d and f Block Elements IIT JEE Notes PDF

d and f block elements IIT JEE notes pdf helps students to have a quick revision before the exam. These notes also help students to save a lot of time right before their exams. We provide all the important points in the d and f block elements IIT JEE notes pdf. Students are recommended to go through the d and f block elements IIT JEE notes pdf, so that they do not miss any important points.

Table of Contents

The elements that can be found from the third group to the twelfth group of the modern periodic table are called d-block elements. The valence electrons of these elements fall under the d orbital. D-block elements are also called transition elements or transition metals because they exhibit transitional behaviour between s block and p block elements. In d-block elements, the valence shell has a constant number of electrons, whereas the number of electrons in the penultimate shell goes on increasing. Elements that have at least one unpaired electron in their d orbital in atomic or any oxidation state are called transition elements. All transition elements are d-block elements, but all d-block elements are not transition elements.

Series of transition elements are given below.
First series: These are called 3d series of elements. They are classified in the 4th period. Atomic numbers are from 21 to 30 (Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn).

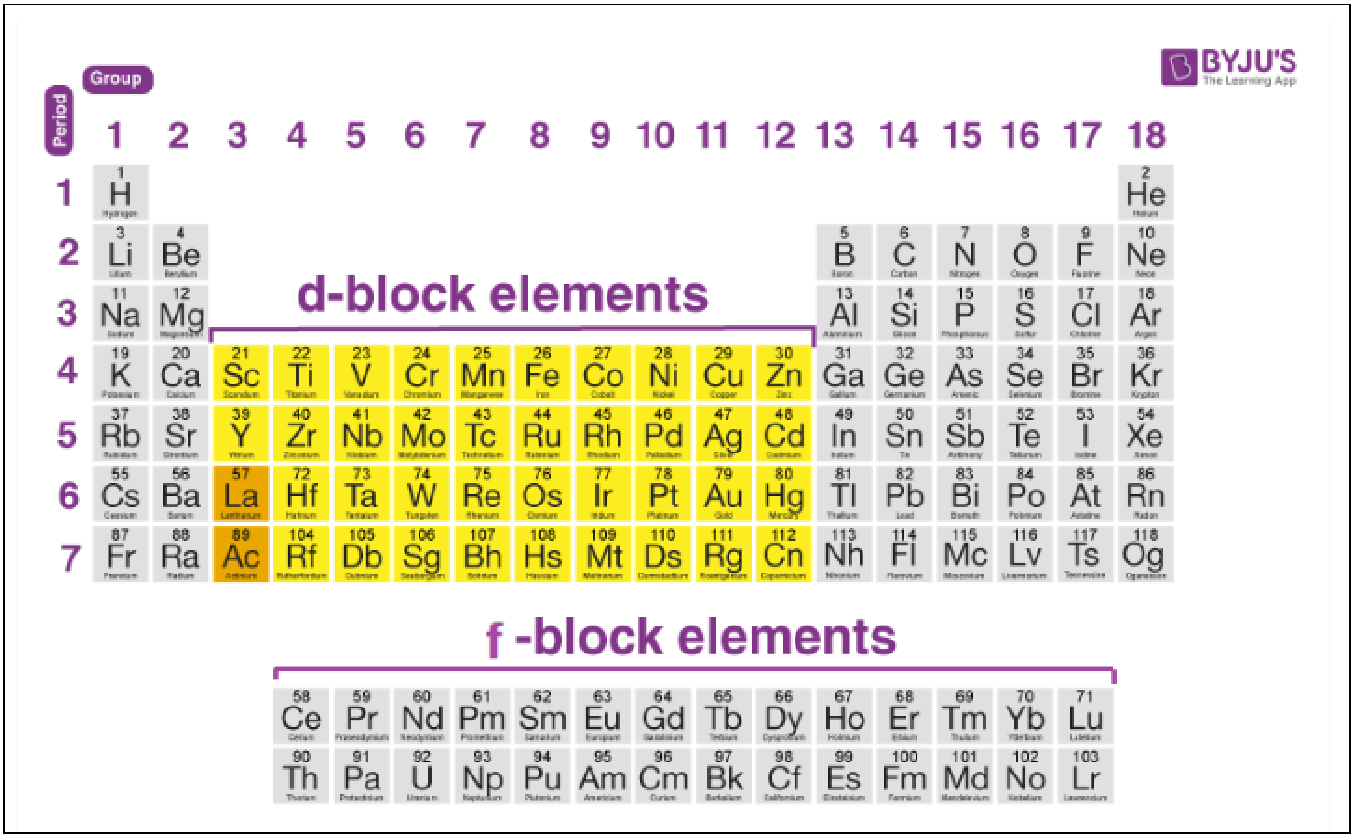
Second series: These are called 4d series of elements. They are classified in the 5th period. Atomic numbers are from 39 to 48 (Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd).

