Coordination Compounds + Metallurgy

1. In which of the following order the given complex ions are arranged correctly with respect to their decreasing spin only magnetic moment ?

(i) $[FeF_6]^{3-}$

(ii) $\left[Co(NH_3)_6\right]^{3+}$

(iii) $[NiCl_4]^{2-}$

(iv) $\left[Cu(NH_3)_4\right]^{2+}$

A. $(iii) > (iv) > (iii) > (i)$

B. $(ii) > (iii) > (i) > (iv)$

C. $(i) > (iii) > (iv) > (ii)$ ✔

D. $(ii) > (i) > (iii) > (iv)$

		Configuration	Unpaired e^- (n)
FeF_6^{3-}	Fe^{3+} (Weak field ligand)	$(t_{2g})^3\ (e_g)^2$	5
$\left[Co(NH_3)_6\right]^{3+}$	Co^{3+} (Strong filed ligand)	$(t_{2g})^6$	0
$[NiCl_4]^{2-}$	Ni^{2+} (Weak field ligand)	$(e)^4(t_2)^4$	2
$\left[Cu(NH_3)_4\right]^{2+}$	Cu^{2+} (square planar complex)	$[Ar]3d^9\ 4s^0\ 4p^0$	1

$\mu = \sqrt{n\,(n+2)}\ B\cdot M$

where, n is unpaired electrons

$\mu \propto n$

So , correct order of spin only magnetic moment is

$(ii) > (iv) > (iii) > (i)$

2. What is the spin-only magnetic moment value (BM) of a divalent metal ion with atomic number 25, in it's aqueous solution?

✔ **A.** 5.92

✖ **B.** 5.26

✖ **C.** 0

✖ **D.** 5.0

The element having atomic number 25 is manganese. The electronic configuration of Mn^{2+} is $Mn^{2+} : 3d^5$

In aqueous solution it exists as $[Mn(H_2O)_6]^{2+}$. Since H_2O is a weak field ligand, it does not cause pairing of unpaired electrons. So, its spin only magnetic moment is
$\mu = \sqrt{n(n+2)}\ B.M$
n = no. of unpaired electrons.
$\mu = \sqrt{5 \times 7} = 5.92\ BM$

3. According to the valence bond theory the hybridization of central metal atom is dsp^2 for which one of the following compounds ?

✖ **A.** $NiCl_2.6H_2O$

✖ **B.** $[Ni(CO)_4]$

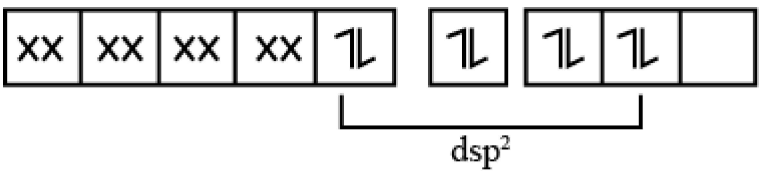
✔ **C.** $K_2[Ni(CN)_4]$

✖ **D.** $Na_2[NiCl_4]$

Cl ligands are weak field so, $NiCl_2.6H_2O$ and $Na_2[NiCl_4]$ form outer orbital complex of sp^3 hybridisation.

In $[Ni(CO)_4]$, the electronic configuration of Ni^0 is $3d^{10}\ 4s^0$. Hence, its hybridisation will be sp^3

In $K_2[Ni(CN)_4]$, the CN is strong field ligand so electrons gets paired and form inner orbital complex of dsp^2 hybridisation.



4. The type of hybridisation and magnetic property of the complex $[MnCl_6]^{3-}$, respectively, are

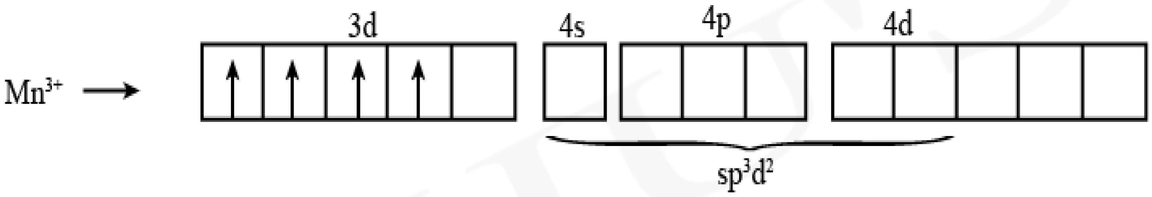
A. d^2sp^3 and diamagnetic

B. sp^3d^2 and diamagnetic

C. d^2sp^3 and paramagnetic

D. sp^3d^2 and paramagnetic ✔

$[MnCl_6]^{3-}$ $\Rightarrow$ Mn^{3+} with weak field ligand
$\Rightarrow$ high spin and outer orbital complex.



