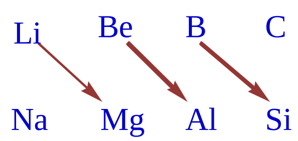
Chemistry of period II elements

Period 2 consists of the following elements as shown in table 7.1 below.

Table 7.1 Period 2 elements

Element:	Li	Be	B	C	N	O	F	Ne
Electron Configuration	$1s^22s^1$	$1s^22s^2$	$1s^22s^22p^1$	$1s^22s^22p^2$	$1s^22s^22p^3$	$1s^22s^22p^4$	$1s^22s^22p^6$.	$1s^22s^22p^5$

The diagonal relationship



Li and Mg, Be and Al, B and Si have similarities in their chemical properties. Such similarities in chemical properties between the first element and the second element in the next higher group are called diagonal relationship. This kind of relation exists between some elements of periods 2 and 3.

Thus **diagonal relationship** is the similarity in chemical properties between elements in the second period with elements which are lying to their right in the 3^{rd} period or lying diagonally opposite to them.

The reason for the diagonal relationship is because the two diagonally related elements (e.g., Li and Mg or Be and Al) have very similar electropositivity. Since electropositivity increases from top to bottom in any periodic group and decreases from left to right across a particular period, the increase in electropositivity in going down one place in the periodic group, (e.g., magnesium is one place lower than lithium) is compensated for by the decrease that occurs in moving one step across a period from left to right (magnesium is one place to the right of lithium).

Alternatively, two diagonally related elements have the same polarizing power since on moving from left to right across a period, the cationic charge increases and cationic size decreases, the magnitude of polarizing power increases, and moving down the group, however, cationic size increases reducing the polarizing power. Since these two variations of polarizing power of cations (along the period and down the group) are opposite each other, they partially cancel (balance) each other when we move diagonally in the periodic table.

Alternatively, two diagonally related elements have the same electronegativity, since an increase in electronegativity one step across the period is cancelled out by a decrease in electronegativity one step down the group.

Similarities between Li and Mg

The following summaries show the ways in which lithium resembles magnesium and, differs from other alkali metals.

Li and Mg	Na, K, Rb and Cs
1. Both form normal oxides when they burn in oxygen. $4Li\ (s) + O_2\ (g) \rightarrow 2Li_2O\ (s)$ $2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)$	Form peroxides, e.g., Na_2O_2 or hyper oxides, e.g., KO_2
2. Their carbonates, hydroxides and peroxides readily decompose to the oxides on heating. $Li_2CO_3\ (s) \rightarrow Li_2O\ (s) + CO_2\ (g)$ $MgCO_3\ (s) \rightarrow MgO\ (s) + CO_2\ (g)$	No similar decomposition.
3. Their nitrates decompose on heating to give oxides, nitrogen dioxide and oxygen. $4LiNO_3\ (s) \rightarrow 2Li_2O(s) + 4NO_2\ (g) + O_2\ (g)$ $2Mg(NO_3)_2\ (s) \rightarrow 2MgO(s) + 4NO_2\ (g) + O_2\ (g)$	Nitrates decompose to give nitrites. $2KNO_3(s) \rightarrow 2KNO_2(s) + O_2(g)$
4. Their carbonates and phosphates are insoluble in water.	Corresponding compounds are more soluble
5. Form strongly hydrated ions in solution	Corresponding ions are not hydrated in solution
6. They form carbides and nitrides by direct combination with the element. $3Mg\ (s) + N_2\ (g) \rightarrow (Mg^{2+})_3(N^{3-})_2\ (s)$ $Mg\ (s) + 2C\ (s) \rightarrow Mg^{2+}(C\equiv C)^{2-}\ (s)$	No reaction with N_2 nor C.
7. Halides (except fluorides) are soluble in organic solvents.	Corresponding compounds much less soluble.
8. Compounds have covalent character. Hydro carbonates known only in solution	Solid hydro carbonates can be made.

Trial 7.1

(i) Explain what is meant by diagonal relationship. (3 ½ mark)

(ii) Name five properties in which lithium resembles magnesium but differs from the rest of group 1 metals. Give one reason for the resemblance between lithium and magnesium. (10 marks)

Similarities between Be and Al.

