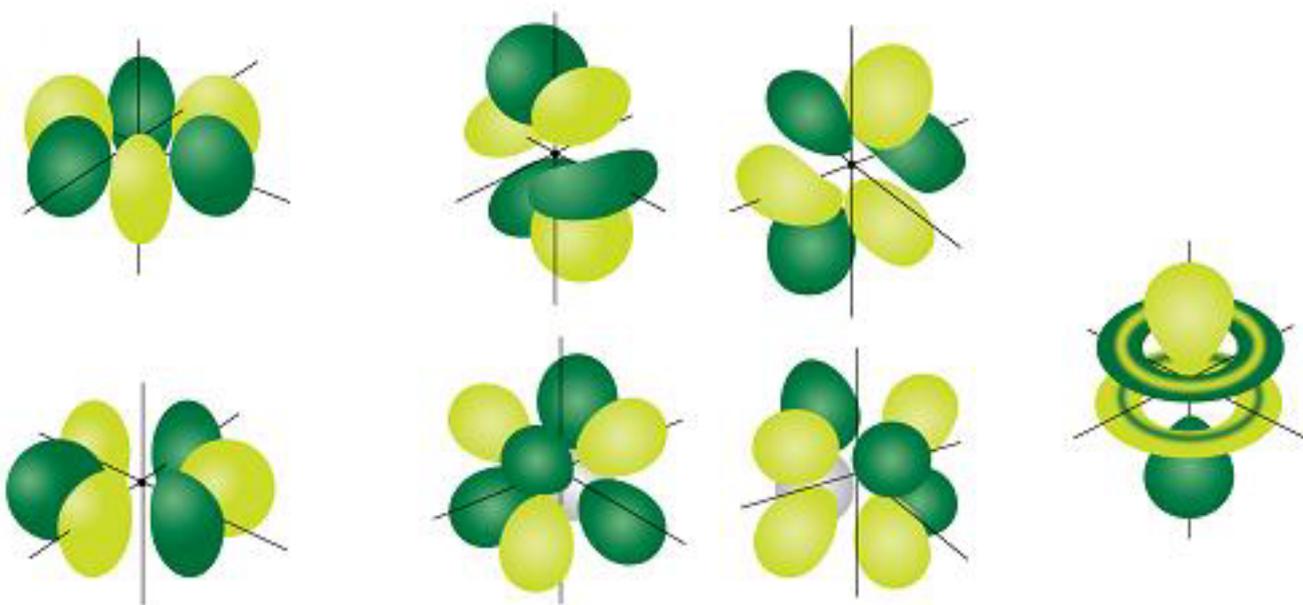


THE STRUCTURE OF ATOMS



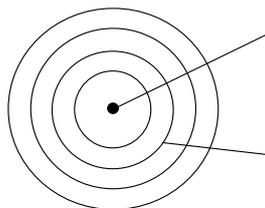
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SECTION 1 – Basics from GCSE

Atoms consist of a central containing protons and The nucleus is compared to the size of the whole atom. The nucleus is surrounded by in energy levels (also called). Atoms have no electric charge because they contain the same number of protons and

sub-atomic particle	relative mass	relative charge
proton		
neutron		
electron		



Atomic number = number of

Mass number = number of + number of

The number of protons, neutrons and electrons in an atom can be worked out using the atomic number and mass number.

Number of protons =

Number of neutrons =

Number of electrons =

Atoms can be represented as follows:

$\begin{matrix} \text{mass number} \\ \text{atomic number} \end{matrix} \text{Symbol}$ e.g. ${}_{9}^{19}\text{F}$ protons = neutrons = electrons =

Atoms of the same element have the same number of In fact, it is the number of that determines what type of atom it is (e.g. all atoms with 6 protons are carbon atoms). Atoms of different elements have different numbers of

Isotopes are atoms with the same number of but a different number of This means they are atoms of the same with the same number but a different number.

	${}_{17}^{35}\text{Cl}$	${}_{17}^{37}\text{Cl}$
protons		
neutrons		
electrons		

Ions are charged particles with an unequal number of and

Most ions have stable electron structures with the same electron structure as the elements in Group

Negative ions have electrons than protons.

Positive ions have electrons than protons.

TASK 1 – Atoms and ions

Species	Atom / ion	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
$^{14}_7\text{N}$	atom					
$^{31}_{15}\text{P}$	atom					
	atom	3	7			
	atom	10			10	
	atom		40	20		
	atom		40		22	
	atom			4	5	
	atom	82			126	
	atom	35			44	
	atom	35			46	
$^{23}_{11}\text{Na}^+$						
$^{16}_8\text{O}$						
$^{16}_8\text{O}^{2-}$						
		17	35			18
		19			20	19
		19			20	18
				20	20	18
		1			0	0
		53			74	54
			14		7	10

TASK 2 – Identify the particle

In each case identify the particle. The first one has been done for you.

1	An atom with 6 protons and the same number of neutrons as a ^{14}N atom	$^{13}_6\text{C}$
2	An atom with one more proton and the same number of neutrons than an atom of ^{39}K	
3	An atom with 10 protons and the same number of neutrons as an atom of ^{24}Mg	
4	An atom with one fewer proton and the same number of neutrons as an atom of ^{66}Zn	
5	An atom with the same number of protons and two more neutrons as an atom of ^{79}Br	
6	An atom with two fewer protons and the same number of neutrons as an atom of ^{50}Cr	
7	An ion with one more proton and two more neutrons as an atom of ^{20}Ne but the same number of electrons	
8	An ion with two fewer protons and two fewer neutrons as an atom of ^{40}Ar but the same number of electrons	
9	An ion with two more protons and two more neutrons as an atom of ^{60}Ni but the same number of electrons	
10	An ion with two more protons and three more neutrons as an atom of ^{20}Ne but the same number of electrons	
11	An ion with one fewer proton, one fewer neutron and the same number of electrons as an atom of ^{129}Xe .	
12	An ion with one more proton, two more neutrons, but the same number of electrons as an ion of $^{85}\text{Rb}^+$	
13	A particle with two fewer protons, two fewer neutrons and the same number of electrons as an atom of ^{20}Ne	
14	A particle with one fewer proton, two fewer neutrons and one more electron as a $^{48}\text{Tl}^{2+}$ ion	
15	A particle with one fewer proton, two more neutrons and the same number of electrons as a $^{127}\text{I}^-$ ion	

SECTION 2 – Development of atomic structure models

	Atoms	Plum-pudding model	Nuclear model		
lead scientist	John Dalton	JJ Thompson	Ernest Rutherford	Neils Bohr	James Chadwick
when	early 1800s	1897	1911	1913	1932
description of model					
what they discovered					
what they did					

SECTION 3 – Time of flight mass spectrometry

Mass spectrometry is a powerful instrumental method of analysis. It can be used to:

- find the abundance and mass of each isotope in an element allowing us to determine its relative atomic mass
- find the relative molecular mass of substances made of molecules.

