Cambridge IGCSE · Chemistry 0620 · Notes

Elements, compounds and atomic structure

Read online at **pastopic.com/cambridge/chemistry-0620/notes/atomic-structure**

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What you need to know

By the end of this topic you should be able to:

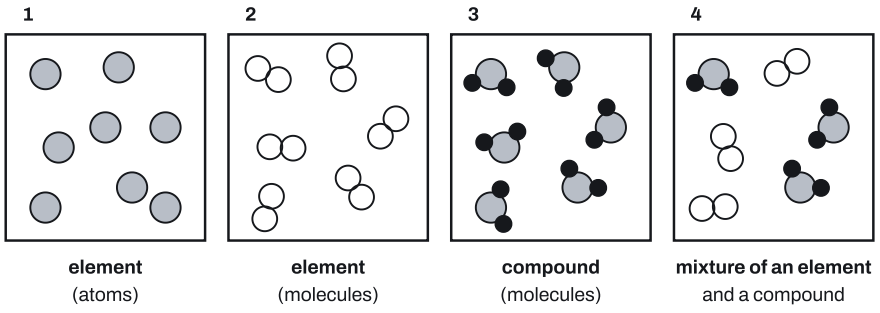
1. **Describe how elements, compounds and mixtures differ**, both in words and from diagrams of their particles.
2. **Describe the structure of an atom**: a tiny central nucleus of protons and neutrons, with electrons arranged in shells around it.
3. **State the relative charge and relative mass** of a proton, a neutron and an electron.
4. **Define proton number (atomic number)**: the number of protons in the nucleus of an atom.
5. **Define mass number (nucleon number)**: the total number of protons and neutrons in the nucleus of an atom.
6. **Work out the electronic configuration** (for example 2,8,3) of the elements with proton numbers 1 to 20 and of their ions.
7. **State three links between electrons and the Periodic Table**: noble gases in Group VIII have a full outer shell; in Groups I to VII the number of outer-shell electrons equals the group number; the number of occupied shells equals the period number.
8. **Define isotopes**: different atoms of the same element, with the same number of protons but different numbers of neutrons.
9. **Read and use symbols** for atoms, such as $^{12}_{6}\mathrm{C}$, and for ions, such as $^{35}_{17}\mathrm{Cl}^{-}$, to find the numbers of protons, neutrons and electrons.
10. **Extended only:** state that isotopes of the same element have the same chemical properties, because they have the same number of electrons and so the same electronic configuration.
11. **Describe relative atomic mass** (syllabus 3.2): the average mass of an element's isotopes, compared with $\frac{1}{12}$ of the mass of a carbon-12 atom.
12. **Extended only:** calculate the relative atomic mass of an element from the masses and abundances of its isotopes.

Understand it

Elements, compounds and mixtures

Everything around you is made of atoms. How those atoms are put together decides what kind of substance you have.

- An **element** contains only **one type of atom**. It cannot be broken down into anything simpler by a chemical reaction. Copper, sulfur and carbon are elements. Some elements exist as single atoms (the noble gases, such as argon, are **monatomic**), and some as molecules of two identical atoms joined together (hydrogen, nitrogen, oxygen and the halogens are **diatomic**: H_2, N_2, O_2, Cl_2). A molecule of O_2 is still an element, because both atoms are oxygen.
- A **compound** contains **two or more different elements chemically joined (bonded) together**, always in the same fixed ratio. Water, H_2O, always has two hydrogen atoms for every oxygen atom. A compound has different properties from the elements it is made from (sodium is a reactive metal and chlorine a toxic gas, but sodium chloride is table salt), and it can only be split up again by a **chemical reaction**.
- A **mixture** contains two or more substances (elements or compounds) that are **not chemically joined**. The amounts can vary, each substance keeps its own properties, and the parts can be separated by **physical methods** such as filtration, evaporation or distillation.



To classify a particle diagram, look at each separate particle (a single atom or a group of atoms joined together):

- all particles identical, each made of one kind of atom: **element**;
- all particles identical, each containing two or more kinds of atom: **compound**;
- two or more different kinds of particle: **mixture**. Then say what it is a mixture of: elements, compounds, or an element and a compound.

