J.D. LEE Concise Inorganic Chemistry for JEE Main & Advanced

JEE Advanced / Multidisciplinary PYQs with Answers and Solutions

Chapter 3 Chemical Bonding

1. The CORRECT statement(s) for cubic close packed *(ccp)* three dimensional structure is(are) _____.

(A) The number of the nearest neighbours of an atom present in the topmost layer is 12.
(B) The efficiency of atom packing is 74%.
(C) The number of octahedral and tetrahedral voids per atom are 1 and 2, respectively.
(D) The unit cell edge length is $2\sqrt{2}$ times the radius of the atom.

(2016, Paper 2)

2. In a galvanic cell, the salt bridge

(A) does not participate chemically in the cell reaction.
(B) stops the diffusion of ions from one electrode to another.
(C) is necessary for the occurrence of the cell reaction.
(D) ensures mixing of the two electrolytic solutions.

(2014, Paper 1)

3. According to Molecular Orbital Theory,

(A) C_2^{2-} is expected to be diamagnetic.
(B) O_2^{2+} expected to have a longer bond length than O_2.
(C) N_2^+ and N_2^- have the same bond order.
(D) He_2^+ has the same energy as two isolated He atoms.

(2016, Paper 2)

4. Among H_2, He^+_2, Li_2, Be_2, B_2, C_2, N_2,O^-_2 and F_2, the number of diamagnetic species is (Atomic numbers: H = 1, He = 2, Li = 3, Be = 4, B = 5, C = 6, N = 7, O = 8, F = 9)

(2017, Paper 1)

5. The correct statement(s) about surface properties is(are) _____.

(A) Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system.
(B) The critical temperatures of ethane and nitrogen are 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen on same amount of activated charcoal at a given temperature.
(C) Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium.
(D) Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution.

(2017, Paper 2)

6. Among the species given below, the total number of diamagnetic species is _____.

H atom, NO_2 monomer, O_2^- (superoxide), dimeric sulphur in vapour phase, Mn_3, O_4, $(NH_4)_2[FeCL_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4, K_2CrO_4 **(2018, Paper 1)**

Answer Key

1. (B, C, D) **2.** (A) **3.** (A, C) **4.** (6) **5.** (A, B)
6. (1)

Chapter 5 Coordination Compounds

1. The correct statement(s) regarding the binary transition metal carbonyl compounds is (are) (Atomic numbers: Fe = 26, Ni = 28)

(A) Total number of valence shell electrons at metal centre in $Fe(CO)_5$ or $Ni(CO)_4$ is 16.
(B) These are predominantly low spin in nature.
(C) Metal-carbon bond strengthens when the oxidation state of the metal is lowered.

(D) The carbonyl C-O bond weakens when the oxidation state of the metal is increased.

(2018, Paper 1)

2. Addition of excess aqueous ammonia to a pink coloured aqueous solution of $MCl_2.6H_2O$(**X**) and NH_4Cl gives an octahedral complex **Y** in the presence of air. In aqueous solution, complex **Y** behaves as 1:3 electrolyte. The reaction of **X** with excess HCl at room temperature results in the formation of a blue coloured complex **Z**. The calculated spin only magnetic moment of **X** and **Z** is 3.87 B.M., whereas it is zero for complex **Y**.

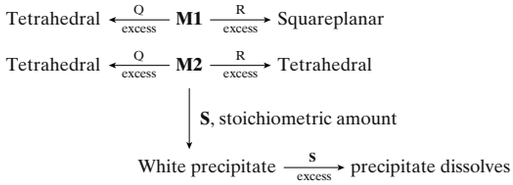
Among the following options, which statement(s) is(are) correct?

(A) The hybridization of the central metal ion in **Y** is d^2sp^3.
(B) **Z** is a tetrahedral complex.
(C) Addition of silver nitrate to **Y** gives only two equivalents of silver chloride.
(D) When **X** and **Z** are in equilibrium at 0^0C, the colour of the solution is pink.

(2017, Paper 1)

3. An aqueous solution of metal ion **M1** reacts separately with reagents **Q** and **R** in excess to give tetrahedral and square planar complexes, respectively. An aqueous solution of another metal ion **M2** always forms tetrahedral complexes with these reagents. Aqueous solution of **M2** on reaction with reagent S gives white precipitate which dissolves in excess of S. The reactions are summarized in the scheme given below.

SCHEME:



3.1 **M1**, **Q** and **R**, respectively are _____.

(A) Zn^{2+}, KCN and HCl
(B) Ni^{2+}, HCl and KCN
(C) Cd^{2+}, KCN and HCl
(D) Co^{2+}, HCl and KCN

3.2 Reagent S is _____.

(A) $K_4[Fe(CN)_6]$
(B) Na_2HPO_4
(C) K_2CrO_4
(D) KOH

(2014, Paper 2)

4. Match each coordination compound in **List-I** with an appropriate pair of characteristics from **List-II** and select the correct answer using the code given below the lists

(en = $H_2NCH_2CH_2NH_2$; atomic numbers: Ti = 22, Cr = 24; Co = 27; Pt = 78)

List – I	List – II
P. $[Cr(NH_3)_4Cl_2]Cl$	**1.** Paramagnetic and exhibits ionization isomerism
Q. $[Ti(H_2O)_5Cl](NO_3)_2$	**2.** Diamagnetic and exhibits *cis-trans* isomerism
R. $[Pt(en)(NH_3)Cl]NO_3$	**3.** Paramagnetic and exhibits *cis-trans* isomerism
S. $[Co(NH_3)_4(NO_3)_2]NO_3$	**4.** Diamagnetic and exhibits ionization isomerism

Code:

	P	Q	R	S
(A)	4	2	3	1
(B)	3	1	4	2
(C)	2	1	3	4
(D)	1	3	4	2

(2014, Paper 2)

5. If the freezing point of a 0.01 molal aqueous solution of a cobalt (III) chloride-ammonia complex(which behaves as a strong electrolyte) is -0.0558^0C, the number of chloride(s) in the coordination sphere of the complex is _____.

[K_f of water = 1.86 K kg mol^{-1}] **(2015, Paper 1)**

6. For the octahedral complexes of Fe^{3+} in SCN^- (thiocyanato-S) and in CN^- ligand environments, the difference between the spin-only magnetic moments in Bohr magnetons (When approximated to the nearest integer) is _____.

[Atomic number of Fe = 26] **(2015, Paper 1)**

7. In dilute aqueous H_2SO_4, the complex diaquodioxalatoferrate(II) is oxidized by MnO_4^-. For this reaction, the ratio of the rate of change of $[H^+]$ to the rate of change of $[MnO_4^-]$ is _____.

(2015, Paper 2)

8. In the complex acetylbromidodicarbonylbis(triethylphosphine)iron(II), the number of Fe-C bond(s) is

(2015, Paper 2)

9. Among the complex ions, $[Co(NH_2\text{-}CH_2\text{-}CH_2\text{-}NH_2)_2C1_2]^+$, $[CrCl_2(C_2O_4)_2]^{3-}$, $[Fe(H_2O)_4(OH)_2]^+$, $[Fe(NH_3)_2(CN)_4]^-$, $[Co(NH_2\text{-}CH_2\text{-}CH_2\text{-}NH_2)_2(NH_3)Cl]^{2+}$ and $[Co(NH_3)_4(H_2O)Cl]^{2+}$, the number of complex ion(s) that show(s) *cis-trans* isomerism is _____.

(2015, Paper 2)

10. Among $[Ni(CO)_4]$, $[NiCl_4]^{2-}$, $[Co(NH_3)_4Cl_2]Cl$, $Na_3[CoF_6]$, Na_2O_2 and CsO_2, the total number of paramagnetic compounds is _____.

(A) 2 **(B)** 3
(C) 4 **(D)** 5

(2016, Paper 1)

11. The number of geometric isomers possible for the complex $[CoL_2Cl_2]^-$ ($L = H_2NCH_2CH_2O^-$) is _____.
(2016, Paper 1)

12. The geometries of the ammonia complexes of Ni^{2+}, Pt^{2+} and Zn^{2+}, respectively, are _____.
(A) octahedral, square planar and tetrahedral.
(B) square planar, octahedral and tetrahedral.
(C) tetrahedral, square planar and octahedral.
(D) octahedral, tetrahedral and square planar.
(2016, Paper 2)

13. The correct option(s) regarding the complex $[Co(en)(NH_3)_3(H_2O)]^{3+}$ ($en = H_2NCH_2CH_2NH_2$) is (are)
(A) It has two geometrical isomers.
(B) It will have three geometrical isomers if bidentate 'en' is replaced by two cyanide ligands.
(C) It is paramagnetic.
(D) It absorbs light at longer wavelength as compared to $[Co(en)(NH_3)_4]^{3+}$.
(2018, Paper 2)

14. Match each set of hybrid orbitals from LIST-I with complex(es) given in LIST-II.

List – I	List – II
P. dsp^2	**1.** $[FeF_6]^{4-}$
Q. sp^3	**2.** $[Ti(H_2O)_3Cl_3]$
R. sp^3d^2	**3.** $[Cr(NH_3)_6]^{3+}$
S. d^2sp^3	**4.** $[FeCl_4]^{2-}$
	5. $Ni(CO)_4$
	6. $[Ni(CN)_4]^{2-}$

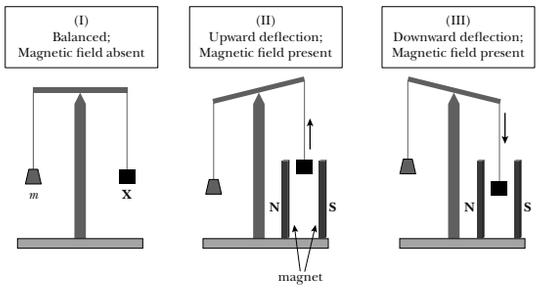
The correct option is
(A) P → 5; Q → 4, 6; R → 2, 3; S → 1
(B) P → 5, 6; Q → 4; R → 3; S → 1, 2
(C) P → 6; Q → 4, 5; R → 1; S → 2, 3
(D) P → 4, 6; Q → 5, 6; R → 1, 2 : S → 3
(2018, Paper 2)

15. At 143 K, the reaction of XeF_4 with O_2F_2 produces xenon compound Y. The total number of lone Pair(s) of electrons present on the whole molecule of Y is _____. **2019, Paper 1**

16. Total number of *cis* N-Mn-Cl bond angles (that is, Mn – N and Mn – Cl bonds in *cis* positions) present in a molecule of *cis*-$[Mn(en)_2Cl_2]$ complex is _____ ($en = NH_2CH_2CH_2NH_2$) **(2019, Paper 2)**

17. Choose the correct statement(s) among the following:
(A) $[FeCl_4]^-$ has tetrahedral geometry
(B) $[Co(en))(NH_3)_2\ Cl_2]^+$ has 2 geometrical isomers
(C) $[FCI_4]^-$ has higher spin – only magnetic moment than $[Co(en))(NH_3)_2Cl_2]^+$
(D) The cobalt ion in $[Co(en)(NH_3)_2Cl_2]^+$ has sp^3d^2 hybridization
(2020, Paper 1)

18. In an experiment, *m* grams of a compound **X** (gas/liquid/solid) taken in a container is loaded in a balance as shown in figure **I** below. In the presence of a magnetic filed, the pan with **X** is either deflected upwards (figure **II**), or deflected downwards (figure **III**), depending on the compound **X**. Identify the correct statements(s).



