7 CHEMISTRY

CHEMISTRY–1

The mole is a basic unit of measurement in chemistry. Which of the following is NOT equal to or the same as 1 mol of the substance indicated?

(A) 22.4 L of nitrogen (N_2) gas at STP
(B) 6.02×10^{23} oxygen (O_2) molecules
(C) 12 g of carbon atoms
(D) 16 g of oxygen (O_2) molecules

Oxygen has a molar mass of 16 g/mol. Therefore, 1 mol of O_2 has a mass of 32 g.

The answer is (D).

CHEMISTRY–2

Which one of the following is standard temperature and pressure (STP)?

(A) 0K and one atmosphere pressure
(B) 0°F and zero pressure
(C) 32°F and zero pressure
(D) 0°C and one atmosphere pressure

By definition, standard temperature and pressure is 0°C and 1 atm pressure.

The answer is (D).

CHEMISTRY–3

An ideal gas at 0.60 atm and 87°C occupies 0.450 L. The gas constant is $R^* =$ 0.0821 L·atm/mol·K. How many moles are in the sample?

(A) 0.000 20 mol (B) 0.0091 mol (C) 0.0120 mol (D) 0.038 mol

Use the ideal gas law.

$$pV = nR^*T$$

$$\begin{aligned} n &= \frac{pV}{R^*T} \\ &= \frac{(0.60 \text{ atm})(0.45 \text{ L})}{\left(0.0821 \ \frac{\text{L·atm}}{\text{mol·K}}\right)(87°\text{C} + 273°)} \\ &= 0.0091 \text{ mol} \end{aligned}$$

The answer is (B).

CHEMISTRY–4

A gas occupies 0.213 L at STP. How many moles are there in this sample of gas?

(A) 0.0089 mol (B) 0.0095 mol (C) 0.089 mol (D) 0.095 mol

$$pV = nR^*T$$

$$n = \frac{pV}{R^*T}$$

At STP,

$$p = 1 \text{ atm}$$

$$T = 273\text{K}$$

$$\begin{aligned} n &= \frac{(1.0 \text{ atm})(0.213 \text{ L})}{\left(0.0821 \ \frac{\text{atm·L}}{\text{mol·K}}\right)(273\text{K})} \\ &= 0.009\,50 \text{ mol} \end{aligned}$$

The answer is (B).

CHEMISTRY–5

An ideal gas is contained in a vessel of unknown volume at a pressure of 1 atmosphere. The gas is released and allowed to expand into a previously evacuated vessel whose volume is 0.500 L. Once equilibrium has been reached, the temperature remains the same while the pressure is recorded as 500 mm of mercury. What is the unknown volume, V, of the first vessel?

(A) 0.853 L (B) 0.962 L (C) 1.07 L (D) 1.18 L

For an ideal gas at a constant temperature,

$$p_1V_1 = p_2V_2$$

$$p_1 = 1.0 \text{ atm} = 760 \text{ mm Hg}$$

$$(760 \text{ mm Hg})V_1 = (500 \text{ mm Hg})(0.5 \text{ L} + V_1)$$

$$V_1 = 0.962 \text{ L}$$

The answer is (B).

CHEMISTRY–6

What is most nearly the combined volume of 1.0 g of hydrogen gas (H_2) and 10.0 g of helium gas (He) when confined at 20°C and 5 atm?

(A) 10 L (B) 12 L (C) 14 L (D) 16 L

Use the ideal gas law.

$$pV = nR^*T$$

$$V = \frac{n_{\text{total}}R^*T}{p}$$

$$\begin{aligned} n_{\text{total}} &= n_{H_2} + n_{He} \\ &= (1.0 \text{ g})\left(\frac{1 \text{ mol } H_2}{2 \text{ g } H_2}\right) + (10.0 \text{ g})\left(\frac{1 \text{ mol He}}{4 \text{ g He}}\right) \\ &= 3.0 \text{ mol} \end{aligned}$$

$$\begin{aligned} V &= \frac{(3.0 \text{ mol})\left(0.0821 \dfrac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)(293\text{K})}{5 \text{ atm}} \\ &= 14 \text{ L} \end{aligned}$$

The answer is (C).

CHEMISTRY–7

The valve between a 9 L tank containing gas at 5 atm and a 6 L tank containing gas at 10 atm is opened. What is the equilibrium pressure obtained in the two tanks at constant temperature? Assume ideal gas behavior.

(A) 5 atm (B) 6 atm (C) 7 atm (D) 8 atm

$$p_{\text{total}} = p_1 + p_2$$

$$p_n = \text{partial pressure of gas } n$$

For an ideal gas at a constant temperature,

$$p_i V_i = p_f V_f$$

$$p_f = p_i \left(\frac{V_i}{V_f}\right)$$

$$p_1 = (5\ \text{atm})\left(\frac{9\ \text{L}}{15\ \text{L}}\right) = 3\ \text{atm}$$

$$p_2 = (10\ \text{atm})\left(\frac{6\ \text{L}}{15\ \text{L}}\right) = 4\ \text{atm}$$

$$p_{\text{total}} = 3\ \text{atm} + 4\ \text{atm} = 7\ \text{atm}$$

The answer is (C).

CHEMISTRY–8

A bicycle tire has a volume of 600 cm^3. It is inflated with CO_2 to a pressure of 5.4 atm at 20°C. Approximately how many grams of CO_2 are contained in the tire?

(A) 3.8 g (B) 4.8 g (C) 6.0 g (D) 6.4 g

$$pV = nR^*T$$

$$n = \frac{pV}{R^*T}$$

$$V = (600\ \text{cm}^3)\left(\frac{1\ \text{L}}{1000\ \text{cm}^3}\right) = 0.6\ \text{L}$$

$$T = 20°\text{C} + 273° = 293\text{K}$$

$$n = \frac{(5.4 \text{ atm})(0.6 \text{ L})}{\left(0.0821 \ \frac{\text{atm·L}}{\text{mol·K}}\right)(293\text{K})}$$
$$= 0.135 \text{ mol}$$

The molecular weight of CO_2, MW_{CO_2}, is

$$MW_{CO_2} = 12 \ \frac{\text{g}}{\text{mol}} + \left(16 \ \frac{\text{g}}{\text{mol}}\right)(2)$$
$$= 44 \text{ g/mol}$$

The mass of CO_2 in the tire, m, is

$$m = n(MW_{CO_2})$$
$$= (0.135 \text{ mol})\left(44 \ \frac{\text{g}}{\text{mol}}\right)$$
$$= 5.94 \text{ g} \quad (6.0 \text{ g})$$

The answer is (C).

CHEMISTRY–9

On a hot day, the temperature rises from 13°C early in the morning to 37°C in the afternoon. What is the ratio of the concentration (in mol/L) of helium in a spherical balloon in the afternoon to the concentration of helium in the balloon in the morning?

(A) 0.51 (B) 0.69 (C) 0.92 (D) 1.1

$$pV = nR^*T$$

The concentration, C, is

$$C = \frac{n}{V}$$
$$= \frac{p}{R^*T}$$

Determine the ratio by dividing the concentration of helium in the balloon in the afternoon, C_2, by the concentration of helium in the balloon in the morning, C_1.

$$\begin{aligned}\frac{C_2}{C_1} &= \frac{T_1}{T_2}\\ &= \frac{13°\text{C} + 273°}{37°\text{C} + 273°}\\ &= 0.92\end{aligned}$$

The answer is (C).

CHEMISTRY–10

When 0.5 g of a liquid is completely evaporated and collected in a 1 L manometer, the pressure is 0.25 atm and the temperature is 27°C. Assuming ideal gas behavior, what is most nearly the molecular weight? The universal gas constant is $R^* = 0.0821$ L·atm/mol·K.

(A) 10 g/mol (B) 12 g/mol (C) 30 g/mol (D) 49 g/mol

$$n = \frac{m}{\text{MW}}$$

$$pV = nR^*T$$

$$\begin{aligned}\text{MW} &= \frac{mR^*T}{pV}\\ &= \frac{(0.5\text{ g})\left(0.0821\ \frac{\text{atm·L}}{\text{mol·K}}\right)(300\text{K})}{(0.25\text{ atm})(1.0\text{ L})}\\ &= 49.3\text{ g/mol}\end{aligned}$$

In the preceding equation, MW is molecular weight.

The answer is (D).

CHEMISTRY–11

200 mL of oxygen gas (O_2) are collected over water at 23°C and a pressure of 1 atm. What volume would the oxygen occupy dry at 273K and 1 atm?

(A) 179 mL (B) 184 mL (C) 190 mL (D) 194 mL

At 23°C, the vapor pressure of water is 0.0277 atm. Find the pressure of the oxygen assuming ideal gas behavior.

$$\begin{aligned}
p_{\text{total}} &= \sum \text{partial pressures} \\
&= p_{O_2} + p_{\text{water vapor}} \\
p_{O_2} &= 1.000 \text{ atm} - 0.0277 \text{ atm} \\
&= 0.9723 \text{ atm} \\
&= p_1
\end{aligned}$$

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$\begin{aligned}
V_2 &= \left(\frac{p_1}{p_2}\right)\left(\frac{T_2}{T_1}\right) V_1 \\
&= \left(\frac{0.9723 \text{ atm}}{1.000 \text{ atm}}\right)\left(\frac{273\text{K}}{296\text{K}}\right)(200 \text{ mL}) \\
&= 179 \text{ mL}
\end{aligned}$$

The answer is (A).

CHEMISTRY–12

8 g of Ag_2O (solid) are heated to produce oxygen gas (O_2) as follows.

$$2Ag_2O \longrightarrow 4Ag + O_2$$

The oxygen gas is collected at 35°C over water. The water vapor pressure at 35°C is 0.0555 atm. Given that the barometric pressure is 1 atm, what (wet) volume of O_2 is collected?

(A) 415 mL (B) 425 mL (C) 434 mL (D) 455 mL

The number of moles of Ag_2O, n_{Ag_2O}, is

$$n_{Ag_2O} = \frac{\text{weight of substance}}{\text{MW}}$$

$$= (8\text{ g})\left(\frac{1\text{ mol}}{(2\text{ mol})\left(108\ \frac{\text{g}}{\text{mol}}\right) + \left(16\ \frac{\text{g}}{\text{mol}}\right)(1\text{ mol})}\right)$$

$$= 0.034\text{ mol}$$

Since 2 mol of Ag_2O produce 1 mol of O_2,

$$n_{O_2} = \left(\frac{1}{2}\right)(0.034\text{ mol})$$

$$= 0.017\text{ mol}$$

$$T = 35°\text{C} + 273°$$

$$= 308\text{K}$$

$$p_{O_2} = p_{\text{total}} - p_{H_2O}$$

$$= 1\text{ atm} - 0.0555\text{ atm}$$

$$= 0.945\text{ atm}$$

$$pV = nR^*T$$

$$V_{O_2} = \frac{n_{O_2}R^*T}{p_{O_2}}$$

$$= \frac{(0.017\text{ mol})\left(0.0821\ \frac{\text{atm·L}}{\text{mol·K}}\right)(308\text{K})}{0.945\text{ atm}}$$

$$= 0.455\text{ L} \quad (455\text{ mL})$$

$\boxed{\text{The answer is (D).}}$

CHEMISTRY–13

A total of 0.1 g of water is held in a closed container at 40°C. The container holds 500 cm^3. The pressure in the container is atmospheric pressure, and the vapor pressure of water at 40°C is 55.3 torr. Most nearly how much water is in liquid form at equilibrium?

