CHIJ ST. NICHOLAS GIRLS' SCHOOL
Sec 2 Science
2024[modified for 2025 9 july 2024]

Diversity 1 : Exploring Diversity of Matter by their Physical properties

D 1.1 Ionic Bonding

Students should be able to :

(a) Describe the formation of ionic bonds between metals and non-metals eg in NaCl and $MgCl_2$, using 'dot and cross' diagrams to illustrate

(b) State that ionic materials contain a giant lattice in which the ions are held by electrostatic attraction, e.g. NaCl (diagrams of ionic lattices will not be required)

(c) Deduce the formulae of other ionic compounds from diagrams of their lattice structures, limited to binary compounds

(d) Relate the physical properties (including electrical property of ionic compounds to their lattice structure)

(e) Explain how to derive the chemical formula from the charges of the ions present

Students should be able to :

(a) explain the choice of the main classes of materials (metals, ceramics, glass, plastics, fibres) in the production of common household items, in terms of their properties, e.g. density ,strength, hardness, flexibility, electrical conductivity, thermal conductivity, boiling/melting point

(b) use data on the properties of different materials to evaluate their uses

(c) relate the properties of substances to type of bonding and structure :

Ionic Bond

What are ions? : http://youtu.be/900dXBWgx3Y

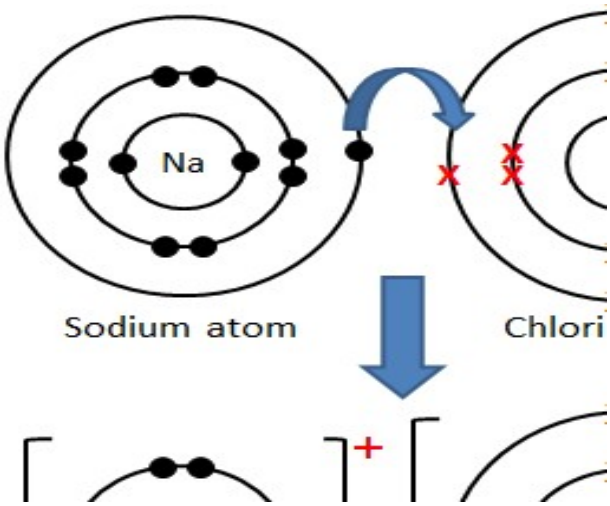
1. Ions are formed when atoms **loses** outer/valence shell electrons or **gain** electrons into the outer/valence shell.
2. The charge on the ion is either **positive** or **negative**.
3. If an atom loses electrons, the ion formed is **positively** charged because the number of **protons** present is more than the number of **electrons** left.
4. If an atom gains electrons, the ion formed is negatively charged because the number of **electron** is more than the number of **protons**.

Ionic compound

An ionic compound is formed when a metal reacts with a non-metal. The metal atom loses electrons to the non-metal aroms. This results in forming positive metal ions and negative non-metal ions. These oppositely charged ions are attracted together to form ionic compound.

http://youtu.be/zpaHPXVR8WU

Using the reaction between sodium and chlorine as an example:



- Metallic atoms **lose** their valence electrons to non-metallic atoms.
- Metallic atoms become positive ions (cations).
- Non-metallic atoms become negative ions (anions).

- Cations and anions are attracted to one another through **strong electrostatic forces of attraction**. This constitutes an **ionic bond**.
- The compound formed is called **sodium chloride**.

Definition of ionic bond

An ionic bond is the **strong electrostatic forces of attraction between oppositely charged ions.**

More practice

Draw the 'dot and cross' diagrams to show the electronic structures of ionic compounds formed by the following elements. Show all the electrons.

(answers on the power point)

a) Lithium and fluorine Chemical name: …… Chemical formula: ……..	b) Beryllium and oxygen Chemical name: …… Chemical formula: ……..
c) Potassium and oxygen Chemical name: …… Chemical formula: ……..	d) Aluminium and sulfur Chemical name: …… Chemical formula: ……..
e) Sodium and oxygen Chemical name: …… Chemical formula: ……..	f) Aluminium and nitrogen Chemical name: …… Chemical formula: ……..

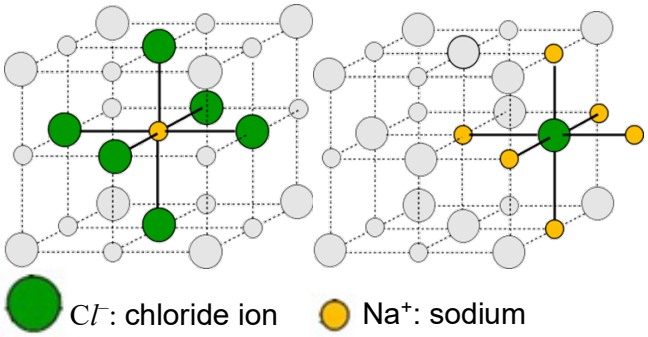
For the following two compounds, **draw only the valence electrons**, given that bromine (Br) is in Group VII of the Periodic Table, while rubidium (Rb) is in Group I.

g) Calcium and bromine Chemical name: …… Chemical formula: ……..	h) Rubidium and chlorine Chemical name: …… Chemical formula: ……..