A common form of mass spectrometry is time of flight (ToF) mass spectrometry. In this technique, particles of the substance are ionised to form 1+ ions which are accelerated so that they all have the same kinetic energy. The time taken to travel a fixed distance is then used to find the mass of each ion in the sample.

Stage 1 – Ionisation

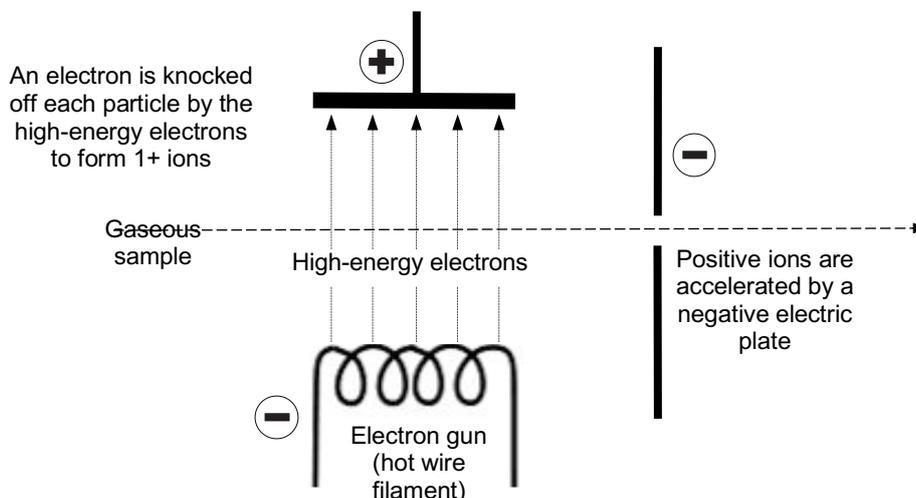
The sample can be ionised in a number of ways. Two of these techniques are electron impact and electrospray ionisation (which are simplified here for AS/A level).

a) Electron impact (also known as electron ionisation)

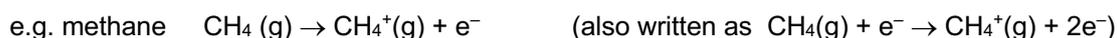
The sample being analysed is vaporised and then high energy electrons are fired at it. The high energy electrons come from an 'electron gun' which is a hot wire filament with a current running through it that emits electrons. This usually knocks off one electron from each particle forming a 1+ ion.



The 1+ ions are then attracted towards a negative electric plate where they are accelerated.



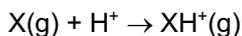
This technique is used for elements and substances with low formula mass (that can be inorganic or organic molecules). When molecules are ionised in this way, the 1+ ion formed is known as a molecular ion.



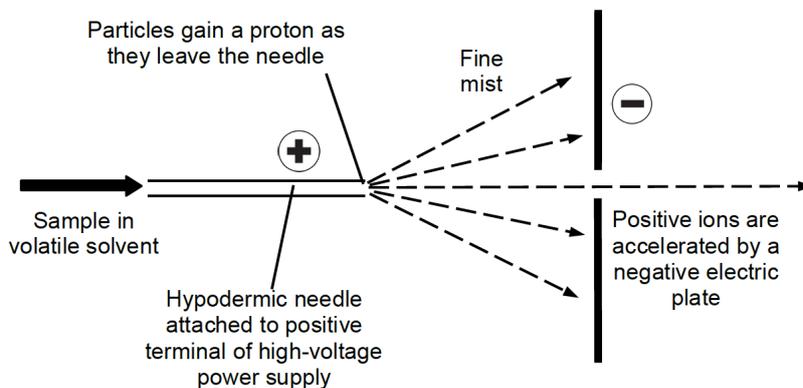
The molecular ion often breaks down into smaller fragments some of which are also detected in the mass spectrum. (Fragmentation of molecular ions is not included on the specification and is only included here as useful background information.)

b) Electrospray ionisation

The sample **X** is dissolved in a volatile solvent (eg water or methanol) and injected through a fine hypodermic needle to give a fine mist (aerosol). The tip of the needle is attached to the positive terminal of a high-voltage power supply. The particles are ionised by gaining a proton (ie an H^+ ion which is simply one proton) from the solvent as they leave the needle producing XH^+ ions (ions with a single positive charge and a mass of $M_r + 1$).



The solvent evaporates away while the XH^+ ions are attracted towards a negative plate where they are accelerated.



This technique is used for many substances with higher molecular mass including many biological molecules such as proteins. This is known as a 'soft' ionisation technique and fragmentation rarely takes place.

Stage 2 – Acceleration

The positive ions are accelerated using an electric field so that they all have the **same kinetic energy**.

$$KE = \frac{1}{2}mv^2$$

KE = kinetic energy of particle (J)
 m = mass of the particle (kg)
 v = velocity of the particle ($m\ s^{-1}$)

Therefore, the velocity of each particle is given by: $v = \sqrt{\frac{2KE}{m}}$

Given that all the particles have the same kinetic energy, the velocity of each particle depends on its mass. Lighter particles have a faster velocity, and heavier particles have a slower velocity.

Stage 3 – Flight tube

The positive ions travel through a hole in the negatively charged plate into a tube. The time of flight of each particle through this flight tube depends on its velocity which in turn depends on its mass.