(A) There is no liquid present.

(B) $^1/_2$ of the water is liquid.

(C) $^2/_3$ of the water is liquid.

(D) $^3/_4$ of the water is liquid.

Use the ideal gas law to determine how much of the water is vapor.

$$\begin{aligned} pV &= nR^*T \\ &= \frac{mR^*T}{\text{MW}} \end{aligned}$$

MW is the molecular weight of the water.

$$\begin{aligned} m &= \frac{pV(\text{MW})}{R^*T} \\ \text{MW} &= 2 \text{ g} + 16 \text{ g} \\ &= 18 \text{ g} \\ p &= \frac{55.3 \text{ torr}}{760 \dfrac{\text{torr}}{\text{atm}}} \\ &= 0.073 \text{ atm} \\ V &= \frac{500 \text{ mL}}{1000 \text{ L}} \\ &= 0.5 \text{ L} \\ T &= 40°\text{C} + 273° = 313\text{K} \\ m_{\text{water}} &= \frac{(18 \text{ g})(0.073 \text{ atm})(0.5 \text{ L})}{\left(0.0821 \dfrac{\text{atm·L}}{\text{mol·K}}\right)(313\text{K})} \\ &= 0.026 \text{ g} \end{aligned}$$

The remainder of the H_2O is liquid.

$$m_{\text{liquid}} = m_{\text{total}} - m_{\text{water}} = 0.1 \text{ g} - 0.026 \text{ g}$$
$$= 0.074 \text{ g}$$

$$\text{fraction that is liquid} = \frac{m_{\text{liquid}}}{m_{\text{total}}}$$
$$= \frac{0.074 \text{ g}}{0.1 \text{ g}}$$
$$= 0.74 \quad (3/4)$$

The answer is (D).

CHEMISTRY–14

Which of the following statements is FALSE for an ideal gas?

(A) The molecules behave as solid spheres of finite radius.

(B) $pV = nR^*T$

(C) Collisions between gas molecules are perfectly elastic and result in no decrease in kinetic energy.

(D) No attractive forces exist between the molecules.

The volume of molecules in an ideal gas is not considered. Real gases consist of molecules of finite volume.

The answer is (A).

CHEMISTRY–15

The following statements are made with regard to the boiling point of a liquid. Which statement is FALSE?

(A) A nonvolatile substance having zero vapor pressure in solution (e.g., sugars or salts) has no true boiling point.

(B) The boiling point is the temperature at which the vapor pressure of a liquid equals the applied pressure on the liquid.

(C) Combinations of liquids having different boiling points can be separated by slowly raising the temperature to draw off each fraction (i.e., by fractional distillation).

(D) At high elevations, water boils at a lower temperature because of a reduction in the surface tension of the water.

A liquid boils when its vapor pressure is equal to the pressure of the surroundings. The lower boiling temperature at high elevations is due to the reduced atmospheric pressure, not to a change in the surface tension of a liquid.

The answer is (D).

CHEMISTRY–16

The critical point for a mixture occurs for which of the following cases?

(A) The vapor and liquid exist in a single form.
(B) The liquid has no absorbed gas.
(C) The vapor phase is stable.
(D) The liquid is completely vaporized.

The critical point for a mixture occurs when the vapor and the liquid have a form that is stable for a "critical temperature and critical pressure." It is both a liquid and a vapor with no boundaries and a uniform composition (a single form). A few substances have a triple point at which a solid, a liquid, and a gas are in equilibrium.

The answer is (A).

CHEMISTRY–17

How is "molality" defined?

(A) the number of moles of solute in 1000 g of solvent
(B) the number of moles of solute in 1 L of solution
(C) the number of gram-formula weights of solute per liter
(D) the number of gram-equivalent weights of solute in 1 L of solution

Molality is defined as the number of moles of solute per 1000 g of solvent. Option (B) is the definition of molarity, option (C) is the definition of formality, and option (D) is the definition of normality.

The answer is (A).

CHEMISTRY–18

L is a nonvolatile, nonelectrolytic liquid. A solid, S, is added to L to form a solution that just boils at 1 atm pressure. The vapor pressure of pure L is 850 torr. What is the mole fraction of liquid L in the solution?

(A) 64.3% (B) 79.4% (C) 85.7% (D) 89.4%

A liquid boils when its vapor pressure equals the pressure of its surroundings. Thus, the vapor pressure of the solution is 760 torr. From Raoult's law,

$$
\begin{aligned}
p_{\text{solution}} &= p_{\text{solvent}}(\text{mol\% of solvent}) \\
760 \text{ torr} &= (850 \text{ torr})(\text{mol\% of L}) \\
\text{mol\% of L} &= \frac{760 \text{ torr}}{850 \text{ torr}} \\
&= 0.894 \quad (89.4\%)
\end{aligned}
$$

The answer is (D).

CHEMISTRY–19

Which of the following postulates does Bohr's model of the hydrogen atom involve?

(A) The electron in an atom has an infinite range of motion allowed to it.

(B) When an atom changes from a low energy state to a high energy state, it emits a quantum of radiation whose energy is equal to the difference in energy between the two states.

(C) In any of its energy states, the electron moves in a circular orbit about the nucleus.

(D) The states of allowed electron motion are those in which the angular momentum of the electron is an integral multiple of $\hbar/\pi$.

Bohr's model of the hydrogen atom involves the following postulates.

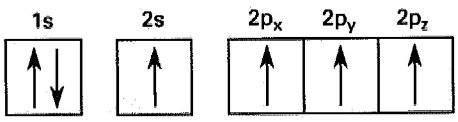
1. Each atom has only certain definite stationary states of motion allowed to it.
2. A quantum of energy is emitted when an atom changes from a higher energy state to a lower energy state.
3. The states of allowed electron motion are those in which the angular momentum of the electron is an integral multiple of $\hbar/2\pi$.

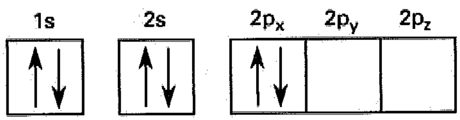
Thus, the only choice that is correct is option (C).

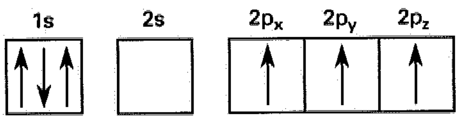
The answer is (C).

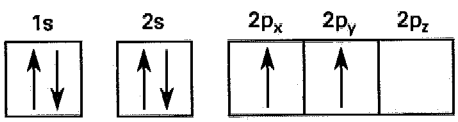
CHEMISTRY–20

Which of the following diagrams best depicts the electron configuration of carbon?

(A)


(B)


(C)


(D)


Carbon has a total of six electrons. Electrons position themselves in orbitals according to the following rules.

1. There is a maximum of two electrons per orbital.
2. Electrons in the same orbital have different spins ($\pm^1/_2$).
3. Electrons usually fill up empty orbitals before moving into the same orbital as another electron.

Thus, option (D) gives the correct electron configuration of carbon.

The answer is (D).

CHEMISTRY–21

Which of the following elements and compounds is reactive in its pure form?

(A) sodium (Na)
(B) helium (He)
(C) carbon dioxide (CO_2)
(D) hydrochloric acid (HCl)

Helium is an inert gas and, therefore, is not very reactive. Hydrochloric acid and carbon dioxide have all of their valence orbitals filled. Thus, they are also not very reactive. Sodium has only one valence electron that is easily ionizable. Therefore, it is very reactive.

The answer is (A).

CHEMISTRY–22

Two major types of chemical bonds are observed in chemical bonding: ionic and covalent. Which of the following has a bond that is the least ionic in character?

(A) NaCl (B) CH_4 (C) H_2 (D) H_2O

The electronegativity difference between two similar atoms is zero. Therefore, the H_2 bond is completely covalent. It has no ionic bond characteristics.

The answer is (C).

CHEMISTRY–23

Which of the following statements is FALSE?

(A) It is not possible for bonds between a pair of atoms to be different (e.g., different bond lengths or bond energies) in different compounds.

(B) The bond length for a pair of atoms is the point of lowest energy.

(C) The electrostatic repulsion between two nuclei increases as the atoms are brought together.

(D) The repulsion between two nuclei increases as their charge increases.

It is possible for bonds between a pair of atoms to be different in different compounds. For example, there is more than one type of carbon-carbon bond.

The answer is (A).

CHEMISTRY–24

Which of the following statements is FALSE?

(A) For a diatomic molecule, the bond dissociation energy is the change in the enthalpy of the reaction when the diatomic molecule is separated into atoms.

(B) The average bond energy is the approximate energy required to break a bond in any compound in which it occurs.

(C) The energy released when a gaseous molecule is formed from its gaseous atoms can be estimated using average bond energies.

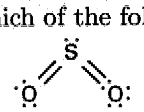
(D) The change in enthalpy is negative when energy is absorbed in the formation of a compound from its elements.

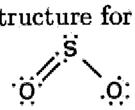
The change in enthalpy is negative for the formation of a compound from elements when energy is released in the process.

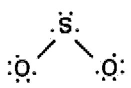
The answer is (D).

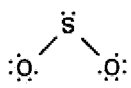
CHEMISTRY–25

Which of the following is the correct Lewis structure for sulfur dioxide?

(A) 

(B) 

(C) 

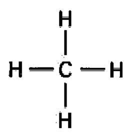
(D) 

Sulfur and oxygen each have six valence electrons. Thus, there are a total of 18 valence electrons in SO_2. Therefore, there is one single S–O bond and one double S=O bond. The Lewis structure of sulfur dioxide is as follows.

The answer is (B).

CHEMISTRY–26

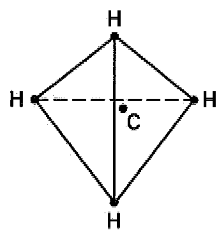
The molecule methane, CH_4, is often represented by the following structural formula.



What is the actual geometric shape of the molecule?

(A) linear
(B) square planar
(C) planar, but not 90° bond angles
(D) tetrahedral

The structure of methane is as follows.

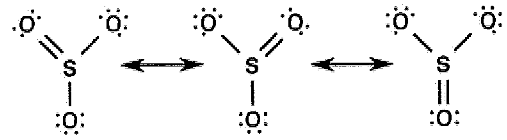


In the tetrahedral structure, bond angles are maximized and repulsions minimized, with bond angles of 109°.

The answer is (D).

CHEMISTRY–27

SO_3 has a structural formula represented as a resonance hybrid.



Which of the following is a true statement about the meaning of such a structure?

(A) One-third of the SO_3 molecules exists as each of the three structures shown.

(B) The true structure is a combination of the three with each S $\overset{--}{=}$ O bond identical to another.

(C) The molecule fluctuates between the three structures.

(D) The arrows indicate equilibrium where an actual chemical reaction is taking place.

The true structure is a combination with each bond identical, somewhere between a single and a double bond.

The answer is (B).

CHEMISTRY–28

Which of the following chemical equations is incorrect?

(A) $S + Fe \rightarrow FeS$
(B) $ZnSO_4 + Na_2S \rightarrow ZnS + Na_2SO_4$
(C) $H_2SO_4 + ZnS \rightarrow ZnSO_4 + H_2S$
(D) $ZnS + O_2 \rightarrow SO_2 + ZnO$

The equation in option (D) does not balance. It needs $^3/_2O_2$ on the left side. The equation $ZnS + {}^3/_2O_2 \rightarrow SO_2 + ZnO$ would be correct.

The answer is (D).

