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Photocopy Master Sheets

Years 9-10

Atoms & Elements

Disk filename = “15.Atoms”

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03.Matter	Solids, Liquids & Gases
04.Mixtures	Separating Mixtures
05.Elements	Elements & Compounds
06.Cells	Living Cells
07.Life	Living Things
08.LifeSystems	Plant & Animal Systems
09.Astronomy	Astronomy
10.Earth	The Earth
11.Ecosystems	Ecosystems

Year 9-10 General Science

Disk Filename	Topic Name
12.Waves	Wave Energy (inc. Light)
13.Motion	Forces & Motion
14.Electricity	Electricity
15.Atoms	Atoms & Elements
16.Reactions	Compounds & Reactions
17.DNA	Cell Division & DNA
18.Evolution	Evolution of Life
19.Health	Health & Reproduction
20.Universe	The Universe
21.EarthScience	Earth Science
22.Resources	Resources & Technology

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Life on Earth
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Options
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Genetics:Code Broken?

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Metals
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Energy
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Water Issues
Dynamic Earth
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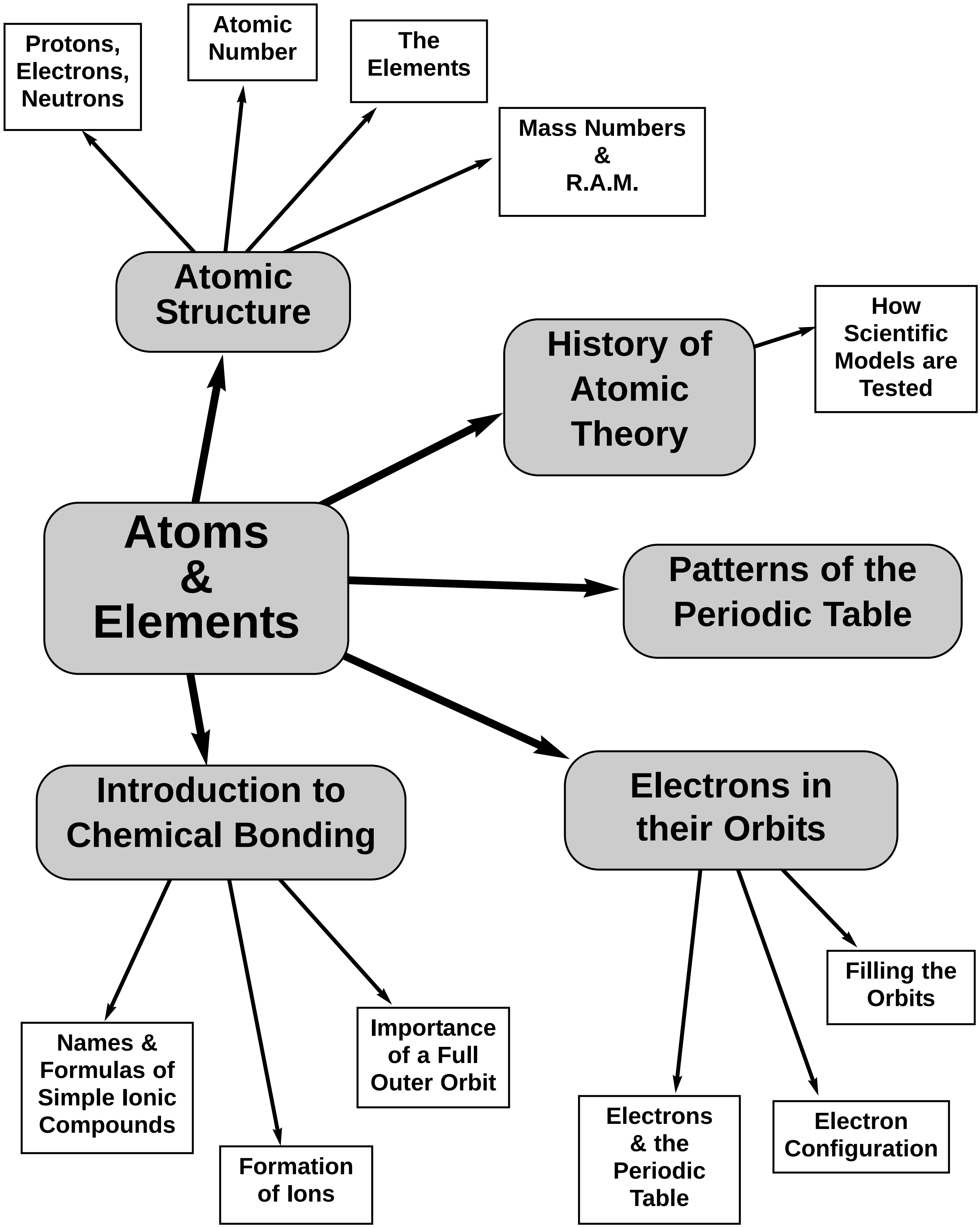
"Mind-Map" Outline of Topic

This topic belongs to the branch of Science called "Chemistry".
Chemistry is the study of matter and materials. Chemistry looks at the properties of substances, and how substances can change into new forms.



Make your own "Mind-Map" TITLE PAGE.
Cut out the boxes. Sort them into an appropriate lay-out on a page of your workbook, then glue them down. Add connecting arrows and colour in.

Atoms & Elements

Introduction to Chemical Bonding

Atomic Structure

Patterns of the Periodic Table

History of Atomic Theory

Electrons in their Orbits

Electron Configuration

The Elements

Formation of Ions

How Scientific Models are Tested

Mass Numbers & R.A.M.

Filling the Orbits

Electrons & the Periodic Table

Names & Formulas of Simple Ionic Compounds

Atomic Number

Protons, Electrons, Neutrons

Importance of a Full Outer Orbit

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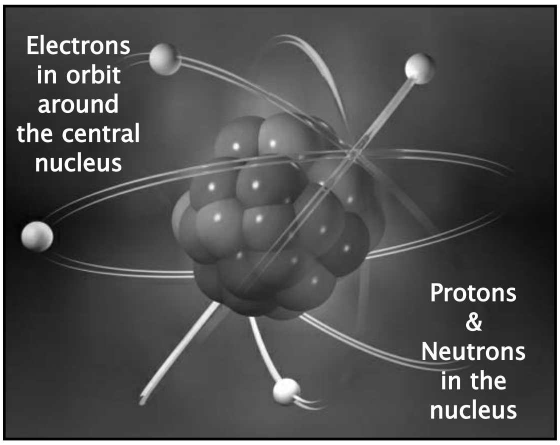
Importance of a Full Outer Orbit

Everything is Made of Atoms

You should already be aware that everything is made of tiny "lumps" of matter called "atoms". Each atom acts as if it was a solid ball, but we know that each one is made up of even smaller particles.

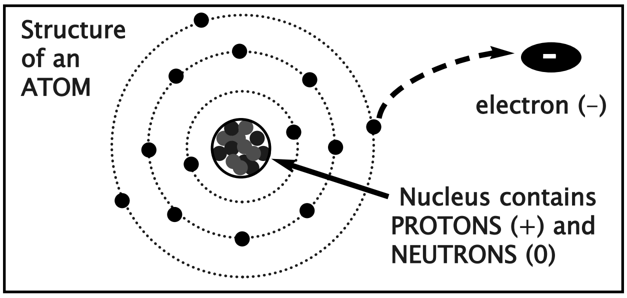
Structure of Atoms

In general terms, each atom is like this:



However, this rather artistic image is wildly inaccurate in size proportions, and in the numbers of smaller particles shown.

Here is another "model" atom. Its proportions are wrong as well, but it does show electrons in different orbits, which we believe to be accurate.



We use various "models" to depict atoms... none of the models is perfect!

Protons, Electrons & Neutrons

The <u>electrons</u> are whizzing around the central <u>nucleus</u>, like miniature planets around the Sun.

Each electron, and each proton in the nucleus, carries an <u>electrical charge</u>.

Electrons carry negative charge.

Protons carry positive charge.

The electrons have a lot of energy and move rapidly. They would instantly fly off in all directions except for their electrical attraction to the protons in the nucleus.

So, the orbit of an electron is the "balance" between its fast movement and the electrical attraction pulling it towards the nucleus.

Protons in the nucleus repel each other electrically, so why doesn't the nucleus fly apart?

The protons and neutrons in the nucleus are held together by an even more powerful force called simply the "<u>strong nuclear force</u>". This force easily overpowers electrical repulsion.

How Small is an Atom?

A "medium-size" atom is less than one millionth of a millimetre in diameter.

There are about a million billion atoms in a single grain of sand... that's about 1,000,000,000,000,000 atoms!

There are more atoms in a single grain of sand, than there are grains of sand on a whole beach!

If every atom in a grain of sand suddenly became a sand grain, you'd have a pile of sand several kilometres high!