It has 4 unpaired electron.
Hence, it is sp^3d^2 with paramagnetic character.

5. The number of geometrical isomers found in the metal complexes $[Pt(Cl)_2(NH_3)_2], [Ni(CO)_4], [Ru(H_2O)_3Cl_3]$ and $[CoCl_2(NH_3)_4]^+$ respectively, are

A. 2, 1, 2, 1

B. 2, 1, 2, 2

C. 2, 0, 2, 2 ✔

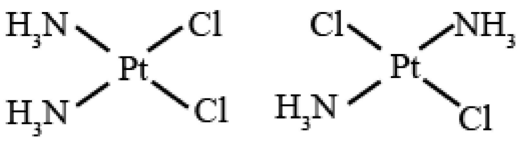
D. 1, 1, 1, 1

$[Pt(Cl)_2(NH_3)_2]$ forms two possible geometrical isomers, cis and trans.
In cis, same group on same side and in trans same groups on opposite side.

In $[Ni(CO)_4]$, the oxidation state of Ni is 0 and it forms a outer orbital complex with sp^3 hybridisation. Thus, it form tetrahedral complex and it lacks geometrical isomerism.

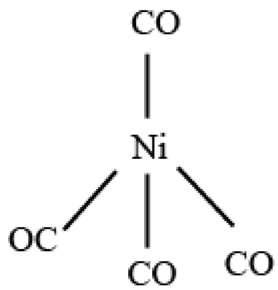
In $[Ma_3b_3]$ type of complex, the possible geometrical isomers are two, facial and meridional.
Facial isomer have three identical ligands on one triangular face.
Meridional isomer have three identical ligands in a plane bisecting the molecule.

$[PtCl_2(NH_3)_2]$

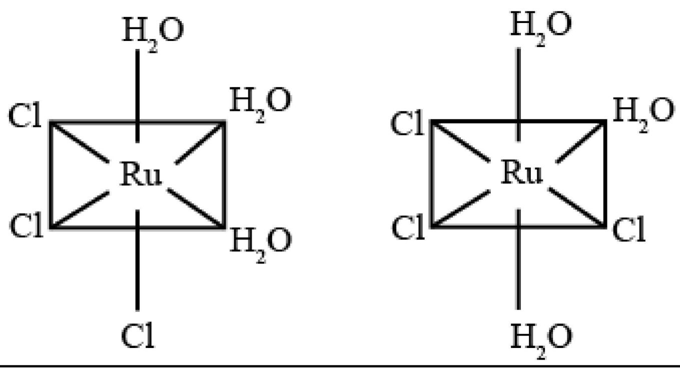


Cis trans

$[Ni(CO)_4]$



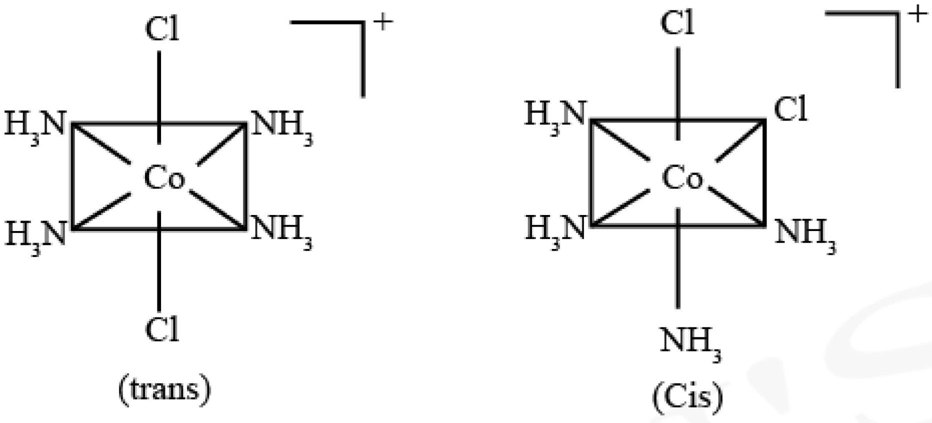
$[Ru(H_2O)_3Cl_3]$



(fac) (mer)

In $[Ma_2b_4]$ type, there are two possible geomerical isomers, cis and trans. These isomers are given below,

$[CoCl_2(NH_3)_4]^+$



Hence, option (c) is correct.

