N4/5

CHEMISTRY

UNIT 1

Chemical Changes and Structure

Learning Outcomes & Homework

Unit 1: Chemical Changes and Structure

TOPIC 1: ATOMIC STRUCTURE

LEVEL N4 N5	After completing this topic, you should be able to:	NOTES (Web 1)	How well I have understood (✓)		
			☺	😐	☹
N4	*State every element is made up of very small particles called atoms.*				
N4	*Describe the structure of the atom as having a nucleus, which contains protons and neutrons, with electrons moving around outside the nucleus.*				
N4	*State protons have a charge of one-positive, neutrons are neutral and electrons have a charge of one-negative.*				
N4	*I can explain that atoms are neutral because the number of positive protons balances the number of negative electrons*				
N4	*State that, atoms of different elements have a different number of protons, called the atomic number, and be able to identify the element in the periodic table from its Atomic Number.*				
N4	*State electrons in an atom are arranged in energy levels and be able to draw an atom from the periodic table with the correct number of electrons in each energy level (written: 2,8,8).*				
N4	*State the elements of the Periodic Table are arranged in terms of their atomic number and chemical properties. The atomic number increases by one as you move left to right across a period of the periodic table.*				
N4	*State those elements with the same number of outer electrons are found in the same group and have similar chemical properties.*				
N4	*State that protons and neutrons have an approximate mass of one atomic mass unit (a.m.u.) and electrons, in comparison, have virtually no mass.*				
N4	*State an atom has a mass number which equals the number of protons plus neutrons.*				
N5	*Write nuclide notation for an atom or an ion, and calculate the number of protons, neutrons and electrons from the mass number and the atomic number for both atoms and ions.*				
N5	*State isotopes are atoms with the same atomic number but different mass numbers due to different numbers of neutrons.*				
N5	*State elements exist as a mixture of isotopes and the average mass of an atom is called the relative atomic mass and is rarely a whole number.*				
N5	*Estimate the relative atomic mass of an element given the mass number and abundance of each isotope.*				

Exercise 1.1

The Periodic Table

1. Copy and complete the following sentences:

   a) Elements can be classified by arranging them in the _____ _____ .
   b) A row of elements is called a _____ .
   c) Elements which have similar chemical properties are in the same _____ .

2.

A Sodium	B Iron	C Argon	D Chlorine
E Fluorine	F Lithium	G Nitrogen	H Zinc

   a) Which element is a noble gas?
   b) Which two elements are alkali metals?
   c) Which two elements are transition metals?
   d) Which two elements are halogens?
   e) Which three elements are in the second period?

3. Using the information on melting and boiling points of elements on page 3 of the data booklet, state if the following will be solid, liquid or gas at room temperature (20°C).

   a) Iodine
   b) Bromine
   c) Sulphur
   d) Chlorine

4. For each of the following lists of elements decide whether the elements are in the same group or period?

   a) Phosphorus, aluminium, chlorine
   b) Chlorine, iodine, fluorine (2)

5. Which element in the following lists does not have similar properties to the others?

   i) A. calcium B. aluminium C. strontium D. magnesium

   ii) A. caesium B. potassium C. selenium D. rubidium

6. The following elements are found in the periodic table

Mercury	Sodium	Bromine
Copper	Lithium	Neon
Nitrogen	Carbon	Calcium

From the table name the element (or elements) which are

a) Transition metal
b) Noble gas
c) Have similar chemical properties
d) In the same period as Chlorine
e) A halogen

7. Which of the following compounds contains both a transition metal ion and a halide (halogen) ion?

A. Sodium chloride
B. Iron oxide
C. Magnesium bromide
D. Cobalt fluoride

8. Use the "drop and swap" method to write the chemical formula for the following:

a) Calcium oxide

b) Sodium chloride

c) Iron (II) sulphide

d) Aluminium oxide

e) Magnesium bromide

9. Some elements have symbols that appear to have nothing to do with their names. For example, the symbol for silver is Ag. Do some research to find the origins of the symbols for gold, silver, mercury, tin and lead.

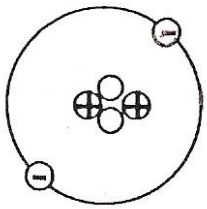
10. Which of the following compounds contains oxygen?

A Calcium chloride
B Lithium sulphide
C Potassium nitrate
D Sodium chloride

Exercise 1.2

Atomic Structure

1. a) Copy and label the diagram of an atom.



b) Explain why the atom is neutral.

c) Which element is represented in the diagram?

2. Copy and complete this table:

Particle	**Charge**	**Mass**	**Where found in atom**
proton		1	Nucleus
	0		
		almost 0	

3. a) Copy and complete the following table:

Element	Atomic Number	Mass Number	Number of protons	Number of neutrons	Number of electrons
Ne		22			
N				7	
Ca		40			
A	4	9			
B		14			6
C		89	36		
D			10	10	
E				17	15

b) Identify elements **A, B, C, D** and **E**.

4. Write the electron arrangements for the following atoms:

   a) Chlorine
   b) Neon
   c) Hydrogen
   d) Calcium

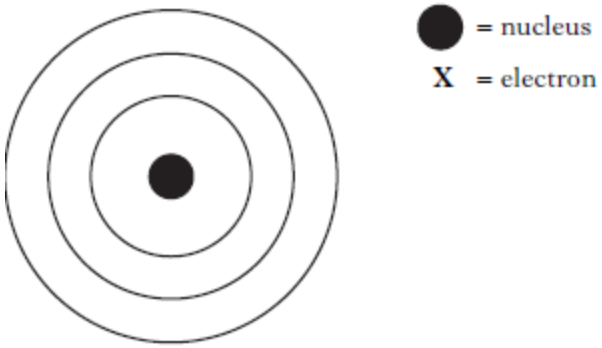
5. Which of the following is the electron arrangement of a metal element?

   A. 2,8
   B. 2,8,1
   C. 2,8,7
   D. 2,8,8

6. This symbol gives some information about an atom: $^{37}_{17}Cl$

   Complete the following:
   i) name of element
   ii) number of protons
   iii) number of neutrons
   iv) number of electrons
   v) electron arrangement
   vi) group number

7. Electrons are arranged in energy levels. Complete the diagram to show how the electrons are arranged in a sodium atom. (You may wish to use the data booklet to help you.)



Exercise 1.3

Nuclide Notation, Isotopes

1. Copy and complete this table:

Atom	Protons	Neutrons	Electrons
${}^{4}_{2}He$			
${}^{19}_{9}F$			
${}^{27}_{13}Al$			
${}^{23}_{11}Na$			
${}^{39}_{19}K$			

2. Write each of the following atoms in nuclide notation:

   a) An oxygen atom with 10 neutrons
   b) An atom with atomic number 6 and with 7 neutrons
   c) An atom with 17 protons and 20 neutrons
   d) An atom of hydrogen, mass number 2
   e) An atom with 5 protons and 6 neutrons.

3. Copper has a relative atomic mass of 63.5. It contains two different kinds of atoms: ${}^{63}_{29}Cu$ and ${}^{65}_{29}Cu$.

   a) How many neutrons are present in each kind of copper atom?
   b) Why are these two atoms called isotopes?
   c) What is meant by the term “relative atomic mass”?
   d) Which kind of atom is more common in copper? Explain your answer.

4. There are three different types of neon atom.

a) Complete the table to show the number of protons and neutrons in each type of neon atom.

Type of atom	Number of protons	Number of neutrons
$^{20}_{10}\mathrm{Ne}$		
$^{21}_{10}\mathrm{Ne}$		
$^{22}_{10}\mathrm{Ne}$		

b) What term is used to describe these different types of Neon atom?

c) A natural sample of Neon has an average atomic mass of 20.2. What is the mass number of the most common type of atom in the sample of Neon?

5. The relative atomic mass of an atom can be calculated from the mass number and proportion of each isotope as shown below for chlorine:

Chlorine consists of two isotopes: 75% is $^{35}_{17}Cl$ and 25% is $^{37}_{17}Cl$

Relative atomic mass = $\dfrac{(75 \times 35) + (25 \times 37)}{100}$

= 35.5

a) Calculate the relative atomic mass of bromine which contains two isotopes: 50% $^{79}_{35}Br$ and 50% $^{81}_{35}Br$.

b) Calculate the relative atomic mass of magnesium which contains three isotopes: 60% $^{24}_{12}Mg$, 10% $^{25}_{12}Mg$ and 30% $^{26}_{12}Mg$.

Unit 1: Chemical Changes and Structure

TOPIC 2: BONDING, STRUCTURE AND PROPERTIES

LEVEL N4 N5	After completing this topic, you should be able to:	NOTES (Web 2)	How well I have understood (✓)		
			☺	😐	☹
N4	*State atoms can be held together by bonds and there are types of bonding called metallic, ionic and covalent.*				
N4	*Ionic compounds are usually formed when metals combine with non-metals.*				
N4	*State covalent bonding usually occurs when non-metal atoms bond.*				
N4	*State in a covalent bond, atoms share pairs of electrons.*				
N4	*State a molecule is a group of atoms held together by covalent bonds.*				
N4	*A diatomic molecule is made up of two atoms, and I can list the six gaseous elements which exist as diatomic molecules: (H_2, N_2, O_2, Cl_2, I_2, Br_2)*				
N4	*Positive ions are formed by metal atoms losing electrons, and negative ions are formed by non-metal atoms gaining electrons, during a transfer of electrons from the metal atom to the non-metal atom.*				
N4	*Covalent substances (solids, liquids, solutions) do not conduct electricity.*				
N4	*Many covalent substances have low melting and boiling points and are insoluble in water but are soluble in other covalent liquids.*				
N4	*Many covalent substances are insoluble in water but are soluble in other covalent liquids.*				
N4	*Ionic compounds do not conduct electricity in the solid, but these compounds do conduct electricity when dissolved in water or when molten.*				
N5	*I can state in forming bonds, atoms can achieve a stable electron arrangement.*				
N5	*I can state the covalent bond is a result of two positive nuclei being held together by their common attraction for the shared pair of electrons.*				
N5	*I can draw diagrams show how the outer electrons are shared to form the covalent bond(s) in a molecule.*				

Unit 1: Chemical Changes and Structure

TOPIC 2: BONDING, STRUCTURE AND PROPERTIES

LEVEL N4 N5	After completing this topic, you should be able to:	NOTES (Web 2)	How well I have understood (✓)		
			☺	😐	☹
N5	*State ionic bonding is the electrostatic force of attraction between oppositely charged ions.*				
N5	*Explain the conduction of ionic compounds in terms of movement of ions and the non-conduction of covalent substances in terms of molecules which are uncharged*				
N5	*Explain why discrete covalent substances have low melting and boiling points due to the weak forces of attraction that need to be overcome.*				
N5	*I can explain that ionic compounds and covalent network substances have high melting and boiling points due to the strong forces of attraction which need to be overcome.*				
N5	*I can state the formula for a discrete covalent substance gives the actual number of atoms in each molecule but in a covalent network substance gives the simplest ratio of atoms of each element.*				
N5	*I can use the valency rules to produce the chemical formulae of a covalent substance*				
N5	*The formula for an ionic compound gives the simplest ratio of positive ions to negative ions, and I can use this ration to produce the chemical and ionic formulae of the ionic compound*				
N5	*I can explain the conduction of ionic compounds in terms of movement of ions and the non-conduction of covalent substances in terms of molecules which are uncharged.*				
N5	*I can explain that an ionic compound breaks down into its elements during conduction and this reaction is called electrolysis.*				
N5	*I can state a dc supply must be used if the products of electrolysis are to be identified at each electrode.*				
N5	*I can explain the formation of atoms/molecules at each electrode during electrolysis in terms of positive ions gaining electrons and negative ions losing electrons.*				
N5	*I can write the ion-electron equations for the reactions which take place on the electrodes during electrolysis for any given ionic compound in solution or in a melt.*				

Exercise 1.4

Chemical Bonding

1. Write the chemical formulae for the following:
   a) Sulphur trioxide
   b) Dinitrogen oxide
   c) Silicon tetrafluoride
   d) Carbon monoxide

2. Write the chemical formulae for the following:
   a) Hydrogen iodide
   b) Magnesium chloride
   c) Calcium sulphide
   d) Lithium oxide
   e) Iron(II) fluoride
   f) Silver (I) bromide
   g) Copper(II) chloride

3. The formula for dinitrogen monoxide is

   A NO
   B NO_2
   C N_2O
   D N_2O_4

4. Draw diagrams, showing outer electrons only, to show how covalent bonds join atoms in the following molecules:

   a) Hydrogen
   b) Oxygen
   c) Nitrogen
   d) Nitrogen Hydride (Ammonia)
   e) Carbon Dioxide

5. Write sentences to explain the meaning of each of the following terms:

   a) Covalent bond
   b) Molecule
   c) Triple bond
   d) Diatomic
   e) Compound

6. Make a drawing to show the shape of each of the following molecules and name each shape.

   a) Silicon bromide
   b) Hydrogen fluoride
   c) Phosphorus hydride
   d) Water
   e) Carbon Hydride (Methane)

7. Ions are formed by atoms losing or gaining electrons. In each of the following changes, say how many electrons are involved and whether they are gained or lost.

   a) Na atom changes to Na^+ ion.
   b) F atom changes to F^- ion.
   c) S atom changes to S^{2-} ion.
   d) Al atom changes to Al^{3+} ion.

8. The electron arrangement for magnesium is 2,8,2.

   a) Draw a diagram to show how the electrons are arranged in a magnesium **atom**.
   b) Draw a diagram to show how the electrons are arranged in a magnesium **ion**.
   c) Write the electron arrangement for a magnesium ion.

9. The electron arrangement for nitrogen is 2,5.

   a) Draw a diagram to show how the electrons are arranged in a nitrogen **atom**.
   b) Draw a diagram to show how the electrons are arranged in a nitride **ion**.
   c) Write the electron arrangement for a nitride ion.

10. Copy and complete the following table to show the number of protons and electrons in each of the following ions.

Ion	**Number of protons**	**Number of electrons**
Ca^{2+}		
Cl^-		
Al^{3+}		
O^{2-}		

11. This table gives information about some ions.

Ion	Number of protons	Number of electrons
zinc	30	28
sulphide	16	18
copper	29	28
tin	50	48

Use the information to write the formula of each of the four ions.

12. The compound sodium chloride is formed from atoms of .sodium and chlorine.

a) Show, using a diagram, what happens to the outer electrons of each atom when the compound is formed.
b) Sodium chloride exists as an ionic lattice. Explain what is meant by an ionic lattice.

13. Ionic compounds contain positively charged metal ions and negatively charged non-metal ions. Identify the compound in which **both** ions have the same electron arrangement as argon.

A strontium chloride	B lithium oxide	C calcium oxide
D barium fluoride	E sodium fluoride	F potassium chloride

14. The Dead Sea is a very small lake left over from a great sea thousands of years ago. The table below gives concentrations of various ions found in the water from the Dead Sea and in water from the Atlantic Ocean.

Ion	Na^+	Cl^-	Mg^{2+}	SO_4^{2-}	Ca^{2+}
Concentration in the Ocean ($g\ l^{-1}$)	10.5	19.0	1.5	2.5	0.5
Concentration in the Dead Sea ($g\ l^{-1}$)	30.0	160.0	40.0	0.5	10.0

a) Plot the bar charts above for the two different types of water.
b) Which ion is more common in the ocean than in the Dead Sea
c) How many times more concentrated is this ion ?

Exercise 1.5

Properties of Substances

1. Some elements conduct electricity and other do not.

   a) Draw a circuit diagram, using conventional symbols, to show the apparatus which can be used to classify elements as conductors or non-conductors
   b) Which type of elements conduct electricity?
   c) Which element is an exception to the general rule?
   c) Sort the following elements into conductors and non-conductors and present the information as a table with suitable headings:

   nickel, iodine, copper, magnesium, sulphur, phosphorus, sodium, scandium, mercury.

2. Some elements and compounds are listed below:
   sugar, sulphur, sodium bromide, paraffin wax, silicon dioxide, silver, carbon chloride, potassium, nickel chloride

   a) Name the substances which conduct electricity when solid.
   b) Name the substances which conduct electricity when in aqueous solution (i.e. dissolved in water).
   c) Explain why the substances you have chosen in answer to (b) do **not** conduct electricity when solid.

3. Neither silicon dioxide nor silicon fluoride conduct electricity. However, silicon dioxide is a solid with a melting point of 1610°C, whereas silicon fluoride is a gas at room temperature.

   a) How do the structures of these two compounds differ?
   b) Why is there such a large difference in melting points? (Make reference to the bonds broken at the melting point.)

4. A pupil investigated the properties of three compounds and obtained the following results:

Substance	Melting point	Electrical conduction
A	high	does not conduct in any state
B	low	does not conduct in any state
C	high	conducts in solution and molten

   For each of A, B and C state whether the structure is covalent molecular, covalent network or ionic and give the reasons for your choice.

5. Some properties of four substances are given in the table below:

Property	P	Q	R	S
Solubility in water	soluble	insoluble	soluble	soluble
Colour of solution	colourless	-	blue	colourless
Electrical conductivity (solid)	does not conduct	conducts	does not conduct	does not conduct
Electrical conductivity (molten)	does not conduct	conducts	conducts	conducts

The four substances are sodium chloride, copper bromide, aluminium and sugar but **not** in that order.

a) Use the table to identify each of the substances labelled P, Q, R and S.
b) State the type of bonding present in each of P, R and S.

6. The table contains some information about some substances:

Substance	Melting point/°C	Boiling point/°C	Conducts as a solid	Conducts as a liquid
A	–7	59	no	no
B	1492	2897	yes	yes
C	1407	2357	no	no
D	606	1305	no	yes
E	–39	357	yes	yes
F	–78	–33	no	no

a) Identify the substance which is a gas at 0°C.
b) Identify the two substances which exist as molecules.
c) Identify the substance which exists as a covalent network.
d) Identify the substance which exists as an ionic lattice.
e) Identify the two substances which are metals

Unit 1: Chemical Changes and Structure

TOPIC 3: RATE OF REACTION

LEVEL N4 N5	After completing this topic, you should be able to:	NOTES (Web 3)	How well I have understood (✓)		
			☺	😐	☹
N4	*I can explain the effect of changing particle size, temperature, concentration and use of a catalyst on the rate of a chemical reaction*				
N4	*I can participate in rates of reaction experiments by measuring changes to mass (or volume) and collect relevant data*				
N4	*I can identify factors that must be kept the same to make these experiments fair*				
N4	*I can convert experimental data into a line graph showing how the speed of a reaction changes with time*				
N4	*I can interpret rates of reaction graphs and identify fast or slow reactions*				
N4	*I can state that exothermic reactions give out heat energy resulting in a temperature rise*				
N4	*I can state that endothermic reactions result in a temperature decrease*				
N4	*I can investigate different chemical reactions and gather data to find out if the reaction is exothermic or endothermic*				
N5	*I can calculate the average rate of a reaction using information from a graph*				

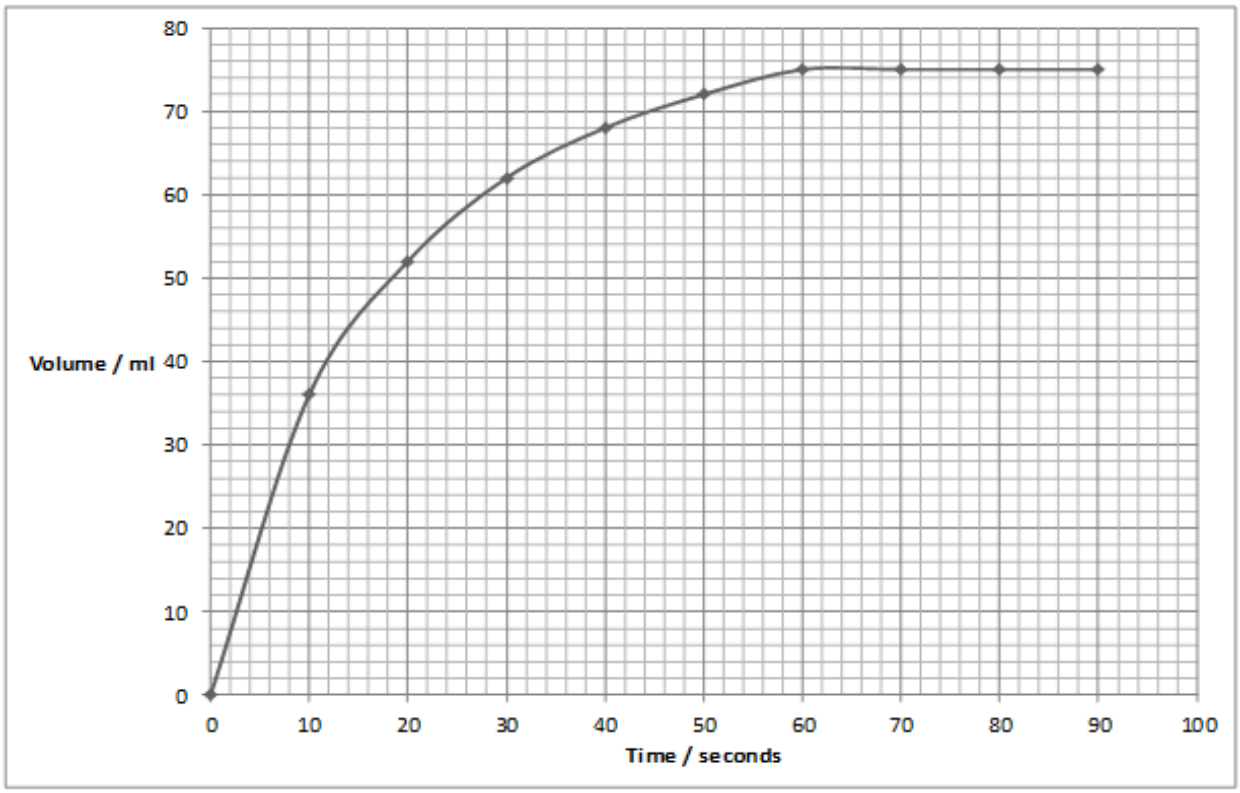
Exercise 1.6

Chemical Reactions and Rate of Reaction

1. A pupil wanted to record data that would allow her to follow the speed of the reaction between zinc and hydrochloric acid. List three ways in which she could do this.

2. Look at the graph below and answer the following questions:

   a) What is the volume of gas produced after 20 seconds?
   b) What is the final volume of gas produced?
   c) At what time is the reaction complete (i.e. when it finished)?

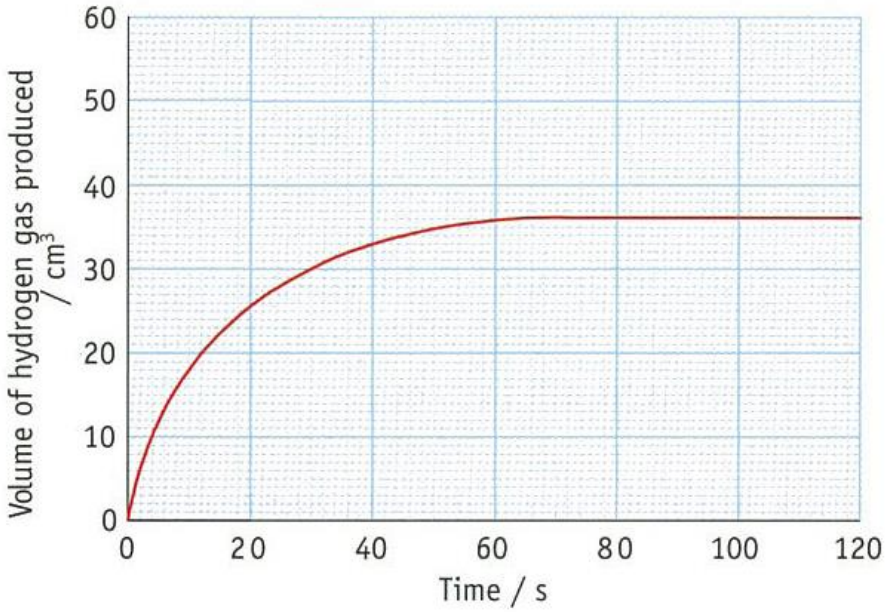


3. Jean carried out an investigation into the rate of reaction of marble chips with dilute hydrochloric acid. She noted the loss in mass as carbon dioxide was given off, taking readings every minute. Her table of results is given below:

Mass of CO_2/g	0	1.5	2.7	3.5	4.1	4.6	4.8	5.0	5.0
Time /mins	0	1	2	3	4	5	6	7	8

a) Draw a graph of the results.
b) What are the units for rate in this experiment?
c) Calculate the average rate over the first 4 minutes?
d) Calculate the average rate over the full 8 minutes?

4. The graph below shows how the volume of hydrogen gas given off, changed with time during a reaction between pieces of zinc and dilute sulphuric acid.



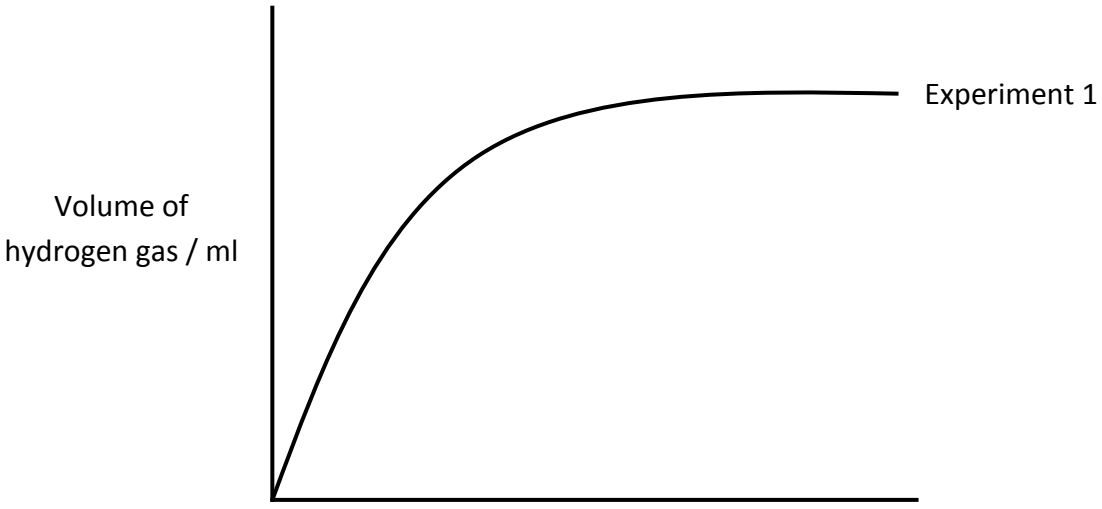
a) Calculate the average rate of reaction over the first 20 second time period.

b) Calculate the average rate of reaction between 20 seconds and 40 seconds.

5. A student carried out three experiments involving the reaction of Magnesium with dilute acid. They measured the volume of hydrogen given off. The same mass of magnesium and volume of acid were used each time.

Experiment	Temperature / °C	Size of particles
1	40	Lumps
2	40	Powder
3	20	Lumps

A curve obtained for experiment one drawn on the graph.



a) Copy the above graph and draw 2 curves on the same axes to show the curves that would be obtained for experiments 2 and 3. Label each curve clearly.

Unit 1: Chemical Changes and Structure

TOPIC 4: STOCHIOMETRY (CALCULATIONS)

LEVEL N4 N5	After completing this topic, you should be able to:	NOTES (Web 4)	How well I have understood (✓)		
			☺	😐	☹
N5	*I can change word equations into formula equations and balance them*				
N5	*I can calculate the formula mass of a substance*				
N5	*I can state that the gram formula mass of a substance is called one mole*				
N5	*I can convert moles into mass and mass into moles*				
N5	*I can calculate the concentration of a solution from the number of moles and the volume*				
N5	*I can state that the units of concentration are moles / litre*				
N4	*I can calculate the mass of a solute needed to prepare a given concentration of solution*				

Exercise 1.7

Writing and Balancing Chemical Equations

Mass (and energy) is conserved. This means that at the moment of Big Bang, when the Universe was created, all matter and energy were created. We can neither destroy nor create new mass or energy. For Chemists, this means that during a chemical reaction, the number of atoms you started with as reactants must appear in the products – we can neither create new atoms, nor destroy them.

There are rules for writing chemical formula equations.

- Write the correct formula for each reactant and product and place it in the equation.
  - If it is an ordinary element write its symbol only. If it is a diatomic element write its symbol and put a 2 after and below the symbol
  - If the chemical is a compound, use the valency rules, except where the compound is named using the prefix rules (mono, di, tri or tetra)
- Balance the equation by multiples of the formula.
- After each reactant and product put in the state symbol: (g), (l), (s), (aq).
- Do not change the formula for a compound or element to balance the equation.
- During a chemical reaction atoms of an element cannot disappear. There must be the same numbers of each element in the reactants and products. To show this we must balance equations.

Balance the following equations.

