CELS Resource

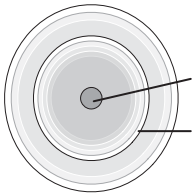
Atomic Structure

Aims

To know about the sub-atomic particles and their properties

To interpret information given on sub-atomic particles.

Less than ninety years ago scientists believed that atoms were tiny solid spheres like minute snooker balls. Since then it has been discovered that atoms are not completely solid but have inner and outer parts.



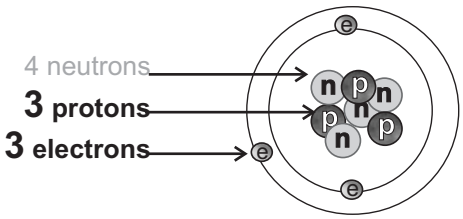
A central **nucleus**

Outer **shell** or orbit

To make a model atom, a golf ball could be used to represent the nucleus and the outermost row of seats in an Olympic Stadium could represent an

Info

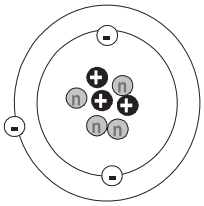
After many experiments atoms were broken up into smaller particles called **electrons, protons** and **neutrons.** These particles have different properties.



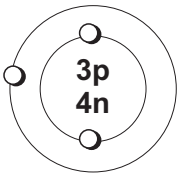
Protons have a **positive** charge
Electrons have a **negative** charge
Neutrons have **no** charge (*they are neutral*)

What can you say about the overall charge of this atom ?

This atom could be drawn in several ways to show the same information.



We could re-draw this atom of **lithium** to show where positive and negative particles are found
OR
we can summarize the numbers of each kind of particle.



$^{7}_{3}Li_{(2,1)}$

Protons determine whether an atom is an atom of gold, lead or whatever. Electrons have can help to balance the protons to make the atom neutral but can also cause atoms to become charged

Neutrons have **no** charge but they are about the same mass as protons and help give the nucleus extra weight. Electrons are much lighter ($^{1}/_{1836}$ the mass of a proton)

Task

1 Which particle is found in shells around the nucleus

2 Where is most of the mass of an atom found ?

3 Look at the numbers used to describe the lithium atom. What do these parts mean ?
7 = 3 = 2,1 =

4 Complete the following table

Proton	Positive charge		Mass = 1
Electron			Mass = 0.0005
		Found in the nucleus	Mass=

CELS Resource

Nucleus Numbers

Aims

To use definitions of mass and atomic numbers to determine nuclear structures

To recall how neutral atoms are balanced

The two numbers used to describe the nucleus of an atom are called the **mass number** (=protons + neutrons) and the **atomic number** (=protons only).

Task

Element	Symbol	Atomic Number	Mass Number	Total number of			Complete Symbol
				Protons	Neutrons	Electrons	
Hydrogen	H	1	1	1	0	1	$^{1}_{1}H$
Helium	He	2	4	2		2	
Lithium	Li	3		3	4		
Beryllium	Be	4			5	4	
Boron	B	5		5	6		
Carbon	C	6	12	6	6	6	$^{12}_{6}C$
Nitrogen	N	7	14	7			
Oxygen	O	8	16	8			$^{16}_{8}O$
Fluorine	F	9			10	9	
Neon	Ne	10	20			10	
Sodium	Na	11			12		$^{23}_{11}Na$
Magnesium	Mg	12			12		
Aluminium	Al	13	27			13	
Silicon	Si	14			14		
Phosphorus	P	15	31	15		15	
Sulphur	S	16			16		$^{32}_{16}S$
Chlorine	Cl	17	35		18		
Argon	Ar	18			22	18	
Potassium	K	19		19	20		
Calcium	Ca	20				20	$^{40}_{20}Ca$

Task

Q1 Why is hydrogen the odd-one-out ?

Q2 Scientists use atomic number to elements in order, if mass number was used instead how would this order change?

CELS Resource

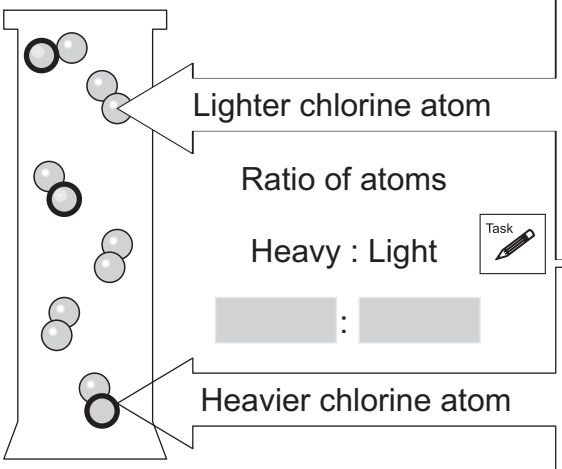
Isotopes

A sample of pure chlorine does not contain identical atoms. Some of its atoms are heavier than others. However apart from their extra mass, they smell and behave the same.

Aims

To relate mass and atomic numbers to amounts of sub-atomic particles

To know what an isotope is.