The time of flight along the flight tube is given by the following expression:

$$t = \frac{d}{v}$$

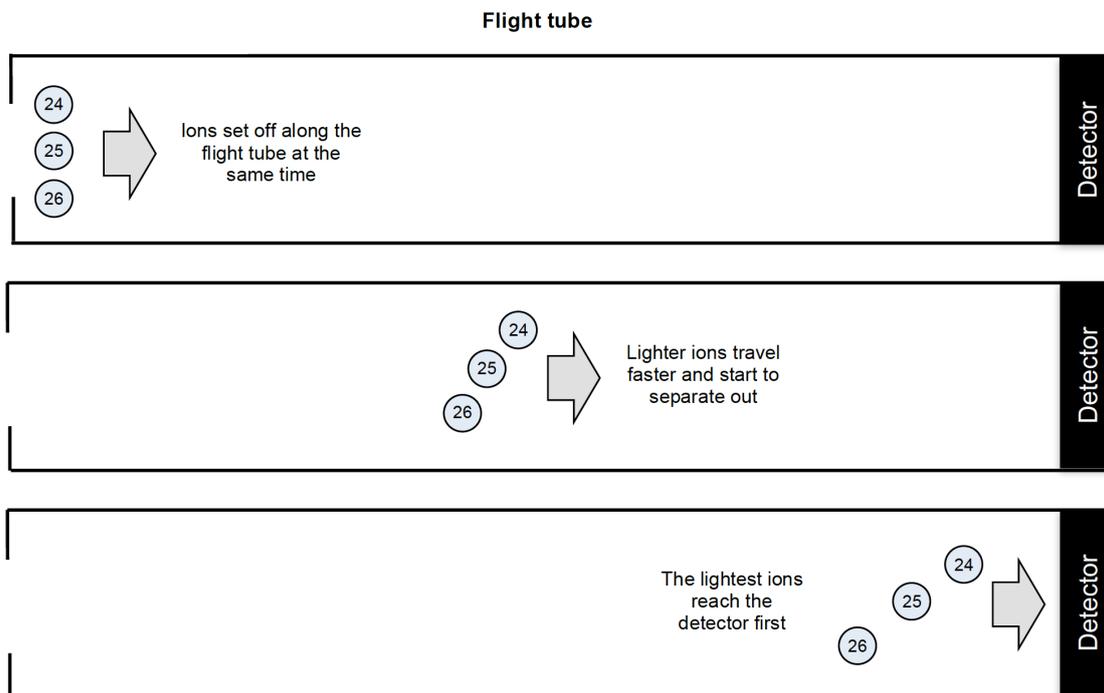
t = time of flight (s)
 d = length of flight tube (m)
 v = velocity of the particle ($m\ s^{-1}$)

$$t = d\sqrt{\frac{m}{2KE}}$$

m = mass of the particle (kg)
 KE = kinetic energy of particle (J)

This shows that the time of flight is proportional to the square root of the mass of the ions. Therefore lighter ions travel faster and reach the detector in less time than the heavier particles that move slower and take longer to reach the detector.

eg ions of the three isotopes of magnesium ($^{24}\text{Mg}^+$, $^{25}\text{Mg}^+$, $^{26}\text{Mg}^+$) will travel at different speeds through the flight tube and separate, with the lightest ion ($^{24}\text{Mg}^+$) reaching the detector first.



Stage 4 – Detection

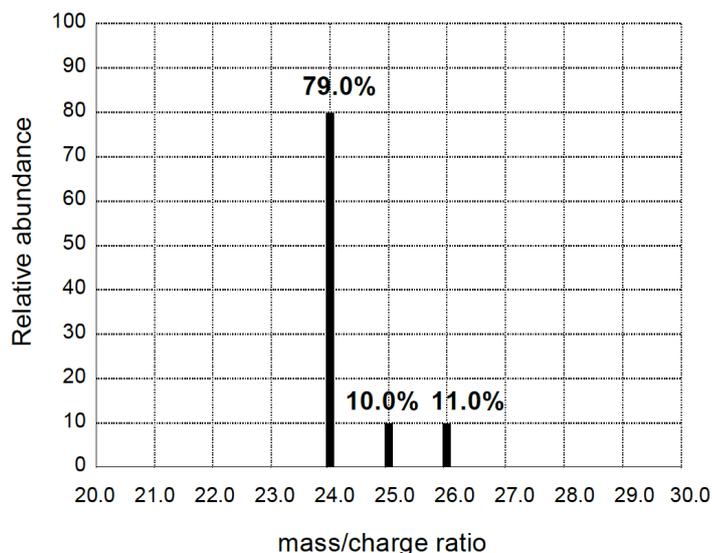
The positive ions hit a negatively charged electric plate. When they hit the detector plate, the positive ions are discharged by gaining electrons from the plate. This generates a movement of electrons and hence an electric current that is measured. The more ions that hit the plate the bigger the current and so the size of the current gives a measure of the number of ions hitting the plate.

The mass spectrum

A computer uses the data to produce a mass spectrum. This shows the mass to charge (m/z) ratio and abundance of each ion that reaches the detector. Given that all ions produced by electrospray ionisation and most of the ions by electron ionisation have a 1+ charge, the m/z is effectively the mass of each ion.

In this example, the mass spectrum of magnesium is shown. Ions with mass to charge ratio 24.0, 25.0 and 26.0 reach the detector. This shows that magnesium is made up of three isotopes: ^{24}Mg , ^{25}Mg and ^{26}Mg .

The relative atomic mass of an element can be found by calculating the mean mass of these isotopes.



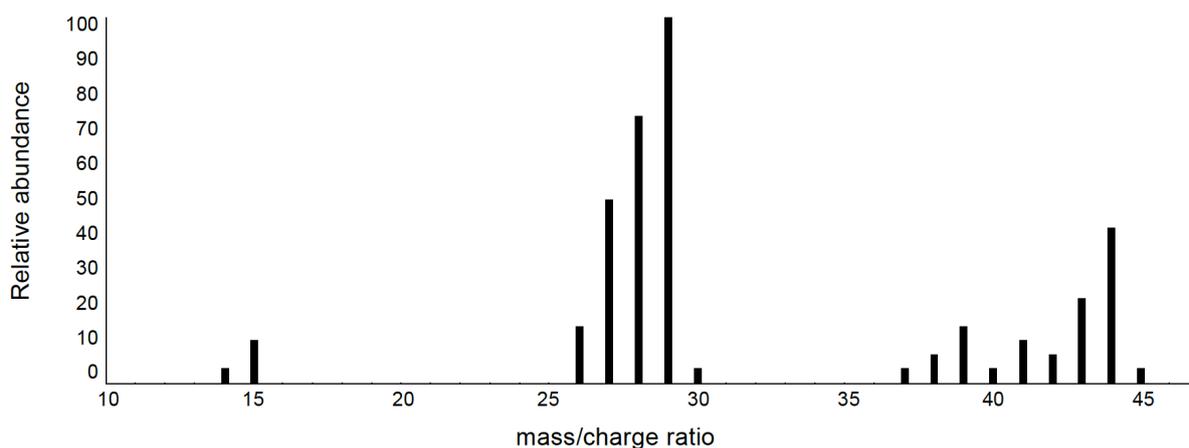
$$\text{relative atomic mass } (A_r) = \frac{\text{combined mass of all isotopes}}{\text{combined abundance of all isotopes}}$$

$$\text{e.g. for magnesium: } (A_r) = \frac{(79.0 \times 24.0) + (10.0 \times 25.0) + (11.0 \times 26.0)}{79.0 + 10.0 + 11.0} = 24.3$$