Physical properties of Ionic Compounds

https://www.youtube.com/watch?v=NfNIn4R8tg4

In the solid state, an ionic compound has a regular arrangement of alternating positive and negative ions. This regular arrangement is known as a **giant ionic lattice.**



Using sodium chloride as an example,

- The ions are arranged in a **giant ionic structure** in a regular repeating manner.
- Each sodium ion is surrounded by **6** chloride ions, and each chloride ion is in turn surrounded by **6** sodium ions.
- Thus the **ratio** of sodium ions to chloride ions is **1:1.**
- Ionic compounds which have ions of **equal and opposite charge** will have the same structure as sodium chloride, **NaCl, MgO, CaO, KFand etc but not $MgCl_2$, Na_2O and etc**

Physical properties of compounds with Giant Ionic Structure

Property	Explanation
Melting point and boiling point • **High and usually exist as solids at room temperature and pressure** **e.g. NaCl (m.p 801 °C, b.p. 1465 °C)**	• **They have ionic bonding and giant ionic structure.** • **A large amount of energy is needed to overcome the strong electrostatic forces of attraction between the oppositely-charged ions in the giant ionic lattice structure**.
Electrical Conductivity https://www.youtube.com/watch?v=NfNIn4R8tg4 • **Unable to conduct electricity in the solid state but can do so in the molten and aqueous states.**	• **They have a giant ionic structure.** • **In the solid state, the oppositely charged ions can only vibrate about their fixed positions due to the strong electrostatic forces of attraction. Therefore, the ions are not mobile to conduct electricity.** • **In the aqueous/molten state, this attractive weakened. Hence, the ions become mobile and are able to conduct electricity**.
Solubility • **Mostly soluble in water**	**(FYI)** **water molecules can separate the positive ions from the negative ions and surround them, forming new interactions with the ions.**

Factor affecting the strength of ionic bonds

Substances	Melting point/°C
Sodium chloride	801
Magnesium oxide	2852

Based on the information given above, what affects the strength of ionic bonds?

The higher charge of the ions, the stronger its ionic bonds (electrostatic forces of attraction)

Explain why MgO has higher melting point than NaCl.

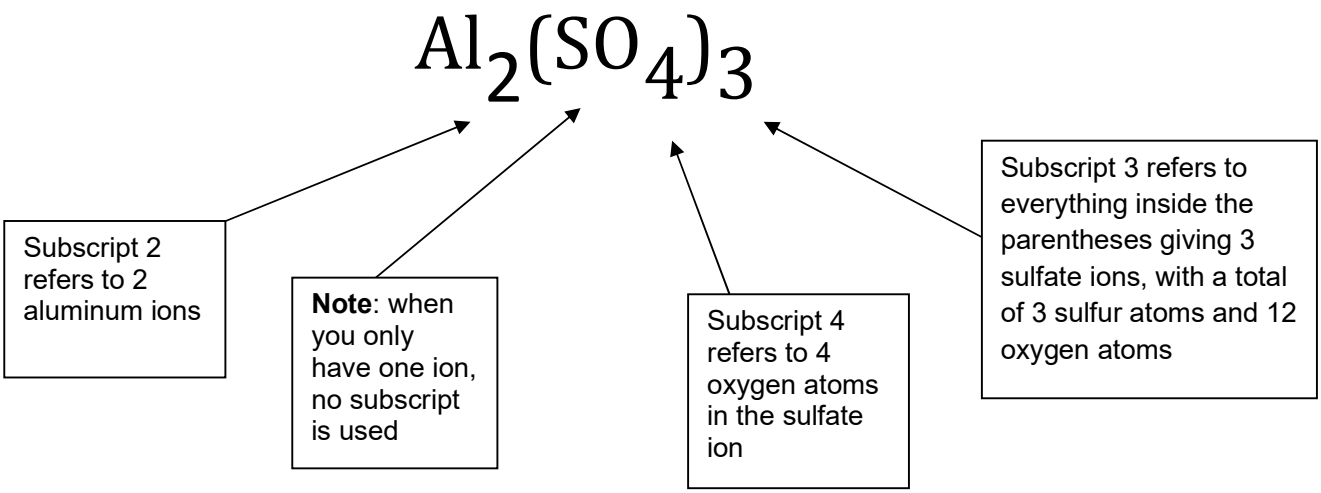
Mg^{2+} has higher ionic charge than Na^{+}.
O^{2-} has higher ionic charge than Cl^{-}.
More energy is needed to overcome the stronger electrostatic forces of attraction between oppositely charged ions (Mg^{2+} and O^{2-}).

Chemical formula of ionic compounds

The formula of an ionic compound is derived by balancing the charges on the positive ions with those on the negative ions.

All the positive charges must equal all the negative charges in an ionic compound.

