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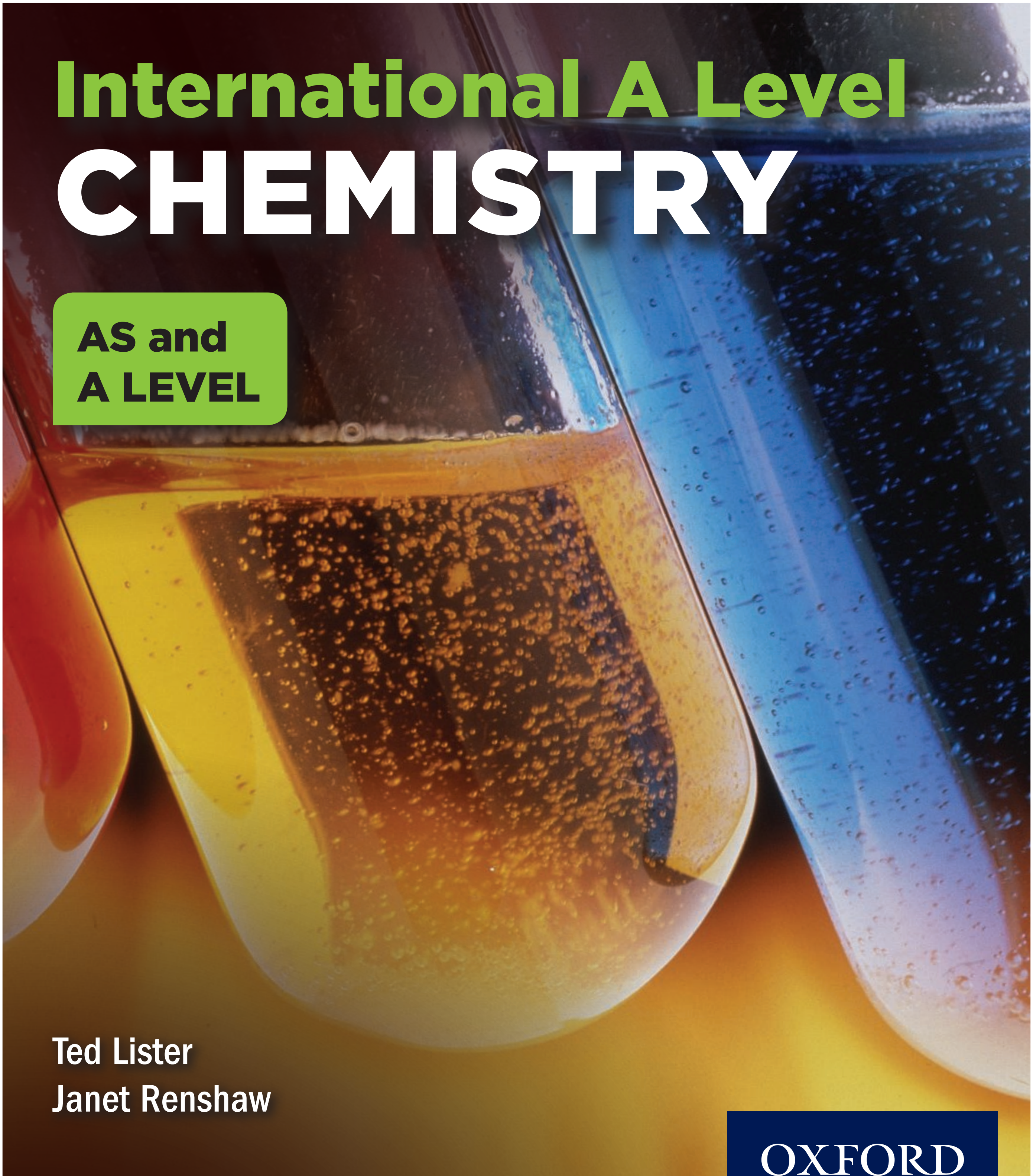
International A Level
CHEMISTRY

AS and A LEVEL



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Contents

Answers to the Practice Questions and Section Questions are available at www.oxfordsecondary.com/oxfordaqaexams-alevel-chemistry

How to use this book

Learning objectives

- → At the beginning of each topic, there is a list of learning objectives.
- → These are matched to the specification and allow you to monitor your progress.
- → A specification reference is also included.

Specification reference: 3.1.1

This book contains many different features. Each feature is designed to foster and stimulate your interest in chemistry, as well as supporting and developing the skills you will need for your examinations.

Terms that it is important you are able to define and understand are highlighted in **bold orange text**. You can look these words up in the glossary.

Sometimes a word appears in **bold**. These are words that are useful to know but are not used on the specification. They therefore do not have to be learnt for examination purposes.

Synoptic link

These highlight how the sections relate to each other. Linking different areas of chemistry together is important, and you will need to be able to do this.

There are also links to the mathematical skills on the specification. More detail can be found in the maths section.

Application features

These features contain important and interesting applications of chemistry in order to emphasise how scientists and engineers have used their scientific knowledge and understanding to develop new applications and technologies. There are also application features to develop your maths skills, and to develop your practical skills.

Extension features

These features contain material that is beyond the specification designed to stretch and provide you with a broader knowledge and understanding and lead the way into the types of thinking and areas you might study in further education. As such, neither the detail nor the depth of questioning will be required for the examinations. But this book is about more than getting through the examinations.

1 Extension and application features have questions that link the material with concepts that are covered in the specification. Short answers are inverted at the bottom of the feature, whilst longer answers where appropriate can be found in the answers section at the back of the book.

Study tips

Study tips contain prompts to help you with your revision. They can also support the development of your practical skills.

Hint

Hint features give other information or ways of thinking about a concept to support your understanding. They can also relate to practical or mathematical skills.

Summary questions

1 These are short questions that test your understanding of the topic and allow you to apply the knowledge and skills you have acquired. The questions are ramped in order of difficulty.

1 Atomic structure

1.1 Fundamental particles

Developing ideas of the atom

The Greek philosophers had a model in which matter was made up of a single continuous substance that produced the four elements – earth, fire, water, and air. The idea that matter was made of individual atoms was not taken seriously for another 2000 years. During this time alchemists built up a lot of evidence about how substances behave and combine. Their aim was to change other metals into gold. Here are a few of the steps that led to our present model.

1661 Robert Boyle proposed that there were some substances that could not be made simpler. These were the chemical elements, as we now know them.

1803 John Dalton suggested that elements were composed of indivisible atoms. All the atoms of a particular element had the same mass and atoms of different elements had different masses. Atoms could not be broken down.

1896 Henri Becquerel discovered radioactivity. This showed that particles could come from inside the atom. Therefore the atom was not indivisible. The following year, J J Thomson discovered the electron. This was the first sub-atomic particle to be discovered. He showed that electrons were negatively charged and electrons from all elements were the same.

As electrons had a negative charge, there had to be some source of positive charge inside the atom too. Also, as electrons were much lighter than whole atoms, there had to be something to account for the rest of the mass of the atom. Thompson suggested that the electrons were located within the atom in circular arrays, like plums in a pudding of positive charge, see Figure 1.

1911 Ernest Rutherford and his team found that most of the mass and all the positive charge of the atom was in a tiny central nucleus.

So, for many years, it has been known that atoms themselves are made up of smaller particles, called sub-atomic particles. The complete picture is still being built up in 'atom smashers' such as the one at CERN, near Geneva.

The sub-atomic particles

Atoms are made of three fundamental particles – **protons**, **neutrons**, and **electrons**.

The protons and neutrons form the **nucleus**, in the centre of the atom.

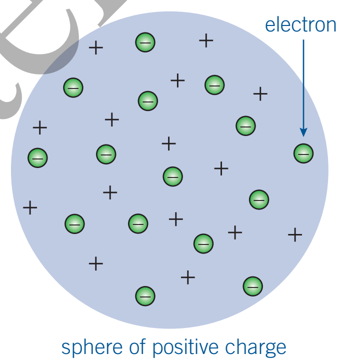
- Protons and neutrons are sometimes called **nucleons** because they are found in the nucleus.
- The electrons surround the nucleus.

