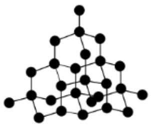
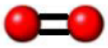
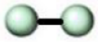
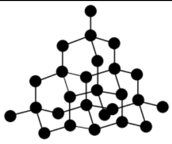
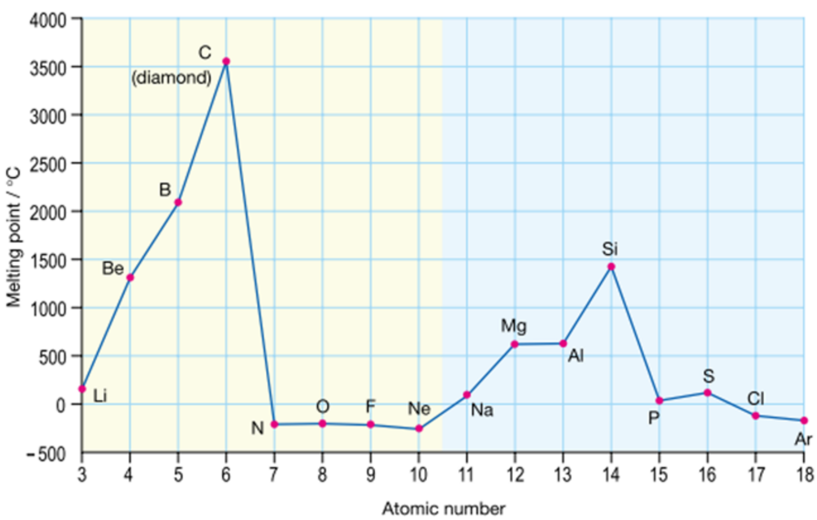
Intensive note (Topic 12: Patterns in chemical worlds)

Unit Education

Structure and bonding of Period 2 elements

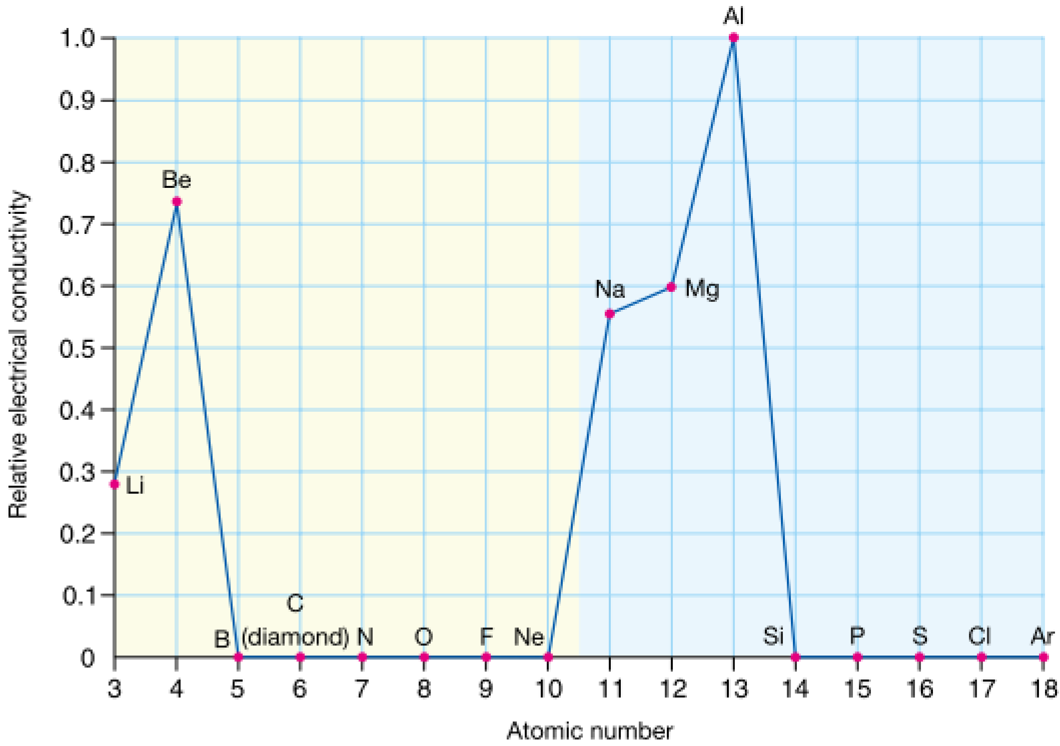
Period 2	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**0**
Element	Li	Be	B	C	N	O	F	Ne
Formula	Li	Be	B	C	N_2	O_2	F_2	Ne
Type	Metal		Metalloid	Non-metal				
Structure	Giant metallic structure		Giant covalent structure		Simple molecular			
Bonding	Strong metallic bond between metal ions and delocalized electrons		Strong covalent bond between atoms		1. Strong covalent bond between atoms (except Ne) 2. Weak van der Waals' forces between molecules			
Diagram								
M.p. (°C)	181	1287	2076	3272	- 210	- 219	- 220	- 249

Period 3	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**0**
Element	Na	Mg	Al	Si	P	S	Cl	Ar
Formula	Na	Mg	Al	Si	P_4	S_8	Cl_2	Ar
Type	Metal			Metalloid	Non-metal			
Structure	Giant metallic structure			Giant covalent structure	Simple molecular			
Bonding	Strong metallic bond between metal ions and delocalized electrons			Strong covalent bond between atoms	1. Strong covalent bond between atoms (except Ar) 2. Weak van der Waals' forces between molecules			
Diagram								
M.p. (°C)	98	650	660	1414	44	115	- 102	- 189



- Melting point of Be > Li:
  The greater the no. of outermost shell electrons per atom, the stronger is the attraction between the metal ions and the delocalized electrons. As Be has more delocalized electrons, metallic bonds in Be are stronger
- Melting point: S > P > Cl > Ar
  Molecular size: $S_8 > P_4 > Cl_2 > Ar$,
  Van der Waals' forces between molecules: $S_8 > P_4 > Cl_2 > Ar$.
- Melting point: $N_2 > O_2$.
  Boiling point: $N_2 < O_2$

Electrical conductivity of Period 2 and Period 3 elements



- Li, Be, Na, Mg, Al:
  They have giant metallic structures. They have delocalized electrons to conduct electricity.
  Number of delocalized electrons per atom increases, electrical conductivity increases.

- C, Si:
  They have giant covalent structures. Since their atoms are held by strong covalent bonds, electrons are NOT delocalized.
  They cannot conduct electricity under room conditions.
  [**Si** can conduct electricity at **elevated temperatures** (as more electrons are delocalized) and the **presence of impurities**]
  [**Graphite** (another form of carbon) can conduct electricity as there are **delocalized electrons**]

- N, O, F, Ne, P, S, Cl, Ar:
  They have simple molecular structures. They have NO delocalized electrons to conduct electricity.
  [F_2 and Cl_2 can conduct electricity in aqueous state as they react with water to give mobile ions]

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Structure and bonding of oxides of Period 3 elements

Period 3	I	II	III	IV	V	VI	VII	0
Formula	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O	---
Structure	Giant ionic			Giant covalent	Simple molecular			---
Bonding	Ionic		Mainly ionic	Covalent				---
Acid-base property	Basic		Amphoteric	Acidic				---
Solubility in water	Soluble	Slightly soluble	Insoluble	Insoluble	Soluble	Soluble	Soluble	---

- Nature of bonding depends on the electronegativity difference
  Electronegativity difference between Na (0.93) and O (3.44) is 2.51. Na_2O therefore is an ionic compound
  Electronegativity difference between Cl (3.16) and O (3.44) is 0.28. Cl_2O therefore is a covalent compound
- In general, oxides of metals are ionic and basic while oxides of non-metals are covalent and acidic

Reactions between oxides of Period 3 elements and water / acid / alkali

	Reaction with water	Reaction with acid (HCl)	Reaction with base (NaOH)
Na_2O	$Na_2O + 2H_2O \rightarrow 2NaOH$ $2NaOH \rightarrow 2Na^+ + 2OH^-$	$Na_2O + 2HCl \rightarrow 2NaCl + H_2O$ $Na_2O + 2H^+ \rightarrow 2Na^+ + H_2O$	*Basic oxide, no reaction*
MgO	$MgO + H_2O \rightarrow Mg(OH)_2$ $Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2OH^-$	$MgO + 2HCl \rightarrow MgCl_2 + H_2O$ $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$	*Basic oxide, no reaction*
***Al_2O_3**	*Insoluble*	$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$ $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$	$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$
SiO_2	*Insoluble*	*Acidic oxide, no reaction*	$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$ $SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$
P_4O_{10}	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ $H_3PO_4 \rightleftharpoons 3H^+ + PO_4^{3-}$	*Acidic oxide, no reaction*	$P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$ $P_4O_{10} + 12OH^- \rightarrow 4PO_4^{3-} + 6H_2O$
SO_2	$SO_2 + H_2O \rightarrow H_2SO_3$ $H_2SO_3 \rightleftharpoons 2H^+ + SO_3^{2-}$	*Acidic oxide, no reaction*	$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$ $SO_2 + 2OH^- \rightarrow SO_3^{2-} + H_2O$
Cl_2O	$Cl_2O + H_2O \rightarrow 2HOCl$ $HOCl \rightleftharpoons H^+ + OCl^-$	*Acidic oxide, no reaction*	$Cl_2O + 2NaOH \rightarrow 2NaOCl + H_2O$ $Cl_2O + 2OH^- \rightarrow 2OCl^- + H_2O$

*Since Al_2O_3 can react with both acid and base, it is classified as an amphoteric oxide (shows both acidic and basic properties)

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Transition metals

- Transition metals occupy the central block of the Periodic Table between Group II and Group III in Periods 4, 5, 6, 7.
- Properties of transition metals:
  1. They share some common properties of main group metals (e.g. malleable, ductile)
  2. Transition metals are generally stronger, harder, have higher melting points and densities than main group metals
  3. Transition metals are generally less reactive than main group metals

Characteristics of transition metals

1. Formation of colored aqueous ions

Co^{2+}	$Cr_2O_7^{2-}$	CrO_4^{2-}	Fe^{3+}	Fe^{2+}	Cr^{3+}	Ni^{2+}	Cu^{2+}	MnO_4^-	Mn^{2+}
Pink	Orange	Yellow	Yellow	Green	Green	Green	Blue	Purple	Pale pink

2. Variable oxidation states in compounds

A variable number of electrons can be removed from the <u>outermost shell and the next inner shell</u> of the atoms of transition metals.

	Transition metals									
Oxidation states	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
			+1	+1	+1		+1	+1	+1	
		+2	+2	+2	+2	+2	+2	+2	+2	+2
	+3	+3	+3	+3	+3	+3	+3	+3	+3	
		+4	+4	+4	+4	+4	+4	+4		
			+5	+5	+5	+5	+5			
				+6	+6	+6				
					+7					

Key: the more common oxidation state(s) of the element

- Metal ions in high oxidation states tend to act as oxidizing agents (undergo reduction)
  ($Cr_2O_7^{2-}$, O.N. of Cr = +6)
  (MnO_4^-, O.N. of Mn = +7)
  *MnO_4^- will be reduced to MnO_2 under alkaline conditions
- Metal ions in low oxidation states tend to act as reducing agents (undergo oxidation)
  (Fe^{2+}, O.N. of Fe = +2)
  (Cu^+, O.N. of Cu = +1)

3. Catalytic properties of transition metals and their compounds

A. Catalytic converter [Platinum (Pt) / Rhodium (Rh)]

$$2CO + 2NO \rightarrow 2CO_2 + N_2 \qquad 2CO + O_2 \rightarrow 2CO_2$$

$$4CO + 2NO_2 \rightarrow 4CO_2 + N_2 \qquad C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$$

B. Catalytic hydrogenation [Nicke(Ni) / Palladium (Pd) / Platinum (Pt)]

$$H_2C{=}CH_2 + H_2 \rightarrow CH_3CH_3$$

C. Haber process [Iron(Fe)]

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

D. Contact process [Vanadium(V) oxide (V_2O_5)]

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

Transition metals in our body

1. Cobalt (synthesis of vitamin B_{12})
2. Manganese (Bones and cartilages)
3. Zinc (Growth and reproductive hormones)
4. Iron (Haemoglobin)