1. (10%, 2%/per) True (**T**) or False (**F**).

(a) According to the Lewis concept of acids and bases, the formation of metal complexes or coordination compounds can be considered as an acid-base reaction.

(b) The *trans* effect means that a good *trans*-directing ligand could weaken the bond between the metal and the *trans* ligand.

(c) A π acid ligand means that a ligand, such as CO, contains filled π^* orbitals to donor electrons.

(d) On the basis of the oxidation state of the metal ion and their acceptor properties, copper(I) is regarded as a soft acid (or acceptor), but copper(II) is in the border region.

(e) A strong-field ligand forms complexes which have high spin.

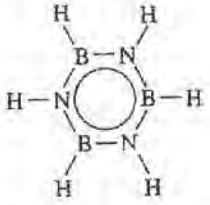
2. (10%, 2%/per) Assign the following molecules to their appropriate point groups.

(a) PF_5

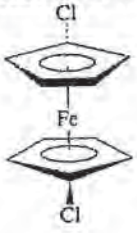
(b) NO_2

(c) P_4

(d) borazine (planar)



(e) 1,1'-dichloroferrocene



3. (10%) ICl_2^- is linear, but NH_2^- is bent. Explain briefly.

4. (10%) Show that atoms occupy 74.0% of the total volume in a face-centered cubic (*fcc*) structure in which all the atoms are identical.

5. (10%, 2%/per) Calculate the ligand-field stabilization energy of octahedral complexes in *Dq* unit.

(a) Ti^{4+} in strong-field

(b) $[Fe(CN)_6]^{4-}$

(c) $[Fe(H_2O)_6]^{3+}$

(d) $[Co(NH_3)_6]^{3+}$

(e) Mn^{3+} in weak-field

6. (10%) Arrange the following compounds in order of decreasing wave-numbers of IR spectroscopic data for CO stretching bands: $[Mn(CO)_6]^+$, $[Cr(CO)_6]$, $[V(CO)_6]^-$, $[Ti(CO)_6]^{2-}$, and briefly explain your answers.

7. (10%) The gas-phase reaction of chlorine with chloroform is described by the equation

$$Cl_2(g) + CHCl_3(g) \longrightarrow HCl(g) + CCl_4(g)$$

A proposed mechanism for this reaction follows:

$$Cl_2(g) \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2Cl(g) \quad \textit{Both fast with equal rates (fast equilibrium)}$$

$$2Cl(g) + CHCl_3(g) \xrightarrow{k_2} HCl(g) + CCl_3(g) \quad \textit{Slow}$$

$$CCl_3(g) + Cl(g) \xrightarrow{k_3} CCl_4(g) \quad \textit{Fast}$$

Derive the rate law for the reaction.

8. (10%, 5%/per) Determine the splitting pattern of *d* orbitals for an octahedral complex of formula MX_6:

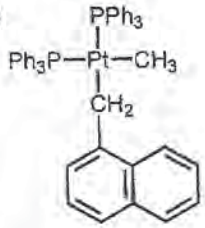
(a) X is a ligand that can act as a σ donor only.

(b) X is a ligand that can act as both a σ donor and a π acceptor.

9. (10%) What is isolobal analogy? With what organic compound is $Ir_4(CO)_{12}$ isolobal?

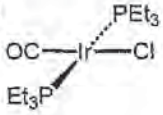
10. (10%, 2%/per) For the following reactions, draw the structures of the products.

(a)



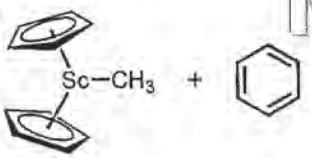
cyclometallation product

(b)



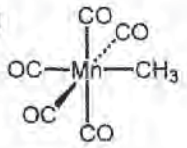
+ CH_3Br → oxidation addition product

(c)



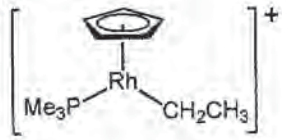
→ CH_4 + sigma-bond metathesis product

(d)



+ CO → carbonyl insertion product

(e)



→ β elimination product