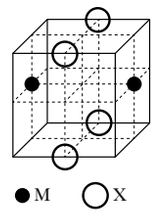
(A) If **X** is $H_2O(l)$, deflection of the pan is upwards.
(B) If **X** is $K_4[Fe(CN)_6]$ (s), deflection of the pan is upwards.
(C) If **X** is $O_2(g)$, deflection of the pan is downwards.
(D) If **X** is $C_6H_6(l)$, deflection of the pan is downwards.
(2020, Paper 2)

Answer Key

1. (B, C) **2.** (A, B, D) **3.1** (B) **3.2** (D) **4.** (B)
5. (1) **6.** (5) **7.** (8) **8.** (3) **9.** (5) **10.** (B)
11. (5) **12.** (A) **13.** (A, B, D) **14.** (C) **15.** (19)
16. (6) **17.** (A, C) **18.** (A, B, C)

Chapter 6 The Solid State

1. The cubic unit cell structure of a compound containing cation **M** and anion **X** is shown below. When compared to the anion, the cation has smaller ionic radius. Choose the correct statement(s).



(A) The empirical formula of the compound is **MX**.
(B) The cation **M** and anion **X** have different coordination geometries.
(C) The ratio of **M – X** bond length to the cubic unit cell edge length is 0.866.
(D) The ratio of the ionic radii of cation **M** to anion **X** is 0.414. **(2020, Paper 1)**

2. The cyanide process of gold extraction involves leaching out gold from its ore with CN^- in the presence of Q in water to form R. Subsequently, R is treated with T to obtain Au and Z. Choose the correct option(s)
(A) Z is $[Zn(CN)_4]^{2-}$
(B) T is Zn
(C) R is $[Au(CN)_4]^-$
(D) Q is O_2 **(2019, Paper 2)**

3. Consider an ionic solid **MX** with NaCl structure. Construct a new structure **(Z)** whose unit cell is constructed front the unit cell of **MX** following the sequential instructions given below. Neglect the charge balance.
(i) Remove all the anions **(X)** except the central one
(ii) Replace all the face centered cations **(M)** by anions **(X)**
(iii) Remove all the corner cations **(M)**
(iv) Replace the central anion **(X)** with cation **(M)**

The value of $\left(\frac{\text{number of anions}}{\text{number of cations}}\right)$ in **Z** is _____.

(2018, Paper 1)

4. Extraction of copper from copper pyrite ($CuFeS_2$) involves
(A) crushing followed by concentration of the ore by froth flotation
(B) removal of iron as slag
(C) self-reduction step to produce 'blister copper' following evolution of SO_2
(D) refining of 'blister copper' by carbon reduction

(2016, Paper 2)

5. Copper is purified by electrolytic refining of blister copper. The correct statement(s) about this process is(are) _____.
(A) Impure Cu strip is used as cathode.
(B) Acidified aqueous $CuSO_4$ is used as electrolyte.
(C) Pure Cu deposits at cathode.
(D) Impurities settle as anode - mud.

(2015, Paper 1)

6. Match the anionic species given in Column I that are present in the ore(s) given in Column II

	Column I		Column II
(A)	Carbonate	**(P)**	Siderite
(B)	Sulphide	**(Q)**	Malachite
(C)	Hydroxide	**(R)**	Bauxite
(D)	Oxide	**(S)**	Calamine
		(T)	Argentite

(2015, Paper 1)

7. Upon heating with Cu_2S, the reagent(s) that give copper metal is/are _____.
(A) $CuFeS_2$
(B) CuO
(C) Cu_2O
(D) $CuSO_4$

(2014, Paper 1)

8. Galena (an ore) is partially oxidized by passing air through it at high temperature. After some time, the passage of air is stopped, but the heating is continued in a closed furnace such that the contents undergo self-reduction. The weight (in kg) of Pb produced per kg of O_2 consumed is___.

(Atomic weights in g mol^{-1}: O = 16, S = 32, Pb = 207)

(2018, Paper 2)

9. Calamine, malachite, magnetite and cryolite, respectively, are _____.
(A) $ZnSO_4$, $Cu(OH)_2$, Fe_3O_4, Na_3AlF_6
(B) $ZnCO_3$, $CuCO_3$, $Cu(OH)_2$, Fe_3O_4, Na_3AlF_6
(C) $ZnSO_4$, $CuCO_3$, Fe_2O_3, AlF_3
(D) $ZnCO_3$, $CuCO_3$, Fe_2O_3, Na_3AlF_6

(2019, Paper 1)

10. Which among the following statement(s) is(are) true for the extraction of aluminium from bauxite?
(A) Hydrated Al_2O_3 precipitates, when CO_2 is bubbled through a solution of sodium aluminate.
(B) Addition of Na_3AlF_6 lowers the melting point of alumina.
(C) CO_2 is evolved at the anode during electrolysis.
(D) The cathode is a steel vessel with a lining of carbon.

(2020, Paper 2)

11. Tin is obtained from cassiterite by reduction with coke. Use the data given below to determine the minimum temperature (in K) at which the reduction of cassiterite by coke would take place.

At 298 K; $\Delta_f H^0$ (SnO_2 (s)) = –581.0 kJ mol^{-1}, $\Delta_f H^0$ ($CO_2(g)$) = –394.0 kJ mol^{-1},

S^0 (SnO_2 (s)) = 56.0 J K^{-1} mol^{-1}, S^0 (Sn(s))= 52.0 J K^{-1} mol^{-1},

S^0 (C (s)) = 6.0 J K^{-1} mol^{-1}, S^0 ($CO_2(g)$)= 210.0 J K^{-1} mol^{-1},

Assume that the enthalpies and the entropies are temperature independent.

(2020, Paper 2)

Answer Key

1. (A, C) **2.** (A, B, D) **3.** (3) **4.** (A, B, C) **5.** (B, C, D) **6.** (A)→(P, Q, S); (B)→(T); (C)→(Q, R); (D)→(R) **7.** (B, C, D) **8.** (6.47 KG) **9.** (B) **10.** (A, B, C, D) **11.** (935)

Chapter 7 Qualitative Salt Analysis

1. The ammonia prepared by treating ammonium sulphate with calcium hydroxide is completely used by $NiCl_2 \cdot 6H_2O$ to form a stable coordination compound. Assume that both the reactions are 100% complete. If 1584 g of ammonium sulphate and 952 g of $NiCl_2 \cdot 6H_2O$ are used in the preparation, the combined weight (in grams) of gypsum and the nickel-ammonia coordination compound thus produced is _____.

(Atomic weights in g mol^{-1}: H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Ca = 40, Ni = 59)

(2018, Paper 1)

2. Among PbS, CuS, HgS, MnS, Ag_2S, NiS, CoS, Bi_2S_3 and SnS_2, the total number of BLACK coloured sulphides is _____.

(2014, Paper 1)

3. The pair(s) of ions where BOTH the ions are precipitated upon passing H_2S gas in presence of dilute HCl, is(are) _____.

(A) Ba^{2+}, Zn^{2+} **(B)** Bi^{3+}, Fe^{3+}
(C) Cu^{2+}, Pb^{2+} **(D)** Hg^{2+}, Bi^{3+}

(2015, Paper 2)

4. The reagent(s) that can selectively precipitate S^{2-} from a mixture of S^{2-} and SO_4^{2-} in aqueous solution is(are) _____.

(A) $CuCl_2$ **(B)** $BaCl_2$
(C) $Pb(OOCCH_3)_2$ **(D)** $Na_2[Fe(CN)_5NO]$

(2016, Paper 1)

5. In the following reaction sequence in aqueous solution, the species X, Y and Z, respectively, are _____.

$$S_2O_3^{2-} \xrightarrow{Ag^+} \underset{\text{clear solution}}{X} \xrightarrow{Ag^+} \underset{\text{white precipitate}}{Y} \xrightarrow{\text{with time}} \underset{\text{black precipitate}}{Z}$$

(A) $[Ag(S_2O_3)_2]^{3-}$, $Ag_2S_2O_3$, Ag_2S
(B) $[Ag(S_2O_3)_3]^{5-}$, Ag_2SO_3, Ag_2S
(C) $[Ag(SO_3)_2]^{3-}$, $Ag_2S_2O_3$, Ag
(D) $[Ag(SO_3)_3]^{3-}$, Ag_2SO_4, Ag **(2016, Paper 2)**

PARAGRAPH 1

Upon heating $KClO_3$ in the presence of catalytic amount of MnO_2, a gas W is formed. Excess amount of **W** reacts with white phosphorus to give **X**. The reaction of **X** with HNO_3 gives **Y** and **Z**.

6. **W** and **X** are, respectively

(A) O_3 and P_4O_6 **(B)** O_2 and P_4O_6
(C) O_2 and P_4O_{10} **(D)** O_3 and P_4O_{10}

Y and **Z** are, respectively

(A) N_2O_3 and H_3PO_4 **(B)** N_2O_5 and HPO_3
(C) N_2O_4 and HPO_3 **(D)** N_2O_4 and H_3PO_3

(2017, Paper 2)

7. The correct option(s) to distinguish nitrate salts of Mn^{2+} and Cu^{2+} taken separately is (are) _____.

(A) Mn^{2+} shows the characteristic green colour in the flame test.
(B) Only Cu^{2+} shows the formation of precipitate by passing H_2S in acidic medium.
(C) Only Mn^{2+} shows the formation of precipitate by passing H_2S in faintly basic medium.
(D) Cu^{2+}/Cu has higher reduction potential than Mn^{2+}/Mn (measured under similar conditions).

(2018, Paper 2)

8. The green colour produced in the borax bead test of a chromium(III) salt is due to

(A) CrB **(B)** Cr_2O_3
(C) $Cr_2(B_4O_7)_3$ **(D)** $Cr(BO_2)_3$

(2019, Paper 1)

9. A colorless aqueous solution contains nitrates of two metals, **X** and **Y**. When it was added to an aqueous solution of NaCl, a white precipitate was formed. This precipitate was found to be partly soluble in hot water to give a residue **P** and a solution **Q**. The residue **P** was soluble in aqueous NH_3 and also in excess sodium thiosulfate. The hot solution **Q** gave a yellow precipitate with KI. The metals **X** and **Y**, respectively are _____.

(A) Ag and Pb
(B) Ag and Cd
(C) Cd and Pb
(D) Cd and Zn

(2020, Paper 1)

10. An acidified solution of 0.05 M Zn^{2+} is saturated with 0.1 M H_2S. What is the minimum molar concentration (M) of H^+ required to prevent the precipitation of ZnS?

Use K_{sp} (ZnS) = 1.25×10^{-22} and overall dissociation constant of H,S. $K_{NET} = K_1K_2 = 1 \times 10^{-21}$

(2020, Paper 2)

Answer Key

1. (2992) **2.** (6) **3.** (C, D) **4.** (A) **5.** (A) **6.** (C, B) **7.** (B, D) **8.** (D) **9.** (A) **10.** (0.20)

Chapter 8 Hydrogen and the Hydrides

1. Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a

(A) reducing agent, oxidising agent
(B) reducing agent, reducing agent
(C) oxidising agent, oxidising agent
(D) oxidising agent, reducing agent

(2014, Paper 2)

Answer Key

1. (A)

Chapter 10 The p-Block Elements and their Compounds

1. With reference to *aqua regia,* choose the correct option(s)

(A) The yellow colour of *aqua regia* is due to the presence of NOCl and Cl_2.
(B) *Aqua regia* is prepared by mixing conc. HCl and conc. HNO_3 in 3 : 1 (*v/v*) ratio.
(C) Reaction of gold with *aqua regia* produces an anion having Au in +3 oxidation state.
(D) Reaction of gold with *aqua regia* produces NO_2 in the absence of air. **(2019, Paper 2)**

2. Consider the following reactions (unbalanced)

$Zn + \text{hot conc. } H_2SO_4 \rightarrow G + R + X$

$Zn + \text{conc. } NaOH \rightarrow T + Q$

$G + H_2S + NH_4OH \rightarrow Z(\text{a precipitate}) + X + Y$

Choose the correct option(s)

(A) The oxidation state of Zn in T is +1.
(B) R is a V-shaped molecule.
(C) Z is dirty white in colour.
(D) Bond order of Q is 1 in its ground state.