6. Which one of the following complexes is violet in colour ?

A. $[Fe(SCN)_6]^{4-}$

B. $[Fe(CN)_5NOS]^{4-}$

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

D. $Fe_4[Fe(CN)_6]_3.H_2O$

$[Fe(CN)_6]^{4-}$ - Plate yellow
$[Fe(CN)_6]^{3-}$ - Yellow
$Fe(SCN)_3$ - Red colouration
$[Fe(CN)_5(NOS)]^{4-}$ - Violet colour

$$Na_2S + \underset{\text{sodium nitroprusside}}{Na_2[Fe(CN)_5NO]} \rightarrow \underset{\text{sodium thionitroprusside (violet)}}{Na_4[Fe(CN)_5NOS]}$$

Coordination Compounds + Metallurgy

7. Arrange the following cobalt complexes in the order of increasing crystal field stabilisation energy (CFSE) value.

Complexes :
A . $[CoF_6]^{3-}$
B . $[Co(H_2O)_6]^{2+}$
C . $[Co(NH_3)_6]^{3+}$
D . $[Co(en)_3]^{3+}$

Choose the correct option :

- ✗ **A.** C < D < B < A
- ✗ **B.** B < C < D < A
- ✗ **C.** A < B < C < D
- ✓ **D.** B < A < C < D

CFSE value increases as the strength of the ligand increases also with increase in positive charge of central atom. According to spectrochemical series, the order of ligand strength is $en > NH_3 > H_2O > F^-$. So , the CFSE value of the given complexes should be $A < B < C < D$. But as complex A contain cobalt in +3 oxidation state, $A > B$. Final order is $B < A < C < D$.
Hence, option (d) is correct.

8. The denticity of an organic ligand, biuret is :

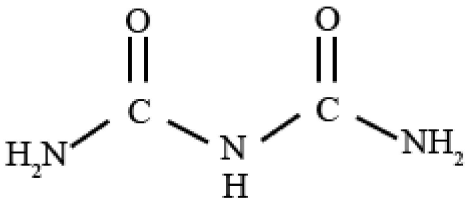
A. 3

B. 2

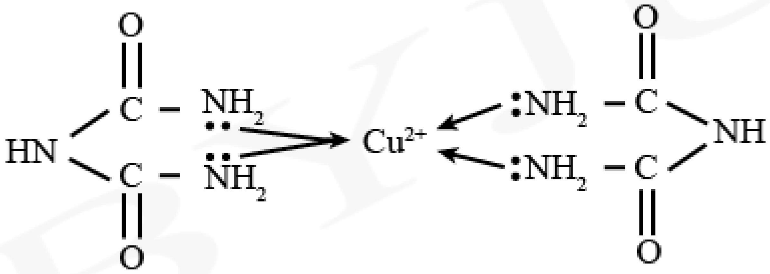
C. 4

D. 6

Biuret ligand is



It is a bidentate ligand and it forms complexes like



9. The complex that can show fac- and mer-isomers is

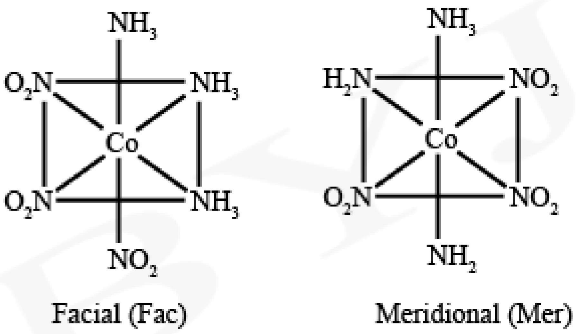
A. $[CoCl_2(en)_2]$

B. $[Co(NH_3)_3(NO_2)_3]$

C. $[Pt(NH_3)_2Cl_2]$

D. $[Co(NH_3)_4Cl_2]^+$

Octaherdral geometry of type $[Ma_3b_3]$ where a and b are unidentate ligands, shows facial and meridional isomers.
Facial isomer have three identical ligands on one triangular face.
Meridional isomer have three identical ligands in a plane bisecting the molecule.
Thus, $[Co(NH_3)_3(NO_2)_3]$ will show fac and mer isomers