1. H_2 + F_2 $\longrightarrow$ HF

2. Mg + HCl $\longrightarrow$ $MgCl_2$ + H_2

3. P + O_2 $\longrightarrow$ P_2O_3

4. Mg + HNO_3 $\longrightarrow$ $Mg(NO_3)_2$ + H_2

5. NaCl + $BaSO_4$ $\longrightarrow$ $BaCl_2$ + Na_2SO_4

6. Fe + O_2 $\longrightarrow$ Fe_2O_3

7. Sodium + Water $\longrightarrow$ Sodium Hydroxide + Hydrogen

8. Methane + Oxygen $\longrightarrow$ Carbon Dioxide + Water

Exercise 1.8

Stochiometry (Chemical Calculations – G.F.M. and the Mole)

The atoms of different elements have different masses compared to each other. These **relative atomic** masses are given on **page 4** of your **data book.** For example, from this list we can see that atoms of magnesium are twice as heavy as atoms of carbon.

Using these relative atomic masses we can work out the total **formula mass** of any substance, e.g.

water

formula = H_2O

1 x 16 = 16

2 x 1 = 2

formula mass = 18

potassium sulphate

formula = K_2SO_4

4 x 16 = 64

1 x 32 = 32

2 x 39 = 78

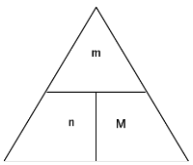
formula mass = 174

The gram formula mass of a substance, (gfm), is simply its formula mass in **grams**.

A mole is a special quantity of a chemical substance. It is defined as the gram formula mass of an element or compound.

1 mole = gram formula mass of a substance

We can either use proportion to convert between g.f.m and moles, or we can use a triangle to help us:



1. Use a finger to cover up the quantity you want to calculate. The other two values show you how to do the calculation. 1.To calculate the number of moles, cover up n and you are left with m / M. Hence, n = m / M

2.To calculate the mass, cover up m and you are left with n M. Hence, m = n × M

3.To calculate the molar mass, cover up M and you are left with m / n. Hence, M = m / n

1. Write the chemical formula **and** ionic formula (showing ionic charges) for each of the following compounds:

a) Ammonium chloride	b) Calcium sulphate
c) Potassium permanganate	d) Sodium carbonate
e) Magnesium nitrate	f) Silver (I) Phosphate
g) Tin (IV) Chloride	h) Lithium nitrate
i) Iron (III) sulphate	j) Ammonium nitrate
k) Calcium hydroxide	l) Aluminium hydroxide

2. For each of the **above** ionic compounds calculate the gram formula mass (mass of one mole in grams).

3. Calculate how many moles are in:

a) 14 g of Nitrogen	b) 20g of Sodium
c) 400g of copper (II) oxide	d) 85g of lithium chloride
e) 30g of aluminium sulphide	f) 2.2g of carbon dioxide
g) 84g of magnesium carbonate	h) 321g of iron (III) hydroxide

4. What is the mass (g) of:

a) 2 moles of Argon	b) 0.5 moles of Copper
c) 3 moles of Sodium Chloride	d) 0.2 moles of Methane [CH_4]
e) 10 moles of Oxygen	f) 0.25 moles of copper (II) oxide
g) 0.01 moles of nitric acid [HNO_3]	h) 0.25 moles of chlorine

5. Five moles of an unknown substance was found to weigh 325g. What was the gram formula mass of the substance?

6. A substance has a gram formula mass of 95g. Its formula is XCl_2. ¬What could element X be?

7. The substance E_2O has a gram formula mass of 62 g. Identify element E.

Exercise 1.9

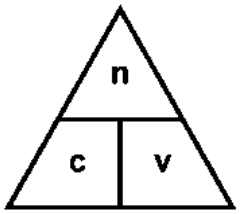
Stochiometry (Chemical Calculations – Concentration)

A solution is made up of a liquid called the **solvent** and a substance dissolved in it is called the **solute.** The **concentration** of a solution is given as the **number of moles** of **solute** dissolved in **one litre** of solution.

The units of concentration are **moles per litre,** written as **mol/1** (or mol/dm^3).

We can make up different concentrations of solution by choosing different volumes of solution and numbers of moles.

We can use an **equation triangle** to help us.



1. To calculate the concentration, cover up c and you are left with n / V. Hence, c = n / V

2. To calculate the number of moles, cover up n and you are left with c V. Hence, n = c × V

3. To calculate the volume, cover up V and you are left with n / c. Hence, V = n / c

The **volume must be in litres**. Any volumes in mls or cm^3 have to be divided by 1000 to change them into litres.

e.g. What is the concentration of a solution made by dissolving two moles of sodium chloride in enough water to make 250 cm^3 of solution? (**250 cm^3 = 0.25litres**)

$$\text{Concentration} = \frac{2}{0.25} = \textbf{8 mol/l}$$

---

1. What **concentration** of solution is obtained by dissolving:

   a) 5 moles of hydrogen chloride in 2 litres of solution
   b) 0.8 moles of copper sulphate in 200 cm3 of solution
   c) 0.5 moles of lithium fluoride in 500 cm3 of solution
   d) 1.25 moles of calcium nitrate in 2000 ml of solution
   e) 0.1 moles of nitric acid in 10 ml of solution
   f) 40 moles of potassium bromide in 100 litres of solution

2. What **volume** of solution is required to make:

   a) 0.4 mol/l solution containing 1 mole of sodium hydroxide
   b) 0.1 mol/l solution containing 0.05 moles of magnesium chloride
   c) 20 mol/l solution containing 4 moles of hydrogen peroxide
   d) 0.025 mol/l solution containing 0.02 moles of barium nitrate
   e) 2.25 mol/l solution containing 0.4 moles of ammonium bromide
   f) 6 mol/l solution containing 0.2 moles of sulphuric acid

3. How **many moles** are dissolved in:

a) 500 ml of 0.5 mol/1 sodium carbonate solution
b) 3000 cm3 of 2 mol/1 barium chloride solution
c) 5 litres of 0.1 mol/1 zinc sulphate solution
d) 250 cm3 of 0.04 mol/1 ammonium nitrate solution
e) 600 ml of 3 mol/1 hydrochloric acid solution
f) 10 cm3 of 0.2 mol/1 potassium permanganate solution

In this section, each question involves a certain **mass of substance** dissolved to make a **solution.** To answer these questions you must use both types of mole equations we have used earlier.

$$n = \frac{m}{gfm} \qquad \text{and} \qquad n = c \times v$$

Example 1: Calculate the mass of copper (II) sulphate required to make 100 ml of a 0.2 mol/1 solution.

Step 1: Use the equation $n = c \times v$ to calculate the number of moles needed.

$n = 0.2 \times 0.1$ **=** 0.02 moles

Step 2: Use the equation $m = n \times gfm$ to calculate the mass needed.

$m = 0.02 \times 160$ g

mass = 3.2 g

$CuSO_4$

64 + 32 + (16 x 4)

gfm = 160 g

Example 2: What is the concentration of a solution containing 4g of sodium hydroxide dissolved in 2 litres of solution?

Step 1: Use the equation: $n = \frac{m}{gfm}$ to calculate the number of moles of NaOH

$n = \frac{4}{40} = 0.1$ moles

NaOH

23 + 16 + 1

gfm = 40 g

Step 2: Use the equation $c = \frac{n}{v}$ to calculate the concentration of the solution.

