6

General Characteristics of Transition Metals : *d*-Block Elements

Introduction

The elements from Sc_{21} to Zn_{30} (ten elements), Y_{39} to Cd_{48} (10 elements) La_{57}, Hf_{72} to Hg_{80} (ten elements), Ac_{89}, Ku_{104}, Ha_{105}, Unh_{106} etc. are called transition metals. Since the last electron in the atoms of these elements enters *d*-sub-shell belonging to penultimate shell. [*i.e.*, $(n-1)$th shell], these elements are also called *d*-block elements. Thus in these elements the last electron goes to $(n-1)d$ sub-shell.

Position of *d*-block elements in the periodic table

The position of *d*-block elements in the periodic table has been shown in Fig. 6.1. From this figure the following points may be noted:

(*i*) *d*-block elements lie in between *s*-and *p*-block elements, *i.e.*, these elements are located in the middle of the periodic table.

(*ii*) *d*-block elements are present in 4th (Sc_{21} to Zn_{30} = 10 elements), 5th (Y_{39} to Cd_{48} = 10 elements), 6th (La_{57}, Hf_{72} to Hg_{80} = 10 elements) and 7th (incomplete) period which contains 8 elements *viz.* Ac_{89}, Ku_{104} to Uun_{110}

(*iii*) *d*-block elements are present in IIIB (3), IVB (4), VB (5), VIB (6), VIIB (7), VIII (8, 9, 10), IB (11) and IIB (12) groups.

Electronic configurations and definition

The electronic configurations of the atoms of *d*-block elements are given in Table 6.1. In this table $[Ar]_{18}$, $[Kr]_{36}$, $[Xe]_{54}$ and $[Rn]_{86}$ indicate the electronic configurations of Ar, Kr, Xe and Rn respectively, which are given below:

$[Ar]_{18}$ = 2, 8, 8 (Three-shells) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

$[Kr]_{36}$ = 2, 8, 18, 8 (Four shells) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^6$

$[Xe]_{54}$ = 2, 8, 18, 18, 8 (Five shells)

$[Rn]_{86}$ = 2, 8, 18. 32, 18, 8 (Six shells)

The configurations given in Table 6.1 show that:

(*a*) *d*-block elements can be defined as those elements in which the last electron (differentiating electron) enters $(n-1)d$ orbitals (*i.e.*, *d*-orbitals of the penultimate shell) or in which $(n-1)d$ orbitals are progressively filled up with electrons.

(*b*) *d*-block elements are also defined as those elements whose two outer-most shells are incomplete (*i.e.*, partially-filled).