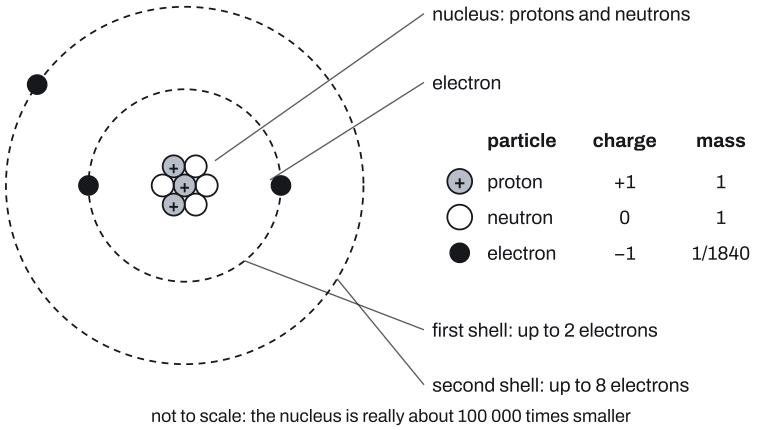
Common examples you should be able to sort:

Elements	Compounds	Mixtures
copper, iron, sulfur, carbon (graphite, diamond), oxygen, nitrogen, argon	water, carbon dioxide, sodium chloride, methane, ethanol, potassium bromide	air, sea water, petroleum, alloys such as brass (copper and zinc) and stainless steel

Air is a mixture of elements (nitrogen, oxygen, argon) **and** compounds (carbon dioxide, water vapour). An **alloy** is a mixture of a metal with other elements, not a compound. A **pure** substance is a single element or a single compound, so pure water and ethanol are pure, but air, brass and petroleum are not.

Inside an atom

An atom has a tiny **nucleus** at its centre. The nucleus contains **protons** and **neutrons**. **Electrons** move around the nucleus in **shells** (energy levels).



not to scale: the nucleus is really about 100 000 times smaller

Particle	Where it is	Relative charge	Relative mass
proton	nucleus	$+1$	1
neutron	nucleus	0	1
electron	shells around the nucleus	-1	$\frac{1}{1840}$ (almost nothing)

Three things follow from this table:

- **Almost all the mass of an atom is in the nucleus**, because protons and neutrons are nearly 2000 times heavier than electrons. The nucleus holds all the protons, so it is positively charged, and nearly all the mass.
- **Most of an atom is empty space.** The nucleus is tiny compared with the whole atom; the electrons' shells take up nearly all the volume.
- **An atom has no overall charge**, because it has the same number of electrons as protons: the -1 charges cancel the $+1$ charges.

Proton number and nucleon number

- The **proton number** (also called **atomic number**) is the number of protons in the nucleus. It decides which element an atom is: every atom with 6 protons is carbon, every atom with 17 protons is chlorine. The Periodic Table is in proton number order.
- The **mass number** (also called **nucleon number**) is the total number of protons **and** neutrons in the nucleus. Protons and neutrons together are called **nucleons**.

Both numbers are written with the symbol. The mass number goes at the top left and the proton number at the bottom left:

$$^{23}_{11}\mathrm{Na} \qquad \text{mass number } 23,\ \text{proton number } 11$$

So a sodium-23 atom has 11 protons, $23 - 11 = 12$ neutrons and 11 electrons. The rule is always:

$$\text{neutrons} = \text{mass number} - \text{proton number}$$

In an exam you can always find an element's proton number on the Periodic Table printed in the paper. Be careful: the other number in each box of that table is the **relative atomic mass**, which is an average (below), not the mass number of one atom.

Ions

An **ion** is an atom (or group of atoms) that has **gained or lost electrons**, so it has a charge. Only the electrons change; the numbers of protons and neutrons stay the same.

- A **positive ion** (a **cation**) has **lost** electrons, so it has more protons than electrons. $^{27}_{13}\mathrm{Al}^{3+}$ has 13 protons, 14 neutrons and $13 - 3 = 10$ electrons.
- A **negative ion** (an **anion**) has **gained** electrons, so it has more electrons than protons. $^{35}_{17}\mathrm{Cl}^{-}$ has 17 protons, 18 neutrons and $17 + 1 = 18$ electrons.

$$\text{electrons} = \text{protons} - \text{charge}$$

(with the charge's sign: for $2+$ subtract 2, for $2-$ add 2). The charge also explains itself: a magnesium ion is $2+$ because it has 12 protons but only 10 electrons, two more positive charges than negative ones.

