne and 36.0 g of Kr

Correct Response: B. Gas pairs with the same number of moles will each have the same number of particles because there are 6.02×10^{23} particles per 1 mole. There are 0.500 mol of SF_6 and 0.50 mol of H_2 in this sample. **A** is incorrect because there is 0.12 mol of O_2 and 0.14 mol N_2 in this sample. **C** is incorrect because there is 0.2 mol of CO_2 and 0.24 mol of C_3H_8 in this sample. **D** is incorrect because there is 0.535 mol of Ne and 0.43 mol of Kr in this sample.

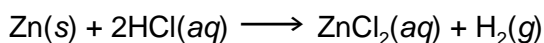
67. What is the pH of a 0.22 M hypochlorous acid (HOCl) solution? ($K_a = 3.5 \times 10^{-7}$)
- A. 0.66
 - B. 3.56
 - C. 5.80
 - D. 6.46

Correct Response: B. $[\text{H}_3\text{O}^+]$ is needed in order to find pH, because $\text{pH} = -\log[\text{H}_3\text{O}^+]$. To find $[\text{H}_3\text{O}^+]$, we write $\text{HOCl}(aq) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OCl}^-(aq)$. We can then use the expression for K_a to find $[\text{H}_3\text{O}^+]$:

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

Substituting 3.5×10^{-7} for K_a , 0.22 M for $[\text{HOCl}]$, x for $[\text{H}_3\text{O}^+]$ and x for $[\text{OCl}^-]$ and then solving for x , we find that $[\text{H}_3\text{O}^+] = 2.77 \times 10^{-4}$ M. This value can then be used to calculate pH ($\text{pH} = -\log(2.77 \times 10^{-4}) = 3.56$). The $[\text{H}_3\text{O}^+]$ is equal to the $[\text{OCl}^-]$, since both are formed in equimolar amounts in the dissociation of HOCl. **A** is incorrect and was calculated using the value of 0.22 M for $[\text{H}_3\text{O}^+]$. **C** is incorrect and was calculated by dividing K_a by 0.22 and using this as the $[\text{H}_3\text{O}^+]$. **D** is incorrect and was calculated by equating K_a with $[\text{H}_3\text{O}^+]$.

68. Use the chemical equation below to answer the question that follows.



Which of the following changes will increase the rate of the reaction shown above?

- A. decreasing the temperature of the reaction
- B. using an open beaker as the reaction vessel
- C. decreasing the initial concentration of HCl
- D. using zinc powder as a reactant

Correct Response: D. Using powdered zinc as the reactant will increase the surface area that is exposed and will therefore increase the rate of the reaction. **A** is incorrect, since decreasing the temperature of the reaction would decrease the number of effective collisions between reactant molecules. **B** is incorrect, since using an open beaker as the reaction vessel would not affect the rate of reaction; rather, it would simply allow for the escape of hydrogen gas into the atmosphere. **C** is incorrect, since decreasing the initial concentration of HCL would decrease the number of collisions between HCl and zinc (reaction rates increase with increasing concentration).

69. Use the chemical equation below to answer the question that follows.



Why does the reaction rate for the combustion of glucose increase with the addition of KClO_3 ?

- A. The presence of KClO_3 lowers the activation energy of the reaction.
- B. The decomposition of KClO_3 increases the concentration of a combustion reactant.
- C. The decomposition of KClO_3 yields a large quantity of heat.
- D. The KCl formed from the decomposition of KClO_3 is very reactive.

Correct Response: B. In the combustion of glucose, oxygen (O_2) reacts with glucose to form carbon dioxide and water. The chemical equation shows that oxygen is a product of the decomposition of KClO_3 . Increasing the concentration of one or more reactants results in an increase in the reaction rate. **A** is incorrect because KClO_3 is not a catalyst. Catalysts lower activation energy. **C** is incorrect because heat is not given off during this reaction. **D** is incorrect because the physical and chemical properties of KCl are the same regardless of its source.

70. Use the table below to answer the question that follows.

Experiment	Initial [A ₂] (M)	Initial [B] (M)	Initial Rate (M/s)
1	0.25	0.10	2.8×10^{-2}
2	0.25	0.30	8.3×10^{-2}
3	0.25	0.40	1.1×10^{-1}
4	0.50	0.10	5.5×10^{-2}
5	0.75	0.30	2.5×10^{-1}

The table above shows initial concentrations and reaction rates for the hypothetical reaction $A_2 + 2B \longrightarrow 2AB$. Using these data, which of the following is the rate law for this reaction?

- A. rate = $k[A_2]$
- B. rate = $k[A_2][B]^2$
- C. rate = $k[A_2][B]$
- D. rate = $k[A_2]^3[B]$

Correct Response: C. A comparison of the results from Experiments 1 and 4 indicates that when the concentration of A is doubled, the reaction rate is also doubled. This result indicates that the reaction is first-order in A₂, meaning that the concentration of A₂ ([A₂]) is raised to the first power in the rate expression. A comparison of the results from Experiments 1 and 2 indicates that when the concentration of B is tripled, the reaction rate is also tripled. This result indicates that the reaction is also first order in B. **A** is incorrect because this expression implies that the reaction rate does not depend on the concentration of B (which is clearly not the case, based on the data). **B** is incorrect because the ratio of concentration to reaction rate is 1:1 in both A and B. **D** is also incorrect because the reaction rate doubles as the concentration of A is doubled (i.e., a 1:1 ratio).

71. Use the table below to answer the question that follows.

Experiment	Initial $[\text{H}_2\text{O}_2]$ (M)	Initial Rate (M/min)
1	1.50×10^{-2}	1.59×10^{-5}
2	3.00×10^{-2}	3.18×10^{-5}
3	4.50×10^{-2}	4.77×10^{-5}
4	7.50×10^{-2}	7.95×10^{-5}

Using the data for the decomposition of H_2O_2 shown above, what is the reaction rate when $[\text{H}_2\text{O}_2] = 6.50 \times 10^{-1}$?