$c = \frac{0.1}{2}$ **concentration = 0.05 mol/l**

4. For the following, calculate the **number of moles** of each substance and from this, calculate the **mass** of solid needed to make the following solutions:

   a) 500 ml of a 4 mol/l solution of potassium chloride
   b) 100 ml of a 0.4 mol/l solution of lithium hydroxide
   c) 2 litres of a 1.6 mol/l solution of magnesium fluoride
   d) 800 cm3 of a 1 mol/l solution of ammonium nitrate
   e) 50 litres of a 2 mol/l solution of sodium carbonate
   f) 10 ml of a 0.05 mol/l solution of aluminium sulphate
   g) 3 litres of a 0.6 mol/l solution of nickel (ii) bromide
   h) 25 cm3 of a 0.1 mol/l solution of silver (I) nitrate

5. What is the concentration of solution if 10g of sodium hydroxide is dissolved in 3 litres of solution?

6. What is the concentration of solution if 10g of sodium hydroxide is dissolved in 3 litres of solution?

7. What concentration of solution is made by dissolving 16.4 g of calcium nitrate in 250 ml of solution?

8. What is the concentration of 100 cm3 of ammonium hydroxide solution containing 0.7 g of dissolved solute?

9. What volume of 4 mole/l sulphuric acid solution contains 9.8 g of solute?

10. What volume of solution is required to make a 0.02 mole/1 solution from 3.9 g of lithium fluoride?

11. What volume of solution is needed to make a 0.5 mole/1 solution from 1.32 g of ammonium sulphate?

Unit 1: Chemical Changes and Structure

TOPIC 5: NUCLEAR CHEMISTRY

LEVEL N4 N5	AFTER COMPLETING THIS TOPIC YOU SHOULD BE ABLE TO:	NOTES (Web 4)	How well I have understood (✓)		
			☺	😐	☹
N4	*I can state that the first elements formed after Big Bang were Hydrogen and Helium*				
N5	*I can state that the heavier elements are made in stars by the fusing of the nuclei of lighter elements, and the heavier elements were distributed through the Universe in supernova explosions*				
N5	*I can state that radioactive elements can become more stable by giving out alpha, beta or gamma radiation*				
N5	*I know these types of radiation have specific properties such as their mass, charge and ability to penetrate different materials. I can make predictions as to radioactive behaviour for each type of emitted particle in an electromagnetic field; and can make recommendations as to how to contain radioactivity safely*				
N5	*The time for half of the nuclei of a particular isotope to decay is fixed and is called the half-life. I can use this to calculate the mass of the original radioactive isotope remaining after a given time*				
N5	*I know the half-life for a particular isotope is a constant and so radioactive isotopes can be used to date materials. I am able to use this fact to date organic and inorganic samples*				
N5	*Nuclear equations can be written to describe nuclear reactions and I am able to write equations for the emission of alpha, beta and gamma radiation, predicting the nucleotide formula for the new element*				
N5	*I can describe the use of radioactive isotopes in medicine, research and industry*				

Exercise 1.10

Nuclear Chemistry

1. $^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$

The above process represents

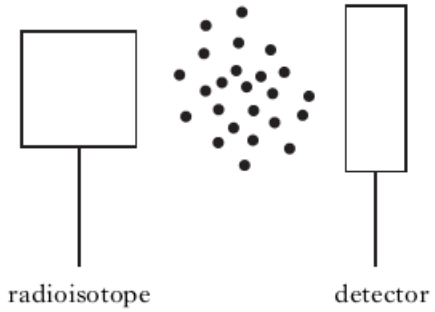
A nuclear fission

B nuclear fusion

C proton capture

D neutron capture.

2 Some smoke detectors make use of radiation which is very easily stopped by tiny smoke particles moving between the radioactive source and the detector.



The most suitable type of radioisotope for a smoke detector would be

A an alpha-emitter with a long half-life

B a gamma-emitter with a short half-life

C an alpha-emitter with a short half-life

D a gamma-emitter with a long half-life.

3. Which particle will be formed when an atom of $^{211}_{83}Bi$ emits an α-particle and the decay product then emits a β-particle?

A $^{207}_{82}Pb$

B $^{208}_{81}Tl$

C $^{209}_{80}Hg$

D $^{210}_{79}Au$

4. From which of the following could $^{32}_{15}P$ be produced by neutron capture?

A $^{33}_{15}P$

B $^{32}_{16}S$

C $^{31}_{15}P$

D $^{31}_{16}S$

5. The half-life of the isotope ^{210}Pb is 21 years.

What fraction of the original ^{210}Pb atoms will be present after 63 years?

A 0·5

B 0·25

C 0·125

D 0·0625

6. An atom of ^{227}Th decays by a series of alpha emissions to form an atom of ^{211}Pb.

How many alpha particles are released in the process?

A 2

B 3

C 4

D 5

7. Strontium-90 is a radioisotope.

What is the neutron to proton ratio in an atom of this isotope?

A 0·730

B 1·00

C 1·37

D 2·37

8. Phosphorus-32 and strontium-89 are two radioisotopes used to study how far mosquitoes travel.

(*a*) Strontium-89 decays by emission of a beta particle.

Complete the nuclear equation for the decay of strontium-89.

$$^{89}Sr \rightarrow$$

(*b*) In an experiment, 10 g of strontium-89 chloride was added to a sugar solution used to feed mosquitoes.

(i) The strontium-89 chloride solution was fed to the mosquitoes in a laboratory at 20 °C. When the mosquitoes were released, the outdoor temperature was found to be 35 °C.

What effect would the increase in temperature have on the half-life of the strontium-89?

(ii) Calculate the mass, in grams, of strontium-89 present in the 10 g sample of strontium-89 chloride, $SrCl_2$.

(*c*) A mosquito fed on a solution containing phosphorus-32 is released.

Phosphorus-32 has a half-life of 14 days.

When the mosquito is recaptured 28 days later, what fraction of the phosphorus-32 will remain?

9. Positron emission tomography, PET, is a technique that provides information about biochemical processes in the body.

Carbon-11, ^{11}C, is a positron-emitting radioisotope that is injected into the bloodstream.

A positron can be represented as $^{0}_{1}e$.

(*a*) Complete the nuclear equation for the decay of ^{11}C by positron-emission.

$$^{11}C \longrightarrow$$

(*b*) A sample of ^{11}C had an initial count rate of 640 counts min^{-1}. After 1 hour the count rate had fallen to 80 counts min^{-1}.

Calculate the half-life, in minutes, of ^{11}C.

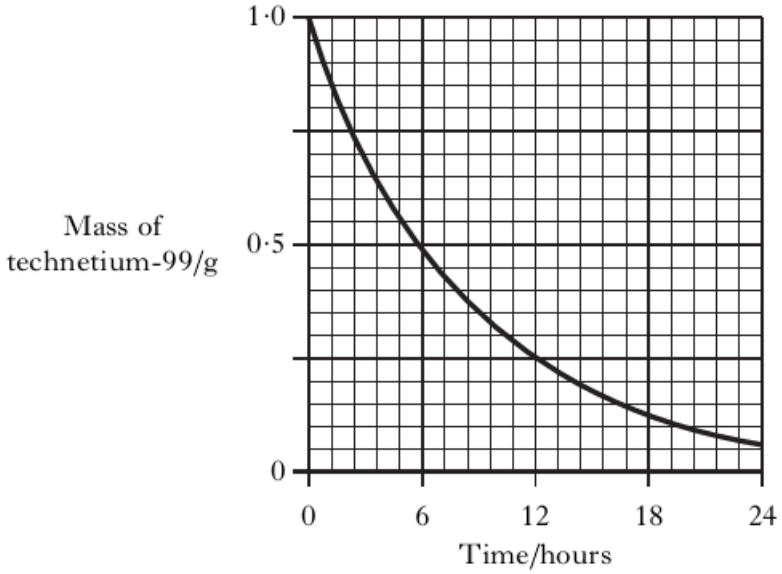
10. All the isotopes of technetium are radioactive.

