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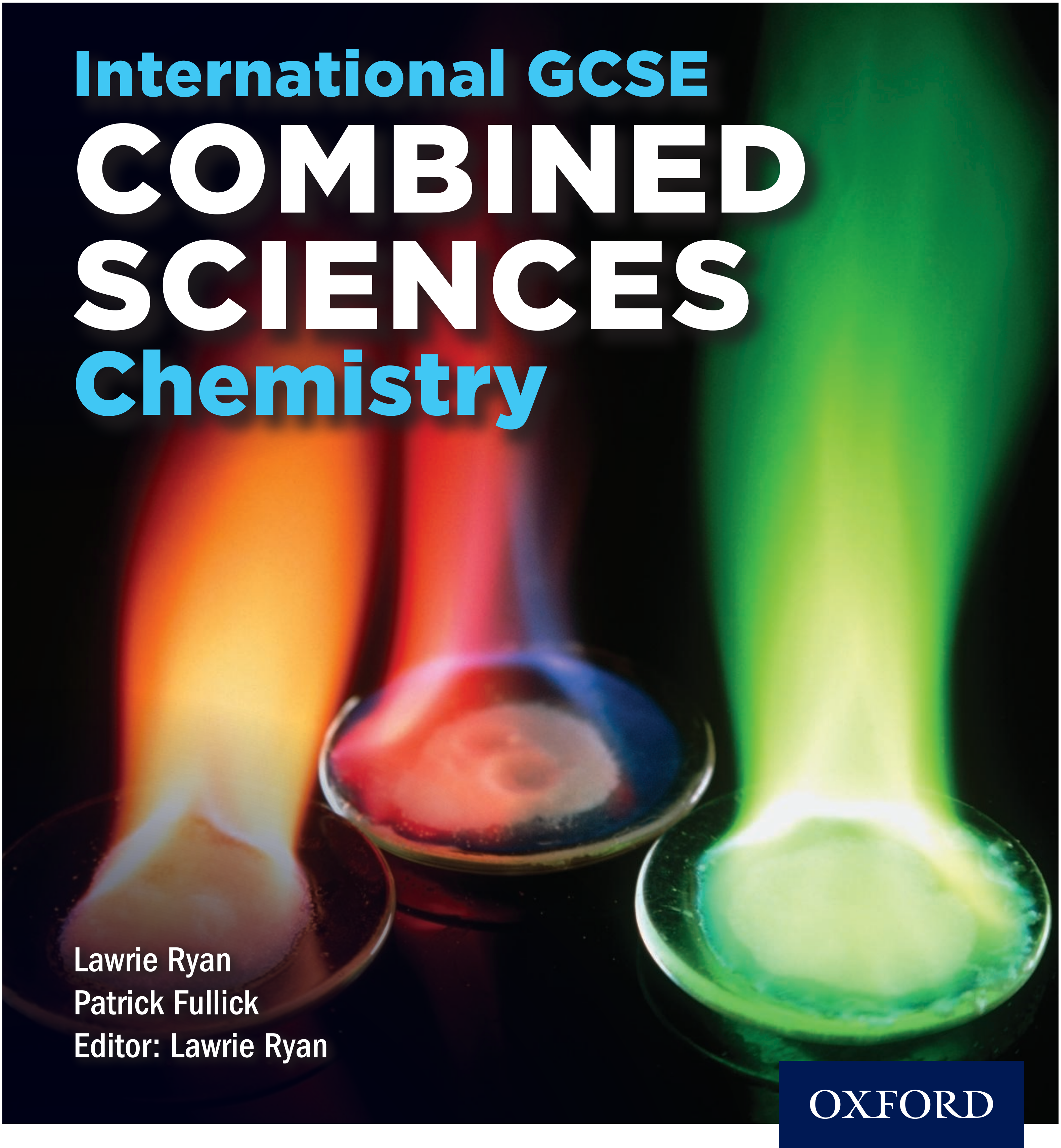
Chemistry



Lawrie Ryan
Patrick Fullick
Editor: Lawrie Ryan

OXFORD

Chemistry

Contents

How to use this book

This book has been written for you by experienced teachers and subject experts. It covers the information you need to know for your exams and is packed full of features to help you achieve the very best that you can.