Get the Picture?

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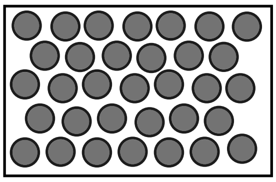
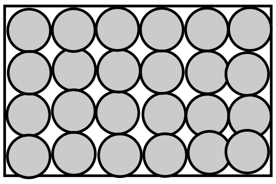
Atoms & Elements

One Type of Atom = Chemical Element

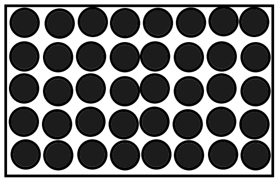
A chemical element is a substance made entirely of identical atoms.



Element 1



Element 2



Element 3

The atoms of each element are all the same as each other.
The atoms of one element are different to the atoms of another element.

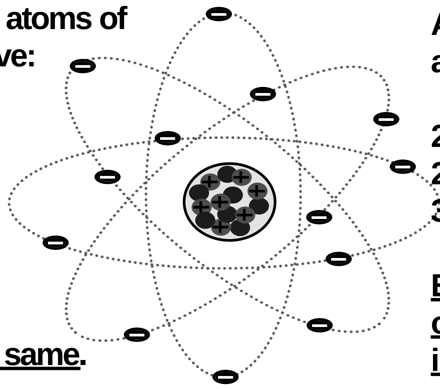
How are the atoms of different elements different?

The atoms of each element have a certain number of protons, electrons and neutrons.

For example, the atoms of aluminium all have:

13 protons
13 electrons
14 neutrons
(not all shown here)

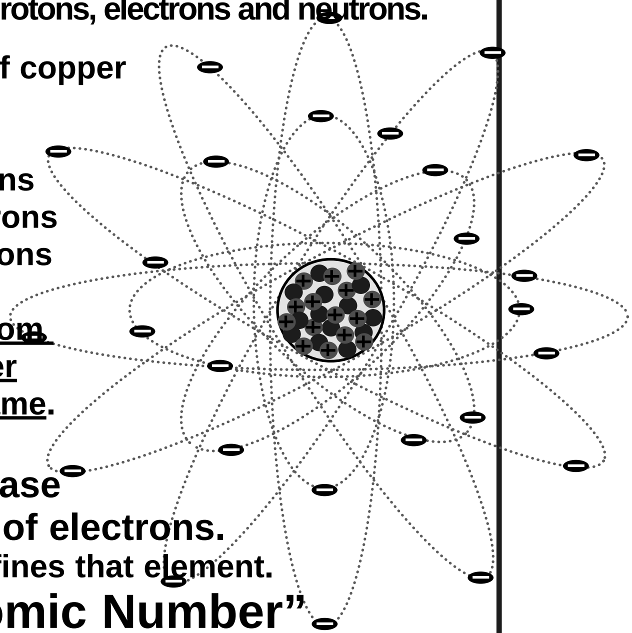
<u>Every atom of aluminium is the same</u>.



Atoms of copper all have:

29 protons
29 electrons
34 neutrons

<u>Every atom of copper is the same</u>.



Notice that in each case
Number of protons = Number of electrons.
This is true for every element, and defines that element.

Protons = Electrons = "Atomic Number"

Electrical Charges Balance

Remember it is the protons (+ve) and the electrons (-ve) which carry an electrical charge. (Neutrons have no charge.)

Since the numbers of electrons and protons are always equal, they cancel out and so atoms have no overall electrical charge.

Atomic Number Defines Elements

If you are told that a certain atom has (say) 8 protons, then you know it must have 8 electrons and its "Atomic Number" = 8.

This is enough to identify it as an atom of oxygen with the characteristic properties of that element.

Actually, it isn't quite true that every atom of an element is exactly the same.
The <u>number of neutrons</u> can vary. However, the number of protons & electrons is always equal, and is a fixed number for each chemical element.
For simplicity (K.I.S.S. Principle!) we will continue to use the concept that atoms of any given element are identical.

The Chemical Elements

How Many Elements?

We now know that about 90 chemical elements occur naturally on Earth. Another 20 (or so) can be made artificially in nuclear reactors.

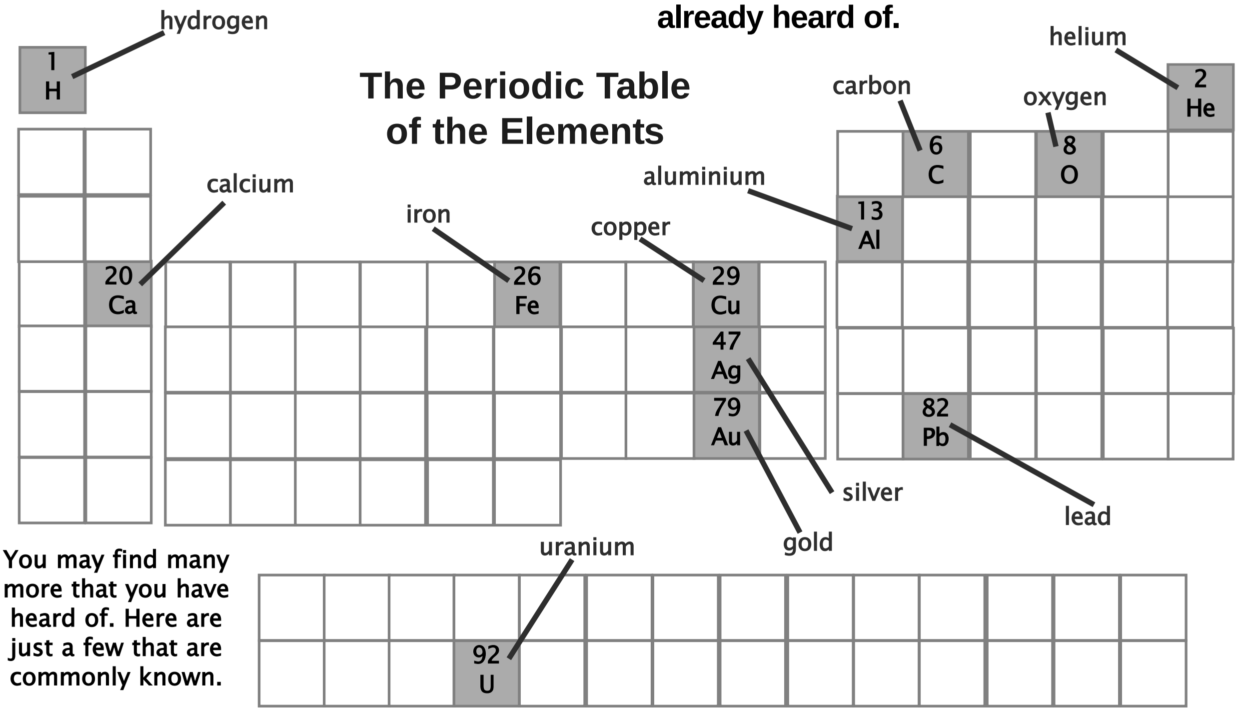
Of these elements, many are very rare. Most of the familiar substances on Earth are made from only about 20-30 of the most common elements.

The Periodic Table

The best way to learn about the elements is to study the "Periodic Table", which is a special list of all the elements.

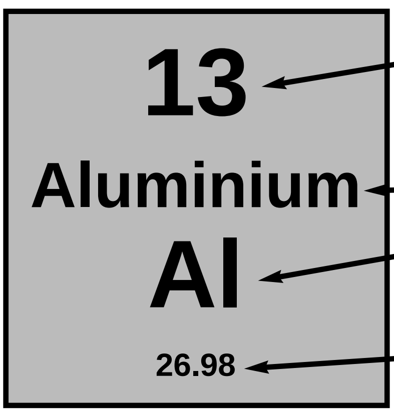
Your teacher may give you a copy, or show you a wall chart.

The first thing to do is to look through it and see how many elements you have already heard of.



You may find many more that you have heard of. Here are just a few that are commonly known.

How to read the information



"Atomic Number"
The elements are numbered, in order, across and then down the table. This puts the elements in a numerical order, but it also tells you how many electrons & protons in each atom.

Name of the Element

Chemical Symbol
Each element has a short-hand symbol. It is always one capital letter, OR if 2 letters, always a capital followed by a lower case letter.

"Relative Atomic Mass" (RAM)
This gives the relative mass, or weight, of an atom of the element.

Why is the table such an odd shape?

Why not put the elements in a simple rectangular box table?
The Periodic Table has this shape so that elements that are similar to each other are under each other, or in "groups" and "blocks'.
It is called "periodic" because it has patterns that re-occur in a regular pattern.
You will learn these patterns as you learn more about Chemistry.

The Mass of Atoms

Obviously a single atom has an extremely small mass if you measure it in grams. In Chemistry we usually consider the relative mass of different atoms. To find relative mass, we simply compare how many particles each atom has within its structure.