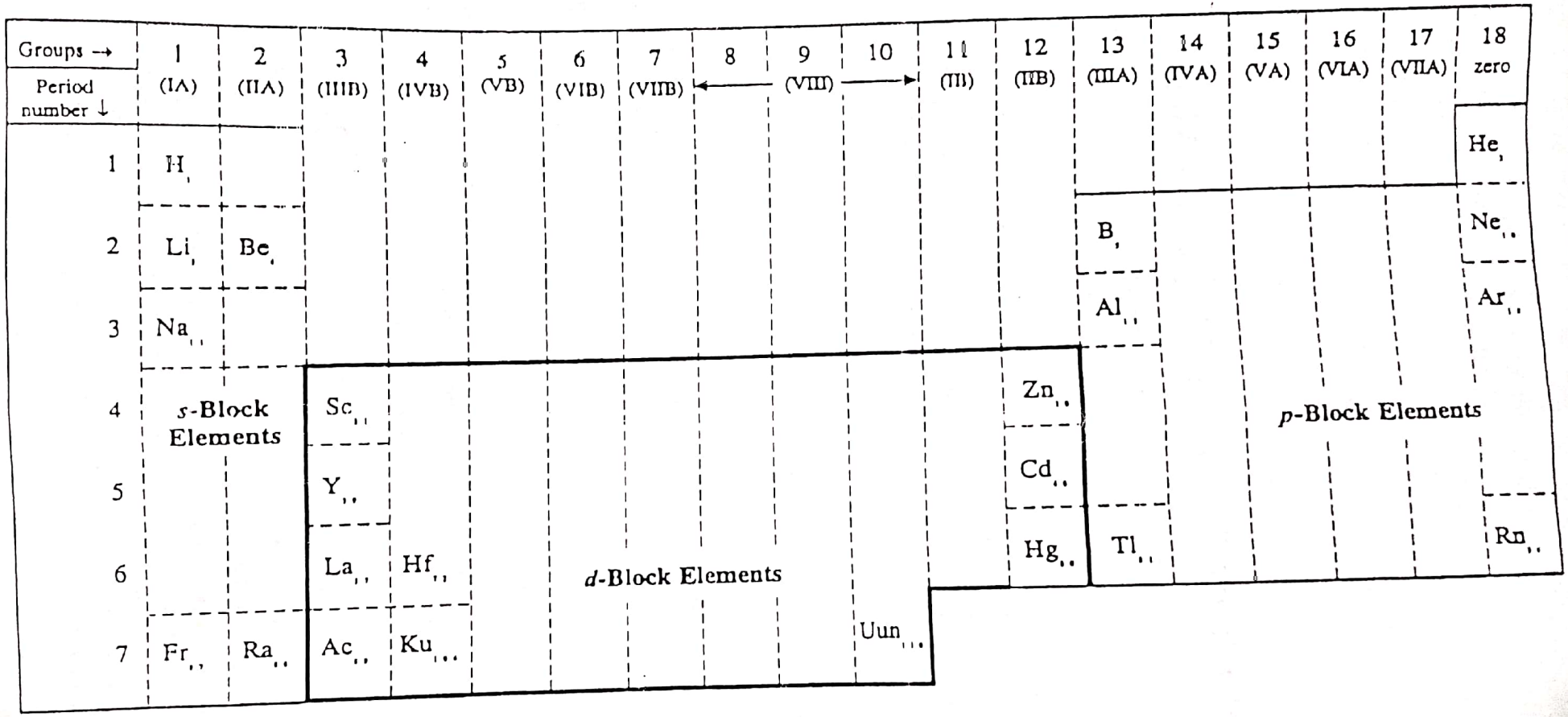

Fig. 6.1. Position of d-block elements in the periodic table

electronic configurations of the atoms of *d*-block elements can be represented by neral electronic configuration $(n-1)\,d^{1\text{-}10}\,ns^{0\text{-}2}$.

Table 6.1. *Complete and valence-shell configurations of the atoms of d-block elements. Here* $[Ar]_{18}$ = 2, 8, 8; $[Kr]_{36}$ = 2, 8, 18, 8; $[Xe]_{54}$ = 2, 8, 18, 18, 8 *and* $[Rn]_{86}$ = 2, 8, 18, 32, 18, 8. *Valence-shell configurations are given in bracket. The elements shown in box have anomalous configurations.*