The following summary shows how beryllium resembles aluminium, and differs from other group 2A metals.

Be and Al	**Mg, Ca, Sr and Ba**
1. Both are passive to nitric acid.	React with nitric acid to form salts .
2. Both react with NaOH solution to evolve hydrogen. $Be (s) + 2^{-}OH (aq) + 2H_2O (l) \rightarrow Be(OH)_4^{2-}(aq) + H_2 (g)$ beryllate ion $Al (s) + 2^{-}OH (aq) + 6H_2O (l) \rightarrow 2Al(OH)_4^{-} (aq) + 3H_2(g)$ aluminate ion	No reaction with alkalis.
3. The oxides and hydroxides of beryllium and aluminium are amphoteric.	Oxides and hydroxides are basic
4. The chlorides are covalent polymeric solids (through dative bonding). When anhydrous $(BeCl_2)_X$ and $(AlCl_3)_X$ which readily dissolve in organic solvents. They are readily hydrolysed by water, with evolution of HCl.	Chlorides and hydroxides have high conductivities and boiling temperatures; they are not hydrolysed and are ionic. e.g., $Ca^{2+}Cl^{-}_2$
5. Beryllium carbide, Be_2C, and aluminium carbide, Al_4C_3, give methane on treatment with water. $Be_2C(s) + 4H_2O(l) \rightarrow 2Be(OH)_2(s) + CH_4(g)$ $2Al_4C_3(s) + 12H_2O(l) \rightarrow 4Al(OH)_3(s) + 3CH_4(g)$	CaC_2 gives ethyne with water. $CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + HC{\equiv}CH(g)$
6. Similar complexes of beryllium and aluminium have similar stabilities, e.g., BeF_4^{2-} and AlF_6^{3-}.	No similar compounds.

Trial 7.2

Beryllium differs in some of its properties from the rest of the elements in the group.

(i) State two properties in which beryllium differs from the rest of the members of the group. (2marks)

(ii) Give reasons why beryllium shows different properties from the rest of the elements. (2marks)

Trial 7.3

Explain the following observations.

(b) Beryllium belongs to group II of the periodic table and yet its Chemistry and that of its compounds resemble that of aluminum.

Trial 7.4

Beryllium, like aluminium can react with sodium hydroxide solution. Other group II elements do not.

(i) Write ionic equations for the reactions of beryllium and aluminium with sodium hydroxide solution.

(ii) List **three** other properties in which beryllium shows similarity to aluminium.

(iii) Explain why beryllium behaves differently from other group II elements.

(iv) Name **two** other elements which have a similar relationship like beryllium and aluminium.

Similarities between B and Si

The ways in which boron resembles silicon and differs from aluminium are summarised below.

B and Si	Al
1. Non-metals with very similar properties; non-conducting.	A metal with different physical properties; conducting.
2. Compounds are covalent.	Compounds are partially ionic.
3. Their oxides (Be_2O_3 and SiO_2) are strongly acidic in character and form oxy-acids (H_3BO_3, H_2SiO_3) with water. These react with aqueous alkalis to produce borates and silicates.	Oxide is amphoteric, with high melting temperature.
4. Form covalent chlorides, BCl_3 and $SiCl_4$, which are readily hydrolyzed.	$AlCl_3$ is less readily hydrolyzed.
5. Form borides, e.g., MgB_2 and CaB_6, and silicides, e.g., Mg_2Si, with metals.	No similar compounds.

Additional exercise

1. (a) *Explain why, the atomic spectrum of hydrogen contains lines in the radio - frequency region of the electromagnetic spectrum.*

   (b) *The Balmer series of the lines in the atomic spectrum of atomic hydrogen arises from electronic transitions from the level n = 2 and m = 3, 4, 5, etc. These lines fit the general equation.*

$$\frac{1}{\lambda} = R_{\infty}\left[\frac{1}{n^2} - \frac{1}{m^2}\right]$$

Where R^{∞} is Rydberg's constant and has the value 109677 cm^{-1} and λ is the wavelength in cm. Calculate the wavelength of the first three spectral lines in this series in nm.

