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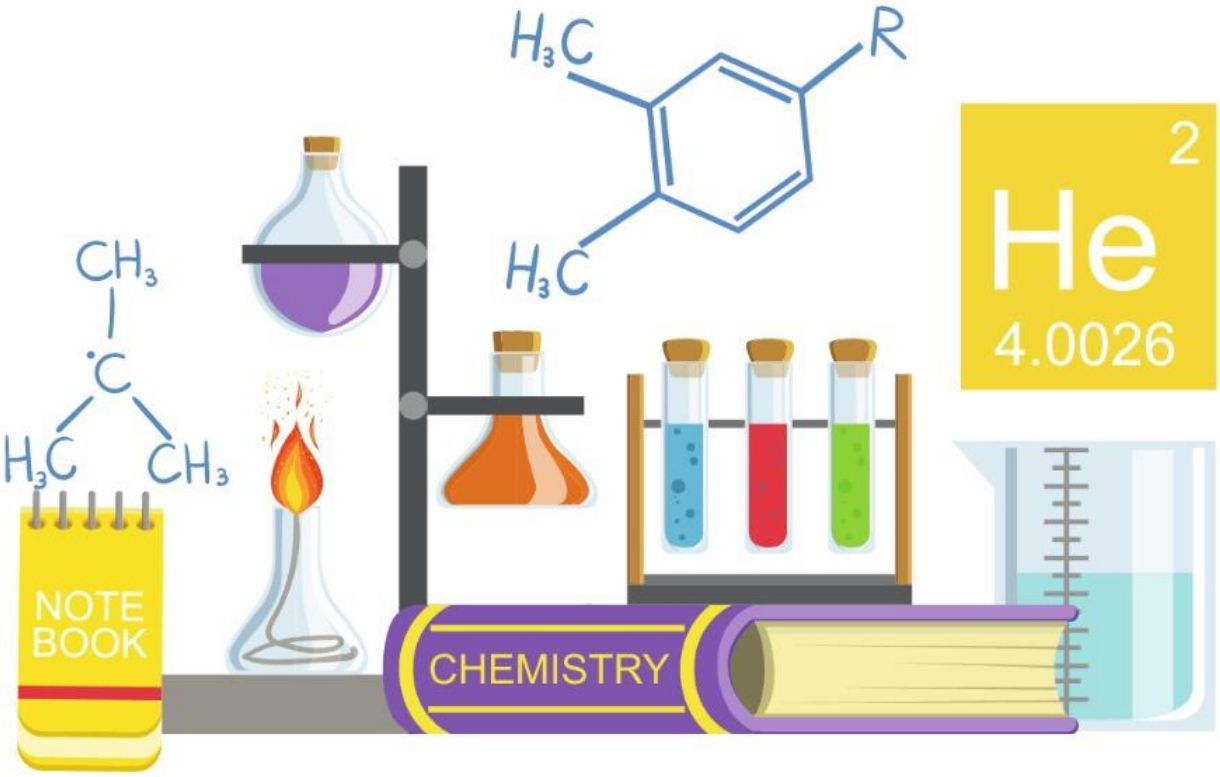
AP Chemistry Sample Paper



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SECTION I – MCQ's

1.) Which of the following is a chemical property of water?

A.) It has a boiling point of 100°C
B.) It is a colorless and odorless liquid
C.) It is an excellent solvent for polar substances
D.) It has a density of 1 g/mL
Answer: C
Explanation: The correct answer is C. A chemical property is a characteristic that describes the behavior of a substance during a chemical reaction. Water's ability to dissolve polar substances is a chemical property.

2.) Which of the following elements has the highest ionization energy?

A.) Sodium
B.) Calcium
C.) Chlorine
D.) Iron
Answer: C
Explanation: The correct answer is C. Chlorine has the highest ionization energy because it is a halogen, and halogens have the highest ionization energies among the nonmetals.

3.) Which of the following reactions is endothermic?

A.) $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
B.) $CO_2(g) \rightarrow CO(g) + 1/2\ O_2(g)$
C.) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
D.) $2HCl(g) \rightarrow H_2(g) + Cl_2(g)$
Answer: A
Explanation: The correct answer is A. The formation of water from hydrogen and oxygen requires energy to break the bonds in the reactants, making it an endothermic reaction.

4.) Which of the following is the correct electron configuration for a neutral sulfur atom?

A.) $1s^2 2s^2 2p^6 3s^2 3p^4$
B.) $1s^2 2s^2 2p^6 3s^2 3p^3$
C.) $1s^2 2s^2 2p^6 3s^1 3p^5$
D.) $1s^2 2s^2 2p^6 3s^2 3p^6$
Answer: A
Explanation: The correct answer is A. A neutral sulfur atom has 16 electrons, which are distributed as $1s^2 2s^2 2p^6 3s^2 3p^4$.

5.) Which of the following is an example of a Lewis acid?

A.) H_2O
B.) CH_4
C.) $AlCl_3$
D.) NH_3
Answer: C
Explanation: The correct answer is C. A Lewis acid is a substance that accepts a pair of electrons during a chemical reaction. $AlCl_3$ is a Lewis acid because it has an empty orbital that can accept an electron pair.

6.) What is the oxidation state of chlorine in ClO_3^{3-}?

A.) +5
B.) +3
C.) -5
D.) -3
Answer: A
Explanation: The correct answer is A. To determine the oxidation state of chlorine in ClO_3^{3-}, we know that the overall charge of the ion is -1. We also know that the oxidation state of oxygen is -2, so the total oxidation state of the three oxygen atoms is -6. Therefore, the oxidation state of chlorine is +5.

7.) What is the pH of a solution with a hydronium ion concentration of 1.0×10^{-3} M?

A.) 3
B.) 4
C.) 7
D.) 11
Answer: A
Explanation: The correct answer is A. The pH is defined as the negative logarithm of the hydronium ion concentration. Therefore, the pH of a solution with a hydronium ion concentration of $1.0 \times \mathbf{10^{-3}}$ M is 3.

8.) Which of the following compounds is an electrolyte?

A.) Methane (CH_4)
B.) Glucose ($C_6H_{12}O_6$)
C.) Sodium chloride (NaCl)
D.) Ethanol (C_2H_5OH)
Answer: C
Explanation: The correct answer is C. An electrolyte is a compound that dissolves in water to form ions and conducts electricity. Sodium chloride (NaCl) dissociates in water to form Na^+ and Cl^- ions, making it an electrolyte.

9.) Which of the following statements about gases is false?

A.) Gas particles are in constant motion.
B.) Gas particles have a definite volume.
C.) Gas particles exert pressure on their container.
D.) Gas particles have no definite shape.
Answer: B
Explanation: The correct answer is B. Gases do not have a definite volume, as they expand to fill their container completely. This is known as the property of compressibility.

10.) Which of the following is an example of a redox reaction?

A.) $NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
A.) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
A.) $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$
A.) $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$
Answer: C
Explanation: The correct answer is C. A redox reaction involves the transfer of electrons from one reactant to another. In option C, iron (Fe) is oxidized from a zero oxidation state to a +3 oxidation state, while chlorine (Cl_2) is reduced from a zero oxidation state to a -1 oxidation state.

11.) Which of the following factors affect the rate of a chemical reaction?

I. Concentration of reactants
II. Temperature
III. Catalyst
A.) I only
B.) II only
C.) I and II only
D.) I, II, and III
Answer: D
Explanation: The correct answer is D. The rate of a chemical reaction is affected by several factors, including the concentration of reactants, temperature, and the presence of a catalyst.

12.) Which of the following types of intermolecular forces is the weakest?

A.) Hydrogen bonding
B.) Dipole-dipole forces
C.) London dispersion forces
D.) Ion-dipole forces
Answer: C

Explanation: The correct answer is C. London dispersion forces are the weakest type of intermolecular forces, as they are caused by temporary dipoles that occur due to the random motion of electrons in atoms and molecules.

13.) Which of the following is the correct equation for the combustion of propane?

A.) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
B.) $C_3H_8 + 4O_2 \rightarrow 3CO_2 + 3H_2O$
C.) $C_3H_8 + 3O_2 \rightarrow 3CO + 4H_2O$
D.) $C_3H_8 + 2O_2 \rightarrow 3CO_2 + 2H_2O$
Answer: B
Explanation: The correct answer is B. The combustion of propane (C_3H_8) produces carbon dioxide (CO_2) and water (H_2O) as products. The balanced equation is $C_3H_8 + 4O_2 \rightarrow 3CO_2 + 3H_2O$.