Group ↓	1st or 3d series (4th period)	2nd or 4d series (5th period)	3rd or 5d series (6th period)	4th or 6d series (7th period)
IIIB (3)	Sc_{21} $[Ar]_{18}\,3d^1\,4s^2$ = 2, 8, 9, 2 $(3d^1\,4s^2)$	Y_{39} $[Kr]_{36}\,4d^1\,5s^2$ = 2, 8, 18, 9, 2 $(4d^1\,5s^2)$	La_{57} $[Xe]_{54}\,4f^0\,5d^1\,6s^2$ = 2, 8, 18, 9, 2 $(4f^0\,5d^1\,6s^2)$	Ac_{89} $[Rn]_{86}\,5f^0\,6d^1\,7s^2$ = 2, 8, 18, 32, 18, 9, 2 $(5f^0\,6d^1\,7s^2)$
IVB (4)	Ti_{22} $[Ar]_{18}\,3d^2\,4s^2$ = 2, 8, 10, 2 $(3d^2\,4s^2)$	Zr_{40} $[Kr]_{36}\,4d^2\,5s^2$ = 2, 8, 18, 10, 2 $(4d^2\,5s^2)$	Hf_{72} $[Xe]_{54}\,4f^{14}\,5d^2\,6s^2$ = 2, 8, 18, 32, 10, 2 $(4f^{14}\,5d^2\,6s^2)$	Ku_{104} $[Rn]_{86}\,5f^{14}\,6d^2\,7s^2$ = 2, 8, 18, 32, 32, 10, 2 $(5f^{14}\,6d^2\,7s^2)$
VB (5)	V_{23} $[Ar]_{18}\,3d^3\,4s^2$ = 2, 8, 11, 2 $(3d^3\,4s^2)$	Nb_{41} $[Kr]_{36}\,4d^4\,5s^1$ = 2, 8, 18, 12, 1 $(4d^4\,5s^1)$	Ta_{73} $[Xe]_{54}\,4f^{14}\,5d^3\,6s^2$ = 2, 8, 18, 32, 11, 2 $(4f^{14}\,5d^3\,6s^2)$	Ha_{105} $[Rn]_{86}\,5f^{14}\,6d^3\,7s^2$ = 2, 8, 18, 32, 32, 11, 2 $(5f^{14}\,6d^3\,7s^2)$
VIB (6)	Cr_{24} $[Ar]_{18}\,3d^5\,4s^1$ = 2, 8, 13, 1 $(3d^5\,4s^1)$	Mo_{42} $[Kr]_{36}\,4d^5\,5s^1$ = 2, 8, 18, 13, 1 $(4d^5\,5s^1)$	W_{74} $[Xe]_{54}\,4f^{14}\,5d^4\,6s^2$ = 2, 8, 18, 32, 12, 2 $(4f^{14}\,5d^4\,6s^2)$	Unh_{106} $[Rn]_{86}\,5f^{14}\,6d^4\,7s^2$ = 2, 8, 18, 32, 32, 12, 2 $(5f^{14}\,6d^4\,7s^2)$
VIIB (7)	Mn_{25} $[Ar]_{18}\,3d^5\,4s^2$ = 2, 8, 13, 2 $(3d^5\,4s^2)$	Tc_{43} $[Kr]_{36}\,4d^5\,5s^2$ = 2, 8, 18, 13, 2 $(4d^5\,5s^2)$	Re_{75} $[Xe]_{54}\,4f^{14}\,5d^5\,6s^2$ = 2, 8, 18, 32, 13, 2 $(4f^{14}\,5d^5\,6s^2)$	
VIII (8)	Fe_{26} $[Ar]_{18}\,3d^6\,4s^2$ = 2, 8, 14, 2 $(3d^6\,4s^2)$	Ru_{44} $[Kr]_{36}\,4d^7\,5s^1$ = 2, 8, 18, 15, 1 $(4d^7\,5s^1)$	Os_{76} $[Xe]_{54}\,4f^{14}\,5d^6\,6s^2$ = 2, 8, 18, 32, 14, 2 $(4f^{14}\,5d^6\,6s^2)$	
VIII (9)	Co_{27} $[Ar]_{18}\,3d^7\,4s^2$ = 2, 8, 15, 2 $(3d^7\,4s^2)$	Rh_{45} $[Kr]_{36}\,4d^8\,5s^1$ = 2, 8, 18, 16, 1 $(4d^8\,5s^1)$	Ir_{77} $[Xe]_{54}\,4f^{14}\,5d^7\,6s^2$ = 2, 8, 18, 32, 15, 2 $(4f^{14}\,5d^7\,6s^2)$	
VIII (10)	Ni_{28} $[Ar]_{18}\,3d^8\,4s^2$ = 2, 8, 16, 2 $(3d^8\,4s^2)$	Pd_{46} $[Kr]_{36}\,4d^{10}\,5s^0$ = 2, 8, 18, 18, 0 $(4d^{10}\,5s^0)$	Pt_{78} $[Xe]_{54}\,4f^{14}\,5d^9\,6s^1$ = 2, 8, 18, 32, 17, 1 $(4f^{14}\,5d^9\,6s^1)$	
IB (11)	Cu_{29} $[Ar]_{18}\,3d^{10}\,4s^1$ = 2, 8, 18, 1 $(3d^{10}\,4s^1)$	Ag_{47} $[Kr]_{36}\,4d^{10}\,5s^1$ = 2, 8, 18, 18, 1 $(4d^{10}\,5s^1)$	Au_{79} $[Xe]_{54}\,4f^{14}\,5d^{10}\,6s^1$ = 2, 8, 18, 32, 18, 1 $(4f^{14}\,5d^{10}\,6s^1)$	
IIB (12)	Zn_{30} $[Ar]_{18}\,3d^{10}\,4s^2$ = 2, 8, 18, 2 $(3d^{10}\,4s^2)$	Cd_{48} $[Kr]_{36}\,4d^{10}\,5s^2$ = 2, 8, 18, 18, 2 $(4d^{10}\,5s^2)$	Hg_{80} $[Xe]_{54}\,4f^{14}\,5d^{10}\,6s^2$ = 2, 8, 18, 32, 18, 2 $(4f^{14}\,5d^{10}\,6s^2)$	

