Q.1 The reaction sequence(s) that would lead to o-xylene as the major product is(are)

(A) \[ \text{MeNH}_2 \rightarrow 1. \text{NaNO}_2/\text{HCl, 273 K} \]
2. CuCN
3. DIBAL-H then \( \text{H}_3\text{O}^+ \)
4. \( \text{N}_2\text{H}_4, \text{KOH} \)

(B) \[ \text{Me} \]
1. \( \text{Mg, CO}_2, \text{H}_3\text{O}^+ \)
2. \( \text{SOCl}_2 \)
3. \( \text{H}_2, \text{Pd-BaSO}_4 \)
4. \( \text{Zn-Hg, HCl} \)

(C) \[ \text{Me} \]
1. i. \( \text{BH}_3 \)
ii. \( \text{H}_2\text{O}_2, \text{NaOH} \)
2. \( \text{PBr}_3 \)
3. \( \text{Zn, dil. HCl} \)

(D) \[ \text{Br} \]
1. \( \text{O}_3, \text{Zn/H}_2\text{O} \)
2. \( \text{N}_2\text{H}_4, \text{KOH, heat} \)

**Q.1. PROVISIONAL ANSWER: A, B**
Q.2 Correct option(s) for the following sequence of reactions is(are)

(A) \( Q = \text{KNO}_2, \ W = \text{LiAlH}_4 \)  \hspace{1cm} (B) \( R = \text{benzenamine}, \ V = \text{KCN} \)

(C) \( Q = \text{AgNO}_2, \ R = \text{phenylmethanamine} \)  \hspace{1cm} (D) \( W = \text{LiAlH}_4, \ V = \text{AgCN} \)

Q.2. PROVISIONAL ANSWER: C, D

Q.3 For the following reaction

\[ 2X + Y \rightarrow P \]

the rate of reaction is \( \frac{d[P]}{dt} = k[X] \). Two moles of \( X \) are mixed with one mole of \( Y \) to make 1.0 L of solution. At 50 s, 0.5 mole of \( Y \) is left in the reaction mixture. The correct statement(s) about the reaction is(are)

(A) The rate constant, \( k \), of the reaction is \( 13.86 \times 10^{-4} \text{ s}^{-1} \).

(B) Half-life of \( X \) is 50 s.

(C) At 50 s, \( \frac{d[X]}{dt} = 13.86 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1} \).

(D) At 100 s, \( \frac{d[Y]}{dt} = 3.46 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1} \).

Q.3. PROVISIONAL ANSWER: B, C, D
Q.4 Some standard electrode potentials at 298 K are given below:

\[
\begin{align*}
\text{Pb}^{2+}/\text{Pb} & \quad 0.13 \text{ V} \\
\text{Ni}^{2+}/\text{Ni} & \quad -0.24 \text{ V} \\
\text{Cd}^{2+}/\text{Cd} & \quad -0.40 \text{ V} \\
\text{Fe}^{2+}/\text{Fe} & \quad -0.44 \text{ V}
\end{align*}
\]

To a solution containing 0.001 M of \( \text{X}^{2+} \) and 0.1 M of \( \text{Y}^{2+} \), the metal rods \( \text{X} \) and \( \text{Y} \) are inserted (at 298 K) and connected by a conducting wire. This resulted in dissolution of \( \text{X} \). The correct combination(s) of \( \text{X} \) and \( \text{Y} \), respectively, is(are)

(Given: Gas constant, \( R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \), Faraday constant, \( F = 96500 \text{ C mol}^{-1} \))

(A) Cd and Ni
(B) Cd and Fe
(C) Ni and Pb
(D) Ni and Fe

**Q.4. PROVISIONAL ANSWER: A, B, C**

Q.5 The pair(s) of complexes wherein both exhibit tetrahedral geometry is(are)

(Note: py = pyridine

Given: Atomic numbers of Fe, Co, Ni and Cu are 26, 27, 28 and 29, respectively)

(A) \([\text{FeCl}_4]^-\) and \([\text{Fe(CO)}_4]^{2-}\)
(B) \([\text{Co(CO)}_4]^-\) and \([\text{CoCl}_4]^{2-}\)
(C) \([\text{Ni(CO)}_4]\) and \([\text{Ni(CN)}_4]^{2-}\)
(D) \([\text{Cu(py)}_4]^+\) and \([\text{Cu(CN)}_4]^{3-}\)

**Q.5. PROVISIONAL ANSWER: A, B, D**

Q.6 The correct statement(s) related to oxoacids of phosphorous is(are)
(A) Upon heating, \( \text{H}_3\text{PO}_3 \) undergoes disproportionation reaction to produce \( \text{H}_3\text{PO}_4 \) and \( \text{PH}_3 \).