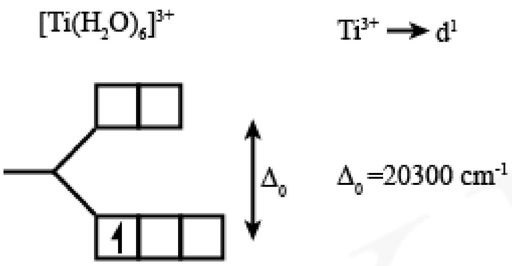
10. The electronic spectrum of $[Ti(H_2O)_6]^{3+}$ shows a single broad peak with a maximum at $20,300\ cm^{-1}$. The crystal field stabilization energy $CFSE$ of the complex ion, in $kJ\ mol^{-1}$, is $(1\ kJ\ mol^{-1} = 83.7\ cm^{-1})$

A. 145.5

B. 97

C. 242.5

D. 83.7



For octahedral,

$$CFSE = -0.4\ \Delta_o = -0.4 \times 20300 = -8120\ cm^{-1}$$

$$CFSE\ (in\ kJ) = \frac{8120}{83.7} = 97\ kJ/mol$$

Coordination Compounds + Metallurgy

11. The complex that can show optical activity

A. $cis - [Fe(NH_2)_2(CN)_4]^-$

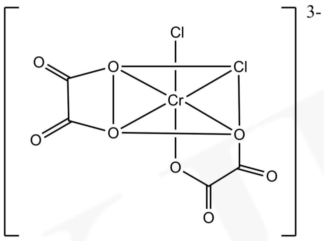
B. $trans - [Cr(Cl_2)(ox)_2]^{3-}$

C. $trans - [Fe(NH_3)_2(CN)_4]^-$

D. $cis - [CrCl_2(ox)_2]^{3-}$ $(ox = oxalate)$

When the oxalate groups are arrangement in cis position, there are in different planes and it does have a plane of symmetry. Hence, $cis - [CrCl_2(ox)_2]^{3-}$ is optically active.

Cis-$[CrCl_2(ox)_2]^{3-}$



Cis and trans form of $[Fe(NH_2)_2(CN)_4]^-$ and $trans - [Cr(Cl_2)(ox)_2]^{3-}$ have plane of symmetry so these compounds are optically inactive.

Hence, option (d) is correct.

12. The major components of German Silver are:

A. $Cu, Zn \; and \; Ni$

B. $Zn, Ni \; and \; Ag$

C. $Ge, Cu \; and \; Ag$

D. $Cu, Zn \; and \; Ag$

German silver contains $Cu \; (50\%), \; Zn \; (30\%), \; Ni \; (20\%)$ respectively.
German silver is also called Nickel silver.
Due to the presence of nickel and zinc metal in German silver, when German silver comes in contact with skin, it may cause rashes, itching, dry patches or redness of the skin. Due to this fact, German silver cannot be used in jewellery despite it having a silvery white appearance.

13. Choose the correct answer :

Match List -I with List - II.

$List - I$ (Ore)	$List - II$ (Element Present)
(a) Kernite	(i) Tin
(b) Cassiterite	(ii) $Boron$
(c) Calamine	(iii) $Fluorine$
(d) Cryolite	(iv) $Zinc$

Choose the most appropriate answer from the options given below :

A. $(a) \rightarrow (ii),\ (b) \rightarrow (i),\ (c) \rightarrow (iv),\ d \rightarrow (iii)$

B. $(a) \rightarrow (iii),\ (b) \rightarrow (i),\ (c) \rightarrow (ii),\ d \rightarrow (iv)$

C. $(a) \rightarrow (ii),\ (b) \rightarrow (iv),\ (c) \rightarrow (i),\ d \rightarrow (iii)$

D. $(a) \rightarrow (i),\ (b) \rightarrow (iii),\ (c) \rightarrow (iv),\ d \rightarrow (ii)$

Kernite : $Na_2B_4O_7.4H_2O$ $(Boron)$

Cassiterite : SnO_2 (Tin)

