Q1. What do you expect when aqeuous solutions of $CaI_2$ is mixed with AgF in 1:2 molar ratio?
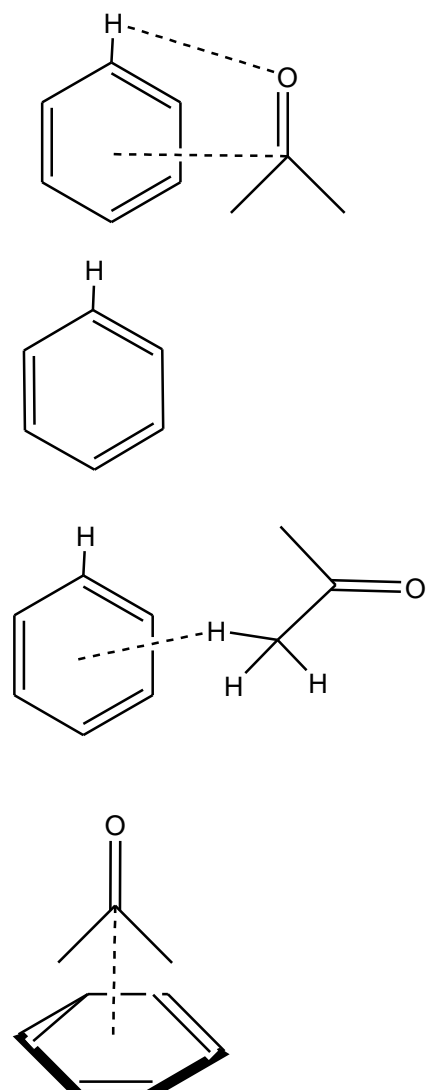(a) Only AgI precipitates
(b) Only $CaF_2$ precipitates
(c) Both AgI and $CaF_2$ precipitate
(d) No precipitate is formed

Answer: C

MARKS=1


Q2. Draw any two stabilizing non-covalent interactions between acetone and benzene molecules.


Note. This is an only MODEL answer. Other scientifically correct structures will be considered case by case basis.

MARKS=2

Q3. Which of the following reactions is(are) NOT example(s) of thermite process?
        (a) $3MnO_2 + 4Al \rightarrow 3Mn + 2Al_2O_3$
        (b) $Al_2O_3 + 2Fe \rightarrow 2Al + Fe_2O_3$
        (c) $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$
        (d) $2HgO + HgS \rightarrow 3Hg + SO_2$

Ans: (b) & (d)

MARKS=1

Q4. The process used in purifying metals by electrolysis is called
        (a) electroplating
        (b) electrometallurgy
        (c) electrolytic refining
        (d) electrodeposition

Ans: (c)

MARKS=1

Q5. Select the correct statements:
        (a) In the decomposition of a metal oxide into oxygen and gaseous metal, entropy increases.
        (b) In the decomposition of a metal oxide into oxygen and gaseous metal, entropy remains constant.
        (c) To make $\Delta G^0$ negative, the temperature should be high enough so that $T\Delta S^0 > \Delta H^0$.
        (d) Decomposition of a metal oxide is an endothermic change.

Ans: (a), (c) and (d)