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Classifications of *d*-block elements in 3*d*, 4*d*, 5*d* and 6*d* series (four series)

The electronic configurations of *d*-block elements as given in Table 6.1 show that depending on whether the last electron enters 3*d*, 4*d*, 5*d* or 6*d* orbitals, these elements can be grouped into the following four series:

1. 3*d*-series (1st series : 4th period). This series contains ten elements *viz.* Sc_{21} to Zn_{30}. These elements are present in 4th period. In the atoms of these elements the last electron goes to 3*d*-orbitals, *i.e.*, in this series 3*d* orbitals are progressively filled up with electrons as we move from Sc_{21} to Zn_{30}. It may be noted that the configurations of Cr_{24} and Cu_{29} (two elements) are anomalous, since Cr_{24} has 5 electrons (instead of 4) in 3*d* orbitals and Cu_{29} has 10 electrons (instead of 9) in these orbitals. Thus the correct electronic configurations of Cr_{24} and Cu_{29} are $[Ar]_{18}\ 3d^5\ 4s^1$ [instead of $[Ar]_{18}\ 3d^4\ 4s^2$] and $[Ar]_{18}\ 3d^{10}\ 4s^1$ [instead of $[Ar]_{18}\ 3d^9\ 4s^2$] respectively. Complete and valence-shell electronic configurations of the atoms of 3*d*-series elements can be written as follows. Here $[Ar]_{18}$ = 2, 8, 8 (*three shells*).

$$\text{Complete configuration} = [Ar]_{18}\ 3d^{1-10}\ 4s^{1-2}$$
$$= 2, 8, (8 + 1 \text{ to } 10), 1 \text{ or } 2 \text{ (four shells)}$$
$$= 2, 8, (9 \text{ to } 18), 1 \text{ or } 2$$
$$= 2, 8, 3s^2p^6d^{1-10}, 4s^{1,2}$$
$$\text{Valence-shell configuration} = 3d^{1-10}\ 4s^{1,2}$$

2. 4*d*-series (2nd series : 5th period). Like 3*d*-series, this series also has ten elements namely Y_{39} to Cd_{48}. These elements are present in 5th period. In this series, the differentiating electron occupies 4*d* orbitals, *i.e.*, the elements of this series involve the progressive filling of 4*d* orbitals as we proceed from Y_{39} to Cd_{48}. In this series there are more elements which have anomalous configurations. The elements having anomolous configurations are Nb_{41}, Mo_{42}, Ru_{44}, Rh_{45}, Pd_{46} and Ag_{47} (*six elements*). These anamolous configurations are explained on the basis of nuclear-electron and electron-electron forces existing in these atoms. Complete and valence-shell electronic configurations of the atoms of 4*d*-series elements can be written as follows. Here $[Kr]_{36}$ = 2, 8, 18, 8 (*four shells*).

$$\text{Complete configuration} = [Kr]_{36}\ 4d^{1-10}\ 5s^{0-2}$$
$$= 2, 8, 18, (8 + 1 \text{ to } 10), 0 \text{ to } 2 \text{ (five shells)}$$
$$= 2, 8, 18, (9 \text{ to } 18), 0 \text{ to } 2$$
$$= 2, 8, 18, 4s^2p^6d^{1-10}, 5s^{0-2}$$
$$\text{Valence-shell configuration} = 4d^{1-10}\ 5s^{0-2}$$

