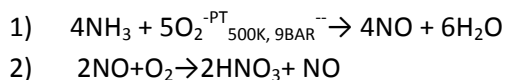


Nitric oxide	NO	+2	Neutral
Dinitrogen trioxide	N ₂ O ₃	+3	Acidic
Dinitrogen tetra oxide	N ₂ O ₄ or NO ₂	+4	Acidic
Dinitrogen pentaoxide	N ₂ O ₅	+5	Acidic

NITRIC ACID

PREPARATION: Ostwald's process – it is based upon catalytic oxidation of ammonia by atmospheric oxidation. The main steps are



PROPERTIES:-

- (i) conc. HNO₃ is a strong oxidizing agent & attacks most metals gold & Pt.
- (ii) Cr & Al do not dissolve HNO₃ because of the formation of a positive film of oxide on the surface.
- (iii) it oxidises non metals like I₂ to HNO₃, C to CO₂, S to H₂SO₄
- (iv) brown ring test is used to detect NO⁻.

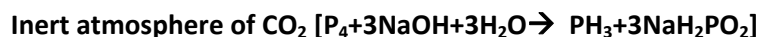
PHOSPHOROUS:-

ALLOTROPIC FORMS: White, red α-black & β-black.

White phosphorous is more reactive than red phosphorous because white P exists as discrete P₄ molecules. In red P several P₄ molecules are linked to form a polymeric chain.

PHOSPHINE

Preparation: It is prepared in laboratory by heating white P with concentrated NaOH solution in an



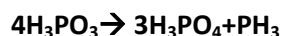
Phosphorous halides

Phosphorous forms two types of halides PX₃ & PX₅ (X=F, I, Br)

Trihalides have pyramidal shape and pentahalides have trigonal bipyramidal structure.

OXOACIDS OF PHOSPHOROUS

- The acids in +3 oxidation state disproportionate to higher & lower oxidation.



- Acids which contains P-H bond have strong reducing properties. EX:- H_3PO_2
Are ionisable and cause the basicity.
- Hydrogen atom which are attached with oxygen in P-OH form are ionisable

GROUP-16 ELEMENTS (CHALCOGENS)

Group 16 Elements: O, S, Se, Te, Po

General electronic configuration: ns^2np^4

Element	Occurrence
Oxygen	Comprises 20.946% by volume of the atmosphere.
Sulphur	As sulphates such as gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, Epsom salt $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ and sulphides Such as galena PbS , zinc blende ZnS , copper pyrites CuFeS_2 As metal selenides and tellurides in sulphide ores.
Se & Te	as a decay product of thorium and uranium minerals.

ATOMIC & PHYSICAL PROPERTIES

- Ionisation enthalpy decreases from oxygen to polonium.
- Oxygen atom has less negative electron gain enthalpy than S because of the compact nature of the oxygen atom. However from the S onwards the value again becomes less negative upto polonium.
- Electronegativity gradually decreases from oxygen to polonium, metallic character increases from oxygen to polonium.
- Oxygen & S are non-metals, selenium and tellurium are metalloids. Po is a radioactive metal.
- Oxygen is a diatomic gas while S, Se & Te are octa atomic S_8 , Se_8 & Te_8 molecules which has puckered 'ring' structure.

CHEMICAL PROPERTIES

- Common oxidation state:- -2,+2,+4 &+6.
- Due to inert effect,the stability of +6 decreases down the group and stability of +4 increases.

Oxygen exhibits +1 state in O_2F_2 ,+2 in OF_2 .

Anamolous behavior of oxygen-due to its small size,high electronegativity and absence of d-orbitals.

TREND IN PROPERTIES

Acidic character- $H_2O < H_2S < H_2Se < H_2Te$

Thermal stability- $H_2O > H_2S > H_2Se > H_2Te$

Reducing character- $H_2S < H_2Se < H_2Te$

Boiling point- $H_2S < H_2Se < H_2Te < H_2O$

Reducing property of dioxides- $SO_2 > SeO_2 > TeO_2$

Stability of halides- $F > Cl > Br > I$

HALIDES

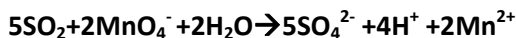
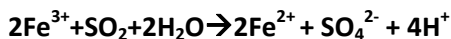
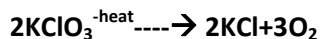
DI HALIDES: sp^3 hybridisation but angular structure.

TETRA HALIDES: sp^3 hybridisation-see-saw geometry

HEXA HALIDES: sp^3d^2 ,octahedral SF_6

DIOXYGEN

Prepared by heating oxygen containing salts like chlorates,nitrares



SO2 molecule is angular.

OXIDES

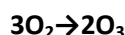
A binary compound of oxygen with another element is called oxide. Oxides can be classified on the basis of nature

- **Acidic Oxides:-** Non metallic oxides. Aqueous solutions are acids. Neutralize bases to form salts.Ex: $\text{SO}_2, \text{CO}_2, \text{N}_2\text{O}_5$ etc.
- **Basic Oxides:**metallic oxides.Aqueous solutions are alkalis. Neutralize acids to form salts.Ex: $\text{Na}_2\text{O}, \text{K}_2\text{O}$,etc.
- **Amphoteric oxides:-**some metallic oxides exhibit a dual behavior. Neutralize bothacids & bases to form salts.
Ex:- $\text{Al}_2\text{O}_3, \text{SbO}_2, \text{SnO}$,etc.....

OZONE

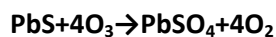
PREPARATION

Prepared by subjecting cold, dry oxygen to silent electric discharge.



PROPERTIES

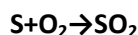
Due to the ease with which it liberates atoms of nascent oxygen, it acts as a powerful oxidizing agent. For eg:- it oxidiseslead sulphide to lead sulphate and iodide ions to iodine.



SULPHUR DIOXIDE

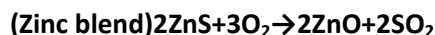
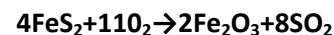
PREPARATION

Burning of S in air



Roasting of sulphide minerals

(Iron pyrites)



PROPERTIES

- Highly soluble in water to form solution of sulphurous acid
 $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$
- SO_2 reacts with Cl_2 to form sulphuryl chloride
 $\text{SO}_2 + \text{Cl}_2 \rightarrow \text{SO}_2\text{Cl}_2$

- It reacts with oxygen to form SO_3 in presence of V_2O_5 catalyst
 $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$
- Moist SO_2 behaves as a reducing agent. It converts Fe(III) ions to Fe(II) ions & decolourises acidified potassium permanganate (VII) solution (It is the test for the gas).

SULPHURIC ACID

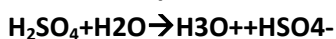
PREPARATION

It is manufactured by contact process which involves 3 steps

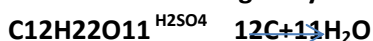
1. Burning of S or Sulphide ores in air to generate SO_2 .
2. Conversion of SO_2 to SO_3 in presence of V_2O_5 catalyst
3. Absorption of SO_3 in H_2SO_4 to give oleum.

PROPERTIES

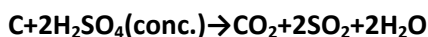
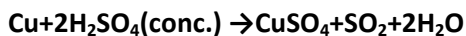
1. In aqueous solution it ionizes in 2 steps



2. It is a strong dehydrating agent Eg:-charring action of sugar



3. It is a moderately strong oxidizing agent.



GROUP 17 ELEMENTS (HALOGENS)

Group 17 elements: F, Cl, Br, I, At

General electronic configuration: $ns^2 np^5$

Element	Occurrence
Fluorine	As insoluble fluorides (fluorspar CaF_2 , Cryolite and fluoroapatite)
Cl, Br, I	Sea water contains chlorides, bromides and iodides of Sodium, potassium, magnesium and calcium, but is mainly sodium chloride solution (2.5% by mass). Certain forms of marine life (various seaweeds)

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ATOMIC & PHYSICAL PROPERTIES

- i. Atomic & ionic radii increase from fluorine to iodine.
- ii. Ionization enthalpy gradually decreases from fluorine to iodine due to increase in atomic size.
- iii. Electron gain enthalpy of fluorine is less than that of chlorine. It is due to small size of fluorine & repulsion between newly added electron & electrons already present in its small 2p orbital.
- iv. Electronegativity decreases from fluorine to iodine. Fluorine is the most electronegative element in the periodic table.
- v. The color of halogens is due to absorption of radiations in visible region which results in the excitation of outer electrons to higher energy level.
- vi. Bond dissociation enthalpy of fluorine is smaller than that of chlorine is due to electron-electron repulsion among the lone pair in fluorine molecules where they are much closer to each other than in case of chlorine. The trend: Cl-Cl > Br-Br > F-F > I-I.