Figure 1 Many diagrams are as important for you to learn as the text, so make sure you revise them carefully

Key words are highlighted in the text. You can look them up in the glossary at the back of the book if you are not sure what they mean.

Required practical

This feature helps you become familiar with key practicals. It may be a simple introduction, a reminder or the basis for a practical in the laboratory.

Summary questions

These questions give you the chance to test whether you have learned and understood everything in the topic. If you get any wrong, go back and have another look. They are designed to be increasingly challenging.

And at the end of each chapter you will find …

Chapter summary questions

These will test you on what you have learned throughout the whole chapter, helping you to work out what you have understood and where you need to go back and revise.

Practice questions

These questions are examples of the types of questions you may encounter in your exam, so you can get lots of practice during your course.

Ext Extension Tier material is shown with this label. This will not be included in the Core Tier exams.

Learning objectives

Each topic begins with key statements that you should know by the end of the lesson.

Study tip

Hints that give you important advice on things to remember and what to watch out for.

Did you know … ?

There are lots of interesting and often strange facts about science. This feature tells you about many of them.

links

Links will tell you where you can find more information about what you are learning and how different topics link up.

Activity

An activity is linked to a main lesson and could be a discussion or task in pairs, groups or by yourself.

Key points

At the end of each topic are the important points that you must remember. They can be used to help with revision and summarising your knowledge.

Practical skills

During this course, you will develop your understanding of the scientific process and the skills associated with scientific enquiry. Practical work is an important part of this as it develops these skills and also reinforces concepts and knowledge developed during the course.

As part of this course, all students are expected to undertake practical work in many topics and are required to carry out the three required practicals listed below:

Required Practicals

1. Identify the metal ion in an unknown compound using flame testing techniques. (3.10.1) [Topic 6.3]
2. Determination of the reacting volumes of solutions of a strong acid and a strong alkali by titration. (3.11.1) [Topic 8.5]
3. Investigate factors affecting the rate of a reaction. (3.13.1) [Topics 9.3 and 9.4]

In Paper 2, you will be assessed on aspects of the practical skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations and evaluate information that is presented to them.

Designing a practical procedure

- Design a practical procedure to answer a question, solve a problem or test a hypothesis.
- Comment on/evaluate plans for practical procedures.
- Select suitable apparatus for carrying out experiments accurately and safely.

Control

- Appreciate that, unless certain variables are controlled, experimental results may not be valid.
- Recognise the need to choose appropriate sample sizes, and study control groups where necessary.

Risk assessment

- Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.

Collecting data

- Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart or graph).

Analysing data

- Recognise and identify the cause of anomalous results and suggest what should be done about them.
- Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results and recognise when it is appropriate to ignore anomalous results in calculating a mean.
- Recognise and identify the causes of random errors and systematic errors.
- Recognise patterns in data, form hypotheses and deduce relationships.
- Use and interpret tabular and graphical representations of data.

Making conclusions

- Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.

Evaluation

- Evaluate data, considering its repeatability, reproducibility and validity in presenting and justifying conclusions.
- Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.
- Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.

1.1 States of matter

Learning objectives

After this topic, you should know:

- there are three states of matter
- the arrangement and motion of the particles in each state of matter
- the names of the processes and energy changes involved in changing state.

You can classify the majority of substances as solids, liquids, or gases. These are called the three **states of matter**.

Solids have a fixed shape and volume. They cannot be compressed. **Liquids** have a fixed volume, but they can flow and change their shape. Liquids occupy just slightly more space than when solid (water and ice are exceptions). **Gases** have no fixed shape or volume. They can be compressed easily.

To explain the properties of solids, liquids, and gases you use the kinetic theory of matter. It is based on the fact that all matter is made up of tiny particles and describes:

- the movement of the particles, and
- the average distance between particles

within each state of matter.

Look at the diagrams to the left that represent the three states of matter.

Each particle in a solid is touching its nearest neighbours and they remain in this fixed arrangement. They cannot move around, but they do vibrate constantly.

The particles in a liquid are also very close together but they can move past each other. This results in a constantly changing, random arrangement of particles.