MARKS=1

Q6. Consider the thermal decomposition of a metal oxide MO(s). Here the melting point of the metal is 2000°C. At 2500°C, MC(s) is expected to form when carbon is added after the complete removal of $O_2$ gas from the reaction mixture. Plot $\Delta G$ vs T for the above processes from 0 to 3000°C noting all the scenarios mentioned.
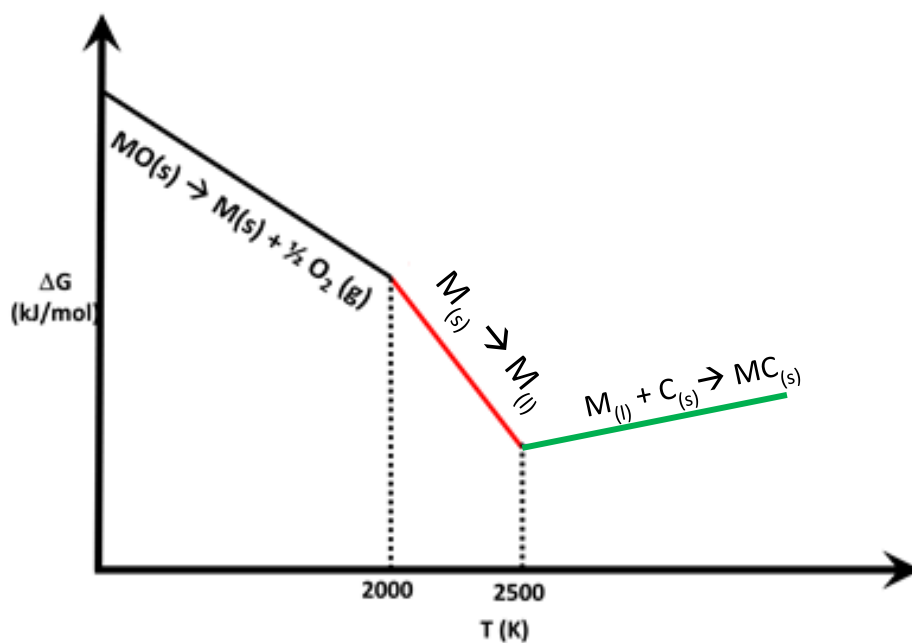
MARKS=2

Q7. The complex in which the metal in its lowest oxidation state is
   a) $[Cr(CO)_6]$
   b) $K_2[Cr_2O_7]$
   c) $[Cr(Cl)_3(H_2O)_3]$
   d) $Na_2[Fe(CO)_4]$

(d)
MARKS=1

Q8. The recipe to stabilize first-row transition metal complex with large coordination number is(are)
   a) Ligand with strong $\pi$-acceptor capability
   b) Use soft ligands
   c) Sterically hindered ligand
   d) A metal ion with large positive charges

Ans: d

Q9. Assume water reacts with $[Mn(Cl)_6]^{4-}$ and $[Mn(CN)_6]^{4-}$ which are kept in two separate reaction flasks. Which reaction will proceed faster? Rationalize your answer ONLY based on the molecular orbital theory.

Ans: In $[Mn(Cl)_6]^{4-}$, $Mn^{2+}$ is high spin, which means that the eg* orbital is also filled. Therefore M-Cl bonds are weaker than the M-CN bonds. While in M-CN complex, there is no electron in antibonding eg*, hence, the ligand can approach metal much closer than in M-Cl complex. So the M-Cl complex is expected to react faster.

Q10. The molecule(s) likely to show Jahn-Teller distortion is(are)
   a) Linear $[Mn(Cl)_2]^{+1}$
   b) $[Co(CO)_6]^{+2}$
   c) $[Cu(CN)_6]^{-3}$
   d) $[Mn(Cl)_6]^{-3}$

PS: Some of the molecules listed here are hypothetical.

Ans: b and d.

Q11. The number of non-bonding $d$-orbitals expected for a square-pyramidal $[Mn(NH_3)_5]^{3+}$ complex is
   a) 3
   b) 5
   c) 4
   d) 2

Ans a

Q12. Among the following, the paramagnetic outer orbital complex(es) is/are:
   a) $[Ni(NH_3)_6]^{2+}$
   b) $[Zn(NH_3)_6]^{3+}$
   c) $[Cr(NH_3)_6]^{2+}$
   d) $[Co(NH_3)_6]^{3+}$

Ans a, b and c

Q13. The correct order of stability for $[Cr(CO)_6]$ (I); $[Fe(CO)_6]$(II); $[Mn(CO)_6]$(III); and $[Co(CO)_6]$ (IV) is:
   a) IV < III< II< I
   b) III< I< II< IV
   c) IV < II < III< I
   d) I< III< II< IV

Ans: c

Q14. In the given plot, the spin state of iron in *deoxy*-hemoglobin represented correctly in



