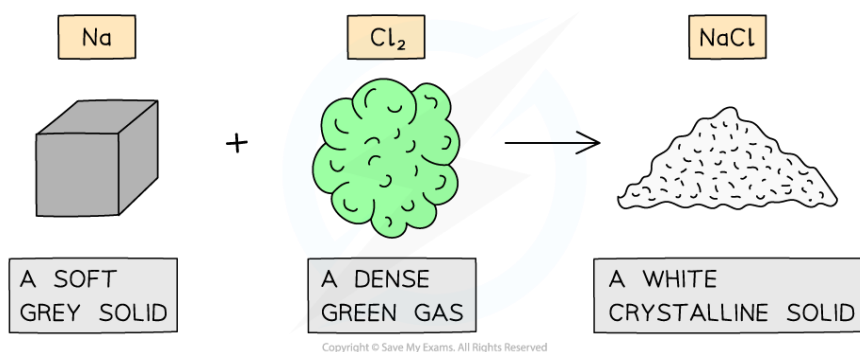


Elements & Compounds

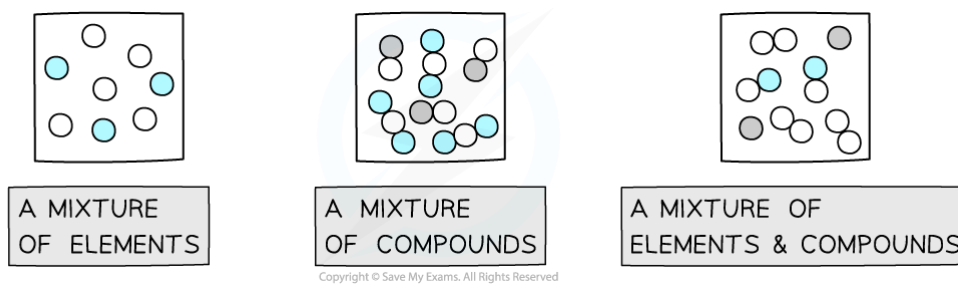
- Elements are substances made from one kind of atom
- Compounds are made from two or more elements chemically combined
- Elements take part in chemical reactions in which new substances are made in processes that most often involve an energy change
- In these reactions, atoms combine together in fixed ratios that will give them full outer shells of electrons, producing compounds
- The properties of compounds can be quite different from the elements that form them



The properties of sodium chloride are quite different from sodium and chlorine

Mixtures

- In a mixture, elements and compounds are interspersed with each other, but are not chemically combined
- This means the components of a mixture retain the same characteristic properties as when they are in their pure form
- So, for example, the gases nitrogen and oxygen when mixed in air, retain the same characteristic properties as they would have if they were separate
- Substances will burn in air because the oxygen present in the air supports combustion



Mixtures at the molecular level

Homogeneous or heterogeneous

- A homogeneous mixture has uniform composition and properties throughout
- A heterogeneous mixture has non-uniform composition, so its properties are not the same throughout
- It is often possible to see the separate components in a heterogeneous mixture, but not in a homogeneous mixture

Types of Mixtures

Mixture	Homogeneous or heterogeneous
Air	Homogeneous
Bronze (an alloy)	Homogeneous
Concrete	Heterogeneous
Orange juice with pulp	Heterogeneous

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Separating Mixtures

- The components retain their individual properties in a mixture and we can often separate them relatively easily. The technique we choose to achieve this will take advantage of a suitable difference in the physical properties of the components