(B) While \( \text{H}_3\text{PO}_3 \) can act as reducing agent, \( \text{H}_3\text{PO}_4 \) cannot.

(C) \( \text{H}_3\text{PO}_3 \) is a monobasic acid.

(D) The H atom of P–H bond in \( \text{H}_3\text{PO}_3 \) is not ionizable in water.

**Q.6. PROVISIONAL ANSWER: A, B, D**
Question Stem for Question Nos. 7 and 8

Question Stem

At 298 K, the limiting molar conductivity of a weak monobasic acid is $4 \times 10^2$ S cm$^2$ mol$^{-1}$. At 298 K, for an aqueous solution of the acid the degree of dissociation is $\alpha$ and the molar conductivity is $y \times 10^2$ S cm$^2$ mol$^{-1}$. At 298 K, upon 20 times dilution with water, the molar conductivity of the solution becomes $3y \times 10^2$ S cm$^2$ mol$^{-1}$.

Q.7 The value of $\alpha$ is ____.

Q.7. PROVISIONAL RANGE OF ANSWER: [0.20 to 0.22]

Q.8 The value of $y$ is ____.

Q.8. PROVISIONAL RANGE OF ANSWER: [0.80 to 0.90]

Question Stem for Question Nos. 9 and 10

Question Stem

Reaction of $x$ g of Sn with HCl quantitatively produced a salt. Entire amount of the salt reacted with $y$ g of nitrobenzene in the presence of required amount of HCl to produce 1.29 g of an organic salt (quantitatively).

(Use Molar masses (in g mol$^{-1}$) of H, C, N, O, Cl and Sn as 1, 12, 14, 16, 35 and 119, respectively).
Question Stem for Question Nos. 11 and 12

Question Stem

A sample (5.6 g) containing iron is completely dissolved in cold dilute HCl to prepare a 250 mL of solution. Titration of 25.0 mL of this solution requires 12.5 mL of 0.03 M KMnO₄ solution to reach the end point. Number of moles of Fe²⁺ present in 250 mL solution is $x \times 10^{-2}$ (consider complete dissolution of FeCl₂). The amount of iron present in the sample is $y\%$ by weight.

(Assume: KMnO₄ reacts only with Fe²⁺ in the solution
Use: Molar mass of iron as 56 g mol⁻¹)

Q.11 The value of $x$ is ____.

Q.11. PROVISIONAL RANGE OF ANSWER: [1.87 to 1.88]

Q.12 The value of $y$ is ____.

Q.12. PROVISIONAL RANGE OF ANSWER: [18.70 to 18.80]
SECTION 3

- This section contains **TWO (02) paragraphs**. Based on each paragraph, there are **TWO (02) questions**.
- Each question has **FOUR options** (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
  
  - **Full Marks**: +3 if ONLY the correct option is chosen;
  - **Zero Marks**: 0 if none of the options is chosen (i.e. the question is unanswered);
  - **Negative Marks**: −1 in all other cases.

Paragraph

The amount of energy required to break a bond is same as the amount of energy released when the same bond is formed. In gaseous state, the energy required for *homolytic cleavage* of a bond is called Bond Dissociation Energy (BDE) or Bond Strength. BDE is affected by $s$-character of the bond and the stability of the radicals formed. Shorter bonds are typically stronger bonds. BDEs for some bonds are given below:

\[
\begin{align*}
\text{H}_3\text{C} – \text{H} (g) & \quad \rightarrow \quad \text{H}_3\text{C}^* (g) \quad + \quad \text{H}^* (g) \quad \Delta H^\circ = 105 \text{ kcal mol}^{-1} \\
\text{Cl} – \text{Cl} (g) & \quad \rightarrow \quad \text{Cl}^* (g) \quad + \quad \text{Cl}^* (g) \quad \Delta H^\circ = 58 \text{ kcal mol}^{-1} \\
\text{H}_3\text{C} – \text{Cl} (g) & \quad \rightarrow \quad \text{H}_3\text{C}^* (g) \quad + \quad \text{Cl}^* (g) \quad \Delta H^\circ = 85 \text{ kcal mol}^{-1} \\
\text{H} – \text{Cl} (g) & \quad \rightarrow \quad \text{H}^* (g) \quad + \quad \text{Cl}^* (g) \quad \Delta H^\circ = 103 \text{ kcal mol}^{-1}
\end{align*}
\]
Q.13 Correct match of the C–H bonds (shown in bold) in Column J with their BDE in Column K is