A) I
B) II
C) III
D) IV
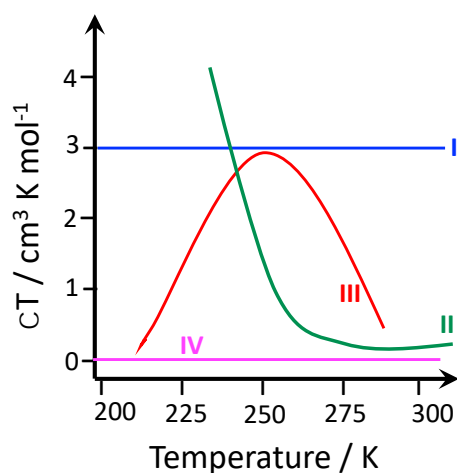
Q15. The relative energies of *d*-orbitals in a trigonal bipyramidal [ML$_5$] complex as per CFT is:

a) $d_z^2 \approx d_{x^2-y^2} > d_{xy} = d_{xz} = d_{yz}$
b) $d_z^2 > d_{x^2-y^2} = d_{xy} > d_{xz} = d_{yz}$
c) $d_z^2 > d_{xz} = d_{yz} > d_{x^2-y^2} = d_{xy}$
d) $d_z^2 = d_{xz} = d_{yz} > d_{x^2-y^2} = d_{xy}$

Q16. Sketch the MO diagram of [ML$_5$(CO)] and trans [ML$_4$(CO)$_2$] (only pi part is sufficient) (Note: assume that the CO ligands are occupied along the X-axis in both cases). Draw on MOs side by side relative to each other and note down the important differences.
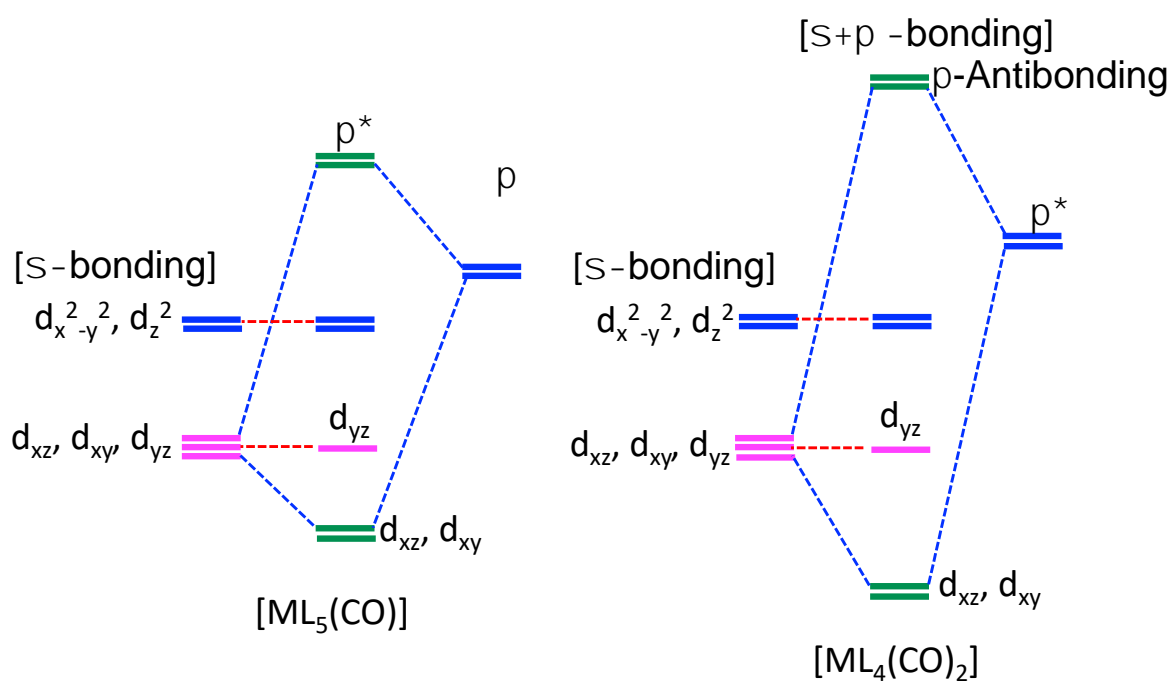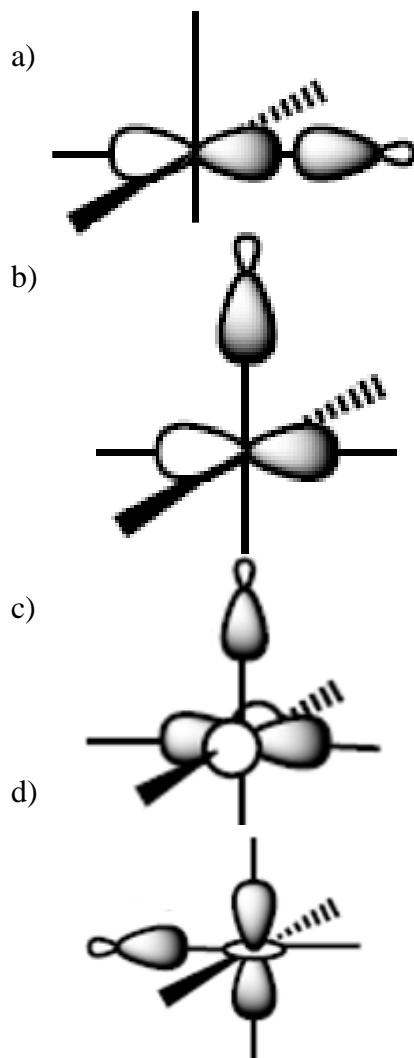
MARKS=3