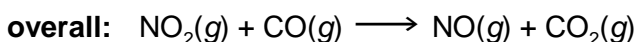
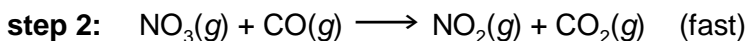
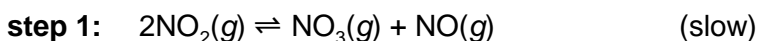
- A. $6.36 \times 10^{-5} M/\text{min}$
- B. $6.89 \times 10^{-4} M/\text{min}$
- C. $4.60 \times 10^{-2} M/\text{min}$
- D. $6.50 \times 10^{-1} M/\text{min}$

Correct Response: B. The first step in determining the reaction rate for the specified concentration of H_2O_2 is to determine the rate constant, k . This is accomplished using the experimental data provided and the rate equation for the reaction: $\text{rate} = k[\text{H}_2\text{O}_2]^n$. The value of n is determined by evaluating the experimental data. Data from experiments 1 and 2 show that when the $[\text{H}_2\text{O}_2]$ is doubled, the initial rate doubles. This corresponds to a value of 1 for n . The values for initial rate and initial $[\text{H}_2\text{O}_2]$ for any given experiment can be obtained from the table and substituted into the equation $k = \frac{\text{initial rate}}{[\text{H}_2\text{O}_2]}$. This

calculation yields a value of $1.06 \times 10^{-3} \text{min}^{-1}$ for k . The calculated value of k along with the specified $[\text{H}_2\text{O}_2]$ can then be substituted into the equation, $\text{rate} = k[\text{H}_2\text{O}_2]$. Multiplying $1.06 \times 10^{-3} \text{min}^{-1} \times 6.50 \times 10^{-1} M$ by gives a reaction rate of $6.89 \times 10^{-4} M/\text{min}$. **A** is incorrect and is obtained using a k value of $9.78 \times 10^{-5} \text{min}^{-1}$ in the rate equation. **C** is incorrect and is obtained using a k value of $7.06 \times 10^{-2} \text{min}^{-1}$ in the rate equation. **D** is incorrect and is obtained by omitting k from the rate equation, $\text{rate} = [\text{H}_2\text{O}_2]$.

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

The proposed mechanism for the reaction between NO_2 and CO at temperatures less than 600 K is shown below.



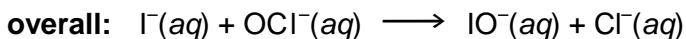
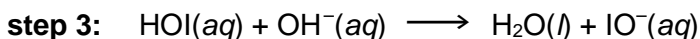
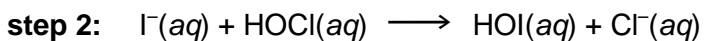
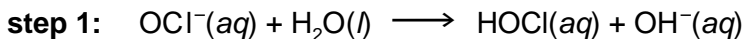
Given this information, which of the following rate laws best represents this reaction mechanism?

- A. rate = $k[\text{CO}]$
- B. rate = $k[\text{NO}_2]^2$
- C. rate = $k[\text{NO}_3][\text{CO}]$
- D. rate = $k[\text{NO}_2]^2[\text{CO}]$

Correct Response: B. This rate law is correct because $k[\text{NO}_2]^2$ corresponds to the slow step of the reaction. The slow step of the reaction is the one that most strongly affects the rate law. Step 2 and the overall equation are not included when writing the rate law. The "2" in the rate law comes from the fact that there is a coefficient of 2 in front of NO_2 in Step 1. **A** is incorrect because the expression for rate must include the reactants in the rate-limiting (slow) step. **C** is incorrect because this expression is based on Step 2, which is the fast step, not the slow step. **D** is incorrect because this expression for the rate law includes some of the reactants in the overall reaction but not the reactants in the slow step.

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

The proposed mechanism for the reaction between I^- and OCl^- is shown below.

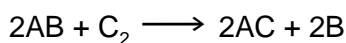


Given the reaction mechanism shown above, how many intermediates are involved in the reaction between I^- and OCl^- ?

- A. 1
- B. 2
- C. 3
- D. 4

Correct Response: C. The three intermediates are HOCl, OH^- , and HOI. These species appear both on the product side of one step and as reactants in a following step. **A** is incorrect because it does not include two of the intermediates. **B** is incorrect because it does not include one of the intermediates. **D** is incorrect because there are only three intermediates.

74. Use the chemical equation below to answer the question that follows.



Experimental data have shown that the reaction above has the following experimental rate law.

$$\text{rate} = k[AB]^2[C_2]$$

What is the overall order for this reaction?

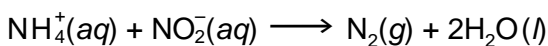
- A. first order
- B. second order
- C. third order
- D. fourth order

Correct Response: C. The order of the reaction is determined by adding the superscripts in the rate law. In this case, the number is 3 (2 + 1). The "2" is the superscript of the [AB] term in the rate law, and the "1" is the superscript on the [C₂] term in the rate law. **A** is incorrect because the rate law contains the concentration of more than one substance. **B** is incorrect because the total of the superscripts is more than 2. **D** is incorrect because the total of the superscripts is 3, not 4.

75. Use the table below to answer the question that follows.

Experiment	Initial $[\text{NH}_4^+]$ (M)	Initial $[\text{NO}_2^-]$ (M)	Initial Rate (M/s)
1	0.08	0.065	1.40×10^{-6}
2	0.16	0.065	2.80×10^{-6}
3	0.16	0.26	1.12×10^{-5}

The table above shows rate data for the following reaction.



Using these data, what is the value of the rate constant for this reaction?