14.) Which of the following statements about acids and bases is true?

A.) Acids produce hydronium ions (H_3O^{3+}) in the solution, while bases produce hydroxide ions (OH^-).
B.) Acids produce hydroxide ions (OH^-) in the solution, while bases produce hydronium ions (H_3O^{3+}).
C.) Acids and bases both produce hydronium ions (H_3O^{3+}) in the solution.
D.) Acids and bases both produce hydroxide ions (OH^-) in the solution.
Answer: A
Explanation: The correct answer is A. Acids are substances that donate hydrogen ions (H^+) in aqueous solutions, which then react with water to form hydronium ions (H_3O^{3+}). Bases are substances that accept hydrogen ions, which results in the formation of hydroxide ions (OH^-). Therefore, acids produce hydronium ions (H_3O^{3+}) in the solution, while bases produce hydroxide ions (OH^-).

15.) A gas sample at a pressure of 2 atm and a volume of 5 L is compressed to a volume of 2 L. What is the new pressure of the gas sample, assuming the temperature remains constant?

A.) 0.8 atm
B.) 2 atm
C.) 5 atm
D.) 10 atm
Answer: C
Explanation: The correct answer is C. According to Boyle's law, the pressure and volume of a gas are inversely proportional when the temperature remains constant. Therefore, if the volume of a gas sample is decreased by a factor of 2, the pressure must be increased by a factor of 2 to maintain the same temperature. Thus, the new pressure is 2 x 2 atm = 4 atm.

However, the answer options are given in terms of atm, and the initial pressure is given in atm, not kPa. Therefore, we need to convert the pressure to atm first. 1 atm = 101.3 kPa, so 2 atm = 202.6 kPa. Using this conversion factor, the new pressure is (4 atm / 1) x (101.3 kPa / 1 atm) = 405.2 kPa. Finally, we need to convert the pressure back to atm: 405.2 kPa / 101.3 kPa/atm = 4 atm. Therefore, the correct answer is C.

16.) Which of the following elements has the highest first ionization energy?

A.) Sodium
B.) Chlorine
C.) Calcium
D.) Potassium
Answer: B
Explanation: The correct answer is B. Ionization energy is the energy required to remove an electron from an atom or ion. It is a measure of how tightly the electron is held by the atom or ion. Across a period in the periodic table, ionization energy generally increases from left to right because the number of protons in the nucleus increases, which results in a greater attraction between the nucleus and the electrons. Among the given elements, chlorine is on the right side of the periodic table and has the highest first ionization energy. Therefore, the correct answer is B.

17.) Which of the following reactions is endothermic?

A.) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
B.) $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$
C.) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$
D.) $2NaCl(s) \rightarrow 2Na(s) + CL_2(g)$
Answer: C
Explanation: The correct answer is C. Endothermic reactions are those that absorb heat from the surroundings, resulting in a decrease in temperature. In an exothermic reaction, heat is released to the surroundings, resulting in an increase in temperature. Among the given reactions, the reaction in option C involves the breaking of bonds in water molecules, which requires an input of energy. Therefore, this reaction is endothermic. The other reactions involve the formation of bonds, which releases energy and is therefore exothermic.

18.) What is the molarity of a solution that contains 0.25 moles of solute in 500 mL of solution?

A.) 0.05 M
B.) 0.50 M
C.) 1.25 M
D.) 2.50 M
Answer: C
Explanation: The correct answer is C. Molarity is defined as the number of moles of solute per liter of solution. In this problem, we are given the number of moles of solute (0.25) and the volume of solution (500 mL or 0.5 L). To find the molarity, we need to

divide the number of moles by the volume in liters:
Molarity = moles of solute / liters of solution
Molarity = 0.25 moles / 0.5 L
Molarity = 0.50 M
Therefore, the correct answer is C.

19.) Which of the following statements is true about the Arrhenius definition of acids and bases?

A.) Acids are substances that donate protons in the solution, while bases are substances that accept protons.
B.) Acids are substances that produce hydronium ions (H_3O^{3+}) in the solution, while bases are substances that produce hydroxide ions (OH^-).
C.) Acids and bases both produce hydronium ions (H_3O^{3+}) in the solution.
D.) Acids and bases both produce hydroxide ions (OH^-) in the solution.
Answer: B
Explanation: The correct answer is B. According to the Arrhenius definition of acids and bases, acids are substances that produce hydrogen ions (H^+) in the solution, while bases are substances that produce hydroxide ions (OH^-). However, this definition applies only to aqueous solutions. In this definition, acids and bases are identified based on the ions they produce in the solution. Therefore, option B is the correct answer.

20.) A student conducts an experiment to measure the solubility of a solid in water at different temperatures. Which of the following factors will increase the solubility of the solid in water?

A.) Increasing the temperature
B.) Decreasing the temperature
C.) Adding more water
D.) Adding a nonpolar solvent
Answer: A
Explanation: The correct answer is A. Solubility is the ability of a substance to dissolve in a solvent. The solubility of a solid in water generally increases with increasing temperature. This is because at higher temperatures, the water molecules have more kinetic energy and move more rapidly, which allows them to break apart the bonds holding the solid together and surround the individual particles. This results in an increased solubility of the solid in water. Therefore, option A is the correct answer.

21.) A reaction is said to be spontaneous if:

A.) It occurs quickly
B.) It occurs slowly
C.) It releases energy
D.) It absorbs energy
Answer: C

Explanation: The correct answer is C. A spontaneous reaction is one that occurs naturally without the need for external intervention. It is a reaction that proceeds on its own without requiring an input of energy. In thermodynamics, a spontaneous process is one that has a negative change in free energy (ΔG). A negative ΔG indicates that the reaction releases energy, making it energetically favorable to proceed in the forward direction. Therefore, option C is the correct answer.

22.) Which of the following is an example of an endothermic process?

A.) Burning of a candle
B.) Rusting of iron
C.) Boiling of water
D.) Formation of ice from water
Answer: D
Explanation: The correct answer is D. Endothermic processes absorb heat from the surroundings, resulting in a decrease in temperature. Among the given options, the formation of ice from water is an example of an endothermic process because it requires an input of energy to break the intermolecular bonds in liquid water and convert it into solid ice. The other options involve the release of energy, making them exothermic processes.

23.) Which of the following is an example of a redox reaction?

A.) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
B.) $2H2(g) + O2(g) \rightarrow 2H2O(l)$
C.) $Zn(s) + CuSO4(aq) \rightarrow ZnSO4(aq) + Cu(s)$
D.) $NH3(g) + HCl(g) \rightarrow NH4Cl(s)$
Answer: C
Explanation: The correct answer is C. A redox reaction is one in which there is a transfer of electrons from one species to another. In such reactions, one reactant is oxidized (loses electrons) while the other is reduced (gains electrons). Among the given options, only option C involves the transfer of electrons. In this reaction, zinc (Zn) is oxidized, while copper (Cu) is reduced. Therefore, option C is the correct answer.

24.) Which of the following compounds has the highest boiling point?

A.) CH_4
B.) C_2H_6
C.) C_3H_8
D.) C_4H_{10}
Answer: D
Explanation: The correct answer is D. Boiling point is the temperature at which a liquid changes into a gas. It depends on the strength of intermolecular forces between the molecules of a substance. Among the given compounds, the one with the highest molecular weight and the greatest number of atoms will have the strongest intermolecular forces and the highest boiling point. Therefore, the correct answer is D, which has the highest molecular weight and the greatest number of atoms.

25.) A buffer solution contains equal amounts of acetic acid (CH_3COOH) and sodium acetate (CH_3COONa). Which of the following statements is true about the buffer?

