Topic 3: **Answers**
Chemical Formulae & Equations

SYLLABUS RELEVANCE & TEXTBOOK CHAPTERS		
O-LEVEL PURE (5072)	✓	Chapter 8
O-LEVEL SCIENCE (5116)	✓	Chapter 7
N-LEVEL SCIENCE (5155)	✓	Chapter 7 & 8

Lesson Package & Accompanying Slides Designed by Alex Lee (2008)
Last Modified by Alex Lee (2011)

1. Formulae of Ionic Compounds

Ionic compounds consist of two parts – a cation (a positive ion), and an anion (a negative ion). For example, let's take a look at calcium chloride.

Ca^{2+} **CATION** Cl^- **ANION**

However, as discussed in the previous chapter, the calcium ion and the chloride ion would not react in a 1:1 ratio; calcium wants to give away two electrons, while chlorine only wants to take in one. Hence the calcium ion will need **two** chloride ions to balance its 2+ charge.

Ca^{2+} **CATION** Cl^- **ANION** Cl^- **ANION**

Placing these ions together, we get the chemical formula for calcium chloride. Note that we use a subscript "2" after the chloride ion to represent two chloride ions. Since there is only one calcium ion, we do not place any number next to it. The cation is generally placed first.

$CaCl_2$ **IONIC COMPOUND**

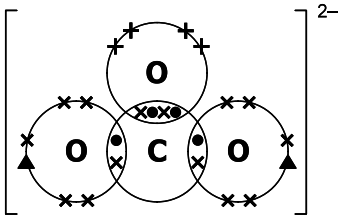
After the ions are balanced, there is no net charge left – all the positive charges should have cancelled off the negative charges. Hence here is **no need to indicate any charge**.

Work out the formulae of the following salts, given the cations and anions below.

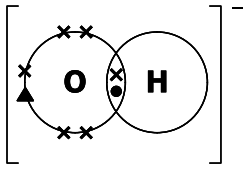
A^+	B^-	AB	A^{2+}	B^{3-}	A_3B_2
A^{2+}	B^-	AB_2	A^{2+}	B^{2-}	AB
A^+	B^{2-}	A_2B	A^{2-}	B^+	B_2A
A^{3+}	B^{3-}	AB	A^-	B^{3+}	BA_3
A^{3+}	B^{2-}	A_2B_3	A^+	B^{3-}	A_3B

2. Molecular Ions

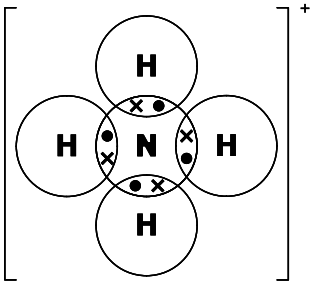
In the past two tutorials, we had looked at atoms which gain or lose electrons to from ions. However, sometimes simple molecules can also gain or lose electrons to form ions! The dot-and-cross diagrams for some molecular ions are shown below.



CARBONATE ION
CO_3^{2-}



HYDROXIDE ION
OH^-



AMMONIUM ION
NH_4^+

Molecular ions are interesting as they form compounds with **both covalent and ionic bonds**. For example, limestone (calcium carbonate) contains calcium ions and carbonate ions, attracted by electrostatic forces of attraction (ionic bonding). However, within the carbonate ion itself, there are covalent bonds holding the carbon and oxygen atoms together.

When constructing a formula containing **more than one** of the same molecular ion, we use brackets. For example, calcium hydroxide. To balance the charges, one calcium ion reacts with two hydroxide ions.

Ca^{2+} OH^- OH^-

CATION **ANION** **ANION**

However, because the hydroxide ion is a molecular ion, **and there is more than one of it**, we place brackets around it.

$Ca(OH)_2$

IONIC COMPOUND

Work out the formulae of the following salts, given the cations and anions below.

NH_4^+	Cl^-	NH_4Cl	Mg^{2+}	OH^-	$Mg(OH)_2$
NH_4^+	O^{2-}	$(NH_4)_2O$	K^+	OH^-	KOH
NH_4^+	N^{3-}	$(NH_4)_3N$	Al^{3+}	OH^-	$Al(OH)_3$
NH_4^+	CO_3^{2-}	$(NH_4)_2CO_3$	Cu^{2+}	CO_3^{2-}	$CuCO_3$
NH_4^+	OH^-	NH_4OH	H^+	CO_3^{2-}	H_2CO_3

3. **Formulae of Common Ions**

In order to construct a chemical formula of an ionic compound, you must first learn the formulae of the various cations and anions. While some of these formulae can be derived from the Periodic Table, **those marked with an asterisk (*) you will need to memorize**.