- A. $1.04 \times 10^{-3} M^{-1}s^{-1}$
- B. $2.70 \times 10^{-4} M^{-1}s^{-1}$
- C. $1.21 \times 10^{-7} M^{-1}s^{-1}$
- D. $7.28 \times 10^{-9} M^{-1}s^{-1}$

Correct Response: B. The rate constant is obtained by substituting appropriate values in the rate law expression for this reaction and then solving for k . The rate law expression for this reaction is $\text{rate} = k[\text{NH}_4^+]^n[\text{NO}_2^-]^m$. The values of n and m are determined by evaluating the experimental data. Data from experiments 1 and 2 show that when the concentration of $[\text{NH}_4^+]$ is doubled, the initial rate doubles. This corresponds to a value of 1 for n . Similarly, data from experiments 2 and 3 show that when the concentration of $[\text{NO}_2^-]$ is increased four-fold, the initial rate increases by a factor of four. This corresponds to a value of 1 for m . The values for initial rate, $[\text{NH}_4^+]$, and $[\text{NO}_2^-]$ for any given experiment can be obtained from the table and substituted into the equation $k = \frac{\text{initial rate}}{[\text{NH}_4^+][\text{NO}_2^-]}$. **A** is incorrect and is

obtained by multiplying a mis-keyed value for the $[\text{NH}_4^+]$ from experiment 2 (0.016) by the $[\text{NO}_2^-]$ from experiment 2. **C** is incorrect and was obtained by multiplying values for initial rate and $[\text{NH}_4^+]$ from experiment 1. **D** is incorrect and was obtained by multiplying values for initial rate, $[\text{NH}_4^+]$, and $[\text{NO}_2^-]$ from experiment 1.

76. Use the entropy equation below to answer the question that follows.

$$S = k \times \log W$$

In the entropy equation shown, S represents entropy, k is the Boltzmann constant, and W represents the number of ways particles can be arranged. Given this information, which of the following best describes what happens to the variables in the equation above as a compound undergoes a phase transition from solid to liquid to gas?

- A. The value of S decreases.
- B. The value of k increases.
- C. The values of S , k , and W decrease.
- D. The value of W increases.

Correct Response: D. The equation $S = k \times \log W$ was derived by Boltzmann and expresses the relationship between entropy and the number of ways particles can be arranged. Because gas and liquid particles can be arranged in more ways than solid particles can, W will increase during the transition of solids to liquids to gases. **A** is incorrect, since the overall entropy (S) will increase because the particles of liquids are not arranged in a regular fashion. **B** is incorrect because k is a constant. **C** is incorrect because the constant k will not change and S and W will both increase.

77. A system undergoes an exothermic process releasing 2.5 kJ of heat. During this process, the system does 0.5 kJ of work. According to the first law of thermodynamics, what is the change in the system's internal energy?
- A. -3.0 kJ
 - B. -2.0 kJ
 - C. 2.0 kJ
 - D. 3.0 kJ

Correct Response: A. The change in the system's internal energy is equal to q (heat) + w (work). In this case Q is negative (-2.5 kJ) because the process is exothermic, and w is negative (-0.5 kJ) because the system does work on its surroundings. Therefore, the system's internal energy is calculated as $-2.5 \text{ kJ} - 0.5 \text{ kJ}$. **B** is incorrect and is calculated as $-2.5 \text{ kJ} + 0.5 \text{ kJ}$. **C** is incorrect and is calculated as $2.5 \text{ kJ} - 0.5 \text{ kJ}$. **D** is incorrect and is calculated as $2.5 \text{ kJ} + 0.5 \text{ kJ}$.

78. Given that the specific heat of copper is $0.385 \text{ J/g}\cdot\text{K}$, how much heat is required to raise the temperature of 50.0 g of copper from 25.0°C to 100°C ?
- A. 1.44 kJ
 - B. 1.93 kJ
 - C. 6.70 kJ
 - D. 7.18 kJ

Correct Response: A. The amount of heat required to raise the temperature of 50.0 g of copper from 25.0°C to 100°C is calculated as $q = ms\Delta T [(50.0\text{g}) (0.385 \text{ J/g}\cdot\text{K})(75\text{K})]$. The temperature difference is calculated by first converting the temperatures to Kelvin and then finding the difference ($373 - 298\text{K}$). **B** is incorrect and can be calculated as $[(50.0\text{g}) (0.385 \text{ J/g}\cdot\text{K})(100\text{K})]$. **C** is incorrect and can be calculated as $[(50.0\text{g}) (0.385 \text{ J/g}\cdot\text{K})(348\text{K})]$. **D** is incorrect and can be calculated as $[(50.0\text{g}) (0.385 \text{ J/g}\cdot\text{K})(373\text{K})]$.

79. When 1.0×10^2 g of an unknown metal at 80.0°C is placed in a calorimeter containing 1.0×10^2 g of water, the temperature of the water rises from 20.0°C to 25.0°C . Given that the specific heat of water is $4.184 \text{ J/g}\cdot\text{K}$, what is the specific heat of the metal?
- A. $0.26 \text{ J/g}\cdot\text{K}$
 - B. $0.38 \text{ J/g}\cdot\text{K}$
 - C. $1.52 \text{ J/g}\cdot\text{K}$
 - D. $1.90 \text{ J/g}\cdot\text{K}$

Correct Response: B. The specific heat of the metal may be calculated by assuming that heat gained by the water was lost by the metal. If we let q represent the amount of heat that was transferred from the water in the calorimeter to the metal, the mathematical expression that results is

$$m_w s_w \Delta T = m_m s_m \Delta T$$

where m represents mass, s represents specific heat, and ΔT is the temperature change. The subscripts in the formula are w (indicating water) and m (indicating the metal). Since heat is calculated as $ms\Delta T$, the left side of the expression represents the amount of heat lost by the water, and the right side represents the amount of heat gained by the metal. Using values for these variables from this

example, the expression becomes $100.\text{g} \left(4.184 \frac{\text{J}}{\text{g}\cdot\text{K}} \right) (5 \text{ K}) = 100.\text{g}(s_m) (353.15 - 298.15 \text{ K})$. Solving

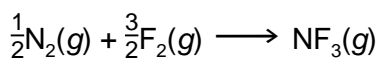
for the specific heat of the metal gives $0.38 \text{ J/g}\cdot\text{K}$, as given in option B. The temperature change could have been determined without first converting to Kelvin because a change of one degree Celsius is equivalent to a change of one Kelvin. **A** is incorrect because $0.26 \text{ J/g}\cdot\text{K}$ is obtained using ΔT of 80 K on the right-hand side of the equation. **C** is incorrect because $1.52 \text{ J/g}\cdot\text{K}$ is obtained using $[(4.184 \text{ J/g}\cdot\text{K})(100. \text{g})]/273.15 \text{ K}$. **D** is incorrect because $1.90 \text{ J/g}\cdot\text{K}$ is obtained using $[(4.184 \text{ J/g}\cdot\text{K})(100. \text{g})]/220 \text{ K}$.