Third series: These are called 5d series of elements. They are classified in the 6th period. Atomic numbers are 57, 72 to 80 (La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg).

Fourth series: These are called 6d series of elements. They are classified in the 7th period. Atomic numbers are 89, 104 to 112 (Ac, Ku to Uub). This is an incomplete series.

General electronic configuration
General configuration for d-block elements is $(n-1)d^{1-10}\ ns^{1-2}$.
Here, (n-1) denotes the penultimate shell, the d orbital may have 1 to 10 electrons, and the s orbital of the ultimate shell (n) may have 1 to 2 electrons.

d-block elements



General Properties of d-block Elements

- Except copper, all the elements of the 3d series are good reducing agents.
- Due to the shielding effect, the ionisation potential of transition elements increases by negligible amounts.
- The reactivity of transition elements is less. The reactivity decreases with increasing atomic number.
- The atomic radii of transition elements decrease by negligible amounts due the shielding of valence shell electrons, provided by the electrons of d orbitals of the penultimate shell.

Metallic character

All the transition elements are metallic in nature. All of them have simple ccp, hcp or bcc lattices. A metallic bond is quite strong due to its greater effective nuclear charge and a large number of valence electrons. These are hard and possess high densities and high enthalpies of atomisation. Due to the presence of free electrons, these are good conductors of heat and electricity. The order of conductivity is Ag > Cu > Au > Al.

Density

The atomic volume of the transition elements is low compared to the s block. Their density is comparatively high. Os and Ir have the highest density. All the d-block elements, except Sc Y and Ti, have densities greater than 5gm cm^{-3}.

In all the groups there is a normal increase in density from 3d to 4d series and from 4d to 5d it increases just double it is due to lanthanide contraction. That means, due to a double increase in atomic mass, the density of 5d elements is nearly twice that of 4d elements. Ti<Zr<<Hf.

In 3d series

Sc→ Cr density increases.

Mn, Fe, Co Ni → almost constant

Cu → Zn decreases

In the 3d series, Cu has the highest density and Sc has the lowest density.

Melting point and boiling point

Due to a stronger metallic bond and the presence of a covalent bond formed by unpaired d electrons, the melting point and boiling point of d-block are greater than s block elements. There is no unpaired electron present in the d orbital of Zn, Cd and Hg. So due to the absence of a covalent bond, their melting point and boiling point are very low.

In 3d series,

Sc → Cr melting point and boiling point increase

Mn → Zn melting point and boiling point decrease

Atomic size

Atomic radii depend on effective nuclear charge Z_{eff} and screening effect.

Ionic radii and atomic radii of d-block elements are smaller than s block elements.

In 3d series,

Sc → Cr radius decreases

Mn → Ni radius remains constant

Cu → Zn radius increases

Characteristic properties of transition metals

- Formation of alloys
- Variable oxidation state
- Coloured ions
- Paramagnetic properties
- Formation of interstitial compounds
- Catalytic properties
- Formation of complexes

Formation of alloy

The reactivity of transition elements is very less and their sizes are almost similar. Because of this, a transition metal atom in the lattice can be easily replaced by other transition metal atoms, and hence they have a maximum tendency to form alloys. These are hard and have a high melting point.

Variable oxidation states

(a) They exhibit variable valency due to the involvement of (ns) and (n-1)d electrons in bonding. This is because of less energy difference between these electrons.

(b) For transition elements, the highest oxidation state can be calculated using the formula n+2, where n is the number of unpaired electrons. (this is not used for Cr and Cu).

(c) The transition metals having stable configurations are stable.

(d) Most common oxidation state among the transition elements is +2.

(e) In an aqueous medium, Cr^{+3} is stable.

(f) Co^{+2} and Ni^{+2} are stable.

(g) The common oxidation state shown by elements Sc, Y, La and Ac is +3 since their divalent compounds are highly unstable.