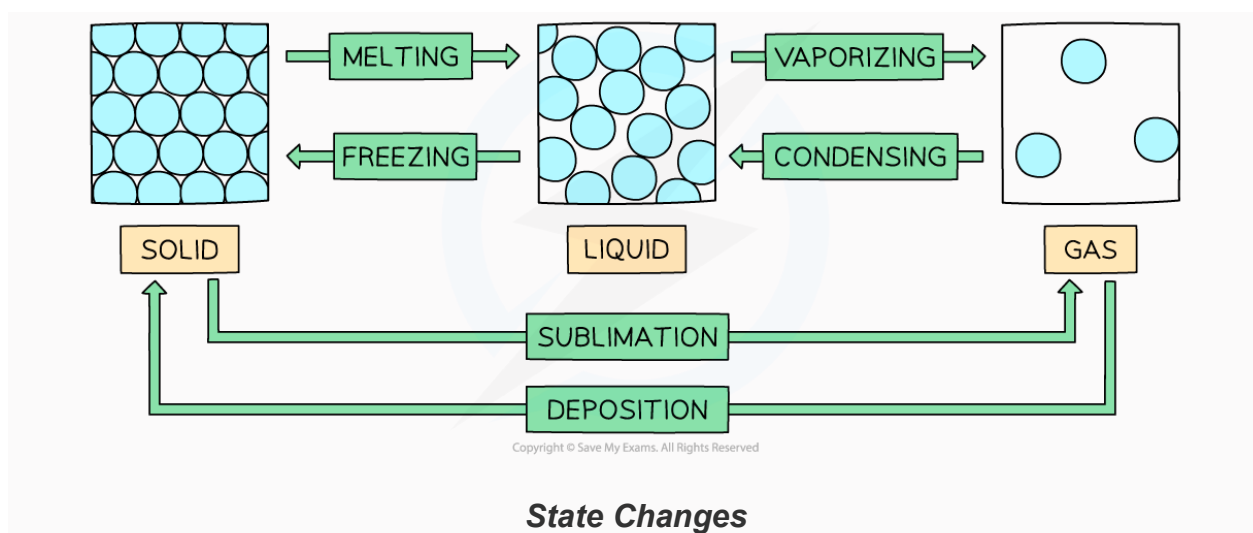
Mixtures & Separation Techniques

Mixture	What technique can be used to separate the components	The property that is different in the components
Air	Fractional distillation (of liquid air)	Boiling points
Salt and sand	Solution and filtration	Solubility in water
Pigments in food colours	Paper chromatography	Adsorption (on cellulose)
Sulfur and iron	Use a magnet	Magnetism

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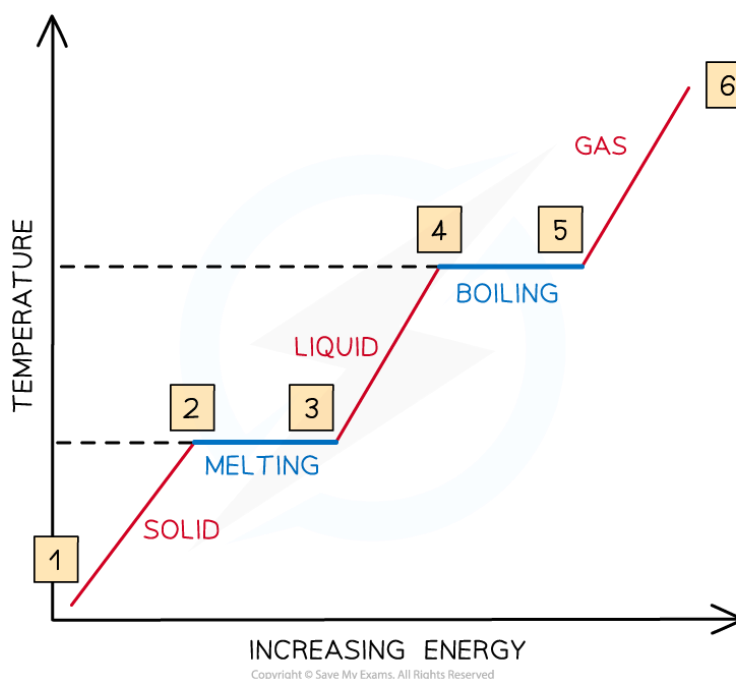
State Changes