<table>
<thead>
<tr>
<th>Column J Molecule</th>
<th>Column K BDE (kcal mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P) H–CH(CH(_3))(_2)</td>
<td>(i) 132</td>
</tr>
<tr>
<td>(Q) H–CH(_2)Ph</td>
<td>(ii) 110</td>
</tr>
<tr>
<td>(R) H–CH=CH(_2)</td>
<td>(iii) 95</td>
</tr>
<tr>
<td>(S) H–C≡CH</td>
<td>(iv) 88</td>
</tr>
</tbody>
</table>

(A) P – iii, Q – iv, R – ii, S – i  
(B) P – i, Q – ii, R – iii, S – iv  
(C) P – iii, Q – ii, R – i, S – iv  
(D) P – ii, Q – i, R – iv, S – iii

**Q.13. PROVISIONAL ANSWER: A**

Q.14 For the following reaction

\[
\text{CH}_4 (g) + \text{Cl}_2 (g) \xrightarrow{\text{light}} \text{CH}_3\text{Cl} (g) + \text{HCl} (g)
\]

the correct statement is

(A) Initiation step is exothermic with \(\Delta H^\circ = -58 \text{ kcal mol}^{-1}\).  
(B) Propagation step involving \(\cdot\text{CH}_3\) formation is exothermic with \(\Delta H^\circ = -2 \text{ kcal mol}^{-1}\).  
(C) Propagation step involving \(\text{CH}_3\text{Cl}\) formation is endothermic with \(\Delta H^\circ = +27 \text{ kcal mol}^{-1}\).  
(D) The reaction is exothermic with \(\Delta H^\circ = -25 \text{ kcal mol}^{-1}\).

**Q.14. PROVISIONAL ANSWER: D**

**Paragraph**

The reaction of \(\text{K}_3[\text{Fe(CN)}_6]\) with freshly prepared \(\text{FeSO}_4\) solution produces a dark blue precipitate called Turnbull’s blue. Reaction of \(\text{K}_4[\text{Fe(CN)}_6]\) with the \(\text{FeSO}_4\) solution in complete absence of air produces a white precipitate \(\text{X}\), which turns blue in air. Mixing the \(\text{FeSO}_4\) solution with \(\text{NaNO}_3\), followed by a slow addition of concentrated \(\text{H}_2\text{SO}_4\) through the side of the test tube produces a brown ring.
Q.15 Precipitate X is

(A) Fe₄[Fe(CN)₆]₃
(B) Fe[Fe(CN)₆]
(C) K₂Fe[Fe(CN)₆]
(D) KFe[Fe(CN)₆]

Q.15. PROVISIONAL ANSWER: C

Q.16 Among the following, the brown ring is due to the formation of

(A) [Fe(NO)₂(SO₄)₂]²⁻
(B) [Fe(NO)₂(H₂O)₄]³⁺
(C) [Fe(NO)₄(SO₄)₂]
(D) [Fe(NO)(H₂O)₅]²⁺

Q.16. PROVISIONAL ANSWER: D

SECTION 4

- This section contains THREE (03) questions.
- The answer to each question is a NON-NEGATIVE INTEGER.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:
  - Full Marks : +4 If ONLY the correct integer is entered;
  - Zero Marks : 0 In all other cases.
Q.17 One mole of an ideal gas at 900 K, undergoes two reversible processes, I followed by II, as shown below. If the work done by the gas in the two processes are same, the value of \( \ln \frac{V_3}{V_2} \) is ____.

\[ \begin{align*}
\text{\( \frac{U}{R} \) (K)} & \quad \text{II} \\
\text{\( S \) (J K\(^{-1}\) mol\(^{-1}\))} & \quad \text{I} \\
(\text{Given: molar heat capacity at constant volume, } C_{V,m} \text{ of the gas is } \frac{5}{2} R)\end{align*}\]

Q.17. PROVISIONAL ANSWER: 10

Q.18 Consider a helium (He) atom that absorbs a photon of wavelength 330 nm. The change in the velocity (in cm s\(^{-1}\)) of He atom after the photon absorption is ____.

(Assume: Momentum is conserved when photon is absorbed.
Use: Planck constant = \(6.6 \times 10^{-34}\) J s, Avogadro number = \(6 \times 10^{23}\) mol\(^{-1}\), Molar mass of He = 4 g mol\(^{-1}\))

Q.18. PROVISIONAL ANSWER: 30

Q.19 Ozonolysis of ClO\(_2\) produces an oxide of chlorine. The average oxidation state of chlorine in this oxide is ____.

Q.19. PROVISIONAL ANSWER: 6

END OF THE QUESTION PAPER