CHEMISTRY–29

Na_2CO_3 reacts with HCl, but not by the stoichiometry implied in the following unbalanced chemical equation.

$$Na_2CO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$

What is the smallest possible whole-number coefficient for Na_2CO_3 in the balanced equation?

(A) 1 (B) 2 (C) 4 (D) 5

The simplest balanced equation is

$$Na_2CO_3 + HCl \longrightarrow 2NaCl + H_2O + CO_2$$

The smallest whole-number coefficient for Na_2CO_3 is 1.

The answer is (A).

CHEMISTRY–30

Which of the following is the result of the reaction given?

$$5SO_2 + 2KMnO_4 + 2H_2O \longrightarrow ?$$

(A) $2MnSO_4 + K_2SO_4 + 2H_2SO_4$
(B) $2MnSO_4 + K_2SO_2 + HSO_4 + H_2O$
(C) $2MnSO_4 + K_2SO_4 + H_2SO_4$
(D) $MnSO_4 + 2K_2SO_4 + 2H_2SO_4$

Only the products listed in option (A) would balance the elements on the right and left sides of the equation.

The answer is (A).

CHEMISTRY–31

What is the balanced form of the equation given?

$$H_2O + P_4 + OH^- \longrightarrow PH_3 + H_2PO_2^-$$

(A) $4OH^- + 4P_4 + H_2O \longrightarrow 6H_2PO_2^- + 2PH_3$
(B) $P_4 + H_2O \longrightarrow H_2PO_2^- + 3PH_3$
(C) $8OH^- + 2P_4 + 2H_2O \longrightarrow H_2PO_2^- + PH_3$
(D) $3OH^- + P_4 + 3H_2O \longrightarrow 3H_2PO_2^- + PH_3$

The two half reactions are

$$8OH^- + P_4 \longrightarrow 4H_2PO_2^- + 4E^-$$
$$12E^- + 12H_2O + P_4 \longrightarrow 4PH_3 + 12OH^-$$

Multiplying the top equation by 3 and adding the two equations together yields

$$12OH^- + 4P_4 + 12H_2O \longrightarrow 12H_2PO_2^- + 4PH_3$$

In order to reduce the equation to the lowest whole number coefficients, divide by 4.

$$3OH^- + P_4 + 3H_2O \longrightarrow 3H_2PO_2^- + PH_3$$

The answer is (D).

CHEMISTRY–32

Which of the following chemical reactions relates to the softening procedure in water purification?

(A) $CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$
(B) $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$
(C) $2H_2O + O_2 \longrightarrow 2H_2O_2$
(D) $NaOH + HCl \longrightarrow NaCl + H_2O$

Option (B) gives the chemical reaction for adding lime to hard water in order to remove calcium salts. The resulting calcium carbonate precipitate can be removed by sedimentation.

The answer is (B).

CHEMISTRY–33

A substance is oxidized when which of the following occurs?

(A) It turns red.
(B) It becomes more negative.
(C) It loses electrons.
(D) It gives off heat.

By definition, a substance is oxidized when it loses electrons.

The answer is (C).

CHEMISTRY–34

In order to assign oxidation states in polyatomic molecules, which of the following rules is followed?

(A) The oxidation of all elements in any allotropic form is zero.

(B) The oxidation state of oxygen is always -2.

(C) The oxidation state of hydrogen is always $+1$.

(D) All other oxidation states are chosen such that the algebraic sum of the oxidation states for the ion or molecule is zero.

Option (B) is false because it does not take into account the peroxides in which the oxidation state of O is -1. Option (C) is false because it does not account for hydrogen combined with metals, where its oxidation state is -1. Option (D) is wrong because the sum of the oxidation states should equal the net charge on the ion or molecule. Thus, only option (A) is correct.

The answer is (A).

CHEMISTRY–35

What is the oxidation state of nitrogen in NO_3^-?

(A) −1 (B) +1 (C) +3 (D) +5

The oxidation state of O is −2, and the net charge on the ion is −1. The oxidation state of nitrogen is given as follows.

$$\begin{aligned} 3(\text{oxidation state of O}) + (\text{oxidation state of N}) &= -1 \\ (3)(-2) + (\text{oxidation state of N}) &= -1 \\ \text{oxidation state of N} &= +5 \end{aligned}$$

The answer is (D).

CHEMISTRY–36

What is the oxidation number of Cr in the dichromate ion $(Cr_2O_7)^{-2}$?

(A) −1 (B) 0 (C) 3 (D) 6

The oxidation number of O is −2. Therefore, the oxidation number of O_7 is −14. The charge on the ion is −2, so the charge on Cr_2 is 12. Thus, the oxidation number of Cr is 6.

The answer is (D).

CHEMISTRY–37

Given the following information, determine the oxidation state of nitrogen in nitric acid, HNO_3.

oxidation state	formula	name
1	$HClO$	hypochlorous acid
3	$HClO_2$	chlorous acid
5	$HClO_3$	chloric acid
7	$HClO_4$	perchloric acid
3	HNO_2	nitrous acid

(A) 2 (B) 3 (C) 4 (D) 5

The outer shell of oxygen is 2 electrons short of being full (inert gases have a full shell). Thus, the oxidation number of oxygen is 2 for both ions. By adding another oxygen atom to nitrous acid, the oxidation level is increased by 2. This situation compares directly with that of $HClO_2$ and $HClO_3$. Thus, the oxidation state of nitric acid is 5.

The answer is (D).

CHEMISTRY–38

Which are the oxidizing and reducing agents in the following reaction?

$$2CCl_4 + K_2CrO_4 \longrightarrow 2Cl_2CO + CrO_2Cl_2 + 2KCl$$

(A) oxidizing agent: chromium; reducing agent: chlorine
(B) oxidizing agent: oxygen; reducing agent: chlorine
(C) oxidizing agent: chromium; reducing agent: oxygen
(D) There are no oxidizing or reducing agents in this reaction.

The oxidation state of chromium is 6 in each compound. Carbon remains with a +4 oxidation state throughout the reaction. The oxidation states of both chlorine and oxygen remain the same throughout this reaction. Thus, nothing is oxidized or reduced in the reaction.

The answer is (D).

CHEMISTRY–39

A volumetric analysis of a gaseous mixture is as follows.

CO_2	12%
O_2	4%
N_2	82%
CO	2%

What is the percentage of CO on a mass basis?

(A) 0.5% (B) 0.8% (C) 1% (D) 2%

name	vol. (%)	mole frac. (mol%)		mol. wt.		mass (g)
CO_2	12	0.12	$\times$	44	=	5.3
O_2	4	0.04	$\times$	32	=	1
N_2	82	0.82	$\times$	28	=	23
CO	2	0.02	$\times$	28	=	0.6
						30.0

The total mass of the mixture is 30.08 kg. Thus, the mass percentage of CO is given as follows.

$$\text{mass \% of CO} = \frac{0.6 \text{ g}}{30.0 \text{ g}} = 0.02 \quad (2\%)$$

$\boxed{\text{The answer is (D).}}$

CHEMISTRY–40

What is the empirical formula for a compound that has the following composition by mass?

element	mass %
Si	30.2
O	8.59
F	61.2

(A) $SiOF_4$ (B) Si_2OF_4 (C) Si_2OF_6 (D) Si_3OF_6

element	mass (%)	mass (g, based on 100 g)	moles	mole (mol%)
Si	30.2	30.2	1.075	22.2
O	8.59	8.59	0.537	11.1
F	61.2	61.2	3.221	66.6

Find the smallest whole-number ratio of the mole percentage of each element to that of oxygen.

$$\frac{\text{Si}}{\text{O}} = \frac{22.2 \text{ g}}{11.1 \text{ g}} = 2$$

$$\frac{\text{F}}{\text{O}} = \frac{66.6 \text{ g}}{11.1 \text{ g}} = 6$$

$$\frac{\text{O}}{\text{O}} = \frac{11.1 \text{ g}}{11.1 \text{ g}} = 1$$

Therefore, the simplest formula is Si_2OF_6.

$\boxed{\text{The answer is (C).}}$

CHEMISTRY–41

The following equation describes the decomposition of potassium chlorate to produce oxygen gas.

$$2KClO_3 \longrightarrow 2KCl\ (\textit{solid}) + 3O_2\ (\textit{gas})$$

Approximately how many grams of $KClO_3$ must be used to produce 4.00 L of O_2 (*gas*) measured at 7400 torr and 30°C?

(A) 110 g (B) 120 g (C) 130 g (D) 140 g

$$p = \frac{7400 \text{ torr}}{760 \ \frac{\text{torr}}{\text{atm}}} = 9.74 \text{ atm}$$

$$V = 4 \text{ L}$$

$$T = 30°\text{C} + 273° = 303\text{K}$$

$$pV = nR^*T$$

$$\begin{aligned} n &= \frac{pV}{R^*T} \\ &= \frac{(9.74 \text{ atm})(4.00 \text{ L})}{\left(0.0821 \ \frac{\text{atm·L}}{\text{mol·K}}\right)(303\text{K})} \\ &= 1.57 \text{ mol} \end{aligned}$$

$$\frac{\text{no. of moles KClO}_3}{\text{no. of moles of O}_2} = 2 \text{ mol}/3 \text{ mol}$$

$$\begin{aligned} \text{no. of moles KClO}_3 \text{ needed} &= \left(\frac{2 \text{ mol}}{3 \text{ mol}}\right)(1.57 \text{ mol}) \\ &= 1.05 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{MW}_{\text{KClO}_3} &= 39.1 \ \frac{\text{g}}{\text{mol}} + 35.5 \ \frac{\text{g}}{\text{mol}} + \left(16 \ \frac{\text{g}}{\text{mol}}\right)(3 \text{ mol}) \\ &= 123 \text{ g/mol} \end{aligned}$$

$$\begin{aligned} \text{no. of grams KClO}_3 &= (1.05 \text{ mol})\left(123 \ \frac{\text{g}}{\text{mol}}\right) \\ &= 129 \text{ g} \quad (130 \text{ g}) \end{aligned}$$

The answer is (C).

CHEMISTRY–42

Determine which of the statements is true, given the following facts.

1. A 40 L sample of H_2 (gas) at 10°C and 740 torr is added to a 75 L sample of O_2 (gas) at 20°C and 730 torr.
2. The mixture is ignited to produce water.

(A) There is an excess of O_2 greater than 0.2 mol.
(B) There is an excess of H_2 greater than 0.2 mol.
(C) There is H_2O only.
(D) There is an excess of H_2 less than 0.2 mol.

The stoichiometric equation is

$$H_2 + \tfrac{1}{2}O_2 \longrightarrow H_2O$$

The number of moles of each gas initially present is

$$\begin{aligned} n_{H_2} &= \frac{pV}{R^*T} \\ &= \frac{\left(\dfrac{740\ \text{torr}}{760\ \dfrac{\text{torr}}{\text{atm}}}\right)(40\ \text{L})}{(10°\text{C} + 273°)\left(0.0821\ \dfrac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)} \\ &= 1.7\ \text{mol} \\ n_{O_2} &= \frac{pV}{R^*T} \\ &= \frac{\left(\dfrac{730\ \text{torr}}{760\ \dfrac{\text{torr}}{\text{atm}}}\right)(75\ \text{L})}{(20°\text{C} + 273°)\left(0.082\ \dfrac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)} \\ &= 3.0\ \text{mol} \end{aligned}$$

For each mole of H_2O formed, 0.5 mol of O_2 and 1 mol of H_2 are required. The oxygen necessary to completely react with 1.7 mol of H_2 is given by

$$\begin{aligned} n &= \frac{1.7\ \text{mol}}{2} \\ &= 0.85\ \text{mol} \end{aligned}$$

Therefore, there is an excess of O_2. The amount of O_2 extra is

$$3.0 \text{ mol} - 0.85 \text{ mol} = 2.15 \text{ mol}$$

The answer is (A).