The properties of the sub-atomic particles are shown in Table 1.

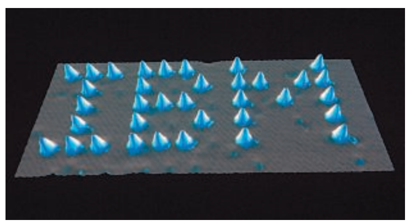
Learning objectives:

- → State the relative masses of protons, neutrons, and electrons.
- → State the relative charges of protons, neutrons, and electrons.
- → Explain how these particles are arranged in an atom.

Specification reference: 3.1.1



▲ **Figure 1** *The plum pudding model of the atom – electrons located in circular arrays within a sphere of positive charge*



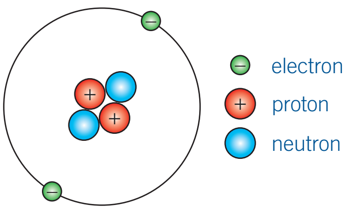
▲ **Figure 2** *Atoms can only be seen indirectly. This photograph of xenon atoms was taken by an instrument called a scanning tunnelling electron microscope*

Maths link

The masses and charges of sub-atomic particles are very small so they are expressed in standard form. Refer to Section 8, Mathematical skills, if you are not sure about this notation.

Study tip

You must remember the relative masses and charges of a proton, neutron, and an electron, as given in Table 2.



▲ **Figure 3** *The sub-atomic particles in a helium atom (not to scale)*

Extension

The diameter of the nucleus of a hydrogen atom is about 2×10^{-15} m, while the diameter of the atom itself is about 1×10^{-10} m, about 50 000 times larger. This means that if the nucleus were the size of a fly, the whole atom would be roughly the size of a cathedral.

St Paul's Cathedral is roughly 200 m long. Estimate the length of a fly and, without using a calculator, check that the analogy is realistic.

▼ **Table 1** *The properties of the sub-atomic particles*

Property	Proton p	Neutron n	Electron e
Mass / kg	1.673×10^{-27}	1.675×10^{-27}	0.911×10^{-30} (very nearly 0)
Charge / C	$+1.602 \times 10^{-19}$	0	-1.602×10^{-19}
Position	in the nucleus	in the nucleus	around the nucleus

These numbers are extremely small. In practice, *relative* values for mass and charge are used. The relative charge on a proton is taken to be +1, so the charge on an electron is −1. Neutrons have no charge, see Table 2.

▼ **Table 2** *The relative masses and charges of the sub-atomic particles*

	Proton p	Neutron n	Electron e
Relative mass	1	1	$\frac{1}{1840}$
Relative charge	+1	0	−1

In a neutral atom, the number of electrons must be the same as the number of protons because their charge is equal in size and opposite in sign.

The arrangement of the sub-atomic particles

The sub-atomic particles (protons, neutrons, and electrons) are arranged in the atom as shown in Figure 3.

The protons and neutrons are in the centre of the atom, held together by a force called the **strong nuclear force**. This is much stronger than the **electrostatic forces** of attraction that hold electrons and protons together in the atom, so it overcomes the repulsion between the protons in the nucleus. It acts only over very short distances, that is, within the nucleus.

The nucleus is surrounded by electrons. Electrons are found in a series of shells, sometimes referred to as orbits or levels, which get further and further away from the nucleus. This is a simplified picture that will develop in Topic 1.5.

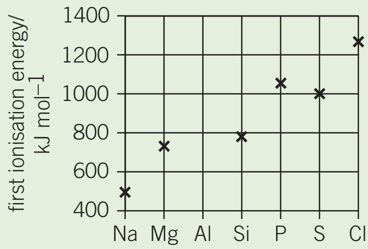
Summary questions

1 a Identify which of the following – protons, neutrons, or electrons:
   - i are nucleons
   - ii have the same relative mass
   - iii have opposite charges
   - iv have no charge
   - v are found outside the nucleus

  b Explain why we assume that there are the same number of protons and electrons in an atom.

