GCSE Combined Science Chemistry

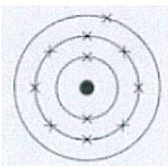
Topic 1 – Atomic Structure and the Periodic Table

Name: ______________________________

C1 Atomic Structure & The Periodic Table

Can you…?	☺	😐	☹
1.1.1 Atoms, elements and compounds			
Define the word 'element' in terms of atoms.			
Recall that there are about 100 different elements which are shown in the periodic table.			
Describe what a compound is and how they are represented.			
Describe how compounds are formed and separated, and what this involves.			
Use the names and symbols of the first 20 elements in the periodic table, the elements in Groups 1 and 7, and other elements in the Chemistry course.			
Name compounds of these elements from formulae or symbol equations.			
Write word equations for chemical reactions.			
Write formulae and balanced chemical equations for chemical reactions.			
1.1.2 Mixtures			
Describe what a mixture is and whether the properties of each substance in the mixture are changed or unchanged.			
State the 5 processes which can be used to separate mixtures, and remember that they do not involve chemical reactions.			
For each process, state the mixture(s) it can be used to separate.			
Describe, explain and give examples of the each of these processes.			
Suggest suitable separation and purification techniques for mixtures when given information.			
1.1.3 The development of the model of the atom			
Explain what may lead to a scientific model being changed or replaced.			
Describe how the model of the atom changed as new evidence was discovered.			
Describe the roles of Niels Bohr and James Chadwick in the development of the model of the atom.			
Explain why the new evidence from the scattering experiment led to a change in the atomic model.			
Describe the difference between the plum pudding model of the atom and the nuclear model of the atom.			
1.1.4 Relative electrical charges of subatomic particles			
State the relative charges of protons, neutrons and electrons.			

C1 Atomic Structure & The Periodic Table

Can you…?	☺	😐	☹
Explain why atoms have no overall electrical charge.			
State what atomic number represents.			
State how atoms of different elements differ from each other.			
Use the nuclear model to describe the structure of atoms.			
1.1.5 Sizer and mass of atoms			
State the radius of an atom.			
State the radius of a nucleus			
State where most of the mass of an atom is.			
State the relative masses of protons, neutrons and electrons.			
State what mass number represents.			
Describe what an isotope is, how they differ from one another and how they are the same.			
Use the mass number and atomic number to calculate the number of protons, neutrons and electrons in an atom or ion.			
Relate the size of atoms to objects that can be seen.			
1.1.6 Relative atomic mass			
State what relative atomic mass is and how it is calculated.			
Calculate relative atomic mass from data given.			
1.1.7 Electronic Structure			
Describe how electrons fill up the energy levels (or 'shells') around the nucleus, starting from the lowest energy level (or innermost available shell).			
Represent the electronic structure of the first 20 elements of the periodic table in the following forms:  sodium 2,8,1			
1.2.1 Periodic table			
Describe how elements in the periodic table are arranged and why it is called the periodic table.			
State the name of the columns in the periodic table and why elements are placed in the			

C1 Atomic Structure & The Periodic Table

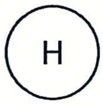
Can you...?	☺	😐	☹
same column.			
Explain how the position of an element in the periodic table is related to the arrangement of electrons in its atoms and its atomic number.			
Predict possible reactions and reactivity of elements from their positions in the periodic table.			
1.2.2 Development of the periodic table			
State how scientists initially classified elements.			
Describe problems with the early periodic table.			
Explain how Mendeleev overcame these problems.			
Explain how Mendeleev was proved right, and why the initial order based on atomic weights was not always correct.			
Describe the steps in the development of the periodic table.			
1.2.3 Metals and non-metals			
Identify where metals and non-metals appear in the periodic table.			
State the type of ion metals form.			
State the type of ion non-metals form.			
Describe the physical and chemical properties of metals.			
Describe the physical and chemical properties of non-metals			
Explain how the atomic structure of metals and non-metals relates to their position in the periodic table.			
Explain how the reactions of elements are related to the arrangement of electrons in their atoms and therefore their atomic number.			
1.2.4 Group 0 (Noble Gases)			
Explain why the noble gases (group 0) are unreactive, in terms of their outer electrons.			
Describe the trend in boiling point going down group 0.			
Predict properties from trends down the group.			
1.2.5 Group 1 (Alkali Metals)			
Describe the electronic structure of the alkali metals (group 1) and explain how their properties depend on this.			