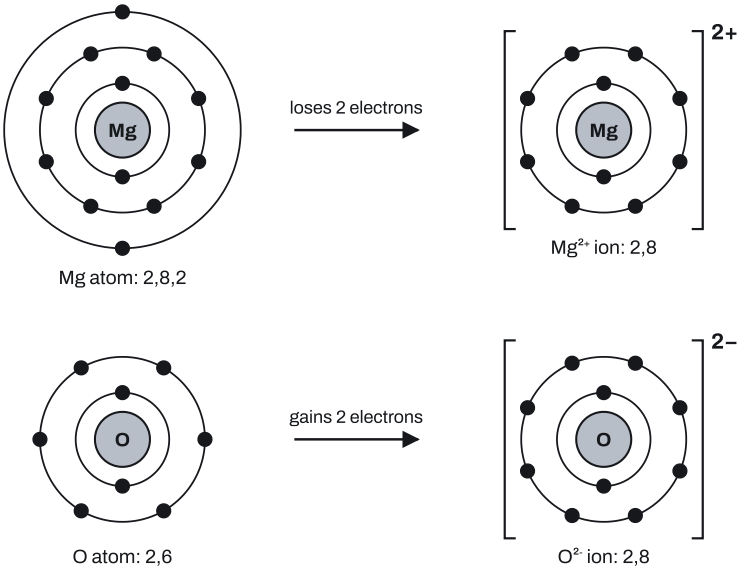
Electronic configuration

Electrons fill shells from the inside out. For the first 20 elements:

- the **first shell** holds up to **2** electrons;
- the **second shell** holds up to **8**;
- the **third shell** takes **8**, and then the next electrons go into the **fourth shell**.

So write the number of electrons in each shell, inside first, separated by commas. Sodium (11 electrons) is 2,8,1. Chlorine (17) is 2,8,7. Potassium (19) is 2,8,8,1 and calcium (20) is 2,8,8,2. The total must equal the number of electrons.

A **diagram** of the configuration shows the nucleus with rings around it, and dots or crosses on each ring for the electrons. For an **ion**, first work out its number of electrons, then fill the shells in the same way. Draw the ion in square brackets with its charge at the top right.



Atoms of the first 20 elements form ions by losing or gaining electrons until they have a **full outer shell**, like a noble gas. So their ions have the configuration **2** (like helium), **2,8** (like neon) or **2,8,8** (like argon). For example Na^{+}, Mg^{2+}, Al^{3+}, F^{-}, O^{2-} and N^{3-} are all 2,8; K^{+}, Ca^{2+}, Cl^{-} and S^{2-} are all 2,8,8. Particles with the same number of electrons have the same configuration, whatever their proton number.

Configuration and the Periodic Table

The Periodic Table is built from electronic configurations.

period	I	II	III	IV	V	VI	VII	VIII
1				1 H 1				2 He 2
2	3 Li 2,1	4 Be 2,2	5 B 2,3	6 C 2,4	7 N 2,5	8 O 2,6	9 F 2,7	10 Ne 2,8
3	11 Na 2,8,1	12 Mg 2,8,2	13 Al 2,8,3	14 Si 2,8,4	15 P 2,8,5	16 S 2,8,6	17 Cl 2,8,7	18 Ar 2,8,8
4	19 K 2,8,8,1	20 Ca 2,8,8,2						

group number (I to VII) = number of outer-shell electrons
period number = number of occupied shells

- **Group number = number of outer-shell electrons** (Groups I to VII). Sulfur is 2,8,6, so it is in Group VI. An atom with configuration 2,8,8,1 is in Group I.
- **Period number = number of occupied shells.** Sulfur has three shells, so it is in Period 3. Potassium (2,8,8,1) has four, so it is in Period 4.
- **Group VIII, the noble gases, have a full outer shell.** Helium's outer shell is full with just **2** electrons (the first shell holds only 2); neon and argon have 8. A full outer shell is why the noble gases are unreactive and exist as single atoms.

Elements in the same group have the same number of outer-shell electrons, which is why they have similar chemical properties: lithium, sodium and potassium all have one outer electron. Hydrogen, with one electron in its only shell, is the only atom with an incomplete first shell. It is usually placed on its own, not in Group I.

These rules are for **atoms**. Na^+ is 2,8, but sodium is still in Group I and Period 3.

To identify an element from its configuration, add up the electrons: 2,8,4 has 14 electrons, so the proton number is 14 (silicon, Group IV, Period 3).

