

## 8

## d and f block elements

### 8.1 d-block elements:

The elements in which the last electron enters the d-orbital of the atom are called d-block elements. All the elements belonging to this section are metals and are represented in table 8.1. This block consists of elements lying between s and p-blocks. The d-block elements are called transition elements. The transition elements consist of four rows or series: 3d-series ( $_{21}\text{Sc}$  to  $_{30}\text{Zn}$ ), 4d-series ( $_{39}\text{Y}$  to  $_{48}\text{Cd}$ ), 5d-series ( $_{57}\text{La}$  to  $_{80}\text{Hg}$ ), and 6d-series ( $_{89}\text{Ac}$  and is incomplete). Since electrons filled in 3d-orbital after 4s orbital so in periodic table first transition series starts from fourth period.

**Table 8.1**

d-block elements									
Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30
V 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48
La <sup>u</sup> 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80
Ac <sup>**</sup> 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Uun 110	Uuu 111	Cn 112

\* Lanthanides → 58–71

\*\* Actinides → 90–103

The transition elements are those elements which have partially filled d-subshells in their elementary form or in their common occurring oxidation states.

Although all elements are transition elements but Zn, Cd and Hg do not exhibit characteristic properties of transition elements as they do not have partly filled d-subshells in their elementary state or in their common occurring oxidation states.

### 8.1.1 Electronic Configuration of Transition Elements

The general electronic configuration for the atom of d-block is  $(n-1) d^{1-10} ns^{1-2}$ . The electronic configuration of first transition series elements is given in table 8.2.

**Table 8.2**

Element	Symbol	Atomic number	Electronic configuration
Scandium	Sc	21	[Ar] $3d^1 4s^2$
Titanium	Ti	22	[Ar] $3d^2 4s^2$
Vanadium	V	23	[Ar] $3d^3 4s^2$
Chromium	Cr	24	[Ar] $3d^5 4s^1$
Manganese	Mn	25	[Ar] $3d^5 4s^2$
Iron	Fe	26	[Ar] $3d^6 4s^2$
Cobalt	Co	27	[Ar] $3d^7 4s^2$
Nickel	Ni	28	[Ar] $3d^8 4s^2$
Copper	Cu	29	[Ar] $3d^{10} 4s^1$
Zinc	Zn	30	[Ar] $3d^{10} 4s^2$

It may be noted that the configuration of Chromium ( $3d^5 4s^1$ ) and copper ( $3d^{10} 4s^1$ ) are anomalous due to following reasons–

- Half filled and completely filled electronic configuration have extra stability associated with them.
- There is negligible energy difference between 3d and 4s subshells.

### 8.1.2 General Characteristics of Transition Elements–

The general characteristics of d-block elements are:

- (1) All elements are metals and conductor of heat and electricity.
- (2) Transition elements have similarity in properties mainly vertically.
- (3) They exhibit several oxidation states.
- (4) They show catalytic properties.
- (5) They have good tendency to form complex.
- (6) Most of them form coloured compounds.
- (7) Their compounds are generally paramagnetic in nature.
- (8) They form interstitial compounds.
- (9) They form alloys with other metals.
- (10) They are hard & brittle metals and have high melting and boiling points.

### 8.1.3 General Trends in Chemistry of Transition Elements

- 1. Atomic and Ionic radius–** It is defined as the distance between nucleus of atom or ion and outer most shell electron. For the elements of first transition series, the atomic radii decreases gradually from scandium to chromium but from chromium to copper it remains practically constant. However we know that the electrons enter the penultimate (last but one) shell and the added d-electrons screen the outermost s-electrons. As the number of d-electrons increases, the screening effect increases. This neutralises the effect of increased nuclear charge due to increase in atomic number and consequently, atomic radius remains almost unchanged.
- 2. Ionisation Energy:** It is defined as the energy required to remove an electron from outer most shell of an atom. As the transition elements involve the gradual filling of (n-1) d-orbitals, the effect of

increase in nuclear charge is partly cancelled by the increase in screening effect. Consequently the increase in ionisation energy along period of d-block element is very small. The lowest common oxidation state of 3d series transition metals is +2. The unusual high value of second ionization energy for Cr and Cu is due to extra stability of half-filled ( $d^5$ ) and completely filled ( $d^{10}$ ) electronic configurations of these elements.