3. 5*d*-series (3rd series: 6th period). Like 3*d* and 4*d* series, this series also consists of ten elements which are La_{57} (one element) and Hf_{72} to Hg_{80} (nine elements). The elements of this series involve the gradual filling of 5*d* orbitals. In between La_{57} and Hf_{72}, there are 14 elements *viz.* Ce_{58} to Lu_{71} which are called *lanthanides* or *lanthanones*. These 14 elements involve the progressive filling of 4*f* orbitals and hence donot belong to 5*d* series. Thus at Lu_{71}, 4*f* orbitals are completely-filled. Consequently at La_{57}, 4*f* orbitals are vacant ($4f^0$ configuration) while in the remaining nine elements (Hf_{72} to Hg_{80}) 4*f* orbitals are completely-filled ($4f^{14}$ configuration). The elements namely Pt_{78} and Au_{79} (*two elements*) have anamolous configurations. Complete and valence-shell electronic configurations of the atoms of 5*d*-series elements can be written as follows. Here $[Xe]_{54}$ = 2, 8, 18, 18, 8 (*five shells*)

$$\text{Complete configuration} = [Xe]_{54}\ 4f^{0,14}\ 5d^{1-10}\ 6s^2$$
$$= 2, 8, 18, 4s^24p^6d^{10}f^{0,14}\ 5s^2p^6d^{1-10}, 6s^2 \text{ (six shells)}$$
$$\text{Valence-shell configuration} = 4f^{0,14}\ 5d^{1-10}\ 6s^2$$

4. 6*d*-series (4th series: 7th period-incomplete period). The elements of this series are present in 7th period which is an incomplete period. At present this series consists of Ac_{89}, Ku_{104}, Ha_{105} and Unh_{106} (*four elements*). These elements involve the gradual filling of 6*d* orbitals.

Between Ac_{89} and Ku_{104} there are 14 elements *viz.* Th_{90} to Lw_{103} which are called *actinides*. These 14 elements involve the progressive filling of 5*f* orbitals and hence donot belong to 6*d* series. Thus at Lw_{103} 5*f* orbitals are completely-filled. Consequently at Ac_{89}, 5*f* orbitals are vacant ($5f^0$ configuration) while in the remaining elements *viz.* Ku_{104}, Ha_{105} and Unh_{106} (three elements), 5*f* orbitals are completely-filled ($5f^{14}$ configuration). Complete and valence-shell configurations of the atoms of 6*d*-series elements can be written as follows. Here $[Rn]_{86}$ = 2, 8, 18, 32, 18, 8 (*six shells*).

Complete configuration = $[Rn]_{86}\ 5f^{0\text{-}14}\ 6d^{1\text{-}4}\ 7s^2$

= 2, 8, 18, 32, $5s^2p^6d^{10}f^{0\text{-}14}\ 6s^2p^6d^{1\text{-}4},\ 7s^2$ (7 shells)

Valence-shell configuration = $5f^{0\text{-}14},\ 6d^{1\text{-}4}\ 7s^2$

Physico-chemical Properties

The transition elements show several properties. Some of these properties and their trends of variation are discussed below:

1. Atomic radii

The atomic radii of the atoms of *d*-block elements are given in Table 6.2. The following trends may be observed :

(i) Variation of atomic radii in a given series (period). The atomic radii of the elements of a particular series decrease gradually upto the midway element and then these values remain almost constant upto the element of group IB (Cu, Ag and Au). The last element of each series (Zn, Cd and Hg) shows an increase in its atomic radius.

For example, for the elements of 1st transition series the atomic radii decrease gradually from Sc to Mn but from Fe to Cu these values remain practically constant. The atomic radius of Zn is higher than that of Cu. Similar behaviour has been observed for the elements of 2nd and 3rd transition series.

Table 6.2. *Atomic radii (pm) of d-block elements*

	IIIB		IVB	VB	VIB	VIIB	← VIII →			IB	IIB
	(3)		(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1st series	Sc_{21}		Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn_{30}
	162		147	134	127	126	126	125	124	128	138
2nd series	Y_{39}		Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd_{48}
	180		160	146	139	136	134	134	137	144	154
3rd series	La_{57}	Ce_{58} — Lu_{71}	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg_{80}
	187	165 156	158	146	139	137	135	136	138	144	157
		↑ 14 lanthanides									

Explanation. For the elements from Sc to Mn the atomic radii decrease. This decrease is because of the gradual increase in nuclear charge with the increase in atomic number. The increased nuclear charge makes the atom to shrink in size and hence the size of the atom decreases. However, since the electrons added to 3*d* orbitals screen the 4*s* electron(s), the attraction between the nucleus and the 4*s* electron(s) decreases, *i.e.*, due to the screening effect caused by 3*d* electrons the magnitude of nuclear charge decreases and consequently the atomic radii for the elements from Fe to Cu remain almost uncharged. Towards the end of each series, there is an increase in electron-electron repulsion between the electrons being added to 3*d* orbitals. This increase in repulsion becomes greater than that of the attraction between the nucleus