Lighter chlorine atom

Ratio of atoms

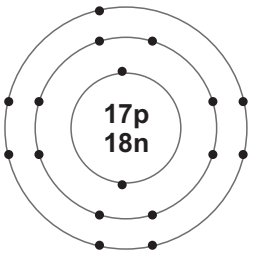
Task

Heavy : Light

____ : ____

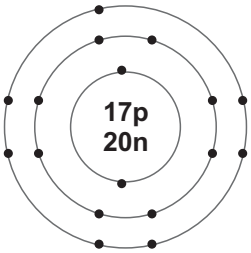
Heavier chlorine atom

Molecules of chlorine are **diatomic** and so are written as Cl_2



This chlorine atom has the symbol and numbers

$^{17}_{\ }Cl$ (2,8,7)



The heavier atom of chlorine has the symbol and numbers

$^{\square}_{\square}Cl$ (, ,)

Atoms of the same element which have the same number ____ (or electrons) but different numbers of ____ are called **isotopes.**

Task Compete the following table on isotopes.

Property	Same for each isotope	Different for each isotope
Chemical reactions	✓	
Mass number		
Atomic number		
Number of protons		
Number of neutrons		
Number of electrons		
Mass of nucleus		✓
Number of shells		

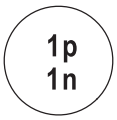
Since one atom in four is heavy we can use this fact to calculate the average mass (number) for chlorine

$^{35}_{17}Cl$ $^{37}_{17}Cl$ $^{35}_{17}Cl$ $^{35}_{17}Cl$ → $^{\square}_{17}Cl$ average

Normally isotopes of a chemical element are given the same name but referred to as (eg) chlorine-35 or chlorine-37. However hydrogen is a special case and its isotopes have special

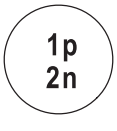
Hydrogen

$^{1}_{1}H$



Deuterium

$^{\square}_{\square}H$



Tritium

$^{\square}_{\square}H$

CELS Resource

Electronic Structure

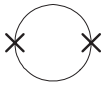
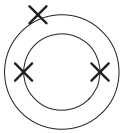
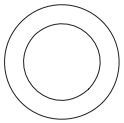
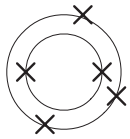
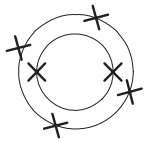
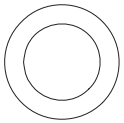
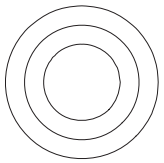
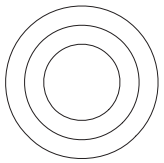
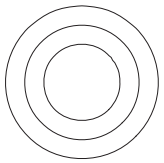
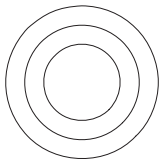
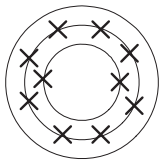
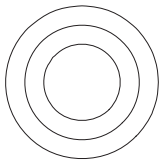
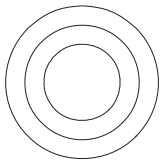
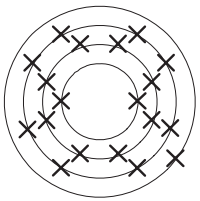
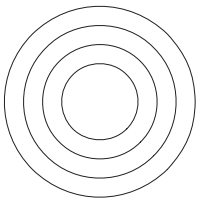
The arrangement of electrons around an atom is closely linked to its position in the periodic table

Aims

AS2bHF

To recognise patterns in the electronic structure of the first 20 elements

To relate shell structure to its position in the Periodic Table

 1							**Helium 2**  2
Lithium 3  2,1	**Beryllium**  2,2	**Boron 5**  2,3	**Carbon 6** 	**Nitrogen 7**  2,5	**Oxygen 8** 	**Fluorine 9** 	**Neon 10**  2,8
Sodium 11  2,8,1	**Magnesium** 	**Aluminium**  2,8,3	**Silicon 14** 	**Phosphorus**  2,8,5	**Sulphur** 	**Chlorine** 	**Argon 18** 
Potassium 	**Calcium 20** 						

Complete each box so that it contains the name of the element and

(a) the atomic number

(b) the correct arrangement of electrons eg 2,8,1

(c) the correct shell/orbit diagram with X's for electrons.

Describe some patterns you have spotted :

CELS Resource

Atoms and Periodic Table

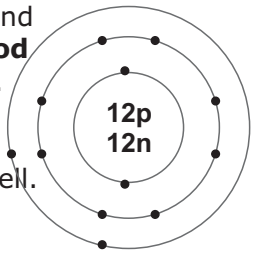
Aims: To relate atomic structure to its place in the Periodic Table

1	2	Group numbers							3	4	5	6	7	0	
H														He	1st period
Li	Be								B	C	N	O	F	Ne	2nd period
Na	Mg								Al	Si	P	S	Cl	Ar	3rd period
K	Ca														4th period
															5th period
															6th period

$^{24}_{12}Mg$

Magnesium is found in the **third period** and in group two.

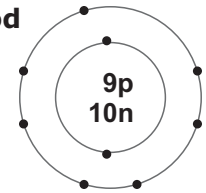
It has **three shells** and two electrons in its outermost shell.



$^{19}_{9}F$

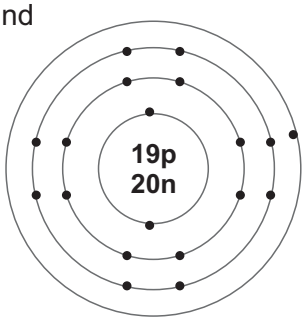
Fluorine is found in the **second period** and in group seven.

It has **two shells** and seven electrons in its outermost shell.