Mass of Protons, Neutrons & Electrons

The mass of an atom depends on how many particles it has within its structure.

It turns out that protons and neutrons are about the same mass. This amount of mass is called the "atomic mass unit" or "amu". (1 amu is about 1 million billion billionth of a gram, but let's not go there.)

Electrons are so light ($^1/_{1,800}$ amu) that, for all practical purposes, they can be ignored when working with atomic mass.

The relative mass of an atom can be found by simply adding together the number of protons and neutrons in the nucleus.

Particle	Charge	Mass
Proton	+1	1 amu
Electron	-1	$^1/_{1,800}$ (ignore it)
Neutron	0	1 amu

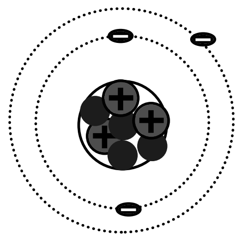
Atomic Mass Number

Atomic Mass Number = No. of Protons + No. of Neutrons

This must be a whole number for any atom.
(You can't have half a proton!)

Example 1

An atom of the element lithium (Li) contains:



3 protons $3\ p^+$
3 electrons $3\ e^-$
4 neutrons $4\ n^0$

From this you can immediately state:

Atomic Number = 3 (No. of p^+ or e^-)
and
Atomic Mass Number = 7 ($p^+ + n^0$)

Example 2
The element fluorine (F) has

Atomic No. = 9 & At. Mass No. = 19

How many particles in a fluorine atom?

Since Atomic No. = 9,
it must have 9 p^+ and 9 e^-.

Since Mass No. = 19, and it has 9 p^+,
it must have 10 n^0.

Mass Numbers & R.A.M.

The "Mass Number" for an individual atom is always a whole number. The "Relative Atomic Mass" (RAM) listed on the Periodic Table is usually not. What's going on?

In fact, the number of neutrons in the atoms of an element can vary, so the Mass Numbers can be slightly different among the atoms of one element.

The RAM shown in the Periodic Table is the average of these slightly different Mass Numbers.

Let's Keep It Simple!

If you want to know the Mass Number for any element:

- Read the RAM for that element from the Periodic Table. (example: Zinc, RAM = 65.37)
- Round-off to the nearest whole number. (= 65)
- Take this to be the Atomic Mass Number for the element. (example: Zinc = 65)

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Worksheet 1
Atoms & Elements

Student Name...

Fill in the blank spaces.

Everything is made up of a).................... Each atom is made of smaller particles. b)...................... (carry a +ve charge) and c)....................... (no charge) are in the central d)............................. In orbit around this are the e)............................, which carry f)....................... electrical charge.

The number of g)...................... is always equal to the number of h)........................., so electrical charges are i).......................

An element is a substance made up entirely of j)......................... ....

The atoms of one element are k)................ to atoms of another element because they have different numbers of l)....................., ... and ....

The number of m).................................. or .... in an atom is called the n) ".....................” Number. The elements are arranged in order of this number in the o)............................. Table.

The relative mass of an atom depends on how many p)........................ plus .... it contains. (The q).......................... are not counted because their mass is insignificant).

Worksheet 2
Describing Atoms & Elements

Complete the blanks in the table.

Student Name...

You will need to refer to a Periodic Table to do some of this.

Element name	Symbol	Atomic Number	Atomic Mass Number	number of protons	number of electrons	number of neutrons
Boron	B	5	a)....................	b)............	c)............	6
Sodium	Na	11	d)....................	e)............	f)............	12
Argon	g)...........	h).............	i)....................	j).............	18	22
k)..................	F	9	19	l)............	m)............	n)...........
Iron	o)...........	26	56	p)............	q)............	r)...........
Uranium	s)...........	t)............	238	92	u)............	v)...........
w).................	x)...........	y)............	z)....................	aa)...........	38	50
ab)...............	ac)..........	79	197	ad)...........	ae)............	af)............
ag)................	Pb	ah).............	ai)......................	aj)............	ak)............	al)............

History of Our Understanding of Atoms, part 1

The history of Chemistry and our understanding of "elements" was covered in an earlier topic. Here we focus on knowledge of atoms.

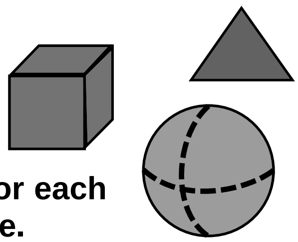
Democtritus
Ancient Greek, 400 BCE

Democritus imagined that he had a "magic" knife and could keep cutting a substance into smaller and smaller pieces. He wondered if he would reach an ultimately small particle that could not be cut any more?

He decided that matter was probably made of ultimate "units" of matter. He called them "atomus", which means something that cannot be cut or divided.

Atomic Model

Unbreakable particles; a different particle for each different substance.



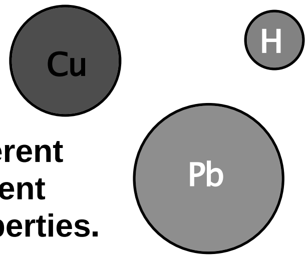
John Dalton
English, 1808

Dalton's experiments with Chemical Reactions showed that substances always reacted and combined in fixed ratios by weight.

He reasoned that each element must have unique atoms which react and combine with each other in simple ratios.

Atomic Model

Unbreakable spheres. Each element has different atoms with different weights and properties.



For about 90 years during the 19th century, there was little progress on the knowledge of atoms. Chemical Science made progress: many new elements were discovered, the Periodic Table was invented, new processes and new substances were discovered, but nothing new about atoms. The key to progress was electricity...

Joseph Thomson, English 1897

Studying the mysterious "cathode rays", Thomson identified a small particle with a negative electrical charge.

Cathode Ray Tube, ancestor of the TV set.

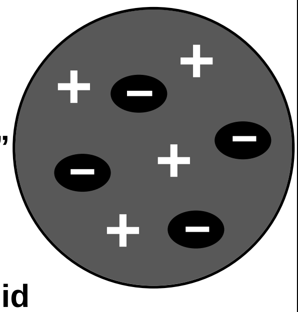
He had discovered the electron.

He proved that exactly the same particles (electrons) were present in every kind of atom tested. This suggested that all atoms contain these small negative particles.

If every atom contains negative particles, there must be a positively charged material in every atom to balance the electrical charge.

Atomic Model

Thomson proposed the "plum-pudding" model in 1904.



He suggested that each atom was a solid ball of positively-charged material with electrons embedded in it.

History of Our Understanding of Atoms, part 2

Ernest Rutherford, English (born New Zealand) 1911

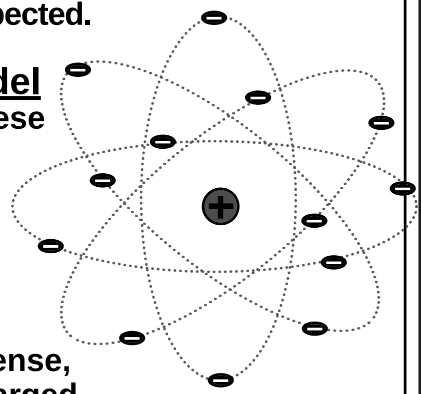
Rutherford and his team set out to test the "plum-pudding model" of the atom by experiment. They used the newly discovered science of "radio-activity" to bombard some atoms with alpha-particles.

Alpha-particles have a positive charge, so Rutherford expected that the positive part of atoms might cause a slight deflection to the speeding alpha-particles. He had already calculated the expected result, if the plum-pudding model was correct.

The result was totally unexpected! Most of the α-particles went straight through the target atoms. A few were deflected much more than expected.

Atomic Model

To explain these results Rutherford suggested that atoms were mostly empty space with a tiny, dense, positively-charged nucleus in the middle. The electrons must orbit around the nucleus.



Rutherford thought it likely that there were individual positively-charged particles in the nucleus. They were named "protons". Their existence was confirmed by experiments a few years later. It was realised that there had to be an extremely powerful force holding the protons together against the electrical repulsion they would exert on each other.

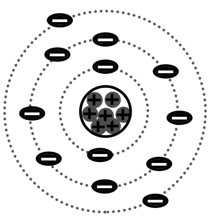
Niels Bohr, Danish 1913

Bohr worked out mathematically that the electrons in Rutherford's model must be in precise, layered orbits.

This arrangement instantly explained the mystery of "spectral lines" which are observed when atoms absorb or emit energy. It also explained the "valency" of different elements and how chemical bonds can form.

Atomic Model

Electrons are in precise orbits which have an exact amount of energy.



Only a certain maximum number of electrons can fit in each orbit.

Einstein's Theory of Relativity (1915) gave a possible explanation for the "nuclear force" which might hold the nucleus together. The first "atom bomb" proved the theory correct.