80. A constant pressure calorimeter with negligible heat capacity contains 200.0 g of H₂O at 25.00°C. When 12.3 g of KClO₃ is dissolved in the H₂O, the temperature of the solution in the calorimeter drops to 20.05°C. Assuming the specific heat of the solution is 4.184 J/g•K, what is the heat of solution of KClO₃?
- A. 0.255 kJ/mol
 - B. 0.337 kJ/mol
 - C. 44.0 kJ/mol
 - D. 168 kJ/mol

Correct Response: C. The total heat change, q , in the constant pressure calorimeter, measured in Joules, is calculated as $ms\Delta T$, where m is the mass, s is the specific heat, and ΔT is the change in temperature. Since 12.3 g of KClO₃ was dissolved in 200.0 g of water, the total mass is 212.3 g. The value of s , the specific heat of the solution, is given in the problem as 4.184 J/g•K. The change in temperature is 4.95 K, since the calorimeter started with a temperature of 25.00°C and dropped to 20.05°C at the end of the experiment and because a change of one degree Celsius is equivalent to a change of one Kelvin. Once q is calculated, it is divided by 1,000 to convert joules to kilojoules and is then divided by the number of moles of KClO₃, which is 0.100. **A** is incorrect and was calculated using $ms\Delta T$, but the mass of the water was left out of this expression and a value of 12.3 g was used for mass. Further, the number of moles of KClO₃ was not considered. **B** is incorrect and was calculated by converting incorrectly from joules to kilojoules and omitting the step of dividing by moles of KClO₃. **D** is incorrect; 168 kJ/mol can be obtained by using incorrect values for mass (200.0 g) and ΔT (5.00 K) and dividing the product of ms by ΔT .

81. Use the table and chemical equation below to answer the question that follows.

Bond	Bond Enthalpy (kJ/mol)
N — N	159
N = N	418
N ≡ N	941
F — F	153
N — F	272



Based on the bond enthalpies and chemical equation shown above, what is the best estimate for the enthalpy of formation for 1 mol of NF_3 ?

- A. -816 kJ/mol
- B. -507 kJ/mol
- C. -387 kJ/mol
- D. -116 kJ/mol

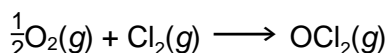
Correct Response: D. The enthalpy of formation is calculated by summing the bond enthalpies for the bonds that are broken and then subtracting the enthalpy of formation for the bonds that are formed. The numbers in the table are given in units per mol, and this is taken into account in the calculations. The correct equation is

$$\frac{1}{2}(941 \text{ kJ/mol}) + \frac{3}{2}(153 \text{ kJ/mol}) - 3(272 \text{ kJ/mol}) = -116 \text{ kJ/mol}$$

The value of 941 kJ/mol is correct for N_2 because the molecule contains a triple bond. **A** (-816 kJ/mol) is incorrect since it takes into consideration only the three nitrogen-fluorine bonds [-3(272 kJ/mol)]. **B** is incorrect, since it was calculated as $1/2(159 \text{ kJ/mol}) + 3/2(153 \text{ kJ/mol}) - 3(272 \text{ kJ/mol})$. **C** is incorrect since it was calculated as [-3(272 kJ/mol) + $1/2(941 \text{ kJ/mol}) + 3/2(153 \text{ kJ/mol})$].

82. Use the table and chemical equation below to answer the question that follows.

Bond	Bond Enthalpy (kJ/mol)
O — O	138
O = O	498
Cl — Cl	243



The standard enthalpy of formation of OCl_2 is 105 kJ/mol. Based on the bond enthalpies and chemical equation shown above, what is the best estimate for the bond enthalpy for an O — Cl bond?

- A. 104 kJ/mol
- B. 194 kJ/mol
- C. 318 kJ/mol
- D. 387 kJ/mol

Correct Response: B. The enthalpy of formation is calculated by summing the bond enthalpies for the bonds that are broken and then subtracting the enthalpy for the bonds that are formed. The numbers in the table are given in units per mol, and this is taken into account in the calculations. The correct equation is

$$\frac{1}{2}(498 \text{ kJ/mol}) + 243 \text{ kJ/mol} - 2x = 105 \text{ kJ/mol}$$

where x is the bond enthalpy for an O — Cl bond. The coefficient of 2 in front of x is needed because there are 2 O — Cl bonds in OCl_2 . Solving for x , we obtain the value given in B. **A** is incorrect and was calculated using the value of 138 kJ/mol for the bond enthalpy of O_2 . This is incorrect because O_2 has a double bond in the correct Lewis structure. **C** is incorrect and was calculated by omitting the coefficient of 1/2 in front of 498 kJ/mol in the expression above. This coefficient is necessary because it is present in the balanced chemical equation. **D** is incorrect and was calculated without the coefficient of 2 in front of the x in the expression given above.