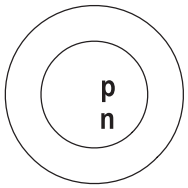
$^{39}_{19}K$

Potassium is found in

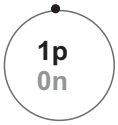


$^{11}_{5}B$

Boron is found in



$^{1}_{1}H$

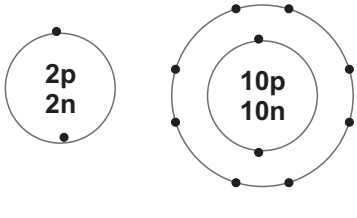


Although hydrogen is a gas it is put in Group 1 with the Alkali Metals because

The Noble Gases - the unreactive elements

$^{4}_{2}He$ $^{20}_{10}Ne$ $^{40}_{18}Ar$

The Noble Gases are special. They are called **Group 0** because



NOTTINGHAM TRENT UNIVERSITY

CELS Resource

Ions

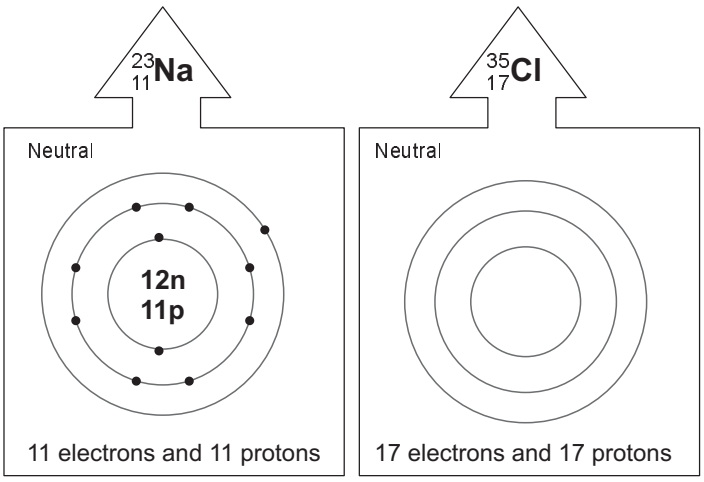
Aims

To know that atoms can lose or gain electrons to become ions

To use atomic diagrams to identify +ve or -ve ions

During a chemical reaction atoms combine with one another. For example

Sodium + Chlorine => _____

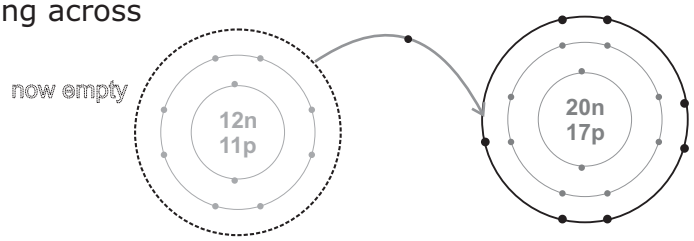


The change in name from chlorine to chloride tells us that the atoms have also undergone a change.

The electron arrangement of chlorine starts off as (, ,).

In a chlorine atom thenumber of electrons equals the number of _____ and so the atom is neutral.

As metal atoms of sodium are brought close to non-metal atoms of chlorine, individual electrons aretransferred- jumping across



The inner shells are ignored because they are already full.

The electron arrangement of sodium now becomes (,).

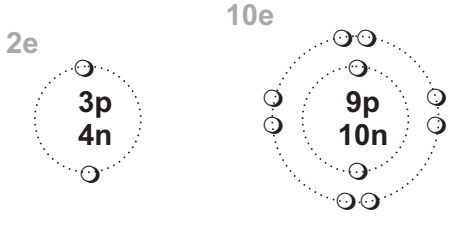
In this sodium particle the number of negative electrons is _____ than the number of positive protons. It is now a charged **ion**

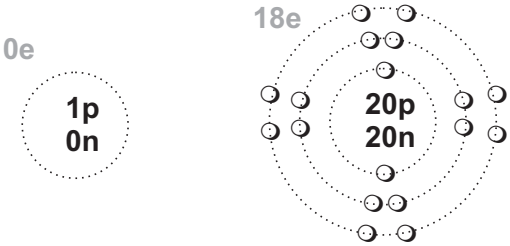
The electron arrangement of <u>chloride</u> now becomes (, ,).

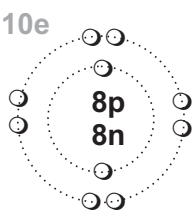
In a <u>chloride</u> particle the number of negative electrons is _____ than the number of positive protons. It is now a charged **ion**

To show that the atoms have changed into ions, chlorine is renamed chloride and each ion is given anew symbol **Na^+** for the **sodium ion** and _____ for the **chloride ion**.

This change from <u>neutral atom</u> to <u>charged ion</u> also happens for many other elements eg **Zn** => **Zn^{++}**







Lithium ion written as **Li^+**	Fluoride ion written as _____	Hydrogen ion written as _____	Calcium ion written as _____	Oxide ion written as _____