Table 6.3. *Ionic radii (pm) of the common cations derived from d-block elements.*

	III B (3)	IV B (4)	V B (5)	VI B (6)	VII B (7)	VIII (8)	VIII (9)	VIII (10)	I B (11)	II B (12)
1st series	Sc_{21} +2 = 81 +3 = 88.5	Ti +2 = 91 +3 = 76 +4 = 74.5	V +2 = 88 +3 = 74 +4 = 72 +5 = 68	Cr +2 = 84 +3 = 69 +4 = 68 +5 = 63 +6 = 58	Mn +2 = 80 +3 = 66 +7 = 60	Fe +2 = 76 +3 = 64	Co +2 = 76 +3 = 63	Ni +2 = 72	Cu +1 = 91 +2 = 69	Zn_{30} +2 = 74
2nd series	Y_{39} +3 = 104	Zr +4 = 86	Nb +3 = 86 +4 = 82 +5 = 78	Mo +3 = 83 +4 = 79 +5 = 75 +6 = 73	Tc +4 = 78.5 +5 = 74 +7 = 70	Ru +3 = 82 +4 = 76 +5 = 70.5	Rh +3 = 80.5 +4 = 74 +5 = 69	Pd +2 = 100 +3 = 90 +4 = 75.5	Ag +1 = 129 +2 = 108 +3 = 89	Cd_{48} +2 = 109
3rd series	La_{57} +3 = 117.2	Hf_{72} +4 = 85	Ta +3 = 86 +4 = 82 +5 = 78	W +4 = 80 +5 = 76 +6 = 74	Re +4 = 77 +5 = 72 +6 = 69 +7 = 67	Os +4 = 77 +5 = 71.5	Ir +3 = 82 +4 = 76.5 +5 = 71	Pt +2 = 94 +4 = 76.5 +5 = 71	Au +1 = 51 +3 = 99 +5 = 71	Hg_{80} +1 = 133 +2 = 116

3. Metallic character and related properties

All the transition elements show metallic character, *i.e.*, all these elements are metals.

Explanation. Since the transition elements have low values for their ionisation energies, *ns* electrons can easily be lost by them to form M^+ or M^{2+} cations and thus these elements show metallic character.

As usual, the metallic character of these elements increases on descending the group, *e.g.* basic character of the pentoxides of the elements of group V B (V_2O_5, Nb_2O_5 and Ta_2O_5) increases as $V_2O_5 < Nb_2O_5 < Ta_2O_5$. Thus V_2O_5 is amphoteric (but more basic than acidic) while Nb_2O_5 and Ta_2O_5 are more basic than acidic.

The metallic character of the transition elements is evident from the following properties of these elements.

(*i*) **Electrical and thermal conductivity.** These elements are good conductors of electricity and heat because of the existance of metallic bonding (*i.e.*, presence of free mobile electrons) among the atoms of these elements. Cu, Ag and Au show exceptionally high thermal and electrical conductivity.

(*ii*) **Hardness.** These elements are hard (*i.e.*, cannot be cut with a knife) and brittle. Their hardness is due to the presence of strong metallic bonding among the atoms of these elements. The metallic bonding arises due to the overlap between the singly-filled orbitals of different atoms of the elements. Greater is the number of unpaired electrons, greater is the number of metallic bonds and, therefore, greater is the strength of these bonds or hardness of the element. Since Cr, Mo and W have maximum number of unpaired electrons, these are very hard metals. Zn, Cd and Hg contain no unpaired electrons, and hence are not very hard. As a matter of fact Hg is a liquid and is soft like alkali metals.

(*iii*) **Crystal structure.** These elements have simple hexagonal close-packed (*hcp*), cubic close-packed (*ccp*) or body-centred cubic (*bcc*) lattices which are characteristic of metals.

4. Atomic volumes and densities

The atomic volumes (in ml) and density (in g/cm^3) of transition elements are given below in Table 6.4. The values given against *ml* are atomic volumes while those given against *g/cm*^{3} represent densities.