Q17. The ligand and metal orbital interaction(s) lead(s) to zero overlap in the following list is(are)

a)



b)



c)



d)



Ans:b, c

Q18. Why is orbital angular momentum quenched significantly due to ligand field in transition metal complexes while in lanthanide ions its effect is negligible?
   a) Lanthanide has more unpaired electrons than the 3d metal ion
   b) Interaction of ligand orbital with lanthanide ions is very poor
   c) 4f-orbitals are buried and hence energetically much higher than the ligand orbital
   d) Because lanthanide ion has a large coordination number

Ans:b and c

**Q19.** Stepwise stability constants ($K_1$, $K_2$, $K_3$) for (en) complexes of some 3d transition metal ions in aqueous solution are shown below. The stability of complexes (with less than 10 d electrons) gradually increases from left to right across the series except for $K_3$ of Cu(II). Why?

$$[Cu(en)_2(H_2O)_2] > [Cu(en)_3]$$
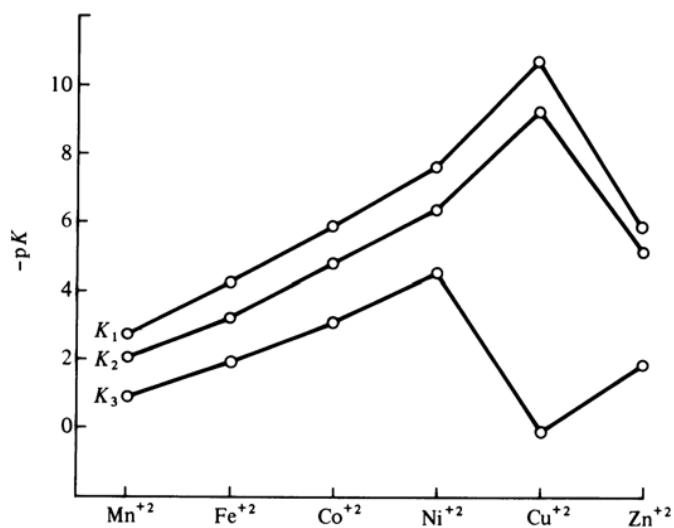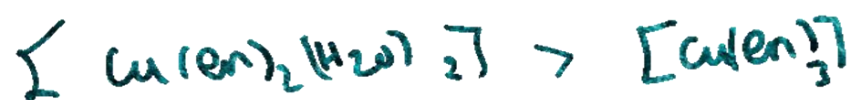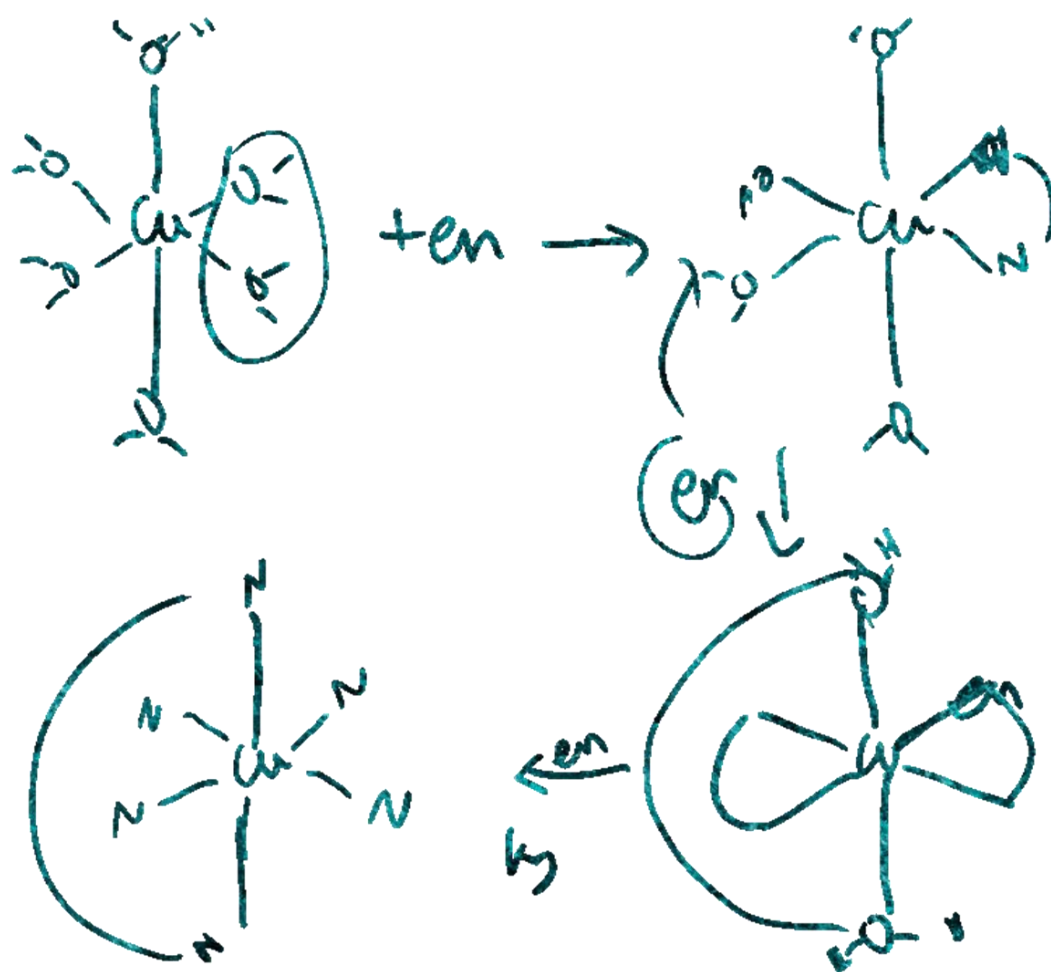