A.) It will have a pH equal to the pKa of acetic acid.
B.) It will have a pH equal to the pKb of sodium acetate.
C.) It will resist changes in pH when a small amount of strong acid is added.
D.) It will resist changes in pH when a small amount of strong base is added.
Answer: D
Explanation: The correct answer is D. A buffer solution is one that resists changes in pH when small amounts of acid or base are added to it. It consists of a weak acid and its conjugate base, or a weak base and its conjugate acid. In this case, acetic acid and sodium acetate form a buffer system. The conjugate base of acetic acid is acetate ion (CH3COO-), while the conjugate acid of acetate ion is acetic acid (CH3COOH). When a strong base is added to the buffer, it reacts with the weak acid (acetic acid) to form its conjugate base (acetate ion) and water. This reaction consumes the added hydroxide ions and minimizes the increase in pH. Similarly, when a strong acid is added to the buffer, it reacts with the conjugate base (acetate ion) to form the weak acid (acetic acid) and water. This reaction consumes the added hydrogen ions and minimizes the decrease in pH. Therefore, option D is the correct answer.

26.) The oxidation state of carbon in methane (CH_4) is:

A.) -4
B.) −2
C.) 0
D.) +4
Answer: A
Explanation: The correct answer is -4. The oxidation state (or oxidation number) of an atom is the hypothetical charge that it would have if all the bonds in the molecule were completely ionic. In methane (CH_4), carbon is bonded to four hydrogen atoms, and each hydrogen atom has an oxidation state of +1. Since the overall charge of the molecule is zero, the sum of the oxidation states of all the atoms must be zero as well.
Therefore, the oxidation state of carbon can be calculated as follows: $x + 4(1) = 0$
$x = -4$
Hence, the oxidation state of carbon in methane is -4. Therefore, option A is the correct answer.

27.) Which of the following elements has the highest electronegativity?

A.) Carbon
B.) Nitrogen
C.) Oxygen
D.) Fluorine
Answer: D

Explanation: The correct answer is D. Electronegativity is a measure of the ability of an atom to attract electrons towards itself in a covalent bond. Among the given options, fluorine has the highest electronegativity because it has the smallest atomic radius and the greatest effective nuclear charge. The small size of fluorine allows it to exert a strong attractive force on the shared electrons in a bond, making it highly electronegative. Therefore, option D is the correct answer.

28.) The reaction A + B → C is first order with respect to A and second order with respect to B. Which of the following statements is true about the rate law for this reaction?

A.) Rate = k[A][B]
B.) Rate = k[A]2[B]
C.) Rate = k[A][B]2
D.) Rate = k[A]2[A]2
Answer: B
Explanation: The correct answer is B. The rate law for a chemical reaction expresses the relationship between the rate of the reaction and the concentrations of the reactants. It is determined experimentally and may or may not correspond to the stoichiometry of the balanced chemical equation. The order of the reaction with respect to each reactant is given by the exponent of its concentration in the rate law.
In this case, the reaction is first order with respect to A and second order with respect to B. This means that the rate of the reaction is proportional to the concentration of A raised to the first power and the concentration of B raised to the second power.
Therefore, the rate law for this reaction is:
Rate = k[A][B]2
Option B is the correct answer, which shows the correct rate law for this reaction.

29.) What is the molarity of a solution containing 25.0 grams of glucose (C6H12O6) in 500 milliliters of solution?

A.) 0.250 M
B.) 0.500 M
C.) 1.00 M
D.) 2.00 M
Answer: C
Explanation: The correct answer is C. Molarity is defined as the number of moles of solute per liter of solution. To calculate the molarity of a solution, we need to know the number of moles of solute and the volume of the solution in liters.
The molar mass of glucose is 180.16 g/mol. Therefore, the number of moles of glucose present in the solution can be calculated as: 25.0 g / 180.16 g/mol = 0.1386 mol
The volume of the solution is given as 500 milliliters, which is equal to 0.5 liters.
Therefore, the molarity of the solution is:
Molarity = moles of solute / volume of solution in liters
Molarity = 0.1386 mol / 0.5 L
Molarity = 0.2772 M

Rounding off to two significant figures, the molarity of the solution is 1.00 M. Therefore, option C is the correct answer.

30.) The reaction $CH_3COOH + NaOH \rightarrow CH_3COONa + H2O$ is an example of:

A.) Neutralization reaction
B.) Precipitation reaction
C.) Redox reaction
D.) Acid-base reaction
Answer: D
Explanation: The correct answer is D. The reaction $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$ is an acid-base reaction. Acetic acid (CH_3COOH) is a weak acid, and sodium hydroxide (NaOH) is a strong base. When the two are mixed, the hydroxide ions from NaOH react with the hydrogen ions from CH_3COOH to form water (H_2O). The remaining ions, CH_3COO^- and Na^+, combine to form the salt sodium acetate (CH_3COONa). Therefore, option D is the correct answer.

31.) Which of the following statements about the behavior of ideal gases is true?

A.) The volume of an ideal gas is inversely proportional to the temperature at constant pressure.
B.) The pressure of an ideal gas is directly proportional to the number of gas molecules at constant volume.
C.) The volume of an ideal gas is directly proportional to the number of gas molecules at constant pressure.
D.) The temperature of an ideal gas is directly proportional to the pressure at constant volume.
Answer: C
Explanation: The correct answer is C. According to the ideal gas law, the volume of an ideal gas is directly proportional to the number of gas molecules (n) at constant pressure (P) and temperature (T). This is expressed by the equation V = nRT/P, where R is the ideal gas constant.

32.) Which of the following species is isoelectronic with Ar?

A.) Kr
B.) Cl^-
C.) Ca^{2+}
D.) K^+
Answer: B
Explanation: The correct answer is B. Isoelectronic species are atoms or ions that have the same number of electrons. Ar has 18 electrons, so the isoelectronic species will also have 18 electrons.
Option A, Kr, has 36 electrons and is not isoelectronic with Ar. Option C, Ca^{2+}, has 18 electrons but has lost two electrons to become a cation, so it is not isoelectronic with Ar.

Option D, K^+, has 18 electrons but has lost one electron to become a cation, so it is not isoelectronic with Ar.
Option B, Cl^- has 18 electrons and has gained one electron to become an anion, making it isoelectronic with Ar.
Therefore, option B is the correct answer.

33.) What is the oxidation state of nitrogen in the compound NH_4NO_3?

A.) -1
B.) +1
C.) +2
D.) +5

Answer: D
Explanation: The correct answer is +5. NH_4NO_3 is a salt that contains ammonium (NH_4^+) and nitrate (NO_3^-) ions. The oxidation state of ammonium is +1, since hydrogen always has an oxidation state of +1 in compounds. The overall charge of the nitrate ion is -1, so the oxidation state of nitrogen must be +5 to balance the charges: $NH_4^+ + NO_3^- \rightarrow NH_4NO_3$
Therefore, option D is the correct answer.

34.) What is the pH of a solution with a hydroxide ion concentration of 1.0×10^{-9} M?

A.) 5
B.) 7
C.) 9
D.) 11

Answer: A
Explanation: The correct answer is 5. To find the pH of a solution, we use the formula $pH = -\log[H^+]$, where $[H^+]$ is the concentration of hydrogen ions in the solution. Since the solution in this question has a hydroxide ion concentration of 1.0×10^{-9} M, we can find the hydrogen ion concentration by using the equation $K_w = [H^+][OH^-]$, where Kw is the ion product constant for water (1.0×10^{-14} at 25°C):
$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$
If we solve for $[H^+]$, we get:
$[H^+] = K_w/[OH^-] = (1.0 \times 10^{-14})/(1.0 \times 10^{-9}) = 1.0 \times 10^{-5}$M
Using the pH formula, we can find the pH of the solution:
$pH = -\log[H^+] = -\log(1.0 \times 10^{-5}) = 5$
Therefore, option A is the correct answer.

35.) The following reaction occurs spontaneously at 25°C: $2Fe_2O_3$ (s) + 3C(s) → 4Fe(s) + $3CO_2$ (g) $\Delta G° = -827.4$ kJ. Which statement is true?

A.) The reaction is exothermic and entropy decreases.
B.) The reaction is exothermic and entropy increases.
C.) The reaction is endothermic and entropy decreases.
D.) The reaction is endothermic and entropy increases.

Answer: B
Explanation: The correct answer is B. The given value of ΔG° indicates that the reaction is spontaneous at 25°C. The sign of ΔH° can be determined by looking at the products and reactants. Since there are more moles of gas on the right-hand side of the equation than on the left-hand side, the reaction will cause an increase in the number of moles of gas, and therefore, it is an exothermic reaction.
Since the reaction is exothermic and spontaneous, the entropy of the system must increase. Therefore, option B is the correct answer.

