

# Electronic Configuration of the d-block Elements

Are you tired of learning the [Periodic Table](#)? Isn't it confusing to remember all the properties of all the elements? We understand how difficult it must be for you! However, we have grouped similar elements into blocks. In this chapter, we will study the [Electronic configuration](#) of the d-block elements. This will make it easier for you to understand and remember the various properties and configurations of the elements that belong to this group.

## Electronic Configuration of the d-Block Elements

The elements which lie in the middle of the Group II A elements and the Group II B elements in the present day periodic table are the d block elements. The d-block elements may also be known as [Transition Elements](#) as they are elements which lie between the metals and non-metals of the periodic table.

Group Period →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	* 72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	* 89 Ac	* 104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
				* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
				* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

(Source: Wikipedia)

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- [Position in the Periodic Table](#)
- [Some Applications of d and f-block elements](#)
- [Some Important Compounds of Transition Elements](#)
- [The Actinoids](#)
- [The Lanthanide](#)
- [General Properties of the Transition Elements \(d-block\)](#)

## Electronic Configuration

Electronic configuration of an element is characterized as an arrangement of **electrons** in the orbital. Orbitals s, p, d, and f are the

four chief nuclear orbitals. These orbitals ought to be filled by the number of electrons and the **energy** level of the orbital. We can arrange the four **orbitals** by their energy level as  $s < p < d < f$ . As indicated by Aufbau's principle the most reduced energy orbital ought to be filled first.

The s orbital can get two electrons while p, d and f orbitals can hold 6, 10 and 14 electrons separately. Generally, the electronic configuration of these elements is  $(n-1) d^{1-10} ns^{1-2}$ . The  $(n-1)$  remains for the inward d orbitals which may have one to ten electrons and the peripheral ns orbital may have one or two electrons.

The d block includes the middle area marked by s and p blocks in the periodic table. The very name “transition” given to the elements of d-block is simply because of their position amongst the s and p block elements. The d-orbitals of the penultimate energy level in their atoms get electrons leading to the three columns of the transition metals, i.e., 3d, 4d and 5d. The fourth line of 6d is still inadequate. These series of the transition elements are displayed in **figures** beneath.

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**The d and f – block Elements**

- [The Lanthanide](#)
- [The Actinoids](#)
- [Some Important Compounds of Transition Elements](#)
- [Position in the Periodic Table](#)
- [General Properties of Transition Elements \(d-block\)](#)
- [Some Applications of d and f block Elements](#)

Be that as it may, this speculation has a few special cases as a result of extremely low energy contrast between  $(n-1)d$  and  $ns$  orbitals.

Moreover, half and totally filled arrangements of orbitals are moderately more stable.

An outcome of this figure is mirrored the electronic configurations of Cr and Cu in the 3d series. Consider the instance of Cr, for instance, which has  $3d^5 4s^1$  rather than  $3d^4 4s^2$ ; the energy gap between the two sets (3d and 4s) of orbitals is sufficiently little to anticipate electron entering the 3d orbitals. Also in the event of Cu, the configuration is  $3d^{10} 4s^1$  and not  $3d^9 4s^2$ .

Learn more about [S Block elements here](#).

1st Series of Electronic Configuration

So, we sum up the external configuration of first-line transition elements as  $4s^23d^n$ . In any case, we already know that chromium and copper don't follow this example. This is a result of very low energy distinction between the 3d shell and 4s shell. It is tentatively found that half and totally filled arrangements of orbitals are more stable.

On account of the elements like chromium and copper, the energy contrast between the orbitals is very less. Therefore, it can't keep the electrons entering in the d shell. The electronic configuration of the d-block elements in the advanced periodic table can be composed as displayed in the table beneath:

### 2<sup>nd</sup> Series of Electronic Configuration

The electronic configuration of the d-block elements in the second series is as follows:

Atomic number	Symbol	Configuration
39	Y	$5s^2 4d^1$
40	Zr	$5s^2 4d^2$
41	Nb	$5s^1 4d^4$
42	Mo	$5s^1 4d^5$
43	Tc	$5s^1 4d^6$
44	Ru	$5s^1 4d^7$
45	Rh	$5s^1 4d^8$
46	Pd	$5s^0 4d^{10}$
47	Ag	$5s^1 4d^{10}$
48	Cd	$5s^2 4d^{10}$

### 3rd Series of Electronic Configuration

The electronic configuration of the d-block elements in the third series is as follows:

Atomic number	Symbol	Configuration
57	La	$6s^2 5d^1$
72	Hf	$6s^2 5d^2$
73	Ta	$6s^2 5d^3$
74	W	$6s^2 5d^4$
75	Re	$6s^2 5d^5$
76	Os	$6s^2 5d^6$
77	Ir	$6s^2 5d^7$
78	Pt	$6s^1 5d^9$
79	Au	$6s^1 5d^{10}$
80	Hg	$6s^2 5d^{10}$

### 4th Series of Electronic Configuration

Zn, Cd and Hg have their orbitals completely filled both in their ground state and in their common **oxidation** states. We can represent it as  $(n-1) d^{10} ns^2$ . So, they are not referred to as transition elements.

Atomic number	Symbol	Configuration
89	Ac	$7s^2 6d^1$
104	Rf	$7s^2 6d^2$
105	Db	$7s^2 6d^3$
106	Sg	$7s^2 6d^4$
107	Bh	$7s^2 6d^5$
108	Hs	$7s^2 6d^6$
109	Mt	$7s^2 6d^7$
110	Ds	$7s^2 6d^8$
111	Rg	$7s^2 6d^{10}$
112	Uub	$7s^2 6d^{10}$

## Solved Examples For You

Question 1: Why are d block elements coloured?

Answer: Compounds of transition elements that are coloured are related with somewhat incompletely filled  $(n-1) d$  orbitals. The transition metal particles containing unpaired d-electrons experience electronic transition starting with one d-orbital then onto the next. Amid this d-d transition **phenomenon**, the electrons ingest certain energy from the radiation and transmit the rest of energy as coloured light. The shade of particle is reciprocal of the shading consumed by

it. Consequently, the coloured **particle** is framed because of d-d transition which falls in the visible area for all transition **components**.

Question 2: Write a note on the melting and boiling points of transition metals.

Answer: Transition metals usually have a very high value of melting and boiling points due to the presence of strong metallic bonds. Zn, Cd and Hg metals have lower melting and boiling points. This is mainly because they have completely filled d orbitals because of which no unpaired electron is available. Because of unavailability of unpaired electrons, these metals do not undergo covalent bonding. Rest of the transition metals does have metallic as well as covalent bonding. **Metals** towards the middle of each transition series have the highest melting point.

## Position in the Periodic Table

The d and f Block elements in the groups of 3 to 11 are also called as **transition elements** and inner transition elements respectively. 4f and 5f orbitals of f-block elements are steadily in later of two long periods. Based on this they are differentiated in lanthanides and actinides. The



d block elements which are transition elements have partially filled  $(n-1)$  d-orbitals. The position in the periodic table of an element is highly reflective of its properties and [nature](#). Let us learn more about the position in the periodic table.

## Position in the Periodic Table

Studying which elements lie in a particular group position in the periodic table, is significant to the understanding of such elements as a whole. There is a reason why we categorize different elements in the periodic table. The d and f block elements hold certain properties, which make them fall into the category. Let us study the d and f block elements' position in the periodic table.

d block										
	3	4	5	6	7	8	9	10	11	12
	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B
3d	21	22	23	24	25	26	27	28	29	30
4d	39	40	41	42	43	44	45	46	47	48
5d	71	72	73	74	75	76	77	78	79	80
6d	103	104	105	106	107	108	109	110	111	112

d and f  
block Elements

f block														
4f	57	58	59	60	61	62	63	64	65	66	67	68	69	70
5f	89	90	91	92	93	94	95	96	97	98	99	100	101	102

## d Block Elements in Modern Periodic Table

The d block position in the periodic table consists of elements in the group of 3 to 12. In this group, the d orbitals are filled progressively. The elements which are present between the s and p block elements in the modern periodic table are called the transition elements. Transition elements usually have partly filled  $(n-1)$  d-orbitals.

In the transition elements, the last electron usually enters the penultimate d orbitals i.e.  $(n-1)$  d orbitals and that is why they are called d-block elements in the modern periodic table. The general valence shell configurations of every transition elements are  $(n-1)d^{1-10}.ns^0, 1, 2$ .

All the d-block elements are classified into four series which are called 3d, 4d, 5d and 6d series corresponding to the filled outer shells of 3d, 4d, 5d, and 6d orbitals. Present in the center of the periodic table, the 'd' block elements lie in the middle of the s block elements on the left, and the non-metals of the p block, to its right.