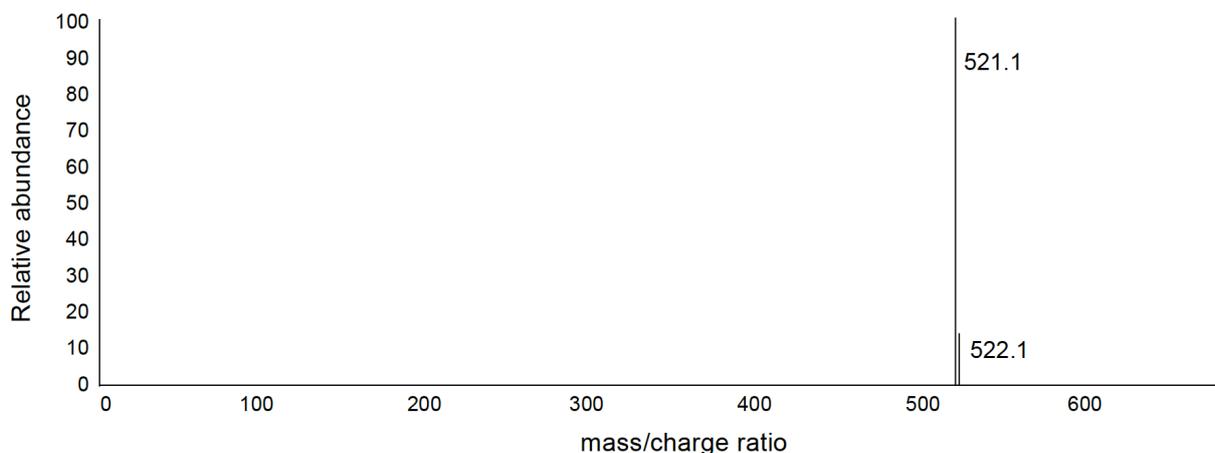
For molecules that are ionised by electron impact the signal with the greatest m/z value is from the molecular ion and its m/z value gives the relative molecular mass. However, there may be some other small peaks present around the molecular ion peak due to molecular ions that contain different isotopes.

When using electron impact ionisation (but not with electrospray ionisation), there may also be peaks at lower m/z values due to fragments caused by the break up of molecular ion. (Fragmentation of molecular ions is not included on the specification and is only included here as useful background information.)

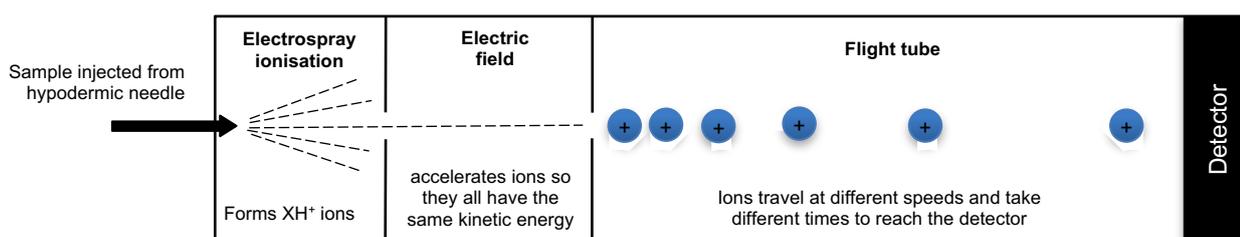
In the example below, the mass spectrum of propane has been produced following electron impact ionisation. The peak with the greatest m/z is at 44 (apart from a small signal at m/z 45 which is due to molecular ions of propane with one atom of ^2H or ^{13}C). This tells us that the relative molecular mass of propane is 44. Peaks at below m/z 44 are due to the fragmentation of molecular ions.



In this example, a protein has been analysed by time of flight spectrometry following electrospray ionisation using protonation. The peak at 521.1 is for MH^+ and so the relative molecular mass of the protein is 520.1. The peak at 522.1 is due to MH^+ ions containing one atom of ^{13}C or ^2H .



Summary



Stage	What happens
1 Ionisation	<p>Electron impact – used for elements and low M_r compounds</p> <ul style="list-style-type: none"> High energy electrons are fired at the sample from an electron gun This knocks off one electron from each atom/molecule to form 1+ ion: $X(g) \rightarrow X^+(g) + e^-$ <p>Electrospray ionisation – used for high M_r compounds (e.g. proteins)</p> <ul style="list-style-type: none"> the sample is dissolved in a volatile solvent (e.g. methanol, water) and injected through a fine hypodermic needle as a fine spray into a vacuum in the ionisation chamber a very high voltage is applied to the end of the needle where the spray emerges (the needle is positively charged) the particles gain a proton and become ions as a fine mist: $X(g) + H^+(g) \rightarrow XH^+(g)$ the solvent evaporates leaving 1+ ions
2 Acceleration of ions	<ul style="list-style-type: none"> the ions are accelerated using an electric field so that all the ions have the same kinetic energy (where kinetic energy = $\frac{1}{2}mv^2$)
3 Separation of charged ions	<ul style="list-style-type: none"> ion drift - the ions then enter the flight tube (length d) Ions with different masses (mass m) have a different time of flight the lighter ions travel faster and take less time to reach the detector where $t = d \sqrt{\frac{m}{2KE}}$
4 Detection	<ul style="list-style-type: none"> the detector is an negatively charged plate a current is produced when the ions hit the plate as electrons flow from the plate to the +ve ions the size of the current is proportional to the number of ions

TASK 3 – Relative atomic mass calculations

- Find the relative atomic mass of lithium using the data from mass spectrometry (give answer to 2 dp).
 ${}^6\text{Li}$ (7.4%) ${}^7\text{Li}$ (92.6%)
- The relative atomic mass of gallium is 69.72. It consists of two isotopes, ${}^{69}\text{Ga}$ and ${}^{71}\text{Ga}$. Find the percentage composition by mass of these two isotopes in gallium.
- The relative atomic mass of neon is 20.18. It consists of three isotopes, ${}^{20}\text{Ne}$, ${}^{21}\text{Ne}$ and ${}^{22}\text{Ne}$. It contains 90.5% ${}^{20}\text{Ne}$. Find the percentage composition by mass of the other two isotopes in neon.
- a) Calculate the relative atomic mass of lead given the mass spectroscopy data below. Give your answer to 2dp.