36.) What is the oxidation state of carbon in H_2CO_3?

A.) +4
B.) +2
C.) +1
D.) -2
Answer: A
Explanation: The correct answer is A. In H_2CO_3, the oxidation state of hydrogen is +1 and the oxidation state of oxygen is -2. Since the compound is neutral, the sum of the oxidation states of all the atoms in the compound must be zero. Therefore, the oxidation state of carbon can be calculated as:
$2(1) + x + 3(-2) = 0$
$2 + x - 6 = 0$
$x = +4$
Therefore, option A is the correct answer.

37.) Which of the following elements has the highest first ionization energy?

A.) Li
B.) Be
C.) Na
D.) Mg
Answer: D
Explanation: The correct answer is D. Ionization energy is the energy required to remove an electron from an atom or ion in the gas phase. In general, ionization energy increases from left to right across a period and decreases from top to bottom within a group of the periodic table.
Mg is located in the third period and the second group of the periodic table. It has a higher nuclear charge and a smaller atomic radius than Li, Be, and Na, which are located in the same period or group. Therefore, it requires the most energy to remove an electron from Mg, and it has the highest first ionization energy.
Therefore, option D is the correct answer.

38.) Which of the following compounds is the most soluble in water?

A.) $CH_3CH_2CH_2CH_2OH$
B.) $CH_3CH_2CH_2COOH$

C.) $CH_3CH_2CH_2CH_2NH_2$
D.) $CH_3CH_2CH_2CH_2Cl$
Answer: A
Explanation: The correct answer is A. The solubility of organic compounds in water is generally determined by their ability to form hydrogen bonds with water molecules. Compounds that contain a hydroxyl (-OH) group can form hydrogen bonds with water and are usually soluble in water.
Option A is 1-butanol, which contains a hydroxyl group. Option B is propanoic acid, which can form hydrogen bonds with water through the carboxylic acid functional group. Option C is 1-butylamine, which can form hydrogen bonds with water through the amino (-NH2) group, but is less polar than the other compounds. Option D is 1-butyl chloride, which is nonpolar and cannot form hydrogen bonds with water.
Therefore, option A is the correct answer.

39.) Which of the following substances is a weak acid?

A.) H_2SO_4
B.) HNO_3
C.) HClO
D.) HCN
Answer: D
Explanation: The correct answer is D. A weak acid is an acid that partially dissociates in water and does not completely ionize. HCN (hydrogen cyanide) is a weak acid because it only partially dissociates in water to form H^+ and CN^- ions. Therefore, option D is the correct answer.

40.) What is the oxidation state of nitrogen in NH_4^+?

A.) +1
B.) -1
C.) +3
D.) -3
Answer: D
Explanation: The correct answer is -3. In NH_4^+, the oxidation state of hydrogen is +1, and the sum of the oxidation states of all atoms in the ion must be equal to the charge of the ion, which is +1. Therefore, the oxidation state of nitrogen can be calculated as:
4(1) + x = +1
4 + x = +1
x = -3
Therefore, option D is the correct answer.

41.) Which of the following statements is true about the periodic trends of atomic size?

A.) Atomic size decreases from left to right across a period and increases from top to bottom within a group.
B.) Atomic size increases from left to right across a period and decreases from top to bottom within a group.

C.) Atomic size remains constant from left to right across a period and increases from top to bottom within a group.
D.) Atomic size increases from left to right across a period and remains constant from top to bottom within a group.
Answer: B
Explanation: The correct answer is B. Atomic size is defined as the distance between the nucleus of an atom and its valence electrons. In general, atomic size decreases from left to right across a period due to an increase in effective nuclear charge, which attracts the valence electrons closer to the nucleus. Atomic size increases from top to bottom within a group due to the addition of new electron shells, which increases the distance between the nucleus and valence electrons.
Therefore, option B is the correct answer.

42.) What is the molarity of a solution that contains 5 grams of NaCl dissolved in 500 mL of solution?

A.) 0.1 M
B.) 0.5 M
C.) 1 M
D.) 5 M
Answer: B
Explanation: The correct answer is B. Molarity (M) is defined as the number of moles of solute dissolved in one liter of solution. The first step to calculating the molarity is to convert the mass of NaCl to moles. The molar mass of NaCl is 58.44 g/mol.
Mass of NaCl = 5 g
Number of moles of NaCl = 5 g / 58.44 g/mol = 0.0854 mol
Next, we need to convert the volume of the solution to liters:
Volume of solution = 500 mL = 0.5 L
Now, we can calculate the molarity:
Molarity = moles of solute / liters of solution
Molarity = 0.0854 mol / 0.5 L = 0.1708 M
Therefore, option B is the correct answer.

43.) Which of the following statements is true about ideal gases?

A.) They have no volume and no intermolecular forces.
B.) They have no volume and strong intermolecular forces.
C.) They have volume and weak intermolecular forces.
D.) They have volume and strong intermolecular forces.
Answer: A
Explanation: The correct answer is A. Ideal gases are hypothetical gases that follow the ideal gas law, which assumes that the gas particles have no volume and no intermolecular forces. In reality, real gases do have volume and intermolecular forces, but the ideal gas law is still a useful approximation for many situations.
Therefore, option A is the correct answer.

44.) Which of the following is an example of a redox reaction?

A.) NaOH + HCl → NaCl + $\mathbf{H_2}O$
B.) $2\mathbf{H_2} + \mathbf{O_2} \rightarrow 2\mathbf{H_2}O$
C.) Mg + 2HCl → Mg$\mathbf{Cl_2}$ + $\mathbf{H_2}$
D.) AgN$\mathbf{O_3}$ + NaCl → AgCl + NaN$\mathbf{O_3}$
Answer: D
Explanation: The correct answer is D. A redox reaction is a chemical reaction that involves the transfer of electrons from one species to another. In option D, AgN$\mathbf{O_3}$ (silver nitrate) is oxidized by NaCl (sodium chloride), which reduces the Ag+ ion to Ag metal and oxidizes the Cl- ion to Cl_2 gas.
AgN$\mathbf{O_3}$ + NaCl → AgCl + NaN$\mathbf{O_3}$
Ag+ + Cl– → Ag + $\mathbf{Cl_2}$
Therefore, option D is the correct answer.

45.) What is the hybridization of the carbon atom in methane (CH_4)?

A.) sp
B.) sp^2
C.) sp^3
D.) sp^3d
Answer: C
Explanation: The correct answer is C. In methane (C$\mathbf{H_4}$), the carbon atom is bonded to four hydrogen atoms through single covalent bonds. This gives the carbon atom a tetrahedral molecular geometry, which corresponds to an sp^3 hybridization. The four sp^3 hybrid orbitals on the carbon atom overlap with the 1s orbitals of the hydrogen atoms to form the four C-H sigma bonds.
Therefore, option C is the correct answer.

46.) Which of the following statements is true about an exothermic reaction?

A.) The reaction absorbs heat from the surroundings.
B.) The reaction releases heat to the surroundings.
C.) The reaction has a positive enthalpy change.
D.) The reaction has a negative entropy change.
Answer: B
Explanation: The correct answer is B. An exothermic reaction is a chemical reaction that releases heat to the surroundings. This means that the enthalpy change (ΔH) for the reaction is negative, indicating that the products have less energy than the reactants.
Therefore, option B is the correct answer.

47.) Which of the following is a strong acid?

A.) $\mathbf{H_2}C\mathbf{O_3}$
A.) HN$\mathbf{O_2}$
A.) HCl$\mathbf{O_4}$

A.) HF
Solution: The correct answer is C. $HClO_4$ is a strong acid, which means it completely dissociates in water to form H^+ and ClO_4^- ions. The other options are weak acids, which only partially dissociate in water.

48.) Which of the following is a correct statement about acids and bases?

A.) An acid is a proton acceptor and a base is a proton donor.
B.) An acid is a proton donor and a base is a proton acceptor.
C.) An acid is a hydroxide ion donor and a base is a hydrogen ion donor.
D.) An acid is a hydrogen ion acceptor and a base is a hydroxide ion acceptor.
Answer: B
Explanation: The correct answer is B. According to the Brønsted-Lowry theory of acids and bases, an acid is a proton donor and a base is a proton acceptor. In other words, an acid donates a hydrogen ion (H^+) to a base, and the base accepts the hydrogen ion to become a conjugate acid.
Therefore, option B is the correct answer.