83. The bond energy for oxygen gas (O_2) is 499 kJ/mol. Based on this information, what is the standard enthalpy of formation of gaseous oxygen atoms (O)?
- A. 0.00 kJ/mol
 - B. 250 kJ/mol
 - C. 499 kJ/mol
 - D. 998 kJ/mol

Correct Response: B. The energy required to break the O_2 bond is equal to the energy released when an O_2 bond forms from two oxygen atoms. Therefore, 499 kJ/mol = sum of the heats of formation of the products (two individual O atoms) minus the heat of formation of the reactant (O_2). The equation is as follows: 499 kJ/mol = 2(x) + 0, where x equals the heat of formation of the individual oxygen atoms and zero is the heat of formation of O_2 , a substance in its elemental state. **A** is incorrect and is the heat of formation of diatomic oxygen. **C** is incorrect and is the bond energy for oxygen gas. **D** is incorrect and is twice the bond energy for oxygen gas.

84. Use the table below to answer the question that follows.

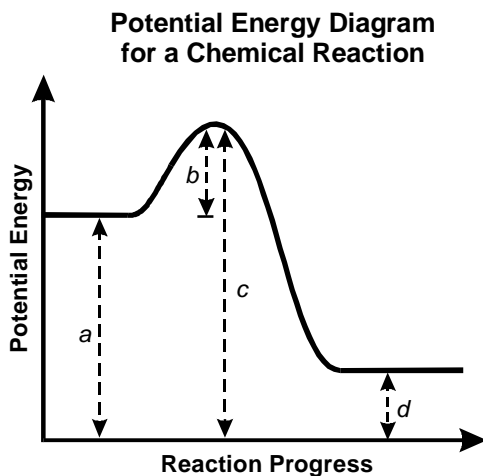
Reaction	Chemical Equation	ΔH° (kJ)	ΔS° (J/K)
1	$2\text{SO}_3(g) \longrightarrow 2\text{SO}_2(g) + \text{O}_2(g)$	198	188
2	$2\text{AsF}_3(l) \longrightarrow 2\text{As}(s) + 3\text{F}_2(g)$	-1643	316
3	$\text{N}_2\text{O}(g) + 2\text{H}_2\text{O}(l) \longrightarrow \text{NH}_4\text{NO}_3(s)$	36	-446
4	$4\text{Fe}(s) + 3\text{O}_2(g) \longrightarrow 2\text{Fe}_2\text{O}_3(s)$	-1650	-549

Which of the reactions shown in the table above is spontaneous only at sufficiently high temperatures?

- A. reaction 1
- B. reaction 2
- C. reaction 3
- D. reaction 4

Correct Response: A. Reactions are spontaneous when Gibbs free energy is negative. Gibbs free energy is equal to $\Delta H^\circ - T\Delta S^\circ$, where the ΔH° term represents the enthalpy change, the ΔS° term represents the entropy change, and T represents temperature. If T is high, the second term in the expression for Gibbs free energy will be greater than the first term, and the overall Gibbs free energy will be negative. **B** is incorrect because the enthalpy term is negative and has a greater magnitude than the entropy term. Gibbs free energy for this reaction will be negative at a range of temperatures. **C** is incorrect because the Gibbs free energy for this expression will be positive at a range of temperatures, since the entropy term is negative. **D** is incorrect because this reaction will have a positive Gibbs free energy at high temperature.

85. Use the diagram below to answer the question that follows.

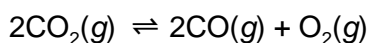


Which of the following expressions best represents the change in enthalpy for the reaction in the potential energy diagram shown above?

- A. $b - c$
- B. $c - b$
- C. $a - d$
- D. $d - a$

Correct Response: D. The change in enthalpy for a reaction is obtained by taking the potential energy of the products and subtracting the potential energy of the reactants. In this case, d represents the potential energy of the products and a represents the potential energy of the reactants. **A** is incorrect and is equal to the energy of the reactants with a minus sign in front. **B** is incorrect and is equal to the energy of the reactants. **C** is incorrect and represents the energy of the reactants minus the energy of the products.

86. Use the chemical equation below to answer the question that follows.

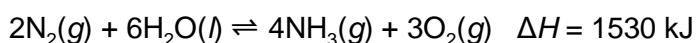


Which of the following changes would affect the value of the equilibrium constant for the reaction shown above?

- A. increasing the pressure
- B. removing O_2 as it is formed
- C. adding a catalyst to the reaction
- D. decreasing the temperature

Correct Response: D. Changes in temperature result in a change in the equilibrium constant. **A** is incorrect, because increasing the pressure will shift the equilibrium position to the left but the equilibrium constant will be unaffected. **B** is incorrect, because removing O_2 as it is formed will shift the equilibrium position to the right but the equilibrium constant will be unaffected. **C** is incorrect, because adding a catalyst will increase the rate of the reaction but the equilibrium constant will be unaffected.

87. Use the chemical equation below to answer the question that follows.



Which of the following changes would cause the equilibrium reaction shown above to shift to the right?

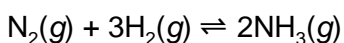
- A. removing $\text{NH}_3(\text{g})$
- B. increasing the pressure
- C. decreasing the temperature
- D. adding $\text{H}_2\text{O}(\text{l})$

Correct Response: A. By Le Châtelier's principle, removal of a product will cause the system to respond in such a way as to form more product in order to restore equilibrium. In this case, restoring equilibrium will require a shift to the right. **B** is incorrect because increasing the pressure will favor the side with the smaller number of moles of gas. In this case, that will cause a shift to the left because there are 7 moles of gas on the right and 2 moles of gas on the left (water is in the liquid state). **C** is incorrect because the reaction given here is endothermic (the enthalpy change is positive). Heat is treated as a reactant in such cases, so its removal will cause a shift to the left. **D** is incorrect because the water is in the liquid phase. Substances in the liquid phase are not considered to have an effect on the equilibrium position.