- Changes of state are physical changes that are reversible
- These changes do not change the chemical properties or chemical makeup of the substances involved
- Vaporisation includes evaporation and boiling
- Evaporation involves the change of liquid to gas, but unlike boiling, evaporation occurs only at the surface and takes place at temperatures below the boiling point
- Boiling occurs at a specific temperature and takes place when the vapour pressure reaches the external atmospheric pressure



- The relationship between temperature and energy during state changes can be represented graphically

The relationship between temperature and energy during state changes



- Between 1 & 2, the particles are vibrating and gaining kinetic energy and the temperature rises
- Between 2 & 3, all the energy goes into breaking bonds – there is no increase in kinetic energy or temperature
- Between 3 & 4, the particles are moving around and gaining in kinetic energy
- Between 4 & 5, the substance is boiling, so bonds are breaking and there is no increase in kinetic energy or temperature
- From 5 & 6, the particles are moving around rapidly and increasing in kinetic energy

Exam Tip

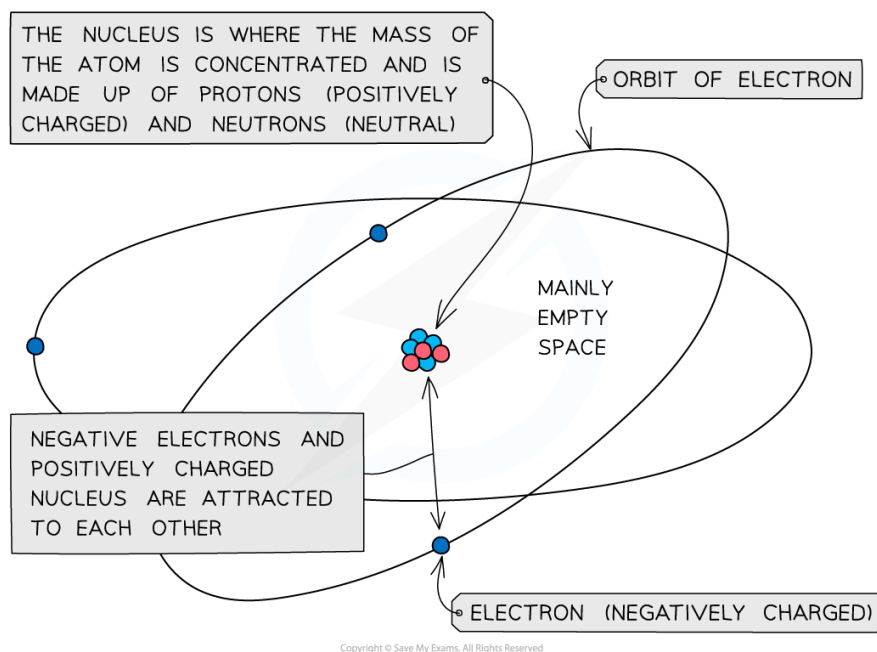
Be careful to match the bond breaking or bond making processes to the flow of energy during state changes.

Remember: To break bonds, energy is always needed to overcome the forces of attraction between the particles

Mass & Charge Distribution

- The mass of an atom is concentrated in the nucleus, because the nucleus contains the heaviest subatomic particles (the neutrons and protons)

- The mass of the electron is negligible
- The nucleus is also positively charged due to the protons
- Electrons orbit the nucleus of the atom, contributing very little to its overall mass, but creating a 'cloud' of negative charge
- The electrostatic attraction between the positive nucleus and negatively charged electrons orbiting around it is what holds an atom together



The mass of the atom is concentrated in the positively charged nucleus which is attracted to the negatively charged electrons orbiting around it

Types of Subatomic Particles

- The protons, neutrons and electrons that an atom is made up of are called subatomic particles
- These subatomic particles are so small that it is not practical to measure their masses and charges using conventional units (such as grams or coulombs)
- Instead, their masses and charges are compared to each other, and so are called 'relative atomic masses' and 'relative atomic charges'
- These are not actual charges and masses, but rather charges and masses of particles relative to each other
 - Protons and neutrons have a very similar mass, so each is assigned a relative mass of 1
 - Electrons are 1836 times smaller than a proton and neutron, and so their mass is often described as being negligible
- The relative mass and charge of the subatomic particles are:

Relative Mass & Charge of Subatomic Particles Table

Subatomic Particle	Relative Charge	Relative Mass
Proton	+1	1
Neutron	0	1
Electron	-1	$\frac{1}{1836}$

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Exam Tip

You can see from the table how the relative mass of an electron is almost negligible. The charge of a single electron is $-1.602189 \times 10^{-19}$ coulombs, whereas the charge of a proton is $+1.602189 \times 10^{-19}$ coulombs. However, relative to each other, their charges are -1 and +1 respectively. This information can also be found in the IB Data Booklet.

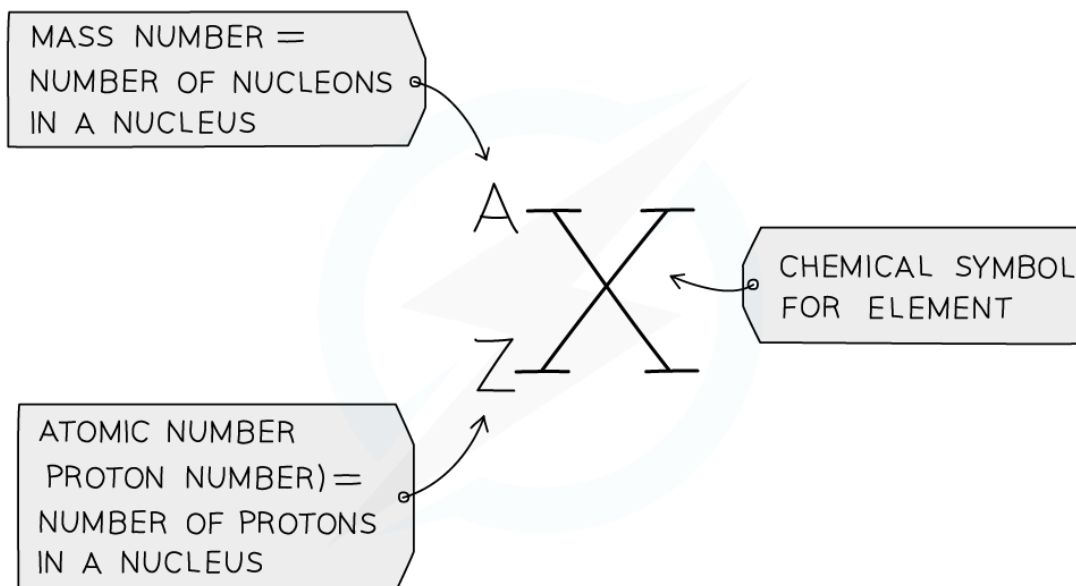
Atoms: Key Terms

- The atomic number (or proton number) is the number of protons in the nucleus of an atom and has the symbol Z
 - The atomic number is also equal to the number of electrons that are present in a neutral atom of an element
 - E.g. the atomic number of lithium is 3, meaning that a neutral lithium atom has 3 protons and, therefore, also has 3 electrons
- The mass number (or nucleon number) is the total number of protons + neutrons in the nucleus of an atom, and has the symbol A
- The number of neutrons can be calculated by:

$$\text{Number of neutrons} = \text{mass number} - \text{atomic number}$$

- Protons and neutrons are also called nucleons, because they are found in the nucleus

Exam Tip

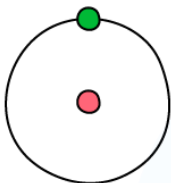
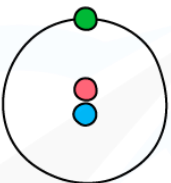
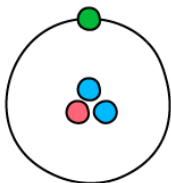
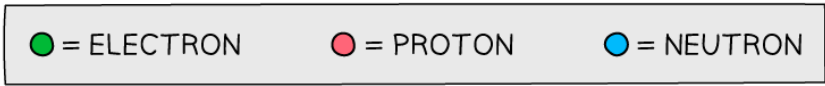