Due to Jahn-Teller distortion, K3 will be smaller than K1 and K2 here.

**Rubrics**

New Marks = 0 / 2.00

Old Marks = 0.00

| | | | |
|---|---|---|---|
| ☐ | Writing the equations or showing the structure where there is a strain in [Cu(en)3] (see model answer) | 1 | ☑ |
| ☐ | Reason as Jahn-Teller distortion | 1 | ☑ |
| ☐ | wrong answer | 0 | ☑ |

Q20. The correct order of crystal field splitting value is:
(a) $[Co(NH_3)_6]^{3+}$  (b) $[Ir(NH_3)_6]^{3+}$ (c) $[Rh(NH_3)_6]^{3+}$ (d) $[CoCl_4]^{2-}$ (e) $[CoF_6]^{3-}$

A. d<a<e< b < c

B. d<e< a <c<b

C. d < e < a < c < b

D. d<b<c<a <e

Q22.  For $[Mn(H_2O)_6]^{3+}$ complex, the correct statement that describes the Zeeman effect is
   (a) A largest negative slope is expected for $m_s=-1$ level.
   (b) A largest negative slope is expected for $m_s=-2$ level.
   (c) A largest positive slope is expected for $m_s=+2$ level.
   (d) A largest positive slope is expected for $m_s=+1$ level.