C1 Atomic Structure & The Periodic Table

Can you...?	☺	😐	☹
Describe the reactions (observations and products) of the first 3 alkali metals with oxygen.			
Describe the reactions (observations and products) of the first 3 alkali metals with chlorine.			
Describe the reactions (observations and products) of the first 3 alkali metals with water.			
Explain the trend in reactivity going down the group.			
Predict properties from trends down the group.			
1.2.6 Group 7 (Halogens)			
Describe the electronic structure of the halogens (group 7) and explain how their properties depend on this.			
State the type of element the halogens are and describe what their molecules consist of.			
Describe the type of compounds formed when they react with metals			
Describe the type of compounds formed when they react with non-metals			
Explain the trend in reactivity going down the group.			
Explain displacement reactions involving halogens and solutions of their salts.			
Predict properties from trends down the group.			

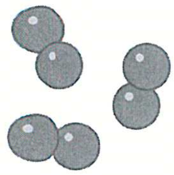
<u>**Atoms, elements, compounds and mixtures**</u>

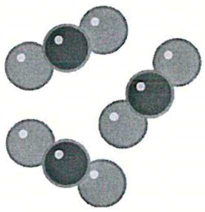
All substances are made of atoms. An atom is the smallest part of an element that can exist – they are often represented as a circle or sphere; for specific elements we write the chemical symbol for that element in the circle e.g.



Atoms of each element are represented by a chemical symbol, e.g. O represents an atom of oxygen, and Na represents an atom of sodium. There are about 100 different elements. Elements and their chemical symbols are shown in the periodic table.

Elements are substances that only contain one type of atom. They can be joined together in a molecule or on their own.





Compounds are formed from elements by chemical reactions. Chemical reactions always involve the formation of one or more new substances, and often involve an energy change.

Compounds contain **two or more elements chemically combined** in fixed proportions and can be represented by formulae using the symbols of the atoms from which they were formed. Compounds can only be separated into elements by chemical reactions and have different properties to the elements that make it.

A mixture consists of two or more elements or compounds not chemically combined together.
The chemical properties of each substance in the mixture are unchanged. The different elements or compounds in a mixture can be separated more easily (by using the **difference in physical properties** of each substance in the mixture).

Mixtures can be separated by physical processes such as filtration, crystallisation, simple distillation, fractional distillation and chromatography. These physical processes do not involve chemical reactions and no new substances are made.

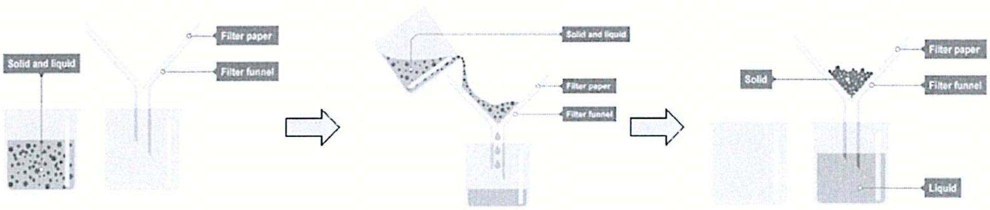
Separating mixtures

Filtration

Used to separate: an insoluble solid from a liquid.

Description:

- Mixture is poured through filter paper.
- The insoluble solid is too big to fit through the holes in the filter paper.
- The insoluble solid stays behind in the filter paper and becomes the residue.
- The water passes through the filter paper and becomes the filtrate.



