# Elements, isotopes and ionisation energies

## Objectives

**Must**

State that $^{12}C$ is used as the standard measurement of relative masses.

**Should**

Define terms relating to isotopic and atomic mass, molecular mass and formula mass.

**Could**

Use data such as relative abundances to calculate relative atomic mass.

# Definitions

**Relative isotopic mass** is the mass of an atom of a single isotope relative to 1/12$^{th}$ of a $^{12}C$ atom.

**Relative atomic mass** is the weighted mean mass of an atom of an element relative to 1/12$^{th}$ of a $^{12}C$ atom, taking into account isotopic abundances.

This is the figure usually quoted on a periodic table, and because it is an average it is often a decimal number. For example 35.5 for chlorine.

# Calculating $A_r$ from isotopic abundances

To have a correct value for the Ar we need to take into account the different isotopes that are present.

Isotopes are atoms with the same number of protons but different numbers of neutrons present in their nucleus.

## Worked example

Chlorine has 2 isotopes which occur naturally. These are $^{35}Cl$ and $^{37}Cl$.

The $A_r$ of chlorine is given on the periodic table as 35.5 – this is because 75% of the atoms that exist are the isotope $^{35}Cl$ and 25% of the atoms are $^{37}Cl$.

$$\left(\frac{75}{100} x35\right)+\left(\frac{25}{100} x37\right)=35.5$$

## Calculating $A_r$

1. Calculate the $A_r$ of naturally occurring neon if the composition is 90.9% neon 20, 0.3% neon 21 and 8.8% neon 22.

2. Calculate the $A_r$ of naturally occurring copper if the composition is 69% copper 63 and 31% copper 65

# Calculating $A_r$ - answers

1. Calculate the $A_r$ of naturally occurring neon if the composition is 90.9% neon 20, 0.3% neon 21 and 8.8% neon 22.

$$\left(\frac{90.9}{100}x20\right)+\left(\frac{0.3}{100}x21\right)+\left(\frac{8.8}{100}x22\right)=20.2$$

2. Calculate the $A_r$ of naturally occurring copper if the composition is 69% copper 63 and 31% copper 65

$$\left(\frac{69}{100}x63\right)+\left(\frac{31}{100}x65\right)=63.6$$

# AfL – using whiteboards

1. A sample of bromine contains 53.00% of bromine 79 and 47.00% of bromine 81. Calculate the relative atomic mass of bromine.

$$\left(\frac{53}{100}x\ 79\right)+\left(\frac{47}{100}x\ 81\right)=79.9$$

1 Europium, atomic number 63, is used in some television screens to highlight colours. A chemist analysed a sample of europium using mass spectrometry. The results are shown in **Table 1.1** below.

| isotope | relative isotopic mass | abundance (%) |
|---|---|---|
| $^{151}Eu$ | 151.0 | 47.77 |
| $^{153}Eu$ | 153.0 | 52.23 |

**Table 1.1**

**(a)** Define the term *relative isotopic mass*.

............................................................................................................................

............................................................................................................................

............................................................................................................................

...................................................................................................................... **[2]**

**(b)** Using **Table 1.1**, calculate the relative atomic mass of the europium sample.
Give your answer to **two** decimal places.

answer = .............................. **[2]**

**(c)** Isotopes of europium have differences and similarities.

**(i)** In terms of protons, neutrons and electrons, how is an atom of $^{151}Eu$ **different** from an atom of $^{153}Eu$?

..........................................................................................................................

.................................................................................................................. **[1]**

**(ii)** In terms of protons, neutrons and electrons, how is an atom of $^{151}Eu$ **similar** to an atom of $^{153}Eu$?

..........................................................................................................................