(*a*) Technetium-99 is produced as shown.

$$^{99}_{42}\text{Mo} \rightarrow {}^{99}_{43}\text{Tc} + \mathbf{X}$$

Identify **X**.

(*b*) The graph shows the decay curve for a 1·0 g sample of technetium-99.



(i) Draw a curve on the graph to show the variation of mass with time for a 0·5 g sample of technetium-99.

(An additional graph, if required, can be found on *Page twenty-eight*.)

(ii) Technetium-99 is widely used in medicine to detect damage to heart tissue. It is a gamma-emitting radioisotope and is injected into the body.

Suggest **one** reason why technetium-99 can be safely used in this way.

Unit 1: Chemical Changes and Structure

TOPIC 6: ACIDS AND BASES

LEVEL N4 N5	AFTER COMPLETING THIS TOPIC YOU SHOULD BE ABLE TO:	NOTES (Web 5)	How well I have understood (✓)		
			☺	😐	☹
N4	*I can state that soluble metal oxides form alkali solutions*				
N4	*I can state that soluble non-metal oxides form acid solutions*				
N4	*I can state that insoluble oxides do not dissolve in water and therefore cannot affect pH*				
N4	*I can state that carbon dioxide gas is produced from burning fossil fuels and from cement manufacture*				
N4	*I can research and present information about non-metal oxides and their impact on the environment such as acid rain, global warming and ocean acidification*				
N4	*I can find and present information about some uses of acids in the food and drink industry and their impact on health*				
N4	*I can explain how the pH of an acid changes during a neutralisation reaction*				
N4	*By experiment, I can use a metal oxide/ hydroxide , or metal carbonate to neutralise an acid*				
N4	*I can state that a base is a substance that neutralises an acid*				
N4	*I can name salts formed during neutralisation reactions*				
N4	*I can construct word equations to describe neutralisation reactions*				
N5	*I can state that water dissociates into equal numbers of hydrogen and hydroxide ions*				
N5	*I can state that pH is a measure of the hydrogen ion concentration*				
N5	*I can state that in a neutral solution there are an equal number of hydrogen and hydroxide ions*				

Unit 1: Chemical Changes and Structure

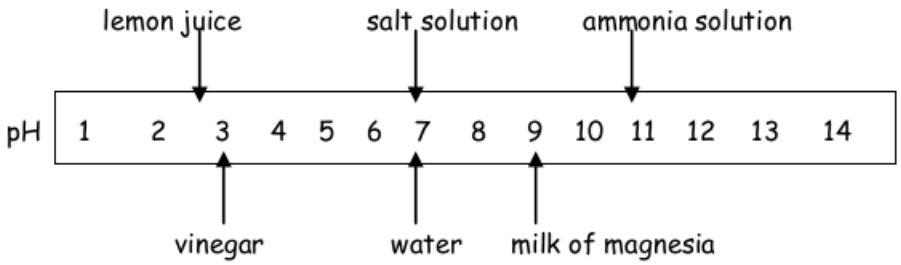
TOPIC 6: ACIDS AND BASES

LEVEL N4 N5	AFTER COMPLETING THIS TOPIC YOU SHOULD BE ABLE TO:	NOTES (Web 5)	How well I have understood (✓)		
			☺	😐	☹
N5	*I can state that a solution is acidic if it contains a higher concentration of H^+ ions compared to OH^- ions*				
N5	*I can state that a solution is alkaline if it contains a higher concentration of OH^- ions compared to H^+ ions*				
N5	*I can state that diluting an acid or an alkali results in changes to its H^+ / OH^- ion concentrations and its pH*				
N5	*I can show by experiment how soluble metal oxides or non-metal oxides affect the pH of water*				
N5	*I can construct balanced formula equations for neutralisation reactions*				
N5	*I can identify the spectator ions in neutralisation reactions and, by removing them, identify the reacting species*				
N5	*I can show by experiment how to make accurate measurements of volumes during a neutralisation reaction*				
N5	*I can use experimental data to accurately calculate the end-point of a titration*				
N5	*I can use experimental data from a titration to calculate the volume or concentration of a reacting solution*				

Exercise 1.11

Acids and Bases

1. The chart shows the pH of some common substances:



A Ammonia solution	B Lemon juice	C Milk of magnesia
D Salt solution	E Vinegar	F Water

   a) Identify the two substances which are acids
   b) Identify the two substances which show a decrease in pH when they are diluted with water

2. There are many substances which contain Nitrogen.

A	HNO_3
B	$Ca(NO_3)_2$
C	KNO_3
D	NH_3
E	$NH_4\ NO_3$

   a) Identify nitric acid.
   b) Identify the compound which gives a pH of greater than 7.

3. Class 4C made some statements about the effect of adding water to an **alkaline** solution.

A	The PH of the solution will rise
B	The solution will become more concentrated
C	The pH of the solution will fall towards 7
D	Adding water will have no effect on the solution

   Identify the correct statement.

4. Pupils in a chemistry class added different chemicals to dilute hydrochloric acid.

A magnesium	B magnesium hydroxide	C silver
D silver carbonate	E zinc carbonate	F zinc oxide

a) Identify the chemical which does not react with dilute hydrochloric acid.
b) Identify the chemical(s) which produced only a salt and water when reacted with dilute hydrochloric acid.

5. The grid shows the names of some chemical compounds:

A sodium hydroxide	B potassium nitrate	C sodium chloride
D lithium carbonate	E sodium phosphate	F barium sulphate

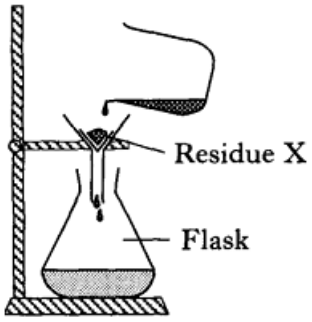
a) Identify the two bases.
b) Identify the compound which could be prepared by precipitation.

You may wish to refer to page 5 of the data booklet.

6. Copper carbonate was added to dilute sulphuric acid in a beaker until no more reacted.

$CuCO_3$ (s) + H_2SO_4 (aq) $\longrightarrow$ $CuSO_4$ (aq) + CO_2 (g) + H_2O (l)

The contents of the beaker were then filtered:



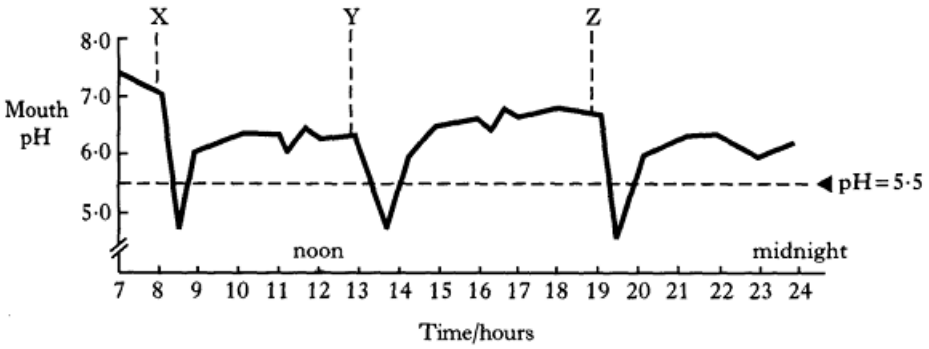
A	copper carbonate, $CuCO_3$
B	sulphuric acid, H_2SO_4
C	copper sulphate, $CuSO_4$
D	carbon dioxide, $CuSO_4$
E	water, H_2O

a) Identify the residue X.
b) Identify the substance(s) which collected in the flask.

