5072 CHEMISTRY (NEW PAPERS WITH SPA)
BASIC TECHNIQUES

5067 CHEMISTRY (NEW PAPERS WITH PRACTICAL EXAM)
BASIC TECHNIQUES

LEARNING OUTCOMES
a) Be able to write formulae of simple compounds b) Be able to write balanced chemical and ionic equations

A Symbols and Formulae

- A symbol is used to represent one atom of an element.
- The symbol can be a letter or two letters, the first of which must be a capital.
  - Ag stands for 1 atom of Silver
  - Au stands for 1 atom of Gold
- An integer in front of a symbol indicates the number of that atom.
  - 3Pb represents 3 atoms of Lead
  - 5Sn represents 5 atoms of Tin
- A formula is used to represent the smallest unit of a substance.
- The formula of a substance gives the composition of the substance, i.e. it shows the relative numbers of atoms or ions that have combined together.
  - *Substance is an element*
    - Br_2 represents 1 molecule of Bromine
    - 1 molecule of Bromine contains 2 Br atoms
    - $2Br_2$ represents 2 molecules of Bromine
    - 2 molecules of Bromine contains 4 Br atoms
  - *Substance is a covalent compound*
    - CO_2 represents 1 molecule of Carbon Dioxide
    - 1 molecule of Carbon Dioxide contains 1 C atom and 2 O atoms
    - $4CO_2$ represents 4 molecules of Carbon Dioxide
    - 4 molecules of Carbon Dioxide contains 4 C atoms and 8 O atoms
  - *Substance is an ionic compound*
    - $CaCl_2$ represents 1 unit of Calcium Chloride
    - 1 unit of Calcium Chloride contains 1 Ca atom and 2 Cl atoms
    - $3CaCl_2$ represents 3 units of Calcium Chloride
    - 3 units of Calcium Chloride contains 3 Ca atoms and 6 Cl atoms

B Writing Formulae of Simple Compounds

- The valency of an element is needed to be able to write the formulae of a compound
- The valency of an element is a number which shows its combining power
- In ionic compounds, the valency of an ion is equal to its charge

Positive Ions (Cations)			Negative Ions (Anions)		
H^+	Hydrogen	1	F^-	Fluoride	1
NH_4^+	Ammonium	1	Cl^-	Chloride	1
Ag^+	Silver (I)	1	Br^-	Bromide	1
Na^+	Sodium	1	I^-	Iodide	1
K^+	Potassium	1	OH^-	Hydroxide	1
Ba^{2+}	Barium	2	NO_2^-	Nitrite	1
Ca^{2+}	Calcium	2	NO_3^-	Nitrate	1
Cu^{2+}	Copper (II)	2	HCO_3^-	Hydrogencarbonate	1
Fe^{2+}	Iron (II)	2	CH_3COO^-	Ethanoate	1
Mg^{2+}	Magnesium	2	S^{2-}	Sulphide	2
Pb^{2+}	Lead (II)	2	O^{2-}	Oxide	2
Sn^{2+}	Tin (II)	2	SO_3^{2-}	Sulphite	2
Zn^{2+}	Zinc	2	SO_4^{2-}	Sulphate	2
Ni^{2+}	Nickel (II)	2	CO_3^{2-}	Carbonate	2
Al^{3+}	Aluminium	3	CrO_4^{2-}	Chromate (VI)	2
Cr^{3+}	Chromium (III)	3	$Cr_2O_7^{2-}$	Dichromate (VI)	2
Fe^{3+}	Iron (III)	3	PO_4^{3-}	Phosphate	3

- In writing formulae of ionic compounds, note that:
  - Ionic compounds are made up of positive and negative ions

- In an ionic compound, the total positive charges must equal the total negative charges, i.e. the total charges in an ionic compound must equal 0.

Example 1	**Sodium Chloride**	
Formula of Ions	Na^{+}	Cl^{-}
Valency of Ions	1	1
Simplest Ratio of combining ions	1	1
Formula	NaCl	
Example 2	**Iron (II) Phosphate**	
Formula of Ions	Fe^{2+}	PO_4^{3-}
Valency of Ions	2	3
Simplest Ratio of combining ions	3	2
Formula	$Fe_3(PO_4)_2$	

- In covalent compounds, the valency of an element is the number of covalent bonds which it can form with Hydrogen atoms.

H	Hydrogen	1	O	Oxygen	2
F	Fluorine	1	N	Nitrogen	3
Cl	Chlorine	1	C	Carbon	4
Br	Bromine	1	P	Phosphorus	3 and 5
I	Iodine	1	S	Sulphur	2, 4 and 6

- In writing formulae of simple binary covalent compounds, the total valency of the two combining elements must be equal

Example 1	**Hydrogen Chloride**	
Formula of Elements	H	Cl
Valency of Elements	1	1
Simplest Ratio of combining atoms	1	1
Formula	HCl	
Example 2	**Tetrafluoromethane**	
Formula of Elements	C	F
Valency of Elements	4	1
Simplest Ratio of combining atoms	1	4
Formula	CF_4	

C Writing Balanced Chemical Equations

- A chemical equation summarises what happens during a chemical equation.
- It provides information about:
  - The nature of the chemicals reacting together (reactants) and the resultant chemicals produced (products)
  - The quantities of reactants reacting together and the amount of products produced
  - The physical states of the reactants and products
- The write an equation,
  1. Write down a word equation using correct formulae for all the reactants and products
  2. Write down the unbalanced equation using correct formulae for all the reactants and products
  3. Balance the equation by inspected, starting with the most complicated molecule first. Write the appropriate numbers in front of each formula to ensure that the same number of each type of atom appears on both sides of the equation.
  4. Write the state symbol after each formula
- Remember:
  - Never adjust the formula of a substance, i.e. do not change the subscripts in the formula of the reactants and/ or products to suit your balanced equation
  - Atoms cannot be created or destroyed during a chemical reaction

- A number in front of each formula multiplies every symbol that follows it.

Example 1	**Formation of Iron (III) Chloride from heating iron wool in Chlorine gas**
Words	Iron + Chlorine → Iron (III) Chloride
Formulae	$Fe + Cl_2 \rightarrow FeCl_3$
Balance	Reactants: 1 atom of Fe, 2 atoms of Cl Products: 1 atom of Fe, 3 atoms of Cl To balance Cl, find lowest common multiple of 2 and 3. Hence, both sides must have 6 atoms of Cl. Thus, change Cl_2 to $3Cl_2$ and $FeCl_3$ to $2FeCl_3$. $Fe + 3Cl_2 \rightarrow 2FeCl_3$ Reactants: 1 atom of Fe, 6 atoms of Cl Products: 2 atoms of Fe, 6 atoms of Cl To balance Fe, find lowest common multiple of 1 and 2. Hence, both sides must have 2 atoms of Fe. Thus, change Fe to 2Fe. $2Fe + 3Cl_2 \rightarrow 2FeCl_3$ Reactants: 2 atoms of Fe, 6 atoms of Cl Products: 2 atoms of Fe, 6 atoms of Cl
States	$Fe\ (s) + 3Cl_2\ (g) \rightarrow 2FeCl_3\ (s)$
Example 2	**Balance: $Pb_3O_4 + HNO_3 \rightarrow PbO_2 + Pb(NO_3)_2 + H_2O$**
Balance	Reactants: 3 atoms of Pb, 7 atoms of O, 1 atom of N, 1 atom of H Products: 2 atoms of Pb, 9 atoms of O, 2 atoms of N, 2 atoms of H To balance Pb, just change $Pb(NO_3)_2$ to $2Pb(NO_3)_2$ $Pb_3O_4 + HNO_3 \rightarrow PbO_2 + 2Pb(NO_3)_2 + H_2O$ Reactants: 3 atoms of Pb, 7 atoms of O, 1 atom of N, 1 atom of H Products: 3 atoms of Pb, 15 atoms of O, 4 atoms of N, 2 atoms of H To balance N, find the lowest common multiple of 1 and 4. Hence, both sides must have 4 atoms of N. Thus, change HNO_3 to $4HNO_3$ $Pb_3O_4 + 4HNO_3 \rightarrow PbO_2 + 2Pb(NO_3)_2 + H_2O$ Reactants: 3 atoms of Pb, 16 atoms of O, 4 atoms of N, 4 atoms of H Products: 3 atoms of Pb, 15 atoms of O, 4 atoms of N, 2 atoms of H To balance H, find the lowest common multiple of 2 and 4. Hence, both sides must have 4 atoms of H. Thus, change H_2O to $2H_2O$ $Pb_3O_4 + 4HNO_3 \rightarrow PbO_2 + 2Pb(NO_3)_2 + 2H_2O$ Reactants: 3 atoms of Pb, 16 atoms of O, 4 atoms of N, 4 atoms of H Products: 3 atoms of Pb, 16 atoms of O, 4 atoms of N, 4 atoms of H
States	$Pb_3O_4\ (s) + HNO_3\ (aq) \rightarrow PbO_2\ (s) + 2Pb(NO_3)_2\ (aq) + H_2O\ (l)$

D Writing Ionic Equations

- Ionic compounds that dissolve in water dissociate completely into ions
- Strong acids and alkalis dissociate completely into ions when dissolved in water
- Spectator ions, i.e. ions that do not take part in the reaction, are omitted from the equation
- An ionic equation must be balanced in terms of:
  - Number of atoms of each element

- Total charges carried by the ions

- The procedure is that:
  - Write the Word Equation
  - Write the formulae of the compounds corresponding the word equation
  - Write the state symbols of the compounds
  - Split up the ions of aqueous compounds ONLY.
  - Omit the spectator ions, i.e. ions that are present on both sides
  - Balance the equation

Example 1	**Neutralisation of Sodium Hydroxide and Sulphuric Acid**
Words	Sodium Hydroxide + Sulphuric Acid → Sodium Sulphate + Water
Formulae	$NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$
States	$NaOH$ (aq) + H_2SO_4 (aq) → Na_2SO_4 (aq) + H_2O (l)
Split up	Na^+ (aq) + OH^- (aq) + H^+ (aq) + SO_4^{2-} (aq) → Na^+ (aq) + SO_4^{2-} (aq) + H_2O (l)
Omission	~~Na^+ (aq)~~ + OH^- (aq) + H^+ (aq) + ~~SO_4^{2-} (aq)~~ → ~~Na^+ (aq)~~ + ~~SO_4^{2-} (aq)~~ + H_2O (l)
	OH^- (aq) + H^+ (aq) → H_2O (l)
Balance	Reactants: 1 O atom, 2 H atoms, Total charge: 0 Products: 1 O atom, 2 H atoms, Total charge: 0 The equation is already balanced
Example 2	**Balance: $MnO_4^- + H^+ + Fe^{2+} \rightarrow Mn^{2+} + Fe^{3+} + H_2O$**
States	MnO_4^- (aq) + H^+ (aq) + Fe^{2+} (aq) → Mn^{2+} (aq) + Fe^{3+} (aq) + H_2O (aq)
Balance	Reactants: 1 Mn atom, 4 O atoms, 1 H atom, 1 Fe atom, Total charge: +2 Products: 1 Mn atom, 1 O atom, 2 H atoms, 1 Fe atom, Total charge: +5 To balance O, find lowest common multiple of 1 and 4. Hence, both sides must have 4 O atoms. Thus, change H_2O to $4H_2O$ MnO_4^- (aq) + H^+ (aq) + Fe^{2+} (aq) → Mn^{2+} (aq) + Fe^{3+} (aq) + $4H_2O$ (aq) Reactants: 1 Mn atom, 4 O atoms, 1 H atom, 1 Fe atom, Total charge: +2 Products: 1 Mn atom, 4 O atom, 8 H atoms, 1 Fe atom, Total charge: +5 To balance H, find the lowest common multiple of 1 and 8. Hence, both sides must have 8 H atoms. Thus, change H^+ to $8H^+$ MnO_4^- (aq) + $8H^+$ (aq) + Fe^{2+} (aq) → Mn^{2+} (aq) + Fe^{3+} (aq) + $4H_2O$ (aq) Reactants: 1 Mn atom, 4 O atoms, 8 H atoms, 1 Fe atom, Total charge: +9 Products: 1 Mn atom, 4 O atom, 8 H atoms, 1 Fe atom, Total charge: +5
	To balance charges, meddle with the figures of Fe^{2+} and Fe^{3+}, such that both sides still have the same number of Fe atoms, and the charges on both sides are the same. If Fe atom on both sides were 3, MnO_4^- (aq) + $8H^+$ (aq) + $3Fe^{2+}$ (aq) → Mn^{2+} (aq) + $3Fe^{3+}$ (aq) + $4H_2O$ (aq) Reactants: 1 Mn atom, 4 O atoms, 8 H atoms, 3 Fe atoms, Total charge: +13 Products: 1 Mn atom, 4 O atom, 8 H atoms, 3 Fe atoms, Total charge: +11 If Fe atom on both sides were 5, MnO_4^- (aq) + $8H^+$ (aq) + $5Fe^{2+}$ (aq) → Mn^{2+} (aq) + $5Fe^{3+}$ (aq) + $4H_2O$ (aq) Reactants: 1 Mn atom, 4 O atoms, 8 H atoms, 5 Fe atoms, Total charge: +17 Products: 1 Mn atom, 4 O atom, 8 H atoms, 5 Fe atoms, Total charge: +17 The equation is now balanced.