CATIONS		ANIONS	
Sodium, Na^+ Potassium, K^+ Magnesium, Mg^{2+} Calcium, Ca^{2+} Barium, Ba^{2+} Aluminium, Al^{3+}	*predicted from the Periodic Table*	Fluoride, F^- Chloride, Cl^- Bromine, Br^- Iodide, I^- Oxide, O^{2-} Sulfide, S^{2-} Nitride, N^{3-} Phosphide, P^{3-}	*predicted from the Periodic Table*
Copper(II), Cu^{2+} Iron(II), Fe^{2+} Iron(III), Fe^{3+} Lead(II), Pb^{2+}	*predicted from the oxidation state (roman numerals)*		
Hydrogen (Acid), H^+ **Silver, Ag^+** **Zinc, Zn^{2+}**	***special exceptions****	**Carbonate, CO_3^{2-}** **Hydroxide, OH^-** **Nitrate, NO_3^-** **Sulfate, SO_4^{2-}** **Sulfite, SO_3^{2-}** **Phosphate, PO_4^{3-}** **Dichromate, $Cr_2O_7^{2-}$** **Permanganate, MnO_4^-**	***molecular ions****
Ammonium, NH_4^+	***molecular ion****		

Write down the chemical formulae for the following compounds:

Aluminium iodide	AlI_3	Ammonium hydroxide	NH_4OH
Barium nitrate	$Ba(NO_3)_2$	Ammonium phosphate	$(NH_4)_3PO_4$
Calcium phosphate	$Ca_3(PO_4)_2$	Ammonium sulfate	$(NH_4)_2SO_4$
Copper(II) hydroxide	$Cu(OH)_2$	Aluminium sulfate	$Al_2(SO_4)_3$
Iron(III) oxide	Fe_2O_3	Cobalt(II) hydroxide	$Co(OH)_2$
Lithium sulfate	Li_2SO_4	Copper(I) oxide	Cu_2O
Lithium sulfide	Li_2S	Iron(II) nitrate	$Fe(NO_3)_2$
Lithium sulfite	Li_2SO_3	Lead(I) chloride	$PbCl$
Potassium carbonate	K_2CO_3	Lead(II) chloride	$PbCl_2$
Silver sulfate	Ag_2SO_4	Nickel(II) nitrate	$Ni(NO_3)_2$
Sodium fluoride	NaF	Potassium hydroxide	KOH
Zinc dichromate	$ZnCr_2O_7$	Rubidium carbonate	Rb_2CO_3

4. Formulae of Acids

As we will learn in the next chapter, acids refer to solutions which contain the hydrogen ion, H^+.

The anion present, however, will depend on the type of acid:

Hydrochloric acid, *hydrobromic acid* and *hydrofluoric acid* possess the **chlor<u>ide</u>**, **brom<u>ide</u>** and **fluor<u>ide</u>** ions respectively. Simply put, acids that contain a 'hydro-' prefix will contain the monoatomic anion ("-ide") of the respective element.

Sulfuric acid, *nitric acid*, *carbonic acid* and *phosphoric acid* posses the **sulf<u>ate</u>**, **nitr<u>ate</u>**, **carbon<u>ate</u>** and **phosph<u>ate</u>** ions respectively. Simply put, acids that have no prefix and contain a '-ic' suffix will contain the molecular ion ("-ate") of the respective element.

Sulfurous acid and *nitrous acid* posses the **sulf<u>ite</u>** and **nitr<u>ite</u>** ions respectively. Simply put, acids that have no prefix and contain a '-ous' suffix will contain the molecular ion ("-ite") of the respective element.

Write down the chemical formulae for the following acids:

Hydrochloric acid	HCl	Carbonic acid	H_2CO_3
Sulfuric acid	H_2SO_4	Phosphoric acid	H_3PO_4
Nitric acid	HNO_3	Sulfurous acid	H_2SO_3

5. Formulae of Covalent Substances

Unlike ionic substances, the formulae of covalent substances may not be as easy to predict from its chemical name.

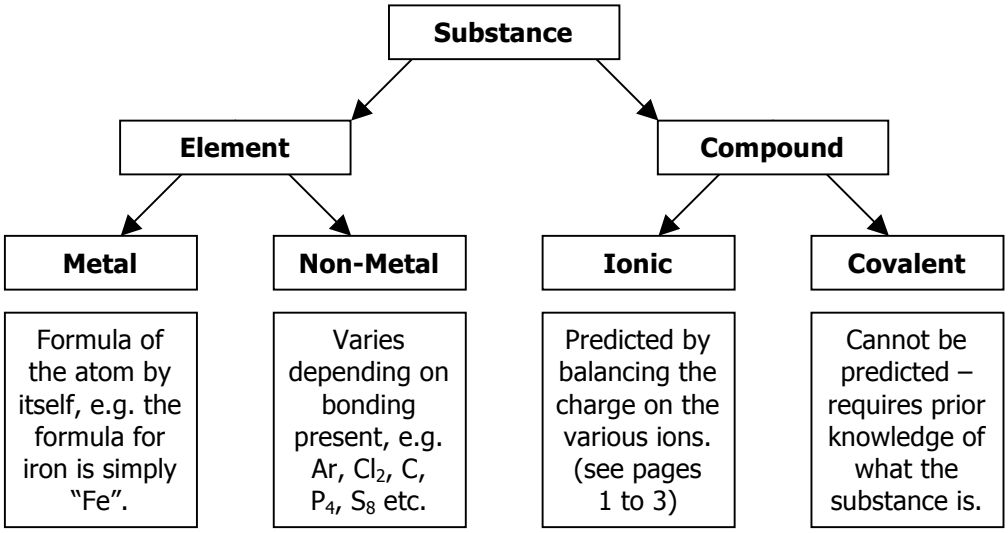
ELEMENTS		COMPOUNDS	
Hydrogen, H_2	Bromine, Br_2	Water, H_2O	Nitrogen Monoxide, NO
Oxygen, O_2	Iodine, I_2	Ammonia, NH_3	Hydrogen Peroxide, H_2O_2
Nitrogen, N_2	Ozone, O_3	Methane, CH_4	Hydrogen Chloride, HCl
Carbon, C	Phosphorus, P_4	Carbon Dioxide, CO_2	Hydrogen Fluoride, HF
Chlorine, Cl_2	Sulfur, S_8	Sulfur Dioxide, SO_2	Ethanol, CH_3CH_2OH

Sometimes we make use of prefixes such as **mono-**, **di-**, **tri-** and **tetra-**; which mean one, two, three and four respectively, to help us determine the formulae.

Write down the chemical formulae for the following compounds:

Carbon monoxide	CO	Dinitrogen trioxide	N_2O_3
Carbon tetrachloride	CCl_4	Phosphorus tribromide	PBr_3
Dichlorine monoxide	Cl_2O	Sulfur Trioxide	SO_3

6. Summary of Chemical Formulae



Write down the chemical formulae for the following substances:

Aluminium	Al	Barium hydroxide	$Ba(OH)_2$
Nitrogen gas	N_2	Copper	Cu
Ammonium carbonate	$(NH_4)_2CO_3$	Krypton	Kr

7. **State Symbols**

In a chemical equation, we indicate physical state by writing **(s)**, **(l)**, **(g)** or **(aq)** (to represent solid, liquid, gaseous or aqueous respectively) in brackets after each substance.

Generally, **metals are solid** at room temperature (with the exception of mercury), and **ionic compounds are either solid or aqueous**, depending on whether they have been dissolved in water. Covalent substances may occur in any state.

Fill in the appropriate state symbols for the chemical reactions described below.

Some calcium carbonate powder was allowed to react with dilute hydrochloric acid in a test-tube. Effervescence was observed, and a temperature change was recorded. A solution of calcium chloride was produced, together with water and carbon dioxide.

$$CaCO_3\ (s) + 2\ HCl\ (aq) \longrightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$$

Two colourless solutions, lead(II) nitrate and potassium sulfate, were mixed in a conical flask. A white precipitate of lead(II) sulfate was formed, causing the colourless solution to turn into a white suspension. The solution remaining was found to be potassium nitrate.

$$Pb(NO_3)_2\ (aq) + K_2SO_4\ (aq) \longrightarrow PbSO_4\ (s) + 2\ KNO_3\ (aq)$$

8. **Balancing Chemical Equations**

For any chemical reaction, the number of atoms which "go into" a reaction would be equal to the number of atoms which "come out from" a reaction. This is simply the principle of conservation of mass – atoms cannot simply disappear into thin space!

Using the chemical formulae that we learnt earlier, we find that many times the number of atoms may not match exactly. For example, the combustion of carbon monoxide:

$$\mathbf{CO\ (g) + O_2\ (g) \longrightarrow CO_2\ (g)}$$

There are three oxygen atoms on the left side of the equation, while there are only two oxygen atoms on the right! We balance the equation by writing large numbers in front of each chemical.

In the example below, there are two carbon atoms and four oxygen atoms on both sides. (Note that there is **no need to write "1"** if there is only one of the reactant; simply state the formula.)

$$\mathbf{2\ CO\ (g) + O_2\ (g) \longrightarrow 2\ CO_2\ (g)}$$

Be careful **not to alter the chemical formula** during balancing. For example, do not change the chemical formula of carbon dioxide to CO_3, just to make it balance!

$$\mathbf{CO\ (g) + O_2\ (g) \longrightarrow CO_3\ (g)}$$

WRONG! Do not alter the chemical formula!

Balance the equations below.

(a) ____ C_3H_8 (g) + 5 O_2 (g) ⟶ 3 CO_2 (g) + 4 H_2O (g)

(b) 2 C_4H_{10} (g) + 13 O_2 (g) ⟶ 8 CO_2 (g) + 10 H_2O (g)

(c) ____ C_6H_{12} (l) + 9 O_2 (g) ⟶ 6 CO_2 (g) + 6 H_2O (g)

(d) 2 C_3H_6 (g) + 9 O_2 (g) ⟶ 6 CO_2 (g) + 6 H_2O (g)

(e) ____ $C_6H_{12}O_6$ (s) + 6 O_2 (g) ⟶ 6 CO_2 (g) + 6 H_2O (g)

(f) ____ $BaCl_2$ (aq) + ____ K_2SO_4 (aq) ⟶ ____ $BaSO_4$ (s) + 2 KCl (aq)

(g) ____ CaO (s) + 2 HCl (aq) ⟶ ____ $CaCl_2$ (aq) + ____ H_2O (l)

(h) 2 Cu (s) + ____ O_2 (g) ⟶ 2 CuO (s)

(i) 2 Fe (s) + 3 H_2O(g) ⟶ ____ Fe_2O_3 (s) + 3 H_2 (g)

(j) ____ Fe_2O_3 (s) + 3 H_2 (g) ⟶ 2 Fe (s) + 3 H_2O (g)

(k) 2 K (s) + 2 H_2O (l) ⟶ 2 KOH (aq) + ____ H_2 (g)

(l) 2 Li (s) + ____ H_2SO_4 (aq) ⟶ ____ Li_2SO_4 (aq) + ____ H_2 (g)

(m) ____ Mg (s) + 2 HCl (aq) ⟶ ____ $MgCl_2$ (aq) + ____ H_2 (g)

(n) ____ N_2 (g) + 3 H_2 (g) ⟶ 2 NH_3 (g)

(o) 2 NaOH (aq) + ____ H_2SO_4(aq) ⟶ ____ Na_2SO_4 (aq) + 2 H_2O (l)

9. **Constructing Chemical Equations**

We are now ready to put all that we have learnt in the previous few pages together, and to begin constructing chemical equations.

Step 1: Interpret the chemical reaction.
sulfuric acid + sodium hydroxide $\longrightarrow$ *sodium sulfate + water*

Step 2: Write down the chemical formulae of all reactants and products.
$H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$

Step 3: Balance the equation.
$H_2SO_4 + 2\ NaOH \longrightarrow Na_2SO_4 + 2\ H_2O$

Step 4: Add in state symbols, if necessary.
$H_2SO_4\ (aq) + 2\ NaOH\ (aq) \longrightarrow Na_2SO_4\ (aq) + 2\ H_2O\ (l)$

Apply the above steps to the two reactions described below.

REACTION #1:
Gaseous hydrogen and gaseous chlorine combine directly under bright sunlight to produce a third gas, hydrogen chloride.

Word Equation: hydrogen + chlorine ⟶ hydrogen chloride

Balanced Chemical Equation (without state symbols): $H_2 + Cl_2 \longrightarrow 2\ HCl$

Balanced Chemical Equation (with state symbols): $H_2\ (g) + Cl_2\ (g) \longrightarrow 2\ HCl\ (g)$

REACTION #2:
In a laboratory experiment, a sample of aluminium foil is allowed to burn in bromine vapour to produce a solid sample of aluminium bromide.

Word Equation: aluminium + bromine ⟶ aluminium bromide

Balanced Chemical Equation (without state symbols): $2\ Al + 3\ Br_2 \longrightarrow 2\ AlBr_3$

Balanced Chemical Equation (with state symbols): $2\ Al\ (s) + 3\ Br_2\ (g) \longrightarrow 2\ AlBr_3\ (s)$

10. **Review Questions**

Construct balanced chemical equations, including state symbols, for the reactions as described below. Remember – not all information is relevant.

(a) A piece of magnesium oxide reacts with hydrochloric acid to form aqueous magnesium chloride and water.

$MgO\ (s) + 2\ HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2O\ (l)$

(b) A piece of sodium is placed into a beaker of water. Effervescence of hydrogen gas was observed, and a solution of aqueous sodium hydroxide was left remaining.

$2\ Na\ (s) + 2\ H_2O\ (l) \longrightarrow 2\ NaOH\ (aq) + H_2\ (g)$

(c) In an industrial process, carbon monoxide is used to convert iron(III) oxide into molten iron, producing carbon dioxide in the process.

$3\ CO\ (g) + Fe_2O_3\ (s) \longrightarrow 2\ Fe\ (l) + 3\ CO_2\ (g)$

(d) Solid calcium nitrate decomposes on heating to become solid lumps of calcium oxide, nitrogen dioxide gas and oxygen.

$Ca(NO_3)_2\ (s) \longrightarrow CaO\ (s) + 2\ NO_2\ (g) + O_2\ (g)$

(e) Calcium carbonate powder reacts with a solution of phosphoric acid to produce solid calcium phosphate, carbon dioxide and water.

$3\ CaCO_3\ (s) + 2\ H_3PO_4\ (aq) \longrightarrow Ca_3(PO_4)_2\ (s) + 3\ CO_2\ (g) + 3\ H_2O\ (l)$

(f) Two solutions of ammonium nitrate and calcium hydroxide react to produce aqueous calcium nitrate, ammonia gas and water.

$2\ NH_4NO_3\ (aq) + Ca(OH)_2\ (aq) \longrightarrow Ca(NO_3)_2\ (aq) + 2\ NH_3\ (g) + 2\ H_2O\ (l)$

Self-Designed Summary

Supplementary Questions

1. Write down the formula of the salt formed between the cation and anion in the table below.

	aluminium	ammonium	calcium	copper(II)	iron(III)	lead(I)	lead(II)	potassium
carbonate								
chloride								
hydroxide								
iodide								
nitrate								
oxide								
phosphate								
sulfate								

2. Balance the following chemical equations.
   (a) … Fe_2O_3 + … CO ⟶ … Fe_3O_4 + … CO_2
   (b) … Fe_3O_4 + … CO ⟶ … FeO + … CO_2
   (c) … $C_{12}H_{22}O_{11}$ + … O_2 ⟶ … CO_2 + … H_2O
   (d) … Fe + … O_2 ⟶ … Fe_2O_3
   (e) … Ca + … H_2O ⟶ … $Ca(OH)_2$ + … H_2
   (f) … $(NH_4)_2Cr_2O_7$ ⟶ … Cr_2O_3 + … N_2 + … H_2O
   (g) … NaCl + … BeF_2 ⟶ … NaF + … $BeCl_2$
   (h) … $FeCl_3$ + … $Be_3(PO_4)_2$ ⟶ … $BeCl_2$ + … $FePO_4$
   (i) … $AgNO_3$ + … LiOH ⟶ … AgOH + … $LiNO_3$
   (j) … CH_4 + … O_2 ⟶ … CO_2 + … H_2O
   (k) … Mg + … Mn_2O_3 ⟶ … MgO + … Mn
   (l) … $KMnO_4$ + … HCl ⟶ … KCl + … $MnCl_2$ + … H_2O + … Cl_2

3. Construct balanced chemical equations, including state symbols, for the following reactions.
   (a) *A piece of pure ice was allowed to melt completely.*
   (b) *Nitric acid decomposes to become water, nitrogen dioxide and water.*
   (c) *A piece of potassium reacts with cold water to produce potassium hydroxide and hydrogen.*
   (d) *Sulfur dioxide, a pollutant, reacts with oxygen and water to produce sulfuric acid.*

Supplementary Questions (Answers)

Question 1

	aluminium	ammonium	calcium	copper(II)	iron(III)	lead(I)	lead(II)	potassium
carbonate	$Al_2(CO_3)_3$	$(NH_4)_2CO_3$	$CaCO_3$	$CuCO_3$	$Fe_2(CO_3)_3$	Pb_2CO_3	$PbCO_3$	K_2CO_3
chloride	$AlCl_3$	NH_4Cl	$CaCl_2$	$CuCl_2$	$FeCl_3$	$PbCl$	$PbCl_2$	KCl
hydroxide	$Al(OH)_3$	NH_4OH	$Ca(OH)_2$	$Cu(OH)_2$	$Fe(OH)_3$	$PbOH$	$Pb(OH)_2$	KOH
iodide	AlI_3	NH_4I	CaI_2	CuI_2	FeI_3	PbI	PbI_2	KI
nitrate	$Al(NO_3)_3$	NH_4NO_3	$Ca(NO_3)_2$	$Cu(NO_3)_2$	$Fe(NO_3)_3$	$PbNO_3$	$Pb(NO_3)_2$	KNO_3
oxide	Al_2O_3	$(NH_4)_2O$	CaO	CuO	Fe_2O_3	Pb_2O	PbO	K_2O
phosphate	$AlPO_4$	$(NH_4)_3PO_4$	$Ca_3(PO_4)_2$	$Cu_3(PO_4)_2$	$FePO_4$	Pb_3PO_4	$Pb_3(PO_4)_2$	K_3PO_4
sulfate	$Al_2(SO_4)_3$	$(NH_4)_2SO_4$	$CaSO_4$	$CuSO_4$	$Fe_2(SO_4)_3$	Pb_2SO_4	$PbSO_4$	K_2SO_4

Question 2

(a) $3\ Fe_2O_3 + CO \longrightarrow 2\ Fe_3O_4 + CO_2$

(b) $Fe_3O_4 + CO \longrightarrow 3\ FeO + CO_2$

(c) $C_{12}H_{22}O_{11} + 12\ O_2 \longrightarrow 12\ CO_2 + 11\ H_2O$

(d) $4\ Fe + 3\ O_2 \longrightarrow 2\ Fe_2O_3$

(e) $Ca + 2\ H_2O \longrightarrow Ca(OH)_2 + H_2$

(f) $(NH_4)_2Cr_2O_7 \longrightarrow Cr_2O_3 + N_2 + 4\ H_2O$

(g) $2\ NaCl + BeF_2 \longrightarrow 2\ NaF + BeCl_2$

(h) $2\ FeCl_3 + Be_3(PO_4)_2 \longrightarrow 3\ BeCl_2 + 2\ FePO_4$

(i) $AgNO_3 + LiOH \longrightarrow AgOH + LiNO_3$

(j) $CH_4 + 2\ O_2 \longrightarrow CO_2 + 2\ H_2O$

(k) $3\ Mg + Mn_2O_3 \longrightarrow 3\ MgO + 2\ Mn$

(l) $2\ KMnO_4 + 16\ HCl \longrightarrow 2\ KCl + 2\ MnCl_2 + 8\ H_2O + 5\ Cl_2$

Question 3

(a) $H_2O\ (s) \longrightarrow H_2O\ (l)$

(b) $4\ HNO_3\ (aq) \longrightarrow 2\ H_2O\ (l) + 4\ NO_2\ (g) + O_2\ (g)$

(c) $2\ K\ (s) + 2\ H_2O\ (l) \longrightarrow 2\ KOH\ (aq) + H_2\ (g)$

(d) $2\ SO_2\ (g) + O_2\ (g) + 2\ H_2O\ (l) \longrightarrow 2\ H_2SO_4\ (aq)$

Lecture Slides

Chemical Formulae & Equations

Anglo-Chinese School (Barker Road)

CHEMISTRY

Prepared by Alex Lee

Chapter Overview

In This Chapter, We Will Learn …

1. Formulae of Substances
   - Ionic Compounds
   - Covalent Compounds
   - Elements
2. State Symbols
3. Balancing Equations
4. Constructing Chemical Equations

Formulae of Ionic Compounds

- Consists of two parts – a positive ion (known as '**cation**') and a negative ion (known as '**anion**').
- Charges are **balanced** so that overall charge is zero.

example: magnesium chloride

Cation: **Mg^{2+}** Anion: **Cl^-**

Two Cl^- ions needed to balance the 2+ charge of the Mg^{2+} ion.