Exercise 1.12

Acids and Bases

7. Inga eats three meals a day. The graph shows how the pH in her mouth varies during the day. X, Y and Z are meal times.



Teeth decay when the pH in the mouth falls below 5.5.

a) What happens to the pH in the mouth after meal times?
b) Some of Inga's friends eat snacks between meals. Why does this lead to more tooth decay?
c) Many toothpastes are alkaline and contain sodium fluoride.
d) Why are toothpastes alkaline?
e) Write the formula for sodium fluoride.

8. A gardener tests the pH of the soil in his garden. The soil has a pH of 5.8. The table shows the pH range in which different vegetables will grow successfully.

Vegetable	pH range
Broad beans	5.5 – 7.0
Carrots	6.0 – 7.5
Lettuce	6.5 – 7.5
Potatoes	5.5 – 6.5

a) Which vegetables will the gardener be able to grow successfully in his garden?
b) Name a substance that the gardener could add to the soil in order to grow all of the vegetables successfully.

9. Write balanced symbol equations for :

a) Copper(II) carbonate and hydrochloric acid
b) Magnesium and nitric acid
c) Sodium hydroxide and sulphuric acid
d) Aluminium Hydroxide and hydrochloric acid

10. Hydrochloric acid and sulphuric acid are 2 common laboratory acids.

A	Equal numbers of positive and negative ions are present
B	A precipitate would be produced with barium hydroxide solution
C	The H+ ion concentration would increase when water was added
D	Electrolysis would produce H2 (g) at the negative electrode
E	1 mole of sodium hydroxide would be neutralised by 0.5 moles of acid

a) Identify the statement which can be applied to both dilute sulphuric acid and dilute hydrochloric acid.

b) Identify the statement(s) which can be applied to dilute sulphuric acid but not to dilute hydrochloric acid.

11. The pH values of 1 mol/l solutions of some salts are shown in the table:

SALT	pH
iron (III) sulphate	1
aluminium chloride	3
zinc sulphate	3
copper (II) nitrate	3
sodium chloride	7
potassium sulphate	7
sodium carbonate	10
potassium carbonate	11

Identify the statement(s) which can be made about the salts in the table.

A	The salts are neutral.
B	The salts of transition metals are acidic.
C	The sulphates are acidic.
D	The salts of group I metals are neutral.
E	The salts of hydrochloric acid are neutral.

12. Cross out the spectator ions in these equations :

a) $2H^+(aq) + SO_4^{2-}(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow 2K^+(aq) + SO_4^{2-}(aq) + 2H_2O(l)$

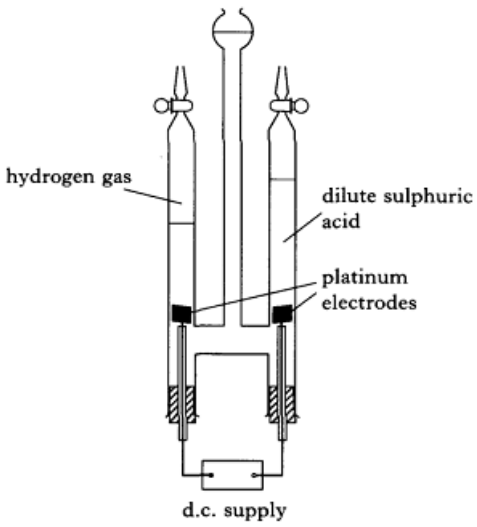
c) $Na^+(aq) + Cl^-(aq) + Ag^+(aq) + NO_3^-(aq) \rightarrow AgCl(s) + Na^+(aq) + Cl^-(aq)$

13. Reactions can be represented using ionic equations.

A	H^+ (aq) + OH^- (aq) $\longrightarrow$ H_2O (l)
B	$2H_2O$ (l) + O_2 (g) + $4e^-$ $\longrightarrow$ $4OH^-$ (aq)
C	$2H^+$ (aq) + CO_3^{2-} (aq) $\longrightarrow$ H_2O (l) + CO_2 (g)
D	SO_2 (g) + H_2O (l) $\longrightarrow$ $2H^+$ (aq) + SO^{2-} (aq)
E	NH_4^+ (s) + OH^- (s) $\longrightarrow$ NH_3 (g) + H_2O (l)

a) Identify the ionic equation representing reduction.
b) Identify the ionic equation which shows the formation of acid rain.
c) Identify the two ionic equations which show the neutralisation of an acid.

14. Acids can be shown to contain H+ (aq) using a Hoffman voltameter.



a) Why must a d.c. supply be used?
b) The volume of hydrogen gas produced over a period of time was measured during the electrolysis of dilute sulphuric acid. The results are shown in the table:

Time (min)	0	5	8	12	20
Volume of gas (cm^3)	0	8.5	13.5	20.0	33.0

Draw a line graph of the results.

c) Predict the volume of hydrogen gas which would be produced during the first 10 minutes.
d) Write the ion-electron equation for the formation of hydrogen gas.

You may wish to use your data booklet to help you.

Titration is a technique by which the concentration of an acid can be worked out by neutralising it with an alkali of known concentration and volume. Neutralisation is complete at the end point, which is determined by a very clear colour change in the indicator you are using.

The following equation can be used:

$$\frac{cV_{(acid)}}{n} = \frac{cV_{(alkali)}}{n}$$

Where:

n acid = the number of moles of acid from the balanced equation

n alkali = the number of mole of alkali from the balanced equation

V acid = Volume of acid (averaged from two burette readings which are within 1 cm^3 of each other)

V alkali = Volume of alkali pipetted into the conical flask

C alkali = concentration of alkali

C acid = concentration of acid (usually the unknown)

Example:

20 cm^3 of 4 mol/l NaOH neutralised 20 cm^3 of H_2SO_4. What was the concentration of the acid?

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

$$\frac{c \times 20}{1} = \frac{4 \times 20}{2}$$

$$20c = 40$$

$$C_{ACID} = 2 \text{ mol/l}$$

---

15. In making a sample of sodium sulphate solution 20 cm^3 of 1 mol/l sodium hydroxide solution was neutralised by 12 cm^3 of sulphuric acid. Calculate the concentration of the acid.

16. 25 cm^3 of hydrochloric acid are neutralised by 30 cm^3 of a 0.3 mol-1 solution of sodium hydroxide. Calculate the concentration of the acid.

17. Sodium hydroxide and nitric acid react as follows:

$$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$$

In a titration, 30 cm3 of nitric acid neutralised 20 cm3 of 0.2 mol/l sodium hydroxide. Calculate the concentration of the nitric acid.

18. 20 cm^3 of 0.5 mol/l Lithium hydroxide solution was neutralised by 30 cm^3 of sulphuric acid. Calculate the concentration of the sulphuric acid.