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The mass (nucleon) and atomic (proton) number are given for each element in the Periodic Table

Isotopes: Basics

- Isotopes are atoms of the same element that contain the same number of protons and electrons but a different number of neutrons
- The way to represent an isotope is to write the chemical symbol (or the word) followed by a dash and then the mass number
 - E.g. carbon-12 and carbon-14 are isotopes of carbon containing 6 and 8 neutrons respectively
 - These isotopes could also be written as ^{12}C or C-12, and ^{14}C or C-14 respectively

	PROTIUM	DEUTERIUM	TRITIUM
			
PROTONS	1	1	1
NEUTRONS	0	1	2
ISOTOPIC SYMBOL	${}^1_1\text{H}$	${}^2_1\text{H}$	${}^3_1\text{H}$
			

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The atomic structure and symbols of the three isotopes of hydrogen

Determining the Subatomic Structure of Atoms & Ions

- An atom is neutral and has no overall charge
- Ions on the other hand have either gained or lost electrons causing them to become charged
- The number of subatomic particles in atoms and ions can be determined given their atomic (proton) number, mass (nucleon) number and charge

Protons

- The atomic number of an atom and ion determines which element it is
- Therefore, all atoms and ions of the same element have the same number of protons (atomic number) in the nucleus
 - E.g. lithium has an atomic number of 3 (three protons) whereas beryllium has atomic number of 4 (4 protons)
- The number of protons equals the atomic (proton) number
- The number of protons of an unknown element can be calculated by using its mass number and number of neutrons:

$$\text{Mass number} = \text{number of protons} + \text{number of neutrons}$$

$$\text{Number of protons} = \text{mass number} - \text{number of neutrons}$$

Worked example

Determine the number of protons of the following ions and atoms:

1. Mg^{2+} ion
2. Carbon atom
3. An unknown atom of element X with mass number 63 and 34 neutrons

Answer:

Answer 1: The atomic number of a magnesium atom is 12 suggesting that the number of protons in the magnesium element is 12

- Therefore the number of protons in a Mg^{2+} ion is also 12 - the number of protons does not change when an ion is formed

Answer 2: The atomic number of a carbon atom is 6 suggesting that a carbon atom has 6 protons in its nucleus

Answer 3: *Use the formula to calculate the number of protons*

$$\text{Number of protons} = \text{mass number} - \text{number of neutrons}$$

$$\text{Number of protons} = 63 - 34$$

$$\text{Number of protons} = 29$$

- Element X is therefore copper

Electrons

- An atom is neutral and therefore has the same number of protons and electrons
- Ions have a different number of electrons to the number of protons, depending on their charge
 - A positively charged ion has lost electrons and therefore has fewer electrons than protons
 - A negatively charged ion has gained electrons and therefore has more electrons than protons

Worked example

Determine the number of electrons of the following ions and atoms:

1. Mg^{2+} ion
2. Carbon atom
3. An unknown atom of element X with mass number 63 and 34 neutrons

Answer:

Answer 1: The atomic number of a magnesium atom is 12 suggesting that the number of protons in the neutral magnesium atom is 12

- However, the 2+ charge in Mg^{2+} ion suggests it has lost two electrons
- It only has 10 electrons left now

Answer 2: The atomic number of a carbon atom is 6 suggesting that the neutral carbon atom has 6 electrons orbiting around the nucleus

Answer 3: The number of protons of element X can be calculated by:

$$\text{Number of protons} = \text{mass number} - \text{number of neutrons}$$

$$\text{Number of protons} = 63 - 34$$

$$\text{Number of protons} = 29$$

- The neutral atom of element X therefore also has 29 electrons

Neutrons

- The mass and atomic numbers can be used to find the number of neutrons in ions and atoms:

$$\text{Number of neutrons} = \text{mass number (A)} - \text{number of protons (Z)}$$