Practice questions

1 The diagram to the right shows the first ionisation energies of some Period 3 elements.



(a) Draw a cross on the diagram to show the first ionisation energy of aluminium.

(1 mark)

(b) Write an equation to show the process that occurs when the first ionisation energy of aluminium is measured.

(2 marks)

(c) State which of the first, second, or third ionisations of aluminium would produce an ion with the electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^1$.

(1 mark)

(d) Explain why the value of the first ionisation energy of sulfur is less than the value of the first ionisation energy of phosphorus.

(2 marks)

(e) Identify the element in Period 2 that has the highest first ionisation energy and give its electron configuration.

(2 marks)

(f) State the trend in first ionisation energies in Group 2 from beryllium to barium. Explain your answer in terms of a suitable model of atomic structure.

(3 marks)

AQA, 2010

2 **(a)** One isotope of sodium has a relative mass of 23.

(i) Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

(ii) Explain why isotopes of the same element have the same chemical properties.

(3 marks)

(b) Give the electronic configuration, showing all sub-shells, for a sodium atom.

(1 mark)

(c) An atom has half as many protons as an atom of ^{28}Si and also has six fewer neutrons than an atom of ^{28}Si. Give the symbol, including the mass number and the atomic number, of this atom.

(2 marks)

AQA, 2004

3 The values of the first ionisation energies of neon, sodium, and magnesium are 2080, 494, and 736 kJ mol^{-1}, respectively.

(a) Explain the meaning of the term *first ionisation energy* of an atom.

(2 marks)

(b) Write an equation using state symbols to illustrate the process occurring when the **second** ionisation energy of magnesium is measured.

(2 marks)

(c) Explain why the value of the first ionisation energy of magnesium is higher than that of sodium.

(2 marks)

(d) Explain why the value of the first ionisation energy of neon is higher than that of sodium.

(2 marks)

AQA, 2004

4 A sample of iron from a meteorite was found to contain the isotopes ^{54}Fe, ^{56}Fe, and ^{57}Fe.

(a) The relative abundances of these isotopes can be determined using a mass spectrometer. In the mass spectrometer, the sample is first vaporised and then ionised.

(i) State what is meant by the term *isotopes*.

(ii) Explain how, in a mass spectrometer, ions are detected and how their abundance is measured.

(5 marks)

(b) (i) Define the term *relative atomic mass* of an element.

(ii) The relative abundances of the isotopes in this sample of iron were found to be as follows.

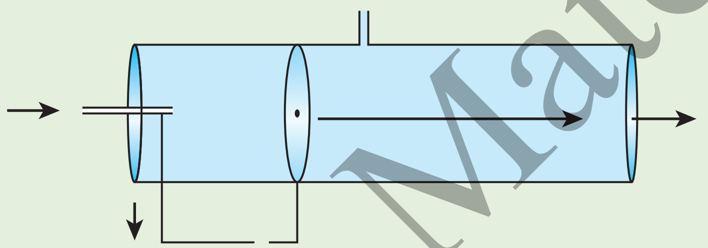
m/z	54	56	57
Relative abundance %	5.80	91.60	2.60

Use the data above to calculate the relative atomic mass of iron in this sample. Give your answer to the appropriate number of significant figures.

(2 marks)

AQA, 2005

5 The diagram shows the layout of a time of flight mass spectrometer.



(a) Explain how positive ions are formed from the sample.

(1 mark)

(b) Explain why the instrument is kept under vacuum.

(1 mark)

(c) Explain how the ions are accelerated and separated by mass in the instrument.

(3 marks)

(d) Explain how an electric current is produced when an ion arrives at the detector.

(1 mark)

(e) The low resolution mass spectrum of magnesium shows three peaks.

Mass / charge	Relative abundance / %
24	79.0%
25	10.0%
26	11.0%

(i) Give the numbers of protons and neutrons in the nuclei of each isotope.

(1 mark)

(ii) Calculate the relative atomic mass of a sample of magnesium. Give your answer to the appropriate number of significant figures.

(2 marks)