- 3. Metallic Nature:** All the transition elements are metals. They exhibit all the characteristics of metals. They all have high density, hardness, high melting and boiling points, high tensile strength, ductility, malleability, high thermal and electrical conductivities and lustre. These elements are harder and more brittle than s-block elements. They have simple hexagonal close packed (hcp), cubic close packed (ccp) or body centred cubic (bcc) lattices which are characteristic of other metals.

The metallic character of transition elements is due to their relatively low ionisation energies and number of vacant orbitals in the outermost shell. The hardness of these metals suggests the presence of strong bonding (metallic bond) due to overlap of unpaired electrons between different metal atoms. Greater the number of unpaired d-electrons, greater is the number of bonds and therefore, greater is strength of these bonds. Cr, Mo and W have maximum number of unpaired electrons and therefore, these are very hard metals. The elements Zn, Cd and Hg do not have any unpaired electrons, therefore these are not very hard.

- 4. Oxidation States:** The transition metals exhibit a large number of oxidation states. The existence of the transition elements in different oxidation state means that their atoms can lose different number of electrons. This is due to the participation of inner (n-1)d electrons in addition to outer ns electrons because the energies of the ns and (n-1)d subshells are almost equal. The oxidation states exhibited by the transition elements of the first series are listed in table 8.3.

**Table 8.3 : Oxidation states of first series of transition elements**

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
no. of s-electron	2	2	2	1	2	2	2	2	1	2
no. of unpaired d-electron	1	2	3	5	5	4	3	2	0	0
oxidation states	+3	+2 +3 +4	+2 +3 +4 +5	+2 +3 +6	+2 +4 +5 +7	+2 +3	+2 +3	+2 +4	+1 +2	+2

The common oxidation states shown by different transition metals reveal the following facts:

- (1) Sc and Zn exhibit +3 and +2 oxidation state as in  $\text{Sc}^{+3}$  and  $\text{Zn}^{+2}$  ions show stable inert gas configuration and pseudo inert gas configuration.
- (2) Except Cu and Cr, the most common oxidation state of first row transition elements is +2 due to  $ns^2$  configurations.
- (3) In each group, the highest oxidation state increases with increase in atomic number, reaches a maximum in the middle and then starts decreasing. For example, for the first transition series the maximum oxidation state is shown by Mn. is +7
- (4) Generally transition elements are more stable in higher oxidation state mainly in fluorides and in oxides. It is due to lower atomic size and higher electronegativity.
- (5) In the +2 and +3 oxidation states, the bonds formed are mostly ionic. In the compounds of higher oxidation states, the bonds are essentially covalent.
- (6) The reactivity and acidity of compounds increases with increasing oxidation state. The oxides are ionic and basic in lower oxidation states. Example–

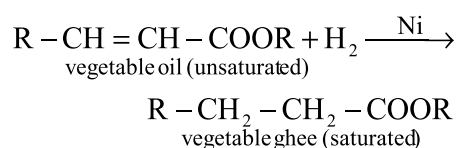
+2	+3	+4	+6	+7
TiO	$\text{V}_2\text{O}_3$		$\text{CrO}_3$	
MnO	$\text{Mn}_2\text{O}_3$	$\text{MnO}_2$	$\text{MnO}_3$	$\text{Mn}_2\text{O}_7$
basic	amphoteric		acidic	acidic

- (7) Transition metals also form compounds in low oxidation states such as zero (0) oxidation state. The common examples are  $[\text{Ni}(\text{CO})_4]$ ,  $[\text{Fe}(\text{CO})_5]$ ,  $[\text{Co}(\text{CO})_6]$ . where, oxidation state of Ni, Fe and Co is zero.