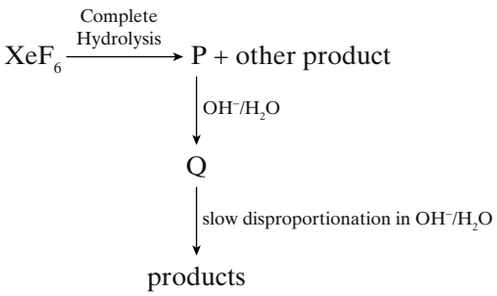
(2019, Paper 2)

3. The correct statement(s) for orthoboric acid is/are _____.

(A) It behaves as a weak acid in water due to self ionization.
(B) Acidity of its aqueous solution increases upon addition of ethylene glycol.
(C) It has a three dimensional structure due to hydrogen bonding.
(D) It is a weak electrolyte in water.

(2014, Paper 1)

4. Under ambient conditions, the total number of gases released as products in the final step of the reaction scheme shown below is _____.



(A) 0 **(B)** 1
(C) 2 **(D)** 3

(2014, Paper 2)

5. The product formed in the reaction of $SOCl_2$ with white phosphorous is _____.

(A) PCl_3 **(B)** SO_2Cl_2
(C) SCl_2 **(D)** $POCl_3$

(2014, Paper 2)

6. Three moles of B_2H_6 are completely reacted with methanol. The number of moles of boron containing product formed is _____.

(2015, Paper 2)

7. The correct statement(s) regarding, (i) HClO, (ii) $HClO_2$, (iii) $HClO_3$ and (iv) $HClO_4$, is (are)

(A) The number of Cl = O bonds in (ii) and (iii) together is two.
(B) The number of lone pairs of electrons on Cl in (ii) and (iii) together is three.
(C) The hybridization of Cl in (iv) is sp^3.
(D) Amongst (i) to (iv), the strongest acid is (i).

(2015, Paper 2)

8. The increasing order of atomic radii of the following Group 13 elements is _____.

(A) Al < Ga < In < Tl
(B) Ga < Al < In < Tl
(C) Al < In < Ga< Tl
(D) Al < Ga < Tl < In

(2016, Paper 1)

9. The crystalline form of borax has

(A) tetranuclear $[B_4O_5(OH)_4]^{2-}$ unit.
(B) all boron atoms in the same plane.
(C) equal number of sp^2 and sp^3 hybridized boron atoms.
(D) one terminal hydroxide per boron atom.

(2016, Paper 1)

10. The nitrogen containing compound produced in the reaction of HNO_3 with P_4O_{10}

(A) can also be prepared by reaction of P_4 and HNO_3.
(B) is diamagnetic.
(C) contains one N–N bond.
(D) reacts with Na metal producing a brown gas.

(2016, Paper 2)

11. The correct statement(s) about the oxoacids, $HClO_4$ and HClO, is(are) _____.

(A) $HClO_4$ is more acidic than HClO because of the resonance stabilization of its anion.
(B) $HClO_4$ is formed in the reaction between Cl_2 and H_2O.
(C) The central atom in both $HClO_4$ and HClO is sp^3 hybridized.
(D) The conjugate base of $HClO_4$ is weaker base than H_2O.

(2017, Paper 1)

12. The colour of the X_2 molecules of group 17 elements changes gradually from yellow to violet down the group. This is due to

(A) the physical state of X_2 at atom temperature changes from gas to solid down the group.
(B) decrease in HOMO-LUMO gap down the group.
(C) decrease in π^*-σ^* gap down the group.
(D) decrease in ionization energy down the group.

(2017, Paper 1)

13. The order of the oxidation state of the phosphorus atom in H_3PO_2, H_3PO_4, H_3PO_3, and $H_4P_2O_6$ is _____.

(A) $H_3PO_3 > H_3PO_2 > H_3PO_4 > H_4P_2O_6$
(B) $H_3PO_4 > H_3PO_2 > H_3PO_3 > H_4P_2O_6$
(C) $H_3PO_4 > H_4P_2O_6 > H_3PO_3 > H_3PO_2$
(D) $H_3PO_2 > H_3PO_3 > H_4P_2O_6 > H_3PO_4$

(2017, Paper 2)

14. Among the following, the correct statement(s) is(are) _____.

(A) $Al(CH_3)_3$ has the three-centre two-electron bonds in its dimeric structure.
(B) BH_3 has the three-centre two-electron bonds in its dimeric structure.

(C) $AlCl_3$ has the three-centre two-electron bonds in its dimeric structure.
(D) The Lewis acidity of BCl_3 is greater than that of $AlCl_3$.

(2017, Paper 2)

15. The option(s) with only amphoteric oxides is(are) _____.
(A) Cr_2O_3, BeO, SnO, SnO_2
(B) Cr_2O_3, CrO, SnO, PbO
(C) NO, B_2O_3, PbO, SnO_2
(D) ZnO, Al_2O_3, PbO, PbO_2

(2017, Paper 2)

16. The compound(s) which generate(s) N_2 gas upon thermal decomposition below 300°C is (are) _____.
(A) NH_4NO_3 **(B)** $(NH_4)_2Cr_2O_7$
(C) $Ba(N_3)_2$ **(D)** Mg_3N_2

(2018, Paper 1)

17. Based on the compounds of group 15 elements, the correct statement(s) is (are) _____.
(A) Bi_2O_5, is more basic than N_2O_5.
(B) NF_3 is more covalent than BiF_3.
(C) PH_3 boils at lower temperature than NH_3.
(D) The N–N single bond is stronger than the P–P single bond. **(2018, Paper 1)**

18. The total number of compounds having at least one bridging oxo group among the molecules given below is _____.

N_2O_3, N_2O_5, P_4O_6, P_4O_7, H_4O_5, $H_5P_3O_{10}$, $H_2S_2O_3$, $H_2S_2O_s$

(2018, Paper 2)

19. Fusion of MnO_2 with KOH in presence of O_2 produces a salt W. Alkaline solution of W upon electrolytic oxidation yields another salt X. The manganese containing ions present in W and X, respectively, are Y and Z, Correct statement(s) is(are)
(A) In aqueous acidic solution, Y undergoes disproportionation reaction to give Z and MnO_2.
(B) In both Y and Z, π-bonding occurs between p-orbitals of oxygen and d-orbitals of manganese.
(C) Y is diamagnetic in nature while Z is paramagnetic.
(D) Both Y and Z are coloured and have tetrahedral shape. **(2019, Paper 1)**

20. A tin chloride Q undergoes the following reactions (not balanced)

$Q + Cl^- \rightarrow X$

$Q + Me_3N \rightarrow Y$

$Q + CuCl_2 \rightarrow Z + CuCl$

X is a monoanion having pyramidal geometry. Both Y and Z are neutral compounds. Choose the correct option(s)
(A) The central atom in Z has one lone pair of electrons.
(B) The central atom in X is sp^3 hybridized.
(C) There is a coordinate bond in Y.
(D) The oxidation state of the central atom in Z is +2.

(2019, Paper 1)

21. In the decay sequence,

$$^{238}_{92}U \xrightarrow{-x_1} {}^{234}_{90}Th \xrightarrow{-x_2} {}^{234}_{91}Pa \xrightarrow{-x_3} {}^{234}Z \xrightarrow{-x_4} {}^{230}_{90}Th$$

x_1, x_2, x_3 and x_4 are particles /radiation emitted by the respective isotopes. The correct option(s) is(are)
(A) x_3 is y-ray
(B) Z is an isotope of uranium
(C) x_2 is β^-
(D) x_1 will deflect towards negatively charged plate

(2019, Paper 1)

22. Which of the following liberates O_2 upon hydrolysis?
(A) Pb_3O_4 **(B)** KO_2
(C) Na_2O_2 **(D)** Li_2O_2

(2020, Paper 1)

23. With respect to hypochlorite, chlorate and perchlorate ions, choose correct statement(s).
(A) The hypochlorite ion is strongest conjugate base.
(B) The molecular shape of only chlorate ion is influenced by the lone pair of electrons of Cl.
(C) The hypochlorite and chlorate ions disproportionate to give rise to identical set of ions.
(D) The hypochlorite ion oxidizes the sulfite ion.

(2020, Paper 1)

24. $^{238}_{92}U$ is known to undergo radioactive decay to form $^{206}_{82}Pb$ by emitting alpha and beta particles. A rock initially contained 68×10^{-6} g of $^{238}_{92}U$. If the number of alpha particles that it would emit during its radioactive decay of $^{238}_{92}U$ to $^{206}_{82}Pb$ in three half-lives is $Z \times 10^{18}$, then what is the value of Z?

(2020, Paper 1)

25. An acidified solution of potassium chromate was layered with an equal volume of amyl alcohol. When it was shaken after the addition of 1 mL of 3% H_2O_2, a blue alcohol layer was obtained. The blue color is due to the formation of a chromium (VI) compound '**X**'. What is the number of oxygen atoms bonded to chromium through only single bonds in a molecule of **X**?

(2020, Paper 2)

Answer Key

1. (A, C) **2.** (B, C, D) **3.** (B, D) **4.** (C) **5.** (A)
6. (6) **7.** (B, C) **8.** (B) **9.** (A, C, D) **10.** (B, D)
11. (A, C, D) **12.** (B, C) **13.** (C) **14.** (A, B, D)
15. (A, D) **16.** (B, C) **17.** (A, B, C) **18.** (6)
19. (A, B, D) **20.** (B, C) **21.** (B, C, D) **22.** (B)
23. (A, B, D) **24.** (1.20) **25.** (4)

Chapter 11 The d-Block Elements and Some of Their Compounds

1. The amount of water produced (in g) in the oxidation of 1 mole of rhombic sulphur by cone. HNO_3 to a compound with the highest oxidation state of sulphur is _____.

(Given data = Molar mass of water = 18 g mol^{-1})

(2019, Paper 2)

2. For the electrochemical cell,

$Mg(s) \mid Mg^{2+}(aq, 1\ M) \parallel Cu^{2+}(aq, 1\ M) \mid Cu(s)$

the standard emf of the cell is 2.70 V at 300 K. When the concentration of Mg^{2+} is changed to x M, the cell potential changes to 2.67 V at 300 K. The value of x is_____.

(given, $\frac{F}{R} = 11500\ K\ V^{-1}$, where F is the Faraday constant and R is the gas constant, ln(10) = 2.30)

(2018, Paper 1)

3. Which of the following combination will produce H_2 gas?

(A) Fe metal and conc. HNO_3
(B) Cu metal and conc. HNO_3
(C) Zn metal and NaOH(aq)
(D) Au metal and NaCN (aq) in the presence of air

(2017, Paper 2)

4. The correct statement(s) about Cr^{2+} and Mn^{3+} is(are)

[Atomic numbers of Cr = 24 and Mn = 25]

(A) Cr^{2+} is a reducing agent
(B) Mn^{3+} is an oxidizing agent
(C) Both Cr^{2+} and Mn^{3+} exhibit d^4 electronic configuration
(D) When Cr^{2+} is used as a reducing agent, the chromium ion attains d^5 electronic configuration

(2015, Paper 1)

5. For the following electrochemical cell at 298 K,

$Pt(s) \mid H_2(g, 1\ bar) \mid H^+(aq, 1\ M) \parallel M^{4+}(aq), M^{2+}(aq) \mid Pt(s)$

$$E_{cell} = 0.092\ V \text{ when } \frac{[M^{2+}(aq)]}{[M^{4+}(aq)]} = 10^x$$

Give: $E^0_{M^{4+}/M^{2+}} = 0.151\ V; 2.303\frac{RT}{F} = 0.059\ V$

The value of x is _____.