In the 1920's it became clear that protons and electrons could NOT account for all the mass of atoms. There must be another type of particle, probably with no electrical charge... neutrons.

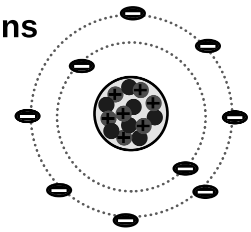
James Chadwick, English 1932

Chadwick devised a clever experiment to prove the existence of the hypothetical "neutrons".
Sure enough, he found them!

Atomic Model

Atomic nucleus contains protons and neutrons.

Electrons orbit the nucleus in "Bohr" energy levels.



Much more has been learned about atoms since the 1930's.
However, the atomic model above is still useful for you to learn Chemistry.
This is the model we will use here.

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Worksheet 3
History of Atomic Theory

Student Name..

Fill in the blank spaces.

The earliest known theory of atoms was put forward by a)............................., an ancient Greek.

The first modern atomic theory was proposed by b)............................ in 1808. He suggested that each chemical c)............................ was made up of identical, unbreakable spheres.

Almost 100 years later, the d).................. was discovered by e)........................ His model was called the f) "................ Pudding Model", because it involved each atom being a g).........................-charged sphere with electrons embedded in it.

Ernest h)............................ tried to test this model in 1911. His famous experiment with i)...................-particles led to the idea that atoms must have a tiny j)............................, with the electrons k).......................... around it.

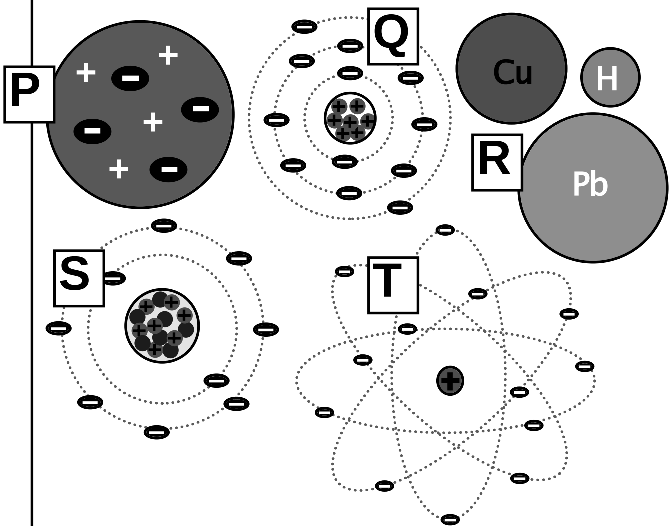
Neils l).......................... (1913) showed mathematically that the orbits must have exact amounts of m)........................ and each can hold a maximum number of n)................................

The positive charge was found to be carried by o)........................., but the known particles could not account for all the p)..................... of atoms. The discovery of the q)....................... by r)................................ (1932) gave us the model still useful for Chemistry.

Worksheet 4
Atomic Models

Student Name..

The following diagrams show some <u>modern</u> atomic models.



1.
Use the letters P,Q,R,S & T to list the models in correct time order.

....

2.
For each model P,Q,R,S,T name the scientist associated with the model.

<u>Choose from scientists in this list</u>.
Rutherford, Thomson, Einstein, Chadwick, Dalton, Bohr, Newton. (Not all will be used)

<u>Model</u>	<u>Scientist</u>
P	....
Q	....
R	....
S	....
T	....

3. List the 3 atomic particles in the order in which they were discovered.

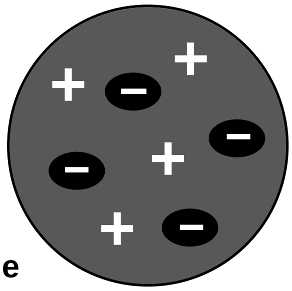
....

How Scientific Models are Tested

The history of atomic research contains several good examples of the general methods of Science itself. It shows how scientists put forward ideas to explain the known facts. These "models" are then tested by experiments. If the experimental results seem to support the model, it gains a little more acceptance. If the results contradict the model, it may be rejected and the whole process begins again with a new, or modified, model.

Rutherford's Testing of the "Plum-Pudding" Atom

J.J.Thomson put forward his "plum-pudding" model of the atom in 1904. It seemed a totally reasonable idea which fitted with all the known facts of the time.



Ernest Rutherford set up an experiment to test Thomson's idea. He was NOT trying to prove it wrong. He thought it was a good model and was looking to add evidence to prove it correct. But, it had to be tested... that's good Science.

When the experiment produced unexpected results, Rutherford was sure the experiment had been done incorrectly and ordered it to be done again and again.

Only when he was convinced that the unexpected results were valid did he realise the truth... Thomson's model was wrong!

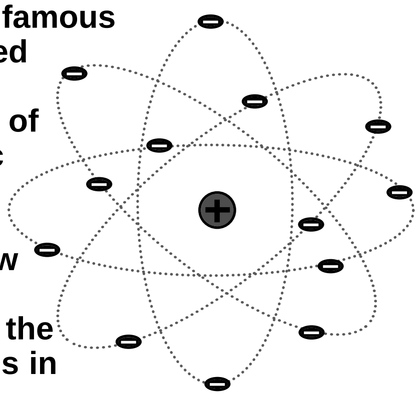
This doesn't mean Thomson had failed. His model was a good one for what was known in 1904. When Rutherford found out more facts, the Thomson model had to be discarded and replaced.

Thomson would have been pleased that his model led to the Rutherford experiment which brought Science a step closer to the whole truth.

We are still learning.

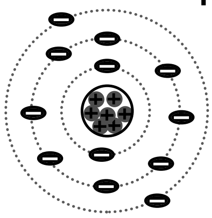
Testing Models with Mathematics

Rutherford's famous experiment led to the development of a new atomic model.



The atom now had a tiny nucleus with the little electrons in orbit.

Niels Bohr set out to analyse this orbital arrangement mathematically using a new idea called "Quantum Theory". This had been developed in 1900 to explain certain aspects of energy radiation.



Bohr found the model only worked if the electrons were in fixed orbits at precise energy levels.

Importantly, his mathematics also explained perfectly a strange phenomenon called "spectral lines" which had been known in detail for over 30 years, but could never be explained.

Bohr's orbits also explained perfectly the observed details of chemical "valency" which governs how atoms join together when compounds are formed.

When a theoretical mathematical analysis leads to a perfect description of an observed set of facts like this, scientists know that the model must contain some truth, no matter how weird it might be.

Patterns of the Periodic Table, part 1

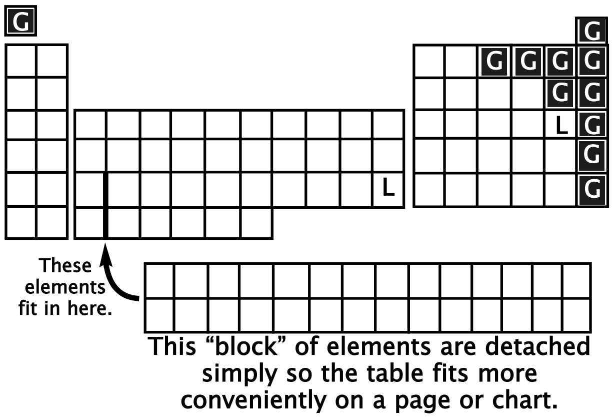
To understand the chemical elements better, you need to study the Periodic Table and learn about some of the "groupings" of elements. Here is a quick review of some facts covered in previous topics.

Solids, Liquids & Gases at room temperature (25ºC)

Solids

The vast majority of elements are solids at room temperature.

All the unshaded boxes in this diagram represent the solid elements.



Liquids

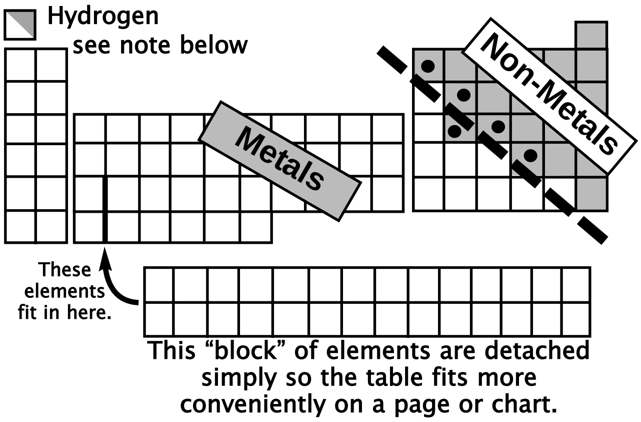
Only 2 elements are liquids at room temperature...

bromine (element 35) and mercury (element 80)

Gases

All the gases are clustered in the top right corner, except hydrogen. These gases also include some elements which are very important to living things, (e.g. oxygen) or are commonly encountered in general chemistry (e.g. chlorine).