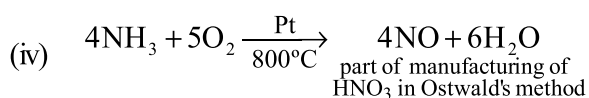
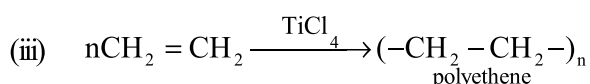
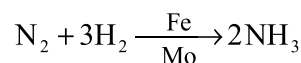
**5. Catalytic Properties:** Many transition metals and their compounds act as good catalysts for various reactions. Of these, the use of Fe, Co, Ni, V, Cr, Mn, Pt. etc. are very common. The main reasons for the catalytic activity of transition metals are:

- (i) The catalytic property of transition metals is due to their tendency to form reaction intermediates with suitable reactants. These intermediates provide reaction paths of lower activation energy and, therefore, increases the rate of the reaction. These reaction intermediates readily decompose yielding the products and regenerating the original substance. The transition metals form these reaction intermediates due to the presence of vacant orbitals or their tendency to form variable oxidation states.
- (ii) In some cases, the transition metals provide a suitable large surface area on which the reactants may be adsorbed and, therefore, come closer to one another for the reaction.

**(i) Formation of vegetable fats:**



**(ii) Synthesis of ammonia by Haber's process:**



**6. Colour–** The compounds of transition elements are usually coloured both in solid state and in

aqueous solution. In the transition elements which have partly filled d-orbitals and transfer of electrons can take place from  $t_{2g}$  orbitals to  $e_g$  orbitals within the same subshell. The energy required for this transition falls in the visible region. So when visible light falls on these compounds they absorb a particular colour from the radiation for the promotion of unpaired electron and the remaining colours are emitted. The ions in which all the d-orbitals are fully filled are colourless because d-d transition is not possible.

**7. Magnetic Properties**—Magnetic properties of transition element compound is mainly due to unpaired d-electrons. The origin of magnetic properties in a substance is due to two types of motion of electron.

- (i) orbital motion                      (ii) spin motion.

The magnetic moment ( $\mu$ ) of a compound is the addition of these two.

$$\mu = \mu^l + \mu^s \text{ B.M.}$$

Where  $\mu^l$  is orbital magnetic moment and  $\mu^s$  is spin magnetic moment. The electron itself behaves as a micromagnet. The unit of magnetic moment is B.M. i.e. Bohr magneton.

$$1\text{B.M.} = \frac{eh}{4\pi mc}$$

The total magnetic moment of a cation depends upon the number of unpaired electrons and is given by the following expression

$\mu = \sqrt{n(n+2)}$  where  $n$  is the number of unpaired electrons. on the basis of magnetic properties, substances are classified into the following three types:

- (i) **Diamagnetic materials**- The substances which are weakly repelled by the magnetic field are known as diamagnetic substances.



**Fig. 8.1 : Behaviour of diamagnetic materials in magnetic field**

- (ii) **Paramagnetic materials**- The substances which have permanent magnetic dipoles and are attracted by the magnetic field are known as paramagnetic substances. These consist of atoms, ions or molecules having one or more unpaired electrons.



**Fig. 8.2 : Behaviour of Paramagnetic materials in magnetic field**

- (iii) **Ferromagnetic substances**- The substances which are strongly attracted by the magnetic field and show permanent magnetism even when the magnetic field is removed are known as ferromagnetic substances. Once such a material is magnetised, it remains magnetised permanently.

**8. Interstitial Compounds**- The transition elements are capable of entrapping smaller atoms of other elements such as H, C and N in the interstitial sites in their crystal lattices. These trapped atoms get bonded to the atoms of transition elements. The presence of these atoms results in decrease in malleability and ductility of the metals, but increases their tensile strength. For example, steel and cast iron are hard due to presence of trapped carbon in the interstitial spaces.

**9. Alloy Formation**- Transition metals form a large number of alloys. For example, manganese dissolves in molten iron to form manganese steel. Such alloys are hard, have high melting points and are more resistant to corrosion than parent metals. The transition metals are quite similar in size and therefore, the atoms of one metal can substitute the atoms of other metal in its crystal lattice. Thus, on cooling a mixture solution of two or more transition metals, solid alloys are formed.

## 8.2 f-Block elements

The elements in which the last electron enters the f-orbital of the atoms are called f-block elements. In these elements, the last electron is added to the third to the outer most (called antepenultimate) energy level i.e.

(n-2)f. The general configuration of f-block elements is—

$$(n-2)f^{1-14} (n-1)d^{0-1} ns^2$$

These elements are also called inner-transition elements. They consists of two series of elements placed at the bottom of the periodic table. These two series are generated by the filling of characteristic electrons in the 4f and 5f orbitals.