Browse more Topics under The D And F Block Elements

- [Electronic configuration of the d-block elements](#)
- [Some Applications of d and f-block elements](#)
- [Some Important Compounds of Transition Elements](#)

- [The Actinoids](#)
- [The Lanthanide](#)
- [General Properties of the Transition Elements \(d-block\)](#)

## Transition Series of d Block Elements

The following are the transition series of the d block elements:

- First transition series or the 3d series: Those elements which have an [atomic number](#) from 21 to 30 are usually included in this series. Included in this series are ten elements which are Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn. They always correspond to the filling of the 3d subshell.
- Second transition series or the 4d series: Included in this series are the elements which have an atomic number from 39 to 48 and are Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, and Cd. All of these elements have a corresponding filling of the 4d subshell.
- Third transition series or the 5d series: Included in this [series](#) are elements that have an atomic number from 72 to 80 and 57.

- Fourth transition series or the 6d series: Elements which have an atomic number from 104 to 112 and 89 form the elements in this group.

## **f Block Elements in Modern Periodic Table**

The 'f' – block elements are also known by the name of inner transition elements. In these elements, the last electron usually enters the penultimate i.e.  $(n - 2)$  f of the orbital. The differentiating electron in transition elements may enter either 4f or 5f orbitals based upon which they are further differentiated into lanthanides and actinides.

In lanthanides, the differentiating electron enters the 4f orbital. These are cerium to lutetium. The name lanthanides fall on the elements because they arrive immediately after lanthanum. In the case of actinides, the differentiating electron enters the 5f orbitals. These are usually thorium to lawrencium.

These elements come immediately after actinium in the periodic table. The General electronic configuration of f – block elements is  $(n-2)f^{1-14}(n-1)d_{0-1}ns^2$ . In the case of Lanthanides, the electronic

configuration is  $[\text{Xe}]4f_{1-14}5d_{0-1}6s^2$  while in the case of Actinides it is  $[\text{Rn}]5f_{1-14}6d_{0-1}7s^2$

## Solved Examples for You

Question: Discuss the electronic configuration of the f block elements and the general characteristics of these elements.

Answer: The general electronic configuration of f-block elements can be written as:  $(n-2) f_{1-14} (n-1) d_{0-2} ns^2$ . The elements included in these two series are called the inner transition elements. It is so because they form transition series within the transition elements of d-block.

Among the general characteristics of the f block elements are the following:

- They are usually heavy [metals](#)
- These elements have a generally higher melting and boiling point
- They display a variety of oxidation states
- These elements tend to form coloured ions

- They form complex compounds

As for the characteristics of Actinoids and Lanthanoids, we can say the following:

- Lanthanoids are silvery white soft metals which tarnish readily when they face exposure to air.
- The hardness of lanthanoids increases with increasing atomic number.
- The melting and boiling points of **actinoids** are moderately high but they are considerably lower than those of transition elements.
- Actinoids show different oxidation state such as +2, +3, +4, +5, +6 and +7. However +3 **oxidation** state is most common among all the actinoids.

## Some Applications of d and f block Elements

Do you agree that the d and f block elements are the lesser known elements of the periodic table as compared to the other elements? Yet they find their use in various [industries](#). In this topic, we are going to learn about the numerous applications of d and f block elements. Let's find out what they are.

## Understanding the d and f block Elements

The d-block of the modern [periodic table](#) consists of elements of the groups 3 to 12 in which the orbitals consist of progressively in each of the four long periods. The elements constituting the f – block is those elements in which the 4 f and 5 f are progressively in the later of the two long periods.

These elements are actually formal members of the group three from which they have been taken out to form a separate f – block of the periodic table. The d – block elements acquire the name of [transition elements](#) as they represent a significant change in properties from highly electropositive s – block elements to the least electropositive [p – block elements](#).

Learn more about [D and F Block elements here in detail](#).

The transition metals are those elements which have filled incompletely d – subshells in their ground state or in any one of their oxidation state or in any compound form. Cu, Ag and Au are the most common transition metals because, in their commonly occurring states, they have partly filled d – subshells.

