TDC Part II
Paper I, Group B
Inorganic Chemistry

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TOPIC: **- Periodic Properties and Their Variation along the First Transtion Series**

Periodic Properties and Their Variation along the Series

The melting and boiling points, atomic and ionic radii, atomic volumes, ionization energies and standard electrode potentials along with reducing properties are the main periodic properties of these metals along the series from Sc to Zn, which are discussed below:

a) Atomic Radii, Atomic Volumes and Ionic Radii

As has been discussed earlier for d-block elements, the atomic radii of the elements of first transition series follow the same trend as is applied for other d-block elements. The values generally decrease along the series up to Ni then increase slightly for Cu but pronouncely for Zn. Thus Zn has exceptional value only lower than those for the first two elements and higher than those of others. This is evident from the following table:

Metal atoms	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Atomic radii: (pm)	144	132	122	118	117	117	116	115	117	125

This happens due to the increased attraction between the outer electrons and increasing nuclear charge along the period. The close values of the atomic radii from Cr to Cu are due to the existence of increased screening effect of 3d-electrons which are added in each step and which shield the 4s-electrons from the inward pull though the nuclear charge increases continuously in the series from one element to the other. The screening effect in Zn ($3d^{10}$) is maximum and hence has exceptional value.

The atomic volumes of these elements as given below are comparatively low because of the filling of 3d-orbitals instead of 4s which is the subshell of the last shell. This causes increased nuclear pull acting on the outer electrons. The densities of these elements are very high. Atomic volumes decrease up to Cu and increase thereafter for Zn.

Metal atoms	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Atomic volume:(cm^3)	15.0	11.0	8.3	7.2	7.3	7.1	6.7	6.6	7.1	9.2

The ionic radii of these elements follow the same trend as the atomic radii, i.e. the radii of the ions with the same charge generally go on decreasing as we move across the series except only for the last element. Radii of the bivalent and trivalent ions of

the elements of this series are listed below:

Bivalent ions	Sc^{2+}	Ti^{2+}	V^{2+}	Cr^{2+}	Mn^{2+}	Fe^{2+}	Co^{2+}	Ni^{2+}	Cu^{2+}	Zn^{2+}
Ionic radii (pm)	95	90	88	84	80	76	74	72	72	74
Trivalent ions	Sc^{3+}	Ti^{3+}	V^{3+}	Cr^{3+}	Mn^{3+}	Fe^{3+}	Co^{3+}	Ni^{3+}	--	--
Ionic radii (pm)	81	76	74	69	66	64	63	62	--	--

b) Melting and Boiling Points

The melting and boiling points of these elements are generally high and have irregular trend in the values as given below:

Elements	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Melting point ^0C	1540	1670	1900	1875	1245	1535	1495	1453	1083	420

As is evident from this table, the highest melting point is for V (1900 ^0C) and Zn, the last element has exceptionally low melting point (420 ^0C). Among other elements

Mn and Cu have lower melting points as compared to other members. The boiling points are very high, >2200^0C except for Zn (906^0C) as expected.

c) Ionization Energies and Reactivity

The first ionization energy values of 3d-series elements show irregular trend as shown below:

Elements:	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
I.E. (KJ):	631	658	650	653	717	759	758	737	746	

But the second and third I.E. values generally show the increasing trend from Sc to Zn. The appreciably higher value of first I.E. for Zn is attributed to the additional stability associated with completely filled 3d-subshell ($3d^{10}4s^2$). The variation or irregularity occurring in the values of I.E. across the series are mainly due to the changes in atomic radii because of the screening effect of extra electrons added to 3d-subshell which is exerted on the nuclear charge.

On account of the factors given above, the elements of first transition series show less reactivity.

d) Standard Electrode Potentials and Reducing Properties

The standard reduction potentials of the elements of

3d-series except copper are lower than that of standard hydrogen electrode.

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
E^{o}_{R} (volts)	-2.10	-1.60	-1.20	-0.74	-1.18	-0.41	-0.28	-0.25	+0.34	-0.76

These elements evolve H_2 from acids though at very low rate. $M + 2H^{+} \rightarrow M^{2+} + H_2$ (g). Cu does not react with acids. It has the tendency to get reduced. Sometimes the metals are protected from the attack of acids by a thin impervious layer of an inert oxide, e.g. Cr. These metals are oxidized easily to their ions and hence are reducing agent though poor due to the obvious reasons given above.