Ans: b and c

Q23.  Among the following compounds: A, B, C, and D. The statement that describes the correct order of magnetic characteristics of A, B, C and D is
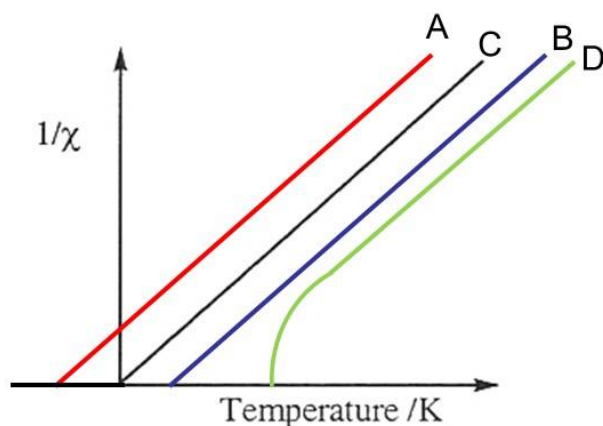


   A.  Anti-ferromagnetic, ferromagnetic, paramagnetic, ferrimagnetic
   B.  Ferromagnetic, antiferromagnetic, diamagnetic, paramagnetic
   C.  Antiferromagnetic, paramagnetic, ferromagnetic, ferromagnetic
   D.  Ferrimagnetic, ferromagnetic, paramagnetic,  antiferromagnetic

Ans: A

Q24. Magnetic susceptibility $\chi$ for a transition metal compound is measured to be 14.33 X 10$^{-3}$ cm$^3$ K mol$^{-1}$. Fitting the susceptibility yield Curie-Weiss constant $\theta$ = -4.95 at 300 K. Predict the number of unpaired electrons are present in the molecule.

$$\boxed{\chi = \frac{C}{T-\theta}}$$

$$\chi = 14. \quad 33 \times 10^{-3}$$
$$C = -4.95$$
$$T = 300$$

$$M_{SO} = 2.828 \sqrt{\chi(T-\theta)}$$

$$M_{SO} = 5.9 \; BM \Rightarrow 5$$

| | Rubrics | | |
|---|---|---|---|
| | New Marks = 0 / 2 | | |
| | Old Marks = 0.00 | | |
| ☐ | Number of unpaired electron as 5 | 2 | ☑ |
| ☐ | Wrong answer (NO marks for steps) | 0 | ☑ |

Q25. Work out the term symbol for Cr(0) free ion.

Cr(0) electronic configuration d5s1 here L = 0 so S and S = 3 so $^7$S. J mentioned or not, is Ok. $^7$S$_3$ or $^7$S

Q26.  The magnetic susceptibility has been measured for the following compounds (**A**) KCr(SO$_4$)$_2$.12H$_2$O, (**B**) (NH$_4$)$_2$Cu(SO$_4$)$_2$.6H$_2$O. (**C**) K$_3$[Mn(CN)$_6$], and (**D**) K$_2$Mn(SO$_4$)$_2$.6H$_2$O (**D**). The magnetic susceptibility estimated at 80 K and at 300 K are; for **A** 3.87 and 3.85 $\mu_B$, for **B** 1.91 and 1.93 $\mu_B$, for **C** 3.5 and 3.1 $\mu_B$ and for D 5.91 and 5.91$\mu_B$.  Pick the correct

statement among the following for compounds A-D regarding orbital angular moment (OAM) the data provided.