(h) Highest oxidation state shown by transition elements of 4d and 5d series is +8. Ruthenium and Osmium are the elements showing this oxidation state.

(i) In the lower oxidation state transition elements form ionic compounds and in the higher oxidation state their compounds are covalent.

(j) Usually higher oxidation states are shown in the compounds that are formed with highly electronegative elements like O and F.

(k) They also show zero oxidation state in their carbonyl compounds like $Ni(CO)_4$.

(l) Transition metal ions in their lower oxidation state act as reducing agents. Ti^{+2}, V^{+2}, Fe^{+2} etc are reducing agents.

(m) Transition metal ions in their higher oxidation state act as oxidising agents. Cr^{+6}, Mn^{+7}, Mn^{+4} etc are oxidising agents.

Colour Property:

Due to the presence of unpaired electrons in their d orbitals, most of the transition metal ions show the colour property. They need only a small amount of energy to excite electrons. Hence, they absorb and emit light in the visible region. Ti^{+2}[Ar]d^2, V^{+2}[Ar]$3d^3$ etc. These have unpaired electrons in their d orbitals. Hence they are coloured.

Transition metals which do not have any unpaired electrons in their d orbitals ($3d^0$ and $3d^{10}$ configuration) do not show any colour property. For example, Sc^{+3}[Ar]$3d^0$, Cu^{+1}[Ar]$3d^{10}$ are colourless ions.

Potassium permanganate $KMnO_4$ (dark pink), $K_2Cr_2O_7$ (orange) have d^0 configuration because of the charge transfer spectrum. The below table shows coloured metal ions.

Ni^{+2}	Green
Cu^{+2}	Blue
Co^{+2}	Blue
Fe^{+2}	Pale green
Ti^{+3}	Purple

Magnetic properties

Diamagnetic substance is one that is slightly repelled by a magnetic field. Paramagnetism is because of the presence of unpaired electrons in atoms or ions. Since most of the transition metals have unpaired electrons in their d orbitals, they are paramagnetic in nature. Those metal ions having $3d^0$ and $3d^{10}$ configurations show a diamagnetic nature.

The magnetic moment due to the spinning of unpaired electrons can be found by using the equation $\mu = \sqrt{(n(n+2))}$.

Here n denotes the number of unpaired electrons in the metal ion. μ is the magnetic moment in Bohr magnetons. For diamagnetic substances, the magnetic moment will be zero. When the number of unpaired electrons increases, the magnetic moment also increases, and thus the paramagnetic nature increases. Transition metal ions with d^5 configuration have the maximum number of unpaired electrons, and hence they have maximum paramagnetic nature.

Catalytic property

Transition elements show catalytic properties because of their variable valency and free valencies on their surfaces. The catalytic properties exhibited will be greater when the transition elements are in a powdered state. This is because of the greater surface area in the powdered state. Transition metals and their compounds exhibiting catalytic properties in various processes are given below.

(a) V_2O_5 is used in the contact process for the manufacture of H_2SO_4.

(b) Fe is used in Haber's process for the manufacture of NH_3.

(c) Ni is used in the hydrogenation of oils.

(d) $FeSO_4$ is used in the oxidation of Benzene with H_2O_2.

(e) Cu is used in the dehydrogenation of alcohols.

(f) $TiCl_4$ is used as a catalyst in Vinyl polymerisation.

(g) Pt is used in Ostwald's process of nitric acid.

Important Alloys

Bronze	Cu (75-90%) + Sn(10 – 25%)
Gun metal	(Cu + Zn + Sn) 87:3:10
Bell metal	Cu (80%) + Sn (20%)
Alnico	Al, Ni, Co
Type metal	Pb +Sn +Sb
Brass	Cu (60-80%) + Zn(20 – 40%)
Nichrome	Ni + Cr + Fe

1. Alloys of steel

(a) Vanadium steel – V (0.2-1%)

(b) Chromium steel – Cr (2-4%)

(c) Nickel steel – Ni (3-5%)

(d) Manganese steel – Mn (10-18%)

(e) Stainless steel Cr (12-14%) and Ni (2-4%)

(f) Tungsten steel – W (10-20%)

(g) Invar – Ni (36%)