CHEMISTRY–43

If 2.25 g of pure calcium metal are converted to 3.13 g of pure CaO, what is the atomic weight of calcium? The atomic weight of oxygen is 16 g/mol.

(A) 28 g/mol (B) 33 g/mol (C) 37 g/mol (D) 41 g/mol

The stoichiometric equation is

$$\text{Ca} + \text{O} \longrightarrow \text{CaO}$$

One mol of oxygen and 1 mol of calcium are required to make 1 mol of CaO.

$$\begin{aligned} n_\text{O} &= \frac{3.13 \text{ g} - 2.25 \text{ g}}{16 \ \frac{\text{g}}{\text{mol}}} \\ &= \frac{0.88 \text{ g}}{16 \ \frac{\text{g}}{\text{mol}}} \\ &= 0.055 \text{ mol} \\ n_\text{Ca} &= 0.055 \text{ mol} \\ &= \frac{2.25 \text{ g}}{\text{atomic weight of Ca}} \\ \text{atomic weight of Ca} &= \frac{2.25 \text{ g}}{0.055 \text{ mol}} \\ &= 41 \text{ g/mol} \end{aligned}$$

The answer is (D).

CHEMISTRY–44

Methane, CH_4, burns to form CO_2 and H_2O according to the equation

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

How many grams of CO_2 will theoretically be formed when a mixture of 50 g of CH_4 and 100 g of O_2 is ignited?

(A) 34 g (B) 68 g (C) 69 g (D) 72 g

$$n = \frac{m}{\text{MW}}$$

In the preceding equation, m is the mass of compound and MW is the molecular weight of compound.

$$\begin{aligned} n_{CH_4} &= \frac{50\ \text{g}}{12\ \frac{\text{g}}{\text{mol}} + \left(4\ \frac{\text{g}}{\text{mol}}\right)\left(1\ \frac{\text{g}}{\text{mol}}\right)} \\ &= 3.125\ \text{mol} \\ n_{O_2} &= \frac{100\ \text{g}}{\left(2\ \frac{\text{g}}{\text{mol}}\right)\left(16\ \frac{\text{g}}{\text{mol}}\right)} \\ &= 3.125\ \text{mol} \end{aligned}$$

Since 1 mol of CH_4 and 2 mol of O_2 are needed for each mole of CO_2 formed, O_2 is the limiting reactant.

$$\frac{\text{no. of moles } CO_2 \text{ formed}}{\text{no. of moles } O_2 \text{ ignited}} = 1\ \text{mol}/2\ \text{mol}$$

$$\begin{aligned} n_{CO_2} &= (3.125\ \text{mol})\left(\frac{1\ \text{mol}}{2\ \text{mol}}\right) \\ &= 1.563\ \text{mol} \\ m_{CO_2} &= n_{CO_2}\text{MW}_{CO_2} \\ &= (1.563\ \text{mol})\left(44\ \frac{\text{g}}{\text{mol}}\right) \\ &= 69\ \text{g} \end{aligned}$$

The answer is (C).

CHEMISTRY–45

Determine the mole percent of CO_2 in the products of combustion of C_8H_{18} when 200% theoretical air is used.

(A) 5.5% (B) 6.5% (C) 7.5% (D) 8.5%

The formula for theoretical air is $O_2 + 3.76N_2$. For 200% theoretical air, the stoichiometric equation is

$$C_8H_{18} + 25(O_2 + 3.76N_2) \longrightarrow 8CO_2 + 9H_2O + 12.5O_2 + 94N_2$$

The mole percent of CO_2 is given by the ratio of the number of moles of CO_2 formed to the total number of moles formed.

$$\begin{aligned}\%CO_2 &= \frac{8 \text{ mol}}{8 \text{ mol} + 9 \text{ mol} + 12.5 \text{ mol} + 94 \text{ mol}} \\ &= 6.5\%\end{aligned}$$

The answer is (B).

CHEMISTRY–46

Approximately what volume of O_2 at 298K and 1 atm is required for complete combustion of 10 L of C_2H_6 (gas) at 500K and 1 atm? The combustion equation is

$$7O_2 + 2C_2H_6 \longrightarrow 6H_2O + 4CO_2$$

(A) 16 L (B) 19 L (C) 21 L (D) 22 L

Assume ideal gas behavior.

$$\begin{aligned}n_{C_2H_6} &= \frac{pV}{R^*T} \\ &= \frac{(1.0 \text{ atm})(10 \text{ L})}{\left(0.0821 \dfrac{\text{atm·L}}{\text{mol·K}}\right)(500\text{K})} \\ &= 0.24 \text{ mol}\end{aligned}$$

$$\frac{n_{O_2}}{n_{C_2H_6}} = 7 \text{ mol}/2 \text{ mol}$$

$$\begin{aligned}n_{O_2} &= \left(\frac{7 \text{ mol}}{2 \text{ mol}}\right)(0.24 \text{ mol}) \\ &= 0.84 \text{ mol}\end{aligned}$$

The volume of 1 mol of ideal gas at STP (standard temperature and pressure) is 22.4 L. Therefore, the volume of O_2 required at 298K is

$$V_{O_2} = n_{O_2}\left(\frac{V_{298}}{V_{STP}}\right)V_{STP}$$

$$\begin{aligned}\frac{V_{298K}}{V_{STP}} &= \frac{T_{298}}{T_{STP}}\\ &= \frac{298K}{273K}\\ &= 1.09\end{aligned}$$

$$\begin{aligned}V_{O_2} &= (0.84\ \text{mol})(1.09)\left(22.4\ \frac{\text{L}}{\text{mol}}\right)\\ &= 20.6\ \text{L}\end{aligned}$$

The answer is (C).

CHEMISTRY–47

One gram of gas made up of carbon and hydrogen is ignited in excess oxygen to produce 3.30 g of CO_2 and 1.125 g of H_2O. What is the empirical formula of the compound?

(A) CH (B) CH_3 (C) C_2H_3 (D) C_3H_5

The stoichiometric equation is

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$$

$$MW_{CO_2} = 44\ \text{g/mol}$$

$$MW_{H_2O} = 18\ \text{g/mol}$$

$$\begin{aligned}x &= \text{moles of C} = \text{moles of } CO_2\\ &= \frac{3.3\ \text{g}}{44\ \frac{\text{g}}{\text{mol}}}\\ &= 0.0750\ \text{mol}\end{aligned}$$

$$\begin{aligned}y &= \text{moles of H} = 2(\text{moles of } H_2O)\\ &= (2)\left(\frac{1.125\ \text{g}}{18\ \frac{\text{g}}{\text{mol}}}\right)\\ &= 0.125\ \text{mol}\end{aligned}$$

$$\begin{aligned}\frac{x}{y} &= \frac{\text{C atoms}}{\text{H atoms}} \\ &= \frac{\text{moles of C}}{\text{moles of H}} \\ &= \frac{0.075\ \text{mol}}{0.125\ \text{mol}} \\ &= 3/5\end{aligned}$$

Thus, the empirical formula of the gas is C_3H_5.

The answer is (D).

CHEMISTRY–48

Complete combustion of 13.02 g of a compound (C_xH_y) produces 40.94 g CO_2 and 16.72 g of H_2O. Determine the empirical formula of the compound.

(A) CH (B) CH_2 (C) CH_4 (D) CH_2O

The stoichiometric equation for combustion is

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$$

$$n = \frac{m}{\text{MW}}$$

In the preceding equation, m is the mass of compound and MW is the molecular weight.

$$\begin{aligned}n_{CO_2} &= \frac{40.94\ \text{g}}{44\ \frac{\text{g}}{\text{mol}}} \\ &= 0.93\ \text{mol} \\ &= n_C\end{aligned}$$

Therefore,

$$\begin{aligned}n_C &= 0.93\ \text{mol} \\ n_{H_2O} &= \frac{16.72\ \text{g}}{18\ \frac{\text{g}}{\text{mol}}} \\ &= 0.93\ \text{mol} \\ &= \frac{n_H}{2}\end{aligned}$$

$$n_{\text{H}} = 1.86 \text{ mol}$$

$$\frac{n_{\text{C}}}{n_{\text{H}}} = \frac{0.93 \text{ mol}}{1.86 \text{ mol}} = 1/2$$

Therefore, the empirical formula for the compound is CH_2.

$\boxed{\text{The answer is (B).}}$

CHEMISTRY–49

When 0.01 mol of a substance consisting of O, H, and C is burned, the following products are obtained.

1. 896 cm^3 of CO_2 at standard temperature and pressure (STP)
2. 0.72 g of water

It is also found that the ratio of oxygen mass to the mass of H plus C in the substance is $^4/_7$. What is the chemical formula of the substance? 1 mol of CO_2 has a volume of 22 400 cm^3 at STP.

(A) CHO_2 (B) $C_4H_6O_2$ (C) CH_2O_2 (D) $C_4H_8O_2$

The stoichiometric equation is

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right) O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$$

$$\frac{n_1}{V_2} = \frac{n_1}{V_1}$$

$$\begin{aligned} n_{\text{C}} &= V_{\text{C}}\left(\frac{n_{\text{STP}}}{V_{\text{STP}}}\right) \\ &= (896 \text{ cm}^3)\left(\frac{1.0 \text{ mol}}{22\,400 \text{ cm}^3}\right) \\ &= 0.04 \text{ mol} \end{aligned}$$

$$\begin{aligned} n_{\text{H}_2\text{O}} &= \frac{m_{\text{H}_2\text{O}}}{\text{MW}_{\text{H}_2\text{O}}} \\ &= \frac{0.72 \text{ g}}{18 \ \frac{\text{g}}{\text{mol}}} \\ &= 0.04 \text{ mol} \\ &= \frac{n_{\text{H}}}{2} \end{aligned}$$

$$n_{\text{H}} = 0.08 \text{ mol}$$

Thus, there are 0.04 mol C and 0.08 mol H in 0.01 mol of the substance $C_xH_yO_z$. For 1 mol of $C_xH_yO_z$, there are $x = 0.04/0.01 = 4$ mol of C and $y = 0.08/0.01 = 8$ mol of H.

$$\begin{aligned}\frac{\text{mass of O}}{\text{mass of H} + \text{mass of C}} &= \frac{\left(16\ \frac{\text{g}}{\text{mol}}\right)(z\ \text{mol})}{(8\ \text{mol})\left(1\ \frac{\text{g}}{\text{mol}}\right) + (4\ \text{mol})\left(12\ \frac{\text{g}}{\text{mol}}\right)} \\ &= 4/7 \\ \frac{16z}{56} &= 4/7 \\ z &= 2\ \text{mol}\end{aligned}$$

Thus, the formula is $C_4H_8O_2$.

$\boxed{\text{The answer is (D).}}$

CHEMISTRY–50

What is most nearly the melting point of sodium chloride, given that the heat of melting is 30 kJ/mol, and the associated entropy change is 28 J/mol·K?