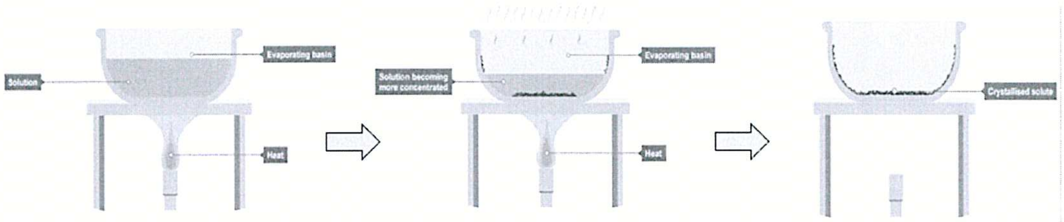
Crystallisation

Used to separate: a soluble solid from a liquid.

For example, copper sulphate is soluble in water – its crystals dissolve in water to form copper sulphate solution.

Description:

- Solution is placed in an evaporating dish.
- The dish is gently heated.
- The liquid starts to evaporate away.
- Eventually all the liquid has evaporated and leaves behind the solid crystals.



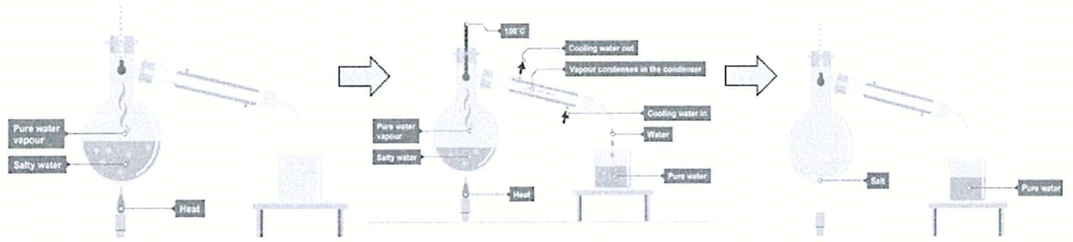
Simple Distillation

Used to separate: a solvent from a solution.

For example, water can be separated from salt solution by simple distillation. This method works because water has a much lower boiling point then salt.

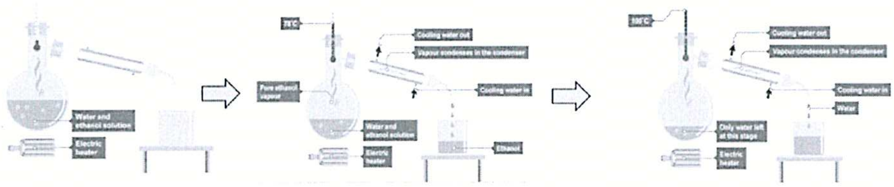
Description:

- The solution is heated.
- The solvent evaporates.
- It is then cooled and condenses into a separate container.
- The soluble solid does not evaporate and stays behind.



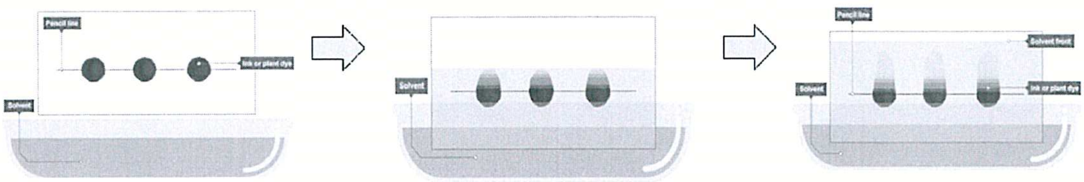
Fractional Distillation
Used to separate: a liquid from a mixture of two or more liquids.
For example, liquid ethanol can be separated from a mixture of ethanol and water by fractional distillation.
This method works because the liquids in the mixture have different boiling points.

Description:
- The mixture is heated.
- The liquid with the lowest boiling point evaporates first.
- This cools and condenses in a separate container and can therefore be collected before another liquid evaporated.
- The higher boiling point liquid(s) stay behind until heated to their boiling point.