CHEMICAL PROPERTIES

OXIDATION STATES:-1. However, chlorine, bromine & iodine exhibit +1, +3, +5, +7 oxidation states also.

Fluorine forms two oxides OF₂ and O₂F₂. These are essentially oxygen fluorides because of the higher electronegativity of fluorine than oxygen.

Anomalous behavior of fluorine- due to its small size, highest electronegativity, low F-F bond dissociation enthalpy and absence of d-orbitals.

TRENDS IN PROPERTIES

Oxidizing property – F₂ > Cl₂ > Br₂ > I₂

Acidic strength- HF < HCl < HBr < HI

Stability & bond dissociation enthalpy- HF > HCl > HBr > HI

Stability of oxides of halogens- I > Cl > Br

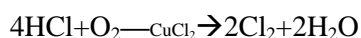
Ionic character of halides – MF > MCl > MBr > MI

CHLORINE

PREPARATION

1. $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
2. $4\text{NaCl} + \text{MnO}_2 + 4\text{H}_2\text{SO}_4 \rightarrow \text{MnCl}_2 + 4\text{NaHSO}_4 + 2\text{H}_2\text{O} + \text{Cl}_2$
3. $2\text{KMnO}_4 + 16\text{HCl} \rightarrow 2\text{KCl} + 2\text{MnCl}_2 + 8\text{H}_2\text{O} + 5\text{Cl}_2$

4. DEACON'S PROCESS



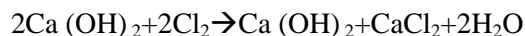
5. By electrolysis of brine solution. Cl₂ is obtained at anode.

PROPERTIES

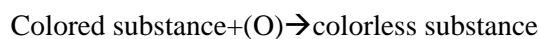
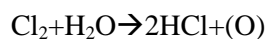
- i. With cold and dilute Cl_2 produces a mixture of chloride and hypochlorite but with hot and concentrated alkalis it gives chloride and chlorate.



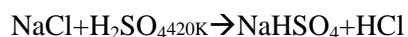
- ii. With dry slaked lime it gives bleaching powder.



- iii. It is a powerful bleaching agent; bleaching action is due to oxidation



- iv. Action of concentrated H_2SO_4 on NaCl give HCl gas.



3:1 ratio of conc. HCl & HNO_3 is known as aquaregia & it is used for dissolving noble metals like Au and Pt .

OXOACIDS OF HALOGENS (SEE TABLE 7.10 & FIG.7.8)

Interhalogen compounds are prepared by direct combination of halogens.

Ex: ClF , ClF_3 , BrF_5 , IF_7

They are more reactive than halogens because $\text{X-X}'$ is weaker than X-X bonds in halogens (except F-F).

TYPE	STRUCTURE
XX'_3	Bent T-shaped
XX'_5	Square pyramidal
XX'_7	Pentagonal bipyramidal

GROUP 18 ELEMENTS

GROUP 18 ELEMENTS: He , Ne , Ar , Kr , Xe & Rn

General electronic configuration: ns^2np^6

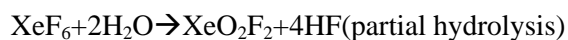
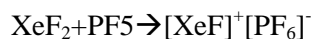
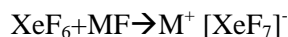
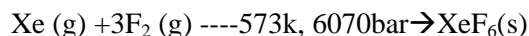
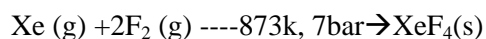
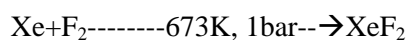
Atomic radii- large as compared to other elements in the period since it corresponds to Vander Waal radii.

Inert – due to complete octet of outermost shell, very high ionization enthalpy & electron gain enthalpies are almost zero.

The first noble compound prepared by Neil Bartlett was $XePtF_6$ & Xenon.

$O_2^+PtF_6^-$ led to the discovery of $XePtF_6$ since first ionization enthalpy of molecular oxygen ($1175kJmol^{-1}$) was almost identical with that of xenon ($1170kJmol^{-1}$).

PROPERTIES

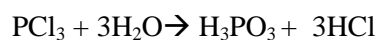


SOLVED QUESTIONS

1 MARK QUESTIONS

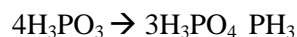
- Ammonia has higher boiling point than phosphine. Why?
-AMMONIA FORMS INTERMOLECULAR H-BOND.
- Why BiH_3 the strongest reducing agent amongst all the hydrides of group 15 elements ?
- Why does PCl_3 fume in moisture ?

In the presence of (H_2O) , PCl_3 undergoes hydrolysis giving fumes of HCl .



- What Happens when H_3PO_3 is Heated ?

It disproportionate to give orthophosphoric acid and Phosphine .



5. Why H_2S is acidic and H_2O is neutral ?

The S---H bond is weaker than O---H bond because the size of S atom is bigger than that of O atom. Hence H_2S can dissociate to give H^+ ions in aqueous solution.

6. Name two poisonous gases which can be prepared from chlorine gas ?

Phosgene (COCl_2), tear gas (CCl_3NO_2)

7. Name the halogen which does not exhibit positive oxidation state.

Fluorine being the most electronegative element does not show positive oxidation state.

8. Iodine forms I_3^- but F_2 does not form F_3^- ions. Why?

Due to the presence of vacant d-orbitals, I_2 accepts electrons from I-ions to form I_3^- ions, but because of d-orbitals F_2 does not accept electrons from F-ions to form F_3^- ions.

9. Draw the structure of peroxosulphuric acid.

10. Phosphorous forms PCl_5 but nitrogen cannot form NCl_5 . Why?

Due to the availability of vacant d-orbital in p.

2 MARK QUESTION (SHORT ANSWER TYPE QUESTION)

1. Why is HF acid stored in wax coated glass bottles?

This is because HF does not attack wax but reacts with glass. It dissolves SiO_2 present in glass forming hydrofluorosilicic acid.



2. What is laughing gas? Why is it so called? How is it prepared?

Nitrous oxide (N_2O) is called laughing gas, because when inhaled it produced hysterical laughter. It is prepared by gently heating ammonium nitrate.



3. Give reasons for the following:

(i) Conc. HNO_3 turns yellow on exposure to sunlight.

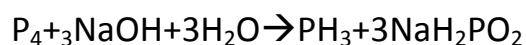
(ii) PCl_5 behaves as an ionic species in solid state.

(i) Conc HNO_3 decompose to NO_2 which is brown in colour & NO_2 dissolves in HNO_3 to it yellow.

(ii) It exists as $[\text{PCl}_4]^+[\text{PCl}_6]^-$ in solid state.

4. What happens when white P is heated with conc. NaOH solution in an atmosphere of CO_2 ? Give equation.

Phosphorus gas will be formed.



5. How is ozone estimated quantitatively?

When ozone reacts with an excess of potassium iodide solution

Buffered with a borate buffer (pH 9.2), Iodide is liberated which can be titrated against a standard solution of sodium thiosulphate. This is a quantitative method for estimating O_3 gas.

6. Are all the five bonds in PCl_5 molecule equivalent? Justify your answer.

PCl_5 has a trigonal bipyramidal structure and the three equatorial P-Cl bonds are equivalent, while the two axial bonds are different and longer than equatorial bonds.

7. NO_2 is coloured and readily dimerises. Why?

NO_2 contains odd number of valence electrons. It behaves as a typical odd molecules. On dimerization; it is converted to stable N_2O_4 molecule with even number of electrons.

8. Write the balanced chemical equation for the reaction of Cl_2 with hot and concentrated NaOH . Is this reaction a disproportionation reaction? Justify:



Yes, chlorine from zero oxidation state is changed to -1 and +5 oxidation states.

9. Account for the following.

(i) SF_6 is less reactive than.