88. What mass of silver ion is present in a 500.0 mL solution of saturated silver acetate ($\text{AgC}_2\text{H}_3\text{O}_2$)? ($K_{sp} = 1.9 \times 10^{-3}$)
- A. 0.10 g
 - B. 0.21 g
 - C. 2.4 g
 - D. 4.7 g

Correct Response: C. The concentration of silver ion, $[\text{Ag}^+]$, is equal to the square root of the K_{sp} , because $K_{sp} = [\text{Ag}^+][\text{C}_2\text{H}_3\text{O}_2^-]$, and $[\text{Ag}^+] = [\text{C}_2\text{H}_3\text{O}_2^-]$. (These are formed in equimolar amounts during dissociation of $\text{AgC}_2\text{H}_3\text{O}_2$.) By this line of reasoning, $[\text{Ag}^+]$ is 0.44 mole per liter. Multiplying 0.44 mol/L by the number of liters (0.500) and then by the molar mass of silver (107.9 g/mol) gives the mass of silver present in the 500.0 mL solution of $\text{AgC}_2\text{H}_3\text{O}_2$. **A** is incorrect and was calculated using $[\text{Ag}^+] = 1.9 \times 10^{-3} \text{ M}$. **B** is incorrect and was calculated using 1.9×10^{-3} as the $[\text{Ag}^+]$ and then multiplying by the molar mass of silver (107.9 g). **D** is incorrect and was calculated using 0.44 mole per liter as $[\text{Ag}^+]$, multiplying by the molar mass of silver, and then dividing by 10.

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



$$K_p = 2.79 \times 10^{-5} \text{ at } 472^\circ\text{C}$$

Compound	Initial Partial Pressure (atm)
N ₂	3.69
H ₂	11.1
NH ₃	0.415

The compounds shown in the table above are placed in a sealed flask at 472°C. Using the given initial partial pressures, what is the value for the reaction quotient (Q_p) and how will the reaction proceed from these initial conditions to reach equilibrium?

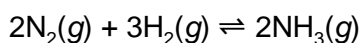
- A. $Q_p = 1.01 \times 10^{-2}$ and the reaction will shift left.
- B. $Q_p = 1.01 \times 10^{-2}$ and the reaction will shift right.
- C. $Q_p = 3.41 \times 10^{-5}$ and the reaction will shift left.
- D. $Q_p = 3.41 \times 10^{-5}$ and the reaction will shift right.

Correct Response: C. The value of the reaction quotient for this reaction, Q_P is equal to

$\frac{(P_{\text{NH}_3})^2}{(P_{\text{H}_2})^3 (P_{\text{N}_2})}$ where the P represents partial pressure. Q_P can be calculated by substituting the initial

partial pressure values in this expression with those from the table. The Q_P that results from this calculation is 3.41×10^{-5} . The calculated Q_P for the reaction is greater than the equilibrium constant (K_p) provided for the reaction (2.79×10^{-5}). As a result, the reaction will shift to the left. The Q_P and equilibrium constant both represent the ratio of products to reactants. **A** is incorrect because Q_P was calculated without raising the partial pressures to the coefficients indicated by reaction stoichiometry. **B** is incorrect, both because Q_P was calculated without raising the partial pressures to the coefficients indicated by reaction stoichiometry and because the reaction will shift to the left, not the right. **D** is incorrect because the reaction will shift to the left since Q_P is larger than the equilibrium constant.

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



Temperature (°C)	K_{eq}
200	4×10^{-1}
300	4×10^{-3}
400	2×10^{-4}
500	2×10^{-5}

The equilibrium constant (K_{eq}) for the formation of NH_3 from N_2 and H_2 at various temperatures is shown in the table above. Given this information, at which temperature is the formation of NH_3 most favored?

- A. 200°C
- B. 300°C
- C. 400°C
- D. 500°C

Correct Response: A. The equilibrium constant for this reaction is given by $\frac{(P_{\text{NH}_3})^2}{(P_{\text{H}_2})^3 (P_{\text{N}_2})}$, where P

represents partial pressure. It is important to note that the product is in the numerator and the reactants are in the denominator. Since NH_3 is the product of this reaction and appears in the numerator of the equilibrium constant expression, formation of NH_3 will be favored when the equilibrium constant is higher. The equilibrium constant at 200°C is greater than that of any of the other temperatures in the table. Answers **B**, **C**, and **D** are all incorrect because each equilibrium constant is less than that for 200°C.

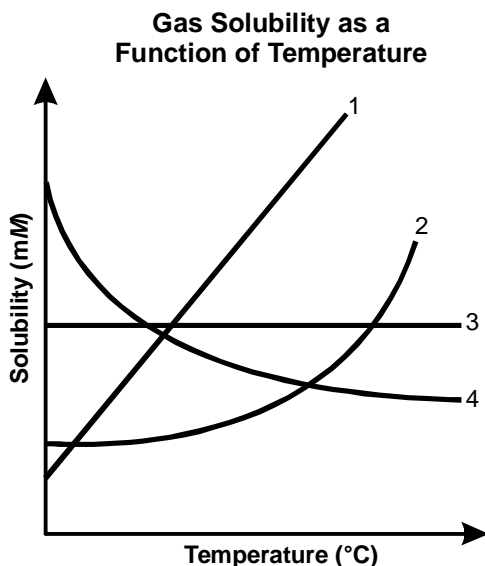
91. Assuming complete dissociation of the solute, what is the freezing point of a solution containing 24.0 g of SrCl_2 and 100.0 g of water?
- A. -2.32°C
 - B. -2.81°C
 - C. -5.62°C
 - D. -8.44°C

Correct Response: D. The freezing point of the SrCl_2 solution will be lower than that of pure water. The depression in freezing point can be calculated by multiplying the molal freezing point depression constant for water (K_f) by the molality of the solute particles in the SrCl_2 solution. K_f is $1.86^\circ\text{C}/m$ and the molality of the particles in the SrCl_2 solution is $4.53 m$, $\left(3 \times \left(\frac{0.151 \text{ mol SrCl}_2}{0.100 \text{ kg H}_2\text{O}} \right) \right)$. The molar mass of SrCl_2 is 158.6 g/mole , and the 3 is needed in the calculation because SrCl_2 dissociates into 3 ions (1 Sr^{2+} ion and 2 Cl^- ions) when dissolved in water. **A** is incorrect and may have been calculated incorrectly using the boiling point depression constant for water. **B** is incorrect and may have been calculated without considering the fact that SrCl_2 dissociates completely in solution (i.e., if the 3 was left out of the equation). **C** is incorrect and was calculated using a coefficient of 2 instead of 3 in calculation of the molality of particles in the SrCl_2 solution.