(A) –2 **(B)** –1
(C) 1 **(D)** 2

(2016, Paper 2)

6. Fe^{3+} is reduced to Fe^{2+} by using

(A) H_2O_2 in presence of NaOH
(B) Na_2O_2 in water
(C) H_2O_2 in presence of H_2SO_4
(D) Na_2O_2 in presence of H_2SO_4

(2015, Paper 1)

7. For the following cell,

$Zn(s) \mid ZnSO_4(aq) \parallel CuSO_4(aq) \mid Cu(s)$

When the concentration of Zn^{2+} is 10 times the concentration of Cu^{2+}, the expression for ΔG (in J mol^{-1}) is [F is Faraday constant; R is gas constant; T is temperature; $E^0(cell)$ = 1.1 V]

(A) 1.1 F **(B)** 2.303 RT–2.2 F
(C) 2.303 RT + 1.1 F **(D)** –2.2 F

(2017, Paper 2)

8. To measure the quantity of $MnCl_2$ dissolved in an aqueous solution, it was completely converted to $KMnO_4$ using the reaction, $MnCl_2 + K_2S_2O_8 + H_2O \rightarrow KMnO_4 + H_2SO_4 + HCl$ (equation not balanced). Few drops of concentrated HCl were added to this solution and gently warmed. Further, oxalic acid (225 mg) was added in portions till the colour of the permanganate ion disappeared. The quantity of $MnCl_2$ (in mg) present in the initial solution is___.

(Atomic weights in g mol^{-1}: Mn = 55, Cl = 35.5)

(2018, Paper 2)

9. The surface of copper gets tarnished by the formation of copper oxide. N_2 gas was passed to prevent the oxide formation during heating of copper at 1250 K. However, the N_2 gas contains 1 mole % of water vapour as impurity. The water vapour oxidises copper as per the reaction given below:

$$2Cu(s) + H_2O(g) \rightarrow Cu_2O(s) + H_2(g)$$

p_{H_2} is the minimum partial pressure of H_2 (in bar) needed to prevent the oxidation at 1250 K. The value of $\ln(p_{H_2})$ is_____.

(Given: total pressure = 1 bar, R (universal gas constant) = 8 J K^{-1} mol^{-1}, ln(10) = 2.3. Cu(s) and $Cu_2O(s)$ are mutually immiscible.

At 1250 K: $2Cu(s) + ½O_2(g) \rightarrow Cu_2O(s); \Delta G^\theta = -78{,}000\ J\ mol^{-1}$

$H_2(g) + ½O_2(g) \rightarrow H_2O(g); \Delta G^\theta = -1{,}78{,}000\ J\ mol^{-1}$; G is the Gibbs energy)

(2018, Paper 2)

10. Consider an electrochemical cell: $A(s) \mid A^{n+}(aq, 2\ M) \parallel B^{2n+}(aq, 1\ M) \mid B(s)$. The value of ΔH^θ for the cell reaction is twice that of ΔG^θ at 300 K. If the emf of the cell is zero, the ΔS^θ (in J K^{-1} mol^{-1}) of the cell reaction per mole of B formed at 300 K is_____.

(Given: In(2) = 0.7, R (universal gas constant) = 8.3 J K^{-1} mol^{-1}. H, S and G are enthalpy, entropy and Gibbs energy, respectively.)

(2018, Paper 2)

11. Aluminium reacts with sulfuric acid to form aluminium sulfate and hydrogen. What is the volume of hydrogen gas in litre (L) produced at 300 K and 1.0 atm pressure, when 5.4 g of aluminium and 50.0 mL of 5.0 M sulfuric acid are combined for the reaction?

(Use molar mass of aluminium as 27.0 g mol^{-1}, R = 0.082 atm L $mol^{-1}K^{-1}$)

(2020, Paper 1)

12. In the chemical reaction between stoichiometric quantities of $KMnO_4$ and KI in weakly basic solution, what is the number of moles of I_2 released for 4 moles of $KMnO_4$ consumed?

(2020, Paper 2)

Answer Key

1. (288) **2.** (10) **3.** (C) **4.** (A, B, C) **5.** (D)
6. (A, B) **7.** (B) **8.** (126) **9.** (–14.6)
10. (–11.62 J mol^{-1} K^{-1}) **11.** (06.15) **12.** (6)

Chapter 12 The f-Block Elements and Their Properties

1. The sum of the number of lone pairs of electrons on each central atom in the following species is $[TeBr_6]^{2-}$, $[BrF_2]^+$, SNF_3, and $[XeF_3]^-$

(Atomic numbers: N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54)

(2017, Paper 1)

Answer Key

1. (6)

ANSWERS WITH EXPLANATION

Chapter 3 Chemical Bonding

1. **Statement A:** In a cubic close-packed (ccp) or face-centered cubic (fcc) structure, each atom has **12 nearest neighbors** in the bulk structure. However, in the *topmost layer*, the number of nearest neighbors may differ depending on the specific stacking arrangement.

   This statement may not be strictly correct for the topmost layer.

   Statement B: The **packing efficiency of ccp (fcc) structure is 74%**, which is a well-known fact.

   This statement is correct.

   Statement C: In a ccp structure, the **number of octahedral voids per atom is 1**, and the **number of tetrahedral voids per atom is 2**.

   This statement is correct.

   Statement D: In a face-centered cubic (fcc) unit cell, the relation between the edge length (a) and atomic radius (r) is:

   $$a = 2\sqrt{2}r$$

   This statement is correct.

   Hence (B), (C) and (D) are correct.

2. Statement A is correct since the salt bridge only facilitates ion movement and maintains electrical neutrality but does not take part in the redox reaction of the cell.

3. The molecular orbital configuration of C_2^{2-} (12 electrons) is:

   $$(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2$$

   Since all electrons are paired, C_2^{2-} **is diamagnetic.**

   Hence A is correct.

   The bond order formula is:

   $$\text{Bond Order} = \frac{(\text{Bonding eletrons} - \text{Antibonding electrons})}{2}.$$

   For O_2 (16 electrons):

   $$\text{BO} = \frac{10-6}{2} = 2$$

   For O_2^{2+} (14 electrons):

   $$\text{BO} = \frac{10-4}{2} = 3$$

   A **higher bond order means a shorter bond length**, so **O_2^{2+} has a shorter bond length than O_2**, not longer.

   Hence B is incorrect.

   For N_2 (14 electrons):

   $$\text{BO} = \frac{10-4}{2} = 3$$

   For N_2^+ (13 electrons):

   $$\text{BO} = \frac{9-4}{2} = 2.5$$

   For N_2^- (15 electrons):

   $$\text{BO} = \frac{10-5}{2} = 2.5$$

   N^+ and N^- have the same bond order.

   Hence C is correct.

   For He_2^+ (3 electrons):

   $$\text{BO} = \frac{2-1}{2} = 0.5$$

   Since the bond order is nonzero, He_2^+ is **weakly bound** and does not have the same energy as two isolated He atoms.

   Hence D is incorrect.

   Hence A and C are right options.

4. **H_2 (2 electrons)**
   - Configuration $(\sigma_{1s})^2$
   - **All electrons paired → Diamagnetic**

   He_2^+ (3 electrons)
   - Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^1$
   - **One unpaired electron → Paramagnetic**

   Li_2 (6 electrons)
   - Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2$
   - **All electrons paired → Diamagnetic**

   Be_2 (8 electrons)
   - Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2$
   - **All electrons paired → Diamagnetic**

   B_2 (10 electrons)
   - Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^2$
   - **Two unpaired electrons in π orbitals → Paramagnetic**

   C_2 (12 electrons)
   - Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4$
   - **All electrons paired → Diamagnetic**

   N_2 (14 electrons)
   - Configuration: $(\sigma_{1s})2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2$
   - **All electrons paired → Diamagnetic**

O^{2-} (17 electrons)

- Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2(\pi^*_{2p})^3$
- **One unpaired electron → Paramagnetic**

F_2 (18 electrons)

- Configuration: $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2(\pi^*_{2p})^4$
- **All electrons paired → Diamagnetic**

The **diamagnetic** species are:

- **H_2**
- **Li_2**
- **Be_2**
- **C_2**
- **N_2**
- **F_2**

Total number of diamagnetic species = 6.

5. A is correct.

Adsorption is an **exothermic** process because when molecules adhere to a surface, energy is released.

ΔH (enthalpy) is negative (decreases).

- When gas molecules get adsorbed on a surface, they become more **ordered,** reducing randomness.

ΔS (entropy) is negative (decreases).

B is correct.

- **Critical temperature (Tc)** is the temperature above which a gas cannot be liquefied by pressure.
- Gases with **higher Tc** (ethane, 563 K) have stronger intermolecular forces and are more easily absorbed than gases with **lower Tc** (nitrogen, 126 K).
- Since ethane has a much **higher critical temperature,** it is more **adsorbable** than nitrogen on activated charcoal.

C is incorrect.

- **Cloud** is actually an **aerosol,** not an emulsion.
- In a cloud, **water droplets (liquid) are dispersed in air (gas),** which is an **aerosol** (not an emulsion).

D is correct.

- **Brownian motion** is the random movement of colloidal particles due to collisions with solvent molecules.
- The motion **depends on both:**
  - **Size of the particles** (smaller particles show more Brownian motion).
  - **Viscosity of the solution** (higher viscosity reduces Brownian motion).

Since Brownian motion **does depend on particle size,** this statement is **incorrect.**

6. **K_2CrO_4 (Potassium chromate)**

- Cr^{6+} (d^0) → **All electrons paired**

Only K_2CrO_4 is diamagnetic, hence the answer is 1.

Chapter 5 Coordination Compounds

1. **(A)** Incorrect: The total number of valence electrons is 18, not 16.

(B) Correct: Both complexes are low spin (diamagnetic).

(C) Correct: The M-C bond strengthens as the oxidation state is lowered.

(D) Incorrect: The C-O bond strengthens (not weakens) when the oxidation state is increased.

2. **(A) The hybridization of the central metal ion in Y is d_2sp_3.**

Correct: Y is $[Co(NH_3)_6]^{3+}$ (Co^{3+}, d^6, low spin, octahedral). Uses two 3d, one 4s, three 4p orbitals: d^2sp^3 hybridization.

(B) Z is a tetrahedral complex.

Correct: Z is $[CoCl_4]^{2-}$ (Co^{2+}, d^7). Four Cl^- ligands form a tetrahedral geometry, typical for Co(II) with Cl^-, and it's blue.

(C) Addition of silver nitrate to Y gives only two equivalents of silver chloride.

Incorrect: Y is $[Co(NH_3)_6]Cl_3$, with 3 Cl^- ions. $AgNO_3$ precipitates 3 equivalents of AgCl, not 2.

(D) When X and Z are in equilibrium at 0ºC, the colour of the solution is pink.

Correct: Equilibrium: $[Co(H_2O)_6]^{2+}$ (pink) ⇌ $[CoCl_4]^{2-}$ (blue) + $6H_2O$. At 0ºC, the exothermic direction

($[Co(H_2O)_6]^{2+}$) is favored, so the solution is pink.

Hence (A), (B) and (D).