The series involving the filling of 4f-orbitals following lanthanum is called lanthanide series. The series involving the filling of 5f-orbitals is called actinide series. Both series consists of 14 elements.

**8.2.1 Lanthanides:** The series involving the filling of 4f orbitals is called lanthanides. There are fourteen elements in this series starting with cerium Ce (58) and ending with lutetium Lu (71). These elements occur very rarely and therefore, these elements have also been called rare earth elements. All Lanthanide elements collectively represented by the symbol 'Ln'.

**8.2.2 Electronic Configuration of Lanthanides:** The commonly accepted electronic configurations of the lanthanides are given in table 8.4.

**Table 8.4**

Symbol	Element	Atomic number	Outer electronic configuration	Oxidation states
La	Lanthanum	57	[Xe] 4f <sup>0</sup> 5d <sup>1</sup> 6s <sup>2</sup>	+3
Ce	Cerium	58	[Xe] 4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	+3, +4
Pr	Praseodymium	59	[Xe] 4f <sup>3</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3, +4
Nd	Neodymium	60	[Xe] 4f <sup>4</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3, +4
Pm	Promethium	61	[Xe] 4f <sup>5</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3
Sm	Samarium	62	[Xe] 4f <sup>6</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+2, +3
Eu	Europium	63	[Xe] 4f <sup>7</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+2, +3
Gd	Gadolinium	64	[Xe] 4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup>	+3
Tb	Terbium	65	[Xe] 4f <sup>9</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3, (+4)
Dy	Dysprosium	66	[Xe] 4f <sup>10</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3, +4
Ho	Holmium	67	[Xe] 4f <sup>11</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3
Er	Erbium	68	[Xe] 4f <sup>12</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+3
Tm	Thulium	69	[Xe] 4f <sup>13</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+2, +3
Yb	Ytterbium	70	[Xe] 4f <sup>14</sup> 5d <sup>0</sup> 6s <sup>2</sup>	+2, +3
Lu	Lutetium	71	[Xe] 4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup>	+3

- (i) The lanthanides involve the gradual filling of 4f-orbitals. The general electronic configuration is [Xe]4f<sup>0-14</sup>, 5d<sup>0-1</sup>, 6s<sup>2</sup> means the valence shell configuration of these elements is 4f<sup>0-14</sup>, 5d<sup>0-1</sup>, 6s<sup>2</sup>.
- (ii) It is clear from the above table that La has the electronic configuration [Xe] 5d<sup>1</sup>, 6s<sup>2</sup>. In the succeeding 14 elements, 14 electrons are successively added to the 4f-subshell. The single

5d-electron shifts to the 4f-subshell in all cases except in gadolinium (Z = 64) where such a shift gives the symmetry of half filled 4f-subshell and in lutetium (Z = 71) where the 4f-subshell has already been completely filled.

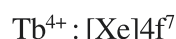
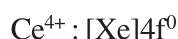
**Oxidation State:** All lanthanides exhibit a common stable oxidation state of +3. In addition, some lanthanides show +2 and +4 oxidation states also. These



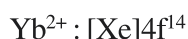
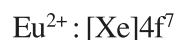
are shown by those elements which by doing so attain the stable  $f^0$ ,  $f^7$  and  $f^{14}$  configurations.

#### Example–

- (i) **Ce and Tb exhibit +4 oxidation state:** Cerium (Ce) and Terbium (Tb) attain  $f^0$  and  $f^7$  configurations respectively when they get +4 oxidation state, as shown below:



- (ii) **Eu and Yb exhibit +2 oxidation states:** Europium and Ytterbium get  $f^7$  and  $f^{14}$  configurations in +2 oxidation state as shown below:



- (iii) **La, Gd and Lu exhibit +3 oxidation states:** These elements show +3 oxidation states only because by losing three electrons, they acquire stable configurations of empty, half-filled and completely filled 4f-subshells.

#### 8.2.3 Chemical Reactivity–

All the lanthanides are highly electropositive metals and have almost similar chemical reactivity. This is due to the fact that the lanthanides differ only in the number of 4f-electron. +3 oxidation state is stable state of these elements so the chemical reactivity is mainly based on  $\text{Ln}^{3+}$  ions.