Table 6.4. *Atomic volumes (ml) and densities (g/cm^3) of d-block elements*

	III B	IV B	V B	VI B	VII B	←	VIII	→	I B	II B
	Sc_{21}	Ti_{22}	V	Cr	Mn	Fe	Co	Ni	Cu	Zn_{30}
ml	15.02	10.60	8.35	7.23	7.39	7.10	6.70	6.60	7.10	9.20
g/cm^3	3.01	4.51	6.10	7.19	7.43	7.86	8.90	8.90	8.96	7.14
	Y_{39}	Zr_{40}	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd_{48}
ml	19.8	14.1	10.8	9.4	—	8.3	8.3	8.9	10.3	13.1
g/cm^3	4.47	6.49	8.40	10.21	11.50	12.20	12.40	12.00	10.51	8.65
	La_{71}	Hf_{72}	Ta	W	Re	Os	Ir	Pt	Au	Hg_{80}
ml	20.50	13.60	10.91	9.53	8.85	8.43	8.54	9.10	10.22	14.80
g/cm^3	6.17	13.10	16.60	19.30	21.00	22.60	22.50	22.40	19.30	13.60

Atomic volumes of *d*-block elements are much lower than those of the elements of *s*- and *p*-blocks.

We know that density and atomic volume are inversely proportional to each other. All the transition metals have low values for their atomic volumes and hence their densities are high. The atomic volumes are low because the electrons are added to $(n-1)$ *d* orbitals and not to *ns* orbital. The increased nuclear charge is partly screened by $(n-1)$ *d* electrons and *ns* electrons

are strongly attracted by the nucleus. Consequently the densities of ... metals high.

Variation of atomic volumes in a given series. In a given transition series, the atomic volumes of the elements first decrease on proceeding from left to right and attain a maximum value for the elements of group VIII. They then start increasing as we proceed further to the elements of group IB and IIB.

Variation of densities in a given series. In a given transition series, the density of the elements increases on moving from left to right and attain a maximum value for the elements of group VIII. It then starts decreasing as we move further to the elements of groups IB and II B. This variation is due to the small radius and close packed structure of the atoms of these elements.

Variation of densities in a given sub-group. Densities of elements belonging to the same sub-group increases on moving down the sub-group. The densities of the elements of 2nd transition series are only slightly higher than those of the corresponding elements of 1st transition series while these values for the transition elements from Hf_{72} to Hg_{80} (elements of 3rd transition series) are almost double these values for the elements from Zr_{40} to Cd_{48} respectively (elements of 2nd transition series). Note that the density of La_{57} (= 6.17) is not double that of the value for Y_{39} (= 4.47).

The variation of densities of transition series elements in a given sub-group, as discused above, can be explained as follows:

(*a*) The atomic weights of the elements of 3rd transition series are almost double the atomic weights of the corresponding elements of 2nd transition series. This makes the densities of the elements of 3rd transition series almost double those of the corresponding elements of 2nd transition series.

(*b*) Because of lanthanide contraction occuring in lanthanides, the atomic sizes of the elements of 3rd transition series coming after Lu_{71} (*i.e.*, elements from Hf_{72} to Hg_{80}) become very small. Consequently the packing of the atoms in their metallic crystals become so much compact that their densities become very high. Thus the densities of the elements of 3rd transition series become almost double the densities of the corresponding elements of 2nd transition series.

5. Melting and boiling points

The melting and boiling points of transition metals are given in Table 6.5. These values suggest that these are very high values. The high values are due to the fact that transition metals have strong metallic bonding between their atoms.

Table 6.5. *Melting and boiling points (°C) of d-block elements.*

3d-series elements:	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
M.P. (°C)	1539	1668	1900	1875	1245	1536	1495	1453	1083	419.5
B.P. (°C)	2730	3260	3450	2665	2150	3000	2900	2730	2595	906.00
4d-series elements:	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
M.P. (°C)	1509	1852	2415	2610	2200	2500	1966	1552	960.8	320.9
B.P. (°C)	2927	1500	3300	5560	—	4900	4500	3980	2210	765
5d-series elements:	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
M.P. (°C)	920	2222	2996	3410	3180	2700	2454	1769	1063	−38.4
B.P. (°C)	3470	5400	5425	5930	5900	5500	5300	4530	2920	357

As we proceed along a particular series, the melting points increase from Sc to Cr in 1st series (V and Cr have almost equal melting points), from Y to Mo in 2nd series and from La to W in 3rd series, and then decrease. This variation can be explained as follows: