extracts from

Science Encyclopedia

Written by

Kirsteen Robson

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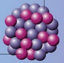
ATOMIC STRUCTURE

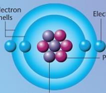
Atoms are the tiny particles of which everything is made. It is impossible to imagine how small an atom is. A hundred million atoms side by side would measure only 1cm, and a sheet of paper, like the ones that make up this book, is probably a million atoms thick.

SUBATOMIC PARTICLES

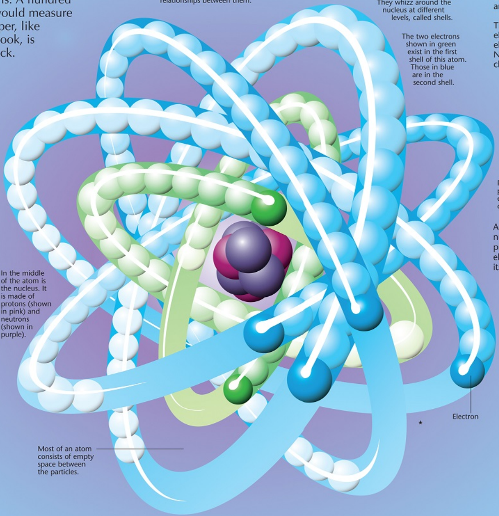
Atoms are made of smaller particles called **subatomic particles**. In the middle of every atom is its **nucleus**. The nucleus contains two types of subatomic particles, called **protons** and **neutrons**.



Subatomic particles of a third type, called **electrons**, move around the nucleus. The electrons exist at different energy levels, called **shells**, around the nucleus. Each shell can have up to a certain number of electrons. When it is full, a new shell is started.



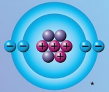
Scientists now think that protons and neutrons are made of even smaller subatomic particles, called **quarks**.



ELECTRICAL CHARGES

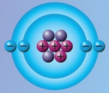
The subatomic particles that make up an atom are held together by electrical charges. Particles with opposite electrical charges are attracted to one another.

The protons have a positive electrical charge and the electrons have a negative charge. Neutrons have no electrical charge, so they are neutral.



Proton: positive electrical charge. Electron: negative electrical charge. Neutron: no electrical charge.

An atom usually has an equal number of positively charged protons and negatively charged electrons. This makes the atom itself electrically neutral.



This atom is electrically neutral.

It has four protons.

It has four electrons.

Its three neutrons have no effect on its electrical charge.

REPRESENTING ATOMS

Although atoms are often represented by diagrams like the main picture, scientists now believe that the electrons are held in cloud-like regions around the nucleus, as in the **electron cloud model** below.

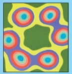
Electron cloud model

Electrons can be anywhere within their cloud, at any time. Sometimes they even move outside it.

ELECTRON DENSITY

In the picture below, different colours show different levels of density of electrons in a group of atoms. The turquoise areas show where the electrons are most dense.

This is a picture of what you might see through an extremely powerful microscope.



Internet links

- Scan the code to discover how small atoms are and what's inside them.
- For links to more websites about atoms and particles, go to **www.usborne.com/quicklinks**

CHANGES OF STATE

An ice cream melts and becomes a liquid in the heat of the Sun.

A substance changes from one **state of matter**, that is solid, liquid or gas, to another, depending on its temperature and pressure. When something changes state, heat is produced or lost as the energy of its particles is increased or decreased. Different substances change state at different temperatures.

The heat from a flame melts candle wax, but th wax sets as it drips away from the flame and cool:

MELTING AND BOILING

When a solid is heated, its temperature rises and its particles gain energy until it reaches its **melting point**. The particles now have enough energy to break away from their neighbours so the solid melts.

This ice melts at a lower temperature than pure water ice because orange juice has been added to it.

Further heat causes the temperature of the liquid to rise until it reaches its **boiling point** and the particles break free of each other completely. The liquid becomes a gas.

Some substances, for example carbon dioxide, change from gas to solid, or solid to gas, without passing through a liquid form. This is called **sublimation**.

The temperature at which a substance melts or boils changes if it contains traces of any other substances. For instance, ice (the solid form of water) melts at 0°C. Adding salt to the ice lowers its melting point.

When steam cools down, it turns back into water.

GEYSERS

Geysers are jets of boiling hot water and steam that shoot out from the Earth's crust.

They occur when water under the ground is heated by hot rocks and begins to boil.

As the water turns to steam, the pressure builds up in the channels between the rocks. The geyser then erupts, shooting a jet of steam and water high up into the air.

How geysers occur

Water flows into cavities between the rocks under the ground.

Pressure builds as the water heats and expands. Eventually, it turns to steam.

The pressure builds until boiling water and steam shoot out of a crack in the ground.

CONDENSATION

When a gas cools down enough, it **condenses**, becoming a liquid. This is because as it cools down, its particles lose energy and are unable to stay as far away from each other.

Condensation

Water vapour in the air in a room condenses on a cold window. Droplets of water are formed on the inside of the window.

FREEZING

When a liquid cools enough, it sets or **freezes**, becoming a solid. Its particles lose further energy and are unable to overcome the attraction between each other.

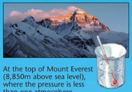
When tiny droplets of water in the atmosphere freeze, they sometimes join together in beautiful patterns of crystals and form snowflakes like these.