49.) Which of the following reactions is an example of an oxidation-reduction reaction?

A.) $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
B.) $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$
C.) $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$
D.) $2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$
Answer: D
Explanation: The correct answer is D. An oxidation-reduction (redox) reaction is a chemical reaction where there is a transfer of electrons between reactants. In this case, the magnesium (Mg) is oxidized (loses electrons) to form Mg^{2+} ions, while the hydrogen ions (H^+) are reduced (gain electrons) to form hydrogen gas (H_2).
Therefore, option D is the correct answer.

50.) Which of the following substances has the highest concentration of hydrogen ions (H^+) in aqueous solution?

A.) pH = 2
B.) pH = 4
C.) pH = 7
D.) pH = 10
Answer: A
Explanation: The correct answer is A. pH is a measure of the concentration of hydrogen ions (H^+) in aqueous solution, with lower pH values indicating higher concentrations of H^+. The pH scale ranges from 0 to 14, where a pH of 7 is neutral (equal concentrations of H^+ and OH^- ions), pH values below 7 are acidic (higher concentrations of H^+ ions), and pH values above 7 are basic (higher concentrations of OH^- ions).

Therefore, option A is the correct answer, as it has the lowest pH value and therefore the highest concentration of **H+** ions.

51.) A gas sample has a volume of 2.0 L at a pressure of 1.0 atm and a temperature of 25°C. What will be the new volume of the gas if the pressure is increased to 2.0 atm at the same temperature?

A.) 0.50 L
B.) 1.0 L
C.) 2.0 L
D.) 4.0 L
Answer: B
Explanation: The correct answer is B. This is a problem involving Boyle's law, which states that at constant temperature, the pressure and volume of a gas are inversely proportional. Mathematically, this can be written as $P_1V_1 = P_2V_2$, where P_1 and V_1 are the initial pressure and volume, respectively, and P_2 and V_2 are the final pressure and volume, respectively.
Using this equation, we can solve for V2:
$P_1V_1 = P_2V_2$
$(1.0\ atm)(2.0\ L) = (2.0\ atm)V_2$
$V_2 = (1.0\ atm)(2.0\ L) / (2.0\ atm) = 1.0\ L$
Therefore, the new volume of the gas is 1.0 L, which corresponds to option B.

52.) Which of the following is an example of a heterogeneous mixture?

A.) Salt water
B.) Air
C.) Sugar dissolved in water
D.) Oil and water
Answer: D
Explanation: The correct answer is D. A heterogeneous mixture is one in which the components are not evenly distributed and can be physically separated from each other. In this case, oil and water do not mix and form distinct layers, making it a heterogeneous mixture.

53.) A sample of gas has a temperature of 273 K and a pressure of 1.0 atm. What will be the new pressure of the gas if the temperature is increased to 373 K, assuming the volume is held constant?

A.) 0.37 atm
B.) 1.0 atm
C.) 1.37 atm
D.) 2.73 atm
Answer: C
Explanation: The correct answer is C. This is a problem involving Charles's law, which states that at constant pressure, the volume and temperature of a gas are directly

proportional. Mathematically, this can be written as $V_1/T_1 = V_2/T_2$, where V_1 and T_1 are the initial volume and temperature, respectively, and V_2 and T_2 are the final volume and temperature, respectively.
Since the volume is held constant, we can use the simplified form of the equation, $P_1/T_1 = P_2/T_2$, where P_1 and T_1 are the initial pressure and temperature, respectively, and P_2 and T_1 are the final pressure and temperature, respectively. Solving for P_2:
$P_2 = (P_1)(T_2) / (T_1)$
$P_2 = (1.0 \text{ atm})(373 \text{ K}) / (273 \text{ K}) = 1.37 \text{ atm}$
Therefore, the new pressure of the gas is 1.37 atm, which corresponds to option C

54.) Which of the following is the correct Lewis structure for the sulfate ion, SOO42-?

A) O=S=O
B) O=S-O
C) O=S=O
D) O-S=O
Answer: C
Explanation: The correct answer is C. The sulfate ion has a total of 32 valence electrons (6 from each oxygen atom and 4 from the sulfur atom). To draw the Lewis structure, we start by placing the atoms around the sulfur atom, with the oxygen atoms forming double bonds with the sulfur atom. This gives us the structure O=S=O, but we still have 2 extra electrons. We add these electrons as a lone pair on one of the oxygen atoms, giving us the final structure of O=S=O with a -2 charge.

55.) Which of the following gases is the most soluble in water at room temperature and standard pressure?

A) Nitrogen
B) Helium
C) Carbon dioxide
D) Hydrogen
Answer: C
Explanation: The correct answer is C. The solubility of a gas in a liquid depends on factors such as the partial pressure of the gas, temperature, and the nature of the gas and solvent. At room temperature and standard pressure, carbon dioxide is the most soluble of the gases listed due to its polar nature and ability to form hydrogen bonds with water molecules.

56.) What is the oxidation state of carbon in CH3OH?

A) +1
B) -1
C) +2
D) -2
Answer: C
Explanation: The correct answer is C. To determine the oxidation state of carbon in CH3OH, we first assign the oxidation states of the other atoms in the molecule.

Hydrogen is always assigned an oxidation state of +1, and oxygen is assigned an oxidation state of -2. Since there are 4 hydrogen atoms in CH3OH, they contribute a total of +4 to the oxidation state of the molecule. The oxygen atom contributes -2, leaving a net oxidation state of -2+4 = +2 for the carbon atom.

57.) The reaction $2H_2O_2$ (aq) → $2H_2O$ (l) + O_2 (g) is an example of what type of reaction?

A.) Combustion
B.) Decomposition
C.) Single-replacement
D.) Double-replacement
Answer: B
Explanation: The answer is B. The reaction is a decomposition reaction, where a single reactant breaks down into two or more products.

58.) Which of the following is a Bronsted-Lowry acid?

A) **Cl**–
B) NaOH
C) H_2SO_4
D) H_2O
Answer: C
Explanation: The correct answer is C. A Bronsted-Lowry acid is a substance that donates a proton (**H**+) to another substance. Among the options listed, only H_2SO_4 is capable of donating a proton.

59.) Which of the following statements about an ideal gas is NOT true?

A) The volume of an ideal gas is directly proportional to its temperature.
B) An ideal gas has no intermolecular forces.
C) The pressure of an ideal gas is directly proportional to its volume.
D) An ideal gas has no mass.
Answer: C
Explanation: The correct answer is C. The pressure of an ideal gas is directly proportional to its volume. According to Boyle's Law, the pressure of an ideal gas is inversely proportional to its volume at constant temperature. This means that as the volume of an ideal gas decreases, its pressure increases.

60.) Which of the following is true for an exothermic reaction at constant temperature and pressure?

A) The entropy of the system decreases.
B) The entropy of the surroundings decreases.
C) The enthalpy of the system decreases.
D) The enthalpy of the surroundings decreases.
Answer: D

Explanation: The correct answer is D. The enthalpy of the surroundings decreases. In an exothermic reaction, heat is released from the system to the surroundings. Since the temperature and pressure are constant, the change in internal energy of the system is equal to the heat released, which means the change in enthalpy of the system is negative. By the conservation of energy, the change in enthalpy of the surroundings must be positive, indicating an increase in the entropy of the surroundings.