(ii) Of the noble gases only xenon chemical compounds.

(i) In SF_6 there is less repulsion between F atoms than in SF_4 .

(ii) Xe has low ionisation enthalpy & high polarising power due to larger atomic size.

10. With what neutral molecule is ClO^- isoelectronic? Is that molecule a Lewis base?

ClF . Yes, it is Lewis base due to presence of lone pair of electron.

3 MARK QUESTIONS

1(i) why is He used in diving apparatus?

(ii) Noble gases have very low boiling points. Why?

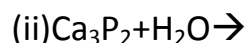
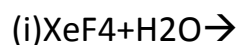
(iii) Why is ICl more reactive than I_2 ?

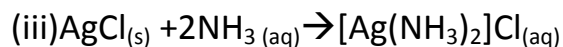
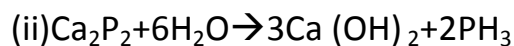
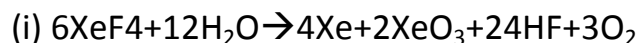
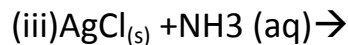
(i) It is not soluble in blood even under high pressure.

(ii) Being monoatomic they have weak dispersion forces.

(ii) I-Cl bond is weaker than I-I bond

2. Complete the following equations.

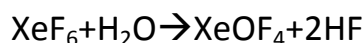




3. (i) How is XeOF₄ prepared? Draw its structure.

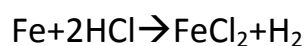
(ii) When HCl reacts with finely powdered iron, it forms ferrous chloride and not ferric chloride. Why?

(i) Partial hydrolysis of XeOF₄



Structure-square pyramidal. See Fig 7.9

(ii) Its reaction with iron produces H₂



Liberation of hydrogen prevents the formation of ferric chloride.

5 MARK QUESTION

1. Account for the following.

(i) Noble gas forms compounds with F₂ & O₂ only.

(ii) Sulphur shows paramagnetic behavior.

(iii) HF is much less volatile than HCl.

(iv) White phosphorus is kept under water.

(v) Ammonia is a stronger base than phosphine.

(i) F₂ & O₂ are best oxidizing agents.

(ii) In vapour state sulphur partly exists as S_2 molecule which has two unpaired electrons in the antibonding π^* orbitals like O_2 and, hence, exhibit paramagnetism.

(iii) HF is associated with intermolecular H bonding.

(iv) Ignition temperature of white phosphorous is very low (303 K). Therefore on exposure to air, it spontaneously catches fire forming P_4O_{10} . Therefore to protect it from air, it is kept under water.

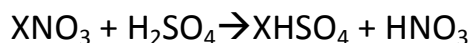
(v) Due to the smaller size of N, lone pair of electrons is readily available.

2. When Conc. H_2SO_4 was added to an unknown salt present in a test tube, a brown gas (A) was evolved. This gas intensified when copper turnings were added in to test tube. On cooling gas (A) changed in to a colourless gas (B).

(a) Identify the gases 'A' and 'B'

(b) Write the equations for the reactions involved

The gas 'A' is NO_2 whereas 'B' is N_2O_4 .



Salt (conc.)



Blue Brown (A)



Colourless(B)

3. Arrange the following in the increasing order of the property mentioned.

(i) $HOCl$, $HClO_2$, $HClO_3$, $HClO_4$ (Acidic strength)

(ii) As_2O_3 , ClO_2 , GeO_3 , Ga_2O_3 (Acidity)

(iii) NH_3 , PH_3 , AsH_3 , SbH_3 (HEH bond angle)

(iv) HF, HCl, HBr, HI (Acidic strength)

(v) MF, MCl, MBr, MI (ionic character)

(i) Acidic strength: $\text{HOCl} < \text{HClO}_2 < \text{HClO}_3 < \text{HClO}_4$

(ii) Acidity: $\text{Ga}_2\text{O}_3 < \text{GeO}_2 < \text{AsO}_3 < \text{ClO}_2$

(iii) Bond angle: $\text{SbH}_3 < \text{AsH}_3 < \text{PH}_3 < \text{NH}_3$

(iv) Acidic strength: $\text{HF} < \text{HCl} < \text{HBr} < \text{HI}$

(v) Ionic character: $\text{MI} < \text{MBr} < \text{MCl} < \text{MF}$

ASSIGNMENTS

Very short answer type questions:

- 1) PH_3 has lower boiling point than NH_3 . Explain.
- 2) Why are halogens coloured.
- 3) What are chalcogens?
- 4) Which noble gas is Radioactive?
- 5) Explain why fluorine always exhibit an oxidation state of - 1 only.
- 6) Which compound led to the discovery of compounds of noble gas?
- 7) Name the most electronegative element.
- 8) Why is OF_6 compound not known?
- 9) Why is N_2 not particularly reactive?
- 10) Ammonia acts as aligned. Explain.

Short answer type questions:

- 1) Write Phosphorous is more reactive than red phosphorous. Explain.

2) Why do noble gases have comparatively large atomic sizes?

3) Arrange in decreasing order of Ionic character

M – F, M – Cl, M – Br, M – I

4) Phosphinic acid behaves as a monoprotic acid

5) Arrange the following in the order of property indicated:

a) As_2O_3 , ClO_2 , GeO_2 , Ga_2O_3 __ Increasing acidity

b) H_2O , H_2S , H_2Se , H_2Te __ Increasing acid strength.

6) Arrange in decreasing order of bond energy:

F_2 , Cl_2 , Br_2 , I_2

7) Complete the following:

i) $\text{HNO}_3 + \text{P}_4\text{O}_{10} \rightarrow$

ii) $\text{IO}_3^- + \text{I}^- + \text{H}^+ \rightarrow$

8) Give the chemical reactions in support of following observations:

a) The +5 oxidation state of Bi is less stable than +3 oxidation state.

b) Sulphur exhibits greater tendency for catenation than selenium.

9) How would you account for following?

i) Enthalpy of dissociation of F_2 is much less than that of Cl_2 .

ii) Sulphur in vapour state exhibits paramagnetism.

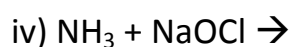
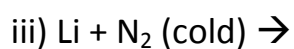
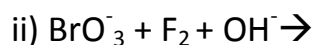
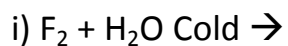
10) Draw structures of following:

a) Pre-oxomonosalphuric acid H_2SO_5

b) XeF_4

Level – III

1. Complete and balance:



2) Despite lower electron affinity of F_2 , is stronger oxidising agent than Cl_2 . Explain.

3) Give reasons:

a) Nitric oxide becomes brown when released in air.

b) PCl_5 is ionic in nature in the solid state.

4) Which of the two is more covalent $SbCl_3$ or $SbCl_5$?

5) Addition of Cl_2 to KI solution gives brown colour but excess of it turns it colourless. Explain.

Identify hybridization state of central atom and use concept of VSEPR theory . also its shape (geometry) and draw the structure.

PCl_3	sp^3	bp=3	lp=1	
PCl_5	sp^3d	bp=5	lp=0	
BrF_3	sp^3d	bp=3	lp=2	
XeF_2	sp^3d	bp=2	lp=3	
XeF_4	sp^3d^2	bp=4	lp=2	
$XeOF_4$	sp^3d^2	bp=5	lp=1	
XeO_3	sp^3	bp=3	lp=1	
XeF_6	sp^3d^3	bp=6	lp=1	
SF_4	sp^3d	bp=4	lp=1	

Formula	Resonance Structures	Bond Parameters
N_2O	$\ddot{N}=\ddot{N}=\ddot{O} \leftrightarrow :N\equiv N-\ddot{O}:$	$N - N - O$ 113 pm 119 pm Linear
NO	$:\ddot{N}=\ddot{O}: \leftrightarrow :\ddot{N}=\ddot{O}:$	$N - O$ 115 pm
N_2O_3		 Planar
NO_2		 Angular
N_2O_4		 Planar
N_2O_5		 Planar