Metals & Non-Metals



<u>Hydrogen</u> does not clearly fit in with the "metal-non-metal" classification and is often shown detached from the table. Hydrogen has the physical properties of a non-metal, but often acts chemically like a metal.

The elements marked with a dot on the diagram above are sometimes called "<u>metalloids</u>". They have some metal-like properties (e.g. shiny) and some non-metal properties (e.g. brittle) and some in-between properties. For now, we will consider them as non-metals.

Comparison of Properties

Metals	Non-metals
• Shiny appearance	• Most not shiny
• All solids (except mercury)	• Some solid, many gases, 1 liquid.
• Good conductors of electricity.	• Most are poor conductors. (exception = carbon)
• Malleable & Ductile	• Brittle, not malleable nor ductile.

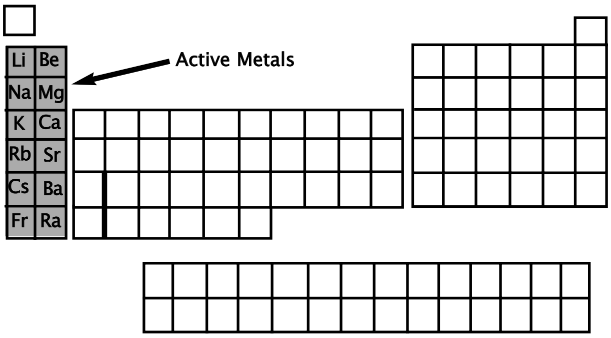
"<u>Malleable</u>" means it can be hammered or pressed and flattened into thin sheets. "<u>Ductile</u>" means it can be stretched and drawn out into wires, especially when hot.

If you tried to make a thin "foil" or a wire from any solid non-metal it would shatter like glass.

Patterns of the Periodic Table, part 2

To understand the chemical elements better, you need to study the Periodic Table and learn about some of the "groupings" of elements.

Active Metals



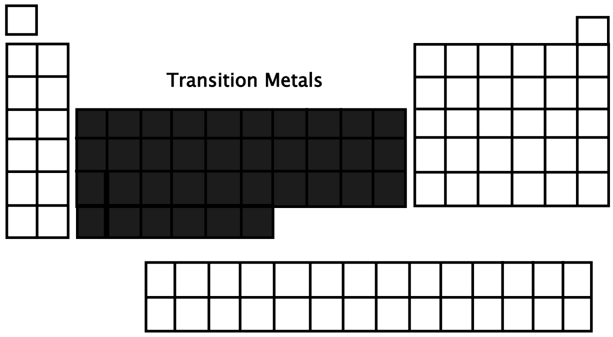
On the far left side of the Periodic Table are 2 columns of metals which are different to most other metals.

They are relatively soft and low density.

More importantly, they are chemically very active and will ignite and burn violently in air.

Some will even explode if dropped into water. These have to be stored in containers filled with oil to keep air and moisture away.

Transition Metals



In the centre block of the table are located most of the common, well known metals including iron, copper, gold and silver.

These are "typical" metals. Most are hard and shiny and many have very high melting points.

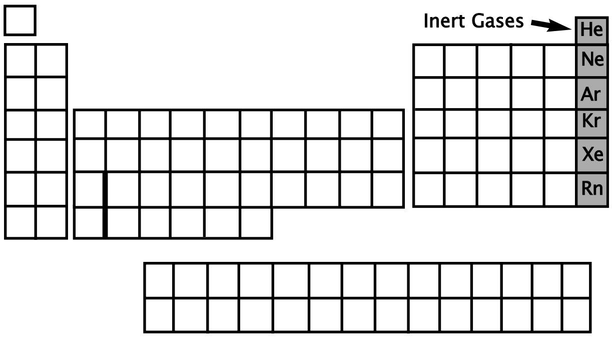
Included here are metals we use for tools and machinery, electrical elements and appliances. We use these metals to build bridges, ships and skyscrapers.

Except for lead, tin and aluminium, all of our most useful metals are here.

The Inert Gases

The far right column of elements are all gases.

Their most important property is that they do NOT react chemically with anything, so they never form chemical compounds.



"Inert" means "to not move or do anything".

Here it refers to being chemically inactive. These elements will not interact with others.

Soon you will find out why.

Practical Uses for Inert Gases

Helium has such low density that it is "lighter than air" and will lift a balloon. It cannot burn, so it is much safer than hydrogen. Argon is used in welding. A cloud of inert gas blankets the hot metal and prevents corrosion in air. Neon fills the tubes of "neon lights".

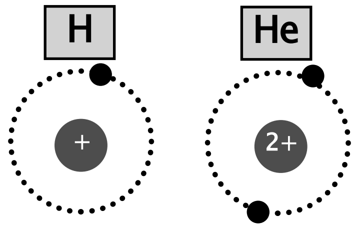
Electron Orbits

It is the electrons which control Chemistry.
How an atom interacts with others to form compounds and undergo chemical reactions, all depends on the number of electrons and how they are arranged.

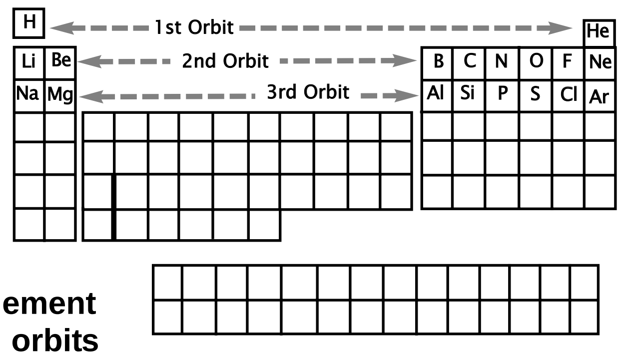
Filling the Orbits

As you go across each row of the Periodic Table, each element has one more electron than the previous. The lowest electron orbits are always filled first.

1st Orbit can hold only 2 electrons



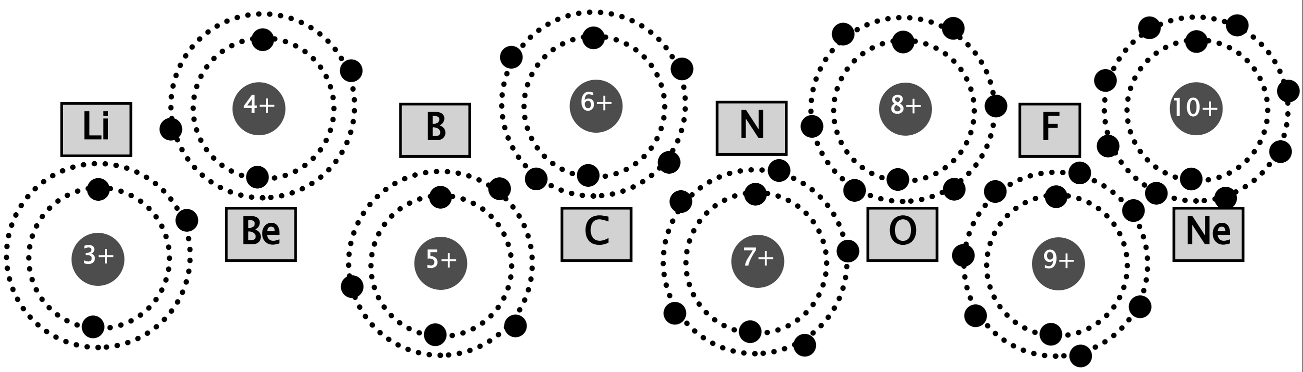
Once an orbit is full, electrons begin filling the next higher orbit.



Hydrogen	Helium
1	2
1	2

Name
Atomic Number
Electron Arrangement in orbits

2nd Orbit can hold 8 electrons



Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
3	4	5	6	7	8	9	10
2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8

3rd Orbit can hold 8 electrons

(This is not quite true, but for simplicity, you should accept this for now)

Na	Mg	Al	Si	P	S	Cl	Ar
Sodium	Magnesium	Aluminium	Silicon	Phosphorus	Sulfur	Chlorine	Argon
11	12	13	14	15	16	17	18
2.8.1	2.8.2	2.8.3	2.8.4	2.8.5	2.8.6	2.8.7	2.8.8

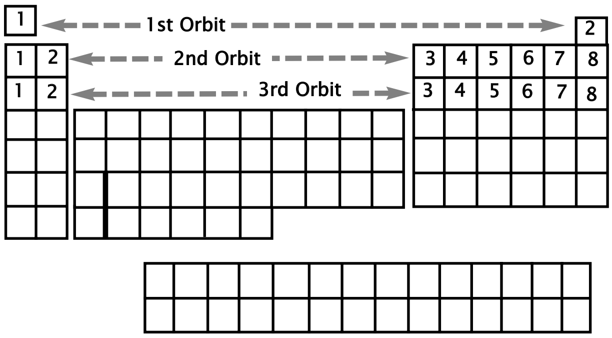
Beyond the 3rd orbit things become more complicated.
You do not need to know the details.