- (i) **Reducing property-** Lanthanide elements are readily oxidised by the loss of three electrons and behaves as strong reducing agent.



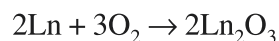
- (ii) **Electropositive character-** Since lanthanides readily give electrons indicates that they are highly electro positive and metallic in character.

- (iii) **Reaction with water–** All react with water slowly in cold but rapidly on heating liberating hydrogen and forming  $\text{Ln}(\text{OH})_3$ .



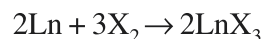
Basicity of hydroxides decreases from Ce to Lu.

- (iv) **With oxygen–** All burn in air to form oxides of the formula  $\text{Ln}_2\text{O}_3$ .

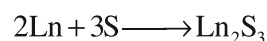
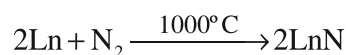


- (v) **With hydrogen–** All these combine with hydrogen at 300–400° C to form  $\text{LnH}_3$  and also  $\text{LnH}_2$  is non stoichiometric.

- (vi) **With halogen–** Lanthanides, form tri halides when react with halogen.



- (vii) **With non-metals–** Lanthanides form binary compounds when heated strongly with carbon, nitrogen and sulphur.



#### 8.2.4 Lanthanide Contraction-

**Atomic or ionic radii and lanthanide contraction :** In the lanthanide series, with increasing atomic number, the atomic and ionic radii decrease from one element to another but the decrease is very small.

The steady decrease in atomic and ionic sizes of lanthanide elements with increasing atomic number is called lanthanide contraction.

In the lanthanide series, as we move from one element to another, the nuclear charge increases by one unit and one electron is added. The new electrons are added to the same inner 4f-subshells. However, the 4f-electrons shield each other from the nuclear charge quite poorly because of the very diffused shapes of the f-orbitals. The nuclear charge however increases by one at each step. Hence with increasing atomic number and nuclear charge, the effective nuclear charge experienced by each 4f-electron increases. As a result, the whole of 4f-electron shell contracts at each successive element, though the decrease is very small. This results in gradual decrease in size of lanthanides with increase in atomic number. The sum of the successive reductions gives the total lanthanide contraction.

**Consequences of lanthanide contraction:** The important consequences of lanthanide contraction are:

- (1) **Resemblance of second and third transition series**– It has significant effect on the relative properties of the elements before and after the lanthanides in the periodic table. As we can see that there is regular increase in size from Sc to Y to La.

However after the lanthanides, the increase in radii from second to third transition series almost vanishes. The pairs of elements : Zr–Hf, Nb–Ta, Mo–W, etc., possess almost the same size. The properties of these elements are also very similar. As a result of lanthanide contraction, the elements of second and third transition series resemble each other much more than the elements of first and second transition series.

- (2) **Similarity among lanthanides**– Because of very small change in radii of lanthanides, their chemical properties are quite similar. Thus, it is very difficult to separate the elements in pure state. Recently, methods based on repeated fractional crystallization or ion exchange technique, which take the advantage of slight differences, in their properties (like solubility, complex ion formation, hydration, etc.) arising from very slight size differences of their trivalent ions have been used.

- (3) **Basicity difference**– Due to lanthanide contraction, the size of lanthanide ions decreases regularly with increase in atomic number. As a result of decrease in size, their covalent character between lanthanide ion and  $\text{OH}^-$  ions increases from  $\text{La}^{3+}$  to  $\text{Lu}^{3+}$ . Therefore, the basic strength of the hydroxides decreases with increase in atomic number. Thus,  $\text{La}(\text{OH})_3$  is most basic while  $\text{Lu}(\text{OH})_3$  is the least basic.

### 8.2.5 Uses of lanthanide elements–

The alloys of lanthanides with other metals find large number of applications in industries. Some common uses of lanthanides and their compounds are listed below:

- (i) **Mischmetal**, an alloy which contains rare earth elements (94-95%), iron (5%) and traces of sulphur, carbon, silicon, calcium and aluminium. The main rare earth elements present in this alloys are cerium (50%), lanthanum (25%) and smallest

amount of neodymium. It is pyrophoric and is used in cigarette and gas lighters, flame throwing tanks, tracer bullets and shells.