(c) *The Lyman's series of spectral lines arises from electronic transitions from n = 1 (ground state level) to m = 2, 3, 4, etc. Calculate the series limit, (which corresponds to complete removal of the electron). Hence, calculate the energy in joules needed to remove the electron completely from the atom.*

(d) *Electromagnetic radiation of wavelength 242 nm is just sufficient to ionise the outermost electron of sodium atom. Calculate the ionisation energy of sodium atom in kJ mol^{-1}.*
(Planck's constant is 6.625 X 10^{-34}J S and the velocity of light is 3 X 10^8 m s^{-1}).

2. (a) *Explain what is meant by the term, "ionisation energy."*
   (b) *Show the trends in ionisation energy across a period and down a group in the Periodic Table.*
   (c) *Give reasons for the trends in (b) above.*

3 (a) *The electronic structure of sodium is 2.8.1 or more precisely, $1s^2 2s^2 2p^6 3s^1$.*
Write down, in similar way, the electronic structures of Be, B, N, O, F and Ne.
(b) *Explain why the first ionisation energy of elements of a given period of a periodic table increases from left to right of the periodic table*
(c) *Use electronic structures (3a) above to explain why*
(i) *the first ionisation energy of beryllium is higher than that of boron.*
(ii) *the first ionisation energy of oxygen is lower than that of nitrogen.*
(iii) *the difference between the first and second ionisation energies of sodium is higher than the corresponding difference for calcium.*

4. (a) *Define the terms atoms, atomic number, mass number.*
   (b) *Name and give relative masses and charges of the three fundamental particles of an atom which are significant in Chemistry.*
   (c) *What explanation can you offer for the following?*
   (i) *Aluminium chloride is essentially covalent, whereas aluminium fluoride is predominantly ionic.*
   (ii) *Aluminium is exclusively 3-valent, whereas transition metals display several valence states.*
   (iii)*The boiling points of the hydrogen halides are: HF,19 ^{0}C; HCl, -85 ^{0}C; HBr, -67 ^{0}C; HI,-35 ^{0}C.*
   (iv) *Calcium oxide has the formula $Ca^{2+}O^{2-}$ and not Ca^+O^-.*

5. *Explain concisely what is meant by the terms: electrovalent bond, covalent bond, and coordinate bond. Compare and contrast the physical properties displayed by common compounds containing electrovalent and covalent bonds.*

   Write electronic formulae for the following compounds containing electrovalent and covalent bonds.
   (i) Magnesium chloride, (ii) ethane (iii) ammonium chloride. Comment on the types of bonds.

6. *The first member of a family (a vertical group) of elements in the periodic table has properties that are not typical of the other members of the family. Discuss and explain this statement with respect to two non-metals and one metal.*

7. *Illustrate how the Chemistry of elements and their compounds changes across a short period by writing a comparative account of the Chemistry of the elements sodium to chlorine in the second period, and of their oxides and hydrides.*

8. *(a) Explain the trends in the atomic radii of the elements both along period 3 (Na-Cl) and down group 7 (F-I) of the periodic table. Show with the aid of examples, how these trends help to explain the changes in chemical properties of the elements.*
   (b) Explain how the effects of (i) heat and (ii) water on sodium chloride and aluminium chloride are influenced by the type of bonding present in each compound.

9. *Define the terms: ionisation energy, electron affinity and electronegativity.*
   Show how a consideration of the trends in the values of these terms may be used to explain the variation in the bond types and chemical properties of chlorides, oxides and hydrides of elements of the period, sodium to chlorine.

10. *Compare sodium, aluminium and sulphur with respect to their reactions with (a) oxygen and (b) chlorine. Your comparisons should include the following:*
    (i) the conditions of the reactions and equations.
    (ii) the bonding in the products;
    (iii) the reactions, including equations of the products with water to which a few drops of universal indicator have been added.
    (iv) how the characteristics (I), (ii) and (iii) show the change in nature of an element on passing from left to right in the periodic table

11. *(a) What is an atom?*
    (b) Give the basic units that form an atom and their physical properties.
    (c) Which of these units (b) above can be used to arrange elements in the periodic table? Develop your reasoning.
    (d) (i) Relate the four quantum numbers of an electron in an atom.
    (ii) Write the s, p and d electronic configurations of the first 20 elements.