Electrons in the Outer Orbit

If you consider just the number of electrons in the <u>outer orbit</u> of each element, another pattern appears on the Periodic Table.

Here are the data for the elements on the previous page.

No. of Electrons in Outer Orbit

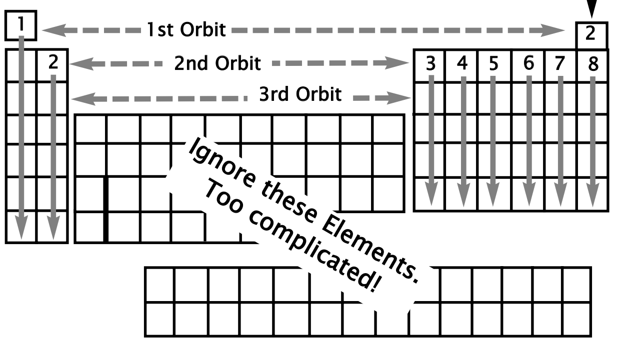


See the pattern?

This pattern is continued downwards through the table. Elements in the same column have the same number of electrons in their outer orbit.

For the elements in the far right column (Inert Gases) you should note that their outer orbit is full.

No. of Electrons in Outer Orbit



Each row of the Periodic Table lists elements which are filling the same orbit.

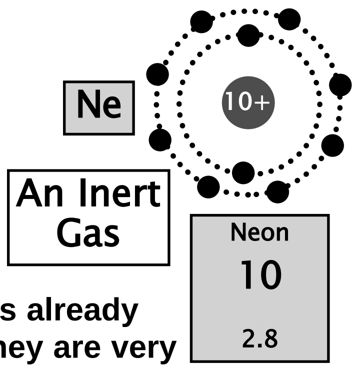
Each column lists elements which have the same number of electrons in their outer orbit.

The Importance of a Full Outer Orbit

Energy Levels

As Niels Bohr worked out in 1913, the orbits of the electrons around the nucleus are not just places for electrons to hang out, they are "<u>Quantum Energy Levels</u>" within the atom.

In the strange world of quantum energy, an atom achieves great <u>energy stability</u> if its <u>outer orbit is full</u>.



All the <u>Inert Gas</u> elements already have a full outer orbit. They are very stable and have no need to do anything to become "perfect".

That is why they do not react with anything and do not form compounds.

How Atoms Get A Full Outer Orbit

All the other elements do NOT have a full outer orbit. To achieve the "perfect" stable energy state atoms can either:

- <u>GAIN ELECTRONS</u> to fill up their outer orbit.

OR

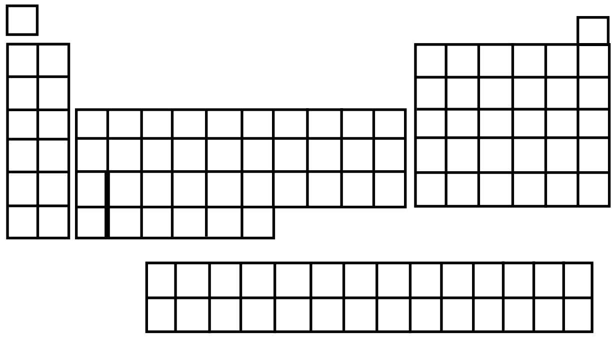
- <u>LOSE ELECTRONS</u> and completely shed their outer orbit. Their "new" outer orbit becomes the one underneath, which is full and "perfect".

As you will see, to gain or lose electrons atoms must interact with each other.

The result is Chemistry!

Worksheet 5
Periodic Table

Student Name...



Answer the following questions.
For some write numbers or letters on the blank Periodic Table, as instructed.

1. Use letter "i" (as many as needed) to show clearly where the "inert gases" are located.

2. Mark one square with the letter "G" to show an element that is a gas at room temperature, <u>apart from</u> the inert gases.

3. Rule a line to show the (approx) dividing line between metals and non-metals.

4. Use number "4" (as many as needed) to show a <u>column</u> of elements which all have 4 electrons in their outer orbit.

5. Draw a circle around part of the table where the "transition metals" are found.

6. Use letter "A" (as many as needed) to show clearly a <u>column</u> of metals which are chemically very active.

7. Mark one square with "X" to show the element which has exactly 7 electrons in its 3rd orbit.

8. Mark one square with "22" to show the element with Atomic Number = 22.

Worksheet 6
Electron Arrangements

Student Name...

Answer these questions from "first principles", <u>without</u> referring to the Periodic Table.

1. Complete this table.

Element	Total electrons	Electron Arrangement
example	11	2.8.1
A	7	
B	15	
C		2.8.8.1
D	18	
E	9	
F	10	
G	17	
H	20	
I	16	
J	12	

2. Use the letters A,B,C, etc from Q1 to answer the following.

a) Which element(s) is/are inert gases?

b) Which element occurs on the Periodic Table in the same column as element "E"?

c) Which element occurs on the Periodic Table in the same column as element "J"?

d) Which element(s) is/are "Active Metals" which occur in the 2 left-hand columns of the Periodic Table?

e) Which elements have an incomplete 2nd orbit of electrons?

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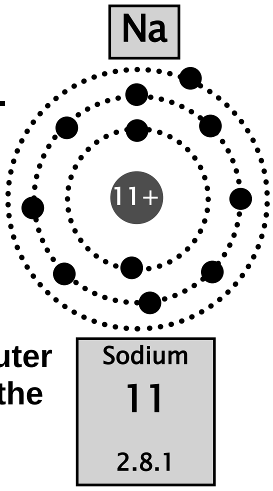
Atoms Form Ions

The easiest way to understand how atoms can achieve a full outer orbit, and what happens after that, is to carefully study some examples.

Metal Atoms Lose Electrons

Consider an atom of the metal sodium.



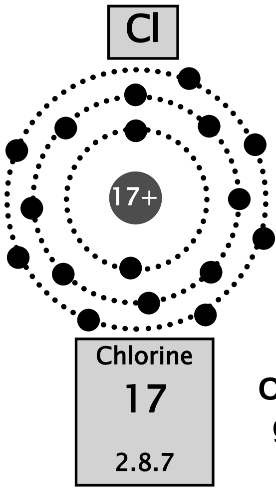
It has just 1 electron in the outer 3rd orbit.

Gaining another 7 electrons is far too difficult.

Instead, if it were to lose 1 electron, its outer orbit would become the full 2nd orbit.

Non-Metal Atoms Gain Electrons

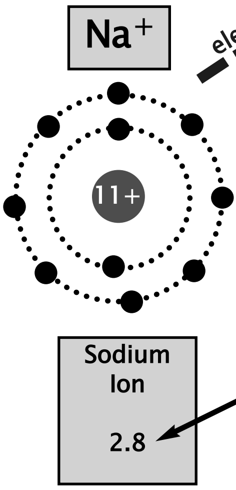
Here's an atom of the non-metal chlorine.

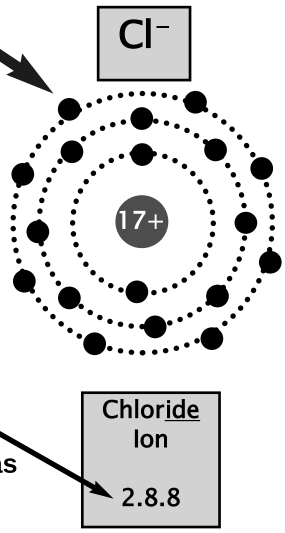


It has 7 electrons in its outer 3rd orbit.

If it gains 1 more electron , the outer orbit would be full.

Can you see what's going to happen?





The sodium atom loses its outer electron.

The chlorine atom gains an electron.

Both atoms have achieved a full outer orbit.

LOOK!

Ions

(Atoms with an electrical charge)

The sodium atom has lost an electron.

It now has 10 electrons (e^-), but it has 11 protons (p^+) in the nucleus.

This means that it has a surplus electrical charge of 1+.

This is now called a "<u>sodium ion</u>", and it behaves differently to a sodium atom.

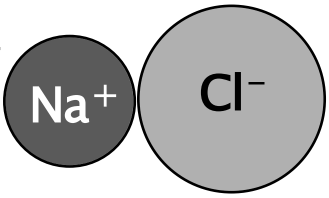
The chlorine atom has gained an electron.

It now has 18 electrons (e^-), but it still has 17 protons (p^+) in the nucleus.

This means that it has a surplus electrical charge of 1-.

This is now called a "<u>chloride ion</u>", and it behaves differently to a chlorine atom.

These ions now become stuck together because of their electrical attraction for each other. (There's never just 2; billions of Na^+ and Cl^- ions join.)



