Division of the Elements into s-, p-, d- and f-Block Elements

A careful examination of the electronic configurations of the elements reveals that they may be divided into four *sections* or *blocks* in the long form of the periodic table on the basis whether the last electron (also called *differentiating electron or extra electron or additional electron*) goes to *s*, *p*, *d* or *f* orbital. Thus the four blocks into which the elements in the long form of the periodic table can be divided are *s*-, *p*-, *d*- and *f*-blocks (See Table 3.2 given on page 190). For the purpose of this type of division of elements we consider only the orbital of the highest energy into which the last electron goes. This orbital may not always belong to the outermost shell.

1. s-Block Elements. In the atoms of these elements *the last electron enters the s-orbital of the ultimate (outermost) shell, i.e., the last electron goes to ns-orbital* where n denotes the number of the outermost shell or the number of the period. In other words, in these elements ns-orbital is being progressively filled. Hence the name *s-block elements*. Consequently, the valence shell electronic configuration of these elements varies from ns^1 to ns^2.

← Metals →

← Non-metals, Metalloids and Inert gases →

← p-Block elements →

← s-Block elements →

	IA	
1s	H 1	He 2 ← Inert gases

	IA	IIA
2s	Li 3	Be 4
3s	Na 11	Mg 12
4s	K 19	Ca 20
5s	Rb 37	Sr 38
6s	Cs 55	Ba 56
7s	Fr 87	Ba 88

d-Block elements

← III B →

5d	La 57
6d	Ac 89

← f-Block elements (Inner transition elements) →

4f	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
5f	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lw 103

← d-Block elements (Transition elements) →

	III B	IV B	V B	VI B	VII B	← VIII →			I B	II B
3d	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30
4d	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48
5d		Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80
6d		Ku 104	Ha 105	106	107	108	109	110	111	112

	III A	IV A	V A	VI A	VII A	Zero
2p	B 5	C 6	N 7	O 8	F 9	Ne 10
3p	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
4p	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
5p	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
6p	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86

from the electronic configurations of *s*-block elements that the principal quantum number (n) of the differentiating electron for these elements is equal to the period number in which these elements are present. The properties of *s*-block elements depend on the number of electrons present in *ns* orbital.

2. p-Block Elements. In the atoms of these elements *the last electron enters the p-orbital of the ultimate (outermost) shell, i.e. the last electron goes to np orbital.* (n = number of the outermost shell or period). In other words, in these elements *np*-orbital is being progressively filled. Hence the name *p-block elements*. In the atoms of these elements the *ns*-orbital is completely filled and hence the valence-shell configuration of these elements varies from ns^2p^1 to ns^2p^6. The elements of groups III A (B to TI), IVA (C to Pb), VA (N to Bi), VIA (O to Po), VII A (F to At) and zero (Ne to Rn) belong to this block, since the valence-shell configurations are ns^2p^1, ns^2p^2, ns^2p^3, ns^2p^4, ns^2p^5 and ns^2p^6 respectively. The elements of this block, like *s*-block elements, are also called *normal elements or representative elements*.

The valence-shell electronic configurations of p-block elements are given in Table 3.4.

Table 3.4. Valence-shell electronic configuration of p-block elements. The number given above the symbol of each element indicates the atomic number of the element.

Period number (n) and the orbital being filled	III A ns^2p^1	IV A ns^2p^2	VA ns^2p^3	VI A ns^2p^4	VII A ns^2p^5	Zero ns^2p^6
n = 2, 2p	5 B $2s^2p^1$	6 C $2s^2p^2$	7 N $2s^2p^3$	8 O $2s^2p^4$	9 F $2s^2p^5$	10 Ne $2s^2p^6$
n = 3, 3p	13 Al $3s^2p^1$	14 Si $3s^2p^2$	15 P $3s^2p^3$	16 S $3s^2p^4$	17 Cl $3s^2p^5$	18 Ar $3s^2p^6$
n = 4, 4p	31 Ga $3d^{10}4s^2p^1$	32 Ge $3d^{10}4s^2p^2$	33 As $3d^{10}4s^2p^3$	34 Se $3d^{10}4s^2p^4$	35 Br $3d^{10}4s^2p^5$	36 Kr $3d^{10}4s^2p^6$
n = 5, 5p	49 In $4d^{10}5s^2p^1$	50 Sn $4d^{10}5s^2p^2$	51 Sb $4d^{10}5s^2p^3$	52 Te $4d^{10}5s^2p^4$	53 I $4d^{10}5s^2p^5$	54 Xe $4d^{10}5s^2p^6$
n = 6, 6p	81 TI $4f^{14}.5d^{10}6s^2p^1$	82 Pb $4f^{14}.5d^{10}6s^2p^2$	83 Bi $4f^{14}.5d^{10}6s^2p^3$	84 Po $4f^{14}.5d^{10}6s^2p^4$	85 At $4f^{14}.5d^{10}6s^2p^5$	86 Rn $4f^{14}.5d^{10}6s^2p^6$