.................................................................................................................. **[1]**

# Mark Scheme

| | | | | | |
|---|---|---|---|---|---|
| 1 | (a) | | **Mass** of the **isotope** compared to 1/12th<br>**OR**<br>**mass** of the **atom** compared to 1/12th ✓<br><br>(the mass of a) carbon-12 **OR** $^{12}C$ (atom) ✓ | 2 | **IGNORE** Reference to average **OR** weighted mean<br>(i.e. correct definition of relative atomic mass will score both marks)<br><br>**ALLOW** mass of a **mole** of the isotope/atom with 1/12th the mass of a **mole OR** 12 **g** of carbon-12 for two marks.<br><br>**ALLOW 2 marks for:**<br>'**Mass** of the isotope **OR mass** of the atom compared to $^{12}C$ atom given a mass of 12.0'<br>i.e. 'given a mass of 12' **OR** C12 is 12 communicates the same idea as 1/12th.'<br><br>**ALLOW** 12C **OR** C12<br><br>**ALLOW 2 marks for:**<br>$\frac{\text{mass of the isotope}}{\text{mass of 1/12th mass of carbon-12}}$<br><br>i.e. fraction is equivalent to 'compared to'<br><br>**ALLOW 1 mark for** a mix of mass of atom and mass of mole of atoms, i.e. 'mass of the isotope/mass of an atom compared with 1/12th the mass of a **mole OR** 12 g of carbon-12.'<br><br>**DO NOT ALLOW** mass of 'ions' OR mass of element |
| | (b) | | $\frac{(151 \times 47.77) + (153 \times 52.23)}{100}$<br>**OR**<br>72.1327 + 79.9119<br>**OR**<br>152.0446 (calculator value) ✓<br>$A_r$ = 152.04 ✓ | 2 | **ALLOW** Correct answer for two marks<br><br>**ALLOW** One mark for ECF from transcription error in first sum provided final answer is to 2 decimal points and is to between 151 and 153 and is a correct calculation of the transcription |

# Mark scheme

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | (c) | (i) | $^{153}$Eu has (2) more neutrons<br>**OR**<br>$^{153}$Eu has 90 neutrons **AND** $^{151}$Eu has 88 neutrons ✓ | 1 | **ALLOW** There are a different number of neutrons<br>**IGNORE** Correct references to protons / electrons<br>**DO NOT ALLOW** Incorrect references to protons / electrons |
| | | (ii) | (It has the) same number of protons **AND** electrons<br>**OR**<br>Both have 63 protons and 63 electrons ✓ | 1 | **ALLOW** Same number of protons **AND** same electron configuration<br><br>**DO NOT ALLOW** 'Same number of protons' without reference to electrons (and vice versa) |

**1** Tin mining was common practice on Dartmoor in pre-Roman times. Most of the tin extracted was mixed with copper to produce bronze.

**(a)** The table below shows the sub-atomic particles of an isotope of tin.

| isotope | protons | neutrons | electrons |
|---|---|---|---|
| $^{118}$Sn | | | |

**(i)** Complete the table. **[1]**

**(ii)** In terms of sub-atomic particles, how would atoms of $^{120}$Sn differ from atoms of $^{118}$Sn?

.............................................................................................................................

........................................................................................................................ **[1]**

# Mark scheme

| | | | | | |
|---|---|---|---|---|---|
| 1 | a | i | $^{118}$Sn 50p 68n 50e Complete row ✓ | 1 | |
| | | ii | $^{120}_{50}$Sn has (two) more neutrons / 70 neutrons ✓<br>ora | 1 | **ALLOW** There is a different number of neutrons<br>**IGNORE** correct reference to protons / electrons<br>**DO NOT ALLOW** incorrect references to protons / electrons<br>**ALLOW** ECF for stated number of neutrons from **1a(i)** |

1 Sir Humphrey Davy, the inventor of the miners' safety lamp, was the first person to isolate the element strontium. Robert Bunsen, the inventor of the Bunsen burner, was partly responsible for the discovery of the element rubidium. Rubidium and strontium occur next to each other in the Periodic Table.