These ions are "<u>chemically bonded</u>" together. They form the compound

sodium chloride, formula NaCl

Ionic Compounds

**When atoms become ions and stick together, they form a new substance.
This is a chemical compound, with different properties to the original elements.
Ionic compounds form crystals, made of billions of ions stuck together.**

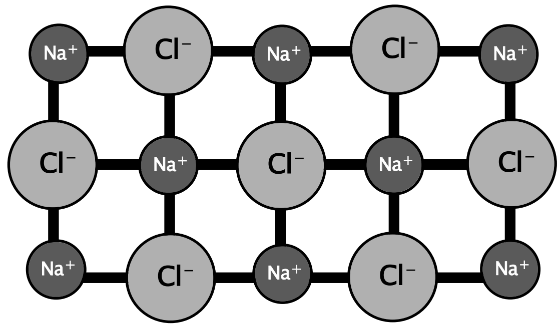
The diagram represents part of a crystal of salt. Salt is the ionic compound sodium chloride, NaCl.

In a real crystal there would be billions of ions in a 3-dimensional "lattice".

The "sticks" joining the ions represent the "ionic chemical bonds" holding the ions together. In reality, the bond is the force of electrical attraction due to their opposite charges.

The formula "NaCl" indicates that the ions stick together in a ratio of 1:1 (in equal numbers).

Other ions may join in a different ratio.



The compound is totally different to the elements it is made from.

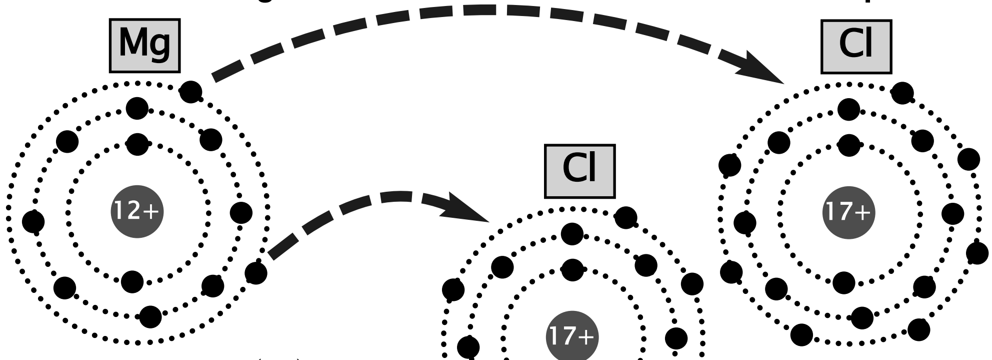
Sodium: shiny, silver, soft metal. Good conductor. Reacts violently with water.
Chlorine: yellow-green gas. Poisonous. Non-conductor.
Salt: White crystals. Dissolves in water. Good on chips!

Another Example: $MgCl_2$

Here is what happens if atoms of magnesium and chlorine react to form a compound.

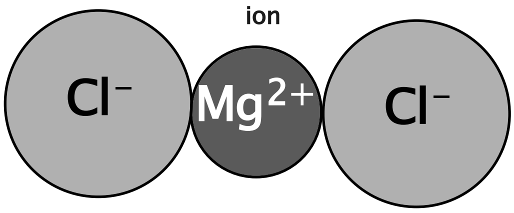
With 2 electrons in the outer orbit, a magnesium atom needs to lose 2 electrons.

It can do so by reacting with 2 chlorine atoms. Each chlorine gains 1 electron to fill its outer orbit.



Magnesium atom (Mg) becomes a magnesium ion (Mg^{2+}). Notice the charge is 2+ because 2 electrons are lost.

2 chlorine atoms (Cl) become 2 chloride ions (2 x Cl^-). Notice the change of name.



The result is the formation of 2 chloride ions for every 1 magnesium ion... a ratio of 1:2.

That's why the compound formula is $MgCl_2$.

(Of course, there will actually be billions of ions in the crystal lattice)

Valency

The "valency" of an element refers to its "combining ratio" when it forms compounds with other elements.
For simple ionic compounds, the valency of each element is the same as the electrical charge that the ion gets when it achieves a full outer orbit of electrons.

3 electrons in outer orbit. Lose 3. Ion charge 3+.

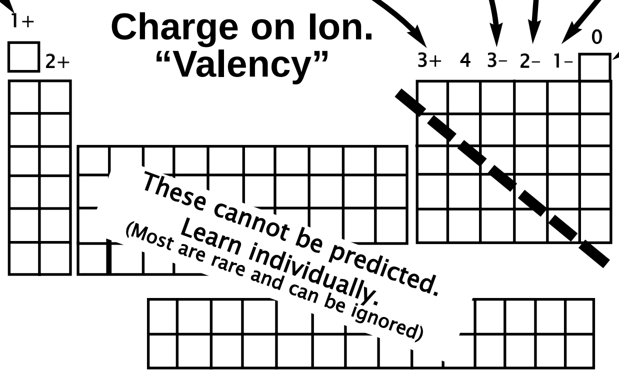
5 electrons in outer orbit. Gain 3. Ion charge 3-.

6 electrons in outer orbit. Gain 2. Ion charge 2-.

These all have 7 electrons in their outer orbit. They gain 1 electron, so the ion has charge 1-.

Active Metals all have either 1 or 2 electrons in their outer orbit.

They lose the outer electron(s) and form an ion with charge 1+ or 2+



Inert Gases full outer orbits.

They do not gain or lose electrons. They do not form ions. They do not form compounds. This is why they are "inert".

What about atoms with 4 electrons? Do they gain or lose? It depends! Elements at the top of the table (e.g. carbon) act like non-metals and gain electrons. Valency = 4-.

Those lower down (e.g. tin, lead) are metals and lose electrons. Valency 4+.

Ions & Valencies of Some Common Laboratory Elements

METALS (lose electrons)				NON-METALS (gain electrons)			
Element	Symbol	Electrons in outer orb.	Valency (ion charge)	Element	Symbol	Electrons in outer orb.	Valency (ion charge)
Hydrogen	H	1	1+	Fluorine	F	7	1-
Sodium	Na	1	1+	Chlorine	Cl	7	1-
Potassium	K	1	1+	Bromine	Br	7	1-
				Iodine	I	7	1-
Magnesium	Mg	2	2+				
Calcium	Ca	2	2+	Oxygen	O	6	2-
Barium	Ba	2	2+	Sulfur	S	6	2-
Aluminium	Al	3	3+	Nitrogen	N	5	3-
				Phosphorus	P	5	3-
				Carbon	C	4	4-

All these can be easily predicted from the Periodic Table.

Naming Simple Ionic Compounds

When atoms gain or lose electrons to form ions, they then get stuck together by their electrical attraction to form a "crystal lattice" of ions.
This forms a new "compound", totally different to the original elements.

What is the name of each compound?

Names of Metal Ions

Metal atoms lose 1 or more electrons to form an ion. The name of the ion is the same as the atom.

e.g. Sodium atom → Sodium ion

Names of Non-Metal Ions

Non-Metals gain electrons to form ions. Their name always changes to end in -IDE.

e.g. Chlor<u>ine</u> atom → Chlor<u>ide</u> ion

Names of Compounds

Simply put the two ion names together, with the <u>metal always first</u>.

<u>Examples</u>:

Compound of sodium + chlorine = "<u>sodium chloride</u>"
Compound of barium + oxygen = "<u>barium oxide</u>"
Compound of sulfur + aluminium = "<u>aluminium sulfide</u>"

Formulas for Simple Ionic Compounds

A chemical formula uses the symbols of the elements to describe a compound.
The symbols identify which elements are involved,
and shows the ratio in which the ions combine.

Steps to Write a Formula

1. Write down the symbols of the elements involved, <u>with the metal always first</u>.

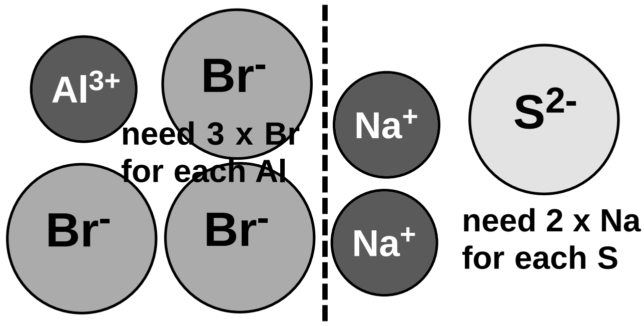
2. For each element, consider its valency, or the charge on its ion.
Work out the simplest ratio which gives <u>equal amounts</u> of (+ve) and (-ve) charge.

3. Write suffix numbers after each symbol to show this ratio.

<u>Number one (1) is not written</u>.
(It is assumed from the symbol.)