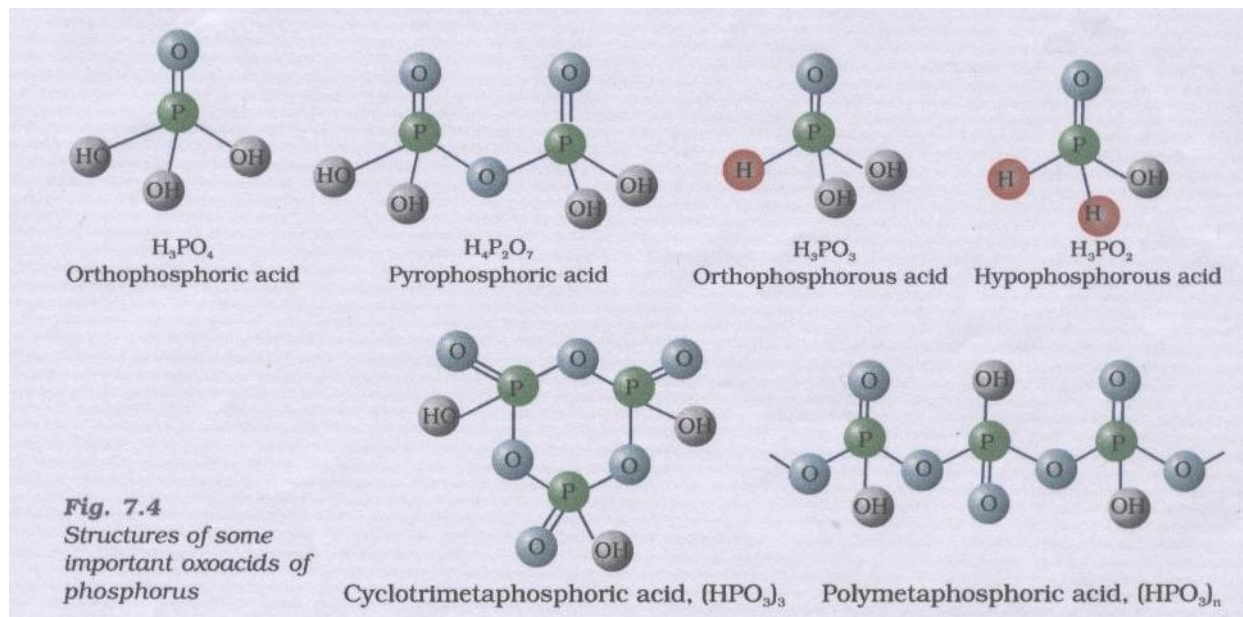
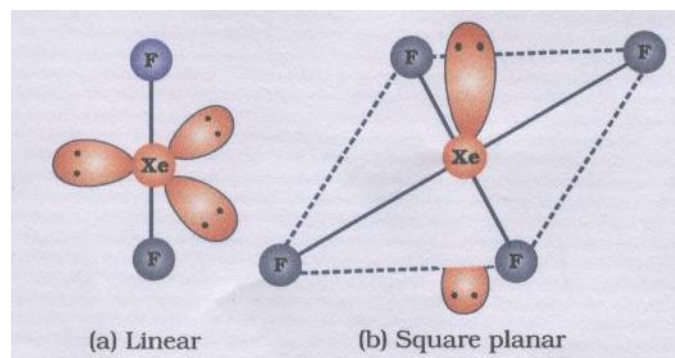
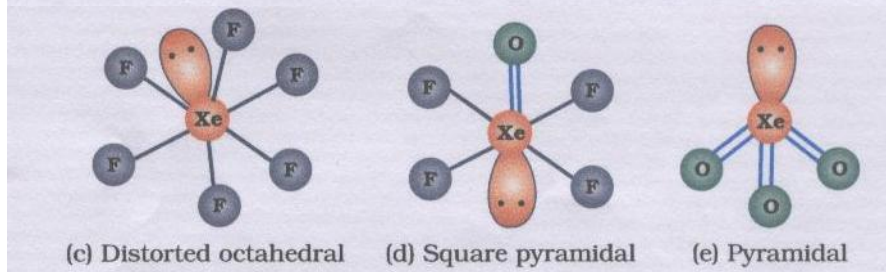
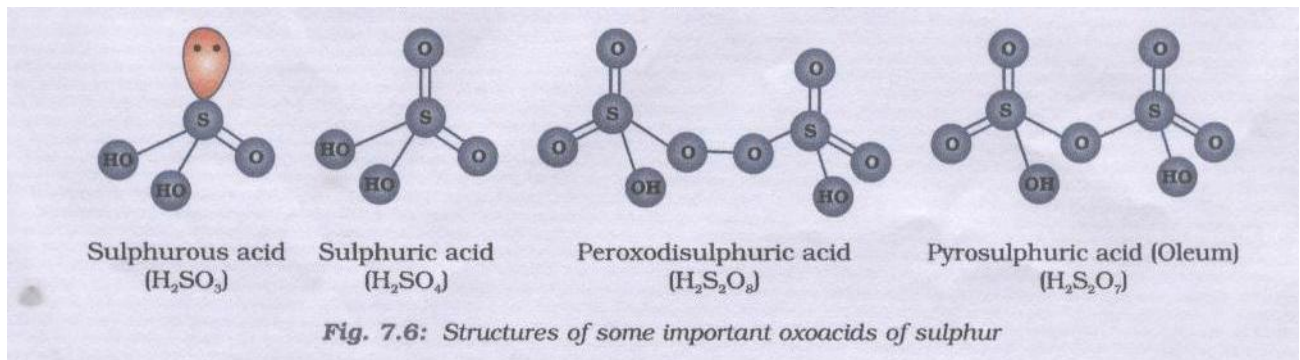
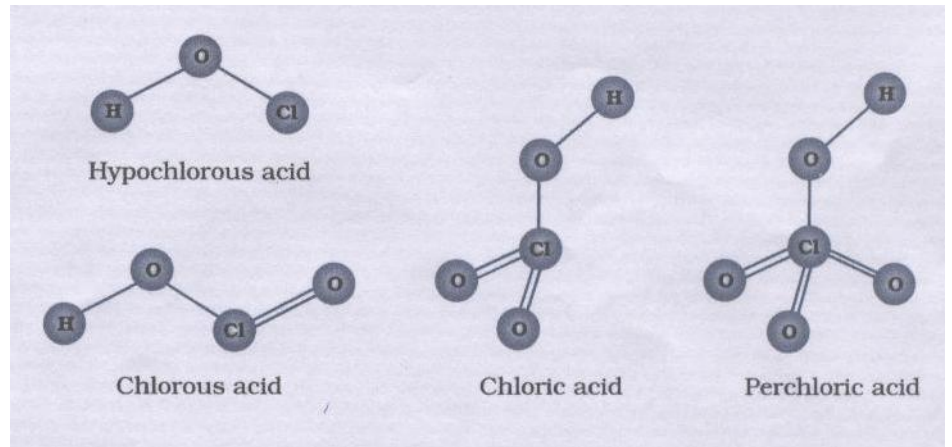
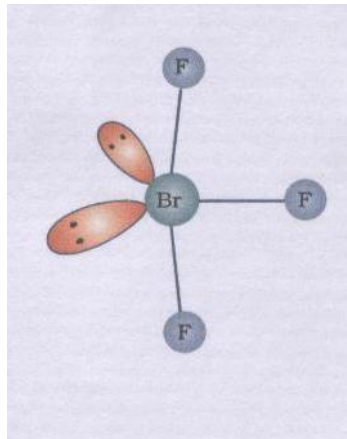
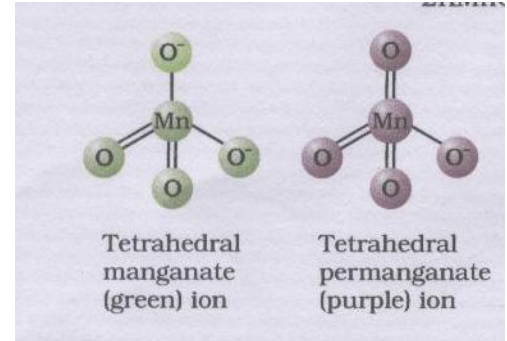
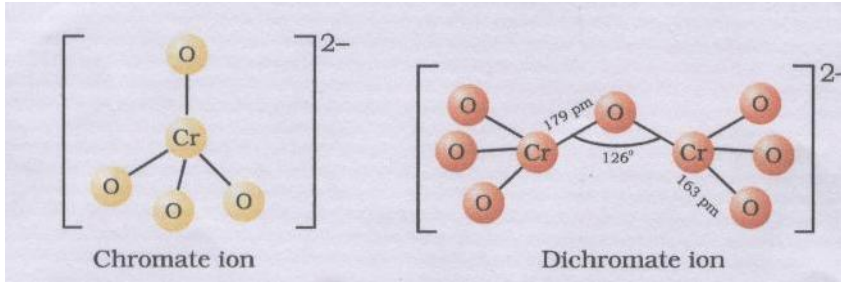