92. Assuming complete dissociation of electrolytes, which of the following solutions would have the lowest boiling point?
- A. 120.0 g of $C_6H_{12}O_6$ in 1.0 L of H_2O
 - B. 100.0 g of $C_3H_8O_3$ in 1.0 L of H_2O
 - C. 80.0 g of $ZnSO_4$ in 1.0 L of H_2O
 - D. 60.0 g of NH_4Cl in 1.0 L of H_2O

Correct Response: A. The boiling point increases linearly with increases in the concentration of species dissolved in solution. This is an example of a colligative property. The boiling point does not depend on the identity of the substance, only the amount. If we calculate the concentration of dissolved substances for each of the solutions in the options, it is clear that option **A** has the lowest boiling point because it has the lowest concentration of dissolved substances (0.67 M). **B** is incorrect and has a concentration of 1.09 M. **C** is incorrect because zinc sulfate separates into 2 ions when dissolved in water. Therefore, the concentration of ions for option **C** is 0.99 M, which is double the value of the concentration of either zinc or sulfate ion. **D** is incorrect because ammonium chloride will separate into 2 ions when dissolved in water. The concentration of the ions is 2.24 M, which is twice the value of the concentration of either ammonium or chloride ion.

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



Which of the lines indicated in the solubility curve above best represents the relationship between temperature and gas solubility at a constant pressure?

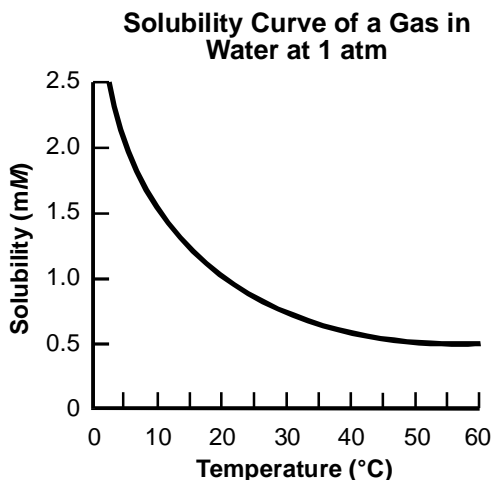
- A. line 1
- B. line 2
- C. line 3
- D. line 4

Correct Response: D. Gas solubility decreases with temperature. Kinetic energy of the gas molecules increases with temperature, causing the intermolecular interactions between the gas and solvent molecules to decrease. **A** is incorrect because Line 1 indicates that solubility would increase with an increase in temperature. **B** is incorrect because Line 2 indicates that solubility would increase with an increase in temperature, as is the case for many solids. **C** is incorrect because Line 3 indicates that solubility is not significantly affected by an increase in temperature.

94. An elevation in temperature will increase the solubility in water of which of the following compounds?
- A. $\text{CO}_2(g)$
 - B. $\text{NaCl}(s)$
 - C. $\text{O}_2(g)$
 - D. $\text{CdS}(s)$

Correct Response: **B.** Sodium chloride, NaCl , is the only option that is a solid. Solubility of solids in liquids generally increases with temperature. **A** is incorrect because carbon dioxide, CO_2 , is a gas. Solubility of gases in liquids generally decreases with temperature. **C** is incorrect because oxygen, O_2 , is a gas. **D** is incorrect because cadmium sulfide, CdS , is an insoluble metal sulfide.

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



Based on the gas solubility curve shown above, which of the following changes will cause gas to be evolved?

- A. cooling a 0.50 mM solution from 25°C to 10°C at constant pressure
- B. warming a 2.0 mM solution from 5°C to 20°C at constant pressure
- C. cooling a 1.5 mM solution from 10°C to 5°C at constant pressure
- D. warming a 1.0 mM solution from 5°C to 15°C at constant pressure

Correct Response: B. The first point corresponds to 5°C and 2.0 mM. The second point corresponds to 20°C and 2.0 mM. The first point is underneath the solubility curve shown in the graph, indicating that the gas is soluble under these conditions. The second point is above the solubility curve shown in the graph, indicating that the gas is insoluble under these conditions. **A** is incorrect because the gas is soluble under both sets of conditions (both points are below the curve). **C** is incorrect because the gas is soluble under both sets of conditions. **D** is incorrect because the gas is soluble under both of these conditions.

96. Use the table below to answer the question that follows.

Standard Reduction Potentials (1.0 M at 25°C)	
Half-reaction	E° (V)
$\text{Ba}^{2+}(\text{aq}) + 2e^- \longrightarrow \text{Ba}(\text{s})$	-2.91
$\text{Na}^+(\text{aq}) + e^- \longrightarrow \text{Na}(\text{s})$	-2.71
$\text{Mn}^{2+}(\text{aq}) + 2e^- \longrightarrow \text{Mn}(\text{s})$	-1.18
$\text{Tl}^+(\text{aq}) + e^- \longrightarrow \text{Tl}(\text{s})$	-0.34
$\text{Ag}^+(\text{aq}) + e^- \longrightarrow \text{Ag}(\text{s})$	+0.80
$\text{Au}^{3+}(\text{aq}) + 3e^- \longrightarrow \text{Au}(\text{s})$	+1.50

Using the standard reduction potentials shown above, which of the following cells is spontaneous at standard conditions?

