QUESTION 1
(a) Give the definition the following terms:
(i) Ligand
Solution: Oppositely charged ions [e.g. Cl] or neutral molecules (possessing lone pairs of electrons e.g. NH₃) that surround (complex/coordinate) a central metal atom (ion).
(ii) Metal Chelate
Solution: A ligand that is capable of forming more than one bond with the central metal atom or ion to produce ring structures e.g. ethylenediamine (en)

(b) What the oxidation state of the central transition metal atom in the following compounds or complexes
(i) K₂[Pt(Cl)₄]
Soln: \[2K^+ \text{ and } [Pt(Cl)_4]^{2-}\] let \(x\) = Pt oxidation state
\[x + (-4) = -2\]
\[x = +2\]
(ii) [Pd(Cl)₂(NH₃)₄]
Soln: let \(x\) = Pd oxidation state
\[(Cl)_2 = -2 \text{ and } (NH₃)_4 = 0\]
\[x + (-2) + 0 = 0\]
\[x = +2\]
(iii) [Fe(CO)₄Cl₂]
Soln: Let \(x\) = Fe oxidation state
\[CO = 0 \text{ and } Cl_2 = -2\]
\[x + (0) + (-2) = 0\]
\[x = +2\]
(iv) [Zn(CN)₄]²⁻
Soln: Let \(x\) = Fe oxidation state
\[(CN)_4 = -4\]
\[x + (-4) = -2\]
\[x = +2\]

(c) What the coordination number for the compounds or complexes in part (b)
(i) K₂[Pt(Cl)₄]
Soln: = 4
(ii) [Pd(Cl)₂(NH₃)₄]
Soln: = 6
(iii) [Fe(CO)₄Cl₂]
Soln: = 6
(iv) [Zn(CN)₄]²⁻
Soln: = 4
(d) Name the complexes:

(i) \([\text{Pt(Br)}_2(\text{NH}_3)_4]\) 
Soln: platinum(II) dibromo tetraamine
Tetraamminedibromoplatinum(II)

(ii) \([\text{Fe(CO)}_4\text{Cl}_2]\) 
Soln: iron(II) tetracarbonyl dichloro
Tetracarbonyldichloroiron(II)

(e) Write the formulas of the following complexes:

(i) diamminetetra(isothiocyanato)chromate(III) 
Soln:
\[
\left(\text{NH}_3\right)_2(\text{NCS})_4\text{Cr}^{3+} = -1 \text{ anion}
\]
\[
\left[\text{Cr(NH}_3)_2(\text{NCS})_4\right]^{-1}
\]

(ii) tris(ethylenediamine)rhodium(III) 
Soln:
\[
\left(\text{en}\right)_3\text{Rh}^{3+} = +3 \text{ cation}
\]
\[
\left[\text{Rh(en)}_3\right]^{3+}
\]

(f) Write the outer electron configuration of:

(i) Cr 
Soln: 
\[
\begin{array}{c}
\text{Cr} = 24 \text{ e-} \\
\text{[Ar] 18 6} \\
\text{4s}^2\text{3d}^5
\end{array}
\]

(ii) Fe\(^{3+}\) 
Soln: 
\[
\begin{array}{c}
\text{Fe} = 26 \text{ e-} \\
\text{[Ar] 18 8} \\
\text{Fe}^{3+} = 23 \text{ e-} \\
\text{[Ar] 18 5} \\
\text{3d}^6
\end{array}
\]

(iii) Cu 
Cu = 29 e- 
\[
\begin{array}{c}
\text{[Ar] 18 11} \\
\text{4s}^1\text{3d}^{10}
\end{array}
\]

QUESTION 2

(a) Give the definition the following terms and provide an example in each case:

(i) Ionization isomers 
Soln: Complexes that rearrangement the ligands or ions differently in solutions.
\[
\begin{array}{c}
\text{[PdCl}_2(\text{NH}_3)_4]\text{Cl}_2 \cong \text{[PdCl}_2(\text{NH}_3)_4]_2\text{Cl}
\end{array}
\]

(ii) Hydration isomers 
Soln: Crystals of complexes containing water molecules in different combination.
\[
\begin{array}{c}
\text{[Co(\text{NH}_3)_6\text{Cl}_3]Cl}_2 \cong \text{[Co(\text{NH}_3)_6\text{Cl}_3]}\text{Cl}_2\text{H}_2\text{O}
\end{array}
\]
(b) Draw the structures of the following:

(i) Geometric isomers of $[\text{Cr}(\text{en})(\text{NH}_3)\text{I}_2]^+$

Soln:

(ii) Linkage isomers of $[\text{Mn(CO)}_2(\text{SCN})]$  

**QUESTION 3**

(a) Give the definition the following terms use illustration if necessary

(i) Back-bonding or back donation

Soln: Formation of $\pi$-bonding as a result of the overlap of metal $d$-orbitals and the ligand $\pi^*$ orbitals

(ii) Crystal Field Theory

Soln: An electrostatic approach used to describe the splitting in the metal $d$-orbitals energies. It provides an approximate description of the electronic energy levels that determine possible origins of photo- and electrochemical properties of the transition metal complexes. It does not describe bonding.

(b) Differentiate between a hard acid and soft acid

Soln:

- **Hard acid**
  - small atomic/ionic radius
  - high oxidation state
  - low polarizability
  - high electronegativity
  - have energy high-lying LUMO

- **Soft acid**
  - large atomic/ionic radius
  - low oxidation state
  - high polarizability
  - low electronegativity
  - have energy low-lying LUMO

(c) Explain why $\text{Cr(CO)}_6^-$ and $\text{Mn(CO)}_6$ are isoelectronic yet stretching frequencies of CO in $\text{Cr(CO)}_6^-$ is lower than that of Mn in $\text{Mn(CO)}_6$

Soln

- $\text{Cr(CO)}_6^-$ is e- rich. It has more ability to back-donate e- to the empty $\pi^*$-orbitals in CO
- $\text{Cr(CO)}_6^-$ makes $\text{Cr-C}$ bond stronger or longer
- $\text{Mn(CO)}_6$ makes $\text{Cr-C}$ bond weaker or longer
- lower frequency
- lower wave number