A sample of rubidium was analysed and found to consist of two isotopes, rubidium-85 and rubidium-87. Information about these isotopes is given in the table.

| isotope | relative isotopic mass | abundance (%) |
|---|---|---|
| rubidium-85 | 85.00 | 72.15 |
| rubidium-87 | 87.00 | 27.85 |

(a) In terms of sub-atomic particles, what is the difference between these isotopes of rubidium?

.......................................................................................................................................

.............................................................................................................................. [1]

(b) Define the term *relative atomic mass*.

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.............................................................................................................................. [3]

(c) Calculate the relative atomic mass of the sample of rubidium.

Give your answer to **two** decimal places.

answer = ............................................................ [2]

# Mark scheme

| Question | | | Answer | Mark | Guidance |
|---|---|---|---|---|---|
| 1 | (a) | | Rb-87 has (two) more neutrons ✓ | 1 | **ALLOW** Different numbers of neutrons<br><br>**ALLOW** 2 neutrons<br><br>**ALLOW** Rb-85 has 48 neutrons **AND** Rb-87 has 50 neutrons<br><br>**IGNORE** correct references to protons and electrons<br><br>**DO NOT ALLOW** incorrect references to protons and electrons |
| | (b) | | The (weighted) mean **mass** of an **atom** (of an element)<br>**OR**<br>The (weighted) average **mass** of an **atom** (of an element) ✓<br><br>compared with 1/12th (the mass) ✓<br><br>of (one atom of) carbon-12 ✓ | 3 | **ALLOW** average atomic mass<br>**DO NOT ALLOW** mean mass of an element<br>**ALLOW** mean mass of isotopes **OR** average mass of isotopes<br>**DO NOT ALLOW** the singular; 'isotope'<br><br>For second **AND** third marking points<br>**ALLOW** compared with (the mass of) carbon-12 which is 12<br><br>**ALLOW** mass of **one mole** of **atoms** ✓<br>compared to 1/12th ✓<br>(mass of) **one mole OR** 12 **g** of carbon-12 ✓<br><br>**ALLOW**<br>$\frac{\text{mass of one mole of atoms}}{\text{1/12th mass of one mole OR 12g of carbon-12}}$ |
| | (c) | | $\frac{(85.00 \times 72.15) + (87.00 \times 27.85)}{100}$ =<br><br>**OR** *61.3275 + 24.2295*<br><br>**OR** *85.557* ✓<br><br>$A_r$ = 85.56 (to 2 decimal places) ✓ | 2 | **ALLOW** two marks for correct answer $A_r$ = 85.56 (with no working)<br><br>**ALLOW** one mark for **ECF** from **seen** incorrect sum provided final answer is between 85 and 87 and is to 2 decimal places, e.g. 85.567 gives **ECF** of 85.57 for one mark |

The relative atomic mass of tin is 118.7.

Define the term *relative atomic mass*.

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

....................................................................................................................................... **[3]**

A bronze-age shield found on Dartmoor contained 2.08 kg of tin.

Calculate the number of tin atoms in this bronze shield.
Give your answer to **three** significant figures.