SECTION II – FREE RESPONSE

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O+(aq) + CH_3COO-(aq)$ $K_a = 1.8 \times 10-5$

1.) Acetic acid, CH_3COOH, ionizes according to the equation above

a.)Write the expression for the equilibrium constant, Ka, for the reaction.
Solution:
$K_c = [H_3O+][CH_3COO-]/[CH_3COOH][H_2O]$
In this expression, the square brackets denote the molar concentrations of the species in the equilibrium mixture. Note that the concentration of water is not included in the expression because it is a pure liquid and its concentration does not change during the reaction.
b.) Calculate the pH of a 0.5 M solution of CH3COOH.
Solution:
$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$
The equilibrium constant expression for this reaction is:
$K_a = [CH_3COO^-][H_3O^+] / [CH_3COOH]$
where Ka is the acid dissociation constant of acetic acid. The Ka value for acetic acid at 25°C is 1.8×10^{-5}. Since we are given the initial concentration of acetic acid as 0.5 M, we can assume that at equilibrium, some of the acetic acid will have dissociated to form acetate ions and hydronium ions. Let's assume that x moles of acetic acid dissociate per liter of solution. Then, at equilibrium, the concentration of hydronium ions will be x M and the concentration of acetate ions will also be x M. The concentration of undissociated acetic acid will be (0.5 – x) M. Now we can use the equilibrium constant expression to solve for x:

$Ka = [CH_3COO^-][H_3O^+] / [CH_3COOH]$
$1.8 \times 10^{-5} = x^2 / (0.5 - x)$
Solving for x, we get:
$x = 0.0074$ M
Therefore, the concentration of hydronium ions in the solution is 0.0074 M, and the pH of the solution can be calculated as:

pH = -log[H_3O^+]
pH = -log(0.0074)
pH = 2.13
So the pH of a 0.5 M solution of CH_3COOH is approximately 2.13.

c.) Show the Lewis electron-dot diagram for CH_3COOH. Show all bonding and nonbonding valence electrons.

Solution:

$H_2NNH_2(aq) + H_2O(l) \rightleftharpoons H_2NNH_3{+}(aq) + OH^-(aq)$

d.) In aqueous solution, the compound H_2NNH_2 reacts according to the equation above. A 75.0 mL sample of 0.10 M H_2NNH_2 (aq) is combined with a 25.0 mL sample of 0.20 M CH_3COOH(aq).

Write the balanced net ionic equation for the reaction that occurs when H_2NNH_2 is combined with CH_3COOH.

Solution:

The balanced net ionic equation for the reaction that occurs when H_2NNH_2 is combined with CH_3COOH in aqueous solution is:

$H_2NNH_2(aq) + CH_3COOH(aq) \rightarrow CH3COO{-}(aq) + H_2NNH_3{+}(aq)$

The complete ionic equation, showing all the ions that are present in the reaction, is:

$H_2NNH_2(aq) + CH_3COOH(aq) \rightarrow CH_3COO{-}(aq) + H3O{+}(aq) + H_2NNH_3{+}(aq)$

In the complete ionic equation, the H_3O^+ ion is produced by the reaction between the H_2NNH_2 and the H_2O in the solution. However, since H_2O is present on both sides of the equation, it can be canceled out, leaving only the net ionic equation shown above.

Is the resulting solution acidic, neutral, or basic? Justify your answer.

Solution:

In the reaction between $H_2NNH_2$and CH_3COOH, the H_2NNH_2 acts as a weak base and the CH_3COOH acts as a weak acid. The net ionic equation for the reaction is:

$H_2NNH_2(aq) + CH_3COOH(aq) \rightarrow CH_3COO{-}\ (aq) + H_2NNH_3{+}(aq)$

In this equation, H_2NNH_2 is accepting a proton from CH_3COOH to form the conjugate acid $H_2NNH_3{+}$. The presence of H2NNH3+ in the solution indicates that the solution is acidic, as H_2NNH_3+ can donate a proton to water to generate H_3O+ ions.

Additionally, the production of acetate ions (CH_3COO^-) in the reaction can also contribute to the acidity of the solution. When acetate ions are present in water, they undergo hydrolysis to generate hydroxide ions which can further increase the pH of the solution.

Therefore, the resulting solution from the reaction between H_2NNH_2 and CH_3COOH is acidic.

When a catalyst is added to a solution of $CH_3COOH(aq)$, the reaction represented by the following equation occurs: $2CH_3COOH(aq) \rightarrow 2H_2(g) + 2CO_2(g)$

e.) Is the reaction a redox reaction? Justify your answer.

Solution:

A redox (reduction-oxidation) reaction involves the transfer of electrons between species. In a redox reaction, one species is oxidized (loses electrons) and another species is reduced (gains electrons).

In the given equation, there is no transfer of electrons between species. The only species involved are H+, CO_2, and CH_3COOH, and there are no changes in oxidation states for any of these elements.

Instead, the catalyst (which is not explicitly given in the equation) facilitates the protonation of CH_3COOH, leading to the formation of H_2CO_3. H_2CO_3 then decomposes into H_2O and CO_2, releasing H+ ions in the process. This leads to the overall reaction:

$2CH_3COOH(aq) \rightarrow 2\ H+(aq) + 2\ CO_2(g) + 2\ H_2O(l)$

As there is no transfer of electrons between species, this reaction is not a redox reaction.

f.) The reaction occurs in a rigid 4.0 L vessel at 25°C, and the total pressure is monitored, as shown in the graph above. The vessel originally did not contain any gas. Calculate the number of moles of CO_2 (g) produced in the reaction when the final pressure is 0.6 atm. (Assume that the amount of CO_2 (g) dissolved in the solution is negligible.)

Solution:

To convert these pressures to the number of moles of gas, we can use the ideal gas law:

PV = nRT where P is the pressure in atm, V is the volume in L, n is the number of moles, R is the gas constant (0.08206 L·atm/mol·K), and T is the temperature in K (25°C = 298 K). For the initial state, we have: P1V = n1RT where P1 = 0 atm, V = 4.0 L, R = 0.08206 L·atm/mol·K, and T = 298 K. Solving for n1, we get:

n1 = P1V/RT = (0 atm)(4.0 L)/(0.08206 L·atm/mol·K)(298 K) = 0 mol

This means that there are initially no moles of gas in the system.

For the final state, we have:

$P_2V = n_2RT$

where P_2 = 0.6 atm, V = 4.0 L, R = 0.08206 L·atm/mol·K, and T = 298 K. Solving for n_2, we get: $n_2 = P_2V/RT$ = (0.6 atm)(4.0 L)/(0.08206 L·atm/mol·K)(298 K) = 0.0728 mol

This means that there is 0.0728 mol of gas in the system at the end of the reaction.

Since the reaction produces 2 moles of CO_2 (g) for every 2 moles of H_2 (g), the number of moles of CO2(g) produced is equal to the number of moles of H2(g) produced, which is half the total number of moles of gas produced:

$nCO_2 = nH_2/2 = n_2/2 = 0.0728/2 = 0.0364$ mol

Therefore, the number of moles of CO_2(g) produced in the reaction is 0.0364 mol.

g.) After the reaction has proceeded for several minutes, does the amount of catalyst increase, decrease, or remain the same? Justify your answer.

Solution:

The amount of catalyst should remain the same during the reaction.

A catalyst is a substance that speeds up a chemical reaction without being consumed itself. In other words, a catalyst is not used up in the reaction and does not appear in the products. Therefore, the amount of catalyst remains constant throughout the reaction.

In the given reaction, the catalyst is not a reactant and is not involved in the reaction. Its only role is to speed up the reaction. As the reaction proceeds, the catalyst continues to facilitate the reaction, but it does not participate in the reaction itself. Therefore, the amount of catalyst should remain the same throughout the reaction.

2.) Answer the following questions about the element C and some of its compounds.

a.) The mass spectrum of a pure sample of C is shown below:

Isotopes	Atomic Mass Unit(amu)	Relative Abundance(%)
12C	12	98.892
13C	13.00335	1.108
14C	14.00317	$2x10^{-10}$

i.) How many protons and how many neutrons are in the nucleus of an atom of the least abundant isotope of C?

Solution:

6 protons and 6 neutrons

ii.) Write the ground-state electron configuration of C

Solution:

The atomic number of carbon (C) is 6, which means it has six electrons in its neutral state. The ground-state electron configuration of C is:

$1s^2 2s^2 2p^2$

Two compounds of Carbon are Ethanol(C_2H_5OH) and Methane(CH_4)

b.) The boiling point of Ethanol is 78.4 °C at standard pressure (1 atm) while the boiling point of Methane is -161.5 °C at standard pressure (1 atm). Using principles of interparticle forces, explain the difference in boiling points.

Solution:

Ethanol is a polar molecule, which means that it has a positive and a negative end due to an unequal distribution of electrons. This polarity leads to strong intermolecular forces of attraction between ethanol molecules, such as hydrogen bonding and dipole-dipole interactions. These intermolecular forces require a significant amount of energy to overcome, which results in a higher boiling point for ethanol.