m/z	204	206	207	208
relative intensity	0.287	4.51	4.32	10.00

- Identify the species responsible for the peak at m/z 208.
 - Which ion will have the shortest time of flight and reach the detector fastest?
- Find the relative atomic mass of the following elements using the data from mass spectrometry (give answers to 2 dp).
 - gallium ${}^{69}\text{Ga}$ (1.00) ${}^{71}\text{Ga}$ (0.66)
 - iron ${}^{54}\text{Fe}$ (5.8%) ${}^{56}\text{Fe}$ (91.6%) ${}^{57}\text{Fe}$ (2.2%) ${}^{58}\text{Fe}$ (0.3%)

TASK 4a – ToF MS calculations

Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

$$\text{Kinetic energy} = \frac{mv^2}{2}$$

- 1 It takes the $^{12}_6\text{C}^+$ ion $1.23 \times 10^{-5} \text{ s}$ to travel along the flight tube in a time of flight mass spectrometer having been given $5.94 \times 10^{-17} \text{ J}$ of kinetic energy. Calculate the length of the flight tube.

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- 2 Find the time it takes the $^7_3\text{Li}^+$ ion to travel down a 78 cm time of flight tube given $1.52 \times 10^{-18} \text{ J}$ of kinetic energy.

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- 3 It takes the $^{81}_{35}\text{Br}^+$ ion $2.83 \times 10^{-5} \text{ s}$ to travel along the flight tube in a time of flight mass spectrometer. How long would it take the $^{79}_{35}\text{Br}^+$ ion to travel down the same flight tube under the same conditions?

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4 An ion takes 3.81×10^{-5} s to travel along the 85 cm flight tube in a time of flight mass spectrometer having been given 1.6×10^{-17} J of kinetic energy. Calculate the mass number of this ion.

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5 The relative atomic mass of lithium is 6.924. It consists of two isotopes, ${}^6_3\text{Li}$ and ${}^7_3\text{Li}$. Find the percentage composition by mass of ${}^6_3\text{Li}$ in lithium.

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6 The relative atomic mass of silicon is 28.109. It consists of three isotopes, ${}^{28}_{14}\text{Si}$, ${}^{29}_{14}\text{Si}$ and ${}^{30}_{14}\text{Si}$. It contains 92.2% ${}^{28}_{14}\text{Si}$. Find the percentage composition by mass of ${}^{29}_{14}\text{Si}$ in silicon.

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TASK 4b – ToF MS calculations

- 1) a) The mass of one mole of $^{18}\text{O}^+$ ions is 18.0 g. The Avogadro constant is $6.022 \times 10^{23} \text{ mol}^{-1}$. Find the mass of a single ion of $^{18}\text{O}^+$ in kg.
- b) Find the time it takes an ion of $^{18}\text{O}^+$ to travel along a flight tube of 75.0 cm length if given $2.50 \times 10^{-15} \text{ J}$ of energy.
- 2) a) Calculate the relative atomic mass of chromium given the mass spectroscopy data below.

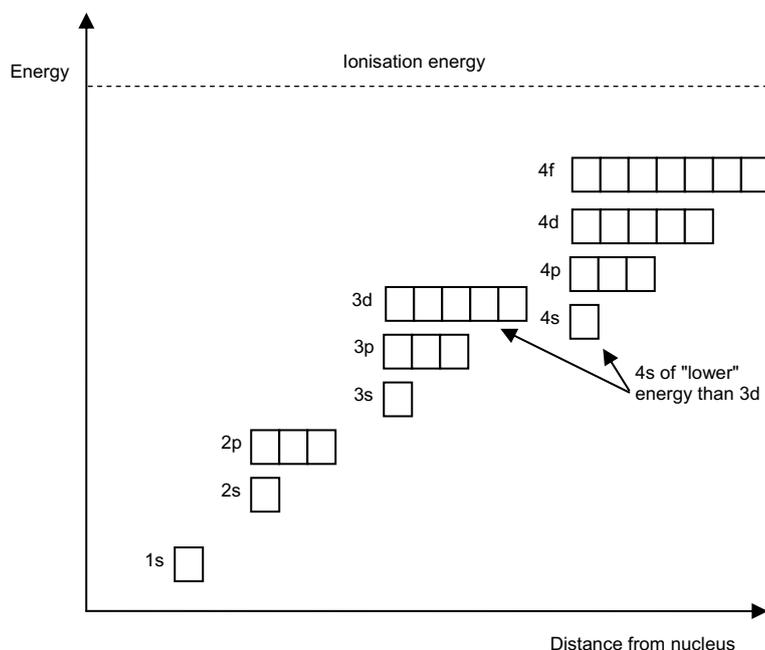
m/z	50	52	53	54
relative abundance (%)	4.3	83.8	9.5	2.4

- b) Identify the species responsible for the peak at m/z 52.
- c) Which ion will have the shortest time of flight and reach the detector fastest?
- d) The time of flight of a $^{54}\text{Cr}^+$ ion is $1.486 \times 10^{-5} \text{ s}$. Calculate the time of flight of a $^{50}\text{Cr}^+$ ion. Give your answer to the appropriate number of significant figures.
- 3) It takes an ion $2.34 \times 10^{-6} \text{ s}$ to travel along a flight tube of length 50 cm having been given $8.35 \times 10^{-16} \text{ J}$ of kinetic energy. Find the mass number of this ion.
- 4) The mass spectrum of butanone shows its main peak at m/z 72. It also has a small signal at m/z 73.
- a) Which ionisation technique is likely to have been used?
- b) What is the relative formula mass of this compound?
- c) Give two reasons for the peak at m/z 73.
- d) There would also be tiny peaks at m/z 74, 75, etc. Explain why some ions with these m/z values may be formed but why their signals may be too small to be seen.
- 5) The mass spectrum of chloromethane (CH_3Cl) shows two main peaks at m/z 50 and m/z 52. (the main two isotopes of chlorine are ^{35}Cl and ^{37}Cl in the ratio 3:1)
- a) Explain why these two peaks are produced.
- b) Predict the relative intensity of these two signals. Explain your answer.
- 6) The element bromine is made of diatomic molecules. There are two isotopes of bromine, namely ^{79}Br and ^{81}Br of roughly equal abundance. Sketch what the time of flight mass spectrum of the element bromine will look like. (the main two isotopes of bromine are ^{79}Br and ^{81}Br in the ratio 1:1)
- 7) Calculate the relative atomic mass of krypton given the mass spectroscopy data below.

m/z	78	80	82	83	84	86
relative abundance (%)	0.3	2.3	11.6	11.5	56.9	17.4

SECTION 4 – Electron structure

- Electrons are arranged in electron shells (energy levels), which themselves have sub-shells (sub-levels). The diagram below represents the first four main shells of electrons (the exact energies and distance from the nucleus vary and are simplified).