answer = .............................. **[2]**

# Mark scheme

| | | |
|---|---|---|
| The (weighted) mean **mass** of an **atom** (of an element)<br>**OR**<br>The (weighted) average **mass** of an **atom** (of an element) ✓<br><br>compared with 1/12th (the mass) ✓<br><br>of (one atom of) carbon-12 ✓ | 3 | **ALLOW** average atomic mass<br>**DO NOT ALLOW** mean mass of an element<br>**ALLOW** mean mass of isotopes **OR** average mass of isotopes<br>**DO NOT ALLOW** the singular; 'isotope'<br><br>For second **and** third marking points<br>**ALLOW** compared with (the mass of) carbon-12 which is 12<br><br>**ALLOW** mass of **one mole** of **atoms** ✓<br>compared to 1/12th ✓<br>(mass of) **one mole OR** 12**g** of carbon-12 ✓<br><br>**ALLOW**<br>$\frac{\text{mass of one mole of atoms}}{\text{1/12th mass of one mole OR 12g of carbon-12}}$ |
| moles of Sn = $\frac{2080}{118.7}$ = 17.52 ✓<br><br>$17.52 \times 6.02 \times 10^{23} = 1.05 \times 10^{25}$ atoms ✓ | 2 | **ALLOW** 17.5 up to (correctly rounded) calculator value of 17.52316765<br>**DO NOT ALLOW** use of 118, which makes moles of Sn = 17.63<br><br>**ALLOW** $105 \times 10^{23}$ atoms<br>**DO NOT ALLOW** answers which are not to three sig figs for second marking point<br>**ALLOW** two marks for answer only of $1.05 \times 10^{25}$<br>**ALLOW** one mark for answer only if not 3 sig figs up to calculator value of $1.054894693 \times 10^{25}$<br>**Eg 100 × 1**<br>**ALLOW** ECF for **any calculated** moles of Sn (based on use of any $A_r$ value) $\times 6.02 \times 10^{23}$ if shown to 3 sig figs<br>**DO NOT ALLOW** mass of Sn $\times 6.02 \times 10^{23}$ |

# Ionisation energies

# Objectives

**Must**

Definition for first ionisation energy

**Should**

Describe the factors affecting the first ionisation energy

**Could**

Explain the trend along a period and down a group

# Introducing Ionisation Energies

Definition:

"The first ionisation energy of an element is the energy required to remove one electron from each atom of one mole of gaseous atoms to form one mole of gaseous +1 ions."

$X(g) \rightarrow X^{+}(g) + e^{-}$

The units are $Jmol^{-1}$ = J/mol

# $2^{nd}$ Ionisation Energies

$2^{nd}$ ionisation energy

"The second ionisation energy of an element is the energy required to remove one electron from each atom of one mole of gaseous +1 ions to form one mole of gaseous +2 ions."

$X^{+}(g) \rightarrow X^{2+}(g) + e^{-}$

The units are $Jmol^{-1}$ = J/mol

# Factors affecting ionisation energy

Ionisation energies are influenced by:

- nuclear charge
- electron shielding; and
- the distance of the outermost electron from the nucleus.

## First IE - Trend down a group

1. Atomic radius increases
2. Shielding increases
3. Nuclear force of attraction decreases
4. Ionisation energy decreases

Remember to refer to the elements that are in the question.

## First IE - Trend along a period

1. Atomic radius decreases
2. Shielding stays the same
3. Charge on the nucleus increases
4. Nuclear force of attraction increases
5. Ionisation energy increases

Remember to refer to the elements that are in the question.

Modern plasma television screens emit light when mixtures of noble gases, such as neon and xenon, are ionised.

The first ionisation energies of neon and xenon are shown in the table below.

| element | 1st ionisation energy / kJ $mol^{-1}$ |
|---|---|
| neon | +2081 |
| xenon | +1170 |

Explain why xenon has a lower first ionisation energy than neon.

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

....................................................................................................................................... **[3]**

# Mark scheme

| | | | |
|---|---|---|---|
| (d) | Xe has a bigger atomic radius **OR** Xe has more shells ✓ | 3 | **ALLOW** Xe has more energy levels<br>**ALLOW** Xe has electrons in higher energy level<br>**ALLOW** Xe has electrons further from nucleus<br>**IGNORE** Xe has more orbitals **OR** more sub-shells<br>**DO NOT ALLOW** 'different shell' or 'new shell' |
| | Xe has **more** shielding ✓ | | **ALLOW More** screening<br>There must be a clear comparison ie **more** shielding **OR increased** shielding.<br>i.e. **DO NOT ALLOW** Xe 'has shielding'<br>**ALLOW** Xe has **more** electron repulsion from inner shells |
| | The nuclear attraction decreases<br>**OR** Outermost electrons of Xe experience less attraction (to nucleus)<br>**OR** Increased shielding / distance outweighs the increased nuclear charge ✓<br>ORA throughout | | **ALLOW** Xe has less nuclear pull<br>**IGNORE** Xe has less effective nuclear charge<br>**DO NOT ALLOW** nuclear charge for nuclear attraction |

**(e)** Ionisation energies allow chemists to determine electron structures. The first two ionisation energies of rubidium and strontium are shown in the table.

| element | first ionisation energy / kJ mol$^{-1}$ | second ionisation energy / kJ mol$^{-1}$ |
|---|---|---|
| rubidium | 403 | 2632 |
| strontium | 550 | 1064 |

**(i)** Write an equation to represent the **second** ionisation energy of strontium.

Include state symbols.