3.1 **(A)** Zn^{2+}, KCN, HCl

Incorrect: Zn^{2+} (d^{10}) forms $[Zn(CN)_4]^{2-}$ (tetrahedral) with KCN (Q), but $[ZnCl_4]^{2-}$ (tetrahedral) with HCl (R), not square planar as required.

(B) Ni^{2+}, HCl, KCN

Correct: Ni^{2+} (d^8) forms $[NiCl_4]^{2-}$ (tetrahedral, high spin) with HCl (Q) and $[Ni(CN)_4]^{2-}$ (square planer, low spin) with KCN (R). M2 (e.g., Zn^{2+}) forms tetrahedral complexes with both.

(C) Cd^{2+}, KCN, HCl

Incorrect: Cd^{2+} (d^{10}) forms $[Cd(CN)_4]^{2-}$ (tetrahedral) with KCN (Q), but $[CdCl_4]^{2-}$ (tetrahedral) with HCl (R), not square planar.

(D) Co^{2+}, HCl, KCN

Incorrect: Co^{2+} (d^7) forms $[CoCl_4]^{2-}$ (tetrahedral) with HCl (Q), but $[Co(CN)_4]^{2-}$ is likely tetrahedral (not square planar) with KCN (R).

Answer: (B) Ni^{2+}, HCl, KCN.

S forms a white precipitate with M2 (likely Zn^{2+}, d^{10}, tetrahedral with Q and R) that dissolves in excess S.

3.2 **(A)** $K_4[Fe(CN)_6]$

Incorrect: Forms $Zn_2[Fe(CN)_6]$ (white precipitate) with Zn^{2+}, but it doesn't dissolve in excess $K_4[Fe(CN)_6]$.

(B) Na_2HPO_4

Incorrect: Forms $ZnHPO_4$ (white precipitate), which may dissolve in excess due to complexation, but this is less standard than KOH's behavior.

(C) K_2CO_3

Incorrect: Forms $ZnCO_3$ (white precipitate), but it doesn't dissolve in excess K_2CO_3 (forms insoluble basic carbonates).

(D) KOH

Correct: Forms $Zn(OH)_2$ (white precipitate) with Zn^{2+}, which dissolve in excess KOH to form$[Zn(OH)_4]^{2-}$, matching the problem.

Answer: (D) KOH.

4. Correct sequence is P: 3, Q: 1, R: 4, S: 2.

5. **Calculate Vant Hoff Factor**

Freezing point depression: $\Delta T_f = i.K_f \cdot m$

Given: ΔT_f = 0.0558ºC, K_f = 1.86K kg mol^{-1}, $m = 0.01$mol/kg.

$0.0558 = i \cdot 1.86 \cdot 0.01 \Rightarrow i = \dfrac{0.0558}{0.0186} = 3$

$i = 3$, so the complex dissociates into 3 ions.

Co (III) complex (octahedral, charge +3). General formula: $[Co(NH_3)_n\ Cl_{6-n}]Cl_{n-3}$.

For $i = 3$: $[Co(NH_3)_5Cl]Cl_2 \rightarrow [Co(NH_3)_5Cl]^{2+} + 2Cl^-$ (3 ions).

Coordination sphere: $[Co(NH_3)_5Cl]$, with 1 Cl^-.

Number of chlorides in the coordination sphere: 1.

6. Fe^{3+} **(d^5)** can be **high-spin** or **low-spin** depending on the ligand:

- **SCN^- (weak field) → high-spin → 5 unpaired electrons**
- **CN^- (strong field) → low-spin → 1 unpaired electron**

Using the spin-only formula:

$\mu_s = \sqrt{n(n+2)}$

- **High-spin Fe^{3+}:** $\sqrt{5(5+2)} = 5.92$ BM
- **Low-spin Fe^{3+}:** $\sqrt{1(1+2)} = 1.73$ BM
- **Difference:** $5.92 - 1.73 = 4.19 \approx 4$ BM

Answer is 4.

7. The oxidation of **diaquodioxalatoferate(II)** by **MnO_4^-** in acidic medium follows this balanced reaction:

$$2[Fe(C_2O_4)_2(H_2O)_2]^{2-} + MnO_4^- \rightarrow 8H^+ \rightarrow 2[Fe(C_2O_4)_3]^{3-} Mn^{2+} + 4H_2O$$

From the reaction, **8 H^+ ions** are consumed for every **1MnO_4^-** ion reduced.

Thus, the **ratio of the rate of change of $[H^+]$ to the rate of change of $[MnO_4^-]$ is:**

$$\frac{\text{Rate of chnage of } [H^+]}{\text{Rate of change of } [MnO_4^-]} = 8$$

8. The Fe-C bonds come from:

- 1 from the acetyl ligand.
- 2 from the dicarbonyl ligands.

In total, there are **3** Fe-C bonds in the complex.

9. 1. **$[Co(en)_2Cl_2]^+$ → Yes** (Octahedral, two Cl^- ligands can be cis or trans).
2. **$[CrCl_2(C_2O_4)_2]^{3-}$ → Yes** (Octahedral, two Cl^- ligands can be cis or trans).
3. **$[Fe(H_2O)_4(OH)_2]^+$ → Yes** (Octahedral, two OH^- ligands can be cis or trans).
4. **$[Fe(CN)_4(NH_3)_2]^-$ → Yes** (Octahedral, two NH_3 ligands can be cis or trans).
5. **$[Co(en)_2(NH_3)Cl]^{2+}$ → Yes** (Octahedral, NH_3 and Cl^- ligands can be cis or trans).
6. **$[Co(NH_3)_4(H_2O)Cl]^{2+}$ → No** (It can show other types of geometrical isomerism, but not true cis-trans).

The total number of complex that show **cis-trans isomerism** is **5**.

10. 1. **$[Ni(CO)_4]$ (Tetrahedral, Ni^0)**
- Ni (Z = 28) → **$3d^8$ $4s^2$**
- CO is a strong field ligand → Causes pairing → **Diamagnetic**

2. **$[NiCl_4]^{2-}$ (Tetrahedral, Ni^{2+})**
- Ni^{2+}→ **$3d^8$**
- Cl^- is a weak field ligand → No pairing → **Paramagnetic (2 unpaired electrons)**

3. **$[Co(NH_3)_4Cl_2]Cl$ (Octahedral, Co^{3+})**
- Co^{3+} → **$3d^6$**
- NH_3 is a strong field ligand → Low spin → **Diamagnetic**

4. **$Na_3[CoF_6]$ (Octahedral, Co^{3+})**
- Co^{3+} → **$3d^6$**
- F^- is a weak field ligand → High spin → **Paramagnetic (4 unpaired electrons)**

5. **Na_2O_2 (Sodium Peroxide, O_2^{2-} species**
- **O_2^{2-} has all paired electrons**, meaning it is → **Diamagnetic**

6. **CsO_2 (Cesium Superoxide, O_2^{2-} species)**
O_2^{2-} has unpaired electrons → **Paramagnetic**

11. The complex $[CoL_2Cl_2]^-$ adopts an octahedral geometry, where the bidentate ligand *L* ($H_2NCH_2CH_2O^-$) can coordinate through both $-NH_2$ and $-O^-$ groups. Geometric isomers arise due to different spatial arrangements of these ligands. The two chloride (Cl^-) ligands can be either **cis** or **trans,** and the asymmetric nature of *L* allows for multiple distinct orientations. Considering all valid ligand arrangements, a total of **five geometric isomers** are possible.

12.
- Ni^{2+} (d^8): Typically octahedral with ammonia (e.g., $[Ni(NH_3)_6]^{2+}$).
- Pt^{2+} (d^8): Prefers square planar due to strong field ligands (e.g., $[Pt(NH_3)_4]^{2+}$).
- Zn^{2+}(d^{10}): Tetrahedral with ammonia (e.g., $[Zn(NH_3)_4]^{2+}$).

13. The given complex is $[Co(en)(NH_3)_3(H_2O)]^{3+}$, where:
- Co^{3+} has a d^6 configuration.
- en (ethylenediamine) is a bidentate ligand.
- NH_3 and H_2O are monodentate ligands.

(A) It has two geometrical isomers.
- The coordination number of Co^{3+} is 6, making it an octahedral complex.
- Since en is a bidentate ligand, it occupies two coordination sites.
- The H_2O ligand and NH_3 ligands can be arranged cis or trans to each other, leading to two geometrical isomers.
- Correct.

(B) It will have three geometrical isomers if bidentate 'en' is replaced by two cyanide ligands.
- If en is replaced by two CN^- ligands, both will act as monodentate ligands.
- This changes the complex to $[Co(CN)_2(NH_3)_3(H_2O)]^+$.
- With two CN^- ligands and one H_2O ligand, different possible arrangements in the octahedral geometry give rise to three geometrical isomers.
- Correct.

(C) It is paramagnetic.
- Co^{3+} (d^6) in an octahedral field can be either low spin (strong field ligands) or high spin (weak field ligands).
- en and NH_3 are moderate to strong field ligands, favoring a low-spin configuration.
- In a low-spin d^6 system, all electrons pair up in the t_2g orbitals (t_2g^6 eg^0), making it diamagnetic.
- Incorrect.

(D) It absorbs light at a longer wavelength as compared to $[Co(en)(NH_3)_4]^{3+}$.
- The ligand H_2O is a weaker ligand compared to NH_3.
- Weaker ligands create a smaller crystal field splitting (Δ_0), causing lower energy d–d transitions.
- Lower energy corresponds to longer wavelengths.
- Therefore, $[Co(en)(NH_3)_3(H_2O)]^{3+}$ absorbs light at a longer wavelength compared to $[Co(en)(NH_3)_4]^{3+}$.
- Correct.

14. dsp^2: Square planar (e.g., $[Ni(CN)_4]^{2-}$).

sp^3: Tetrahedral (e.g., $[FeCl_4]^{2-}$, $Ni(CO)_4$).

sp^3d^2: Octahedral, outer d (e.g., $[Ti(H_2O)_3Cl_3]$, $[Cr(NH_3)_6]^{3+}$

d^2sp^3: Octahedral, inner d (e.g., $[FeF_6]^{4-}$).

Correct: (C) **P** → 6, **Q** → 4,5, **R** → 1, **S** → 2,3.

15. Reaction at 143 K: $XeF_4 + O_2F_2 \rightarrow XeF_6 + O_2$. Y = XeF_6.

XeF_6: Xe (8 valence e^-), 6 F (6 bonds), 1 lone pair on Xe (distorted octahedral).

Total lone pairs on molecule (Xe + 6 F, each F has 3 lone pairs): $1 + 6 \times 3 = 19$.

16. **Determine the Geometry**
- Mn^{2+} has a coordination number of 6, so the complex adopts an octahedral geometry.
- The two bidentate en (ethylenediamine) ligands each occupy two coordination sites.
- The two Cl^- ligands are positioned cis to each other.

Identify the cis **N–Mn–Cl Bond Angles**
- We need to count the number of N–Mn–Cl bond angles where Mn–N and Mn–Cl bonds are in cis positions.

Bond Placement in an Octahedral Geometry:
- The four nitrogen atoms (from two en ligands) and the two chloride ligands occupy the six coordination sites around Mn^{2+}.
- Each Cl ligand is cis to two nitrogen atoms from different en ligands.

Counting the cis N–Mn–Cl Bond Angles:
- Since each Cl ligand is cis to two N atoms, and there are two Cl ligands, we get:

  $2 \times 2 = 4$ angles
- Additionally, each N from one en ligand is also cis to another N from the second en ligand, contributing 2 more angles.

Thus, the total number of cis N–Mn–Cl bond angles is 6.

17. (A) $[FeCl_4]^-$ has tetrahedral geometry.