Calamine : $ZnCO_3$ $(Zinc)$

Cryolite : Na_3AlF_6 $(Fluorine)$

$(a) - (ii),\ (b) - (i),\ (c) - (iv),\ (d) - (iii)$

14. The process that involves the removal of sulphur from the ores is

- ✗ A. Smelting
- ✗ B. Refining
- ✓ C. Roasting
- ✗ D. Leaching

Removal of sulphur from the ore is done by Roasting.
Roasting: In roasting, the ore is heated in a regular supply of air in a furnace at a temperature below the melting point of the metal. Some of the reactions involving sulphide ores are:

$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

The sulphide ores of copper are heated in reverberatory furnace.

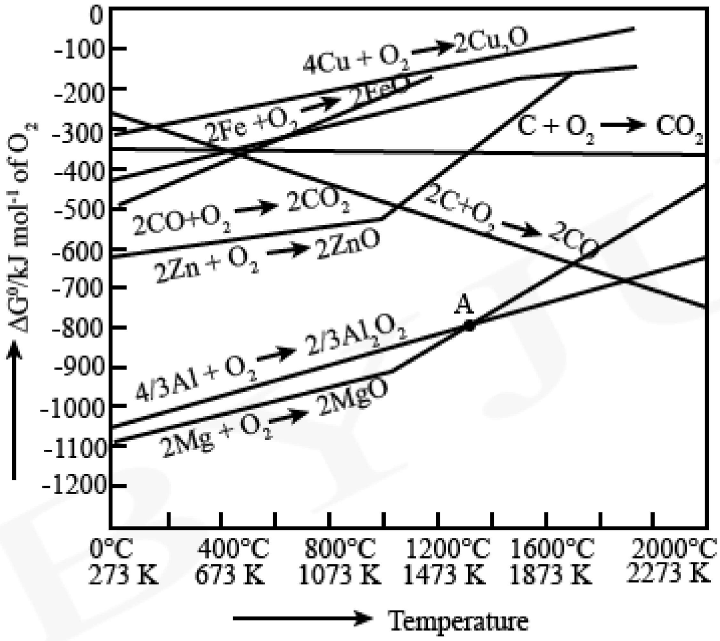
15. Which of the following reduction reaction cannot be carried out with coke ?

A. $Cu_2O \rightarrow Cu$

B. $Fe_2O_3 \rightarrow Fe$

C. $Al_2O_3 \rightarrow Al$

D. $ZnO \rightarrow Zn$



Any metal will reduce the oxide of other metal which lie above it in Ellingham diagram. Fe, Zn, Cu reduction can be carried out with coke since they lie above. Also,from the Ellingham diagram, the difference in the ΔG° values is very much positive, that's why reduction of Al_2O_3 with coke is non-spontaneous.
Option (c) is correct

16. Choose the correct answer :

Match List-I with List-II :

List-I	List-II
(a) Haematite	(i) $Al_2O_3 \cdot xH_2O$
(b) Bauxite	(ii) Fe_2O_3
(c) Magnetite	(iii) $CuCO_3 \cdot Cu(OH)_2$
(d) Malachite	(iv) Fe_3O_4

Choose the **correct** answer from the option given below .

A. $(a)-(i),(b)-(iii),(c)-(ii),(d)-(iv)$

B. $(a)-(ii),(b)-(i),(c)-(iv),(d)-(iii)$

C. $(a)-(iv),(b)-(i),(c)-(ii),(d)-(iii)$

D. $(a)-(ii),(b)-(iii),(c)-(i),(d)-(iv)$

(a) Haematite $\rightarrow (ii)\ Fe_2O_3$

(b) Bauxite $\rightarrow (i)\ AI_2O_3 \cdot xH_2O$

(c) Magnetite $\rightarrow (iv)\ Fe_3O_4$

(d) Malachite $\rightarrow (iii)\ CuCO_3 \cdot Cu(OH)_2$

Coordination Compounds + Metallurgy

17. Given below are two statements :

Statement I : Sphalerite is a sulphide ore of zinc and copper glance is a sulphide ore of copper .