............................................................................................................................ **[1]**

**(ii)** Why is the **first** ionisation energy of strontium larger than the **first** ionisation energy of rubidium?

*In your answer you should use appropriate technical terms spelled correctly.*

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

............................................................................................................................ **[3]**

# Mark scheme

| | | | | |
|---|---|---|---|---|
| **(e)** | **(i)** | $Sr^{+}(g) \rightarrow Sr^{2+}(g) + e^{-}$ ✓ | 1 | **ALLOW** e for electrons<br>**ALLOW** $Sr^{+}(g) - e^{-} \rightarrow Sr^{2+}(g)$<br>**DO NOT ALLOW** $Sr^{+}(g) + e^{-} \rightarrow Sr^{2+}(g) + 2e^{-}$<br>**IGNORE** state symbols for electrons |
| **(e)** | **(ii)** | Sr has one **more** proton<br>**OR** greater nuclear charge ✓<br><br>(Outermost) electrons are in the same shell<br>**OR** (outermost) electrons experience same shielding<br>**OR** Atomic radius of Sr is smaller ✓<br><br>Sr has greater nuclear attraction (on outer electrons / outer shell/s)<br>**OR** the (outer) electrons are attracted more strongly (to the nucleus) ✓ | 3 | **Use annotations with ticks, crosses ECF etc. for this part**<br><br>Comparison should be used for each mark<br><br>**ALLOW** Sr has more protons **ALLOW** 'across the period' for 'Sr'<br>**IGNORE** 'atomic number increases', but **ALLOW** 'proton number' increases<br>**IGNORE** 'nucleus gets bigger'<br>'Charge increases' is insufficient<br>**ALLOW** 'effective nuclear charge increases' **OR** 'shielded nuclear charge increases'<br>***Quality of Written Communication*** *– Nuclear **OR** proton(s) **OR** nucleus spelled correctly **ONCE** for the **first** marking point*<br><br>**ALLOW** shielding is similar<br>**ALLOW** screening for shielding<br>**IGNORE** sub-shells<br>**DO NOT ALLOW** 'distance is similar'<br><br>**ALLOW** 'greater nuclear pull' for 'greater nuclear attraction'<br>**DO NOT ALLOW** 'nuclear charge' for nuclear attraction<br>**ORA** throughout |

**(iii)** Why is the **second** ionisation energy of rubidium larger than the **second** ionisation energy of strontium?

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

.................................................................................................................... **[2]**

# Mark scheme

| Question | | | Answer | Mark | Guidance |
|---|---|---|---|---|---|
| **1** | **(e)** | **(iii)** | 2nd IE of Rb involves removing electron from shell closer to nucleus ✓<br><br>Stronger nuclear attraction on (outermost electron) of Rb **OR** (outermost electron) of Rb experiences **less** shielding ✓ | 2 | **IGNORE** new shell<br><br>**ALLOW** There is one shell fewer in Rb($^+$) (than $Sr^+$)<br>**ALLOW** Rb($^+$) has a smaller radius (than $Sr^+$)<br>**ALLOW** Rb($^+$) loses an electron from the 4th shell **AND** Sr($^+$) loses an electron from the 5th shell.<br><br>**ALLOW** responses which do not specifically say 'nuclear' attraction (e.g. Rb has greater attraction) as long as nucleus is seen in first point<br>A comparison of Rb to Sr must be used, e.g. 'Because of shielding' is not enough<br><br>**ORA** |

## Why do successive ionisation energies get larger?

Once you have removed the first electron you are left with a positive ion.