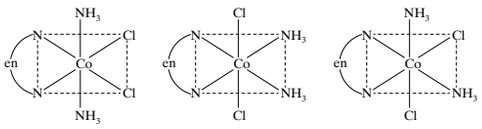
- Fe^{3+} in $[FeCl_4]^-$ is in a +3 oxidation state with a d^5 configuration. Since Cl^- is a weak field ligand, it favors a tetrahedral geometry. Correct Statement.

(B) $[FeCl_4]^-$ has higher spin and only magnetic moment than $[Co(en)(NH_3)_2(Cl_2]^+$.

- $[FeCl_4]^-$ is a high-spin tetrahedral complex, while $[Co(en)(NH_3)_2Cl_2]^+$ is a low-spin octahedral complex, leading to a higher spin and greater magnetic moment for the former. Correct Statement.

(C) $[Co(en)(NH_3)_2Cl_2]^+$ has 2 geometrical isomers.

- This complex has three geometrical isomers. Incorrect Statement.



(D) The cobalt ion in $[Co(en)(NH_3)_2Cl_2]^+$ has sp^3d^2 hybridization.

- Tetrahedral complexes exhibit sp^3 hybridization. Incorrect Statement.

18. (A) $H_2O(l)$: Diamagnetic, upwards deflection. **True.**

(B) $K_4[Fe(CN)_6]$: Fe^{2+} (d^6), strong field, diamagnetic, upward. **True.**

(C) $O_2(g)$: Paramagnetic (2 unpaired e^-), downward. **True.**

(D) $C_6H_6(l)$: Diamagnetic, upward. **False.**

Correct: (A), (B), (C).

Chapter 6 Metallurgy

1. (A) Empirical formula MX: The structure is likely a CsCl type. **True.**

(B) Different coordination geometries: In CsCl structure both M and X have octahedral coordination (6.6). **False.**

(C) M – X bond length to edge length ratio = 0.866: For CsCl,

$\sqrt{3}/2 = 0.866$

True.

(D) Ionic radii ratio = 0.414: For CsCl, the radius ratio for stability in a cubic structure is around 0.732, not 0.414 (which is for octahedral coordination).

False.

2. Reaction: $4Au + 8CN^- + O_2 + 2H_2O \rightarrow 4\,[Au(CN)_2]^- + 4OH^-$, then

$2\,[Au(CN)_2]^- + Zn \rightarrow [Zn(CN)_4]^{2-} + 2Au$.

(A) Z is $[Zn(CN)_4]^{2-}$: Correct, as Zn forms this complex during reduction.

(B) T is Zn: Correct, Zn is used to reduce $[Au(CN)_2]^-$.

(C) R is $[Au(CN)_4]^-$: Incorrect, R is $[Au(CN)_2]^-$ in the cyanide process.

(D) Q is O_2: Correct, oxygen is required for leaching.

3. NaCl unit cell: 4 M (corner + face centers), 4 X (edge centers + body center).

Step (i): Keep only central X (1 X), remove others (3 X remove).

Step (ii): Replace face – centered M (6 positions, 6/2 = 3M) with X. Now, 3 X added.

Step (iii): Remove corner M (8 positions, 8/8 = 1 M). Total M left = 4 – 3 (face) – 1 (corner) = 0.

Step (iv): Replace central X with M. Now, 1 M, X = 3(from step ii).

Ratio = 3/1 = 3.

4. (A) Froth flotation: Correct, used to concentrate the ore.

(B) Iron removal as slag: Correct, $FeO + SiO_2 \rightarrow FeSiO_3$ (slag).

(C) Self-reduction: Correct, $Cu_2S + O_2 \rightarrow Cu_2O + SO_2$, then $Cu_2S + Cu_2O \rightarrow Cu + SO_2$.

(D) Carbon reduction: Incorrect, blister copper is refined electrolytically, not by carbon.

5. (A) Impure Cu as cathode: Incorrect, impure Cu is the anode.

(B) Acidified $CuSO_4$: Correct, used as electrolyte.

(C) Pure Cu at cathode: Correct, Cu deposits at the cathode.

(D) Impurities as anode mud: Correct, impurities settle below the anode.

6. (A) Carbonate: Siderite ($FeCO_3$), Malachite ($CuCO_3 \cdot Cu(OH)_2$), Calamine ($ZnCO_3$).

(B) Sulphide: Argentite (Ag_2S).

(C) Hydroxide: Malachite (has OH^-), Bauxite ($Al(OH)_3$).

(D) Oxide: Bauxite (after processing to Al_2O_3).

7. (A) $CuFeS_2$: Needs processing, not direct. **False.**

(B) CuO: $Cu_2S + CuO \rightarrow Cu + SO_2$. **True.**

(C) Cu_2O: $Cu_2S + Cu_2O \rightarrow Cu + SO_2$. **True.**

(D) $CuSO_4$: Decomposes to CuO, then reacts. **True.**

8. Reaction: $2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$, then $PbS + 2PbO \rightarrow 3Pb + SO_2$.

Overall: $3PbS + 3O_2 \rightarrow 3Pb + 3SO_2$.

3 moles O_2 (96 g) produce 3 moles Pb (621 g).

Per 1 kg O_2: (621/96) × 1 = 6.47 kg.

9. Calamine: $ZnCO_3$.

Malachite: $CuCO_3 \cdot Cu(OH)_2$.

Magnetite: Fe_3O_4.

Cryolite: Na_3AlF_6.

10. (A) **Hydrated Al_2O_3 precipitation:** Correct, in Bayer's process.

(B) Na_3AlF_6 **lowers melting point:** Correct, in Hell-Héroult process.

(C) CO_2 **at anode:** Correct, from carbon anode reaction.

(D) **Cathode lining:** Correct, carbon-lined steel vessel.

11. $\mathbf{SnO_2\,(s) + C(s) \rightarrow Sn(s) + CO_2\,(g)}$

$\mathbf{\Delta H_r^0 = -394.0 + 581 = 187\ kJmol^{-1}}$

$\mathbf{\Delta S^0 = 210 + 52 - 6 - 56 = 200\ Jmol^{-1}K^{-1}}$

Equilibrium temperature $(T)_{eq} = \dfrac{187 \times 1000}{200} = 935K$

So, T > 935 K (for spontaneity)

Chapter 7 Qualitative Salt Analysis

1. Reaction 1: $(NH_4)_2\,SO_4 + Ca(OH)_2 \rightarrow CaSO_4 \cdot 2H_2O + 2NH_3$.

- Molar mass of $(NH_4)_2\,SO_4$ = 132 g/mol, 1584 g = 1584/132 = 12 mol.
- Produces 12 mol gypsum ($CaSO_4 \cdot 2H_2O$, molar mass = 172), mass = 12 × 172 = 2064 g.
- Produces 24 mol NH_3.

Reaction 2: $NiCl_2 \cdot 6H_2O + 6NH_3 \rightarrow [Ni(NH_3)_6]\,Cl_2 + 6H_2O$.

- Molar mass of $NiCl_2 \cdot 6H_2O$ = 238 g/mol, 952 g = 952/238 = 4 mol.
- Requires 4 × 6 = 24mol NH_3, which matches.
- Produces 4 mol $[Ni(NH_3)_6]\,Cl_2$, molar mass = 232, mass = 4 × 232 = 928 g.

Total mass = 2064 + 928 = 2992 g.

2. Black: PbS, CuS, HgS, Ag_2S, NiS, CoS.

Hence 6 is the answer.

3. In acidic medium (HCl), H_2S precipitates Group II cations (low K_{sp}): Hg^{2+}, Cu^{2+}, Pb^{2+}, Bi^{3+}.

(A) Ba^{2+}, Zn^{2+}: Ba^{2+} (Group V), Zn^{2+} (Group IV), neither precipitate. **False.**

(B) Bi^{3+}, Fe^{3+}: Bi^{3+} precipitates, but Fe^{3+} does not (Group III). **False.**

(C) Cu^{2+}, Pb^{2+}: Both are Group II, precipitate. **True.**

(D) Hg^{2+}, Bi^{3+}: Both are Group II, precipitate. **True.**

4. (A) $CuCl_2$: Forms CuS (low K_{sp}), does not react with SO_4^{2-}. **True.**

(B) $BaCl_2$: Forms $BaSO_4$, not selective. **False.**

(C) $Pb(OOCCH_3)_2$: Forms PbS and $PbSO_4$, not selective. **False.**

(D) $Na_2\,[Fe(CN)_5NO]$: Used for S^{2-} detection (violet color), but not for precipitation. **False.**

5. $Ag^+ + S_2O_3^{2-} \rightarrow [Ag(S_2O_3)_2]^{3-}$ (X).

$[Ag(S_2O_3)_2]^{3-} \xrightarrow{H_2O} Ag_2S_2O_3$ (Y).

$Ag_2S_2O_3 + H_2O \rightarrow Ag_2S + H_2SO_4$ (Z = Ag_2S).

Option (A) matches: X = $[Ag(S_2O_3)_2]^{3-}$, Y = $Ag_2S_2O_3$, Z = Ag_2S.

6. $KClO_3 \xrightarrow{MnO_2} KCl + O_2$ (W = O_2).

$P_4 + O_2 \rightarrow P_4O_{10}$ (X = P_4O_{10}, option C).

$P_4O_{10} + HNO_3 \rightarrow HPO_3 + N_2O_5$ (Y = N_2O_5, Z = HPO_3, option B).

7. (A) Mn^{2+} **green flame:** Incorrect, Mn^{2+} has no characteristic flame color.

(B) Cu^{2+} **with** H_2S: Cu^{2+} precipitates as CuS in acidic medium, Mn^{2+} does not. **True.**

(C) Mn^{2+} **with** H_2S: Mn^{2+} precipitates in basic medium, not faintly basic. **False.**

(D) **Reduction potential:** Cu^{2+}/Cu(+0.34 V) > Mn^{2+}/Mn(−1.18 V). **True.**

8. Borax bead test: Cr(III) forms a green bead due to $Cr(BO_2)_3$ (chromium metaborate). Option (D) is correct.

9. NaCl gives white precipitate: $AgNO_3 \rightarrow AgCl$, $Pb(NO_3)_2 \rightarrow PbCl_2$.

$PbCl_2$ soluble in hot water (Q), AgCl insoluble (P).

P (AgCl) soluble in NH_3 and sodium thiosulfate.

Q ($PbCl_2$) with KI → PbI_2 (yellow).

X = Ag, Y = Pb, option (A).

10. $ZnS(s) \Rightarrow Zn^{2+}(aq) + S^2(aq)$

$$[S^{2-}] = \frac{K_{sp}}{[Zn^{2+}]} = \frac{1.25 \times 10^{-22}}{0.05} = 10^{-22}$$

$H_2S \Rightarrow 2H^+ + S^{2-}$

$$10^{-21} = \frac{[H^+]^2 \times 25 \times 10^{-22}}{0.1}$$

$$[H^+]^2 = \frac{10^{-22} \times 10^{22}}{25} = \frac{1}{25}$$

$$[H^+] = \frac{1}{5} = 0.20M$$

Chapter 8 Hydrogen and the Hydrides

1. **Reaction with** KIO_4**:** In this reaction, H_2O_2 reduces KIO_4 to a lower oxidation state.

   Therefore, H_2O_2 itself gets oxidized and acts as a reducing agent.

   Reaction with NH_2OH**:** In this reaction, H_2O_2 oxidizes NH_2OH. Therefore, H_2O_2 itself gets reduced and acts as an oxidizing agent.

Chapter 10 The p-Block Elements and their Compounds

1. **(A) Yellow color due to** NOCl **and** Cl_2: Aqua regia ($HCl + HNO_3$) produces NOCl and Cl_2, giving a yellow color. **True**.