Statement II : It is possible to separate two sulphide ores by adjusting proportion of oil to water or by using depressants in a froth flotation method .

Choose the most appropriate answer from the options given below :

- ✗ **A.** Statement I is true but Statement II is false
- ✗ **B.** Statement I is false but Statement II is true
- ✗ **C.** Both Statement I and Statement II are false
- ✓ **D.** Both Statement I and Statement II are true

Sphalerite $- ZnS$

Copper glance $- Cu_2S$

Yes it is possible to separate two sulphide ores by adjusting proportion of oil to water or by using depressants in froth flotation process.

Eg : $ZnS$and PbS can separated by using $NaCN$.

$$ZnS + 4NaCN \rightarrow Na_2\left[Zn(CN)_4\right] + Na_2S$$

18. Which refining process is generally used in the purification of low melting metals ?

- ✗ **A.** Electrolysis
- ✗ **B.** Zone refining
- ✓ **C.** Liquation
- ✗ **D.** Chromatographic method

Liquation is used for the refining of metals having low melting point and are associated with high melting impurities . For example Pb, Sn, Sb, Bi and Hg . THe impure metal is heated on the sloping hearth of a furnace . The pure metal flows down leaving behind the non-fusible material on the hearth .

19. Given below are the two statements : one is labelled as Assertion (a) and the other is labelled as Reason (R).

Assertion (A) : Aluminium is extracted from bauxite by the electrolysis of molten mixture of Al_2O_3 with cryolite.

Reason(R) : The oxidation state of Al in cryolite is $+3$.

In the light of the above statements , choose the most appropriate answer from the options given below :

- ✗ **A.** (A) is true but (R) is false
- ✗ **B.** (A) is false but (R) is true
- ✓ **C.** Both (A) and (R) are correct but (R) is not the correct explanation of (A)
- ✗ **D.** Both (A) and (R) are correct but (R) is not the correct explanation of (A)

(A) is correct - Aluminium is extracted from bauxite by electrolysis of molten mixture of Al_2O_3 with cryolite

Na_3AlF_6 :

$3 + x - 6 = 0$

$x = +3$

Statement given in (R) is correct i.e, oxidation state of Al in cryolite (Na_3AlF_6) is +3 but it is not correct reason of (A)

Coordination Compounds + Metallurgy

20. The purest form of commercial iron is

- A. Scrap iron and pig iron
- B. Cast iron
- C. Wrought iron ✓
- D. Pig iron

1. Wrought Iron: It is a form of commercial iron having a very low carbon content (less than 0.10%), the impurities such as sulphur, phosphorus, silicon and manganese are less than 0.25%. It has the largest amount of pure iron in its constituents and is hence known as the purest form of commercial iron.
2. Cast Iron: It is a large family of ferrous alloys. These are multi-component ferrous alloys. The major constituents of cast iron are iron, carbon (2% or more), silicon (1% to 3%), minor elements (less than 0.1%) and often alloying elements (less than 0.1%). The common types of cast iron are (i) white cast iron, (ii) grey cast iron, (iii) ductile cast iron, and (iv) malleable cast iron.
3. Pig Iron: It is an iron-carbon alloy that has other elements such as silicon, manganese, sulphur, phosphorus. It has 3.5% to 4.5%, sulphur less than 0.05 % and phosphorus is up to 0.12%.

Therefore, wrought iron is the purest form of commercial iron. Hence, option (c) is the correct answer.

Coordination Compounds + Metallurgy

21. Among statements (a) - (d), the correct ones are

(a) Lime stone is decomposed to CaO during the extraction of iron from its oxides.

(b) In the extraction of silver, silver is extracted as an anionic complex.

(c) Nickel is purified by Mond's process.

(d) Zr and Ti are purified by Van Arkel method.

✗ **A.** (a), (c) and (d) only

✗ **B.** (c) and (d) only

✗ **C.** (b), (c) and (d) only

✓ **D.** (a), (b), (c) and (d)

$$CaCO_3 \xrightarrow{500-800\ K} CaO + CO_2$$

In extraction of silver, silver is extracted as an anionic complex $[Ag(CN)_2]^-$.