Fig. 7.4
Structures of some important oxoacids of phosphorus





Chapter:-8 The d-and f-Block Elements

POINTS TO BE REMEMBERED: ---

1. The elements of periodic table belonging to group 3 to 12 are known as d-Block elements.
2. The general electronic configuration of these elements is $(n-1)d^{1-10} ns^{1-2}$
3. d-Block elements are collectively known as Transition Elements because properties of these elements vary in between s-Block and p-Block elements.
4. A transition element should have partially filled $(n-1) d$ orbital.
5. Group 12 elements i.e. Zn, Cd, Hg have completely filled $(n-1) d$ -orbital in atomic & ionic state & thus these elements are considered as Typical Transition Elements.
6. All these elements are metals. They are less electropositive than s-block elements & more electropositive than p-block elements.
7. The atomic radii decreases from group 3 to 6 (i.e. Sc to Cr) because of increase in effective nuclear charge gradually.
8. The atomic radii of group 7,8 9 &10 elements (i.e. Fe,Co,Ni) is almost same because pairing of electrons take place in $(n-1)d$ orbital causing repulsion i.e. shielding of $(n-1)d$ orbital.
9. Group 11 &12 elements i.e. Cu & Zn have bigger size due to strong shielding of completely filled $(n-1)d$ orbital.
10. The transition elements show variable oxidation state due to small energy difference between $(n-1)d$ & ns orbital as a result both $(n-1)d$ & ns electrons take part in bond formation.
11. The highest oxidation state of an element is equal to number of unpaired electrons present in $(n-1)d$ & ns orbital.
12. Transition elements have high enthalpy of atomization/ sublimation Because of large number of unpaired electrons in their atoms, they have stronger interatomic interaction and hence strong metallic bonding is present between atoms.
13. Most of transition elements are paramagnetic due to presence of unpaired electrons in $(n-1) d$ orbital.
14. Most of transition elements are used as catalyst. It is due to (i) partially filled $(n-1) d$ orbital (ii) Variable oxidation state (iii) Ability to change oxidation state frequently.
15. Most of transition elements form coloured compounds due to presence of unpaired electrons in $(n-1) d$ orbital & thus they can undergo d-d transition.
16. Most of transition elements form complex compounds due to (i) small size (ii) high charge (iii) presence of vacant d-orbital of suitable energy.
17. Transition elements have lower value of Reduction Potential due to high ionization potential, high heat of sublimation & low enthalpy of hydration.
18. Transition elements form interstitial compounds because size of interstitial voids is similar to size of non- metals C, N, O, H.
19. Transition elements form alloys due to similar ionic radii.
20. The oxides of transition metals in lower oxidation state are BASIC, intermediate oxidation state are AMPHOTERIC, highest oxidation state are ACIDIC.

LANTHANOIDS: ---

1. The 14 elements after Lanthanum having atomic number 58 to 71 are collectively known as Lanthanoids.
2. The general electronic configuration of these elements is $[Xe] 4f^{1-14}, 5d^{0-1}, 6s^2$.
3. Most common oxidation state of these elements is +3, but Ce shows +4, Eu +2, because they acquire stable configuration.
4. The size of Lanthanoids and its trivalent ion decreases from La to Lu due to poor shielding of 4f electrons. It is known as lanthanoids contraction.

ACTINOIDS:--

1. The 14 elements after Actinium having atomic number 90 to 113 are collectively known as Actinoids.

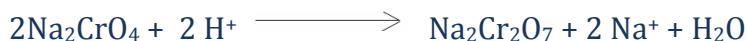
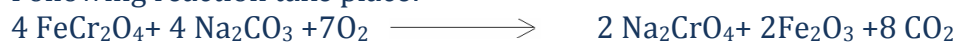
- The general electronic configuration of these elements is $[Rn] 5f^{1-14}, 6d^{0-1}, 7s^2$.
- The size of actinoids and its trivalent ion decreases from Ac to Lw due to poor shielding of 5f electrons. It is known as actinoids contraction.
- The elements after U (92) are man made known as transuranic elements.

POTASSIUM DICHROMATE:--

Preparation: - It takes place in three steps-

- Conversion of chromite ore to sodium chromate.
- Conversion of sodium chromate to sodium dichromate.
- Conversion of sodium dichromate to potassium dichromate

Following reaction take place:--

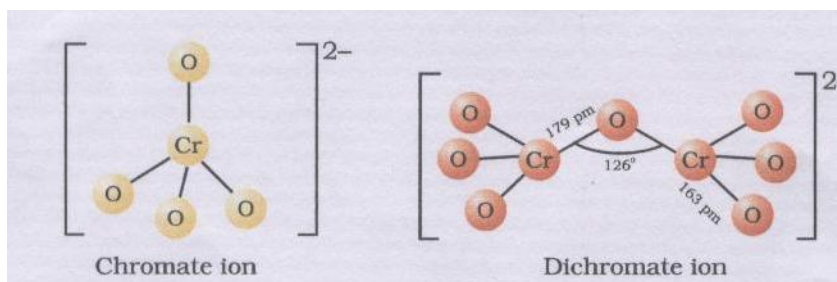


The chromates and dichromates are interconvertible in aqueous solution depending upon Ph of the solution.

A) In Acedic medium(PH<7)



B) In basic medium (PH >7)



POTASSIUM PERMANGNATE:--

Preparation: --

It takes place in two steps:-

- Conversion of pyrolusite ore into potassium magnate
- Conversion of potassium magnate to potassium permanganate

Following reactions take place:-



QUESTION ANSWERS

(TWO MARK QUESTIONS)

Q.1-Explain briefly how +2 oxidation state becomes more and more stable in the first half of the first row transition elements with increasing atomic number.

A.1-In M^{2+} ions, 3d-orbitals get occupied gradually as the atomic number increases. Since, the number of empty d-orbitals decreases, the stability of cations increases from Sc^{2+} to Mn^{2+} . Mn^{2+} is most stable as all d-orbitals are singly occupied.

Q.2- Explain why transition elements have many irregularities in their electronic configurations?

A.2-In the transition elements, there is a little difference in the energy of (n-1) d-orbitals and ns-orbitals. Thus, incoming electron can occupy either of shell. Hence, transition elements exhibit many irregularities in their electronic configurations.

Q.3-What are different oxidation states exhibited by Lanthanides?

A.3-The common stable oxidation state of lanthanides is +3. However some members also show oxidation states of +2 & +4.

Q.4-How is the variability in oxidation states of transition metals different from that of the non-transition metals? Illustrate with examples.

A.4-The transition elements use its (n-1)d, ns and np orbital and the successive oxidation states differ by unity. For example, Mn shows all the oxidation states from +2 to +7. On other hand non transition elements use its ns, np and nd orbitals and the successive oxidation states differ by two units e.g. Sn²⁺, Sn⁴⁺ etc.

Q.5- Why do transition elements show variable oxidation states?

A.5- The transition elements show variable oxidation state due to small energy difference between (n-1) d & ns orbital as a result both (n-1)d & ns electrons take part in bond formation.

Q.6-Why are Mn²⁺ compounds more stable than Fe²⁺ compounds towards oxidation to +3 state?

A.6-The electronic configuration of Mn²⁺ is [Ar] 3d⁵, i.e. all five d-orbitals are singly occupied. Thus this is stable electronic configuration and further loss of electron requires high energy. On other hand side the electronic configuration of Fe²⁺ is [Ar] 3d⁶, i.e. Loss of one electron requires low energy.

Q.7-To what extent do the electronic configuration decide the stability of oxidation state in the first series of the transition elements? Illustrate your answer with an example.

A.7-In a transition series, the oxidation state which lead to exactly half filled or completely filled orbitals are more stable. e.g. the electronic configuration of Fe is [Ar] 3d⁶ 4s². It shows various oxidation state but Fe(III) is more stable than Fe(II).