It may be seen from these configurations that the last electron goes into 2p orbital in B to Ne (2*nd* period, n = 2), into 3p orbital in Al to Ar (3*rd* period

The elements of group IA (H to Fr : *Alkali metals*), group II A (Be to Ra : *alkaline earth metals*) and He (zero group) belong to this block, since their valence-shell configuration is ns^1 and ns^2-respectively where n is the number of the period or the principal quantum number. The elements of this block are collectively known as *normal elements or representative elements.*

The valence-shell electronic configurations of s-block elements are given in Table 3.3.

Table 3.3. Valence-shell electronic configuration of s-block elements. The number given above the symbol of each element indicates the atomic number of the element.

Period number (n) and the orbital being filled	IA ns^1	IIA ns^2	Zero
n = 1, 1s	1 H $1s^1$		2 He $1s^2$
n = 2, 2s	3 Li $2s^1$	4 Be $2s^2$	
n = 3, 3s	11 Na $3s^1$	12 Mg $3s^2$	
n = 4, 4s	19 K $4s^1$	20 Ca $4s^2$	
n = 5, 5s	37 Rb $5s^1$	38 Sr $5s^2$	
n = 6, 6s	55 Cs $6s^1$	56 Ba $6s^2$	
n = 7, 7s	87 Fr $7s^1$	88 Rn $7s^2$	

It may be seen from these configurations (Table 3.3) that the last electron goes into 1s orbital in H and He (*1st period*, n = *1*) into 2s orbital in Li and Be (*2nd period*, n = *2*), into 3s orbital in Na and Mg (*3rd period*, n = 3), into 4s orbital in K and Ca (*4th period*, n = 4), into 5s orbital in Rb and Sr (*5th period*, n = 5), into 6s orbital in Cs and Ba (*6th period*, n = 6) and into 7s orbital in Fr and Ra (*7th period*, n = 7). Thus we see that s-block elements are located at the extreme left of the periodic table and consist of active metals. It may also be seen

= 3), into $4p$ orbital in Ga to Kr (4*th* period, $n = 4$), into $5p$ orbital in In to Xe (5*th* period, $n = 5$) and into $6p$ orbital in TI to Rn (6*th* period, $n = 6$). Thus the principal quantum number for these elements is equal to the period number in which these elements are present.

It may also be seen that *p*-block elements are located at the extreme right of the periodic table and consist of *metals, non-metals, metalloids* and *inert gases.*

The properties of p-block elements are determined by the number of electrons present in *np* orbitals. These elements have a general electronic configuration of the outermost shell as $ns^2.np^{1...6}$ where n stands for the number of the period.

3. d-Block Elements (Transition Elements). In these elements, either in their atomic state or in any of their common oxidation state, *the last electron enters the d-orbital of the penultimate (inner to ultimate) shell, i.e. the last electron goes to (n–1)d orbital.* In other words, in these elements $(n-1)d$ orbitals are being progressively filled. Hence the name ***d-block elements***. With the exceptions of Cr, Cu, Nb, Mo, Ru, Rh, Pd, Ag, Pt and Au, in the atoms of these elements the *ns*-orbital is completely filled (ns^2 configuration). Consequently, the valence-shell configuration of most of these elements varies from $(n-1)d^1.ns^2$ (Group III B) to $(n-1)d^{10}.ns^2$ (Group II B) configuration. The elements of groups III B, IV B, VB, VI B, VII B, VIII, I B and II B belong to this block as is evident from their valence-shell configurations given in Table 3.5.

These elements are located in the middle of the periodic table [*i.e.* between s (electropositive elements) and p-block (electronegative elements) elements] and consist of metals only. *d*-block elements are also called *transition elements,* since their properties are intermediate between those of *s* and *p*-block elements.