<u>Examples</u>
Compound of:

<u>aluminium</u> & <u>bromine</u>	<u>sulfur</u> & <u>sodium</u>
Al Br	**Na S**



$AlBr_3$ aluminium bromide	**Na_2S** sodium sulfide

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Worksheet 7
Atoms Form Ions

Student Name..

Fill in the table from "first principles", without referring to the Periodic Table.

Element	Total electr.	Electron Arrange.	Gain or Lose e^-?	How many?	Ion Charge?	Valency	Metal or Non-met?
example	3	2.1	lose	1	1+	1+	metal
example2	8	2.6	gain	2	2-	2-	non-met.
A	13						
B	17						
C	10						
D	19						
E	11						
F	16						
G	12						
H	2						
I	7						
J	18						
K	9						
L	20						

Worksheet 8
Names and Formulas

Student Name..

1. What is the name of the compound made from the elements:

a) barium and fluorine?

....

b) sodium and iodine?

....

c) hydrogen and sulfur?

....

d) chlorine & aluminium?

....

e) oxygen & calcium?

....

f) sulfur and barium?

....

2. What is the formula of each compound in Q1?

a)

....

b)

....

c)

....

d)

....

e)

....

f)

....

3. What is the name of a compound if its formula is:

a) KBr

....

b) Al_2S_3

....

c) BaO

....

d) Na_3N

....

e) MgI_2

....

f) H_2O

....

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Topic Test
Atoms & elements

Student Name.. Score = /30

You will need to refer to the Periodic Table to answer some questions in this test.

Answer all questions in the spaces provided.

1. (5 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

Description matches with **List Item**

a) Particles in atoms with no electrical charge. ....
b) Don't count these when adding up the Mass Number. ....
c) An atom that has lost or gained electrons. ....
d) Scientist who described electrons in energy-level orbits. ....
e) Element with full outer orbit. ....

List Items Not all will be used. Some may be used more than once.

A. neutrons
B. Einstein
C. ion
D. inert gas
E. electrons
F. Bohr

2. (9 marks)
A certain atom has 15 protons and 16 neutrons in its nucleus.

a) How many electrons? ....

b) What is its Atomic Number? ....

c) Name the element. ....

d) What is its Mass Number? ....

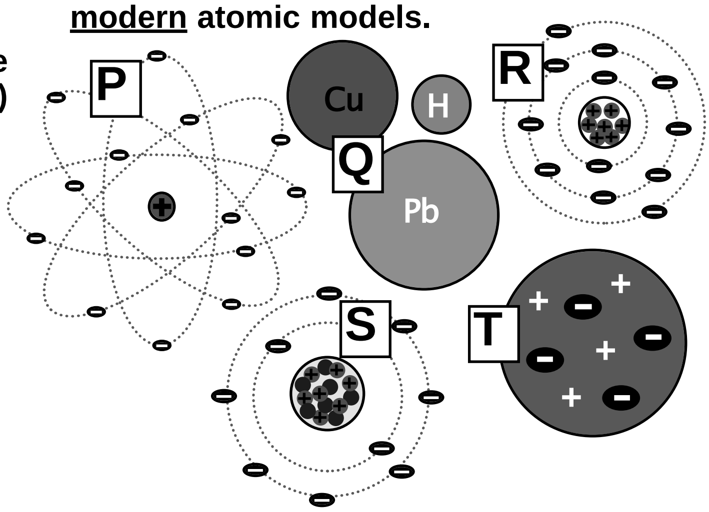
e) How would the electrons be arranged in orbits in this atom? ....

f) What would this atom do to achieve a full outer orbit?
....

g) What is this element's valency? ....

h) Would you expect this element to conduct electricity? Explain your answer.

3. (4 marks)
The following diagrams show some modern atomic models.



Use the letters P,Q,R,S & T to list the models in correct time order in the history of Atomic Theory.

....

4. (6 marks)
Write the name and formula for a compound made up of:

a) magnesium & fluorine

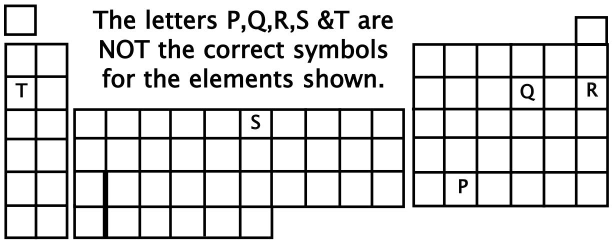
....

b) oxygen & potassium

....

5. (6 marks)

The letters P,Q,R,S &T are NOT the correct symbols for the elements shown.



Which of the indicated elements (P,Q,R,etc):
a) is/are metal(s)? ....
b) is an inert gas? ....
c) would form an ion by losing 1 electron?..............
d) has a valency of 2-? ....

Answer Section

Worksheet 1

a) atoms b) Protons
c) neutrons d) nucleus
e) electrons f) negative
g) protons h) electrons
i) equal/cancelled j) identical atoms
k) different
l) protons, electrons and neutrons
m) protons or electrons
n) Atomic o) Periodic
p) protons plus neutrons
q) electrons

Worksheet 2

a) 11 b) 5 c) 5
d) 23 e) 11 f) 11
g) Ar h) 18 i) 40 j) 18
k) fluorine l) 9 m) 9 n) 10
o) Fe p) 26 q) 26 r) 30
s) U t) 92 u) 92 v) 146
w) strontium x) Sr y) 38 z) 88 aa) 38
ab) gold ac) Au ad) 79 ae) 79 af) 118
ag) lead ah) 82 ai) 207 aj) 82 ak) 82 al) 125

Worksheet 3

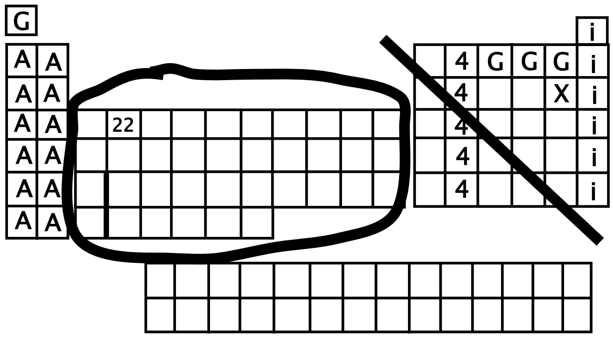
a) Democritus b) John Dalton
c) element d) electron
e) Thomson f) Plum-
g) positively h) Rutherford
i) alpha j) nucleus
k) orbiting l) Bohr
m) energy n) electrons
o) protons p) mass
q) neutrons r) Chadwick

Worksheet 4

1. R, P, T, Q, S

2.
P = Thomson
Q = Bohr
R = Dalton
S = Chadwick
T = Rutherford

Worksheet 5



Worksheet 6

1. (missing info. shown only)
A 2.5
B 2.8.5
C 19
D 2.8.8
E 2.7
F 2.8
G 2.8.7
H 2.8.8.2
I 2.8.6
J 2.8.2

2.
a) D, F
b) G
c) H
d) example, C, H, J
e) A, E

Worksheet 7

Element	Total electr.	Electron Arrange.	Gain or Lose e^-?	How many?	Ion Charge?	Valency	Metal or Non-met?
example	3	2.1	lose	1	1+	1+	metal
example2	8	2.6	gain	2	2-	2-	non-met.
A	13	2.8.3	lose	3	3+	3+	metal
B	17	2.8.7	gain	1	1-	1-	non-met.
C	10	2.8	neither	0	no ion	0	non-met.
D	19	2.8.8.1	lose	1	1+	1+	metal
E	11	2.8.1	lose	1	1+	1+	metal
F	16	2.8.6	gain	2	2-	2-	non-met.
G	12	2.8.2	lose	2	2+	2+	metal
H	2	2	neither	0	no ion	0	non-met.
I	7	2.5	gain	3	3-	3-	non-met.
J	18	2.8.8	neither	0	no ion	0	non-met.
K	9	2.7	gain	1	1-	1-	non-met.
L	20	2.8.8.2	lose	2	2+	2+	metal

Worksheet 8

Q1.
a) barium fluoride
b) sodium iodide
c) hydrogen sulfide
d) aluminium chloride
e) calcium oxide
f) barium sulfide

Q2.
a) BaF_2
b) NaI
c) H_2S
d) $AlCl_3$
e) CaO
f) BaS

Q3.
a) potassium bromide
b) aluminium sulfide
c) barium oxide
d) sodium nitride
e) magnesium iodide
f) hydrogen oxide... WATER!

Topic Test

1.
a) A b) E c) C d) F e) D

2.
a) 15
b) 15
c) phosphorus
d) 31
e) 2.8.5
f) gain 3 more electrons
g) 3-

3. Q, T, P, R, S

4.
a) magnesium fluoride, MgF_2

b) potassium oxide, K_2O

5.
a) T,S,P
b) R
c) T
d) Q