Paper Chromatography
Used to separate: soluble substances from one another.
It is often used when the dissolved substances are coloured, such as inks, food colourings and plant dyes.
It works because some of the coloured substances dissolve in the solvent used better than others and so they travel further up the paper.

Description:
- Samples of the mixture are dotted onto filter paper.
- The paper is lowered into a solvent (that the samples dissolve in).
- The solvent travels up the paper, taking the solutes with it.
- As the solvent continues to travel up the paper the different solutes spread apart based on how well they dissolve in the solvent.



Atoms, elements and compounds

1. Which of these is an element?

Tick **one** box.

- [ ] Oxygen
- [ ] Water
- [ ] Air
- [ ] Carbon dioxide

[1 mark]

Remember
Elements are listed on the periodic table. You will be supplied with one in the exam.

2. Write the symbol or formula for each element.

Worked Example Atom of sodium Na — Marks gained: [0.5 marks]

Atom of calcium ____________________

Molecule of oxygen O_2 — Marks gained: [0.5 marks]

Molecule of chlorine ____________________ [1 mark]

3. Iron can be extracted from iron oxide by reacting it with carbon. The products are iron and carbon dioxide.

a Name two elements mentioned.

1 ____________________ 2 ____________________ [2 marks]

b Name two compounds mentioned.

1 ____________________ 2 ____________________ [2 marks]

4. Define what a compound is

____

____

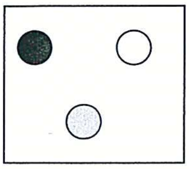
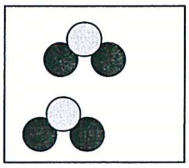
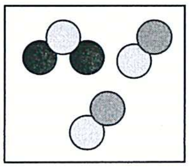
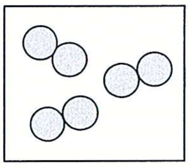
____ [2 marks]

Command word
Define means to state the meaning of something. So, in this question you need to say what a compound is.

Mixtures

1. Synoptic

Draw **one** line from each diagram to the description. [4 marks]

Diagram	Description
	A pure compound
	A pure element
	A mixture of elements
	A mixture of compounds

2. Practical

A student is given a mixture of iron filings and sulfur powder.

a Suggest a suitable way of separating the iron and sulfur.

Describe how the technique will work.

____

____ [2 marks]

b The student heats the mixture to form iron sulfide.

Explain why it is easy to separate the iron and sulfur in the mixture, but not in the compound.

____

____

____ [2 marks]

Compounds, formulae and equations

1. Sodium nitrate contains three oxygen atoms and one nitrogen atom for every sodium atom.

What is its formula?

Tick **one** box.

☐ NaN_3O ☐ $NNaO_3$ ☐ O_3NaN ☐ $NaNO_3$ [1 mark]

2. Draw one line from each formula to the compound it represents.

Worked Example

Formula	Compound
Fe_2O_3	Magnesium sulfide
KI	Magnesium sulfate
MgS	Potassium iodide
$MgSO_4$	Iron oxide

[4 marks]

3. The gas freon-11 has the formula CCl_2F.

Name the elements it contains.

1 ____________________ 2 ____________________ 3 ____________________ [3 marks]

4. Metals react with acids to produce a salt and hydrogen.

Complete the word and symbol equations to show an example.

magnesium + hydrochloric acid → ____________________ + hydrogen

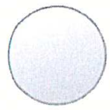
____________________ + 2HCl → $MgCl_2$ + ____________________ [4 marks]

> **Remember**
> Some tips for writing symbol equations:
>
> Use the periodic table supplied to find the symbols of elements
>
> Elements that are gases at room temperature (other than the group 0 elements) exist as pairs e.g. O_2
>
> Symbol equations must be balanced. You can only change the number in front of the formulae
>
> You may be asked to provide state symbols (s, l, g, aq)

<u>**History of the atom**</u>

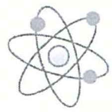
Several discoveries from different scientists led to the model of the atom we have today, our findings changed as technology improved and more experiments could be done to determine what the atom looks like.