Isotopes

The number of protons fixes the element, but the number of neutrons can vary. **Isotopes** are **different atoms of the same element** that have the **same number of protons** but **different numbers of neutrons**. So they have different mass numbers.

Isotope	Protons	Neutrons	Electrons
$^{12}_{6}\mathrm{C}$	6	6	6
$^{13}_{6}\mathrm{C}$	6	7	6
$^{14}_{6}\mathrm{C}$	6	8	6

Isotopes are also named with their mass number: carbon-12, chlorine-37.

Extended only: isotopes of the same element have the **same chemical properties**. Chemical reactions involve electrons, and the isotopes have the same number of electrons and so the **same electronic configuration**. The different number of neutrons changes only the mass.

Relative atomic mass

Most elements are a mixture of isotopes, so a sample's atoms do not all have the same mass. The **relative atomic mass**, A_r, is the **average mass of the isotopes** of the element, compared with $\frac{1}{12}$ of the mass of an atom of **carbon-12** (syllabus 3.2). Carbon-12 is the standard that all relative masses are measured against.

Extended only: the average is weighted by how common each isotope is (its **abundance**, usually a percentage):

$$A_r = \frac{(\text{mass}_1 \times \text{abundance}_1) + (\text{mass}_2 \times \text{abundance}_2) + \dots}{100}$$

Chlorine is 75% chlorine-35 and 25% chlorine-37:

$$A_r = \frac{35 \times 75 + 37 \times 25}{100} = \frac{2625 + 925}{100} = 35.5$$

The answer always lies between the lightest and heaviest isotope, and closer to the more common one. It is not a whole number, which is how you can tell a relative atomic mass from a mass number.

Key facts and formulas

The only data printed in the exam for this topic is the **Periodic Table** (proton numbers, symbols and relative atomic masses). Everything else here is **Learn it**.

Formula	Status
Proton number and relative atomic mass of each element, from the Periodic Table	Given
Proton: charge $+1$, mass 1; neutron: charge 0, mass 1; electron: charge -1, mass $\frac{1}{1840}$	Learn it
Proton number (atomic number) = number of protons in the nucleus	Learn it
Mass number (nucleon number) = number of protons + neutrons in the nucleus	Learn it
Neutrons = mass number – proton number	Learn it
In an atom, electrons = protons; in an ion, electrons = protons – charge	Learn it
Shells for proton numbers 1–20 hold 2, then 8, then 8, then the rest	Learn it
Group number (I–VII) = outer-shell electrons; period number = occupied shells	Learn it
Noble gases (Group VIII) have a full outer shell	Learn it
Isotopes: atoms of the same element, same number of protons, different numbers of neutrons	Learn it
Extended only: isotopes have the same chemical properties: same number of electrons, same configuration	Learn it
Relative atomic mass A_r = average mass of an element's isotopes, compared with $\frac{1}{12}$ of the mass of a carbon-12 atom	Learn it
Extended only: $A_r = \frac{\sum(\text{isotope mass} \times \text{abundance})}{100}$	Learn it

How to do it

In the questions we have tagged for this topic (223 questions, 2021–2025, on Papers 1–4), the types came up this often. 49 of the 223 questions mix types, so the counts add up to more than 223.

Question type	Questions
Protons, neutrons and electrons in atoms and ions	94
Isotopes	47
Electronic configuration of atoms and ions	41
Group and period from the configuration	34
The particles in an atom and their definitions	32
Elements, compounds and mixtures	31
Relative atomic mass from isotopes	23

1. Protons, neutrons and electrons in atoms and ions (94 questions)

Usually a table to complete, or "deduce the number of protons, neutrons and electrons in the ion shown".

1. **Protons** = the bottom number (proton number). If it is not given, find the element's proton number on the Periodic Table.
2. **Neutrons** = top number – bottom number.
3. **Electrons** = protons for an atom. For an ion, **subtract** the positive charge or **add** the negative charge.

For example, $^{65}_{29}\mathrm{Cu}^{2+}$: 29 protons, $65 - 29 = 36$ neutrons, $29 - 2 = 27$ electrons.