For instance, aluminum sulfate consists of aluminum cations and sulfate anions



(A) For simple ions

View the following video :

Writing Ionic Formulas: Introduction (https://www.youtube.com/watch?v=URc75hoKGLY)

Practice

Write down the chemical formulas of each of the following compounds :

	Name of compound	Formula of positive ion	Formula of negative ion	Chemical formula of compound
1	sodium fluoride	Na^+	F^-	NaF
2	calcium chloride	Ca^{2+}	Cl^-	$CaCl_2$
3	aluminium fluoride	Al^{3+}	F^-	AlF_3
4	potassium oxide	K^+	O^{2-}	K_2O
5	magnesium sulfide	Mg^{2+}	S^{2-}	MgS
6	iron(III) oxide	Fe^{3+}	O^{2-}	Fe_2O_3

(B) For polyatomic ions

A **polyatomic ion**, is a charged particle which is made up of two or more atoms covalently bonded. It can be considered to be acting as a single unit.

There are many polyatomic ions. Here are the more common ones:

Name	ammonium	hydroxide	nitrate	carbonate	sulfate
Formula	NH_4^+	OH^-	NO_3^-	CO_3^{2-}	SO_4^{2-}

Rules for Naming Ionic Compounds and Writing Formulae

Rule	Example
The metal is written first, followed by the non-metal.	Sodium chloride ($NaCl$) Magnesium chloride ($MgCl_2$)
The positive ion is written first, followed by the negative ion.	Copper (II) sulfate ($CuSO_4$) Ammonium chloride (NH_4Cl)
The number of ions is written as a subscript.	Al_2O_3 (not Al2O3) $MgCl_2$ (not MgCl2 or 2MgCl)

Rule	Example
It is not necessary to write down the subscript "1" in formulae.	$NaCl$ (not Na_1Cl_1) $MgCl_2$ (not Mg_1Cl_2)
Metals that form more than one ion, such as iron, add a Roman numeral to the name to indicate the charge	Fe^{2+} is called iron (II) Fe^{3+} is called iron (III)
Special ions are treated as single element NH_4^+, OH^-, CO_3^{2-}, NO_3^-, SO_4^{2-}	

More practice

Write down the chemical formulas of each of the following compounds:

	Name of compound	Formula of positive ion	Formula of negative ion	Chemical formula of compound
1	sodium hydroxide	Na^+	OH^-	$NaOH$
2	magnesium hydroxide	Mg^{2+}	OH^-	$Mg(OH)_2$
3	aluminium nitrate	Al^{3+}	NO_3^-	$Al(NO_3)_3$
4	potassium sulfate	K^+	SO_4^{2-}	K_2SO_4
5	calcium carbonate	$Ca^{2=}$	CO_3^{2-}	$CaCO_3$
6	iron(III) sulfate	Fe^{3+}	SO_4^{2-}	$Fe_2(SO_4)_3$

Complete the table below on the chemical formulae of the common ionic compounds:

		Cl^-	OH^-	NO_3^-	O^{2-}	SO_4^{2-}	CO_3^{2-}	N^{3--}
		chloride	hydroxide	nitrate	oxide	sulfate	carbonate	nitride
Na^+	sodium	NaCl	NaOH	$NaNO_3$	Na_2O	Na_2SO_4	Na_2CO_3	Na_3N
NH_4^+	ammonium	NH_4Cl	NH_4OH	NH_4NO_3	NA	$(NH_4)_2SO_4$	$(NH_4)_2CO_3$	$(NH_4)_3N$
Ag^+	silver	AgCl	AgOH	$AgNO_3$	Ag_2O	Ag_2SO_4	Ag_2CO_3	Ag_3N
Mg^{2+}	magnesium	$MgCl_2$	$Mg(OH)_2$	$Mg(NO_3)_2$	MgO	$MgSO_4$	$MgCO_3$	Mg_3N_2
Zn^{2+}	zinc	$ZnCl_2$	$Zn(OH)_2$	$Zn(NO_3)_2$	ZnO	$ZnSO_4$	$ZnCO_3$	Zn_3N_2
Fe^{2+}	iron(II)	$FeCl_2$	$Fe(OH)_2$	$Fe(NO_3)_2$	FeO	$FeSO_4$	$FeCO_3$	Fe_3N_2
Pb^{2+}	lead(II)	$PbCl_2$	$Pb(OH)_2$	$Pb(NO_3)_2$	PbO	$PbSO_4$	$PbCO_3$	Pb_3N_2
Al^{3+}	aluminium	$AlCl_3$	$Al(OH)_3$	$Al(NO_3)_3$	Al_2O_3	$Al_2(SO_4)_3$	$Al_2(CO_3)_3$	AlN
Fe^{3+}	iron(III)	$FeCl_3$	$Fe(OH)_3$	$Fe(NO_3)_3$	Fe_2O_3	$Fe_2(SO_4)_3$	$Fe_2(CO_3)_3$	FeN
Cr^{3+}	Chromium(III)	$CrCl_3$	$Cr(OH)_3$	$Cr(NO_3)_3$	Cr_2O_3	$Cr_2(SO_4)_3$	$Cr_2(CO_3)_3$	CrN

To practise writing formula at your own time:
http://apps.apple.com/sg/app/write-formula/id934269976