Q.8-What is meant by disproportionation? Give two examples.

A.8-Those reactions in which same substance undergoes oxidation as well as reduction are called disproportionation reactions. e.g.



Q.9- Which metal in the first series of transition metals exhibits +1 oxidation state most frequently and why?

A.9- Copper with configuration [Ar] 3d¹⁰ 4s¹ exhibits +1 oxidation state. Copper loses 4s¹ electron easily and achieved a stable configuration 3d¹⁰ by forming Cu⁺.

Q.10- What are inner transition elements?

A.10- The f-block elements in which the last electron accommodated on (n-2) f-subshell are called inner transition elements. These include atomic numbers 58 to 71 and from 90 to 103.

Q.11- The paramagnetic character in 3d-transition series elements increases upto Mn and then decreases. Explain why?

A.11- In the 3d-transition series as we move from Sc (21) to Mn (25) the number of unpaired electrons increases and hence paramagnetic character increases. After Mn, the pairing of electrons in the d-orbital starts and the number of unpaired electrons decreases and hence, paramagnetic character decreases.

Q.12- Comment on the statement that elements of the first transition series possess many properties different from those of heavier transition metal

A.12-The following points justify that the given statement is true:-

(i) Ionization enthalpies of heavier transition elements are higher than the elements of 3d series. Consequently, heavier transition elements are less reactive in comparison to 3d-elements.

(ii) Melting points of heavier transition elements are higher than 3d-elements.

(iii) Higher oxidation states of heavier transition elements are stable whereas lower oxidation states are stable in 3d-elements.

Q.13-What are transition elements? Which d-block elements are not regarded as transition elements and why?

A.13- An element which has partially filled (n-1) d orbital is known as transition elements. Group 12 elements i.e. Zn, Cd, Hg have completely filled (n-1) d-orbital in atomic & ionic state & thus these elements are not considered as Transition Elements.

Q.14-What are interstitial compounds? Why are such compounds well known for transition metal?

A.14- Compounds of transition metal with relatively smaller non-metals are known as interstitial compounds. These compounds are well known for transition metals because size of C, N, O, and B is similar to size of interstitial voids of transition metal

Q.15-For the first row of transition metals the E^0 values are:-

E^0 values	V	Cr	Mn	Fe	Co	Ni	Cu
M^{2+}/M	-1.18	-0.91	-1.18	-0.44	-0.28	-0.25	+0.34

Explain the irregularity in the above values.

A.15-The E^0 (M^{2+}/M) values are not regular which can be explained from the irregular variation of ionization energy and sublimation energy of Mn due to half-filled orbitals.

(THREE MARK QUESTIONS)

Q.1- Decide giving reason which one of the following pairs exhibits the property indicated:

- (i) Sc^{3+} or Cr^{3+} exhibits paramagnetism
- (ii) V or Mn exhibits more number of oxidation states
- (iii) V^{4+} or V^{5+} exhibits colour

A.1- (i) $Sc=[Ar] 3d^1 4s^2$; $Sc^{3+}=[Ar]$; it has no unpaired electron so diamagnetic
 $Cr=[Ar] 3d^5 4s^1$; $Cr^{3+}=[Ar] 3d^3$; it has three unpaired electrons paramagnetic
 (ii) $V=[Ar] 3d^3 4s^2$ $Mn=[Ar] 3d^5 4s^2$ Thus V exhibit oxidation states of +2, +3, +4, +5
 Whereas Mn exhibit oxidation states of +2 to +7.

(iii) $V^{4+}=[Ar] 3d^1 \rightarrow$ coloured $V^{5+}=[Ar] \rightarrow$ colourless

Q.2-(a) Describe the general trends in the following properties of the first series of the transition elements:-

- (i) Stability of +2-oxidation state
- (ii) Formation of oxometal ions

(b) Write steps involved in the preparation of $KMnO_4$ from K_2MnO_4

A.2- (a) i-The elements of first transition series show decreasing tendency to form divalent cation as we move left to right in the series. This trend is due to general increase in the first and second ionization energy. The greater stability of Mn^{2+} is due to half filled d^5 configuration and that of zinc is due to d^{10} configuration.

(ii) All metal except Sc from oxide of type MO which are basic. The highest oxidation number in all oxide, coincide with the group number and is attain in Sc_2O_3 to Mn_2O_7 . Formation of oxoanions is due to high electro negativity and small size of oxygen atom.

2-(b) It takes place in two steps:-

- (iii) Conversion of pyrolusite ore into potassium manganate.
- (iv) Conversion of potassium manganate to potassium permanganate.

Following reactions take place:-



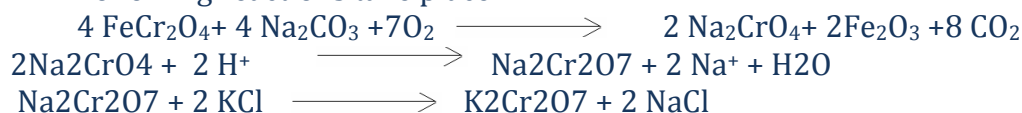
Q.3-(a) Write the steps involve in the preparation of $K_2Cr_2O_7$ from chromite ore.

(b) What is the effect of pH on dichromate ion solution?

A.3-(a):- It takes place in three steps-

- (iv) Conversion of chromite ore to sodium chromate.
- (v) Conversion of sodium chromate to sodium dichromate.
- (vi) Conversion of sodium dichromate to potassium dichromate

Following reactions take place:-



(b) Dichromate ion is orange in acidic solution ($\text{pH} < 7$) and turns yellow in basic solution. It is due to interconversion of dichromate ion to chromate ion. Following reactions take place:-



Q.4- (a) What is lanthanide contraction? What effect does it have on the chemistry of the elements, which follow lanthanoids?

(b) The chemistry of actinoid elements is not so much smooth as that of lanthanoids. Justify these statements by giving some examples from the oxidation state of these elements.

A.4- (a) The size of Lanthanoids and its trivalent ion decreases from La to Lu. It is known as lanthanoids contraction.

Cause: - It is due to poor shielding of 4f electrons.

Consequences of lanthanide contraction: - (i) Basic strength of hydroxide decreases from $\text{La}(\text{OH})_3$ to $\text{Lu}(\text{OH})_3$. (ii) Because of similar chemical properties lanthanides are difficult to separate.

(b) Lanthanoids show limited number of oxidation states i.e. +2, +3, +4 (out of which +3 is most common). This is because of a large energy gap between 4f, 5d and 6s subshell. The dominant oxidation state of actinides is also +3 but they show a number of other oxidation state also e.g. +4, +5, and +7. This is due to small energy difference between 5f, 6d and 7s orbitals.

Q.5- Give examples and suggest reasons for the following features of the transition metal chemistry:

(i) The lowest oxide of transition metal is basic, the highest is amphoteric/acidic.

(ii) A transition metal exhibits highest oxidation state in oxides and fluorides.

(iii) Of the d^4 species, Cr^{2+} is strongly reducing while manganese(III) is strongly oxidizing.

A.5-(i) The oxide of transition metals in lower oxidation states are generally basic while those in the higher oxidation states are acidic. Acidic character increases with increase in oxidation state is due to decrease in size of metal ion and increase in charge density. e.g. MnO (basic), Mn_3O_4 (amphoteric), Mn_2O_7 (acidic).

(ii) A transition metal exhibits higher oxidation states in oxides and fluorides because oxygen and fluorine are the most electronegative elements and thus easily can unpair electrons of metal atom.

(iii) Because oxidizing and reducing property depends on E^0 value. Since E^0 value of $\text{Cr}^{3+}/\text{Cr}^{2+}$ is negative while that of $\text{Mn}^{3+}/\text{Mn}^{2+}$ is positive, as a result $\text{Cr}(\text{II})$ act as reducing agent and $\text{Mn}(\text{III})$ is strong oxidizing.