Variations you will meet:

- **Working backwards to the symbol.** Given the particle numbers, the **protons** tell you the element (look it up on the Periodic Table), **protons + neutrons** gives the mass number, and **protons – electrons** gives the charge. For 16 protons, 17 neutrons and 18 electrons: sulfur, mass number 33, charge $16 - 18 = -2$, so $^{33}_{16}\mathrm{S}^{2-}$. Write the mass number top left, the proton number bottom left and the charge top right, as the question's format shows.
- **Deciding atom, cation or anion** from a table: equal protons and electrons is an atom; more protons than electrons is a positive ion (cation); more electrons is a negative ion (anion).
- **Which particles have the same number of neutrons**, or **more neutrons than protons**: work out neutrons for every particle first, then compare. Charges do not affect neutrons.
- **Identifying the element** from a nucleus drawing or a description ("an atom with 15 protons, 16 neutrons and 15 electrons"): use only the number of protons (phosphorus).
- **Counting nucleons**: protons + neutrons. Never add the electrons.
- **"Describe this atom"** in terms of where the particles are, how many there are, and its configuration: protons and neutrons in the nucleus, electrons in shells; the numbers; then the configuration.

2. Isotopes (47 questions)

1. **Define** them with all three parts: **atoms** of the same element, the **same number of protons**, **different numbers of neutrons**.

2. **Spot isotopes** in a list: the particles with the **same proton number** but different mass numbers. If you are given the mass number and neutrons, protons = mass number – neutrons.
3. **Extended only: explain why isotopes have the same chemical properties**: they have the same number of electrons, so the same electronic configuration (the same number of outer-shell electrons).

Variations you will meet:

- **"State the term"** for atoms of the same element with different nucleon numbers: isotopes.
- **What is the same and what is different.** Same: protons, electrons, configuration, outer electrons, proton number, chemical properties. Different: neutrons, mass (nucleon) number.
- **Two different elements with the same mass number** (such as $^{40}_{18}\mathrm{Ar}$ and $^{40}_{20}\mathrm{Ca}$) are **not** isotopes: different proton numbers mean different elements, so different numbers of electrons and different groups.
- **A table of W, X, Y and Z**, some of them ions: isotopes must match in protons; ignore the electrons, because an ion of the same element has a different number.
- **Symbols with letters** such as $^{m}_{n}\mathrm{S}$ and $^{p}_{q}\mathrm{S}$: isotopes of one element share the bottom number ($n = q$) and differ in the top one.
- **Why an isotope has no overall charge**: it has equal numbers of protons and electrons.

3. Electronic configuration of atoms and ions (41 questions)

1. **Count the electrons**: the proton number for an atom; adjusted by the charge for an ion.
2. **Fill the shells**: 2, then 8, then 8, then the rest. Write them as 2,8,5.
3. **For a diagram**, draw one electron per dot or cross on the right ring, and for an ion add square brackets and the charge.

Variations you will meet:

- **"Which particles have the configuration 2,8,8?"** Count electrons: Ar (18), K^+ (19 – 1), Ca^{2+} (20 – 2), Cl^- (17 + 1), S^{2-} (16 + 2) all have 18.
- **"Give an atom and an ion with the same configuration as X."** Find a noble gas with the same number of electrons, then an ion from the element just before or after it. For 2,8: Ne atom; Na^+ or Mg^{2+} (positive); F^- or O^{2-} (negative).
- **"Explain why the ion has a charge of 2–"**: the atom (for example sulfur, 2,8,6) gains 2 electrons to fill its outer shell, so it has 18 electrons but only 16 protons.
- **"Maximum number of electrons in the second shell"**: 8. The first shell: 2.
- **Statements to check**, for example "the configuration of Al^{3+} is 2,8,3" (false: it is 2,8) or "hydrogen is the only atom with an incomplete first shell" (true).
- **Pick the diagram** that shows a given atom: count the electrons on each ring.

4. Group and period from the configuration (34 questions)

1. **Write the configuration** of the atom (or read it).
2. **Group** = electrons in the outer shell (a full outer shell means Group VIII). **Period** = number of shells.

Variations you will meet:

- **"Explain why nitrogen is in Group V"**: its atoms have five electrons in the outer shell.
- **"Give the symbol of the element whose atom has only three occupied shells"** from part of a Periodic Table: pick an element in Period 3.
- **Choose from lettered configurations**: a noble gas (full outer shell, such as 2,8 or 2,8,8); an atom in Group VI (6 outer electrons); an atom forming a 2– ion (6 outer electrons); a reactive metal (1 or 2 outer electrons); an atom with proton number 17 (electrons add to 17).
- **"Explain why argon (or helium) is unreactive"**: its atom has a full outer shell of electrons. For helium, that is 2 electrons, not 8.
- **"Explain why Li, K and Rb have similar chemical properties"**: they have the same number of outer-shell electrons (one).
- **Element Y has 8 more protons than X** (with X in Period 2): Y is in the same group, one period down, so it has one more shell and the same outer electrons.
- **Statements to test**, for example "aluminium is in Period 2" (false: 2,8,3 is three shells, Period 3).