Trying to remove a negative electron from a positive ion is going to be more difficult than removing it from an atom.

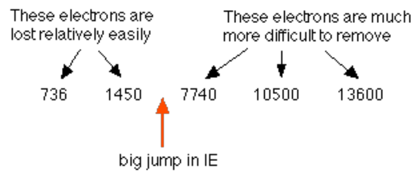
Removing an electron from a 2+ or 3+ (etc) ion is going to be progressively more difficult.

## Successive Ionisation Energies

- You can then have as many successive ionisation energies as there are electrons in the original atom.
- The first four ionisation energies of aluminium, for example, are given by
- 1st I.E. = 577 kJ $mol^{-1}$
- 2nd I.E. = 1820 kJ $mol^{-1}$
- 3rd I.E. = 2740 kJ $mol^{-1}$
- 4th I.E. = 11600 kJ $mol^{-1}$

# Using ionisation energies to work out which group an element is in.

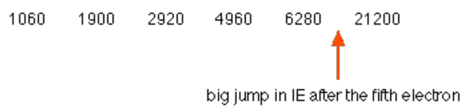
- Magnesium is in group 2 of the Periodic Table and has successive ionisation energies:




- This big jump between two successive ionisation energies is typical of suddenly breaking in to an inner level. You can use this to work out which group of the Periodic Table an element is in from its successive ionisation energies.

# AfL quick question…

Decide which group an atom is in if it has successive ionisation energies:




The ionisation energies are going up one or two thousand at a time for the first five. Then there is a huge jump of about 15000. There are 5 relatively easy electrons - so the element is in group 5.

**(d)** The successive ionisation energies of aluminium are shown in the table below. Some of these ionisations involve the removal of an electron from an s sub-shell.

| **ionisation energy / kJ mol$^{-1}$** | 578 | 1817 | 2745 | 11 578 | 14 831 | 18 378 | 23 296 | 27 460 | 31 862 | 38 458 | 42 655 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ionisation number** | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th |

**(i)** State **all** the ionisation numbers that involve the removal of an electron from s sub-shells.

.................................................................................................................. **[2]**

**(ii)** Write the equation that represents the third ionisation energy of A*l*.
Include state symbols.

.................................................................................................................. **[2]**

# Mark scheme

| | | | | |
|---|---|---|---|---|
| **d** | **i** | 2nd, 3rd<br>**OR**<br>1817, 2745 ✓<br><br>10th, 11th<br>**OR**<br>38458, 42655 ✓ | 2 | Mark as pairs<br>**IGNORE** references to 12th and 13th<br>Three answers with one correct pair = 1 mark<br>Four answers with one correct pair = 1 mark<br>Five answers with both pairs correct = 1 mark<br>Five answers with only one pair correct = 0 marks<br>Six (or more) answers = 0 marks |
| | **ii** | $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$ ✓✓ | 2 | **ALLOW** $Al^{2+}(g) - e^{-} \rightarrow Al^{3+}(g)$ for 2 marks<br>**ALLOW** 1 mark for $Al(g) \rightarrow Al^{3+}(g) + 3e^{-}$ as states are correct<br>**ALLOW** 1 mark for $Al^{2+}(g) + 2e^{-} \rightarrow Al^{3+}(g) + 3e^{-}$ as states are correct<br>**ALLOW** 1 mark if symbol of Al is incorrect, but equation is otherwise fully correct.<br>**ALLOW** e for electron (i.e. no charge)<br>**IGNORE** states on electron |

# Electron configurations

## Objectives

**Must**

Describe the shapes and energy of orbitals

**Should**

Write an electronic configuration in terms of s, p and d orbitals

**Could**

Deduce the electron configuration of ions

# Energy levels and orbitals

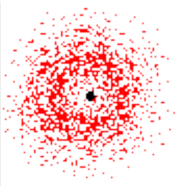
- Each energy level n=1, 2, 3 and so on is made up of ORBITALS

Definition

- An orbital is a region of space around the nucleus that can hold 2 electrons with paired spins

# S-orbitals

The first type of orbital at lowest energy is called 1s and it will hold 2 electrons.



a 1s orbital

The ***"1"*** represents the fact that the orbital is in the energy level closest to the nucleus.