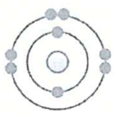
Before the discovery of the electron, atoms were thought to be tiny spheres that could not be divided.



The discovery of the electron led to the plum pudding model of the atom. Thomson's plum pudding model suggested that the atom is a ball of positive charge with negative electrons embedded in it.

The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. This nuclear model replaced the plum pudding model.





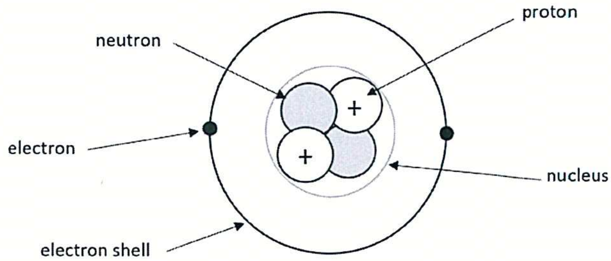
Niels Bohr adapted the nuclear model by suggesting that electrons orbit the nucleus at specific distances. The theoretical calculations of Bohr agreed with experimental observations.

Later experiments led to the idea that the positive charge of any nucleus could be subdivided into a whole number of smaller particles, each particle having the same amount of positive charge. The name proton was given to these particles.

The experimental work of James Chadwick provided the evidence to show the existence of neutrons within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea.

<u>**Modern model of the atom (nuclear model)**</u>

Atoms are made up of even smaller particles called subatomic particles. In the centre of the atom is the nucleus,
where protons and neutrons are contained. Electrons are arranged outside the nucleus in electron shells or levels and are constantly moving around the nucleus.



In this atomic model, the mass of the atom is concentrated in the nucleus as both protons and neutrons have a higher mass than the very light electrons that orbit them.

Scientific models of the atom

1. **Figure 1** is a diagram of an early model of the atom.

a Name the model.

Tick **one** box.

☐ nuclear model ☐ billiard ball model

☐ plum pudding model ☐ Bohr model [1 mark]

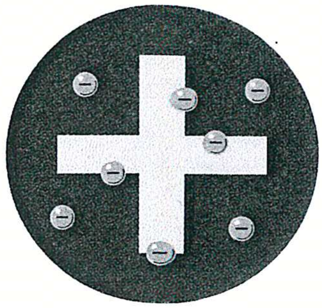


Figure 1

b Use the words in the box to complete the sentence about this model.

electrons	negatively	neutrally	neutrons	positively	protons

The atom is a ______________ charged ball with ______________

charged particles called ______________ in it. [3 marks]

2. In 1909, scientists carried out the alpha particle scattering experiment to test this model **(Figure 1)**.

- They made a prediction based on the model.
- They carried out the experiment.
- The results did not agree with their prediction.
- The experiment was repeated by other scientists. They got the same results.

Literacy

When you are asked to explain something, write down the reasons why it happens.

You will get marks for how clear your answer is as well as using key terms correctly. Some that you might use are: evidence, data, validity, reproducible.

Explain why this experiment led to a change in the model of the atom.

____

____

____

____

____

____

____ [6 marks]

Relative charges and masses of subatomic particles

In an atom, there are three sub-atomic particles: protons, neutrons and electrons.

- Protons have a +1 charge and a mass of 1.
- Neutrons have a 0 (neutral) charge and a mass of 1.
- Electrons have a -1 charge and are so small they are considered to have no mass.

Subatomic Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	0	-1

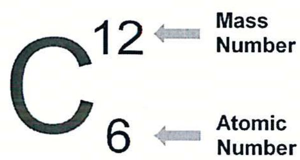
Atoms are neutral and have no overall charge because the number of electrons is equal to the number of protons in the nucleus.

The number of protons in an atom of an element is its atomic number. All atoms of a particular element have the same number of protons.