Q.6- For M^{2+}/M and $\text{M}^{3+}/\text{M}^{2+}$ systems, the E^0 values for some metals are as follows:

Cr^{2+}/Cr	-0.9V	$\text{Cr}^{3+}/\text{Cr}^{2+}$	-0.4V
Mn^{2+}/Mn	-1.2V	$\text{Mn}^{3+}/\text{Mn}^{2+}$	+1.5V
Fe^{2+}/Fe	-0.4V	$\text{Fe}^{3+}/\text{Fe}^{2+}$	+0.8V

Use this data to comment upon :-

(i) the stability of Fe^{3+} in acid solution as compared to Cr^{3+} or Mn^{3+} and

(ii) the ease with which iron can be oxidized as compared to a similar process for either chromium or manganese metal.

A.6- (i) E^0 for $\text{Cr}^{3+}/\text{Cr}^{2+}$ is -0.4V i.e. negative, this means Cr^{3+} ions in the solution cannot be reduced to Cr^{2+} easily i.e. Cr^{3+} is stable. As $\text{Mn}^{3+}/\text{Mn}^{2+}$ is +1.5V i.e. positive means Mn^{3+} can easily reduced to Mn^{2+} ions in comparison to Fe^{3+} ions. Thus relatively stability of these ions is:-



(ii) The oxidation potentials for the given pairs will be +0.9V, +1.2V and 0.4V. Thus, the order of their getting oxidized will be in the order $\text{Mn} > \text{Cr} > \text{Fe}$.

Q.7- Account for the following statements:

(i) Cobalt (II) is stable in aqueous solution but in the presence of strong ligands and air, it can be oxidized to Co (III).

(ii) The d^1 configuration is very unstable in ions.

(iii) One among the lanthanides, Ce (III) can be easily oxidized to Ce (IV).

A.7- (i) Strong ligands force cobalt (II) to lose one more electron from 3d-subshell and thereby induced d^2sp^3 hybridisation.

(ii) The ion with d^1 configuration try to lose the only electron in order to acquire inert gas configuration.

(iii) The configuration of Ce is $[Xe] 4f^1, 5d^1, 6s^2$. There is no much difference between the energy of 4f, 5d and 6s orbitals and thus, Ce can utilize electrons present in these orbitals and hence oxidation state of +4.

Q.8- Compare the chemistry of actinides with that of the lanthanoids with special reference to:

- | | |
|---------------------------------|--------------------------|
| (i) electronic configuration | (iii) oxidation state |
| (ii) atomic and ionic sizes and | (iv) chemical reactivity |

A.8-

Comparison of Lanthanoids and Actinides

Properties	Lanthanoids	Actinides
Electronic configuration	$[Xe] 4f^{1-14}, 5d^{0-1}, 6s^2$	$[Rn] 5f^{1-14}, 6d^{0-1}, 7s^2$
Atomic/ionic sizes	Size decreases from La to Lu, and size is more than actinides.	Size decreases from Ac to Lw, and size is smaller than lanthanoids due to poorer shielding of 5f electrons
Oxidation states	Common oxidation is +3 where other oxidation states are +2, +4. It is due to a large energy gap between 4f, 5d and 6s subshell	Common oxidation is +3 where other oxidation states are +2, +4, +5 and +7 due to small energy difference between 5f, 6d and 7s orbitals
Chemical reactivity	The earlier member quite reactive but with increasing atomic number they behave like aluminum.	The actinides highly reactive, especially in finely divided.
Complex formation	Less tendency to form complex due to less charge density.	More tendency to form complex due to high charge density.

Q.9-(a) What is actinides contraction? What effect does it have on the chemistry of the elements, which follow actinides?

(b) Name an important alloy, which contains some of the lanthanide metals. Mention its uses.

A.9- (a) The size of actinoid and its trivalent ion decreases from Ac to Lw. It is known as actinides contraction.

Cause: - It is due to poor shielding of 5f electrons.

Consequences of actinides contraction: - (i) Basic strength of hydroxide decreases from $Ac(OH)_3$ To $Lw(OH)_3$. (ii) Because of similar chemical properties actinides are difficult to separate.

(b) An important alloy containing lanthanoid metals is mischmetal, which contains 95% lanthanide metal and 5% Fe along with traces of S, C, Ca and Al. It is used in Mg-based alloy to produce bullets, shells and lighter flint.

Q.10- Complete following reactions:-



(FIVE MARK QUESTIONS)

Q.1-Explain giving reasons:

- (i) Transition metals and many of their compounds show paramagnetic behaviour.

- (ii) The enthalpies of atomisation of the transition metals are high.
- (iii) The transition metals generally form coloured compounds.
- (iv) Transition metals and their many compounds act as good catalyst.
- (v) Transition metals have a strong tendency to form complexes.

A.1- (i) Transition metals and many of their compounds show paramagnetic behaviour due to presence of unpaired electrons in (n-1) d orbital.

- (ii) The enthalpies of atomisation of the transition metals are high Because of large number of unpaired electrons in their atoms, they have stronger interatomic interaction and hence strong metallic bonding is present between atoms.
- (iii) The transition metals generally form coloured compounds due to presence of unpaired electrons in (n-1) d orbital & thus they can undergo d-d transition.
- (iv) Transition metals and their many compounds act as good catalyst It is due to (i) partially filled (n-1) d orbital (ii) Variable oxidation state (iii) Ability to change oxidation state frequently.
- (v) Transition metals have a strong tendency to form complexes Most of transition elements form complex compounds due to (i) small size (ii) high charge (iii) presence of vacant d-orbital of suitable energy.

Q.2- Give reasons for the following:-

- (i) Fe has higher melting point than Cu.
- (ii) $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ is coloured while $[\text{Sc}(\text{H}_2\text{O})_6]$ is colourless.
- (iii) The 4d and 5d series of transition metals have more frequent metal-metal bonding in their compound than do the 3d metals.
- (iv) Transition metals some time exhibit very low oxidation state such as +1 and 0.
- (v) Hg is not considered a transition metal.

A.2-(i) This is because Fe ($3d^6, 4s^1$) has four unpaired electrons in 3d-subshell. While Cu ($3d^{10}, 4s^1$) only one unpaired electron in 4s shell. Hence metallic bonding is stronger in Fe than those in Cu.

(ii) The oxidation state of Ti in $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ is +3 and its configuration is $[\text{Ar}] 3d^1$ i.e one unpaired electron and hence it is coloured. Whereas the oxidation state of Sc in $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$ is +3 and its configuration is $[\text{Ar}] 3d^0$ i.e no unpaired electron and hence it is colourless.

(iii) In the same group of d-block elements, the 4d and 5d transition elements are larger size than that of 3d elements. Hence, the valence electrons are less tightly held and form metal-metal bond more frequently.

(iv) +1 oxidation state is shown by elements like Cu because after loss of one electron, it acquire stable configuration. Zero oxidation state is shown in metal carbonyl, because π -electrons donated by CO are accepted into the empty orbital.

(v) The characteristic properties of transition metal are due to partially filled d-orbitals. Hg has completely filled d-orbital, as a result it doesn't show properties of transition metals and hence is not considered as transition metal.

Q.3-(a) write electronic configuration of element having atomic number 101.

- (b) Which element show maximum oxidation state in 3d transition series?
- (c) What is mischmetal?
- (d) Explain why Cu^+ ion is not stable in aqueous solution?
- (e) Name the transition metal which is well known to exhibit +4 oxidation state?

A.3-(a) $[\text{Rn}] 5f^{13}, 6d^0, 7s^2$.

(b) Mn, Which shows +7 oxidation state in KMnO_4 .

(c) It is an important alloy, which contains 95% lanthanide metal and 5% Fe along with traces of S, C, Ca and Al. It is used in Mg-based alloy to produce bullets, shells and lighter flint.

(d) Water is a good complexing agent and thus Cu forms complex by losing one more electron from 3d orbital.

(e) Cerium (Z=58)

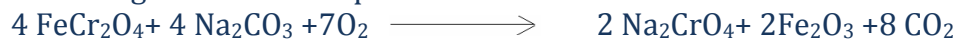
Q.4-(a) Write the preparation of potassium dichromate from iron chromite. What happens when potassium dichromate reacts with (i) Hydrogen sulphide (ii) FeSO_4 ?

- (b) Why do Zr and Hf exhibit almost similar properties?
- (c) Why is $\text{La}(\text{OH})_3$ stronger base than $\text{Lu}(\text{OH})_3$.