PRESSURE

Air pressure has an effect on the melting or boiling point of a substance. The air naturally presses down on the Earth with a force called **atmospheric pressure**. At sea level, this is described as **one atmosphere**, or **standard pressure**.

At sea level, pure water boils at 100°C.

Higher up, the atmospheric pressure is less. It is easier for the particles in liquids to escape into the air, so their boiling points are lower.



At the top of Mount Everest (8,850m above sea level), where the pressure is less than one atmosphere, pure water boils at 71°C.

WATERLESS PLANET

The surface of Mars is dry. Scientists think that this is because the atmospheric pressure is very low, so any water immediately boils away.

Most of Mars is covered by a reddish dust.

SOLID LIQUID OR GAS?

Whether something is classified as a solid, liquid or gas depends on its state at room temperature (20°C).

Mercury melts at -40°C. It is a liquid at room temperature.

Chlorine boils at -35°C so is a gas at room temperature.

See for yourself

Fill a metal container with ice cubes. Stand it in a warm place and leave it for a few minutes. Then look at the container. You will see drops of water on the outside of it.

Water molecules in the warm air lose energy and slow down when they are cooled by the ice. They stick to each other, forming water droplets.

Droplets of water on the side of the can

Internet links

- Scan the code to watch a video about how snowflakes form.
- For links to more websites where you can watch substances change state, go to **www.usborne.com/quicklinks**

THE PERIODIC TABLE

The **periodic table** is an arrangement of the elements placed in order of increasing atomic number (the number of protons in the nucleus). Each element is represented by a box containing its chemical symbol, atomic number and relative atomic mass (see far right). Some versions, such as the one shown here, also give the elements' names. New elements are added when they are discovered.

READING THE TABLE

The table is arranged into rows and columns. Looking at the table you will see that it has numbered rows (called **periods**) and columns (**groups**).

PERIODS

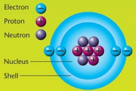
Each period is numbered, from 1–7. The atoms of all the elements in one period have the same number of shells, which contain electrons. For example, elements in period 2 have two shells and those in period 3 have three.

Moving from left to right across a period, each successive element has one more electron in the outer shell of its atoms. This leads to a fairly regular pattern of change in the chemical behaviour of the elements across a period.

GROUPS

Each group has a Roman numeral, from I-VIII. Elements in the same group have the same number of electrons in their outer shell. This means that, chemically, they behave in similar ways.

Structure of an atom



Hydrogen is the lightest element. It has an atomic number of 1. It is not a metal so it is placed separately.

Key

Each element has a separate box in the periodic table containing the information below.

50	Atomic number
Sn	Chemical symbol
Tin	Name
118.7	Relative atomic mass

Period number — 1; Group number — I

Period	I	II											III	IV	V	VI	VII	VIII
1	1 H Hydrogen 1.0																	2 He Helium 4
2	3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
3	11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulphur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
4	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 96.0	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Caesium 132.9	56 Ba Barium 137.3	71 Lu Lutetium 175.0	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	103 Lr Lawrencium (262)	104 Rf Ruther-fordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (277)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Uut Ununtrium (284)	114 Fl Flerovium (289)	115 Uup Ununpentium (288)	116 Lv Livermorium (293)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)

Transition metals

The relative atomic masses for unstable, radioactive* elements are shown in brackets.

Inner-transition metals

The elements with atomic numbers 57-70 belong to period 6.	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseo-dymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.1
The elements with atomic numbers 89-102 belong to period 7.	89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)

Elements 57-70 are called the **lanthanoids** or **rare earth elements**.

Elements 89-102 are called the **actinoids** or **radioactive rare earth elements**.

SIMILAR BEHAVIOUR

On this periodic table, all elements that behave more-or-less in similar ways have the same coloured background. The colour-coding is explained here.

Non-metals
Mostly solid or gas, and non-shiny. Melt and boil at low temperatures.

Semi-metals
Also called metalloids, these have a mixture of the properties of metals and non-metals.

Behaviour unknown

Metals
All are solid (except mercury, a liquid). Generally, they are shiny and have high melting points.

Transition metals are mostly hard and tough. Many are used in industry or jewellery.

Inner-transition metals are rare and tend to react easily with other elements, which makes them difficult to use in their natural state.

RELATIVE ATOMIC MASS

Relative atomic mass is the average mass number of the atoms in a sample of an element. (The mass number is the total number of protons and neutrons in a nucleus.) Moving through the periodic table, elements are progressively heavier. For example, hydrogen (relative atomic mass: 1) is the lightest element. Ruthenium (101.1) is over a hundred times heavier.

GROUPS WITH NAMES

Some of the groups in the periodic table have names. For example, the metals in group I are all alkali metals and group II are alkaline earth metals. The elements in group VII are halogens and group VIII (sometimes called group 0) are called noble gases.

DIFFERENT VERSION

An alternative version of the periodic table shows it split into 18 groups rather than eight. This is achieved by treating each column in the transition metals section of the table as a separate group, numbered from 3-12. In this version, all groups are referred to by ordinary numbers, not Roman numerals.

Internet links

- Scan the code for a link to a video about the periodic table of elements.

* Radioactivity, 114-115.