The particles in a gas have much more space, on average, between them. They can move around at high speeds and in any direction. This means the particles have a random arrangement. The hotter the gas is, the faster the particles move. The pressure of a gas is caused by the particles colliding with the sides of the container. The more frequent and energetic the collisions are, the higher the pressure of the gas. So, in a sealed container, the pressure of the gas increases with temperature.

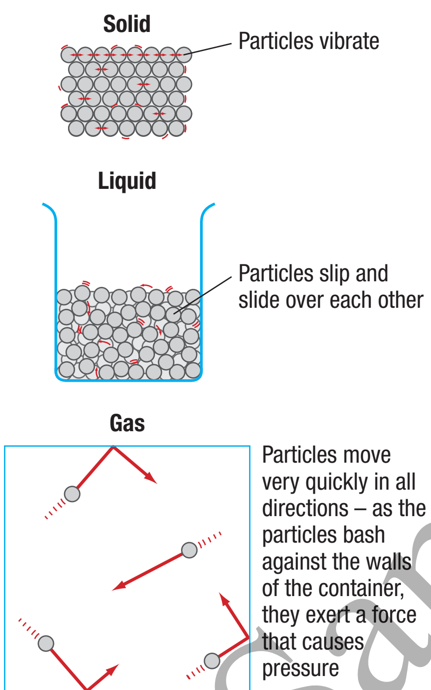


Figure 1 *The particles in the three states of matter*

Changing state

If a solid is heated and changes directly to a gas without melting, that is, it does not pass through the liquid phase, the change of state is called sublimation.

Look at the changes of state that occur when water is heated and cooled:

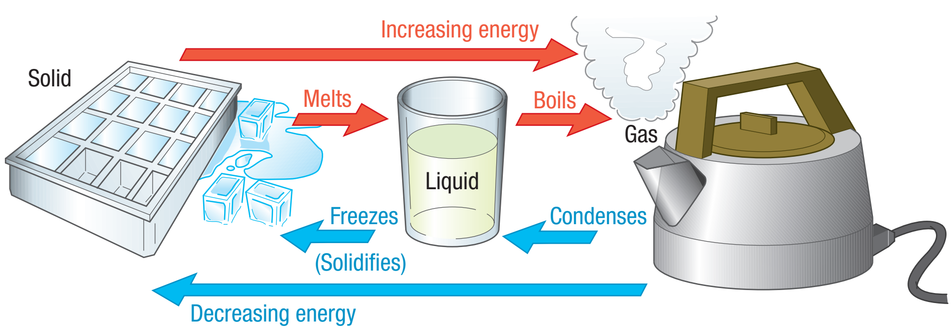


Figure 2 *The changes of state in water*

The hotter a solid is, the faster its particles vibrate. Eventually, the vibrations will be so strong that the particles begin to break free from their neighbours. At this point the solid starts to melt and become a liquid.

links

To find out how to indicate a substance's state in a balanced symbol equation, see Topic 1.5 Chemical equations.

The hotter a liquid is, the faster its particles move around. As the temperature rises, more and more particles gain enough energy to escape from the surface of the liquid. Its rate of evaporation increases. Eventually, the liquid boils and bubbles of gas rise and escape from within the liquid.

Each change of state is reversible. They are examples of physical changes. No new substances are formed in changes of state. For example, water molecules (H_2O) are the same in ice as they are in liquid water or in water vapour.

Energy changes during changes of state

When you monitor the temperature of a solid as you heat it to beyond its melting point, the results are surprising. The temperature stops rising at the solid's melting point. It remains constant until all the solid has melted, and only then starts to rise again.

At its melting point, the energy provided in heating the solid is being absorbed to break the forces between the particles in the solid. Once all the solid has melted, the energy from the heat source raises the temperature of the liquid as expected.

Changes of state which involve particles becoming closer together, that is, condensing and freezing (solidifying), transfer energy to the surroundings as stronger forces form between particles.