On the other hand, methane is a nonpolar molecule, which means that it has no net dipole moment and no positive or negative ends. The only intermolecular force present in methane is the weak van der Waals force, which is much weaker than the intermolecular forces present in ethanol. Therefore, methane requires much less energy to overcome these weak intermolecular forces and boil, resulting in a lower boiling point than ethanol.

c.) Write a balanced equation for the thermal decomposition of ethanol at high temperatures in the absence of oxygen

Solution:

$C_2H_5OH(g) \rightarrow CH_4(g) + CO(g)$

A table of absolute entropies of some substances is given below.

Substance	S° ($JK^{-1}mol^{-1}$)
Methane(g)	186.3
Carbon Monoxide(g)	197.9
Ethanol(l)	164.8

d.) Explain why the absolute molar entropy of Methane is greater than that of Carbon Monoxide.

Solution:

The absolute molar entropy of a substance is a measure of the number of different ways that the particles in the substance can be arranged in a given state. Generally, substances with more particles or more complex molecular structures tend to have higher absolute molar entropy values.

Methane (CH_4) has a molecular structure that consists of one carbon atom bonded to four hydrogen atoms. The molecule has a tetrahedral shape and can undergo various rotational and vibrational motions, leading to a larger number of possible arrangements of the particles. In addition, methane has a larger number of particles than carbon monoxide (CO), which has only one carbon atom and one oxygen atom bonded together. Carbon monoxide, on the other hand, has a simpler molecular structure consisting of only two atoms, with a linear shape. This linear structure allows for fewer rotational and vibrational motions than methane, and therefore, carbon monoxide has a lower absolute molar entropy value.

e.) Calculate the value, in J/(mol·K), of ΔS° for the reaction.
Solution:
To calculate the standard entropy change, ΔS°, for the reaction $C_2H_5OH(g) \rightarrow CH_4(g) + CO(g)$, we need to know the standard molar entropies of the reactants and products.
The standard molar entropies of the reactant, $C_2H_5OH(g)$, and products, $CH_4(g)$ and $CO(g)$, are:
$\Delta S°\_r(C_2H_5OH,g) = 282.7\ J/(mol·K)$
$\Delta S°\_r(CH_2,g) = 186.3\ J/(mol·K)$
$\Delta S°\_r(CO,g) = 197.9\ J/(mol·K)$
The stoichiometric coefficients of the reaction are 1 for $C_2H_5OH(g)$, and 1 each for $CH_4(g)$ and $CO(g)$, so the change in entropy for the reaction is:
$\Delta S° = \Sigma n\Delta S°\_r(products) - \Sigma m\Delta S°\_r(reactants)$
$\Delta S° = (1)(186.3\ J/(mol·K)) + (1)(197.9\ J/(mol·K)) - (1)(282.7\ J/(mol·K))$
$\Delta S° = 101.5\ J/(mol·K)$
Therefore, the standard entropy change for the reaction is 101.5 J/(mol·K).

f.) Using principles of atomic structure, explain why the first ionization energy of C is greater than that of Si and Ge.
Solution:
The first ionization energy is the energy required to remove the outermost electron from an atom in the gaseous state. The ionization energy depends on the effective nuclear charge experienced by the outermost electron and the distance between the electron and the nucleus.
In general, as we move from left to right across a period in the periodic table, the atomic radius decreases, and the effective nuclear charge experienced by the outermost electron increases. This makes it harder to remove the electron, resulting in an increase in the ionization energy.

Carbon, silicon, and germanium are all in the same period of the periodic table. However, the atomic number of carbon is smaller than that of silicon and germanium. As a result, carbon has a smaller atomic radius and a higher effective nuclear charge experienced by its outermost electron compared to silicon and germanium. This means that it takes more energy to remove the outermost electron from carbon than from silicon and germanium.

Furthermore, the electronic configuration of carbon is $1s^2 2s^2 2p^2$, which means that the outermost electron is in a half-filled p orbital. Half-filled orbitals are more stable than partially filled or completely filled orbitals, which makes it harder to remove the outermost electron from carbon. In contrast, the electronic configuration of silicon and germanium has partially filled p orbitals, which makes it easier to remove the outermost electron.

Therefore, the first ionization energy of carbon is greater than that of silicon and germanium due to the smaller atomic radius, higher effective nuclear charge, and the stability of the half-filled p orbital in carbon.

g.) A single photon with a wavelength of 5.40×10^{-7} m is absorbed by a carbon atom. Calculate the energy of the photon in joules.

Solution:

To calculate the energy of a photon, we can use the following formula:

$E = hc/\lambda$

where E is the energy of the photon, h is Planck's constant (6.626×10^{-34} J s), c is the speed of light (2.998×10^{8} m/s), and λ is the wavelength of the photon. Substituting the given values, we get:

$E = (6.626 \times 10^{-34}\ \text{J s}) \times (2.998 \times 10^{8}\ \text{m/s}) / (5.40 \times 10^{-7}\ \text{m})$

$E = 3.69 \times 10^{-19}\ \text{J}$

Therefore, the energy of the photon in joules is 3.69×10^{-19} J.

3.) For the precipitation experiment, the student adds 25.0 mL of 0.100 M $Pb(NO_3)2$to 50.0 mL of the KI(aq). The reaction goes to completion, and a yellow precipitate forms. The student filters the precipitate and dries it overnight. The data are given in the following table:

Mass of dry filter paper	0.512 g
Volume of KI(aq)	50.0 mL

Volume of 0.100 M Pb(NO3)2	25.0 mL
Mass of filter paper and dried precipitate	1.284 g

a.) Calculate the moles of $Pb(NO_3)_2$ used
Solution:
moles of $Pb(NO_3)_2$ = Molarity × Volume (in L)
moles of $Pb(NO_3)_2$ = 0.100 M × 0.025 L
moles of $Pb(NO_3)_2$ = 0.0025 mol
b.) Use stoichiometry to calculate the moles of KI that reacted
Solution:
From the balanced chemical equation: $Pb(NOO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$
1 mol of $Pb(NOO_3)_2$ reacts with 2 mol of KI
moles of KI = 2 × moles of $Pb(NOO_3)_2$
moles of KI = 2 × 0.0025 mol
moles of KI = 0.005 mol
c.) Calculate the molarity of the KI solution
Solution:
Molarity = moles of solute / volume of solution (in L)
Volume of solution = volume of KI(aq) + volume of $Pb(NOO_3)_2(aq)$
Volume of solution = 0.050 L + 0.025 L
Volume of solution = 0.075 L
Molarity = 0.005 mol / 0.075 L
Molarity = 0.067 M
Therefore, the molar concentration of the KI solution is approximately 0.067 M.
d.) The student uses a 0.1000 M solution of KI (aq) to make three more solutions of known concentration (0.0500 M , 0.0300 M , and 0.0100 M) in 50.00 mL volumetric flasks. Calculate the volume of 0.1000 M KI (aq) needed to make 50.00 mL of 0.0500 M KI(aq).
Solution:
To prepare a 50.00 mL solution of 0.0500 M KI(aq), you can use the following calculation:
Use the formula: $M_1V_1 = M_2V_2$
Where:
M_1 = initial molar concentration of KI(aq) = 0.1000 M
V_1 = volume of KI(aq) needed
M_2 = final molar concentration of KI(aq) = 0.0500 M
V_2 = final volume of KI(aq) = 50.00 mL
Rearrange the formula to solve for V1:

$V_1 = (M_2 \times V_2) / M_1$

$V_1 = (0.0500\ M \times 50.00\ mL) / 0.1000\ M$

$V_1 = 25.00\ mL$

Therefore, you will need to measure out 25.00 mL of the 0.1000 M KI(aq) solution and dilute it to 50.00 mL with distilled water to prepare a 50.00 mL solution of 0.0500 M KI(aq).

e.) Describe the procedure the student should follow to make 50.00 mL of 0.1000 M KI(aq) using 0.500 M KI(aq),a 50.00 mL volumetric flask, and other standard laboratory equipment.