- (ii) An alloy containing magnesium and about 3% mischmetal is used in jet engine parts.
- (iii) Ceric sulphate,  $\text{Ce}(\text{SO}_4)_2$  is used as oxidising agent in volumetric analysis.
- (iv) Cerium salts are also used in dyeing cotton, in lead accumulators and also as catalysts.
- (v)  $\text{La}_2\text{O}_3$  is used in Crookes lenses, which give protection from ultra-violet light by absorbing it.
- (vi) Many lanthanide oxides are used as phosphors in colour TV tubes.
- (vii)  $\text{CeO}_2$  is used to polish glass.

### 8.2.6 Actinides

The series of elements involving the filling of 5f-orbital is called actinide series. They come just after actinium (Ac -89) and include 14 elements from Th (90) to Lr(103). They are placed just below the lanthanide series due to following reasons :-

- (i) Very much similarity in properties
- (ii) Similar electron configurations like lanthanides and
- (iii) Less places available in main periodic table.

Like lanthanides, electrons are filled in (n-2)f of these actinides. It means that in these elements also the three shells are partly filled. So these are also called 'inner transition element'. So Lanthanides are called elements of first inner transition series and actinides are called elements of second inner transition series.

After uranium (92) all elements are unstable and does not found in nature. These are also called transuranic elements or super heavy elements.

All actinides are radioactive generally represented by the symbol An and their stability decreases with increasing atomic number.

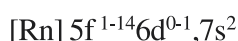
### Electronic Configuration–

The actinides involves the filling of 5f-subshell. Actinium has the electronic configuration  $6d^1 7s^2$ . From thorium (Z=90) onwards, 5f orbitals get progressively

filled, because of almost equal energy of 5f and 6d subshells. The electron may enter either of these two subshells. Therefore, there is a doubt whether thorium contains 5f electrons or not and two electronic configurations are suggested for this:



Because of these uncertainties, different workers suggested different configurations. The widely accepted electronic configurations of these elements are given in Table 9.12. The general electronic configurations of actinides may be written as:



**Table 8.5 : Electronic configuration of Actinides**

Atom	Element	Symbol	Electronic Configuration
89	Actinium	Ac	$[\text{Rn}] 5f^0, 6d^1, 7s^2$
90	Thorium	Th	$[\text{Rn}] 5f^0, 6d^2, 7s^2$
91	Proactinium	Pa	$[\text{Rn}] 5f^2, 6d^1, 7s^2$
92	Uranium	U	$[\text{Rn}] 5f^3, 6d^1, 7s^2$
93	Neptunium	Np	$[\text{Rn}] 5f^4, 6d^1, 7s^2$
94	Plutonium	Pu	$[\text{Rn}] 5f^6, 6d^0, 7s^2$
95	Americium	Am	$[\text{Rn}] 5f^7, 6d^0, 7s^2$
96	Curium	Cm	$[\text{Rn}] 5f^7, 6d^1, 7s^2$
97	Berkelium	Bk	$[\text{Rn}] 5f^9, 6d^0, 7s^2$
98	Californium	Cf	$[\text{Rn}] 5f^{10}, 6d^0, 7s^2$
99	Einsteinium	Es	$[\text{Rn}] 5f^{11}, 6d^0, 7s^2$
100	Fermium	Fm	$[\text{Rn}] 5f^{12}, 6d^0, 7s^2$
101	Mendelevium	Md	$[\text{Rn}] 5f^{13}, 6d^0, 7s^2$
102	Nobelium	No	$[\text{Rn}] 5f^{14}, 6d^0, 7s^2$
103	Lawrencium	Lr	$[\text{Rn}] 5f^{14}, 6d^1, 7s^2$

### 8.2.7 Differences between Lanthanides and Actinides–

Lanthanides	Actinides
1. Lanthanides show mainly +3 oxidation state except in few cases where it is +2 and +4	1. In addition to +3 oxidate state, actinides also show higher oxidation state such as +4, +5, +6, +7.
2. Except promethium, these are non radioactive	2. All the actinides are radioactive
3. They do not form oxo ions	3. They do form oxo ions. Example $\text{UO}^+$ , $\text{UO}_2^+$ , $\text{PuO}_2^+$ etc.
4. The tendency to form complex is less	4. They have greater tendency to form complexes
5. Lanthanide compounds are less basic	5. Actinide compounds are more basic
6. Most of their trivalent ions are colourless	6. Most of their trivalent and tetravalent ions are coloured.