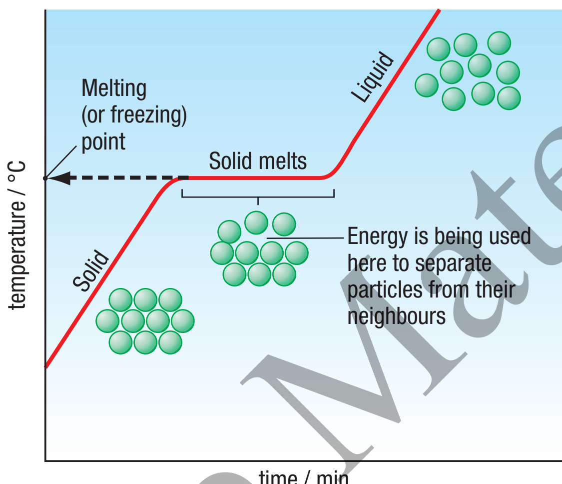
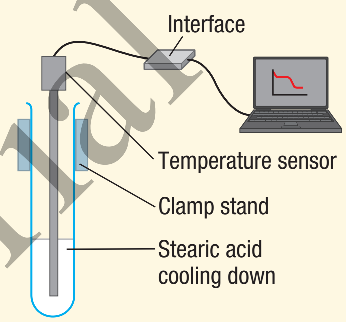


Figure 3 *The heating curve of a solid*

Practical

Cooling curve

Heat a test tube of stearic acid clamped in a water bath until its temperature reaches about 75 °C. Then remove the test tube from the hot water and monitor the temperature as it falls. Plot or print off a graph of the results.



- What is the melting point of stearic acid?
- Explain the shape of the line on your graph.

Safety: Wear eye protection.

Summary questions

1 Draw a table to summarise the general properties of solids, liquids, and gases, as well as the average distance, arrangement, and movement of their particles.

2 Describe the changes that occur to the particles as a gas is cooled down to a temperature below its freezing point.

3 Name the following changes:
a liquid → solid **b** gas → liquid **c** solid → liquid
d liquid → gas **e** solid → gas (in a single step)

4 Using the kinetic theory of matter, predict how temperature and pressure affect the density of a fixed mass of gas.

5 Explain why substances have different melting points in terms of their particles.

6 Evaporation is the change of state that occurs when a liquid changes to a gas below its boiling point. You can investigate the factors that affect the rate of evaporation using a wet paper towel on a high resolution electronic balance.
Plan an investigation into one factor that might affect the rate of evaporation of water from the paper towel, writing a brief method.

Key points

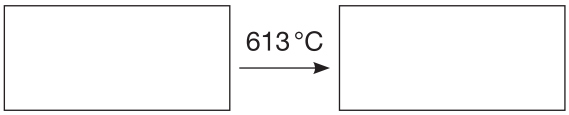
- **The three states of matter are solids, liquids, and gases.**
- **The particles in a solid are packed closely together, fixed in their positions and vibrate.**
- **The particles in a liquid are also close together but can slip and slide over each other in random motion.**
- **The particles in a gas have, on average, lots of space between them and zoom around randomly.**
- **Melting and boiling take in energy from the surroundings as they take place, whereas freezing and condensing transfer energy to the surroundings when they occur.**

Chapter summary questions

1 Arsenic (As) is a solid element that sublimes at 613 °C.

a What is sublimation?

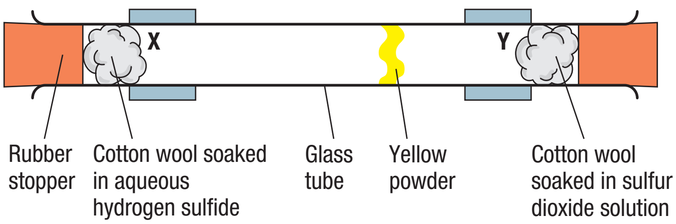
b Assuming arsenic exists as atoms, draw a diagram to show the arrangement of some of its particles in boxes like the ones below:



c Which of these processes take in energy from the surroundings?

boiling melting freezing condensation sublimation

2 Look at the experiment below:



Hydrogen sulfide gas is released from the cotton wool at X and sulfur dioxide gas from the cotton wool at Y.

a The yellow powder inside the glass tube forms after 10 minutes. Explain how the yellow powder forms using the kinetic theory of matter.

b Name the physical process that this experiment demonstrates.

c Why is the yellow powder formed nearer to end Y of the tube?

d Draw a long tube and show the possible path of a hydrogen sulfide particle (molecule) travelling down the tube.

e The original experiment was carried out at 18 °C. Predict any difference you might notice if the experiment was repeated at 25 °C.