CELS Resource

Ionic Bonding

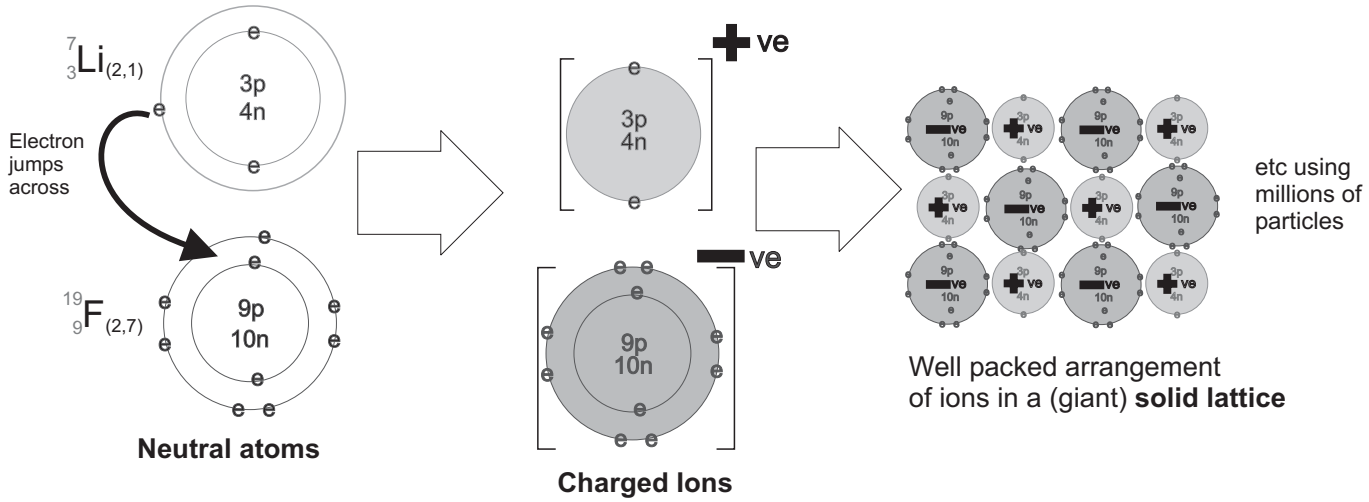
Aims

To be familiar with the different types of bonding

To show how different atoms change as they bond together.

Atoms are neutral particles. Under certain conditions, when atoms combine they become charged particles called **ions**.

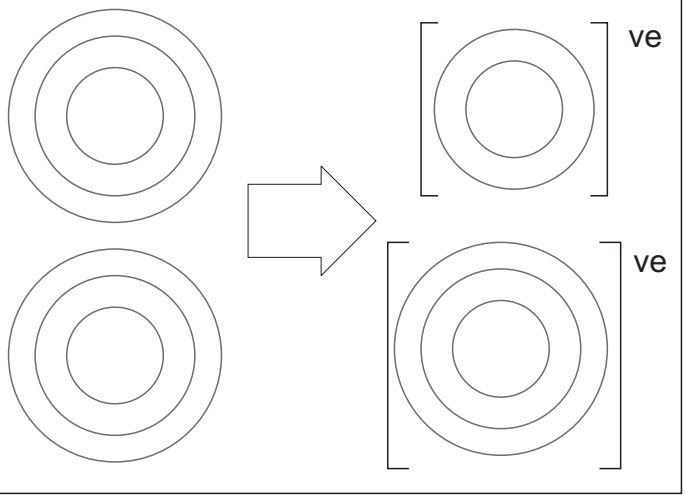
We say that the charged particles are held together by **ionic bonding**



Using the following information on the *starting* **neutral** atoms, show how these would form **ions** which would then cling togther to form a solid compound.