(A) 370K (B) 880K (C) 930K (D) 1100K

For the phase change,

$$\begin{aligned}\Delta G &= \Delta H - T_m\Delta S = 0 \\ T_m &= \frac{\Delta H}{\Delta S} \\ &= \frac{30\,000\ \frac{\text{J}}{\text{mol}}}{28\ \frac{\text{J}}{\text{mol·K}}} \\ &= 1071\text{K} \quad (1100\text{K})\end{aligned}$$

$\boxed{\text{The answer is (D).}}$

CHEMISTRY–51

The temperature of 100 g of liquid water at 0°C is raised by 1°C. The number of calories consumed is most nearly

(A) 1.2 cal (B) 4.2 cal (C) 99 cal (D) 100 cal

By definition, 1 cal is the energy needed to heat 1 g of liquid water by 1°C. Therefore, the heat needed to heat 100 g of water by 1°C is

$$q = mc_p\Delta T = (100\ \text{g})\left(1\ \frac{\text{cal}}{\text{g}\cdot{}^\circ\text{C}}\right)(1^\circ\text{C} - 0^\circ\text{C}) = 100\ \text{cal}$$

The answer is (D).

CHEMISTRY–52

Ice with a volume of 50 cm^3 and at a temperature of 0°C is added to 100 g of water at 20°C. Assume that there is no spurious heat loss. The density of ice is 0.92 g/cm^3, and the heat of fusion of ice is 1.44 kcal/mol at 0°C. Approximately how much ice is left unmelted after the mixture reaches thermal equilibrium?

(A) 13 cm^3 (B) 19 cm^3 (C) 23 cm^3 (D) 39 cm^3

The ice will melt until the temperature of the water reaches 0°C. The heat necessary to lower the water temperature from 20°C to 0°C is

$$\begin{aligned} q &= mc_p\Delta T \\ &= (100\ \text{g})\left(1\ \frac{\text{cal}}{\text{g}\cdot{}^\circ\text{C}}\right)(20^\circ\text{C}) \\ &= 2000\ \text{cal} \end{aligned}$$

The heat necessary to melt all the ice is

$$\begin{aligned} q &= \rho V h_{sf} = \frac{\rho V H_{sf}}{\text{MW}} \\ &= \frac{\left(0.92\ \frac{\text{g}}{\text{cm}^3}\right)(50\ \text{cm}^3)\left(1440\ \frac{\text{cal}}{\text{mol}}\right)}{18\ \frac{\text{g}}{\text{mol}}} \\ &= 3680\ \text{cal} \end{aligned}$$

The amount of unmelted ice is

$$V = (50\ \text{cm}^3)\left(\frac{3680\ \text{cal} - 2000\ \text{cal}}{3680\ \text{cal}}\right)$$
$$= 22.83\ \text{cm}^3 \quad (23\ \text{cm}^3)$$

The answer is (C).

CHEMISTRY–53

What is most nearly the final temperature when 10 g of copper and 20 g of lead at −100°C are added to 50 g of H_2O at 50°C? Disregard spurious heat losses. The atomic weight of copper is 63.55 g/mol, and the specific heat of lead is 0.032 cal/g·°C (0.134 J/g·°C).

(A) 33°C (B) 38°C (C) 39°C (D) 45°C

The law of Dulong and Petit is

$$\begin{aligned}&(\text{atomic weight})\quad [\text{in g/mol}]\\ &\qquad \times (\text{specific heat})\quad [\text{in cal/g·°C}]\\ &= \left(6.4\ \frac{\text{cal}}{\text{mol·°C}}\right)\left(4.184\ \frac{\text{J}}{\text{cal}}\right)\\ &= 26.8\ \text{J/mol·°C}\end{aligned}$$

Since there are no spurious heat losses, the heat loss by the water equals the heat gained by the copper and lead.

$$q = mc_p\Delta T$$

In the preceding equation, m is the mass (in grams), c_p is the specific heat capacity, and ΔT is the change in temperature.

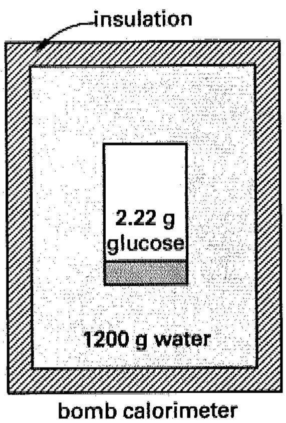
$$(50\ \text{g})\left(1\ \frac{\text{cal}}{\text{g}\cdot{}^\circ\text{C}}\right)(50^\circ\text{C} - T_f) = \left(\begin{array}{l}(10\ \text{g})\left(\dfrac{6.4\ \dfrac{\text{cal}}{\text{mol}\cdot{}^\circ\text{C}}}{63.55\ \dfrac{\text{g}}{\text{mol}}}\right) \\ \quad + (20\ \text{g})\left(0.032\ \dfrac{\text{cal}}{\text{g}\cdot{}^\circ\text{C}}\right)\end{array}\right) \times (T_f - (-100^\circ\text{C}))$$

$$T_f = 45.21^\circ\text{C} \quad (45^\circ\text{C})$$

$\boxed{\text{The answer is (D).}}$

CHEMISTRY–54

A bomb calorimeter is used to determine thermal properties. What is most nearly the enthalpy of reaction (in kcal/mol) of the combustion of glucose (molecular weight = 180 g/mol) when 2.22 g of glucose are ignited, and the water in the well-insulated calorimeter rises in temperature from 18.00°C to 23.19°C? Assume that the water absorbs all of the heat given off.



(A) 100 kcal/mol
(B) 320 kcal/mol
(C) 510 kcal/mol
(D) 730 kcal/mol

$$q = mc_p\Delta T$$

$$q_{H_2O} = (1200 \text{ g})\left(1 \ \frac{\text{cal}}{\text{g}\cdot{}^\circ\text{C}}\right)(23.19^\circ\text{C} - 18.00^\circ\text{C})$$

$$= 6228 \text{ cal}$$

$$q_{\text{glucose}} = 6228 \text{ cal}$$

$$n = \frac{m}{\text{MW}}$$

$$n_{\text{glucose}} = \frac{2.22 \text{ g}}{180 \ \frac{\text{g}}{\text{mol}}}$$

$$= 0.0123 \text{ mol}$$

$$\text{molar enthalpy} = \frac{6228 \text{ cal}}{0.0123 \text{ mol}}$$

$$= 506.34 \text{ kcal/mol} \quad (510 \text{ kcal/mol}$$

The answer is (C).

CHEMISTRY-55

What is most nearly the standard heat of reaction, $\Delta\hat{H}^\circ$, per mole of C_6H_6 for the following reaction?

$$C_6H_6(g) \longrightarrow 3C_2H_2(g)$$

The enthalpy of reaction for C_2H_2 is 226 757 J/gmol; for C_6H_6, it is 82 923 J/gmol.

(A) −650 kJ (B) −600 kJ (C) 600 kJ (D) 650 kJ

$$n_{C_6H_6} = 1 \text{ mol}$$

$$n_{C_2H_2} = 3 \text{ mol}$$

$$\hat{H}_R^\circ = \sum_i n_i \hat{h}_i^\circ \Big|_{\text{reactants}}$$

$$= 82\,923 \text{ J/mol} \quad (82.9 \text{ kJ})$$

$$\hat{H}_P^\circ = \sum_i n_i \hat{h}_i^\circ \Big|_{\text{products}}$$

$$= (3 \text{ mol})\left(226\,757 \ \frac{\text{J}}{\text{mol}}\right)$$

$$= 680\,300 \text{ J} \quad (680.3 \text{ kJ})$$

$$\begin{aligned}\Delta\hat{H}^\circ &= \hat{H}_P^0 - \hat{H}_R^0 \\ &= 680.3\ \text{kJ} - 82.9\ \text{kJ} \\ &= 597.4\ \text{kJ} \quad (600\ \text{kJ})\end{aligned}$$

The answer is (C).

CHEMISTRY–56

The heats of reaction for three equations are as follows.

$$\begin{array}{llll} \text{I.} & -2C_2H_2 - 5O_2 + 4CO_2 + 2H_2O & & = -620\,000\ \text{cal} \\ \text{II.} & \quad - O_2 + CO_2 & -C & = -\ 96\,960\ \text{cal} \\ \text{III.} & \quad - O_2 + 2H_2O - 2H_2O & -2H_2 & = -136\,800\ \text{cal} \end{array}$$

What is the heat of formation of C_2H_2?

(A) 4.14 kcal/mol
(B) 45.7 kcal/mol
(C) 47.7 kcal/mol
(D) 95.7 kcal/mol

Adding (−Eq. I) + 4(Eq. II) + (Eq. III) gives the formation of 2 mol of C_2H_2.

$$\begin{array}{llll} 2C_2H_2+5O_2-4CO_2-2H_2O & & & = \ \ 620\,000\ \text{cal} \\ \quad -4O_2+4CO_2 & & -4C & = -387\,840\ \text{cal} \\ \quad -\ O_2 \qquad\quad +2H_2O & & -2H_2 & = -136\,800\ \text{cal} \end{array}$$

Therefore,

$$2C_2H_2 - 4C - 2H_2 = 95\,360\ \text{cal}$$

Because H_2 and C are at the standard reference state, $\hat{h}_C = 0$, and $\hat{h}_{H_2} = 0$. Therefore,

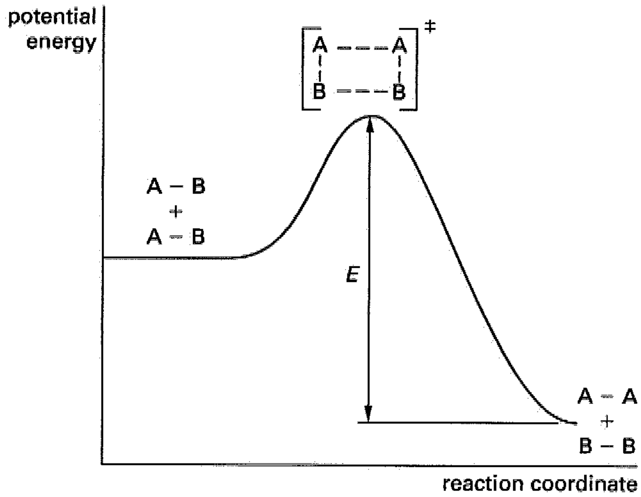
$$\begin{aligned} 2\hat{h}_{C_2H_2} &= 95\,360\ \text{cal} \\ \hat{h}_{C_2H_2} &= 47\,680\ \text{cal/mol} \quad (47.7\ \text{kcal/mol}) \end{aligned}$$

The answer is (C).

CHEMISTRY–57

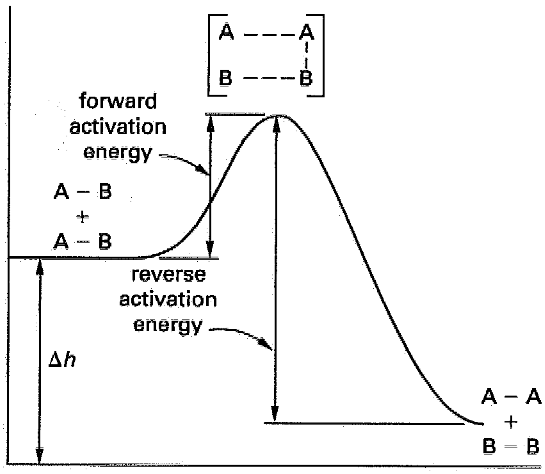
A chemical reaction involving the collision of two molecules of A and B goes through the following energy profile.

$$A_2 + B_2 \longrightarrow 2AB$$



The energy, E, shown on the diagram represents which of the following?