A.4- (a) Preparation:- It takes place in three steps-

- (i) Conversion of chromite ore to sodium chromate.
- (ii) Conversion of sodium chromate to sodium dichromate.
- (iii) Conversion of sodium dichromate to potassium dichromate

Following reaction takes place:-



Reactions: - (i) $\text{Cr}_2\text{O}_7^{2-} + 8 \text{H}^+ + 3 \text{H}_2\text{S} \rightarrow 2\text{Cr}^{3+} + 7 \text{H}_2\text{O} + 3\text{S}$

(ii) $\text{Cr}_2\text{O}_7^{2-} + 14 \text{H}^+ + 6 \text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 7 \text{H}_2\text{O} + 6 \text{Fe}^{3+}$.

(b) Because both have similar ionic size

(c) Due to lanthanoid contraction size of La^{3+} is smaller than Lu^{3+} as a result Lu-O bond will be stronger than La-O bond.

Q.5- Give reasons for the following:-

(i) Transition metals have high enthalpy of hydration.

(ii) Zn, Cd and Hg are not regarded as transition metal.

(iii) d block elements exhibit a large number of oxidation states than f block elements.

(iv) The second and third members in each group of transition elements have similar atomic radii.

(v) $\text{K}_2[\text{PtCl}_6]$ is a well known compound whereas the corresponding Ni compound is not known.

A.5-(i) Transition metal ions are smaller and have higher charge, therefore they have high enthalpy of hydration.

(ii) Group 12 elements i.e. Zn, Cd, Hg have completely filled (n-1) d-orbitals in atomic & ionic state & thus these elements are not considered as transition elements.

(iii) The difference in the energy of (n-1) d orbital and ns orbital is very small and thus both subshells are used for bond formation. Whereas in f block elements (n-2)f orbitals lie underneath and hence are not available for bond formation.

(iv) The second and third members in each group of transition elements have similar atomic radii due to lanthanoid contraction. It arises due to poor shielding of d and f electrons.

(v) The oxidation state of Pt is +4 which is stable for Pt. The +4 oxidation state for Ni is very difficult to achieve because the sum of the first four ionization energies is very high. Hence, the corresponding Ni(II) compound is known.

UNIT 9: CO-ORDINATION COMPOUNDS

The compounds which contain dative bonds between metal atom and surrounding species is called co-ordination compounds

The branch of inorganic chemistry which deals with the study of preparation properties of coordination compound is called co-ordination chemistry.



POINTS TO REMEMBER:

1. Coordination compounds

Coordination compounds are compounds in which a central metal atom or ion is linked to a number of ions or neutral molecules by coordinate bonds or which contain complex ions.

Examples- $K_4[Fe(CN)_6]$; $[Cu(NH_3)_4]SO_4$; $Ni(CO)_4$

2. The main postulates of Werner's theory of coordination compounds

- i) In coordination compounds metals show two types of linkages or valencies- Primary and Secondary.
- ii) The primary valencies are ionisable and are satisfied by negative ions.
- iii) The secondary valencies are non- ionisable and are satisfied by neutral molecules or negative ions. The secondary valence is equal to the C.N and is fixed for a metal.
- iv) The ions or groups bound by secondary linkages to the metal have characteristic spatial arrangements corresponding to different coordination nos.

3. Difference between a double salt and a complex

Both double salts as well as complexes are formed by the combination of two or more stable compounds in stoichiometric ratio. However, double salts such as carnallite, $KCl.MgCl_2.6H_2O$, Mohr's salt, $FeSO_4.(NH_4)_2SO_4.6H_2O$, potash alum, $KAl(SO_4)_2.12H_2O$, etc. dissociate into simple ions completely when dissolved in water. However, complex ions such as $[Fe(CN)_6]^{4-}$ of $K_4[Fe(CN)_6]$, do not dissociate into Fe^{2+} and CN^- ions.

IMPOTANT TERMINOLOGY

(i) **Coordination entity:** It constitutes the central metal ion or atom bonded to a fixed number of ions or molecules represented within a square bracket.

(ii) **Central atom/ ion:** In a coordination entity, the atom/ion to which a fixed number of ions/groups are bound in a definite geometrical arrangement around it, is called the central atom or ion.

iii) **Ligands:** The neutral or negative ions bound to the central metal or

ion in the coordination entity. These donate a pair/s of electrons to the central metal atom /ion.

Ligands may be classified as-

- a) **Monodentate/Unidentate:** Ligands bound to the central metal atom/ion through a single donor atom. Ex- Cl^- ; H_2O ; NH_3 ; NO_2^- .
- b) **Didentate:** Ligates through two donor atoms. Ex- $\text{C}_2\text{O}_4^{2-}$ (ox); $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ (en)
- c) **Polydentate:** which ligates through two or more donor atoms present in a single ligand. Ex- $(\text{EDTA})^{4-}$
- d) **Chelating ligands:** Di- or polydentate ligands that uses two or more donor atoms to bind to a single metal ion to form ring- like complexes. (Ox); (edta)
- e) **Ambidentate ligand:** A ligand that can ligate through two different atoms, one at a time. Ex- NO_2^- ; SCN^-
- v) **Coordination number:** The no. of ligand donor atoms to which the metal is directly bonded through sigma bonds only. It is commonly 4 or 6.
- vi) **Counter ions:** The ionisable groups written outside the square bracket. Ex- K^+ in $\text{K}_4[\text{Fe}(\text{CN})_6]$ OR 3Cl^- in $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
- vii) **Coordination Polyhedron:** The spatial arrangement of the ligand atoms which are directly attached to the central metal atom/ion. They are commonly Octahedral, Square-planar or Tetrahedral
Oxidation number: The charge that the central atom would carry if all the ligands are removed along with their pairs of electrons shared with the central atom. It is represented in parenthesis.
- viii) **Homoleptic complexes:** Complexes in which a metal is bonded to only one kind of donor groups. Ex- $[\text{Co}(\text{NH}_3)_6]^{3+}$
- ix) **Heteroleptic complexes:** Complexes in which a metal is bonded to more than one kind of donor groups. Ex- $[\text{Co}(\text{NH}_3)_4 \text{Cl}_2]^+$

5. NAMING OF MONONUCLEAR COORDINATION COMPOUNDS

The principle of additive nomenclature is followed while naming the coordination compounds. The following rules are used-

- i The cation is named first in both positively and negatively charged coordination entities.
- ii The ligands are named in an alphabetical order before the name of the central atom/ion

- iii The name of the anionic ligands end in -o, those of neutral and cationic ligands are the same except aqua for H_2O , ammine for NH_3 , carbonyl for CO and nitrosyl for NO . these are placed within enclosing marks .
- iv When the prefixes mono, di, tri, etc., are used to indicate the number of the individual ligands in the coordination entity. When the names of the ligands include a numerical prefix, then the terms, bis, tris , tetrakis are used, the ligand to which they refer being placed in parenthesis.
- v Oxidation state of the metal in cation, anion, or neutral coordination entity is indicated by roman numeral in parenthesis.
- vi If the complex ion is a cation , the metal is same as the element.
- vii The neutral complex molecule is named similar to that of the complex cation.

6.NAMES OF SOME COMMON LIGANDS

NEGATIVE LIGANDS		CHARGE	NEUTRAL LIGANDS		CHARGE
CN-	Cyano	-1	NH_3	Ammine	0
Cl-	Chlorido	-1	H_2O	Aqua/aquo	0
Br-	Bromido	-1	NO	Nitrosyl	0

F ⁻	Fluoride	-1	CO	Carbonyl	0
SO ₄ ²⁻	Sulphato	-2	PH ₃	Phosphine	0
C ₂ O ₄ ²⁻	Oxalato	-4	CH ₂ -NH ₂ CH ₂ NH ₂	(1,2-Ethane diamine)	0
NH ₂ ⁻	Amido	-1	POSITIVE LIGANDS		
NH ₂ ⁻	Imido	-2	NH ₂ -NH ₃ ⁺	Hydrazinium	+1
ONO ⁻	Nitrito-O	-1	NO ⁺	Nitrosonium	+1
NO ₂ ⁻	Nitro	-1	NO ₂ ⁺	Nitronium	+1
NO ₃ ⁻	Nitrato	-1			
SCN ⁻	Thiocyanato	-1			
NCS ⁻	Isothiocyanato	-1			
CH ₂ (NH ₂)COO ⁻	Glycinato	-1			

-OH	Hydroxo	-1			
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