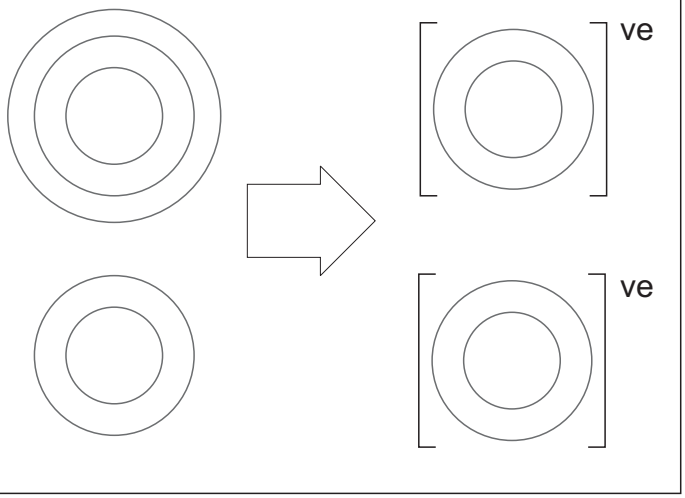
Sodium chloride

$^{23}_{11}Na_{(2,8,1)}$ $^{35}_{17}Cl_{(2,8,7)}$



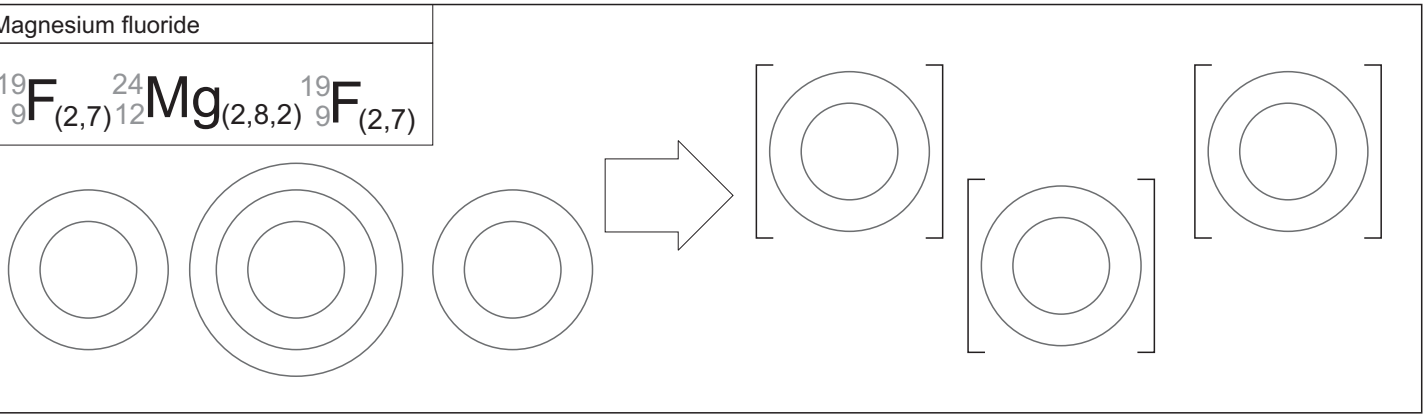
Magnesium oxide

$^{24}_{12}Mg_{(2,8,2)}$ $^{16}_{8}O_{(2,6)}$



Magnesium fluoride

$^{19}_{9}F_{(2,7)}$ $^{24}_{12}Mg_{(2,8,2)}$ $^{19}_{9}F_{(2,7)}$



Now on lined paper show how TWO **sodium atoms** would form ions with ONE **oxygen** atom would turn into sodium oxide.

NOTTINGHAM TRENT UNIVERSITY

CELS Resource

Ionic Structures

Aims

To know how ions can interact with each other.

To suggest how positive and negative ions will pack together and how this influences their properties

As atoms interact **electrons** can be lost and gained. This turns atoms into charged **ions.** Positive ions will be attracted to negative ions.

Carefully cut around each of the positive (lithium) and negative (fluoride) ions shown below.

Stick them in a regular pattern to show how they would line up in a solid.

You must **not** stick two of the **same** type of ions next to one another.

If you are successful, then try with the second set of ions which differ in size.

There are also less of the larger negative ion which is a sulphide ion.

You might need to put gaps into your structure

Cut Paste

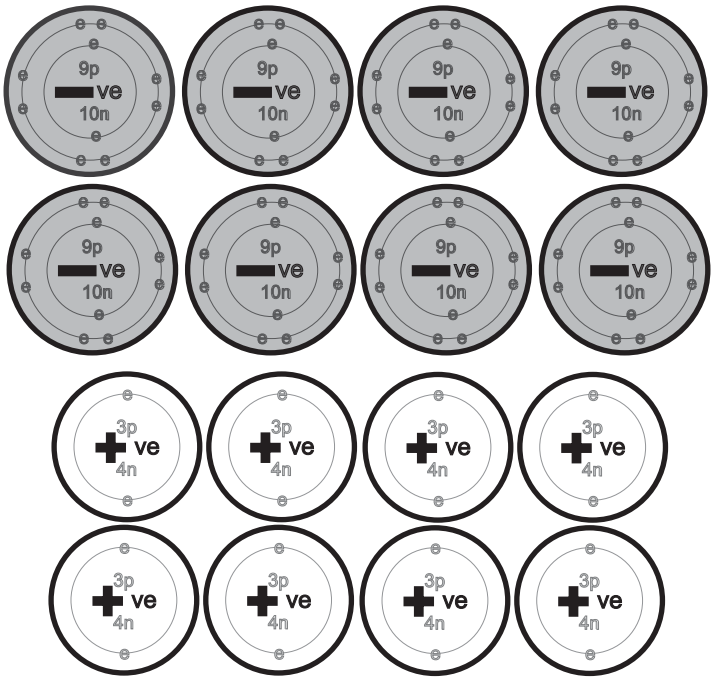
Why have you arranged the ions as you have?
(ie what would happen if a positive lithium ion was put next to another positive lithium ion?)

The heat needed to melt the solids arranged in your diagrams can require a lot of energy.
What does this tell you about the strength of attraction between ions ?

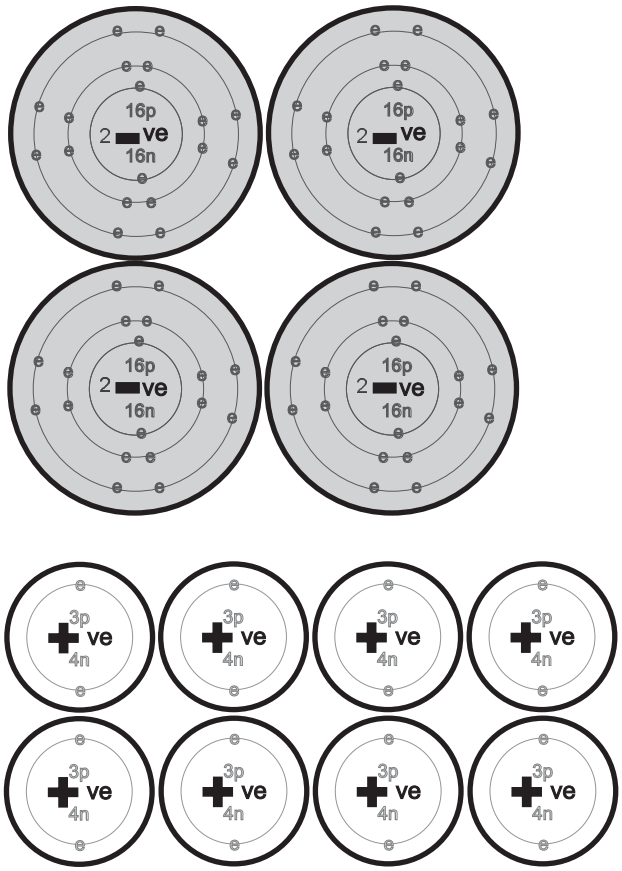
When these substances are melted and two electrical probes (electrodes) are pushed into the liquid the ions separate. Which ion will be attracted to the negative electrode (cathode) ?