(A) entropy of reaction
(B) enthalpy of reaction
(C) forward activation energy
(D) reverse activation energy



E is the energy required for the reverse reaction (A–A + B–B $\longrightarrow$ A–B + A–B) to proceed. Thus, E is the reverse activation energy.

The answer is (D).

CHEMISTRY–58

Reactions generally proceed faster at higher temperatures because of which of the following?

(A) The molecules collide more frequently.
(B) The activation energy is less.
(C) The molecules are less energetic.
(D) Both options (A) and (B).

At higher temperatures, the molecules travel faster and, therefore, have a higher kinetic energy. This means that the molecules will collide more frequently and that the activation energy for a chemical reaction will be smaller.

The answer is (D).

CHEMISTRY–59

Which of the following statements is FALSE?

(A) In general, as reaction products are formed, they react with each other and re-form reactants.
(B) The net rate at which a reaction proceeds from left to right is equal to the forward rate minus the reverse rate.
(C) At equilibrium, the net reaction rate is zero.
(D) The differential rate law is the mathematical expression that shows how the rate of a reaction depends on volume.

The differential rate law is the mathematical expression that shows how the rate of a reaction depends on concentration, not volume.

The answer is (D).

CHEMISTRY–60

For the reaction $3A + 2B \longrightarrow C + D$, the differential rate law is

$$\left(\frac{1}{3}\right)\frac{dA}{dr} = \frac{dC}{dt} = k[A]^n[B]^m$$

Which of the following statements is FALSE?

(A) The order of the reaction with respect to A is called n.

(B) The sum of $n + m$ is called the overall order of the reaction.

(C) The exponents of [A] and [B], n and m, are not necessarily equal to the stoichiometric coefficients of A and B in the net reaction.

(D) The overall order for the reaction can be predicted by or deduced from the equation for the reaction.

The order for the reaction must be found experimentally and cannot be determined from the equation for the reaction.

The answer is (D).

CHEMISTRY–61

Which of the following statements is FALSE?

(A) When the temperature is raised, the rate of any reaction is always increased.

(B) In general, when any two compounds are unmixed, a large number of reactions may be possible, but those which proceed the fastest are the ones observed.

(C) It is possible to influence the products of a chemical change by controlling the factors which affect reaction rates.

(D) Heterogeneous reactions are the reactions that take place at the boundary surface between two faces.

When temperature is increased, the rates of most reactions increase. However, the rates of some reactions do decrease.

The answer is (A).

CHEMISTRY–62

The following rate expression was found to accurately represent the kinetics of a chemical reaction.

$$r = kC_A^2 C_B$$

If C represents concentration in units of mol/L, what are the units of the rate constant, k?

(A) unitless (B) s^{-1} (C) L/mol·s (D) $L^2/mol^2 \cdot s$

The reaction rate always has units of mol/L·s. The units of k may be found as follows.

$$\frac{\text{mol}}{\text{L}\cdot\text{s}} = k\left(\frac{\text{mol}}{\text{L}}\right)^2\left(\frac{\text{mol}}{\text{L}}\right)$$

$$k = \left(\frac{\text{mol}}{\text{L}\cdot\text{s}}\right)\left(\frac{\text{L}}{\text{mol}}\right)^3 = \frac{\text{L}^2}{\text{mol}^2\cdot\text{s}}$$

The answer is (D).

CHEMISTRY–63

Let C represent the concentration of a reagent. For a first-order reaction, what would a plot of $\ln C$ versus t yield?

(A) a straight line whose slope is $-k$
(B) a straight line whose slope is k
(C) a logarithmic curve approaching a value of k
(D) an exponential curve approaching a value of k

For a first-order reaction,

$$-\frac{dC}{dt} = kC$$

In the preceding equation, k is the rate constant and c is the concentration.

$$-\frac{dC}{C} = kdt$$

$$-\int_{C_0}^{C} \frac{dC}{C} = k \int_0^t dt$$

$$-\ln \frac{C}{C_0} = kt$$

$$\ln \frac{C}{C_0} = -kt$$

$$\ln C = -kt + \ln C_0$$

This is of the form $y = ax + y_0$. Therefore, the graph is a straight line with a slope of $-k$.

The answer is (A).

CHEMISTRY–64

The following kinetic data were collected for a specific chemical reaction. What is the rate constant for the reaction?

reaction: $A + B \longrightarrow$

experiment	C_A (mol/L)	C_B (mol/L)	initial rate (mol A/L·s)
1	0.10	0.10	0.0010
2	0.20	0.10	0.0020
3	0.30	0.10	0.0030
4	0.10	0.20	0.0010
5	0.10	0.30	0.0010

(A) 0.01 s^{-1}
(B) 0.02 s^{-1}
(C) 0.02 L/mol·s
(D) 0.03 L/mol·s

First, determine the rate law. Experiments 4 and 5 show that the rate is not a function of c_B. Experiments 1, 2, and 3 show that the rate is directly proportional to c_A. Therefore,

$$r = kC_A$$

$$k = \frac{r}{C_A}$$

Use the data from experiment 1 to determine k.

$$k = \frac{0.0010\ \frac{\text{mol}}{\text{L·s}}}{0.10\ \frac{\text{mol}}{\text{L}}}$$
$$= 0.01\ \text{s}^{-1}$$

The answer is (A).

CHEMISTRY–65

A certain temperature-dependent reaction proceeds 10 times faster at 500K than it does at 300K. Approximately how much faster will it react at 1000K than it does at 300K?

(A) 10 (B) 20 (C) 30 (D) 60

$$r = kf(C_i)$$
$$k = A\left(\exp\left(-\frac{E_A}{R^*T}\right)\right)$$

In the preceding equation, E_A is the activation energy.

Therefore,

$$r \propto \exp\left(-\frac{E_A}{R^*T}\right)$$
$$\frac{r_1}{r_2} = \frac{\exp\left(\frac{-E_A}{R^*T_2}\right)}{\exp\left(\frac{-E_A}{R^*T_1}\right)}$$
$$= \exp\left(\frac{E_A}{R^*}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right)$$
$$\ln 10 = \frac{E_A}{R^*}\left(\frac{1}{300\text{K}} - \frac{1}{500\text{K}}\right)$$
$$\frac{E_A}{R^*} = 1726.94$$
$$\frac{r_{1000}}{r_{300}} = \exp\left((1727)\left(\frac{1}{300\text{K}} - \frac{1}{1000\text{K}}\right)\right)$$
$$= 56 \quad (60)$$

The answer is (D).

CHEMISTRY–66

A reaction rate is observed to triple as the result of raising the temperature from 0°C to 20°C. What is most nearly the activation energy of the reaction? (R^* is the universal gas constant.)

(A) $3900R^*$ (B) $4400R^*$ (C) $4700R^*$ (D) $5100R^*$

$$r = C\exp\left(-\frac{E_A}{R^*T}\right)$$

In the preceding equation, C is a constant, and E_A is the activation energy.

$$\frac{r_1}{r_2} = \left(\exp\left(\frac{E_A}{R^*}\right)\right)\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\frac{1}{3} = \left(\exp\left(\frac{E_A}{R^*}\right)\right)\left(\frac{1}{0°\text{C} + 273°} - \frac{1}{20°\text{C} + 273°}\right)$$

$$\ln\frac{1}{3} = -\frac{E_A}{R^*}\left(\frac{1}{273\text{K}} - \frac{1}{293\text{K}}\right)$$

$$E_A = -\frac{R^*\ln\frac{1}{3}}{\frac{1}{273\text{K}} - \frac{1}{293\text{K}}}$$

$$= 4394R^* \quad (4400R^*)$$

The answer is (B).

CHEMISTRY–67

In the troposphere, ozone is produced during the day and consumed during the night. Determine the half-life of ozone if it is depleted to 10% of its initial value after 10 h of darkness.

(A) 3.0 h (B) 3.5 h (C) 4.0 h (D) 4.5 h

$$C = C_0e^{-kt}$$

$$C_{10} = 0.1C_0$$

$$0.1 = e^{-10k}$$

$$-k = \frac{\ln 0.1}{10}$$

$$= -0.2303\ \text{h}^{-1}$$

In the preceding equation, $t_{1/2}$ is the half-life.

$$
\begin{aligned}
C_{t_{1/2}} &= 0.5C_0 \\
0.5 &= e^{-0.2303t_{1/2}} \\
t_{1/2} &= \frac{\ln 0.5}{-0.2303\ \text{h}^{-1}} \\
&= 3.0\ \text{h}
\end{aligned}
$$

The answer is (A).

CHEMISTRY–68

Which of the following statements is FALSE?

(A) In considering chemical equilibrium, the relative stabilities of products and reactants are important.

(B) In considering chemical equilibrium, the pathway from the initial state to the final state is important.

(C) In treating reaction rates, the rate at which reactants are converted to products is important.

(D) In treating reaction rates, the sequence of physical processes by which reactants are converted to products is important.

Considerations of chemical equilibrium do not take into account the pathway from initial to final states.

The answer is (B).

CHEMISTRY–69

Consider the following reaction at equilibrium.

$$3H_2\ (gas) + N_2\ (gas) \rightleftharpoons 2NH_3\ (gas) \qquad \Delta\hat{H} = -11.0\ \text{kcal/mol}$$

Which single change in conditions will cause a shift in equilibrium toward an increase in production of NH_3?

(A) removal of hydrogen gas
(B) increase in temperature
(C) increase in volume of the system
(D) increase in pressure on the system

According to Le Châtelier's principle, the effects of each change in condition are as follows.

removal of hydrogen	shifts equilibrium to the reactants
increase in temperature	shifts equilibruim to the reactants
increase in volume	shifts equilibrium to the reactants
increase in pressure	shifts equilibrium to the products

The answer is (D).

CHEMISTRY–70

Consider the following reaction at equilibrium.

$$\tfrac{1}{2}N_2 + \tfrac{3}{2}H_2 \rightleftharpoons NH_3 \qquad \Delta\hat{H} = -11.0 \text{ kcal/mol}$$

What would be the expected effect on the amount of NH_3 produced under each of the following conditions?

I. raise the temperature
II. compress the mixture
III. add additional H_2

(A) I: decrease, II: increase, III: increase
(B) I: increase, II: increase, III: decrease
(C) I: increase, II: decrease, III: decrease
(D) I: decrease, II: increase, III: decrease

According to Le Châtelier's principle, each change has the following effects.

I. raise the temperature: shifts equilibrium to the reactants0. because the reaction is exothermic
II. compress the mixture: shifts equilibrium to the products because products contain a smaller number of moles
III. add hydrogen gas: shifts equilibrium to the products because adding addtional reactants will force the formation of more products

The answer is (A).

CHEMISTRY–71

Consider the following reaction.

$$MgSO_4\ (solid) \rightleftharpoons MgO\ (solid) + SO_3\ (gas)$$

What is the equilibrium constant for the given reaction?

(A) $k = \dfrac{[Mg][SO_3]}{2[MgSO_4]}$ (B) $k = \dfrac{[MgSO_4]}{[MgO][SO_3]}$

(C) $k = [MgO][SO_3]$ (D) $k = [SO_3]$

Solids have a concentration of 1. Therefore, $k = [SO_3]$.

The answer is (D).

CHEMISTRY–72

The solubility of barium sulfate, $BaSO_4$, is 0.0091 g/L at 25°C. The molecular weight of barium sulfate is 233 g/mol. What is the value of the solubility product constant k_{sp} for $BaSO_4$?