    A.  A – has no OAM, B has no OAM, C has OAM and D has no OAM.

    B.  A – has  OAM, B has no OAM, C has OAM and D has OAM.

    C.  A – has OAM, B has no OAM, C has no OAM and D has no OAM.

    D.  A – has no OAM, B has OAM, C has no OAM and D has no OAM.

Ans: (A)

Q27. Magnetic susceptibility plot of a dinuclear $Fe^{II}$ compound (Molecular structure and magnetic data are given below for [Fe(bithiazole)(NCS)$_2$]$_2$(bpym)] are shown below. In the curve A, B and C respectively correspond to
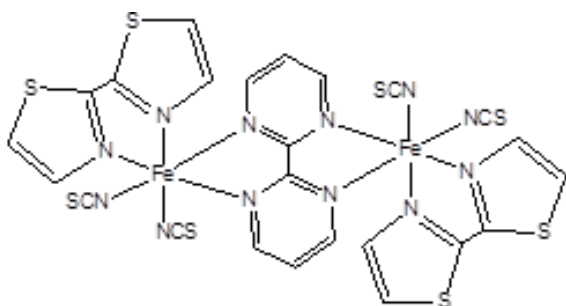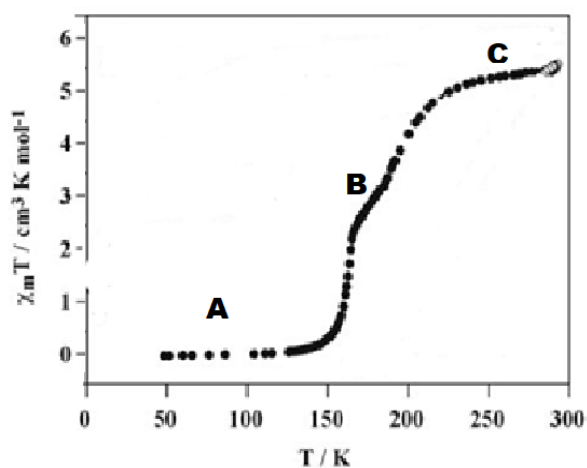
A. LS-Fe1 –LS –Fe2,  LS-Fe1 –HS –Fe2 and HS-Fe1 –HS –Fe2
B. LS-Fe1 –LS –Fe2,  LS-Fe1 –LS –Fe2 and HS-Fe1 –LS –Fe2
C. LS-Fe1 –LS –Fe2,  HS-Fe1 –HS –Fe2 and HS-Fe1 –HS –Fe2
D. LS-Fe1 –HS –Fe2,  LS-Fe1 –HS –Fe2 and LS-Fe1 –HS –Fe2

PS. Here HS and LS refer to high-spin and low-spin state of $Fe^{II}$ ions, respectively.

Q28. Magnetic susceptibility plot of compounds A and B  which follows Curie law are given below. Choose the correct set of compound(s) which fit the data provided.
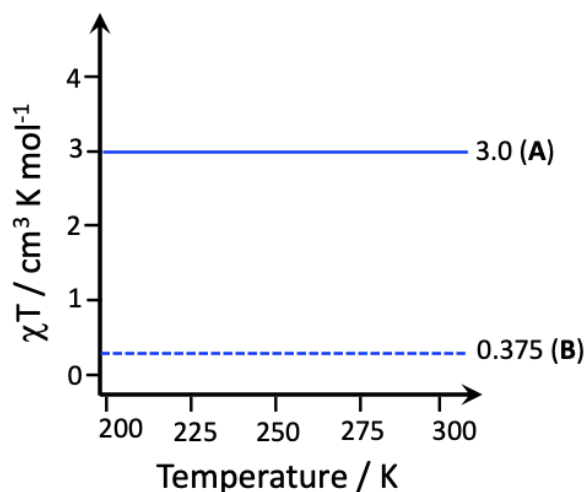