These elements are classified into *four series viz.* 3*d*, 4*d*, 5*d*, and 6*d* series corresponding to the filling of 3*d*, 4*d*, 5*d*, and 6*d* orbitals of 3rd (M-shell, $n = 3$), 4th (N-shell, $n = 4$), 5th (O-shell, $n = 5$) and 6th (P-shell, $n = 6$) shells respectively.

(*a*) **3d-series** (*1st transition series*). In the elements of this series 3*d* orbitals are being progressively filled up with electrons. This series has ten elements, beginning with Sc ($Z = 21$) and ending at Zn ($Z = 30$). The elements of this series lie in 4th period ($n = 4$).

(*b*) **4d-series** (*2nd transition series*). In the elements of this series 4*d* orbitals are being progressively filled up with electrons. This series also has ten elements, beginning with Y ($Z = 39$) and ending at Cd ($Z = 48$). The elements of this series lie in 5th period ($n = 4$).

(*c*) **5d-series** (*3rd transition series*). In the elements of this series 5*d* orbitals are being filled up with electrons. This series also has ten elements *viz.* La ($Z = 57$), Hf ($Z = 72$) to Hg ($Z = 80$). The elements of this series lie in 6th period ($n = 6$).

(*d*) **6d-series** (*4th transition series*). In the elements of this series 5*d* orbitals are being filled up with electrons. At present this series has three elements *viz.*

Ac (Z = 89), Ku (Z = 104) and Ha (Z = 105). The elements of this series lie in 7th period (n = 7) which is an incomplete period. It is expected that the elements with atomic number 106, 107, 108, 109, 110, 111 and 112 which are still to be discovered will be the members of 6*d* series, *i.e.* in these unknown elements the additional electron will enter 6*d* orbital.

All the transition elements are metals, since the number of electrons in the outer-most shell is very small, being equal to 2. They are hard, malleable and ductile and possess high tensile strength. They exhibit all the three types of structures *viz. face centred cubic (fcc), hexagonal close packed (hcp)* and *body centrered cubic (bcc).*

4. *f*-Block Elements (Inner-transition Elements). In these elements, either in their atomic state or in any of their common oxidation state, *the last electron enters the f-orbital of ante-penultimate (inner to the penultimate) shell i.e. the last electron goes to (n–2) f-orbital.* In other words, in these elements $(n-2)f$-orbitals are being progressively filled. Hence the name *f-block elements.* The valence shell electronic configuration of the atoms of these elements is represented as :

$$(n-2)\, f^{1...7,\, 9...14} \,.\, (n-1)d^{0,\,1} \,.\, ns^2$$ as shown in Table 3.6.

These elements are located in group III B and have been given a separate place at the bottom of the periodic table. *f*-block elements are also called *inner-transition elements* and are classified into two series *viz.* 4*f* and 5*f* corresponding to the filling of 4*f* and 5*f* orbitals of 4th (N-shell, $n = 4$) and 5th (O-shell, $n = 5$) shells respectively. (See Table 3.6).

(a) **4f-series.** (*1st inner transition series*). In the elements of this series, the extra electron enters 4*f* orbital, *i.e.* 4*f* orbitals are being progressively filled with electrons. This series has 14 elements beginning with Ce (Z = 58) and ending at Lu (Z = 71). The elements of this series lie in 6th period ($n = 6$) and are called *rare-earths or lanthanides or lanthanones.*

(b) **5f-series.** (*2nd inner transition series*). In the elements of this series, 5*f* orbitals are being progressively filled, *i.e.*, the extra electron goes to 5*f* orbital. This series, like 4*f* series, also has 14 elements beginning with Th (Z = 90) and ending at Lu (Z = 103). The elements of this series lie in *7th* period (incomplete period with $n = 7$) and are called *actinides or actinones.* The elements after U(Z = 92) are called *trans-uranic elements* which have been obtained as a result of atomic research. Thus *trans-uranic elements* are synthetic (man-made) elements.

Classification of Elements on the Basis of their Complete and Incomplete Electron Shells

There are four types of elements based on the presence of the complete and incomplete electron shells in them.

1. Noble Gases. *In the atoms of these elements the outermost shell which has ns^2p^6 configuration* (He which has $1s^2$ configuration is an exception) *is completely filled* (See Table 3.4). ns^2p^6 configuration is stable and hence these elements generally do not enter into ordinary chemical reactions. These elements are present in zero group of the periodic table.