You have shown arrangements of ions inside lithium fluoride and lithium sulphide. One is a dense substance and the other feels 'lightweight'. Which do you think is the dense substance and why?

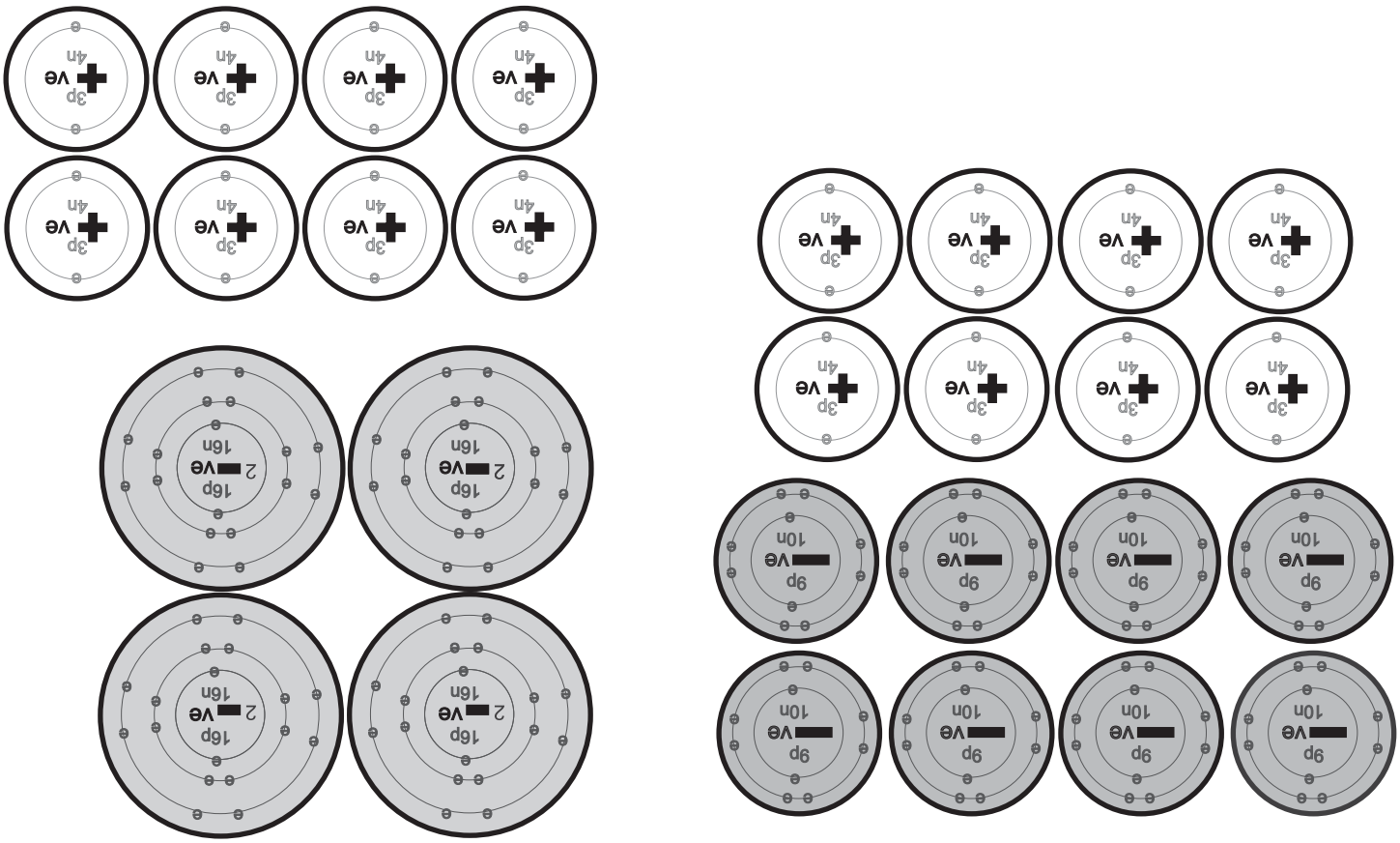
Lithium ions and Fluoride ions



Lithium ions and Sulphide ions



Lithium ions and Fluoride ions



Lithium ions and Sulphide ions

CELS Resource

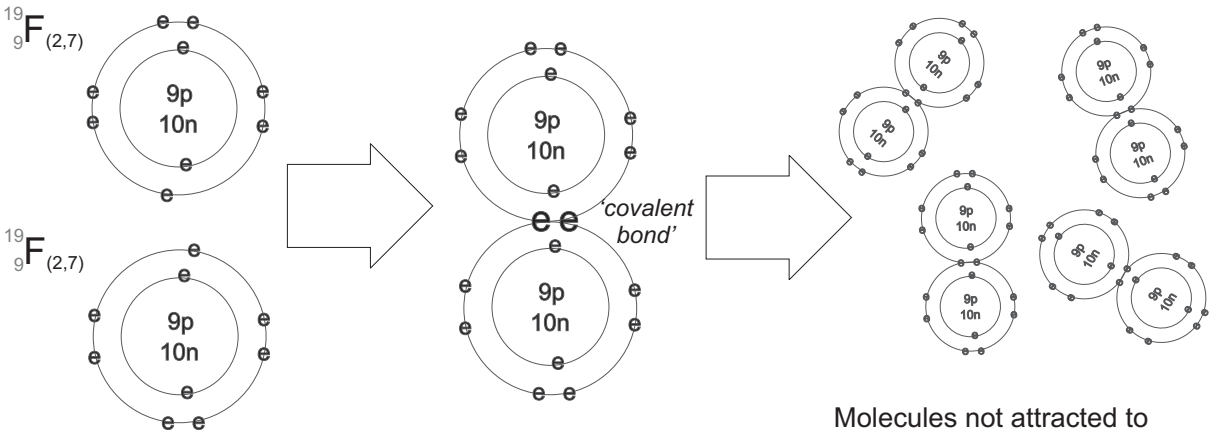
Covalent Bonding

Aims

To be familiar with the different types of bonding

To show how different atoms change as they bond together.

It is possible for atoms to join together and stay **neutral**. This is called **covalent bonding**. The word covalent means to share (a pair of) electrons



Neutral atoms

Neutral molecule

Molecules not attracted to each other and so normally form a **liquid** or a **gas**

Remember the whole point of atoms joining together is so that their outermost ring of electrons becomes filled completely.

Task

Tasks

Draw 'dot and cross' diagrams to show the covalent bonding that keeps together these molecules.

Methane gas

Made from these atoms

$C_{(2,4)}H_{(1)}H_{(1)}H_{(1)}H_{(1)}$

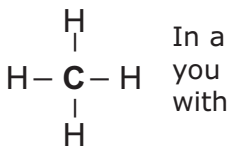
dot & cross picture

Ammonia gas

Made from these atoms

$N_{(2,5)}H_{(1)}H_{(1)}H_{(1)}$

dot & cross picture



In a previous topic about Oil you drew methane gas out with a **stick** picture

Draw out ammonia as a stick picture

In a stick picture, each dash represents a covalent bond. It also represents a certain number of electrons - how many electrons is this ?

Some substances contain a double bond eg oxygen O=O. How many electrons are involved in the double bond which holds the atoms togther ?