Hence the formula is $MgCl_2$.

Formulae of Common Ions

Common Cations

- Sodium, Na^+
- Potassium, K^+
- Magnesium, Mg^{2+}
- Calcium, Ca^{2+}
- Barium, Ba^{2+}
- Aluminium, Al^{3+}

formulae can be deduced from the periodic table

- Copper(II), Cu^{2+}
- Iron(II), Fe^{2+}
- Iron(III), Fe^{3+}
- Lead(II), Pb^{2+}

charge can be deduced from the oxidation state

- Hydrogen (Acid), H^+
- Silver, Ag^+
- Zinc, Zn^{2+}
- Ammonium, NH_4^+

Common Anions

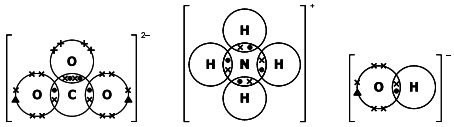
- Fluoride, F^-
- Chloride, Cl^-
- Bromide, Br^-
- Iodide, I^-
- Oxide, O^{2-}
- Sulfide, S^{2-}
- Phosphide, P^{3-}

formulae can be deduced from the periodic table

- Carbonate, CO_3^{2-}
- Hydroxide, OH^-
- Nitrate, NO_3^-
- Sulfate, SO_4^{2-}
- Phosphate, PO_4^{3-}
- Dichromate, $Cr_2O_7^{2-}$
- Permanganate, MnO_4^-

Molecular Ions & Brackets

- Some of the ions in the previous slides are actually made up of more than one atom – i.e. **molecular ions**.
- These ions contain **both covalent and ionic bonds**.



- To identify a molecular ion, its formula must have **more than one capital letter** – e.g. SO_4^{2-}, NH_4^+, MnO_4^-.

Molecular Ions & Brackets

- If the formula of an ionic compound requires **2 or more of each molecular ion**, we use **brackets** to "multiply".
- We do not use brackets otherwise.

example: ammonium sulfate

Cation: **NH_4^+** Anion: **SO_4^{2-}**

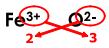
Two NH_4^+ ions needed to balance the 2- charge of the SO_4^{2-} ion.

Hence the formula is $(NH_4)_2SO_4$.

Formulae of Ionic Compounds

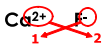
- Sometimes we can use the 'criss-cross' method to balance the charges.
- Remember to simplify the ratio after 'criss-crossing'.

example: iron(III) oxide



Formula is Fe_2O_3

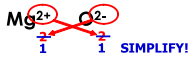
example: calcium fluoride



Formula is CaF_2

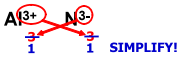
Formulae of Ionic Compounds

example: magnesium oxide



Formula is **MgO**

example: aluminium nitride

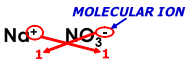


Formula is **AlN**

example: calcium nitrate

Formula is $Ca(NO_3)_2$

example: sodium nitrate



Formula is $NaNO_3$

Formulae of Acids

- Acids contain the **hydrogen cation** (H^+).
- The **anion**, however, depends on the type of acid.

Acid	Anion	Acid (Example)	Anion (Example)
hydro-	-ide	hydrochloric acid	chloride ion
		hydrobromic acid	bromide ion
-ic	-ate	sulfuric acid	sulfate ion
		nitric acid	nitrate ion
		carbonic acid	carbonate ion
-ous	-ite	sulfurous acid	sulfite ion
		nitrous acid	nitrite ion

Formulae of Acids

- Like ionic compounds, the formula of acids involves placing the cation (H^+) first, followed by the anion.
- Charges are then balanced.

example: phosphoric acid

Cation: H^+ Anion: PO_4^{3-}

Three H^+ ions needed to balance the 3- charge of the PO_4^{3-} ion.

Hence the formula is H_3PO_4.