Worked example

Determine the number of neutrons of the following ions and atoms:

1. Mg^{2+} ion
2. Carbon atom
3. An unknown atom of element X with mass number 63 and 29 protons

Answer:

Answer 1: The atomic number of a magnesium atom is 12 and its mass number is 24

$$\text{Number of neutrons} = \text{mass number (A)} - \text{number of protons (Z)}$$

$$\text{Number of neutrons} = 24 - 12$$

$$\text{Number of neutrons} = 12$$

- The Mg^{2+} ion has 12 neutrons in its nucleus

Answer 2: The atomic number of a carbon atom is 6 and its mass number is 12

$$\text{Number of neutrons} = \text{mass number (A)} - \text{number of protons (Z)}$$

$$\text{Number of neutrons} = 12 - 6$$

$$\text{Number of neutrons} = 6$$

- The carbon atom has 6 neutrons in its nucleus

Answer 3: The atomic number of an element X atom is 29 and its mass number is 63

$$\text{Number of neutrons} = \text{mass number (A)} - \text{number of protons (Z)}$$

$$\text{Number of neutrons} = 63 - 29$$

$$\text{Number of neutrons} = 34$$

- The neutral atom of element X has 34 neutrons in its nucleus

Relative Atomic Mass Calculations

- Isotopes are different atoms of the same element that contain the same number of protons and electrons but a different number of neutrons
 - These are atoms of the same elements but with different mass numbers
- Because of this, the mass of an element is given as relative atomic mass (A_r) by using the average mass of all of the isotopes
- The relative atomic mass of an element can be calculated by using the percentage abundance values
 - The percentage abundance of an isotope is either given or can be read off the mass spectrum
 - Firstly, find the mass of 100 atoms by multiplying the percentage abundance by the mass of each isotope
 - Secondly, divide by 100 to find the average atomic mass
 - For example, if you have two isotopes A and B:

$$\text{total mass of 100 atoms} = (\% \text{ abundance}_A \times \text{mass}_A) + (\% \text{ abundance}_B \times \text{mass}_B)$$

$$\text{mass of 1 atom} = \frac{\text{total mass}}{100}$$

Worked example

A sample of oxygen contains the following isotopes

Isotope	Percentage abundance
^{16}O	99.76
^{17}O	0.04
^{18}O	0.20

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What is the relative atomic mass of oxygen to 2 dp?

- A 16.00
- B 17.18
- C 16.09
- D 17.00

Answer:

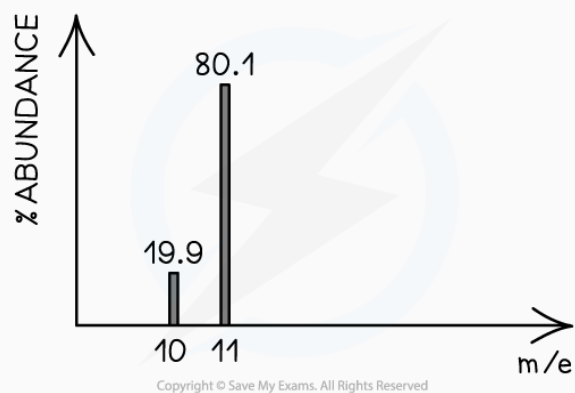
The correct answer is A

- Total mass of 100 atoms = $(99.76 \times 16) + (0.04 \times 17) + (0.20 \times 18) = 1600.44$
- Mass of 1 atom = $1600.44 \div 100 = 16.0044 = 16.00$ (2 dp)

- Here is another example, but this time using a mass spectrum to obtain the information:

Worked example

Calculate the relative atomic mass of boron using its mass spectrum, to 2 dp:



Answer:

- Total mass of 100 atoms = $(19.9 \times 10) + (80.1 \times 11) = 1080.1$
- Mass of 1 atom = $1080.1 \div 100 = 10.801 = 10.80$ (2 dp)