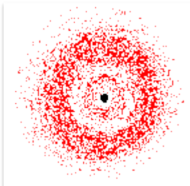
The ***"s"*** tells you about the shape of the orbital.

S orbitals are spherically symmetric around the nucleus - like a hollow ball made of cloud-like material with the nucleus at its centre

# S- orbitals

The second type of orbital is a ***2s orbital.***

This is similar to a 1s orbital except that the region where there is the greatest chance of finding the electron is further from the nucleus



a 2s orbital

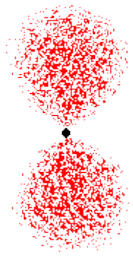
This is an orbital at the second energy level and holds two electrons.

***So in the first period***

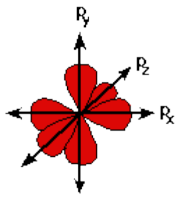
Hydrogen has its only electron in the 1s orbital - $\mathbf{1s^1}$, and at helium the first level is completely full - $\mathbf{1s^2}$**.**

The next electron goes into the 2s orbital so lithium is $\mathbf{1s^2\ 2s^1}$ and beryllium is $\mathbf{1s^2\ 2s^2}$

# P-orbitals



a p orbital




A p orbital is like 2 identical balloons tied together at the nucleus. The diagram on the right is a cross-section through that 3-dimensional region of space.

We call it a dumbbell shape

There are three p-orbitals of equal energy.

Each of them can hold 2 electrons (so 6 in total).

***So after beryllium***

Now the 2p levels start to fill. These levels all have the same energy, and so the electrons go in singly at first.

B – $1s^2 2s^2 \mathbf{2p_x^1}$

C - $1s^2 2s^2 \mathbf{2p_x^1 2p_y^1}$

**N -** $1s^2 2s^2 \mathbf{2p_x^1 2p_y^1 2p_z^1}$

The next electrons to go in will have to pair up with those already there.

**O -** $1s^2 2s^2 \mathbf{2p_x^2 2p_y^1 2p_z^1}$

Shorthand Version:

All the various p electrons can be lumped together.

For example, fluorine could be written as $1s^2 2s^2 2p^5$, and neon as $1s^2 2s^2 2p^6$.

Challenge question…
Why do you think electrons might not like to pair up?

**d orbitals**

In addition to s and p orbitals, there are two other sets of orbitals available for electrons at higher energy levels. These are d and f.

You only need to know about d. There are 5 d-orbitals in energy levels from 3 onwards. Each d-orbital holds <u>2 electrons.</u>

$3s^2\ 3p^6\ 3d^{10}$

**The electron configuration of Krypton (Kr) with 36 electrons is:**

**$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$**

Can you write the electron configuration of Germanium?

# Don't make it too complicated!

**$1s^2$**

**$2s^2\ 2p^6$**

**$3s^2\ 3p^6 3d^{10}$**

**$4s^2 4p^6$...**

**You only need to know up to Kr $4p^6$**

## Let the periodic table help you…

The s block have 's' outer shell electrons (eg Na, Mg etc)

The p block have 'p' outer shell electrons (eg Al, C, N etc)

The d block have 'd' outer shell electrons (eg Cu, Fe, Ag etc)