2. Magnalium – Mg (10%) + Al (90%)

3. Duralumin – (Al + Mn + Cu)

4. Artificial Gold – Cu (90%) + Al (10%)

5. Constantan – Cu (60%) + Ni (40%)

6. 14 carat gold – 54% Au +Ag(14 to 30%) + Cu (12-28%)

7. 24 Carat Gold – 100% Au

8. Solder – Pb + Sn

Percentage of carbon in different types of iron

Name	Percentage of carbon
Wrought iron	0.1 to 0.25
Steel	0.25 to 2.0
Cast iron	2.6 to 4.3
Pig iron	3.5 to 4.6

Formation of Interstitial Compounds

Transition elements react with elements like nitrogen, hydrogen, boron, etc to form interstitial compounds. The smaller sized atoms get trapped in between the interstitial spaces of the metal lattices. These interstitial compounds are non-stoichiometric in nature. So they cannot be given any definite formula. Weak Vander Waals forces of attraction are responsible for holding smaller sized elements in interstitial spaces of transition elements. The interstitial compounds have the same chemical properties as the parent metals. But they differ in physical properties, such as hardness and density.

Physical and chemical properties

The physical and chemical properties of the interstitial compounds are as follows.

- These compounds are chemically inert in nature.
- These compounds have very high melting points (Greater than that of the parent transition metals).
- These compounds are very hard.
- The conductivity exhibited by them is similar to their parent metal.

Non stoichiometry

Non-stoichiometry is shown by transition metal compounds of group 16 elements. The transition elements form non-stoichiometric compounds because of variable valency. These compounds are of indefinite proportion and structure. Non-stoichiometry is caused by a defect in the solid structure.

f Block Elements

f block elements are also called inner transition elements. The elements in which the electrons enter in (n-2)f orbitals are called the f block elements. The electronic configuration of f block elements is $(n\text{-}2)f^{(0-14)}(n\text{-}1)d^{(0-1)}ns^2$.

Position of F block elements

F block elements are placed separately at the bottom of the periodic table. They are a subset of the 6th and 7th periods.

Properties of F block elements

(a) Properties are similar to d-block elements.

(b) f block elements have electrons added to the f sub-orbitals of (n-2) level.

Lanthanides

They are called lanthanides because the elements in the series are chemically similar to lanthanum. These are reactive elements. So these are not found in nature in the free state.

Lanthanides are non-radioactive (except for promethium, which is radioactive).

Properties of Lanthanides

(a) Lanthanides are good conductors of electricity and heat.

(b) They have melting points ranging from 1000K to 1200K (Samarium is an exception, 1623K).

(c) These are soft metals with a silvery-white colour.

(d) When exposed to air, their brightness reduces rapidly and their colour dulls.

(e) A decrease in atomic and ionic radii from lanthanum to lutetium is observed. This is called the lanthanoid contraction.

(f) They are non-radioactive in nature except for Promethium.

Actinides

The second series of elements are called actinides. These are elements with atomic numbers starting from 89 and ending at 103. These elements are radioactive in nature.

Properties of Actinides

(a) Actinides have a radioactive nature.

(b) These elements appear to be silvery.

(c) A decrease in atomic and ionic radii from Actinium to Lawrencium is seen. This is known as the actinoid contraction.

(d) These metals usually exhibit an oxidation state of +3. Elements belonging to the first half of the series are known to exhibit higher oxidation states.

(e) These metals are highly reactive. The reactivity increases when they are finely divided.

The following table shows the difference between lanthanides and actinides.

Lanthanides	**Actinides**
Lanthanides are non-radioactive in nature except promethium.	All actinides are radioactive.
The paramagnetic properties of lanthanides can be easily explained.	This is difficult in the case of actinides.
Lanthanides are involved in the filling of 4f-orbitals.	Actinides are involved in the filling of 5f-orbitals.
The compounds formed by lanthanides are less basic.	The compounds of actinides are highly basic.
Lanthanides do not have a tendency to form oxo-cations.	Oxo-cations of actinide series exist.
Less reactive than actinides.	More reactive.

Similarities between Lanthanides and Actinides

The lanthanides and actinides are characterized by filling of (n-2) f subshell. They have almost similar outermost electronic configurations. Thus, they exhibit similar properties.

Following are some similarities:

(a) They are involved in the filling of (n-2) f orbitals.

(b) Lanthanides and actinides have a prominent oxidation state of +3.

(c) Lanthanides and actinides are highly electropositive and very reactive in nature.

(d) They show magnetic properties.

(e) As the atomic number increases, there is a decrease in atomic and ionic size.

Lanthanide Contraction

The gradual decrease in the atomic and ionic size of lanthanoids with an increase in atomic number is called lanthanide contraction.

The gradual decrease in the size of the ions and atoms of the lanthanoids with increasing atomic numbers from lanthanum (atomic number 57) to lutetium (atomic number 71) is termed as lanthanide contraction. For every consecutive atom, the nuclear charge can be more positive by a single unit, followed by the corresponding increase in the electron count present in the 4f orbitals surrounding the nucleus. The 4f electrons imperfectly protect each other from the increased positive charge of the nucleus. This results in a steady rise in the effective nuclear charge attracting every electron as the lanthanide elements progress, resulting in a decrease in ionic and atomic radii.

Consequences of lanthanide contraction

(a) Difficulty in the separation of Lanthanides:

Since there is only a small change in the ionic radii of the Lanthanides, their chemical properties are the same. Thus, it becomes difficult to separate the elements in the pure state.

(b) Atomic Size:

The size of the atom of the third transition series is almost similar to that of the atom of the second transition series. For example, the radius of Nb = radius of Ta.

(c) Electronegativity:

It increases from the elements La to Lu.

(d) Effect on the Basic Strength of Hydroxides

The size of the lanthanides decreases from the elements La to Lu. Then the covalent character of the hydroxides increases. Hence, their basic strength decreases. So $Lu(OH)_3$ is said to be the least basic, and La $(OH)_3$ is more basic.

(e) Ionization Energy

The Ionization energy of the 5d elements is much larger compared to 4d and 3d. In the 5d series, the total elements except Pt and Au contain a filled s-shell. Elements from Hafnium to rhenium have similar Ionization energy, and after that, the Ionization energy increases with the number of shared d-electrons, such that Gold and Iridium have the maximum Ionization Energy.

Solved Examples

Question 1:

Why do d-block elements form complexes?

a) Due to large size and high nuclear charge.

b) Due to small size and low nuclear charge.

c) Due to small size and high nuclear charge.

d) None of the above

Solution:

The d-block elements are smaller in size and have high electropositive density, and they consist of (n-1)d free orbitals to accept the free electrons from the ligand, and they form complexes easily.

Hence option c is the answer.

Question 2:

The catalytic activity of the transition metals and their compounds is described by

a) their chemical reactivity.

b) their magnetic behaviour.

c) their unfilled d-orbitals.

d) their ability to adopt multiple oxidation states and their complexing ability.

e) None of the above

Solution:

The catalytic activity of the transition metals and their compounds is described by their ability to adopt multiple oxidation states and their complexing ability. Catalysis at a solid surface involves the formation of bonds between reactant molecules and atoms of the surface of the catalyst. This increases the concentration of the reactants at the catalyst surface and also weakens the bonds in the reacting molecules. Since the transition metal ions can change their oxidation states, they become more effective as catalysts.

Hence option d is the answer.

Question 3:

Which of the following is not correct about transition metals?

a) Their compounds are generally coloured.

b) They can form ionic or covalent compounds.

c) Their melting and boiling points are high.

d) They do not exhibit variable valency.

Solution:

Transition elements exhibit variable valency. The high melting points of these metals are attributed to the involvement of a greater number of electrons from (n-1)d in addition to the ns electrons in the interatomic metallic bonding. They show variable valency due to the presence of vacant d-orbitals.

Hence option d is the answer.

Question 4:

Carbon content of

a) steel is in between those of cast iron and wrought iron.

b) cast iron is in between those of steel and wrought iron.

c) wrought iron is in between those of steel and cast iron.

d) steel is higher than that of pig iron.

Solution:

Cast iron contains 2.2 to 4.4% of carbon. Wrought iron contains 0.1 to 0.25% of carbon. Steel contains 0.25 to 2% of carbon. The carbon content of steel is in between those of cast iron and wrought iron.

Hence option a is the answer.

Question 5:

Formation of coloured ions by transition metals signifies

a) absorption of light from UV range.

b) emission of light.

c) presence of unpaired electrons in s and p-orbitals.

d) complementary colours to the absorbed light.

Solution:

Coloured compounds of transition elements are associated with partially filled (n-1)d orbitals. The transition undergoes electronic unpaired d- electrons undergo an electronic transition from one -d-orbital to another. During this d-d transition process, the electrons absorb certain energy from the radiation and emit the remainder of energy as coloured light. The colour of the ion is complementary to the colour absorbed by it. Hence, the coloured ion is formed due to the d-d transition, which falls in the visible region for all transition elements.

Hence option d is the answer.

Practice Problems

Question 1. Which one of the following statements is not true with regard to transition elements?

a) They readily form complex compounds.

b) They show variable oxidation states.

c) All their ions are colourless.

d) Their ions contain partially filled d-electrons.

Question 2. The actinides exhibit more number of oxidation states in general than the lanthanides. This is because

a) the 5f-orbitals are more buried than the 4f-orbitals.

b) there is a similarity between 4f and 5f-orbitals in their angular part of the wave function.

c) the actinoids are more reactive than the lanthanoids.

d) the 5f-orbitals extend further from the nucleus than the 4f-orbitals.

Question 3. Identify the incorrect statement among the following.

a) d-block elements show irregular and erratic chemical properties among themselves.

b) La and Lu have partially filled d-orbitals and no other partially filled orbitals.

c) The chemistry of various lanthanoids is very similar.

d) 4f and 5f-orbitals are equally shielded.

Question 4. Irons exhibit + 2 and + 3 oxidation states. Which of the following statements about iron is incorrect?

a) Ferrous oxide is more basic in nature than the ferric oxide.

b) Ferrous compounds are relatively more ionic than the corresponding ferric compounds.

c) Ferrous compounds are less volatile than the corresponding ferric compounds.

d) Ferrous compounds are more easily hydrolysed than the corresponding ferric compounds.

Question 5. Mohr salt is made up of which combination of salt?

a) Ammonium sulphate and potash

b) Ammonium sulphate and ferrous sulphate

c) Ammonium sulphate and copper sulphate

d) Ammonium sulphate and magnesium sulphate

Question 6. Mercury is a liquid metal because

a) it has a completely filled s-orbital.

b) it has a small atomic size.

c) it has a completely filled d-orbital that prevents d-d overlapping of orbitals.

d) it has a completely filled d-orbital that causes d-d overlapping.

Question 7. Pick out the correct statements from the following.

I. Cobalt (III) is more stable in octahedral complexes.

II. Zinc forms coloured ions or complexes.

III. Most of the d-block elements and their compounds are ferromagnetic.

IV. Osmium shows (VIII) oxidation state.

V. Cobalt (II) is more stable in octahedral complexes.

a) I and II

b) I and III

c) II and IV

d) I and IV

e) II and V

Question 8. Due to lanthanide contraction

a) Fe, Co, Ni have equal sizes.

b) Zr and Hf have equal sizes.

c) all f-block ions have equal sizes.

d) all isoelectric ions have equal sizes.

Question 9. In the context of lanthanoids, which of the following statements is not correct?

a) There is a gradual decrease in the radius of the members with increasing atomic number in the series.

b) All the members exhibit a +3 oxidation state.

c) Because of similar properties the separation of lanthanoids is not easy.

d) Availability of 4f-electrons results in the formation of compounds in + 4 state for all members of the series.

Question 10. The point of dissimilarity between lanthanides and actinides is

a) three outermost shells are partially filled.

b) they show an oxidation state of + 3 (common).

c) they are called inner-transition elements.

d) they are radioactive in nature.

Frequently Asked Questions

What are d-block elements?

The elements which are present in the middle of the periodic table between s-block and p-block elements (i.e elements between groups 2 and 13) are known as d-block elements. They are also called transition elements.

Give 4 general characteristics of transition elements.

Transition elements have high melting points and boiling points. They have high densities and hardness. They form paramagnetic compounds. They also form coloured compounds.

What are Lanthanides and Actinides?

Lanthanides are elements from atomic numbers 58 to 71. They are known as lanthanides because lanthanum, the first element in the group, exhibits identical chemical properties. The actinides are elements with atomic numbers from 89 to 103. They are radioactive. They are named after actinium, the first element in the series.

Why do transition elements show variable oxidation states?

The transition elements show variable oxidation states because of the incompletely filled d-orbitals and the presence of unpaired electrons (ns) and (n -1) d electrons have almost equal energies.

Define lanthanide contraction.

The gradual decrease in the atomic and ionic size of lanthanoids with an increase in atomic number is called lanthanide contraction.