5. The particles in an atom and their definitions (32 questions)

1. Learn the table of charges and masses **exactly**, including the electron's mass, $\frac{1}{1840}$.
2. Learn the two definitions word for word in meaning: proton number = number of **protons**; nucleon (mass) number = **protons + neutrons**, both "in the nucleus of an atom".

Variations you will meet:

- **Which particles are in the nucleus?** Protons and neutrons.
- **Relative mass 1 and charge 0**: the neutron. **Mass less than 1, charge 1–, found outside the nucleus**: the electron.
- **Statements to check**: the centre of an atom is positive and holds most of its mass (true); protons and electrons are in the nucleus (false); protons and electrons have the same mass (false); the nucleus takes up most of the volume (false).
- **"State one other term** for the number of protons and neutrons": nucleon number (or mass number).
- **A nucleus with 9 positive and 10 uncharged particles**: proton number 9, nucleon number 19.
- **Which diagram shows a helium atom**: 2 protons and 2 neutrons in the nucleus, 2 electrons outside.

6. Elements, compounds and mixtures (31 questions)

1. **Element**: one type of atom. **Compound**: different atoms (elements) chemically joined in a fixed ratio; separated only by chemical reactions. **Mixture**: substances not chemically joined; separated by physical methods.
2. **For a diagram**, look at each separate particle as in "Understand it".

Variations you will meet:

- **Sort named substances**: learn the table in "Understand it". Brass, stainless steel, air, sea water and petroleum are mixtures; ethanol, water and sodium chloride are pure compounds; copper and carbon are elements.
- **"Which is a mixture of one element and one compound?"** For example oxygen dissolved in water (O_2 is an element, H_2O a compound). Clean air contains several of each; aqueous glucose is two compounds.
- **"State two characteristics of a mixture"**: its parts are not chemically joined; they can be separated by physical methods; its composition can vary; each part keeps its own properties.
- **Deduce from an experiment**: if a solid gives a blue solution in water **and** leaves a solid that conducts electricity, it contained a soluble compound and a metal, so it was a **mixture** containing a metal.
- **Count elements and compounds in a list**: calcium nitrate, iron(II) sulfate and water are compounds; oxygen is an element.
- **"Why is water a compound?"** Its hydrogen and oxygen atoms are chemically joined and can only be separated by chemical means.

7. Relative atomic mass from isotopes (23 questions)

Extended only.

1. **Multiply** each isotope's mass by its percentage abundance.
2. **Add** these and **divide by 100** (or by the total abundance if it is not 100, for example a ratio of 3 : 7 means divide by 10).
3. Give the answer to the accuracy asked, usually **one decimal place**.

Variations you will meet:

- **Three isotopes**: the same method with three terms. An element with 80% of mass 24, 10% of mass 25 and 10% of mass 26 gives $\frac{24\times80+25\times10+26\times10}{100} = \frac{1920+250+260}{100} = 24.3$.
- **Finding an abundance from** A_r (two isotopes). Call the lighter isotope's percentage x; the other is $100 - x$. Solve $m_1x + m_2(100 - x) = 100A_r$. For boron ($A_r = 10.8$, isotopes 10 and 11): $10x + 11(100 - x) = 1080$, so $x = 20$: 20% boron-10.
- **Quick check for multiple choice**: if A_r is exactly halfway between two isotopes, they are 50% each; a value closer to one isotope means that isotope is more common. Copper at 63.5 with isotopes 63 and 65 is a quarter of the way from 63, so 75% copper-63.
- **Finding a missing isotope mass** from A_r and the abundances: put the unknown mass as a letter in the formula and solve.
- **"Aluminium's only isotope has nucleon number 27, and $A_r = 27$: what can you conclude?"** Aluminium has only one naturally occurring isotope.