   (C) Gold forms Au^{3+} **anion:** Au + aqua regia → $[AuCl_4]^-$, where Au is +3. **True**.

2. Zn + hot conc. $H_2SO_4 \rightarrow ZnSO_4 + SO_2 + H_2O$ (G = $ZnSO_4$, R = SO_2, X = H_2O)

   Zn + conc. NaOH → $Na_2[Zn(OH)_4] + H_2$ (T = $[Zn(OH)_4]^{2-}$, Q = H_2)

   $ZnSO_4 + H_2S + NH_4OH \rightarrow ZnS + (NH_4)_2SO_4 + H_2O$ (Z = ZnS)

   (A) Zn **in T is + 1:** Zn in $[Zn(OH)_4]^{2-}$ is +2. **False**.

   (B) R (SO_2) is V-shaped: Correct, SO_2 is bent. **True**.

   (C) Z (ZnS) is dirty white: Correct, ZnS is white/dirty white. **True**.

   (D) Bond order of Q (H_2) is 1: Correct, H_2 has a single bond. **True**.

3. **(A) Self-ionization:** H_3BO_3 ionizes by accepting OH^- from water, not self-ionization. **False.**

   (B) Acidity increases with ethylene glycol: Forms a stable complex, increasing acidity. **True.**

   (C) 3D structure: H_3BO_3 has a 2D layered structure via H-bonding. **False.**

   (D) Weak electrolyte: Does not ionize significantly in water. **True.**

4. $XeF_6 + 3H_2O \longrightarrow XeO_3 + 3H_2F_2$

   $\downarrow OH^-$

   $HXeO_4^-$

   $\downarrow OH^- / H_2O$ (disproportionation)

   $XeO_6^{4-}{}_{(s)} + Xe_{(g)} + H_2O_{(\ell)} + O_{2(g)}$

   Xe and O_2 are the two gases.

5. $P_4 + 8SOCl_2 \rightarrow 4PCl_3 + 4SO_2 + 2S_2Cl_2$

   Product involving phosphorus is PCl_3.

6. $B_2H_6 + 6CH_3OH \rightarrow 2B(OCH_3)_3 + 6H_2$

   3 moles B_2H_6 produce 3 × 2 = 6 moles $B(OCH_3)_3$.

7. Structures: (i) HClO: 1 Cl = O, 2 lone pairs; (ii) $HClO_2$: 1 Cl = O, 1 lone pair; (iii) $HClO_3$: 2 Cl = O, 0 lone pairs; (iv) $HClO_4$: 3 Cl = O, 0 lone pairs.

   (A) Cl = O **in (ii) + (iii) = 3:** Incorrect, it's 1 + 2 = 3. **False**.

   (B) Lone pairs in (ii) + (iii) = 1 + 2 = 3: Correct. **True**.

   (C) Cl **in (iv) is** sp^3: $HClO_4$ has 4 sigma bonds, sp^3. **True**.

   (D) Strongest acid is (i): $HClO_4$ (iv) is the strongest due to highest oxidation state. **False**.

8. Trend: Al > Ga (due to d-block contraction in Ga), then increases down the group: Ga < Al < In < Tl.

9. Borax: $Na_2[B_4O_5(OH)_4] \cdot 8H_2O$

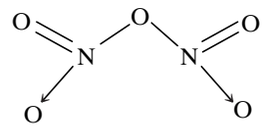
   (A) Tetranuclear unit: Correct, $[B_4O_5(OH)_4]^{2-}$. **True**.

   (B) Boron in same plane: Incorrect, 3D structure. **False**.

   (C) Equal sp^2 **and** sp^3 **boron**: 2 sp^2, 2 sp^3. **True**.

   (D) One terminal OH: Each boron has one OH. **True**.

10. $2HNO_3 \xrightarrow[\text{(dehydration, } -H_2O)]{P_4O_{10}} N_2O_5$

    $Na + N_2O_5 \longrightarrow NaNO_3 + NO_2 \uparrow$ (brown)

11. **(A)** $HClO_4$ **more acidic**: Resonance stabilizes ClO_4^-. **True**.

    (B) $Cl_2 + H_2O \rightarrow HClO_4$: Produces HClO, not $HClO_4$. **False**.

    (C) sp^3 **hybridization**: Both have 4 sigma bonds around Cl. **True**.

    (D) ClO_4^- **weaker base than** H_2O: ClO_4^- is a very weak base. **True**.

12. Color change (yellow to violet): Due to decreasing HOMO-LUMO gap ($\pi^* - \sigma^*$) down the group, absorbing lower energy light.

    (A) Physical state: Not the cause. **False.**

    (B) HOMO-LUMO gap: Correct. **True.**

    (C) $\pi^* - \sigma^*$ **gap:** Same as HOMO-LUMO, correct. **True.**

    (D) Ionization energy: Not directly related to color. **False.**

13. H_3PO_4: +5; HP_2O_6: +4; H_3PO_3: +3; H_3PO_2: +1

Order: +5 > +4 > +3 > +1.

14. **(A)** $Al(CH_3)_3$: Dimeric with 3c-2e bonds. **True**.

(B) BH_3: Forms B_2H_6 with 3c-2e bonds. **True**.

(C) $AlCl_3$: Dimeric, but via coordinate bonds, not 3c-2e. **False**.

(D) BCl_3 > $AlCl_3$ **acidity**: BCl_3 has stronger back-bonding, higher acidity. **True**.

15. Amphoteric: React with both acids and bases.

(A) Cr_2O_3, BeO, SnO, SnO_2: All amphoteric. **True.**

(B) CrO: Basic, not amphoteric. **False.**

(C) NO: Not amphoteric. **False.**

(D) ZnO, Al_2O_3, PbO, PbO_2: All amphoteric. **True.**

16. **(A)** NH_4NO_3: Decomposes at ~200°C to N_2O, not N_2. **False.**

(B) $(NH_4)_2$ Cr_2O_7: Decomposes at ~200°C to N_2. **True.**

(C) $Ba(N_3)_2$: Decomposes to N_2 below 300°C. **True.**

(D) Mg_3N_2: Needs high temperature. **False.**

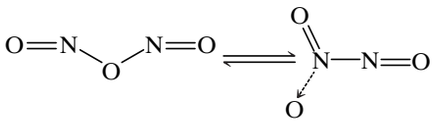
17. **(A)** Bi_2O_5 > N_2O_5: Basicity increases down the group. **True.**

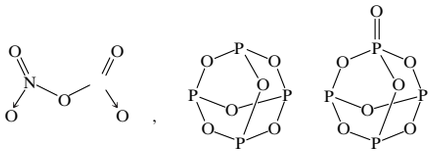
(B) NF_3 > BiF_3: NF_3 is more covalent (electronegativity). **True.**

(C) PH_3 **lower boiling than** NH_3: NH_3 has H-bonding. **True.**

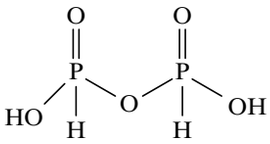
(D) N – N > P – P: N – N is weaker due to lone pair repulsion. **False.**

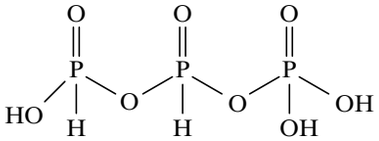
18.

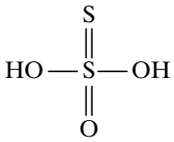




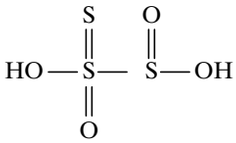
$2H_3PO_3 \longrightarrow H_4P_2O_5 + H_2O$







$2H_2SO_3 \longrightarrow H_2S_2O_3 + H_2O$



19. MnO_2 + KOH + O_2 → K_2MnO_4 (W, Y = MnO_4^{2-}, +6)

Electrolytic oxidation: MnO_4^{2-} → MnO_4^- (X, Z = MnO_4^-, + 7).

(A) **Disproportionation:** $3MnO_4^{2-} + 2H^+ \rightarrow 2MnO_4^- + MnO_2 + H_2O$. **True.**

(B) **π-bonding:** Both have Mn = O bonds. **True.**

(C) **Diamagnetic Y:** Mn^{6+} (d^1), paramagnetic; Z (Mn^{7+}, d^0) diamagnetic. **False.**

(D) **Colored, tetrahedral:** Both are colored and tetrahedral. **True.**

20. Q = $SnCl_2$:

- $SnCl_2 + Cl^- \rightarrow [SnCl_3]^-$ (X, pyramidal, sp^3).
- $SnCl_2 + Me_3N \rightarrow Me_3N \cdot SnCl_2$ (Y, coordinate bond).
- $SnCl_2 + CuCl_2 \rightarrow SnCl_4 + CuCl$ (Z = $SnCl_4$).

(A) **Z lone pair:** $SnCl_4$ has no lone pair. **False.**

(B) **X** sp^3: Correct. **True.**

(C) **Coordinate bond in Y:** Correct. **True.**

(D) **Z oxidation state +2:** Sn in $SnCl_4$ is +4. **False.**

21. **(A)** x_3 **is** γ: It's α. **False.**

(B) Z is uranium: $^{234}_{92}U$. **True.**

(C) x_2 is β: Correct. **True.**

(D) x_1 **deflects to negative:** α (positive) deflects to negative plate. **True.**

22. **(A)** Pb_3O_4: No O_2.

(B) KO_2: $2KO_2 + 2H_2O \rightarrow 2KOH + O_2$. **True.**

(C) Na_2O_2: Produces H_2O_2, not O_2.

(D) Li_2O_2: Similar to Na_2O_2.

23. **(A)** **Hypochlorite** (ClO^-) **strongest base:** ClO^- (weakest acid conjugate). **True.**

(B) **Chlorate** (ClO_3^-) **influenced by lone pair:** Has 1 lone pair, affects shape (trigonal pyramidal). **True.**

(C) **Disproportionation products:** ClO^- gives Cl^-, ClO_3^-; ClO_3^- gives ClO_4^-, Cl^-. Different sets. **False.**

(D) **ClO^- oxidizes** SO_3^{2-}: Possible, as ClO^- is an oxidizing agent. **True.**

24. Decay: 8 α (mass decreases by 32), 6 β.

Initial $^{238}_{92}U$: 68×10^{-6} g = $(68 \times 10^{-6})/238 = 2.857 \times 10^{-7}$ mol.

After 3 half-lives, 7/8 decays: α emitted = $8 \times (7/8) \times 2.857 \times 10^{-7} \times 6.022 \times 10^{23} = 1.20 \times 10^{18}$.

Z = 1.20.

25. $K_2CrO_4 + H_2O_2 \rightarrow CrO_5$ (blue, peroxo compound).

CrO_5: 1 Cr = O, 4 Cr – O (single bonds in two peroxo groups).

Number = 4.

Chapter 11 The d-Block Elements and some of their Compounds

1. $S_8 + 48HNO_3 \rightarrow 8H_2SO_4 + 48NO_2 + 16H_2O$

Mass of $H_2O = 18 \times 16 = 288$ gram.