3 Look at the data in the table below:

Chemical element	Melting point (°C)	Boiling point (°C)	Density (g/cm³)
Bromine	–7	59	3.12
Caesium	29	669	1.88
Fluorine	–220	–188	0.00158
Strontium	769	1384	2.6
Xenon	–112	–108	0.0055

a What is the physical state of each element in the table at 25 °C?

b Which element exists as a liquid over the widest range of temperature?

c Explain the large differences in the densities of the elements in the table using the kinetic theory of matter.

d What is the chemical symbol for atoms of each element in the table?

e Classify each element in the table as a metal or a non-metal.

4 **a** **i** Which sub-atomic particles are found in the nucleus?

ii What is the maximum number of electrons that can occupy each of the first two energy levels or shells?

b **i** Explain the overall charge on any atom.

ii Define 'atomic number' and 'mass number'.

5 This question is about some of the elements in the periodic table.

You will need to use the periodic table to help you answer some parts of the question. See page 41.

a Neon (Ne) is the 10th element in the periodic table.

i Is neon a metal or a non-metal?

ii Are there more metals or non-metals in the periodic table?

iii How many protons does an neon atom contain?

iv The mass number of a neon atom is 20. How many neutrons does it contain?

v State the name and number of the group to which neon belongs.

vi Name two other elements in the same group as neon.

vii Write the electronic structure of a neon atom.

viii What is special about the electronic structure of neon and the other elements in its group?

b The element radium (Ra) has 88 electrons.

i How many protons are in the nucleus of each radium atom?

ii How many electrons does a radium atom have in its highest energy level (outermost shell)? How did you decide on your answer?

iii Is radium a metal or a non-metal?

iv Calcium is in the same group as radium. Its atomic number is 20. Write down its electronic structure.

Practice questions

1 Use words from the list to complete the table to show the state of matter described.

gas liquid solid

Description	State
particles close together but not moving around	
particles very far apart	
particles close together but continuously moving around	

(3)

2 **a** Explain the difference between an element and a compound. (2)

b Why is ammonia classified as a compound but air is classified as a mixture? (2)

c Name the change of state in each of these processes.

i $H_2O(g) \rightarrow H_2O(l)$ (1)

ii $H_2O(l) \rightarrow H_2O(g)$ (1)

iii $I_2(s) \rightarrow I_2(g)$ (1)

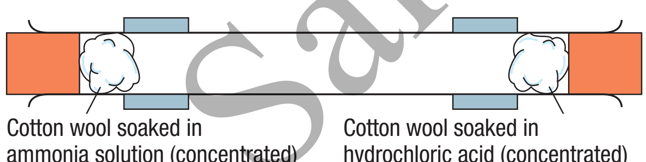
3 A crystal of copper(II) sulfate is placed at the bottom of a beaker of water and left for a few days.

a Describe the appearance of the liquid in the beaker after a few days. (2)

b How does the appearance of the crystal change during the experiment? (1)

c Name **two** processes that occur during the experiment. (2)

4 The diagram shows the apparatus used in a teacher demonstration.



a Describe the observations you would make after a few minutes. (2)

b Use state symbols to complete the symbol equation for the reaction that occurs.

$NH_3(...) + HCl(...) \rightarrow NH_4Cl(...)$ (1)

c Explain how this experiment shows that ammonia molecules have a smaller mass than hydrogen chloride molecules. (1)

5 Electrons in atoms are arranged in energy levels (or shells) at different distances from the nucleus. Copy these statements and use numbers to complete them.

a The maximum number of electrons in the first shell is .... (1)

b The maximum number of electrons in the second shell is .... (1)

c Atoms of sodium have electrons in .... shells. (1)

d The number of electrons in the third shell of an atom of phosphorus is .... (1)

e The atomic number of an atom with the electronic structure 2,8,6 is .... (1)

f Copy these statements and use numbers to complete them.

i The number of protons in an atom of $^{20}_{10}Ne$ is .... (1)

ii The number of electrons in an atom of $^{22}_{10}Ne$ is .... (1)

iii The number of neutrons in an atom of $^{20}_{10}Ne$ is .... (1)

iv The mass number of $^{22}_{10}Ne$ is .... (1)