Zn, Cd and Hg of group 12 do not have partly filled d – subshell in their elementary state or commonly occurring oxidation state, and hence, are not considered as transition elements. However, being the end members their [chemistry](#) becomes understood with transition elements. The Electronic Configuration is  $(n-1)d^{1-10} ns^{1-2}$

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- [Position in the Periodic Table](#)
- [Some Important Compounds of Transition Elements](#)
- [The Actinoids](#)
- [The Lanthanide](#)
- [General Properties of the Transition Elements \(d-block\)](#)

## Applications of d and f Block Elements



## Uses of d Block Elements

- **Iron** and its amalgam, steel, are utilized broadly in the development industry.
- Titanium is as a part of the **manufacture** of airship and spaceship.
- Tungsten comes in use in making electrical fibres.
- Manganese dioxide comes in use as a part of dry battery cells.

- Zinc comes in use as the negative anode in fixed dry batteries.
- Niobium composites are perfect as a part of fly motors.
- Tantalum comes into use to make expository [weights](#).
- Silver bromide comes into use as a part of photography.
- Many d- block or transition metals and their compounds find their use as impetuses in the [chemical reactions](#).
- Palladium chloride comes into use in the Wacker process of oxidation of ethane to ethanol.
- Iron comes in use in the production of ammonia in Haber's process.
- Ziegler-Natta, a complex of trimethyl [aluminium](#) and titanium tetrachloride come into use in the polymerisation of ethene to polythene.

## Uses of f Block Elements

Some applications of the f block elements are:

- Lanthanide alloys (mischmetal) utilized for the creation of instrumental steels and heat resistance.

- Carbides, Borides, and nitrides of lanthanides come in use as refractories.
- Lanthanide oxides come in use in cleaning glass as abrasives.
- Thorium is a part of cancer treatment and glowing gas mantles.
- We utilize Uranium as an atomic fuel.
- Plutonium is a part of nuclear reactors and nuclear bombs.

## Solved Question for You

Q: Discuss some of the properties of the d block elements.

Ans: The elements with a halfway filled d-subshell are d-block elements. They also go by the name ‘transition elements’ because they form a transition between metals and non-metals. The d and f block contains both metals and non-metals. The transition elements can be either regular transition elements or the non-typical transition elements. The d – block has three arrangements, each of ten elements.

These arrangements are described by the totally filled 3d, 4d, and 5d subshells and are named as 3d – (first series) which include Sc – Zn,

4d arrangement (second series) which includes Y-Cd and the 5d arrangement (third series) which includes La-Hg separately.

There is a deficient fourth series comprising of just three elements in particular Ac, Ku, and Ha. In these elements, the 6d subshell begins to fill at Ac. Out of these, elements like iron, cobalt and nickel are used in making magnets.

## Some Important Compounds of Transition Elements

We come in contact with various transition [metals](#) on a daily basis, without even coming to realize the fact. For example, take iron. From ships and [buildings](#), iron is used even in the cutlery around us. Some of the important compounds of transition elements are also used in our daily lives in much the same manner. Let us take a look at some of the important compounds of transition elements and study their properties as well.

## Transition Elements

Main-group Elements		Transition Metals										Main-group Elements					
H																	
Li	Be															H	He
Na	Mg											B	C	N	O	F	Ne
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Al	Si	P	S	Cl	Ar
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Ga	Ge	As	Se	Br	Kr
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	In	Sn	Sb	Te	I	Xe
Fr	Ra	Ac	Rf	Ha	106	107	108	109				Tl	Pb	Bi	Po	At	Rn
Lanthanides		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
Actinides		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

(Source: Purdue University)

Transition metals are usually defined as those elements that have or can readily form partially filled ‘d’ orbitals. The d-block elements in the groups of 3 to 11 are known as transition elements. The f block elements are also called inner transition metals, which are also known as the lanthanides and actinides. They also meet this criterion because the d orbital is only partially occupied before the f orbitals.

The d orbitals are usually filled with the copper family which is the group 11 and for this reason, the next in the family which is group 12 is technically not defined as compounds of transition elements.

However, the group 12 elements surely display some of the same chemical properties and are commonly included in the discussions

related to transition metals. Some chemists, however, do treat the group 12 elements as transition metals.

The d-block elements are divided into the first transition series, which are the elements Sc through Cu, the second transition series which are the elements Y through Ag, and the third transition series which are the element La and the elements Hf through Au. Actinium, Ac, is the first member of the fourth transition series, which also includes Rf through Rg. The f-block elements are the elements Ce through Lu, which usually constitute the lanthanide series, and the elements Th through Lr, which **constitute** the actinide series.

Learn more about [Inner Transition Elements](#) in detail here.