**The row (period) is equal to the energy level eg n=1, 2, 3, 4 etc.**

## AfL – write the electron configuration

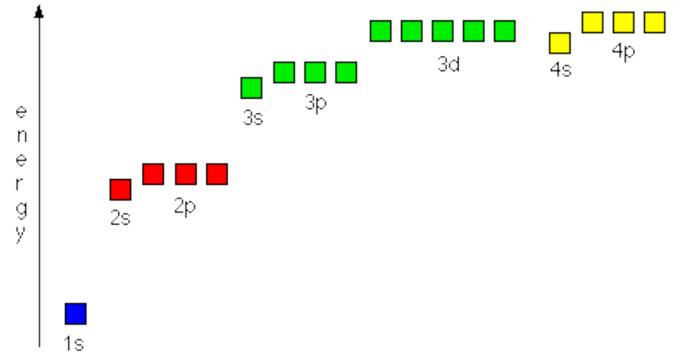
For example Nitrogen (7 electrons) $1s^2 2s^2 2p^3$

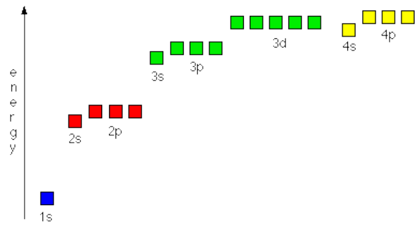
1. Magnesium (12 electrons)
2. Beryllium (4 electrons)
3. Sulphur (16 electrons)

# Energy and filling orbitals

Electrons fill low energy orbitals (closer to the nucleus) before they fill higher energy ones.

Where there is a choice between orbitals of equal energy, they fill the orbitals singly as far as possible.




Remember that 4s fills before 3d

K - $1s^22s^22p^63s^23p^6$**$4s^1$**

Sc - $1s^22s^22p^63s^23p^6$**$3d^1$**$4s^2$

AfL - Write the electron configuration of iron (26 electrons).

# Charged ions

To work out a **positive** ion **take electrons away**.

- Attempt the electron configuration of the $Mg^{2+}$ ion.

To work out a **negative** ion **add electrons on**.

- Attempt the electron configuration of the $Cl^-$ ion.

# Charged ions - answers

- Attempt the electron configuration of the $Mg^{2+}$ ion.
- $1s^2 2s^2 2p^6$
- Attempt the electron configuration of the $Cl^-$ ion.
- $1s^2 2s^2 2p^6 3s^2 3p^6$

In an atom the electrons occupy sub-shells in order of increasing energy.

**(a)** Complete the table below to show the order in which the next two sub-shells are filled.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1s | 2s | 2p | 3s | 3p | 4s | | |

increasing energy →

**[1]**

**(b)** Sub-shells are made up of orbitals.

**(i)** What is meant by an *orbital*?

..........................................................................................................................................

.......................................................................................................................................... **[1]**

**(ii)** State the total number of electrons occupying the p orbitals in one chlorine atom.

answer = ................................. **[1]**

**(c)** How many electrons are there in one ion of $Ca^{2+}$?

answer = ................................. **[1]**

# Mark scheme

| | | | | | |
|---|---|---|---|---|---|
| 3 | a | | 3d 4p ✓ | 1 | Correct order is essential<br>**ALLOW** '3D' |
| | b | i | A region (within an atom) that can hold (up to) two electrons ✓ (with opposite spin) | 1 | **ALLOW** 'can be found' for 'can hold'<br>**ALLOW** 'area' **OR** 'volume' **OR** 'space' for region<br>**DO NOT ALLOW** 'place' for region<br>**DO NOT ALLOW** path of an electron<br>**IGNORE** references to 'orbitals being parts of sub-shells' |
| | | ii | 11 ✓ | 1 | |
| | c | | 18 ✓ | 1 | |

The electron configuration of bromine contains outermost electrons in the 4th shell.

Using your knowledge of Group 7 elements, complete the electron configuration of bromine.

$1s^2 2s^2 2p^6 3s^2 3p^6$ .................................................................................................... **[1]**

# Mark scheme

| | | | | |
|---|---|---|---|---|
| **(b)** | | $3d^{10}$ $4s^2$ $4p^5$ ✓ | **1** | **ALLOW** $4s^2$ $3d^{10}$ $4p^5$<br>**ALLOW** subscripts or $3D^{10}$<br>**ALLOW** answers with $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ appearing twice |