Draw out the following molecules using dot and cross (you do not have to show the nucleus)

Covalent	Covalent	Covalent (Double bond)
$^{35}_{17}Cl_{(2,8,7)}$ $^{35}_{17}Cl_{(2,8,7)}$	$^{1}_{1}H_{(1)}$ $^{16}_{8}O_{(2,6)}$ $^{1}_{1}H_{(1)}$	$^{16}_{8}O_{(2,6)}$ $^{16}_{8}O_{(2,6)}$

CELS Resource

Covalent Bonding

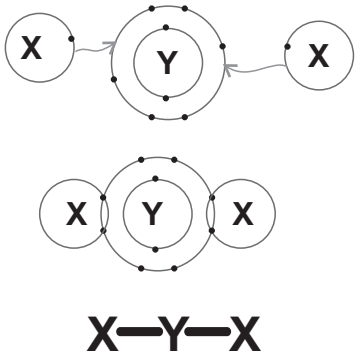
Aims

To be familiar with the different types of bonding

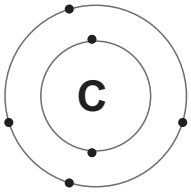
To show how different atoms change as they bond together.

In covalent bonding, electrons are not completely transferred from one atom to another like ionic bonding Instead they are **shared** by both atoms.

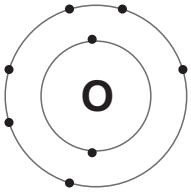
Covalent Bonding



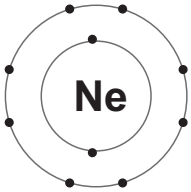
The normal number of bonds which an atom will make can be easily worked out.



Carbon has **four** outermost electrons (it is also in Group 4) and will form **four** covalent bonds



Oxygen has **six** outershell electrons (it is also in Group 6) and will form **two** covalent bonds

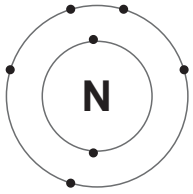


Neon has **eight** outershell electrons and will form **no** covalent bonds

There is a link between the number of covalent bonds which an atom will form and its outermost electrons

Describe this link

Task

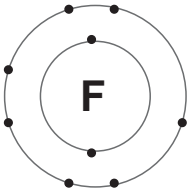


Q1 Which Group of the Periodic Table is **Nitrogen** found in ?

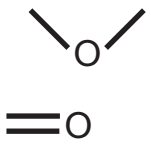
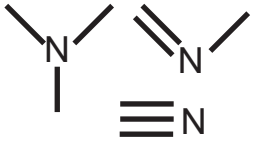
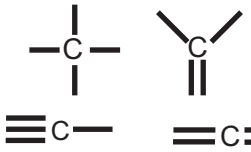
Q2 How many covalent bonds will it form ?

Q3 Which Group of the Periodic Table is **Fluorine** found in ?

Q4 How many covalent bonds will it form ?