Core too: "Identify the isotope that all relative masses are compared to" needs carbon-12 (say carbon-**12**, not just carbon), and "describe relative atomic mass" needs "the average mass of the isotopes" compared with $\frac{1}{12}$ of a carbon-12 atom.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

(a) Copper, carbon dioxide, air and brass are four substances. State which is an element, which is a compound and which two are mixtures. **[2]**

(b) Explain why sodium chloride is described as a compound. **[2]**

(c) State two ways in which a mixture differs from a compound. **[2]**

(a) Element: **copper**. Compound: **carbon dioxide**. **B1** Mixtures: **air** and **brass**. **B1**

(b) It contains two different elements, sodium and chlorine, **B1** which are **chemically joined** (bonded) together. **B1**

(c) Any two of: the parts of a mixture are **not chemically joined**; a mixture can be **separated by physical methods**; its **composition can vary**; its parts **keep their own properties**. **B1 B1**

Example 2

Complete the table. **[5]**

Particle	Protons	Neutrons	Electrons
$^{27}_{13}\mathrm{Al}$			
$^{32}_{16}\mathrm{S}^{2-}$			
?	20	24	18

Row 1: an atom: 13 protons, $27 - 13 = 14$ neutrons, 13 electrons. **B1**

Row 2: 16 protons and $32 - 16 = 16$ neutrons **B1**; the $2-$ charge means 2 extra electrons: $16 + 2 = 18$ electrons. **B1**

Row 3: 20 protons means calcium; the mass number is $20 + 24 = 44$ **B1**; 2 fewer electrons than protons gives a charge of $2+$. So the particle is $^{44}_{20}\mathrm{Ca}^{2+}$. **B1**

Example 3

Element X has proton number 15.

(a) Write the electronic configuration of an atom of X. **[1]**

(b) State the group and the period of X in the Periodic Table. Explain how you decided. **[2]**

(c) X forms an ion with a charge of $3-$. Explain why, and give the configuration of the ion. **[2]**

(d) Give the formula of one atom and one positive ion that have the same configuration as the ion of X. **[2]**

(a) 15 electrons: **2,8,5**. **B1**

(b) Group V, because there are 5 electrons in the outer shell; **Period 3**, because 3 shells are occupied. **B1 B1**

(c) The atom **gains 3 electrons** to fill its outer shell ($5 + 3 = 8$), so it has 18 electrons and 15 protons: charge $3-$. **B1** The configuration is **2,8,8**. **B1**

(d) Any particle with 18 electrons. Atom: **Ar**. **B1** Positive ion: **K^+** (or **Ca^{2+}**). **B1**

Example 4

Extended. Gallium has two isotopes, gallium-69 and gallium-71.

(a) Define the term isotopes. **[2]**

(b) Explain why the two isotopes of gallium have the same chemical properties. **[1]**

(c) A sample of gallium contains 60% gallium-69 and 40% gallium-71. Calculate the relative atomic mass of gallium in this sample. Give your answer to one decimal place. **[2]**

(d) Antimony has two isotopes, antimony-121 and antimony-123, and a relative atomic mass of 121.8. Calculate the percentage of antimony-121 in antimony. **[2]**

(a) Atoms of the same element with the **same number of protons B1** but **different numbers of neutrons**. **B1**

(b) They have the same number of electrons, so the **same electronic configuration**. **B1**

(c)

$$A_r = \frac{69 \times 60 + 71 \times 40}{100} = \frac{4140 + 2840}{100} = 69.8$$

M1 for multiplying each mass by its abundance and dividing by 100, **A1** for 69.8.

(d) Let the percentage of antimony-121 be x.

$$121x + 123(100 - x) = 12\,180 \;\Rightarrow\; 12\,300 - 2x = 12\,180 \;\Rightarrow\; x = 60$$

M1 for the equation, **A1** for **60%**. Check: $121 \times 60 + 123 \times 40 = 12\,180$, and $12\,180 \div 100 = 121.8$.