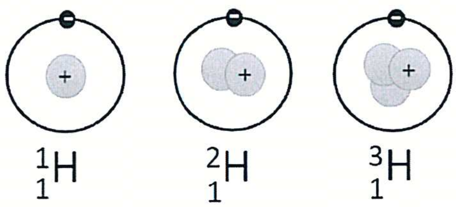
Size and mass of atoms

Atoms are very small, having a radius of about 0.1 nm (1×10^{-10} m). The radius of a nucleus is less than 1/10,000 of that of the atom (about 1×10^{-14} m).

Since protons and neutrons are the only subatomic particles with mass and they are found in the centre of the atom, almost all of the mass of an atom is in the nucleus.



The sum of the protons and neutrons in an atom is its mass number.



Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element. These atoms have the same chemical properties as the elements but can have different physical properties.

Relative atomic mass

The relative atomic mass of an element is an average atomic mass value that takes account of the other isotopes of the element.

Higher tier only to calculate average relative atomic mass use this formula:

$$\text{Average } A_r = \frac{(A_r \text{ of isotope 1} \times \% \text{ abundance}) + (A_r \text{ of isotope 2} \times \% \text{ abundance})}{100}$$

Relative masses and charges of subatomic particles

1. **Figure 4** is a model of an atom.

a Complete the table to show the names and relative charge on the particles in an atom.

Letter on diagram	Name of particle	Relative charge
X		0
Y		+1
Z		

[4 marks]

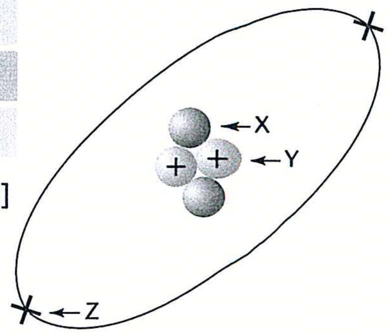


Figure 4

b Atoms have no overall charge.

Which sentence explains why?

Tick **one** box.

- [ ] There are the same number of negative and positive particles in the nucleus.
- [ ] The charge on the neutrons cancels out the charges on the other particles.
- [ ] They contain the same number of protons and electrons.
- [ ] They contain the same number of neutrons and electrons. [1 mark]

c For the atom in **Figure 4**, state its:

i Atomic number ______________ **ii** Mass number ______________

iii Symbol ______________ [3 marks]

2. **Figure 5** shows two different isotopes of carbon.

$^{12}_{6}C$ $^{14}_{6}C$

Carbon -12 Carbon -14

Figure 5

Compare the numbers of particles in the atoms of each isotope.

____

____

____

____

[4 marks]

Command word
When you are asked to **compare** you need to describe similarities and differences.

You must write about both things, not just one.

Sizes of atoms and molecules

1. Maths

Draw **one** line from each number to the same number in standard form.

Number	Standard form
1000	1×10^6
100	1.1×10^4
11 000	1×10^3
1 million	1×10^2

Maths

Because atoms are very small, standard form is used to show their size.

You need to be able to use numbers when in the standard form.

[4 marks]

2. Maths

Nanometres (nm) are a unit of measurement.

1 nm = 1×10^{-9} m

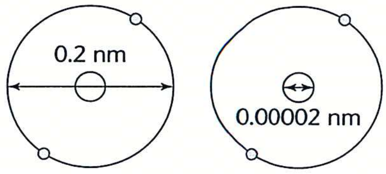


Figure 2 Figure 3

Figure 2 shows the diameter of a hydrogen atom.

What is 0.2 nm in metres?

Tick **one** box.

☐ 1×10^{-2} m ☐ 1×10^{-10} m ☐ 2×10^{-9} m ☐ 2×10^{-10} m [1 mark]

3. **Figure 3** shows the diameter of the nucleus.

Worked Example

Use the information in Figures 2 and 3 to calculate how many times larger the diameter of the atom is than the diameter of the nucleus. [2 marks]

$$\frac{0.2 \text{ (diameter of the whole atom)}}{0.00002 \text{ (diameter of the nucleus)}} = 10\,000$$

The diameter of the atom is 10 000 times larger than the diameter of the nucleus *Marks gained:* *[2 marks]*

4. Maths

A teacher uses a circular sports stadium as a **scale model** of the hydrogen atom.