(A) $1.52 \times 10^{-9}\ mol^2/L^2$
(B) $4.24 \times 10^{-8}\ mol^2/L^2$
(C) $8.63 \times 10^{-7}\ mol^2/L^2$
(D) $2.98 \times 10^{-6}\ mol^2/L^2$

$$BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$$
$$k_{sp} = [Ba^{2+}][SO_4^{2-}]$$
$$[BaSO_4] = \left(0.0091\ \frac{g}{L}\right)\left(\frac{1\ mol}{233\ g}\right)$$
$$= 3.9 \times 10^{-5}\ mol/L$$
$$[Ba^{2+}] = [SO_4^{2-}] = [BaSO_4]$$
$$k_{sp} = \left(3.9 \times 10^{-5}\ \frac{mol}{L}\right)^2$$
$$= 1.52 \times 10^{-9}\ mol^2/L^2$$

The answer is (A).

CHEMISTRY–73

Consider the reaction shown.

$$H_2\ (gas) + I_2\ (gas) \rightleftharpoons 2HI\ (gas)$$

With $k_{eq} = 25$, determine the number of moles of H_2 remaining when 1 mol each of H_2 and I_2 reach equilibrium in a 1 L vessel.

(A) 1/6 mol (B) 2/7 mol (C) 5/7 mol (D) 5/6 mol

	$H_2\ (gas)$	+	$I_2\ (gas)$	$\rightleftharpoons$	$2HI\ (gas)$
initial moles	1		1		0
final moles	$1-x$		$1-x$		$2x$

$$k = \frac{\left[HI\ \frac{mol}{L}\right]^2}{\left[H_2\ \frac{mol}{L}\right]\left[I_2\ \frac{mol}{L}\right]} = \frac{(2x)^2}{(1-x)(1-x)} = 25$$

$$\frac{4x^2}{(1-x)^2} = 25$$

$$4x^2 = (25)(1 - 2x + x^2)$$

$$21x^2 - 50x + 25 = 0$$

$$x = \frac{+50 \pm \sqrt{(50)^2 - (4)(25)(21)}}{(2)(21)} = 5/3 \text{ mol or } 5/7 \text{ mol}$$

Only the second value for x makes sense, because the first value is greater than the initial amounts of H_2 and I_2. Thus, the remaining number of moles of H_2 at equilibrium is $1 - {}^5/_7 = {}^2/_7$ mol.

$\boxed{\text{The answer is (B).}}$

CHEMISTRY–74

Consider the reaction.

$$A + B \rightleftharpoons 2C$$

With $k_{eq} = 50$, what is most nearly the final concentration of C when 1 mol of both A and B are added to a 1 L container containing 0.1 mol of C?

(A) 0.77 mol (B) 0.95 mol (C) 1.5 mol (D) 1.6 mol

	A (mol)	+	B (mol)	$\rightleftharpoons$	2C (mol)
initial moles	1		1		0.1
final moles	$1-x$		$1-x$		$2x+0.1$

$$k_{eq} = \frac{\left[C\ \frac{\text{mol}}{\text{L}}\right]^2}{\left[A\ \frac{\text{mol}}{\text{L}}\right]\left[B\ \frac{\text{mol}}{\text{L}}\right]}$$

$$= \frac{(2x + 0.1\ \text{mol})^2}{(1\ \text{mol} - x)(1\ \text{mol} - x)} = 50$$

$$4x^2 + 0.4x + 0.01 = 50x^2 - 100x + 50$$

$$46x^2 - 100.4x + 49.99 = 0$$

$$x = 0.7685\ \text{mol or } 1.4141\ \text{mol}$$

However, x cannot be 1.4141 mol because this is greater than the initial amounts of A and B, and this value would make $1-x$ negative. Therefore, $x = 0.7685$ mol. The final number of moles of C is $2x = (2)(0.7685\ \text{mol}) = 1.537$ mol.

$$2x + 0.1 = (2)(0.7685\ \text{mol}) + 0.1 = 1.637\ \text{mol} \quad (1.6\ \text{mol})$$

The answer is (D).

CHEMISTRY–75

The voltage of a galvanic cell does NOT depend on which of the following parameters?

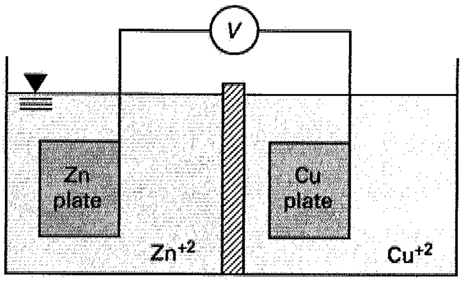
(A) concentration of solutions
(B) temperature of solutions
(C) pressure of solutions
(D) volume of solutions

The cell potential is dependent on all of the above except volume.

The answer is (D).

CHEMISTRY–76

Given the electrochemical cell shown, what is the reaction at the anode?



(A) $Cu \longrightarrow Cu^{2+} + 2e^-$
(B) $Cu^{2+} + 2e^- \longrightarrow Cu$
(C) $Zn \longrightarrow Zn^{2+} + 2e^-$
(D) $Zn^{2+} + 2e^- \longrightarrow Zn$

Zinc has a higher potential and will, therefore, act as the anode. By definition, the anode is where electrons are lost. Thus, the reaction at the anode of the electrochemical cell is $Zn \longrightarrow Zn^{2+} + 2e^-$.

The answer is (C).

CHEMISTRY–77

Which of the following statements regarding a galvanic cell is FALSE?

(A) A negative value of cell voltage $\Delta\mathcal{E}$ means that the reaction in the cell proceeds spontaneously from right to left.

(B) If the standard potential of a cell is zero, a concentration difference alone is sufficient to generate a voltage.

(C) When a current I flows through the voltage difference $\Delta\mathcal{E}$ for a time, t, the electrical work performed is $(\Delta\mathcal{E})It$.

(D) The cell voltage, $\Delta\mathcal{E}$, is totally independent of the number of electrons transferred in a given reaction.

For the reaction $a\mathrm{A} + b\mathrm{B} \longrightarrow c\mathrm{C} + d\mathrm{D}$, the Nernst equation states

$$\Delta\mathcal{E} = \Delta\mathcal{E}^0 - \frac{0.059}{n} \log \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b}$$

Here, n is the number of moles of electrons transferred in the reaction. Therefore, the cell voltage does depend on the number of electrons transferred in a given reaction.

The answer is (D).

CHEMISTRY–78

Consider the Nernst equation.

$$\Delta\mathcal{E} = \Delta\mathcal{E}^0 - \frac{0.059}{n} \log \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b}$$

Which of the following statements is FALSE?

(A) n is the number of moles of electrons transferred in the reaction.

(B) The cell must be operating at a temperature of 25°C.

(C) The equation holds for the reaction $a\mathrm{A} + b\mathrm{B} \longrightarrow c\mathrm{C} + d\mathrm{D}$.

(D) The factor of 0.059 is common to all cells, regardless of temperature.

The factor of 0.059 applies only to cells with an operating temperature of 25°C.

The answer is (D).

CHEMISTRY–79

A zinc-copper standard cell with $\Delta\mathcal{E}^0 = 1.10$ V is connected to an independent variable voltage supply such that the variable voltage opposes the cell voltage. Given the following reaction, what happens?

$$Zn + Cu^{2+} \rightleftharpoons Cu + Zn^{2+} \qquad \Delta\mathcal{E}^0 = 1.10\text{ V}$$

(A) When the variable voltage is below 1.10 V, the cell reaction $Cu + Zn^{2+} \longrightarrow Cu^{2+} + Zn$ predominates.

(B) When the variable voltage is above 1.10 V, the cell reaction $Cu + Zn^{2+} \longrightarrow Cu^{2+} + Zn$ predominates.

(C) When the variable voltage is above 1.10 V, the cell reaction $Zn + Cu^{2+} \longrightarrow Cu + Zn^{2+}$ predominates.

(D) When the variable voltage is equal to 1.10 V, the cell reaction $Cu + Zn^{2+} \longrightarrow Cu^{2+} + Zn$ predominates.

When the variable voltage is below 1.10 V, the reaction $Zn + Cu^{2+} \longrightarrow Cu + Zn^{2+}$ predominates. When it is equal to 1.10 V, no net reaction occurs. When the variable voltage is above 1.10 V, the reverse reaction, $Cu + Zn^{2+} \longrightarrow Zn + Cu^{2+}$ predominates.

The answer is (B).

CHEMISTRY–80

Given that $\Delta\mathcal{E}^0 = 0.03$ V, [Ni] = 1 M, [Co] = 0.1 M, and $T = 25°C$, calculate the cell voltage for the following equation.

$$Co + Ni^{2+} \longrightarrow Co^{2+} + Ni$$

(A) 0.01 V (B) 0.03 V (C) 0.06 V (D) 0.09 V

Use the Nernst equation.

$$\Delta\mathcal{E} = \Delta\mathcal{E}^0 - \frac{0.059}{n}\log\frac{[Co^{2+}]}{[Ni^{2+}]}$$

$$n = 2$$

$$\begin{aligned}\Delta\mathcal{E} &= 0.03\text{ V} - \frac{0.059\text{ V}}{2}\log\frac{0.1}{1.0}\\ &= 0.03\text{ V} + 0.03\text{ V}\\ &= 0.06\text{ V}\end{aligned}$$

The answer is (C).

CHEMISTRY–81

In organic chemistry, which compound families are associated with the following bonds?

I. C – C
II. C = C
III. C ≡ C

(A) I: alkene, II: alkyne, III: alkane
(B) I: alkyne, II: alkane, III: alkene
(C) I: alkane, II: alkene, III: alkyne
(D) I: alkane, II: alkyne, III: alkene

An alkane is a saturated organic compound. Thus, the carbons may only have single bonds. In an alkene, the carbon atoms may have double bonds. In alkynes, the carbon atoms may have triple bonds.

$\boxed{\text{The answer is (C).}}$

CHEMISTRY–82

Which one of the following statements regarding organic substances is FALSE?

(A) Organic matter is generally stable at very high temperatures.
(B) All organic matter contains carbon.
(C) Organic substances generally do not dissolve in water.
(D) Organic substances generally dissolve in high-concentration acids.

Organic matter contains carbon, is generally insoluble in water, soluble in high-concentration acids, not easily ionizable, and unstable at high temperatures.

$\boxed{\text{The answer is (A).}}$

CHEMISTRY–83

Which one of the following is most likely to prove that a substance is inorganic?

(A) The substance is heated together with copper oxide and the resulting gases are found to have no effect on limestone.

(B) The substance evaporates in room temperature and pressure.

(C) Analysis shows that the substance contains hydrogen.

(D) The substance floats in water.

The carbon from organic matter generally reacts with copper oxide to produce carbon dixoide. This gas darkens limestone.

The answer is (A).

CHEMISTRY–84

Which of the following organic chemicals is most soluble in water?

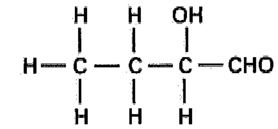
(A) CH_3CH_3
(B) CH_3OH
(C) CCl_4
(D) $CH_3\text{-}(CH_2)_n\text{-}CH_3$

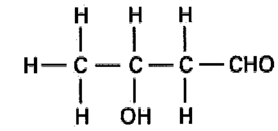
Water is a polar molecule. Thus, a polar substance is more likely to dissolve in water than a nonpolar substance. Methanol (CH_3OH) is polar and, therefore, very miscible in water. All of the other molecules are nonpolar.

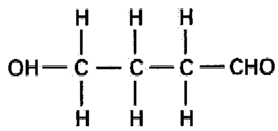
The answer is (B).