Common mistakes

- **Writing the wrong thing for "electronic configuration".** Examiners see $^{12}_{6}\mathrm{C}$, a formula, or just the number of electrons. The answer is the shells: carbon is 2,4.
- **Using the mass number to fill the shells.** Carbon-12 is not 2,8,2. Only the number of electrons (the proton number for an atom) counts.
- **Getting ion electrons the wrong way round.** A positive charge means electrons were **removed**: Rb^+ has $37 - 1 = 36$ electrons, not 38. A negative charge means electrons were **added**.
- **Adding instead of subtracting for neutrons.** Neutrons = mass number – proton number. Adding them gives nonsense such as 327 neutrons for uranium.
- **Leaving out the fourth shell of potassium or calcium.** K is 2,8,8,1, not 2,8,9. The third shell takes 8 before the fourth starts for these elements.
- **Defining isotopes without the word "atoms"**, or saying "different neutrons" instead of "different **numbers** of neutrons", or "different relative masses" (relative atomic mass is an average for the element, not one atom's mass).
- **Mixing up isotopes with isomers** or with other words ending in "-topes".
- **Saying carbon instead of carbon-12** for the standard in relative atomic mass.
- **Saying helium is unreactive because it has 8 outer electrons.** It has 2, and that is a full first shell.
- **Confusing the numbers on the Periodic Table.** The relative atomic mass (for example 24 for magnesium) is not the proton number (12).
- **Calling an alloy or air a compound.** Both are mixtures; an alloy's definition must include the word "mixture".
- **Rounding too early in A_r calculations**, or giving a whole number when one decimal place is asked for.

How to get the marks

- **Definitions are marked on key words.** Isotopes: "atoms", "same number of protons", "different numbers of neutrons" (two marks, so include all three ideas). Nucleon number: "protons **and** neutrons". Proton number: "protons in the nucleus".
- **"Deduce the number of protons, neutrons and electrons"** needs three numbers, one per line. Tables are marked row by row or even cell by cell, so check each one.
- **Symbols must be exact.** Write the mass number top left, the proton number bottom left and the charge top right (as $2+$ or $2-$), and make two-letter symbols clear: Cl, not CL.
- **Configurations** are written with commas (2,8,1). In a diagram, the right number of electrons on each ring earns the mark; for an ion, add the charge.
- **"Explain" questions about groups, periods and reactivity** need the link to electrons: "five outer-shell electrons", "three occupied shells", "a full outer shell".
- **Extended: "Explain why isotopes have the same chemical properties"** needs "same number of electrons" or "same electronic configuration". "Same number of protons" alone does not score.

- **Extended: relative atomic mass calculations** earn a method mark for the sum of mass × abundance over 100, then the answer mark for the value to the stated number of decimal places.
- **"State"** needs a short answer (a word, a number, a symbol). **"Deduce"** means work it out from the information given. **"Describe"** means say what something is like, for example where each particle is.
- **Multiple-choice questions** often hinge on one detail: "atom" versus "ion", "number of" versus "mass", or both columns of a table row. Check every part of each option.

Quick check

1. Classify each substance as an element, a compound or a mixture: nitrogen, water, brass, ethanol, air.
2. State the numbers of protons, neutrons and electrons in $^{56}_{26}\mathrm{Fe}^{3+}$.
3. Write the electronic configurations of an aluminium atom and an aluminium ion, Al^{3+}, and state the group and period of aluminium.
4. A particle has 17 protons, 18 neutrons and 18 electrons. Write its symbol, with its mass number, proton number and charge.
5. **Extended.** A sample of silicon is 92% silicon-28, 5% silicon-29 and 3% silicon-30. Calculate the relative atomic mass of silicon to one decimal place.

Answers

1. Nitrogen: **element**. Water: **compound**. Brass: **mixture** (an alloy). Ethanol: **compound**. Air: **mixture**.
2. **26 protons**; $56 - 26 =$ **30 neutrons**; $26 - 3 =$ **23 electrons**.
3. Al has 13 electrons: **2,8,3**. Al^{3+} has $13 - 3 = 10$: **2,8**. Aluminium is in **Group III** (3 outer electrons) and **Period 3** (3 shells).
4. 17 protons is chlorine; mass number $17 + 18 = 35$; charge $17 - 18 = -1$. The particle is $^{35}_{17}\mathrm{Cl}^{-}$.
5. $A_r = \dfrac{28 \times 92 + 29 \times 5 + 30 \times 3}{100} = \dfrac{2576 + 145 + 90}{100} = \dfrac{2811}{100} = 28.11$, which is **28.1** to one decimal place.

Past questions to try

- **0620/41/O/N/24 Q2**: nucleon number, periods, configurations, a particle table and an A_r from a ratio.
- **0620/43/O/N/23 Q2**: atoms, anions and cations from a table, with configuration, group and period.
- **0620/41/M/J/25 Q2**: particle charges and masses, isotopes, A_r and matching configurations.
- **0620/42/F/M/21 Q1**: particles A to I: ions, noble gases, isotopes and the carbon-12 standard.