3055 BA SANGAM COLLEGE

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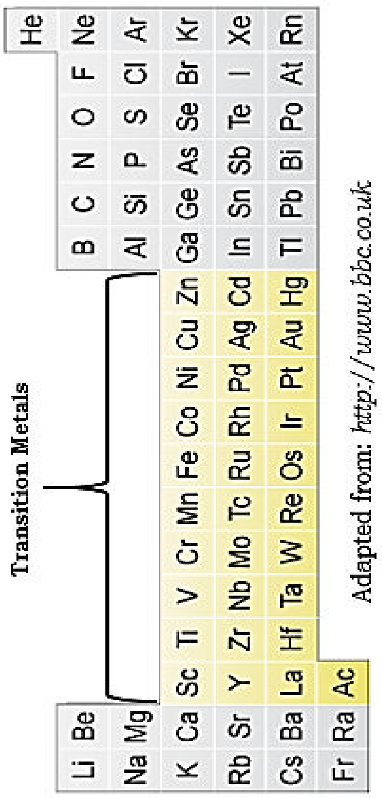
WORKSHEET 9

School: Ba Sangam College **Year:** 13
Subject: Chemistry **Name:**

Strand	**4 - Materials**
Sub strand	**4.1- Inorganic Chemistry**
Content Learning Outcome	**-Investigate the properties and reactions of hydrides, oxides and chlorides.**

Transition Metals (d-block elements)

Transition metals have partially filled ‘d’ orbitals or they can form one or more ions which have partially filled ‘d’ orbitals.



Note

Zn

- is not a transition metal but has similar properties.

-Zinc has a fully filled 3d orbital ([Ar] $3d^{10}4s^2$]) and forms Zn^{2+} ion, which also has a fully filled 3d orbital ([Ar] $3d^{10}$]).

Electron configuration of transition metals

The electrons fill the lower energy orbitals (closer to the nucleus) before they fill the higher energy orbitals.

Electron configuration of the transition metal ions

Element	Symbol	Atomic Number	Electron Configuration	Abbreviated Electron Conf.
Scandium	Sc	21	$1s^22s^22p^63s^23p^63d^14s^2$	$[Ar]3d^14s^2$
Titanium	Ti	22	$1s^22s^22p^63s^23p^63d^24s^2$	$[Ar]3d^24s^2$
Vanadium	V	23	$1s^22s^22p^63s^23p^63d^34s^2$	$[Ar]3d^34s^2$
Chromium	Cr	24	$1s^22s^22p^63s^23p^63d^54s^1$	$[Ar]3d^54s^1$
Manganese	Mn	25	$1s^22s^22p^63s^23p^63d^54s^2$	$[Ar]3d^54s^2$
Iron	Fe	26	$1s^22s^22p^63s^23p^63d^64s^2$	$[Ar]3d^64s^2$
Cobalt	Co	27	$1s^22s^22p^63s^23p^63d^74s^2$	$[Ar]3d^74s^2$
Nickel	Ni	28	$1s^22s^22p^63s^23p^63d^84s^2$	$[Ar]3d^84s^2$
Copper	Cu	29	$1s^22s^22p^63s^23p^63d^{10}4s^1$	$[Ar]3d^{10}4s^1$

Note

1. Chromium

Instead of having $3d^4$ and $4s^2$, one of the electrons from 4s orbital jumps to 3d orbital, so that both orbitals can become half–filled orbitals, which is more stable ($3d^5$,$4s^1$).

2. Copper

Instead of having $3d^9$ and $4s^2$, one of the electrons from 4s orbital jumps to 3d orbital, so that the 4s orbital can become half-filled orbital and the 3d orbital can become completely filled orbital, which is more stable ($3d^{10}$,$4s^1$).

Exercise

1. Write the electron configuration of the following atoms or ions using the s,p,d notation. **(7 marks)**

a. Fe : ____________________________
b. V : ______________________________
c. Cr :______________________________
d. Cu^+: ____________________________
e. Zn^{2+}:____________________________
f. Mn^{2+} ____________________________

2. Explain why the electron configuration of:

a. Chromium is [Ar] $3d^5$ $4s^1$ and not [Ar] $3d^4$ $4s^2$. **(1 mark)**

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b. Copper is [Ar] $3d^{10}$ $4s^1$ and not [Ar] $3d^9$ $4s^2$.

(1 mark)

Orbital diagram of the Transition Metals

Element		3d					4s
1. Scandium (Sc)	[Ar]	↑					↑↓
2. Titanium (Ti)	[Ar]	↑	↑				↑↓
3. Vanadium (V)	[Ar]	↑	↑	↑			↑↓
4. Chromium (Cr)	[Ar]	↑	↑	↑	↑	↑	↑
5. Manganese (Mn)	[Ar]	↑	↑	↑	↑	↑	↑↓
6. Iron (Fe)	[Ar]	↑↓	↑	↑	↑	↑	↑↓
7. Cobalt (Co)	[Ar]	↑↓	↑↓	↑	↑	↑	↑↓
8. Nickel (Ni)	[Ar]	↑↓	↑↓	↑↓	↑	↑	↑↓
9. Copper (Cu)	[Ar]	↑↓	↑↓	↑↓	↑↓	↑↓	↑

Note: [Ar] represents: $1s^22s^22p^63s^23p^6$; the electron configuration of Argon (Ar)

Electron configuration of the transition metal ions

The 3d subshell is closer to the nucleus, repels the 4s electrons, making the 4s electrons less stable. Thus, when d block elements form ions, the 4s electrons are lost first and the most common ions formed are $X^{2+;}$ (X can be any transition metal).

Name of element	Electron configuration of the element	Ion	Electron configuration of the ion
Scandium	$1s^22s^22p^63s^23p^63d^14s^2$	Sc^{3+}	$1s^22s^22p^63s^23p^6$
Titanium	$1s^22s^22p^63s^23p^63d^24s^2$	Ti^{3+}	$1s^22s^22p^63s^23p^63d^1$
		Ti^{4+}	$1s^22s^22p^63s^23p^6$
Vanadium	$1s^22s^22p^63s^23p^63d^34s^2$	V^{3+}	$1s^22s^22p^63s^23p^63d^2$
		V^{5+}	$1s^22s^22p^63s^23p^6$
Chromium	$1s^22s^22p^63s^23p^63d^54s^1$	Cr^{3+}	$1s^22s^22p^63s^23p^63d^3$
		Cr^{6+}	$1s^22s^22p^63s^23p^6$
Manganese	$1s^22s^22p^63s^23p^63d^54s^2$	Mn^{2+}	$1s^22s^22p^63s^23p^63d^5$
		Mn^{4+}	$1s^22s^22p^63s^23p^63d^3$
		Mn^{7+}	$1s^22s^22p^63s^23p^6$
Iron	$1s^22s^22p^63s^23p^63d^64s^2$	Fe^{2+}	$1s^22s^22p^63s^23p^63d^6$
		Fe^{3+}	$1s^22s^22p^63s^23p^63d^5$
Cobalt	$1s^22s^22p^63s^23p^63d^74s^2$	Co^{2+}	$1s^22s^22p^63s^23p^63d^7$
		Co^{3+}	$1s^22s^22p^63s^23p^63d^6$
Nickel	$1s^22s^22p^63s^23p^63d^84s^2$	Ni^{2+}	$1s^22s^22p^63s^23p^63d^8$
Copper	$1s^22s^22p^63s^23p^63d^{10}4s^1$	Cu^{+}	$1s^22s^22p^63s^23p^63d^{10}$
		Cu^{2+}	$1s^22s^22p^63s^23p^63d^9$

Note: Atoms or ions with the same electronic configuration are said to be **isoelectronic**. Examples include: Mn^{2+} and Fe^{3+}.

Properties of Transition Metals

1. Oxidation state of the transition metals

The incompletely filled 'd' orbitals allow transition metals to lose varying number of electrons forming variable oxidation states. This is because **of the closeness in energy of both 3d and 4s level. Thus, they have similar stability by losing different number of electrons**.

Transition Metal	Symbol	Oxidation states
Scandium	Sc	**+3**
Titanium	Ti	+1, +2, **+3**, **+4**
Vanadium	V	+1, **+2**, **+3**, **+4**, **+5**
Chromium	Cr	**+2**, **+3**, +4, +5, **+6**
Manganese	Mn	+1, **+2**, +3, **+4**, +5, **+6**, **+7**
Iron	Fe	+1, **+2**, **+3**, +4, +5, +6
Cobalt	Co	+1, **+2**, **+3**, +4, +5
Nickel	Ni	**+2**, +3, +4
Copper	Cu	**+1**, **+2**, +3

Note: The common Oxidation States are in bold.

- There is an increase in the number of oxidation states from Sc to Mn.
- All possible oxidation states only exhibited by Manganese (Mn).
- There is a decrease in the number of oxidation state from Mn to Cu due to the pairing of d-electrons which occurs after Mn (Hund's Rule).
- The stability of higher oxidation states decreases along Sc to Cu.
- Down the group, the stability of higher oxidation states increases due to easier availability of both 3d and 4s electrons for ionisation.
- Because of the multiplicity of oxidation states and being able to act as catalysts, the transition elements are often involved in oxidation reduction reactions.

3. Explain why scandium cannot form compounds in +4 oxidation state while titanium can. **(1 mark)**