Lanthanum behaves very much like the lanthanide elements, which is why it is considered a lanthanide element, even though its electron configuration makes it the first member of the third transition series. Similarly, the behaviour of actinium means that it is part of the actinide series, although its **electron** configuration makes it the first member of the fourth transition series.

## Transitions and Inner Transition Elements

## Compounds of Transition Elements

Ferrous Sulphate (Green Vitriol),  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

Hydrated and anhydrous  $\text{FeSO}_4$  is green and white in colour respectively. It is isomorphous with Epsom salt,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  and  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ . It effervesces on exposure to air. Like other ferrous salts, it takes up  $\text{HNO}_3$  forming brown coloured double compound,  $\text{Fe}(\text{NO})\text{SO}_4$ , nitroso ferrous sulphate.

It forms double salts with sulphates of alkali metals with general [formula](#)  $\text{R}_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$ . With ammonium sulphate, it forms a double salt known as ferrous ammonium sulphate or Mohr's salt,  $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ . It does not effervesce. It ionises in [solution](#) to give  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$  and  $\text{SO}_4^{2-}$  ions.

Ferric Oxide,  $\text{Fe}_2\text{O}_3$

Anhydrous salt is yellow, deliquescent compound and highly soluble in  $\text{H}_2\text{O}$ . On heating, it gives  $\text{FeCl}_2$  and  $\text{Cl}_2$ . Its aqueous solution is acidic due to hydrolysis.

Silver Nitrate,  $\text{AgNO}_3$

Silver nitrate forms precipitate with some salt solutions which help in the detection of acid radicals. It decomposes on heating.

Mercury (I) Chloride / Mercurous Chloride / Calomel, ( $\text{Hg}_2\text{Cl}_2$ )

It is a white **power** insoluble in water but soluble in **chlorine** water. On treatment with ammonia, it turns black due to the formation of finely divided mercury.

Mercury (II) Chloride  $\text{HgCl}_2$

It is a white crystalline solid sparingly soluble in cold water but soluble in hot water. Its solubility can be increased by adding  $\text{Cl}$ . When treated with  $\text{SnCl}_2$  it is reduced to mercury.

Mercury-II Iodide

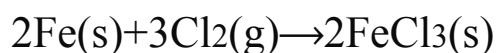
Mercuric iodide exists in two forms, i.e. red and yellow. The yellow form is stable above 400 K while the red form is stable below this temperature. An alkaline solution of  $\text{K}_2\text{HgI}_4$  is called Nessler's reagent and is used to detect the presence of  $\text{NH}_4^+$  with which it gives a brown precipitate due to the formation of iodide of Millon's base.

## Solved Examples for You

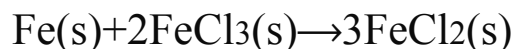


Question: Depict through chemical equations how the halides of transition elements react?

Answer: Anhydrous halides of each of the transition elements can be prepared by the direct reaction of the metal with halogens.



Heating a metal halide with additional metal can be used to form a halide of the metal with a lower oxidation state:



The preparation of stable water solutions of the halides of the metals of the first transition series is by the addition of a hydrohalic acid to carbonates, hydroxides, oxides, or other compounds that contain basic anions.  $\text{NiCO}_3\text{(s)} + 2\text{HF(aq)} \longrightarrow \text{NiF}_2\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$

## The Actinoids

How many elements can you name? You know just **nitrogen**, **oxygen**, **carbon**? That's it? What about actinoids? Do you know what these

are? If not, don't panic, we are here to clear your doubts regarding these new set of elements. Let's learn about not-so-known elements.

## Actinoids

Actinoids or actinides are 15 consecutive chemical elements in the periodic table from actinium to lawrencium (atomic numbers 89-103). As a group, they are significantly large because of their [radioactivity](#). Although several members of the group, including uranium (the most familiar), occur naturally, most are man-made.

Both uranium and plutonium have been used in atomic weapons for their explosive power and currently are being employed in nuclear plants for the production of [electrical power](#).

Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
↓ Period	The Periodic Table of the Elements																		
1	1 H																	2 He	
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba			72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra			104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
Lanthanides		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu			
Actinides		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr			

These elements are also called the actinide elements. However, the International Union of Pure and Applied Chemistry [IUPAC], the

International body in-charge of chemical nomenclature, prefers the term actinoid, since the ‘-ide’ ending is usually reserved for negatively charged ions.

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- [Electronic configuration of the d-block elements](#)
- [Position in the Periodic Table](#)
- [Some Applications of d and f-block elements](#)
- [Some Important Compounds of Transition Elements](#)
- [The Lanthanide](#)
- [General Properties of the Transition Elements \(d-block\)](#)

## Discovery

The first actinoids discovered were uranium in pitchblende ore by Klaproth in 1789 and Thorium by Berzelius in 1829. Actinium was discovered 1899 by André-Louis Debierne, an assistant of Marie Curie.

## Location in the Periodic Table

Actinoids form the bottommost row of the periodic table. They include fifteen elements starting from Actinium (Ac) and further include Thorium (Th), Protactinium (Pa), Uranium (U), Neptunium (Np), Plutonium (Pu), Americium (Am), Curium (Cm), Berkelium (Bk), Californium (Cf), Einsteinium (Es), Fermium (Fm), Mendelevium (Md), Nobelium (No), and Lawrencium (Lr).

## **Are all the actinoids found naturally?**

Actinium, thorium, protactinium, and uranium are the only actinoid elements found in nature to a significant extent. The remaining actinoid elements, commonly called the transuranic elements, are all man-made by bombarding naturally occurring actinoids with [neutrons](#) in reactors or with heavy ions in particle accelerators.

Thorium and uranium are the most abundant actinoids in nature with respective mass concentrations of 16ppm and 4 ppm. Uranium mostly occurs in the earth's crust as a mixture of oxides in the [minerals](#) uraninite also known as pitchblende because of its black colour. The abundance of actinium in the earth's crust is about  $5 \times 10^{-15}\%$ . Actinium is mostly present in uranium-containing, but also in other minerals, though in much smaller quantity.

## Characteristics

- Actinoids are typical metals. All of them are soft and have a silvery colour which tarnishes in air.
- They have relatively high density and [plasticity](#). Some of them can be cut with a knife.
- All actinoids are radioactive, paramagnetic with the exception of actinium, have several [crystalline](#) phases.
- All actinoids are pyrophoric, especially when finely divided, that is, they spontaneously ignite upon reaction with air.
- Together with radium and transuranic elements, actinium is one of the most dangerous radioactive poisons. The real danger with the actinoid elements lies in the radioactive properties of these elements. They are emitters of tissue-destroying and cancer producing rays (alpha, beta, or gamma radioactivity). Actinium can accumulate and remain in the surface layer of skeletons. Less than one-millionth of a gram of some actinoid isotope can be fatal.

## Valency

All actinoids, unlike lanthanides, are highly reactive with halogens. Thorium is rather active chemically owing to lack of electrons on 6d and 5f orbitals. Protactinium exhibits two valence states; the +5 is stable and the +4 state easily oxidizes to protactinium (V). Uranium has a valency from 3 to 6, the last being most stable.

Neptunium has valence states from 3 to 7, which can be simultaneously observed in solutions. Plutonium also exhibits valence states between 3 and 7 inclusive and thus is chemically similar to Neptunium and uranium. It is highly reactive and quickly forms an oxide film in air.

Americium shows the diversity from other actinoids by showing valency between 2 and 6. Valency 3 is dominant in all subsequent elements up to lawrencium with the exception of nobelium.

## Applications

- Actinide is mostly used in nuclear weapons and as a fuel in nuclear reactors. The most important isotope for nuclear power is uranium-235. This isotope strongly absorbs thermal neutrons releasing much energy. One fission act of 1 gram of uranium-235 converts into about 1 MW power.

- About half of the produced thorium is used as the light emitting material of gas mantles.

There is a challenge to develop stable and durable actinoid-bearing materials which provide safe storage, use, and final disposal.

## Solved Examples for You

Question: How are the actinoids extracted?

Answer: Owing to their low abundance, the extraction of actinoids is a complex and a multistep process. Fluorides of actinoids, which are reduced with calcium, magnesium or barium, are usually used because they are insoluble in water and can be easily separated by redox reactions. Among the actinoids, uranium and thorium are the easiest to extract.

## The Lanthanide

What according to you are the number of elements present in and around us? They are countable, but difficult to count them on fingers as there are 118 of them. Among these are certain hidden elements (in

the periodic table) like the lanthanides that cannot be ignored. Let us see the lanthanide elements are in detail.

## Lanthanides

Lanthanoids, also called lanthanides are 15 consecutive chemical elements in the periodic table from lanthanum to lutetium (atomic numbers 57–71). With scandium and yttrium, they make up the rare-earth metals. Their atoms have similar configurations and similar physical and chemical behaviour; the most common valencies are 3.

1																	18			
1	H																	2	He	
2	Li	Be																	10	Ne
3	Na	Mg																	18	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
<div>Lan</div> <div>Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu</div>																				

(Source: Wikimedia)

As the elements in the series are chemically similar to lanthanum, they are termed as lanthanoids. Even though these elements are called lanthanides, the International Union of Pure and Applied Chemistry



[IUPAC], the international body in charge of chemical nomenclature, prefers the term lanthanoid, since the ‘-ide’ ending is usually reserved for negatively charged ions.

Browse more Topics under The D And F Block Elements

- [Electronic configuration of the d-block elements](#)
- [Position in the Periodic Table](#)
- [Some Applications of d and f-block elements](#)
- [Some Important Compounds of Transition Elements](#)
- [The Actinoids](#)
- [General Properties of the Transition Elements \(d-block\)](#)

## Location in the Periodic Table

In the periodic table, two additional rows below the main body of the table as parts of the table's sixth and seventh row (periods) are the lanthanides and the actinides.

## Elements

The fifteen lanthanide elements start from Lanthanum (La) and further go with Cerium (Ce), Praseodymium (Pr), Neodymium (Nd),

Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and finally Lutetium (Lu).

## Characteristics

- The lanthanide metals are soft; their hardness increases across the series.
- Resistivity of the lanthanide metals is relatively high, ranging from 29 to 134  $\mu\text{Ohm}\cdot\text{cm}$ .
- The lanthanides are strongly paramagnetic. Gadolinium becomes ferromagnetic at below 16°C (Curie point). The other heavier lanthanides – terbium, dysprosium, holmium, erbium, thulium, and ytterbium – become ferromagnetic at much lower temperatures.
- Compared to most other nondietary elements, non-radioactive lanthanides are classified as having low toxicity.
- The lanthanides obey the Oddo-Harkins rule – odd-numbered elements are less abundant than their even-numbered neighbours.

## Oxidation States

All lanthanide elements commonly have the +3 oxidation state. All of the lanthanides can form +2 complexes in solution.

## Applications

- Nearly 15,000 tons/year of lanthanides is consumed as catalysts to produce glasses. These 15,000 tons correspond to about 85% of the lanthanide production.
- The optoelectronics applications use lanthanide ions as active ions in luminescent materials. The most notable application is the Nd: YAG laser. Erbium-doped fibre amplifiers are significant devices in optical-fibre communication systems. The television sets contain phosphors with lanthanide dopants. The earliest colour television CRTs had a poor-quality red; europium as a phosphor dopant made good red phosphors possible.
- TIG welding uses a mixture of lanthanide oxides tungsten to improve their high-temperature properties.
- Magnetic resonance imaging (MRI) uses the complex Gd (DOTA).

- Currently, lanthanides elements can also be used as anticancer agents as per research. The main role of the lanthanides in these studies is to inhibit proliferation of the cancer cells. Cerium and lanthanum have been especially studied for their role as anti-cancer agents.

The lanthanides have a low availability in the biosphere because of their sparse distribution in the earth's crust and low aqueous solubility.

## **Solved Examples for You**

Question: What are rare earth metals?

Answer: Lanthanides are 'rare earth' metals. However, the IUPAC disagrees with this term as the elements are neither rare nor earth.

## **General Properties of Transition Elements (d-block)**

We daily come across many transition elements. Tons of useful items, right from the kitchen cutlery, ships, to the jewellery have transition elements. Most abundantly found transition elements are iron and

titanium. To know more about these elements, let us have a closer look at their various properties.

## Transition Elements

Transition elements are those elements that have partially or incompletely filled  $d$  orbital in their ground state or the most stable [oxidation](#) state. The partially filled subshells of  $d$ -block elements incorporate  $(n-1)$   $d$  subshell. All the  $d$ -block elements carry a similar number of [electrons](#) in their furthest shell. Hence, they possess similar chemical properties.

## Placement of Transition Elements in the Periodic table

Metals										Nonmetals							Unknown chemical properties
Pre-transition metals	Rare earths		Transition metals	Poor metals	Metalloids	Core nonmetals	Noble gases										
	Actinides																
Group names**																	
1 Hydrogen & the alkali metals										14 Carbon Group							
2 Alkaline earth metals										15 Pnictogens							
11 Coinage metals (Cu, Ag & Au)										16 Chalcogens							
12 Volatile metals										17 Halogens							
13 Boron Group										18 Noble gases							
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(Source: Wikimedia)

The transition elements are placed between S and P block elements. They are divided as first transition series (the elements from Sc to Cu), the second transition series (the elements from Y to Ag), and the third transition series (the element La and the elements from Hf to Au).

Actinium (Ac) is the first member of the fourth transition element series, which also consists elements from Rf to Rg. II- B Zn, Cd, and Hg and III- A Sc, Y, La, and Ac are non-typical transition elements while the remaining are typical transition elements.

## General Properties

All transition elements exhibit similar properties because of the identical **electronic configuration** of their peripheral shell. This happens as each additional electron enters the penultimate 3d shell. This creates an effective shield between the nucleus and the outer 4s shell. The peripheral shell configuration of these elements is  $ns^2$ . The general properties of the transition elements are as follows:

- form stable complexes
- Have high melting and boiling points
- Contain large charge/**radius ratio**
- Form compounds which are often paramagnetic
- Are hard and possess high densities
- Form compounds with profound **catalytic activity**
- Show variable oxidation states
- form coloured **ions** and compounds.

### Metallic Nature

As there is less number of electrons in the peripheral shell, all the transition elements are metals. They demonstrate the qualities of

metals, such as ductility and malleability they are excellent conductors of **electricity** and heat. Apart from Mercury, which is fluid and delicate like **alkali metals**, all the transition elements are hard and fragile.

### Melting and boiling points

They show high melting and boiling points. This is due to the overlapping of  $(n-1)d$  orbitals and covalent bonding of the unpaired  $d$  orbital electrons. Zn, Cd, and Hg have totally filled  $(n-1)d$  orbitals. They cannot form covalent bonds. Thus, they have a lower melting point than other  $d$ -block elements.

### Ionic Radii

The transition elements are highly denser than the  $s$  block elements. Their densities gradually decrease from scandium to copper because of an irregular decrease in metallic radii and a relative increase in atomic mass. The pattern of the ionic radius is same as that of the atomic radii pattern. Hence, for ions of a given charge, the ionic radius gradually decreases with an increment in atomic number.

### Ionization Potential



The ionization potential of transition elements lies between s and p block elements. They are less electropositive than the S-block elements. Henceforth, they do not form ionic compounds but covalent compounds. They possess high ionization energy because of their small size.

The ionization potential of *d*-block elements increases from left to right. The ionization energies of the primary transition elements increase with the increase in the nuclear number. For example, Cr and Cu have high energies than their neighbours.

### Electronic configuration

The external electronic configuration is consistent. There is a gradual filling of 3d orbitals across the series starting from scandium.

However, this filling is not regular, since, at chromium and copper, the population of 3d orbitals increases by acquiring an electron from the 4s shell. At chromium, both the 3d and 4s orbitals are occupied, but neither of the orbitals is completely filled. This indicates that the energies of the 3d and 4s orbitals are relatively close for atoms in this row. The electronic configurations of first, second, and third series elements are as follows:

First series:  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Second series:  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1-10 5s^2$

Third series:  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1-10 5s^2 4d^1-10 6s^2$

These three series of elements depend on the  $n-1$  d orbital that is being filled. An orbital of lower energy is filled first. Therefore, 4s orbital with lesser energy is filled first to its full degree. After 4s, the 3d orbital with higher energy is filled. The precisely, half-filled and totally filled d-orbitals are exceptionally stable.

### Oxidation state

All the transition elements, apart from the first and the last, display various oxidation states. There is an increase in the number of common oxidation states at first to a maximum toward the middle of the table, and then there is a decrease when we move from left to right across the first transition series.

The elements scandium through manganese (the first half of the first transition series), show the highest oxidation state as their valence shell shows loss of all of the electrons in both the *s* and *d* orbitals. Iron forms oxidation states from  $2+$  to  $6+$ . Elements in first transition series

form ions with a charge of  $2+$  or  $3+$ . The elements belonging to the second and third transition series generally are more stable in higher oxidation states than the elements of the first series. In general, as the atomic radius increases down a group, ions of the second and third series become larger than the ions in the first series.

## Solved Examples for You

Question: What are inner transition elements?

Answer: These are a group of elements in the periodic table which are normally shown in two separate rows below all the other elements. They consist elements 57-71 (lanthanides) and 89-103 (actinides).