Formulae of Covalent Substances

- Unlike ionic substances, the chemical formula of **covalent substances** are **harder to predict**.

some examples:

- *Water,* H_2O
- *Ammonia,* NH_3
- *Methane,* CH_4
- *Ethanol,* C_2H_5OH

Formulae of Covalent Substances

- Sometimes we can use **prefixes** to help us.

prefix	mono-	di-	tri-	tetra-	penta-	hexa-
number	1	2	3	4	5	6

some examples:

- *carbon dioxide* CO_2
- *difluorine monoxide* F_2O
- *nitrogen monoxide* NO

Formulae of Elements

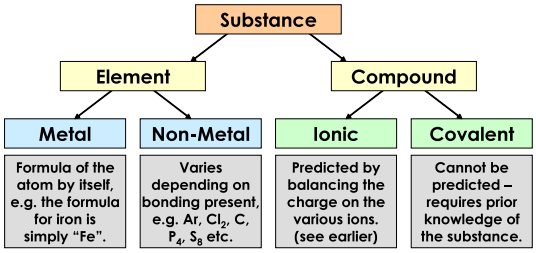
- Metals have the same symbol as the atom alone, i.e. the formula for sodium is simply Na, not Na_2 or Na_3.

  e.g. *potassium* *K*
  copper *Cu*
  platinum *Pt*

- Non-metals, on the other hand may have varying formulae, depending on their structures.

  e.g. *argon* *Ar*
  chlorine Cl_2
  sulfur S_8

Formulae – A Summary



State Symbols

- Sometimes we indicate the state of each reactant or product in brackets after the chemical symbol.

For example:

$MgCO_3\ (s) + H_2SO_4\ (aq) \rightarrow MgSO_4\ (aq) + H_2O\ (l) + CO_2\ (g)$

SOLID *(below melting point at room temp).*
AQUEOUS *(dissolved in water; e.g. solution.)*
LIQUID *(between melting and boiling points.)*
GAS *(above boiling point at room temp).*

State Symbols

States at room temperature:

Elements	Metals	**Solid** (except mercury)
	Non-Metals	**Various States** (e.g. iodine is solid, bromine is liquid and chlorine is gaseous)
Compounds	Ionic	**Solid** (or if dissolved in water, **Aqueous**)
	Covalent	**Various States** (e.g. sand is solid, water is liquid and carbon dioxide is gaseous)

Balancing Chemical Equations

- In any chemical equation, the number of atoms on both sides has to balance.
- This follows the rationale that no atoms can be created or destroyed in a reaction (conservation of mass).
- To balance an equation, we generally start with the chemical with the most complicated formula.

start with the most complicated formula
3. balance the 10 oxygen atoms
$C_3H_8\ (g) + 5\,O_2\ (g) \longrightarrow 3\,CO_2\ (g) + 4\,H_2O\ (g)$
1. balance the 3 carbon atoms
2. balance the 8 hydrogen atoms

Balancing Chemical Equations

- Sometimes we may use fractions <u>temporarily</u>.

start with the most complicated formula
3. balance the 13 oxygen atoms
$2\,C_4H_{10}\ (g) + 13/2\,O_2\ (g) \longrightarrow 8\,CO_2\ (g) + 10\,H_2O\ (g)$
1. balance the 4 carbon atoms
2. balance the 10 hydrogen atoms

$1/2\,N_2\ (g) + 3/2\,H_2\ (g) \longrightarrow 2\,NH_3\ (g)$
1. balance 1 nitrogen atom
2. balance 3 hydrogen atoms

Chemical Equations – Framework

Step 1: What is the Reaction?

carbon dioxide + water ——→ sugar + oxygen

Step 2: Replace With Chemical Symbols

$CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$

Step 3: Balance the Equation

$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$

Step 4: Add State Symbols (If Necessary)

$6\ CO_2\ (g) + 6\ H_2O\ (l) \longrightarrow C_6H_{12}O_6\ (aq) + 6\ O_2\ (g)$

Chemical Equations – Example #1

Chemical Reaction (Step 1):

hydrogen + chlorine ——→ hydrogen chloride

Step 2: Replace With Chemical Symbols

$H_2 + Cl_2 \longrightarrow HCl$

Step 3: Balance the Equation

$H_2 + Cl_2 \longrightarrow 2\ HCl$

Step 4: Add State Symbols

$H_2\ (g) + Cl_2\ (g) \longrightarrow 2\ HCl\ (g)$

Chemical Equations – Example #2

Chemical Reaction (Step 1):

aluminium + bromine ——→ aluminium bromide

Step 2: Replace With Chemical Symbols

$Al + Br_2 \longrightarrow AlBr_3$

Step 3: Balance the Equation

$2\ Al + 3\ Br_2 \longrightarrow 2\ AlBr_3$

Step 4: Add State Symbols

$2\ Al\ (s) + 3\ Br_2\ (g) \longrightarrow 2\ AlBr_3\ (s)$


THE BEST IS YET TO BE