The stadium has a diameter of 150 m.

The nucleus is modelled by a sphere in the centre of the stadium.

Using information from Q3, calculate the diameter that the sphere needs to be **in mm**.

______________ mm [3 marks]

Relative atomic mass

1. Synoptic

The nucleus of an atom contains 11 protons and 12 neutrons.

Which statements about the atom are true?

Tick **two** boxes.

☐ It has a mass number of 23. ☐ It has a mass number of 12.

☐ It has an atomic number of 11. ☐ It has an atomic number of 12. [2 marks]

2. Bromine has two isotopes: $^{79}_{35}Br$ (bromine -79) and $^{81}_{35}Br$ (bromine-81).

a How many neutrons does bromine-81 contain?

Tick **one** box.

☐ 35 ☐ 46 ☐ 81 ☐ 116 [1 mark]

> **Common misconception**
> Not all atoms of one element have the same mass number. The relative atomic mass is an average value that takes account of the abundance of the isotopes of the element

Worked Example

Maths

b In any sample of bromine, 50% would be bromine-79 atoms and 50% would be bromine-81 atoms.

Calculate the relative atomic mass of bromine. [3 marks]

First, multiple the mass number of each isotope by the relative abundance (the percentage)

Bromine–79 = 79 × 50 = 3950

Bromine–81 = 81 ×50 = 4050 [1 mark]

Then, add these numbers together and divide by 100:

(3950 + 4050) / 100 [1 mark]

The relative atomic mass of bromine is 80: [1 mark]

Marks gained: [3 marks]

3. Maths

Chlorine has two isotopes: ^{35}Cl and ^{37}Cl.

In any sample of chlorine, 75 % of the atoms are ^{35}Cl and 25 % are ^{37}Cl.

Calculate the relative atomic mass of chlorine. [3 marks]

Relative atomic mass of chlorine = ____________________ [1 mark]

Electronic structure

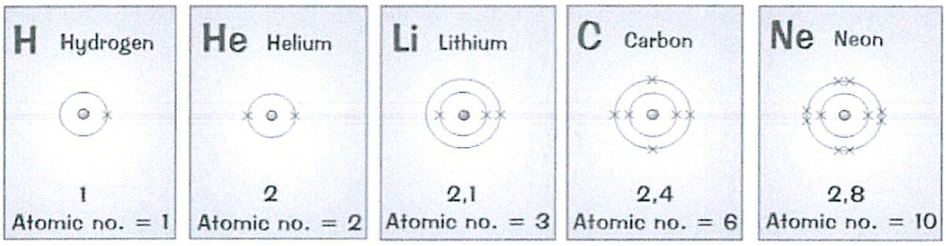
The electrons in an atom occupy energy levels/shells.

The inner shells fill up first and fill up that shell before moving on to the next one:

- 1st shell = 2 electrons
- 2nd shell = 8 electrons
- 3rd shell = 8 electrons
- 4th shell = 2 electrons

The electronic structure of an atom can be represented by numbers or by a diagram.

For example, the electronic structure of sodium is 2,8,1 or showing two electrons in the lowest energy level, eight in the second energy level and one in the third energy level.