- Each sub-level consists of electron orbitals (region of space in which the electron spends most of its time).
- Each orbital can hold 2 electrons with opposite spins (one electron spins clockwise and one anticlockwise).
- Orbitals are regions of space that electrons are most likely to be in. The shapes of some orbitals are shown, but you do **not** have to be able to draw these shapes.

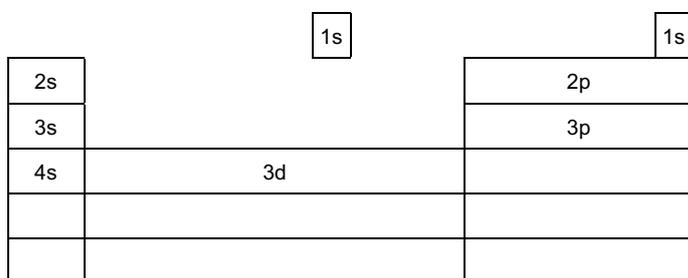
Sub-level	Number of orbitals in sub-level	Shape (no need to learn)	Maximum number of electrons in sub-level
s	1		2
p	3		6
d	5		10
f	7	Even more complicated (see front page)	14

- The way the electron orbitals are filled up:

1) Electrons enter the lowest energy orbital available (**Aufbau principle**).

This version of the Periodic Table helps you to work out the order in which the orbitals fill up

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p

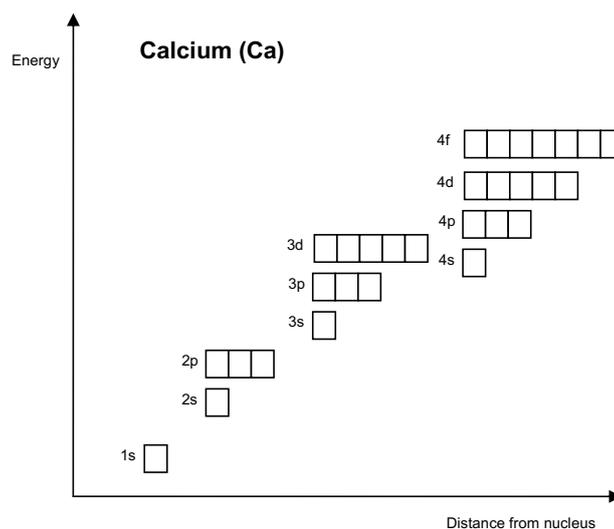
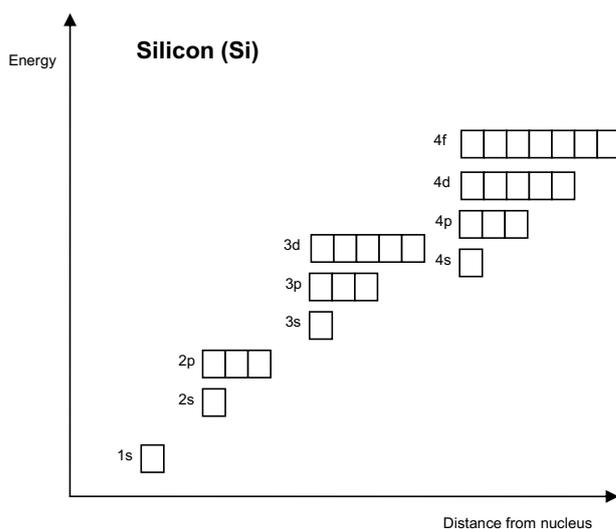


Remember that:

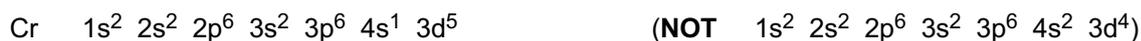
- 4s fills before 3d
- 4s also empties before 3d (in ions)

2) Electrons prefer to occupy orbitals on their own, and only pair up when no empty orbitals of the same energy are available (**Hund's Rule**).

Complete the diagrams below to show the electron structure of the atoms shown:



- In ions, the electrons in the highest energy levels are lost first, but note that when losing electrons, electrons are lost from 4s before 3d (the energy levels are very close, and when electrons fill them, 4s goes above 3d).
- Note these two exceptions to the expected pattern, both of which stem from the 4s and 3d levels being very close in energy:



This is a slightly lower energy arrangement as the reduced e⁻e⁻ repulsion makes up for the fact one electron is in a slightly higher energy level.



This is a slightly lower energy arrangement.

TASK 5 – Electron structure

	e ⁻ s	full structure	short structure	1s	2s	2p	3s	3p	4s	3d	4p
Li	3	1s ² 2s ¹	[He] 2s ¹	1↓	1	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
C				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
O				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
F				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Mg				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
S				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
K				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Ti				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Fe				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Cr				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Ni				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Cu				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Br				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Ca ²⁺				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
S ²⁻				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
V ³⁺				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Cu ²⁺				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Sc ³⁺				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □
Fe ³⁺				□	□	□ □ □	□	□ □ □	□	□ □ □ □ □	□ □ □

SECTION 5 – Evidence for electron structure

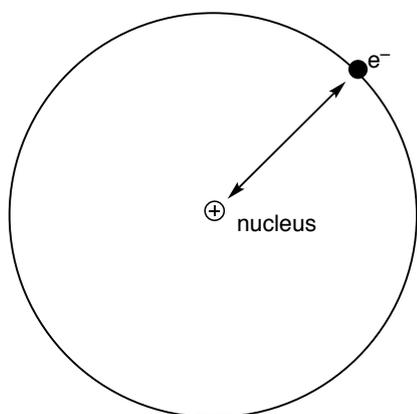
What is ionisation energy?