Mond's process is used for purification of Ni
Vapour Phase Refining
Step 1:
Ni is heated in stream of CO to form nickel tetracarbonyl

$$Ni + 4CO \xrightarrow{330-350K} \underset{\text{Volatile}}{Ni(CO)_4}$$

Step2:
Volatile compound is subjected to higher temperature

$$Ni(CO)_4 \xrightarrow{450-470K} \underset{\text{Pure metal}}{Ni} + 4CO$$

$Ti\ and\ Zr$ metal is refined by the Van-Arkel method. Metal is converted (by heating with little iodine) to volatile (covalent) tetraiodide which is then decomposed (by electrically heating above 1800 K with tungsten filament) to pure metal which is deposited on a tungsten filament.
Reactions:

$$Zr + 2I_2 \rightarrow \underset{\substack{\text{More Covalent} \\ \text{Volatilises}}}{ZrI_2}$$

$$ZrI_2 \rightarrow \underset{\text{Pure Metal}}{Zr} + 2I_2$$

All the statements are correct

22. Cast iron is used for the manufacture of

A. Wrought iron, pig iron and steel

B. Pig iron, scrap iron and steel

C. Wrought iron and pig iron

D. Wrought iron and steel

Cast iron used for the manufacture of wrought iron and steel.

Cast iron or Pig iron were the starting material used in the finery forge and pudding furnace to produce wrought iron and steel.
Cast iron has higher carbon content than wrought iron, but has a lower melting point than iron or steel.

Coordination Compounds + Metallurgy

23. Among the reactions (a)-(d) , the reactions (s) that does/do not occur in the blast furnance during the extraction of iron is/are

(a) $CaO + SiO_2 \rightarrow CaSiO_3$
(b) $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
(c) $FeO + SiO_2 \rightarrow FeSiO_3$
(d) $FeO \rightarrow Fe + \frac{1}{2}O_2$

- ✔ **A.** (c) and (d)
- ✘ **B.** (d)
- ✘ **C.** (a)
- ✘ **D.** (a) and (d)

In extraction of iron from its oxide ore, hot air in blown from bottom of blast furnace so that coke is burnt to give high temperature upto 2200 K at lower portion of furnace only.
Then, CO and heat moves to upper part of furnace.
The temperature is lower in upper part where the iron oxide get reduce in different temperature.

At 500-800 K, iron oxide get reduced only by CO.
$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$
$Fe_2O_3 + CO \rightarrow 2FeO + CO_2$

At 900-1500 K, iron oxide is reduced by both C and CO.
$C + CO_2 \rightarrow 2CO$
$FeO + CO \rightarrow Fe + 2CO$

Limestone is added to the furnance to remove the SiO_2 as slag $(CaSiO_3)$.
$CaCO_3 \rightarrow CaO + CO_2$
$CaO + SiO_2 \rightarrow CaSiO_3$

So,
(c) $FeO + SiO_2 \rightarrow FeSiO_3$

(d) $FeO \rightarrow Fe + \frac{1}{2}O_2$

Reactions (c) and (d) do not occur in the blast furnace in the metallurgy of iron.

Coordination Compounds + Metallurgy

24. The method used for the purification of Indium is

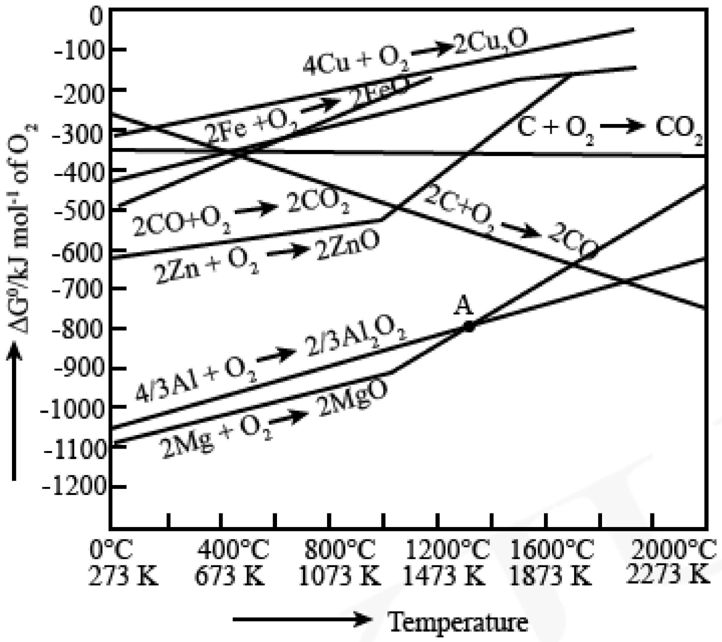
- A. Vapour phase refining
- B. Zone refining
- C. Liquation
- D. van Arkel method