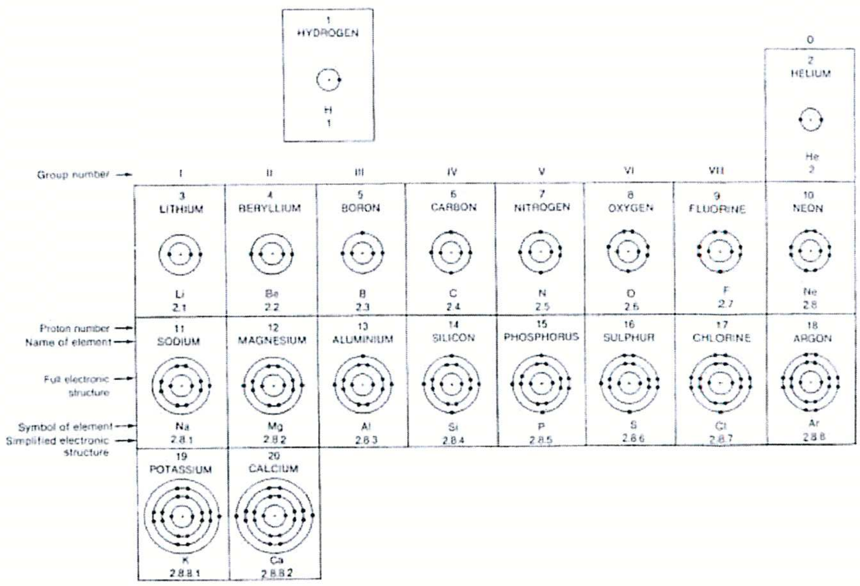


Electronic Structure and the Periodic Table

The elements in the periodic table are arranged in order of atomic (proton) number and so that elements with similar properties are in columns, known as groups.

The table is called a periodic table because similar properties occur at regular intervals.

Elements in the same group in the periodic table have the same number of electrons in their outer shell (outer electrons) and this gives them similar chemical properties. Elements in the same period of the periodic table have the same number of electron shells.



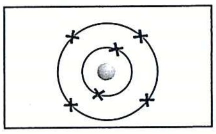
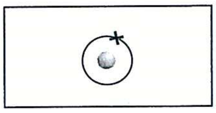
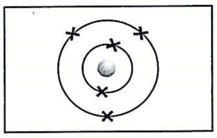
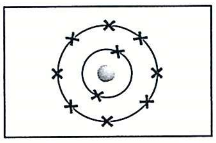
4. Define what relative atomic mass means.

____

____ [2 marks]

Electronic structure

1. Draw **one** line from each element to its electronic structure.

Element	Electronic structure
Boron Atomic number = 5	
Hydrogen Atomic number = 1	
Neon Atomic number = 10	
Carbon Atomic number = 6	

Analysing the question
To work out electronic structure you need to know the atomic number of the element. This will tell you how many electrons each atom has and where it can be found on the periodic table.

[4 marks]

2. Use the words in the box to complete the sentences.

eight	energy	nucleus	one	shell	two

Electrons in an atom orbit the ________________ in ________________ levels.

An atom can hold ________________ electrons in the lowest level and ________________ in the second level. [4 marks]

3. A sodium atom has an atomic number of 11.

When a sodium atom loses its outermost electron it forms a sodium ion.

a In the space to the right draw a diagram to show the electronic structure of a sodium ion. [2 marks]

Synoptic **b** Explain why a sodium ion has a positive charge.

____

____

____

____ [2 marks]

Electronic structure and the periodic table

1. How are the elements arranged in the periodic table?

Tick **one** box.

- ☐ In order of atomic number.
- ☐ In order of mass number.
- ☐ In order of reactivity.
- ☐ In order of number of neutrons.

[1 mark]

2. Why do elements in the same group of the periodic table have similar chemical properties?

Tick **one** box.

- ☐ They have the same atomic number.
- ☐ They have the same reactivity.
- ☐ They have the same number of electrons on their outer shell.
- ☐ They are the same size.

[1 mark]

3. **Figure 6** shows the periodic table. Some elements are shown by letters.

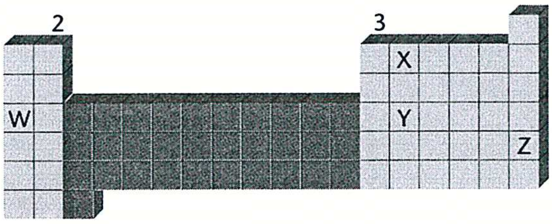


Figure 6

a The atoms of which element (W, X, Y or Z) has:

i One electron on its outer shell? ____________________

ii A full outer shell of electrons? ____________________

iii The highest atomic number? ____________________

iv The fewest protons? ____________________ [4 marks]