- Evidence for how the electrons are arranged in atoms comes from ionisation energies.
- 1st ionisation energy is the energy required to remove one electron from each atom in a mole of gaseous atoms producing one mole of 1+ gaseous ions.
- Note that 2nd ionisation energy is the energy required to remove the second electron (not both electrons).

e.g. 1st ionisation energy of Na:

2nd ionisation energy of Na:

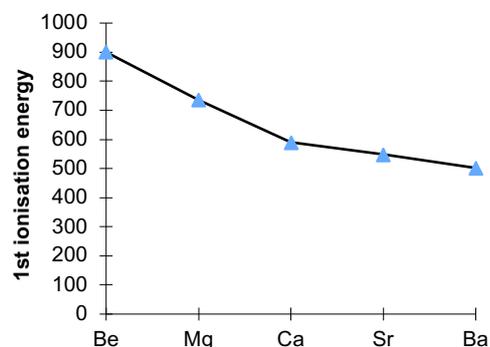
Factors affecting ionisation energy



Factor	Effect
1) Atomic radius	
2) Number of protons	
3) Shielding	shielding = repulsion by electrons in shells between the electron and the nucleus)

How and why ionisation varies:

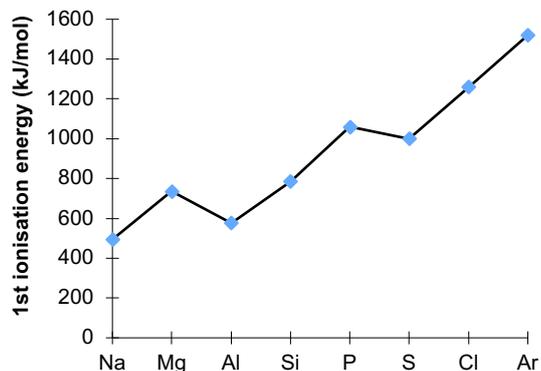
Down a group (e.g. Group 2)



Across a period (e.g. period 3)

General increase across period:

Group 2 to 3 dip:

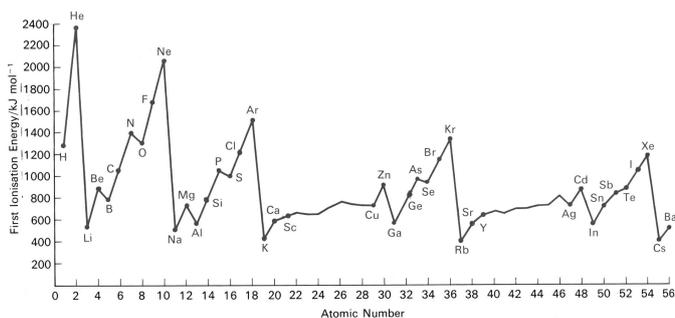


Group 5 to 6 dip:

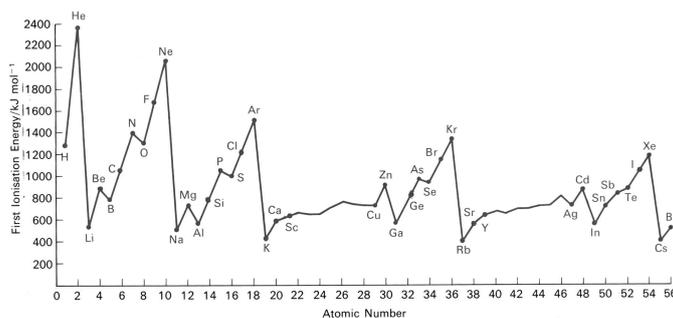
First ionisation energy (up to element 56)