2. Case I:

$$E_{cell} = E^0_{cell} - \frac{RT}{2F}\ell n\frac{1}{1}$$
$$= 2.7 - 0 = 2.7V$$

Case II:

$$E_{cell} = E^0_{cell} - \frac{RT}{2F}\ell n\frac{X}{1}$$

$$2.67 = 2.7 - \frac{R \times 300}{2F}\ell nx$$

$$-0.03 = -\frac{R \times 300}{2F}\ell nx$$

$$\ell nx = \frac{0.03 \times 2 \times F}{300 \times R}$$

Replacing F/R as 11500

$\ell nx = 2.3$

x = 10

3. Zn + NaOH(aq): $Zn + 2NaOH + 2H_2O \rightarrow Na_2[Zn(OH)_4] + H_2$

4. **(A)** Cr^{2+} **reducing:** Cr^{2+} (d^4) oxidizes to Cr^{3+} (d^3), favorable. **True.**

(B) Mn^{3+} **oxidizing:** Mn^{3+} (d^4) reduces to Mn^{2+} (d^5), favorable. **True.**

(C) **Both d_4:** Cr^{2+} (24 – 2 = 22 e^-, d^4), Mn^{3+} (25 – 3 = 22 e^-, d^4). **True.**

(D) Cr^{2+} **to d^5**: Cr^{2+} (d^4) to Cr^{3+} (d^3), not d^5. **False.**

5. Cell: $H_2|H^+||M^{4+}, M^{2+}|Pt$.

Reaction: $H_2 + M^{4+} \rightarrow 2H^+ + M^{2+}$, $n = 2$.

$$E = E^0 - \frac{2.303RT}{nF}\log Q,\ Q = \frac{[M^{2+}]}{[M^{4+}]}.$$

Given: $\frac{[M^{2+}]}{[M^{4+}]} = 10^x$, $E = 0.092V$, $E^0 = 0.151V$,

$$\frac{2.300RT}{F} = 0.059\ V.$$

$$0.092 = 0.151 - \frac{0.059}{2}\log(10^x).$$

$$0.059 = \frac{0.059}{2}x \rightarrow x = 2.$$

6. **(A)** H_2O_2 + NaOH: $H_2O_2 \rightarrow OOH^-$, reduces Fe^{3+} to Fe^{2+}. **True.**

(B) $Na_2O_2 + H_2O$: Forms H_2O_2, reduces Fe^{3+}. **True.**

(C) $H_2O_2 + H_2SO_4$: H_2O_2 oxidizes Fe^{2+} to Fe^{3+}. **False.**

(D) $Na_2O_2 + H_2SO_4$: Oxidizing conditions, not reducing. **False.**

7. Reaction: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$, $n = 2$.

$$\Delta G = -nFE,\ E = E^0 - \frac{RT}{nF}\ln Q,\ Q = \frac{[Zn^{2+}]}{[Cu^{4+}]} = 10.$$

$$E = 1.1 - \frac{2.303RT}{2F}\log 10 = 1.1 - \frac{2.303RT}{2F}.$$

$$\Delta G = -2F\left(1.1 - \frac{2.303RT}{2F}\right) = -2.2F + 2.303RT.$$

8. $MnCl_2 \rightarrow KMnO_4$: $Mn^{2+} \rightarrow Mn^{7+}$, 5 e^- per Mn.

$KMnO_4$ + oxalic acid: $Mn^{7+} + 5e^- \rightarrow Mn^{2+}$.

Oxalic acid ($C_2H_2O_4$): 90 g/mol, 225 mg = 0.225/90 = 0.0025 mol.

1 mole oxalic acid loses 2 e^-, so 0.0025 mol loses $0.0025 \times 2 = 0.005$ mol e^-.

0.005 mol e^- reduces 0.005/5 = 0.001 mol $KMnO_4$, which came from 0.001 mol $MnCl_2$.

$MnCl_2$: 126 g/mol, mass = $0.001 \times 126 = 126$ mg.

9. Reaction: $2Cu + H_2O \rightarrow Cu_2O + H_2$.

Given: $2Cu + \frac{1}{2} + O_2 \rightarrow Cu_2O$, $\Delta G^0 = -78{,}000$ J/mol.

$H_2 + \frac{1}{2}O_2 \rightarrow Cu_2O$, $\Delta G^0 = -178{,}000$ J/mol.

Net: $\Delta G^0 = -78{,}000 - (-178{,}000) = 100{,}000$ J/mol.

$$\Delta G = \Delta G^0 + RT \ln\left(\frac{P_{H_2}}{P_{H_2O}}\right) = 0 \text{ at equilibrium.}$$

$P_{H_2O} = 0.01$ bar, $RT = 8 \times 1250 = 10000$.

$$0 = 100{,}000 + 10000 \ln\left(\frac{P_{H_2}}{0.01}\right) \rightarrow \ln\left(\frac{P_{H_2}}{0.01}\right) = -10 \rightarrow$$

$$\ln P_{H_2} + 4.6 = -10 \ln P_{H_2} = -14.6$$

10. $A(s) \mid A^{n+}(aq, 2M) \parallel B^{2n+}(aq, 1M) \mid B(s)$

$2A(s) \rightarrow 2A^{n+} + 2ne^-$

$B^{2n+} + 2ne^- \rightarrow B(s)$

$2A(s) + B^{2n+} \rightarrow 2A^{n+} + B(s)$

$$Q = \frac{\left[A^{n+}\right]^2}{\left[B^{2n+}\right]} = \frac{2 \times 2}{1} = 4$$

$\Delta G° = AH° - TAS°$

$\Delta H° = 2\Delta G°$

$$E^0_{cell} = \frac{RT}{2nF} \ln 4$$

$$\Delta G^0 = -2n \times F \times \frac{RT}{2nF} \ln 4$$

$\Delta G^0 = -RT \ln 4$

$$\Delta S^0 = \frac{\Delta H^0 - \Delta G^0}{T} = \frac{\Delta G^0}{T} = \frac{RT \ln 4}{T}$$

$\Delta S^0 = -8.314 \times 1.4$

$= -11.62 \text{ J mol}^{-1}\text{K}^{-1}$

11. $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO)(aq) + 3H_2(g)$

- Moles Al = 5.4 g/27 g/mol = 0.2 mol
- Moles H_2SO_4 = 5.0 M × 0.050 L = 0.25 mol

The balanced equation ($2Al + 3H_2SO_4 \rightarrow \ldots$) shows H_2SO_4 is limiting because the mole ratio (0.25/0.2 = 1.25) is less than the required 1.5.

From the balanced equation, moles H_2 = moles H_2SO_4 = 0.25 mol.

$$V = \frac{nRT}{P}$$

$$V_{H_2} = \frac{0.25 \times 0.0821 \times 300}{1} = 6.1575 \text{ litre}$$

12. Balanced Ionic Equation:

$2MnO_4^-(aq) + 4H_2O(l) + 6I^-(aq) \rightarrow 2MnO_2(s) + 8OH^-(aq) + 3I_2(s)$

Mole Ratio:

From the equation, 2 moles $KMnO_4$ produce 3 moles I_2.

Calculation:

(4 moles $KMnO_4$) × (3 moles I_2 / 2 moles $KMnO_4$) = 6 moles I_2

6 moles of I_2 are released.

Chapter 12 The f-Block Elements and their Properties

1. **$[TeBr_6]^{2-}$:** Te has 6 valence electrons. It forms 6 bonds with Br. The –2 charge adds 2 more electrons, so there are 8 electrons around Te. Te uses 6 electrons for bonding, leaving 2 electrons or 1 lone pair.

$[BrF_2]^+$: Br has 7 valence electrons. It forms 2 bonds with F. The +1 charge means one electron is removed, so there are 7 – 2 – 1 = 4 electrons around Br. These form 2 lone pairs.

SNF_3: S has 6 valence electrons. It forms 3 bonds with F and one bond with N. So, S uses all 6 valence electrons for bonding, leaving no lone pairs.

$[XeF_3]^-$: Xe has 8 valence electrons. It forms 3 bonds with F. The –1 charge adds 1 more electron, so there are 8 – 3 + 1 = 6 electrons around Xe. These form 3 lone pairs.

Total lone pairs = 1 (on Te) + 2 (on Br) + 0 (on S) + 3 (on Xe) = 6.

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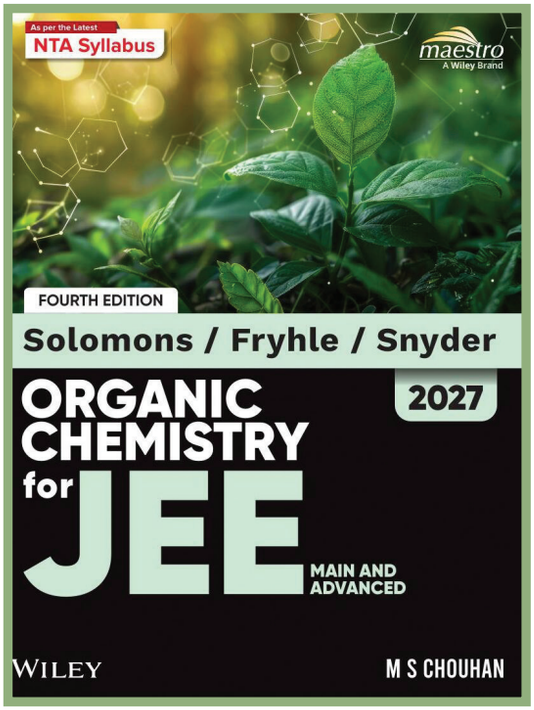

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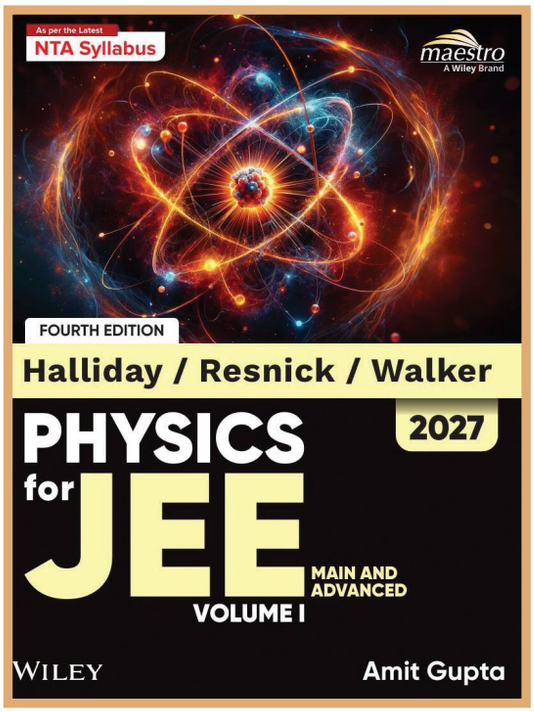

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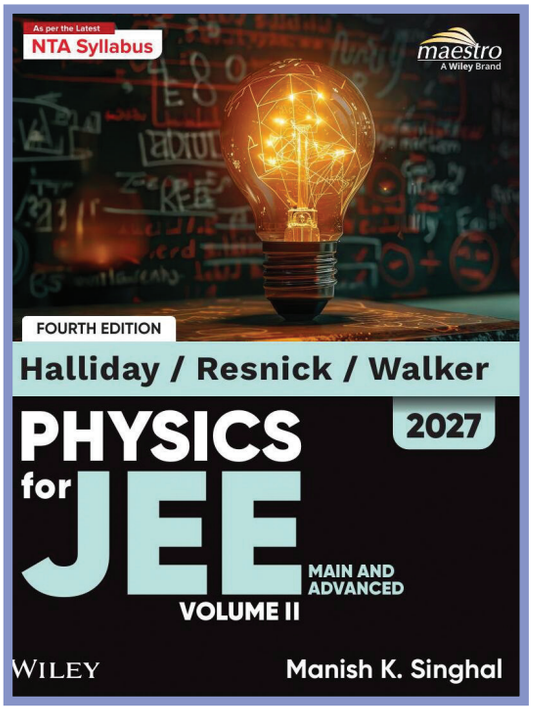

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