Q.1 If the distribution of molecular speeds of a gas is as per the figure shown below, then the ratio of the most probable, the average, and the root mean square speeds, respectively, is

(A) $1 : 1 : 1$
(B) $1 : 1 : 1.224$
(C) $1 : 1.128 : 1.224$
(D) $1 : 1.128 : 1$

Q.2 Which of the following liberates $O_2$ upon hydrolysis?

(A) $\text{Pb}_3\text{O}_4$
(B) $\text{KO}_2$
(C) $\text{Na}_2\text{O}_2$
(D) $\text{Li}_2\text{O}_2$

Q.3 A colorless aqueous solution contains nitrates of two metals, $X$ and $Y$. When it was added to an aqueous solution of NaCl, a white precipitate was formed. This precipitate was found to be partly soluble in hot water to give a residue $P$ and a solution $Q$. The residue $P$ was soluble in aq. NH$_3$ and also in excess sodium thiosulfate. The hot solution $Q$ gave a yellow precipitate with KI. The metals $X$ and $Y$, respectively, are

(A) Ag and Pb
(B) Ag and Cd
(C) Cd and Pb
(D) Cd and Zn
Q.4 Newman projections P, Q, R and S are shown below:

Which one of the following options represents identical molecules?

(A) P and Q  
(B) Q and S  
(C) Q and R  
(D) R and S

Q.5 Which one of the following structures has the IUPAC name 3-ethynyl-2-hydroxy-4-methylhex-3-en-5-ynoic acid?

(A)  
(B)  
(C)  
(D)
Q.6 The Fischer projection of D-erythrose is shown below.

D-Erythrose and its isomers are listed as P, Q, R, and S in **Column-I**. Choose the correct relationship of P, Q, R, and S with D-erythrose from **Column II**.

<table>
<thead>
<tr>
<th>Column-I</th>
<th>Column-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.</td>
<td>1.</td>
</tr>
<tr>
<td>Q.</td>
<td>2.</td>
</tr>
<tr>
<td>R.</td>
<td>3.</td>
</tr>
<tr>
<td>S.</td>
<td></td>
</tr>
</tbody>
</table>

(A) P→2, Q→3, R→2, S→2  
(B) P→3, Q→1, R→1, S→2  
(C) P→2, Q→1, R→1, S→3  
(D) P→2, Q→3, R→3, S→1
Q.7 In thermodynamics, the $P - V$ work done is given by

$$w = - \int dV \, P_{\text{ext}}.$$  

For a system undergoing a particular process, the work done is

$$w = - \int dV \left( \frac{RT}{V - b} - \frac{a}{V^2} \right).$$

This equation is applicable to a

(A) system that satisfies the van der Waals equation of state.
(B) process that is reversible and isothermal.
(C) process that is reversible and adiabatic.
(D) process that is irreversible and at constant pressure.

Q.8 With respect to the compounds I-V, choose the correct statement(s).

(A) The acidity of compound I is due to delocalization in the conjugate base.
(B) The conjugate base of compound IV is aromatic.
(C) Compound II becomes more acidic, when it has a -NO$_2$ substituent.
(D) The acidity of compounds follows the order I > IV > V > II > III.
Q.9 In the reaction scheme shown below, Q, R, and S are the major products.

The correct structure of

(A) S is

(B) Q is

(C) R is

(D) S is
Q.10 Choose the correct statement(s) among the following:

(A) \([\text{FeCl}_4]^-\) has tetrahedral geometry.

(B) \([\text{Co(en)}(\text{NH}_3)_2\text{Cl}_2]^+\) has 2 geometrical isomers.

(C) \([\text{FeCl}_4]^-\) has higher spin-only magnetic moment than \([\text{Co(en)}(\text{NH}_3)_2\text{Cl}_2]^+\).

(D) The cobalt ion in \([\text{Co(en)}(\text{NH}_3)_2\text{Cl}_2]^+\) has \textit{sp}^3\textit{d}^2 hybridization.