highlight these trends

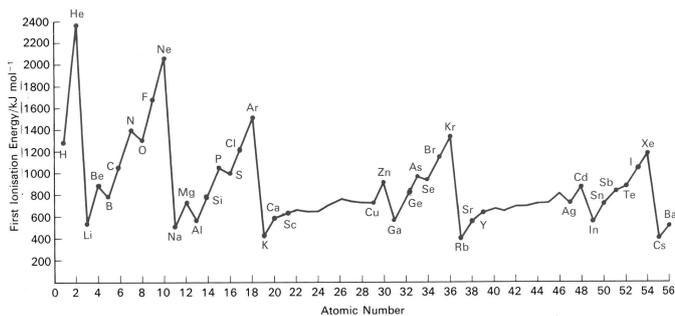
down group 1



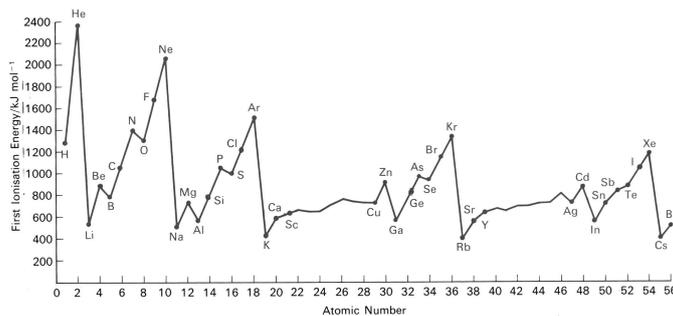
down group 0



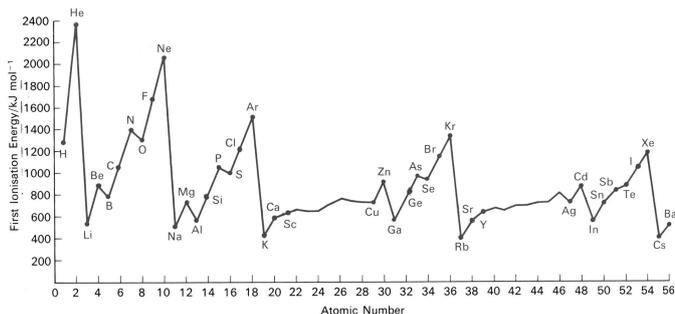
across period 2



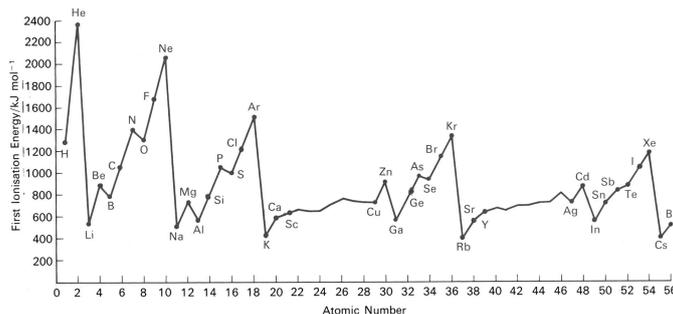
across period 3



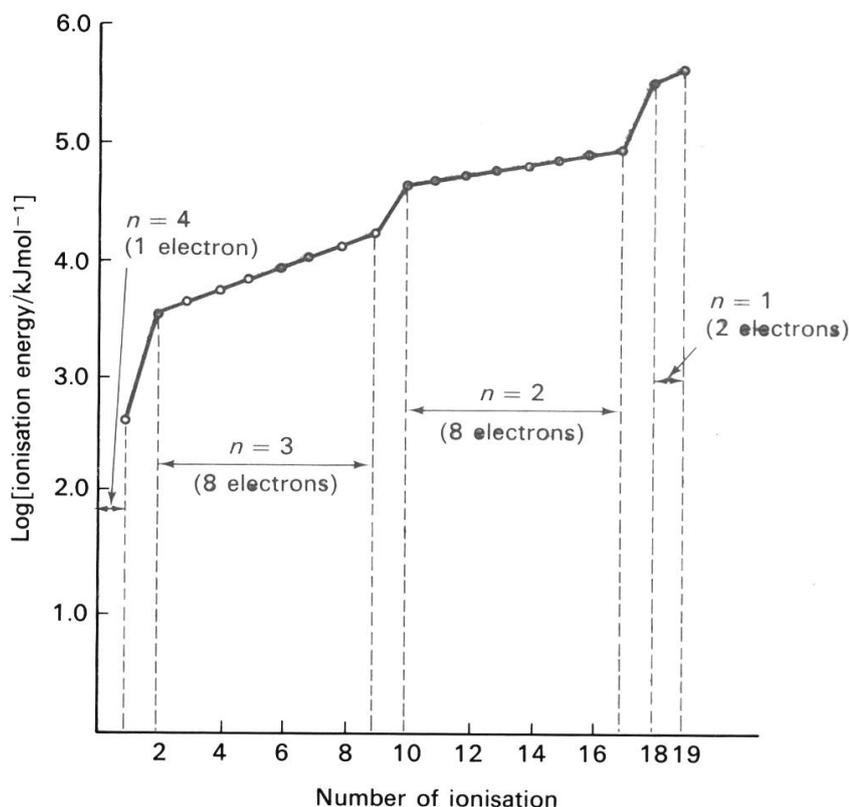
across period 4



end of a period



Successive ionisation energies



Logarithmic plot of successive ionisation energies (of potassium)

When an electron is taken from a different shell that is closer to the nucleus, there is a big jump in ionisation energy (as the electron is closer to the nucleus plus there is one fewer shell of shielding)

In this example, there is a big jump after the 1st IE suggesting the element is in Group 1.

As it is potassium with electron structure 2,8,8,1 in GCSE terms (or $1s^2 2s^2 2p^6 3s^3 3p^6 4s^1$ in A level terms), there are jumps after the

- 1st IE (shell 3 rather than 4)
- 9th IE (shell 2 rather than 3)
- 17th IE (shell 1 rather than 1)

TASK 6 – Successive ionisation energies

In each case identify which the element belongs to by studying values of successive ionisation energies. They are all elements in Groups 0-7 and none of them are transition metals, lanthanides or actinides.

	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	Group
1	736	1450	7740	10500	13600	18000	21700	25600	
2	1680	3370	6040	8410	11000	15100	17900	91600	
3	762	1540	3300	4390	8950	11900	14900	18200	
4	418	3070	4600	6480	8120	10700	12300	14600	
5	941	2080	3090	4140	7030	7870	16000	19500	
6	577	1820	2740	11600	14800	18400	23400	27500	
7	1310	3390	5320	7450	11000	13300	71000	84100	
8	590	1150	4940	6480	8120	10700	12300	14600	
9	1060	1900	2920	4960	6280	21200	25900	30500	
10	2080	3950	6150	9290	12100	15200	19500	23000	

TASK 7 – Which has the higher ionisation energy?

First ionisation energy

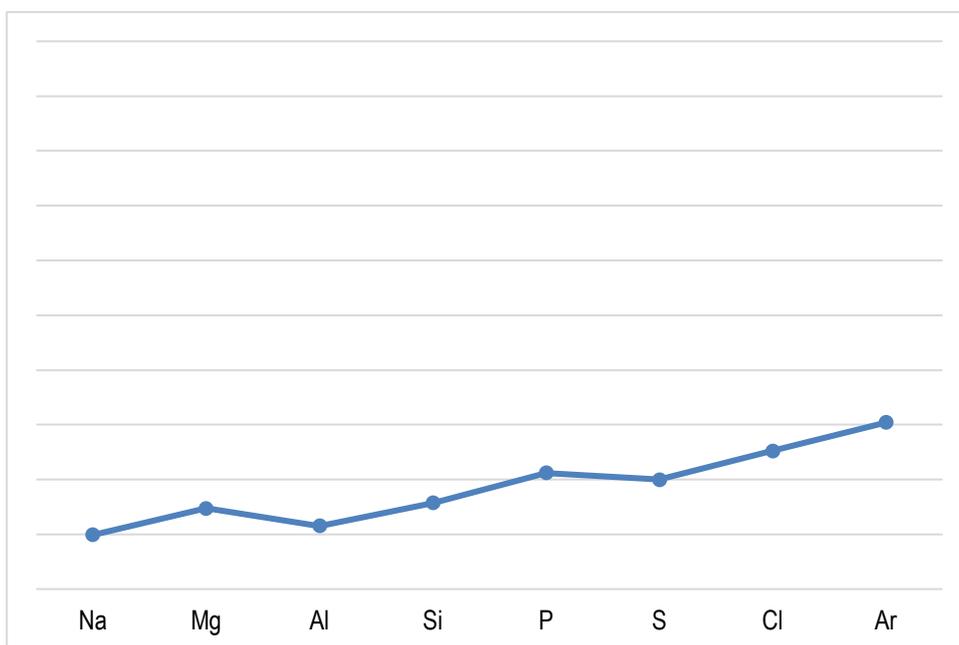
Circle the element with the higher first ionisation energy.

Give the electron structure of each atom. Use this to explain which has the higher first ionisation energy.

	circle the higher one	electron structure	explanation
1	argon v potassium	Ar K	
2	phosphorus v sulfur	P S	
3	magnesium v calcium	Mg Ca	
4	magnesium v aluminium	Mg Al	
5	oxygen v fluorine	O F	

Second ionisation energy

The diagram below shows the first ionisation energy for some elements. Sketch a line to show the second ionisation energy for these same elements.



Circle the element with the higher **second** ionisation energy and explain why it is higher.

Give the electron structure of each atom. Use this for your explanation.

	circle the higher one	electron structure	explanation
6	sodium v magnesium	Na ⁺ Mg ⁺	
7	neon v sodium	Ne ⁺ Na ⁺	
8	aluminium v silicon	Al ⁺ Si ⁺	