(a)  $[Mn(H_2O)_4]^{3+}$; $[Co(PPh_3)_2(PMe_3)_4]$
(b)  $[Cr(H_2O)_6]^{2+}$; $[Fe(CN)_6]^{3-}$
(c)  $[FeCl_4]^{2-}$ ; $[Ti(H_2O)_6]^{3+}$
(d)  $[MnCl_4]^-$  ; $[RuF_6]^{3-}$
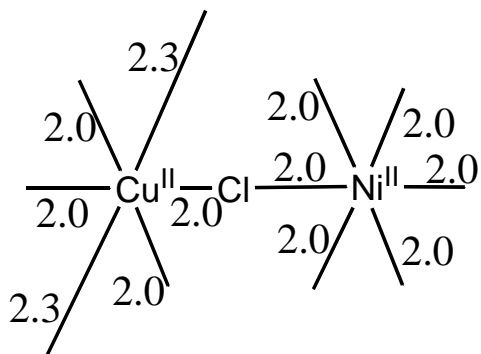
Q29. Two dinuclear $Cu^{II}$-$Ni^{II}$ compounds I and II with their metal-ligand bond distances are given below (Å). Using appropriate orbital diagrams, predict the nature of exchange coupling in these two complexes.

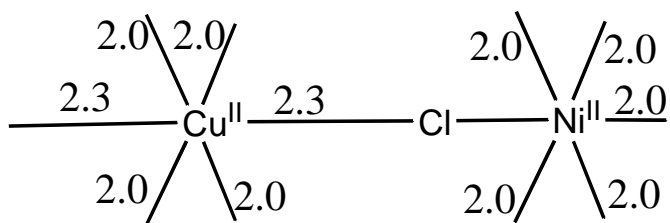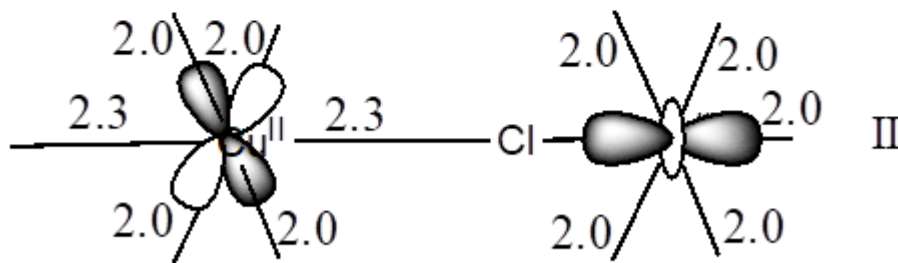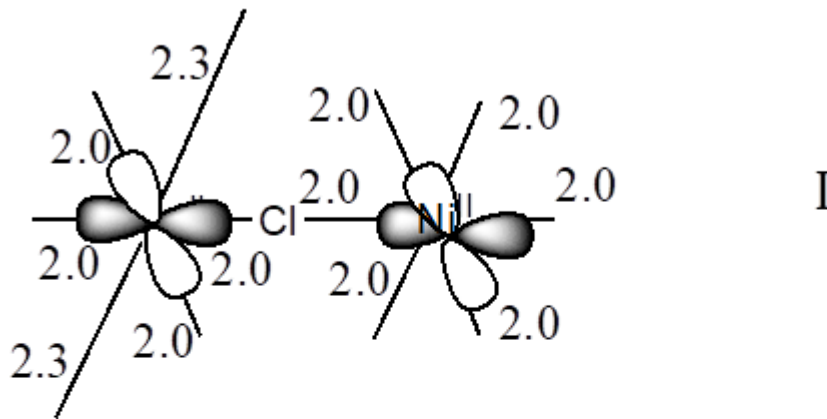## Antiferromagnetic as two orbitals overlap



I



II

## ferromagnetic as NO two orbitals overlap

Q30. Which of the following species is NOT a reactive oxygen species (ROS)?
A. $H_2O_2$
B. $O_2^{\bullet-}$
C. $OH^-$
D. $OH^{\bullet}$

Answer: C

Q31. Which of the following protein state(s) is/are stable in the tissue ($p_{O2} \sim$ 20-40 mm of Hg)?
A. Oxy-hemoglobin
B. Oxy-myoglobin
C. Deoxy-hemoglobin
D. Deoxy-myoglobin

Answer: B, C

Q32. Which of the following factor(s) influence the *bent mode* of $O_2$ binding to iron centre present in haemoglobin?
A. Fe-oxidation and spin-state
B. $O_2$ frontier orbitals
C. The presence of distal histidine
D. The partial pressure of $O_2$

Answer: A, B and C