Q.11 With respect to hypochlorite, chlorate and perchlorate ions, choose the correct statement(s).

(A) The hypochlorite ion is the strongest conjugate base.

(B) The molecular shape of only chlorate ion is influenced by the lone pair of electrons of Cl.

(C) The hypochlorite and chlorate ions disproportionate to give rise to identical set of ions.

(D) The hypochlorite ion oxidizes the sulfite ion.

Q.12 The cubic unit cell structure of a compound containing cation \(M\) and anion \(X\) is shown below. When compared to the anion, the cation has smaller ionic radius. Choose the correct statement(s).

(A) The empirical formula of the compound is \(MX\).

(B) The cation \(M\) and anion \(X\) have different coordination geometries.

(C) The ratio of \(M-X\) bond length to the cubic unit cell edge length is 0.866.

(D) The ratio of the ionic radii of cation \(M\) to anion \(X\) is 0.414.
Q.13 5.00 mL of 0.10 M oxalic acid solution taken in a conical flask is titrated against NaOH from a burette using phenolphthalein indicator. The volume of NaOH required for the appearance of permanent faint pink color is tabulated below for five experiments. What is the concentration, in molarity, of the NaOH solution?

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Vol. of NaOH (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>2</td>
<td>10.5</td>
</tr>
<tr>
<td>3</td>
<td>9.0</td>
</tr>
<tr>
<td>4</td>
<td>9.0</td>
</tr>
<tr>
<td>5</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Q.14 Consider the reaction \( A \rightleftharpoons B \) at 1000 K. At time \( t' \), the temperature of the system was increased to 2000 K and the system was allowed to reach equilibrium. Throughout this experiment the partial pressure of \( A \) was maintained at 1 bar. Given below is the plot of the partial pressure of \( B \) with time. What is the ratio of the standard Gibbs energy of the reaction at 1000 K to that at 2000 K?
Q.15 Consider a 70% efficient hydrogen-oxygen fuel cell working under standard conditions at 1 bar and 298 K. Its cell reaction is

\[ \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \].

The work derived from the cell on the consumption of \(1.0 \times 10^{-3}\) mol of \(\text{H}_2(g)\) is used to compress 1.00 mol of a monoatomic ideal gas in a thermally insulated container. What is the change in the temperature (in K) of the ideal gas?

The standard reduction potentials for the two half-cells are given below.

\[ \text{O}_2(g) + 4\text{H}^+(aq) + 4e^- \rightarrow 2\text{H}_2\text{O}(l), \quad E^0 = 1.23 \text{ V}, \]

\[ 2\text{H}^+(aq) + 2e^- \rightarrow \text{H}_2(g), \quad E^0 = 0.00 \text{ V}. \]

Use \(F = 96500 \text{ C mol}^{-1}, R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}\).

Q.16 Aluminium reacts with sulfuric acid to form aluminium sulfate and hydrogen. What is the volume of hydrogen gas in liters (L) produced at 300 K and 1.0 atm pressure, when 5.4 g of aluminium and 50.0 mL of 5.0 M sulfuric acid are combined for the reaction?

(Use molar mass of aluminium as 27.0 g mol\(^{-1}\), \(R = 0.082 \text{ atm L mol}^{-1} \text{ K}^{-1}\))

Q.17 \(^{238}\text{U}\) is known to undergo radioactive decay to form \(^{206}\text{Pb}\) by emitting alpha and beta particles. A rock initially contained \(68 \times 10^{-6}\) g of \(^{238}\text{U}\). If the number of alpha particles that it would emit during its radioactive decay of \(^{238}\text{U}\) to \(^{206}\text{Pb}\) in three half-lives is \(Z \times 10^{18}\), then what is the value of \(Z\)?

Q.18 In the following reaction, compound \(Q\) is obtained from compound \(P\) via an ionic intermediate.

![Diagram of the reaction]

What is the degree of unsaturation of \(Q\)?

END OF THE QUESTION PAPER