- A. $\text{Mn} | \text{Mn}^{2+} || \text{Tl}^+ | \text{Tl}$
B. $\text{Ag} | \text{Ag}^+ || \text{Mn}^{2+} | \text{Mn}$
C. $\text{Ag} | \text{Ag}^+ || \text{Na}^+ | \text{Na}$
D. $\text{Na} | \text{Na}^+ || \text{Ba}^{2+} | \text{Ba}$

Correct Response: A. The standard cell potential or electromotive force (emf) can be calculated using the following equation; $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$. The E° values used for *both* the cathode and the anode in the equation are the standard reduction potentials of the electrodes shown in the table. The net cell potential is positive in this case and equals 0.84V ($-0.34\text{V} - (-1.18\text{V})$). The cell given in **A** is the only option in which the net potential is positive, which indicates the cell is spontaneous at standard conditions. A positive net cell potential corresponds to a negative value for Gibbs free energy, which indicates the formation of products is favored. **B** is incorrect because the net cell potential is -1.98V ($-1.18\text{V} - 0.80\text{V}$). **C** is incorrect, because the net potential is -3.51V ($-2.71\text{V} - 0.80\text{V}$). **D** is incorrect because the net cell potential is -0.20V ($-2.91\text{V} - (-2.71\text{V})$).

97. Use the table below to answer the question that follows.

Standard Reduction Potentials (1.0 M at 25°C)	
Half-reaction	E° (V)
$\text{Sn}^{2+}(\text{aq}) + 2e^- \longrightarrow \text{Sn}(\text{s})$	-0.138
$\text{Pb}^{2+}(\text{aq}) + 2e^- \longrightarrow \text{Pb}(\text{s})$	-0.126

A voltaic cell using the half-reactions shown in the table above begins operation at standard conditions. At what ratio of the concentration of Sn^{2+} to Pb^{2+} will the cell potential become zero?

- A. 0.331
 B. 0.930
 C. 1.11
 D. 2.53

Correct Response: D. The ratio of the concentration of Sn^{2+} to Pb^{2+} is obtained using the Nernst equation

$$E = E^\circ - \frac{0.0592\text{V}}{n} \log Q$$

where Q is $[\text{Sn}^{2+}]/[\text{Pb}^{2+}]$, n is 2 for this reaction (the number of electrons transferred), and E° is 0.012 V for the reaction $\text{Sn}(\text{s}) + \text{Pb}^{2+}(\text{aq}) \longrightarrow \text{Pb}(\text{s}) + \text{Sn}^{2+}(\text{aq})$. E° is calculated as $E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$ ($-0.126 \text{ V} - (-0.138 \text{ V})$), where the values of *both* E°_{cathode} and E°_{anode} are the standard reduction potentials of the electrodes. Substituting 0.012V for E° , $n = 2$, and 0 for E (correct for 25°C), we find that $Q = 2.53$. **A** is incorrect since 0.331 would correspond to an E° of -0.014V . **B** is incorrect since 0.930 would correspond to an E° of -0.00093V . **C** is incorrect and was obtained by a computation error in which E° is added to $\frac{0.0592\text{V}}{n}$ instead of being divided by it when solving for $\log Q$.

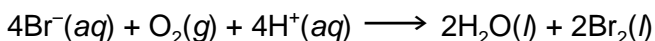
98. Ni-Cd storage batteries are rechargeable, whereas standard Zn-MnO₂ dry-cell batteries are not rechargeable. Which of the following statements best accounts for this difference between these two types of batteries?
- A. The salt bridge in a Ni-Cd battery is unidirectional.
 - B. An applied current can be used to reverse the reaction of a Ni-Cd battery.
 - C. In a Zn-MnO₂ battery, either electrode can serve as the anode.
 - D. In a Zn-MnO₂ battery, the oxidation and reduction reactions are not linked.

Correct Response: B. The chemical reactions that occur with a discharge of the Ni-Cd battery can be reversed to recharge the battery. This requires an applied current because the oxidation and reduction reactions in this direction are not spontaneous. **A** is incorrect because salt bridges are not specific, and they allow for the flow of ions in either direction. **C** is incorrect because the potential for oxidation or reduction of metals does not change, and no current is applied. Zn is always the anode in Zn-MnO₂ batteries. **D** is incorrect because oxidation and reduction reactions are always linked. These reactions do not occur in isolation, and the electrons that are the product of the oxidation reaction are reactants in the reduction reaction.

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

Standard Reduction Potentials (1.0 M at 25°C)	
Half-reaction	E° (V)
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \longrightarrow 2\text{Br}^-(\text{aq})$	+1.08

The following reaction takes place at 25°C.



Using the equations and half-reactions shown above, what is the value of the equilibrium constant (K) for this chemical reaction?

- A. 1.1×10^{39}
- B. 1.9×10^{20}
- C. 1.4×10^{10}
- D. 3.5×10^2

Correct Response: C. The equilibrium constant, K , is calculated as $E^\circ = \left(\frac{0.0592}{4}\right)\log K$. This is a variation of the Nernst equation. The 4 in this expression arises because there are 4 electrons transferred. E° is 0.15 and is calculated as $1.23 - 1.08$. The sign of the second reaction listed in the table is changed because this reaction is reversed in the overall reaction given in the stem. Substituting 0.15 for E° results in 1.4×10^{10} for K . **A** is incorrect and is obtained if a value of 0.5778 for E° is used. **B** is incorrect and is calculated assuming 8 electrons were transferred instead of 4. **D** is incorrect and is obtained if a value of 0.0376 is used for E° .

100. An oxidation-reduction reaction has a negative electrochemical potential at standard conditions. Which of the following is true about the standard free energy change (ΔG°) and equilibrium constant (K) for this reaction at 25°C?
- A. $\Delta G^\circ > 0, K < 1$
 - B. $\Delta G^\circ > 0, K > 1$
 - C. $\Delta G^\circ < 0, K < 1$
 - D. $\Delta G^\circ < 0, K > 1$

Correct Response: A. Given that $\Delta G^\circ = -nFE^\circ_{\text{cell}}$, if the electrochemical potential is negative, ΔG is positive (a negative number multiplied by a negative number gives a positive number), and the reactant side is favored. Therefore K , which is the ratio of products over reactants, will be less than 1. **B** is incorrect because $K > 1$ indicates that the product side of the reactant is favored. **C** is incorrect because ΔG is positive. **D** is incorrect because ΔG is positive and $K > 1$.