Option (b)
Indium is purified by zone refining method.
Zone refining refers to the method of purifying a crystal wherein a thin region of the crystal undergoes melting. This 'molten zone' is now moved across the crystal.

The impurities in the metal are melted at the forward edge by the molten zone and move through the block of metal, leaving the solidified pure element behind.

As they move through the block of metal, the impurities in the metal are concentrated in the melt and are transported to one end of the metal block.
The principle of zone refining is that the impurities in an ingot or ore of metal are more soluble in the melt state when compared to the corresponding solid state of the impurities

25. The point of intersection and sudden increase in the slope., in the diagram given below, respectively indicates :



A. $\Delta G = 0$ and reduction of the metal oxide

B. $\Delta G < 0$ and decomposition of the metal oxide

C. $\Delta G = 0$ and melting or boiling point of the metal oxide

D. $\Delta G > 0$ and decomposition of the metal oxide

From the Ellingham diagram given, the point of intersection represents $\Delta G = 0$ and the temperature at which sudden increase in the slope occurs is indicated by melting or boiling.

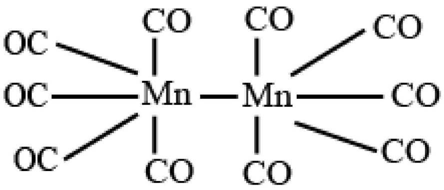
26. Number of bridging CO ligands in $[Mn_2(CO)_{10}]$ is __________ .

Accepted Answers

0

Solution:

$[Mn_2(CO)_{10}]$



The given compound obeys 18 e^- rule,
$Mn \to 7$
$Mn - Mn\ bond \to 1$
5 terminal CO's $\to 10$
hence, the given structure is correct.
$\therefore$ No. of bridging CO ligands = 0

27. The total number of unpaired electrons present in the complex $K_3[Cr(\text{oxalate})_3]$ is ________.

Accepted Answers

3 3.0 3.00

Solution:

Oxidation state of Cr in complex = +3
Electronic configuration of $Cr^{3+} = [Ar]3d^3$
$\therefore$ Number of unpaired electrons = 3

28. Three moles of $AgCl$ get precipitated when one mole of an octahedral co-ordination compound with empirical formula $CrCl_3.3NH_3.3H_2O$ reacts with excess of silver nitrate. The number of chloride ions satisfying the secondary valency of the metal ion is________.

Accepted Answers

0

Solution:

Since, 3 moles of $AgCl$ is formed, all 3 Cl^- should present outside the coordination sphere.
$[Cr(NH_3)_3(H_2O)_3]Cl_3 + AgNO_3 \rightarrow 3AgCl(s) + [Cr(NH_3)_3(H_2O)_3](NO_3)_3$

None of the chloride ion is directly bonded to metal ion. Hence number of chloride ions satisfying the secondary valence of the metal ion is zero.

29. 3 moles of metal complex with formula $Co(en)_2Cl_3$ gives 3 moles of silver chloride on treatment with excess of silver nitrate. The secondary valency of Co in the complex is ______. (Round off to the Nearest integer).

Accepted Answers

6 6.0 6.00

Solution:

Each mole of complex gives one mole of $AgCl$ which indicates two chloride ions present in coordination sphere, So, the complex is $[Co(en)_2Cl_2]Cl$ having a coordination number of 6. Secondary valency is equal to the coordination number.

30. In the electrolytic refining of blister copper , the total number of main impurities , from the following , removed as anode mud is
$Pb, Sb, Se, Te, Ru, Ag, Au$ and Pt

Accepted Answers

6 6.0 6.00

Solution:

Impurities from the blister copper deposit as anode mud which contains antimony , selenium, tellurium, silver, gold and platinum.
Correct answer is 6