CHEMISTRY–85

Which statement describes all of the following three chemical structural formulas?







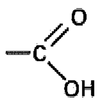
(A) They are isotopes of a certain substance.
(B) They are the only possible forms of $C_4H_2O_2$.
(C) They are incorrectly written.
(D) They are isomers.

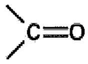
When a compound has one chemical formula, but different possible physical structures, the different structures are called isomers. The three formulas are all possible structures of $C_4H_8O_2$. Therefore, they are isomers.

The answer is (D).

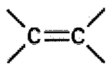
CHEMISTRY–86

What structures do both aldehydes and ketones contain?

(A) the carboxyl group 

(B) the carbonyl group 

(C) the hydroxyl group —OH

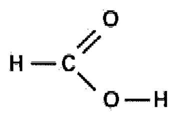
(D) the carbon-carbon double bond 

Aldehydes and ketones both contain the carbonyl group.

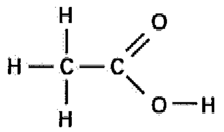
The answer is (B).

CHEMISTRY–87

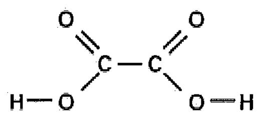
Identify the following acid structures.



I.



II.



III.

(A) I: formic acid, II: oxalic acid, III: acetic acid
(B) I: oxalic acid, II: acetic acid, III: formic acid
(C) I: acetic acid, II: formic acid, III: oxalic acid
(D) I: formic acid, II: acetic acid, III: oxalic acid

HCOOH is formic acid. CH_3COOH is acetic acid. $C_2H_2O_4$ is oxalic acid.

The answer is (D).

CHEMISTRY–88

According to the Bohr model of the hydrogen atom, which of the following statements are true?

I. As the electron orbits the proton, it constantly radiates light with a frequency equal to its frequency of revolution.
II. The electron orbits the proton in certain orbits that can be found by assuming that its angular momentum is quantized.
III. Because of the quantization of angular momentum, calculations using the Bohr model and those based on classical physics can never give the same results.
IV. When an electron orbiting a proton changes states to a lower energy level, the frequency of the radiation given off is proportional to the change in energy. This accounts for the hydrogen spectrum.

(A) I and II (B) II and IV (C) I, II, and III (D) II, III, and IV

The Bohr postulates are

1. The electron moves in a certain orbit without radiating.
2. The frequency of the emitted photon is proportional to the change in energy of the electron.
3. The correspondence principle states that, in the limit as energies and orbits become large, quantum calculations must agree with classical calculations.

Thus, only II and IV are true.

The answer is (B).

CHEMISTRY–89

In a three-level laser, electrons in atoms are excited into an energy state, E_3, then decay spontaneously to an energy E_2, which is a metastable state. The atoms are struck by photons of a specific frequency, and make stimulated emissions to the ground state, E_1. If the photons cause all of the emissions to be of the same frequency, the light will be amplified. What frequency must the photons be for this to occur?

(A) $f = \frac{E_2 - E_1}{\hbar}$

(B) $f = \frac{E_3 - E_1}{\hbar}$

(C) $f = \frac{E_3 - E_1}{\hbar} + \frac{E_2 - E_1}{\hbar}$

(D) $f = \frac{E_3 - E_1}{\hbar} - \frac{E_2 - E_1}{\hbar}$

The transition that must be amplified is the E_2 to E_1 transition. Thus, the frequency of the radiated light is $(E_2 - E_1)/\hbar$. Photons of this frequency will be more likely to cause this transition. Therefore, if photons of this frequency are used, more transitions will take place, and the light will be amplified.

The answer is (A).

CHEMISTRY–90

In an atom such as sodium, there is one electron in the outermost shell (in this case, $n = 3$). Which of the following statements is true regarding the energy required to excite an electron in the $n = 1$ shell compared to that required to excite an electron in the $n = 2$ shell?

(A) It is greater because the electron is closer to the proton, and thus the Coulomb attractive force is much stronger.

(B) It is greater because the shell next to it is full. Thus, by the Pauli exclusion principle, it must jump to the first shell that is not full, in this case, the $n = 3$ shell.

(C) It is greater because an electron must first jump to the $n = 3$ shell from the $n = 2$ shell. Then the electron from the $n = 1$ shell can jump to the $n = 2$ shell.

(D) It is equal to the energy required to excite an electron in the $n = 2$ shell because in both cases the electron makes a jump to the next shell.

In an atom, an excited electron will jump to the next highest unfilled shell (in this case, the $n = 3$ shell). So the electrons in both the $n = 1$ shell and the $n = 2$ shell will jump to the $n = 3$ shell. However, the energy difference between the $n = 1$ and the $n = 3$ shell is greater than the energy difference between the $n = 2$ shell and the $n = 3$ shell. Thus, option (B) is correct.

$$\boxed{\text{The answer is (B).}}$$

CHEMISTRY–91

A state of energy E_1 with a lifetime of t_1 decays into the state of energy E_2. The state of E_2 then decays with a lifetime of t_2 into the state of E_3. The decay constants are related by $\tau_1 = 2\tau_2$. Initially, all of the atoms (quantity N_0) are in the E_1 state. Calculate the number of atoms N_2 that are in the state E_2 at any instant in time, t.

(A) $N_0\left(e^{-t/\tau_1} - e^{-2t/\tau_1}\right)$

(B) $N_0\left(e^{-t/\tau_1} + e^{-2t/\tau_1}\right)$

(C) $2N_0\left(e^{-t/\tau_1} - e^{-2t/\tau_1}\right)$

(D) $2N_0\left(e^{-t/\tau_1} + e^{-2t/\tau_1}\right)$

The number of atoms that decay from E_1 to E_2 is

$$N_1 = N_0 e^{-t/\tau_1}$$

The number of atoms in state E_2 equals the number of atoms coming from E_1 to E_2 minus the number of atoms decaying from E_2 to E_3. Thus, the number of atoms in state E_2 at a given time is

$$\begin{aligned} N_2 &= N_0 e^{-t/\tau_1} - N_{2,0} e^{-t/\tau_2} \\ &= N_0 e^{-t/\tau_1} - N_{2,0} e^{-2t/\tau_1} \end{aligned}$$

Since there are no atoms in state E_2 at $t = 0$, the initial conditions are

$$\begin{aligned} N_2(0) &= 0 \\ 0 &= N_0 e^0 - N_{2,\,0} e^0 \\ N_0 &= N_{2,\,0} \\ N_2 &= N_0 \left(e^{-t/\tau_1} - e^{-2t/\tau_1}\right) \end{aligned}$$

The answer is (A).

CHEMISTRY–92

A source of radiation has a mean nucleus life of $\tau = 35.8$ s. There are initially $N_0 = 5.37 \times 10^{10}$ nuclei in the source. Which of the following statements are true?

I. The decay constant is $\lambda = 0.0279\ \text{s}^{-1}$.
II. The half-life is $t_{1/2} = 24.8$ s.
III. If a rate counter with an 80% efficiency is placed near the source, it will show a rate of 4.2×10^7 after 2 min.
IV. The sample will essentially have all decayed (0.01% remaining) in 5.5 min.

(A) I and III
(B) II and III
(C) I, III, and IV
(D) I, II, III, and IV

First, find the decay constant.

$$\begin{aligned} \lambda &= \frac{1}{\tau} \\ &= \frac{1}{35.8\ \text{s}} \\ &= 0.0279\ \text{s}^{-1} \end{aligned}$$

Therefore, statement I is true.

Next, find the half-life.

$$\frac{1}{2} = e^{t_{1/2}/\tau}$$

$$\begin{aligned} t_{1/2} &= \tau \ln 2 \\ &= (35.8\ \text{s}) \ln 2 \\ &= 24.8\ \text{s} \end{aligned}$$

Thus, statement II is true.

Next, find the count rate after 2 min. The count rate at time t (in seconds) is

$$R = R_0 \mathrm{e}^{-\lambda t}$$

The initial count rate, R_0, is

$$R_0 = \lambda N_0$$

Since the detector is only 80% efficient, the rate shown by the detector after 2 min, R_d, is

$$\begin{aligned} R_d &= 0.80R = 0.8\ \lambda N_0 e^{-\lambda t} \\ &= (0.8)\left(0.0279\ \frac{1}{\text{s}}\right)(5.37 \times 10^{10} e^{-\lambda t}) \\ &= (0.8)\left(1.50 \times 10^{9}\ \frac{1}{\text{s}}\right) e^{-(0.0279\ 1/\text{s})(120\ \text{s})} \\ &= 4.2 \times 10^{7}\ \text{decays s}^{-1} \end{aligned}$$

Therefore, statement III is true.

The time it takes for the sample to decay to an amount N is

$$\begin{aligned} t &= \frac{-1}{\lambda} \ln \frac{N}{N_0} \\ N &= 1 \times 10^{-4} N_0 \\ \frac{N}{N_0} &= 1 \times 10^{-4} \\ t &= \frac{\left(\dfrac{-1}{0.0279\ \dfrac{1}{\text{s}}}\right) \ln(1 \times 10^{-4})}{60\ \dfrac{\text{s}}{\text{min}}} \\ &= \frac{330\ \text{s}}{60\ \dfrac{\text{s}}{\text{min}}} \\ &= 5.5\ \text{min} \end{aligned}$$

Thus, IV is also true. Statements I, II, III, and IV are all true.

The answer is (D).

CHEMISTRY–93

A fossil fern containing 49.9 g of carbon is carbon dated to determine its age. The decay rate of C^{14} in the fossil is 191 decays/min. How old is the fern? (The half-life of C^{14} is 5730 years, and the rate of decay of C^{14} in a living organism per g of carbon is 15.0 decays/min-g.)

(A) 7290 yr (B) 11 300 yr (C) 14 100 yr (D) 23 800 yr

The rate of decay of C^{14} in a dead organism is given by

$$R = R_0 e^{-\lambda t}$$

In the preceding equation, λ is the decay constant, R_0 is the initial decay rate, and t is the time elapsed.

R_0 is simply the decay rate of carbon-14 in a living organism, because up to the point it dies, it replenishes its carbon. Thus, until the organism's death, the decay rate is fairly constant.

$$\begin{aligned}
R_0 &= \left(15.0\ \frac{\text{decays}}{\text{min-g}}\right)(49.9\ \text{g}) \\
&= 749\ \text{decays/min} \\
\lambda &= \frac{\ln 2}{t_{1/2}} \\
&= \frac{\ln 2}{5730\ \text{yr}} \\
&= 1.21 \times 10^{-4}\ \text{yr}^{-1} \\
t &= -\frac{1}{\lambda} \ln \frac{R}{R_0} \\
&= -\left(\frac{1}{1.21 \times 10^{-4}\ \text{yr}}\right) \ln \left(\frac{191\ \frac{\text{decays}}{\text{min}}}{749\ \frac{\text{decays}}{\text{min}}}\right) \\
&= 11\,300\ \text{yr}
\end{aligned}$$

The answer is (B).

CHEMISTRY–94

What is the total relativistic energy of a particle if its mass is equal to 1 kg when it is traveling at a speed of $\sqrt{2}c$?

(A) $c/2$ (B) $c^2 - 1$ (C) c^2 (D) $c^2 + 1$

Regardless of the particle's speed, the total relativistic energy is

$$\begin{aligned} E_{\text{total}} &= mc^2 \\ &= (1 \text{ kg})(c^2) \\ &= c^2 \end{aligned}$$

$\boxed{\text{The answer is (C).}}$