The number of covalent bonds which element can form is shown below in a different way with sticks

Hydrogen only 1 bond	**Oxygen** always 2 bonds	**Nitrogen** always 3 bonds	**Carbon** always 4 bonds
			

Task

Use these to help draw out the stick diagrams for the following substances on lined paper

Methane, CH_4 Ethane, C_2H_6 Water, H_2O, Ammonia, NH_3 Methanal, CH_2O

These are slightly more difficult challenges

Ethene, C_2H_4 Carbon dioxide, CO_2 Dinitrogen trioxide, N_2O_3

CELS Resource

Metallic Bonding

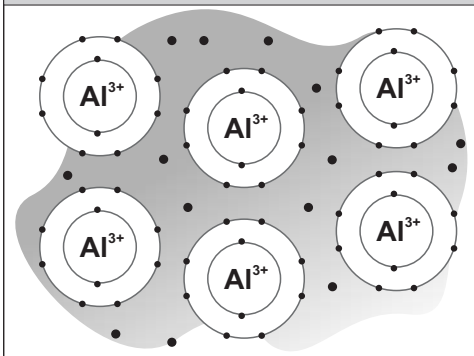
Aims

To be familiar with the different types of bonding

To show how different atoms change as they bond together.

Chemical bonding involves electrons which are either shared or transferred between atoms. Electrons are particularly important in holding metal atoms together.

Metallic Bonding



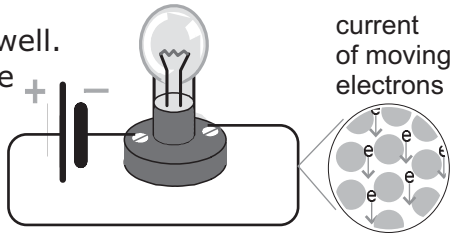
The outer shell electrons on each metal atom are free to move between atoms. This gives positive ions surrounded by a 'glue' of electrons.

Task Use the information opposite answer these questions :

1 Which type of bonding (covalent/ionic) is metallic bonding most like ? Explain your choice.

2 What <u>differences</u> are there between this type of bonding and metallic bonding ?

Metals conduct electricity well. This diagram shows a close up of current flowing through copper wire.



3 Why are metals able to conduct electricity ?

The following table looks at Group 1 of the Periodic Table, the family of reactive metals called **Alkali metals**.

Property	Lithium	Sodium	Potassium	Rubidium	Caesium
					
Atomic mass	6.9	23	39	85	133
Melting point (ºC)	453	371	337	312	302
Density (g/cm^3)	0.53	0.97	0.86	1.53	1.87
Conductivity Electrical (Ω m^{-1})	0.12	0.23	0.15	0.09	0.05
Conductivity Thermal (W m^{-1}K^{-1}	85	141	102	58	36

4 Why are these elements placed in the same group of the Periodic Table?

5 Which one is held together with the strongest metallic bonding? Explain your answer

6 Which element do you think loses its outermost electron most easily? Explain your answer.

7 Plot a line graph of <u>either</u> the thermal <u>or</u> electricity conductivities against density. What general relationship is there between the conductivity of these metals and their densities.

CELS Resource

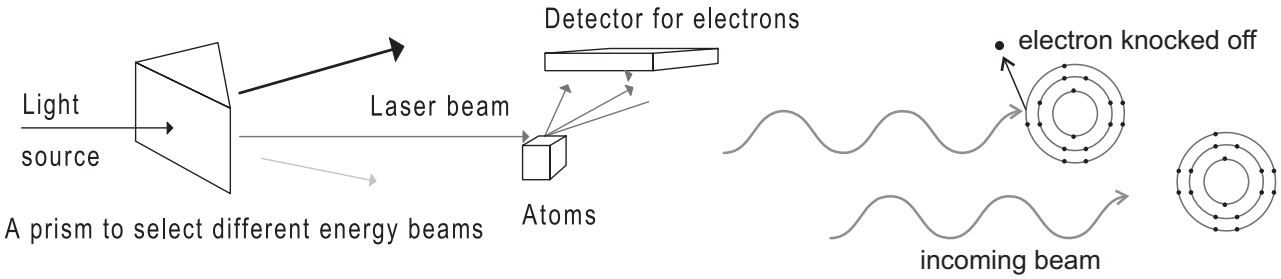
Explaining Reactivity

Aims

To appreciate that different atoms require different I.E.'s

To relate reactivity of atoms to their Ionization Energies.

Some elements are more reactive than others. This is closely related to the electrons in the outermost shell.



By focusing a beam of laser light on to a sample of separate atoms, one electron in the outermost shell can be made to fly off. This is called **ionization.**

The energy of the laser beam has to be carefully selected to take into account the number of electrons, the number of shells and the number of protons (which try to keep the electrons in place).

The energy of the beam used to knock out electrons is called the **ionization energy**.

This is shown below for the first twenty elements in the Periodic Table

Element	Proton number	Group number	Number of shells	Ionization energy / eV
Hydrogen	1	1	1	13.6
Helium	2	0	1	24.6
Lithium	3	1	2	5.4
Beryllium	4	2	2	9.3
Boron	5	3	2	8.3
Carbon	6	4	2	11.3
Nitrogen	7	5	2	14.5
Oxygen	8	6	2	13.6
Fluorine	9	7	2	17.4
Neon	10	0	2	21.6
Sodium	11	1	3	5.1
Magnesium	12	2	3	7.6
Aluminium	13	3	3	6.0
Silicon	14	4	3	8.2
Phosphorus	15	5	3	10.5
Sulphur	16	6	3	10.4
Chlorine	17	7	3	13.0
Argon	18	0	3	15.8
Potassium	19	1	4	___
Calcium	20	2	4	6.1

Task

Plot a graph of atomic number (x-axis) against ionization energy (y-axis)
Suggest a value for the ionization of potassium
On your graph label Group 1 elements (H, Li, Na and K) and Noble Gases (He, Ne, Ar).
Explain why Noble Gases are the least reactive elements and Group 1 are the most