Solution:

To make 50.00 mL of 0.1000 M KI(aq) using 0.500 M KI(aq), the student can follow the following procedure:

Using a pipette, measure out 10.00 mL of 0.500 M KI(aq) and transfer it into a clean, dry 50.00 mL volumetric flask.

Add distilled water to the volumetric flask until the level of the solution is at the mark on the neck of the flask.

Stopper the flask and mix the solution thoroughly by inverting the flask several times.

The resulting solution is now 50.00 mL of 0.1000 M KI(aq). The student can verify this concentration by performing a suitable analytical test, such as titration or spectrophotometry.

Note: It is important to ensure that all glassware is clean and dry before use, and to accurately measure and transfer the volumes of the solutions to ensure the desired concentration is achieved. Additionally, the student should wear appropriate personal protective equipment, such as gloves and safety glasses, and follow all safety precautions when working with chemicals.

f.) A second student performs the same experiment. There are a few drops of water in the cuvette before the second student adds the KI(aq) solution of unknown concentration. Will this result in a KI(aq) concentration for the unknown that is greater than, less than, or equal to the concentration determined in part (f) ? Justify your answer.

Solution:

The presence of a few drops of water in the cuvette before the addition of the KI(aq) solution by the second student will result in a calculated KI concentration that is less than the actual concentration of the solution.

The reason for this is that the addition of water to the cuvette will increase the total volume of the solution, but it will not increase the amount of KI present in the solution. As a result, the concentration of KI in the solution will be lower than if the solution had been added to an empty cuvette.

When using the Beer-Lambert Law to determine the concentration of a solution from its absorbance, we assume that the total volume of the solution is known and constant. If the actual volume of the solution is greater than what was assumed, the calculated concentration will be lower than the actual concentration. This is because the same amount of solute is spread out over a larger volume, resulting in a lower concentration.
Therefore, the presence of a few drops of water in the cuvette will result in a calculated KI concentration that is less than the actual concentration of the solution.

Short Response Questions:

Question 1: A gas mixture contains 2.50 moles of H_2, 1.00 mole of N_2, and 1.50 moles of He in a 10.0 L container at 25°C. Calculate the partial pressure of each gas in the mixture and the total pressure.

Solution:

To calculate the partial pressure of each gas, we need to use the ideal gas law:
PV = nRT
where P is pressure, V is volume, n is the number of moles, R is the gas constant, and T is the temperature.

First, we need to calculate the total number of moles of gas in the container:
n(total) = 2.50 mol H_2 + 1.00 mol N_2 + 1.50 mol He
n(total) = 5.00 mol
Next, we can use the mole fraction of each gas to calculate its partial pressure:
X(H_2) = 2.50 mol H_2 / 5.00 mol total = 0.500
X(N_2) = 1.00 mol N_2 / 5.00 mol total = 0.200
X(He) = 1.50 mol He / 5.00 mol total = 0.300
Now we can use the ideal gas law to calculate the partial pressure of each gas:
P(H_2) = X(H_2) * P(total) = 0.500 * P(total)

$P(N_2) = X(N_2) * P(total) = 0.200 * P(total)$
$P(He) = X(He) * P(total) = 0.300 * P(total)$
Finally, we can use the ideal gas law again to calculate the total pressure:
$P(total) = n(total) * RT / V$
$P(total) = 5.00\ mol * 0.0821\ L\ atm\ mol^{-1}\ K^{-1} * 298\ K / 10.0\ L$
$P(total) = 12.2\ atm$

Plugging in P(total) into the equations above gives:
P(H2) = 0.500 * 12.2 atm = 6.10 atm
P(N2) = 0.200 * 12.2 atm = 2.44 atm
P(He) = 0.300 * 12.2 atm = 3.66 atm

Therefore, the partial pressure of each gas in the mixture is 6.10 atm for H2, 2.44 atm for N2, and 3.66 atm for He, and the total pressure is 12.2 atm.

Question 2: The following reaction is exothermic:

$2NO_2(g) \rightleftharpoons N_2O_4(g) + heat$

a) At a certain temperature, the equilibrium constant (Kc) is 4.63×10^{-3}. If 0.25 mol of NO2 and 0.50 mol of N_2O_4 are mixed in a 2.00 L container at this temperature, calculate the equilibrium concentrations of each species.
b) How would each of the following changes affect the equilibrium position (shift left, shift right, or no change)? Explain your reasoning in each case.
i) Adding more NO_2 to the container at constant volume and temperature.
ii) Decreasing the volume of the container at constant temperature.
iii) Raising the temperature of the container at constant volume.
Solution:
a) We can use the equilibrium constant expression and the initial concentrations of NO_2 and $N_2O_4$to determine the equilibrium concentrations:
$Kc = [N_2O_4] / ([NO_2]^2)$
$4.63 \times 10^{-3} = [N_2O_4] / ([0.25\ mol / 2.00\ L]^2)$
$[N_2O_4] = 0.0367\ mol/L$
Now we can use the equilibrium constant expression again to find [NO2]:
4.63 × 10^-3 = 0.0367 mol/L / ([NO2]2)
[NO2] = 0.210 mol/L
Therefore, the equilibrium concentrations are [NO2] = 0.210 mol/L and [N2O4] = 0.0367 mol/L.
b)
i) Adding more NO2will increase the concentration of NO2and decrease the concentration of N_2O_2. According to Le Chatelier's principle, the system will shift

to the left to alleviate the stress of the increased NO2concentration, meaning the equilibrium position will shift left.
ii) Decreasing the volume of the container will increase the pressure, causing the system to shift in the direction that decreases the number of gas molecules. In this case, that means the equilibrium position will shift to the side with fewer gas molecules, which is the side with N_2O_4. Therefore, the equilibrium position will shift right.
iii) Raising the temperature will increase the amount of heat in the system, causing the system to shift in the endothermic direction to absorb some of the heat. In this case, that means the equilibrium position will shift right to produce more N_2O_4. Therefore, the equilibrium position will shift right.

Question 3: What is the relationship between the energy of an electron and its distance from the nucleus in a hydrogen atom?

Solution:
The energy of an electron in a hydrogen atom is inversely proportional to its distance from the nucleus. This is described by the equation:
$E = -R\_H / n_2$
where E is the energy, R_H is the Rydberg constant for hydrogen, and n is the principal quantum number. As n increases, the distance from the nucleus increases, and the energy of the electron decreases. Therefore, the energy of an electron in a hydrogen atom decreases as its distance from the nucleus increases.

Question 4: A student reacts 25.0 mL of 0.150 M HCl with 25.0 mL of 0.150 M NaOH.

a) What is the net ionic equation for the reaction between HCl and NaOH?
Solution:
The balanced equation for the reaction between HCl and NaOH is:
HCl + NaOH → NaCl + H2O
To write the net ionic equation, we need to eliminate the spectator ions, which are Na+ and Cl-. The complete ionic equation is:
$H^+ + Cl^- + Na^+ + OH^- \rightarrow Na^+ + Cl^- + H_2O$
Canceling the spectator ions gives the net ionic equation:
$H^+ + OH^- \rightarrow H_2O$
Therefore, the net ionic equation for the reaction between HCl and NaOH is $H^+ + OH^- \rightarrow H_2O$.
b) What is the pH of the resulting solution?
Solution:
Since HCl and NaOH react in a 1:1 ratio to form H_2O and NaCl, we can assume that after the reaction, the moles of H+ ions will be equal to the

moles of OH- ions. Therefore, we can use the following equation to determine the concentration of H+ ions:

M H+ = (M HCl × V HCl – M NaOH × V NaOH) / V total

where V HCl and V NaOH are the volumes of HCl and NaOH used, respectively, and V total is the total volume of the resulting solution.

Substituting the given values:

M H+ = (0.150 M × 0.0250 L – 0.150 M × 0.0250 L) / 0.0500 L

M H+ = 0 M

Since the concentration of H+ ions is 0, the resulting solution is basic with a pH greater than 7. To determine the pH, we can use the equation:

pH = 14 – pOH

Since the concentration of OH- ions is equal to the concentration of NaOH, we can use the following equation to determine the concentration of OH- ions:

M OH- = M NaOH = 0.150 M

Substituting into the equation:

pOH = -log(0.150 M)

pOH = 0.823

Therefore, the pH of the resulting solution is:

pH = 14 – pOH

pH = 14 – 0.823

pH = 13.18

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