### Exercise Questions

#### Multiple choice answer questions :

- Highest oxidation state (+7) is shown by the element–  
 (a) Co (b) Cr  
 (c) Mn (d) V
- Number of unpaired electrons in  $\text{Fe}^{+2}$  is–  
 (a) 4 (b) 5  
 (c) 3 (d) 6
- In which compound, oxidation number of Fe is zero–  
 (a)  $\text{FeSO}_4$  (b)  $[\text{Fe}(\text{CO})_5]$   
 (c)  $\text{K}_4[\text{Fe}(\text{CN})_6]$  (d)  $\text{FeCl}_3$
- Which of the following has maximum magnetic moment–  
 (a)  $\text{V}^{3+}$  (b)  $\text{Cr}^{3+}$   
 (c)  $\text{Fe}^{+3}$  (d)  $\text{Co}^{3+}$



5. The general oxidation state of Lanthanide series is—  
 (a) +1 (b) +4  
 (c) +2 (d) +3
6. The increasing factor which cause Lanthanide contraction is—  
 (a) effective nuclear charge  
 (b) atomic number  
 (c) size of 4f orbital  
 (d) none of the above
7. An element which shows +4 oxidation state in Lanthanide series is—  
 (a) Ce (b) Lu  
 (c) Eu (d) Pm
8. Which one is diamagnetic—  
 (a)  $\text{Cu}^{2+}$  (b)  $\text{Zn}^{2+}$   
 (c)  $\text{Cr}^{2+}$  (d)  $\text{Ti}^{+2}$
9. Which element has the highest first ionisation potential—  
 (a) Ti (b) Mn  
 (c) Fe (d) Ni
10. Which ion have all electrons in paired state—  
 (a)  $\text{Cr}^{+2}$  (b)  $\text{Cu}^{+2}$   
 (c)  $\text{Cu}^{+1}$  (d)  $\text{Ni}^{+2}$

### Very short answer questions

11. Explain why Zn is not considered as transition element?
12. Explain why  $\text{Ti}^{+4}$  ion is colourless.
13. Define transuranic elements.
14. Explain why any metal shows highest oxidation state only in oxides and fluorides?
15. Arrange  $\text{MnO}$ ,  $\text{Mn}_2\text{O}_3$ ,  $\text{MnO}_2$  in decreasing order of acidity.
16. Write general electronic configuration of Inner transition elements.
17. Why do the transition elements show variable oxidation states.
18. All compounds of Sc are colourless. Explain.
19. What will be the number of unpaired electrons in Gd ( $Z = 64$ ).
20. The magnetic moment of a compound of transition metal is 3.9BM. Write number of unpaired electrons.

### Short answer questions—

21. Describe Lanthanide contraction.
22. What is mischmetal? write its one use.
23. Write electronic configuration of  $\text{Cu}^{+2}$  ion. Calculate its magnetic moment.
24. Explain why transition metals generally form coloured compounds.
25. Account for the following—  
 (a) Mn shows maximum oxidation state in 3d series of transition elements.  
 (b) The outer electronic configuration of  $\text{Cr}^{+2}$  &  $\text{Mn}^{+3}$  is  $d^4$  but  $\text{Cr}^{+2}$  is reducing agent and  $\text{Mn}^{+3}$  is oxidising.
26. Explain  
 (a) The atomic radii of 5d transition elements are very similar to 4d transition elements.  
 (b) Transition elements form complex compounds.
27. Give four differences of Lanthanide and Actinide series.
28. Give reason why Zr(40) and Hf(72) have almost same atomic radius.
29. Give reason why Au(79), Ag(47) have almost same Ionization potential.
30. Determine magnetic moment of Mn in  $\text{KMnO}_4$ .

### Answers (Multiple Choice Questions)

1. (c) 2. (b) 3. (b) 4. (c)
5. (d) 6. (a) 7. (a) 8. (b)
9. (b) 10. (c)

