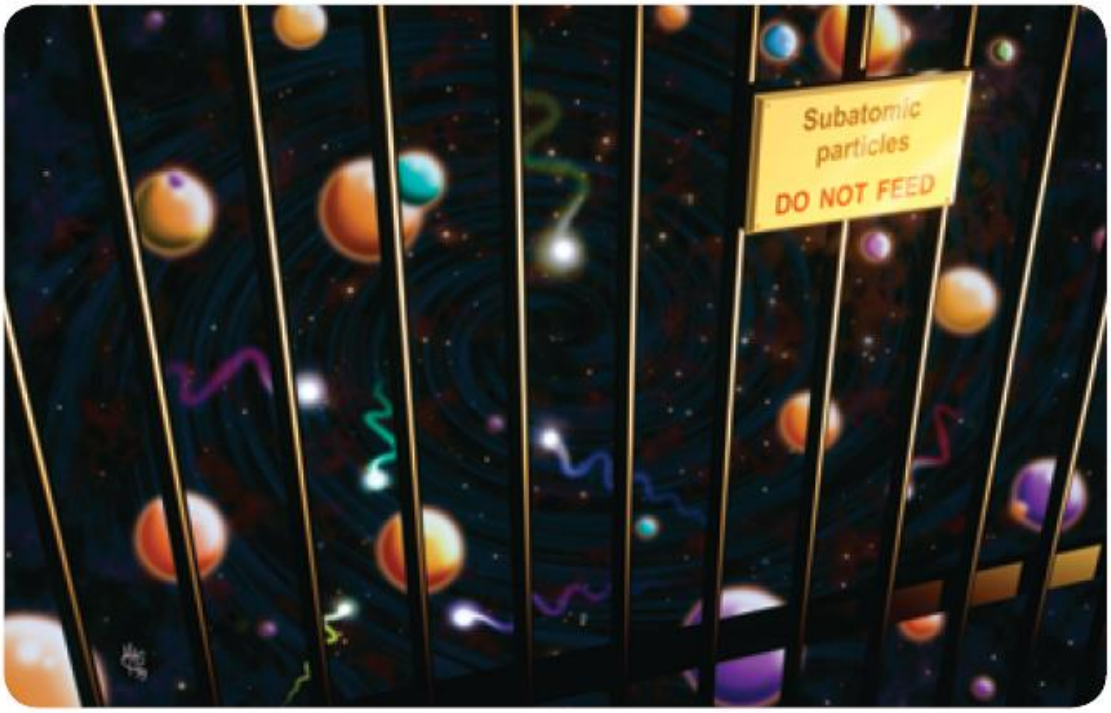
An atom is the smallest piece of a substance that is still that substance. It is the smallest part of an element. But atoms themselves are made up of even smaller particles called subatomic particles.



9.3.1 There are so many and varied subatomic particles they are sometimes referred to as a 'particle zoo'.

Subatomic particles

The atom is built from three types of basic subatomic particles:

- the **proton**: protons carry a positive charge (+). They sit at the very centre of the atom in a heavy core called the **nucleus**. Protons are often given the symbol p^+
- the **neutron**: neutrons have no charge. This is referred to as being **neutral**. Neutrons are the heaviest of all the subatomic particles, being just a little heavier than a proton. Neutrons sit in the nucleus with the protons. Neutrons are often given the symbol n
- the **electron**: electrons have a negative charge (–). Electrons are very light. They are only about $\frac{1}{2000}$th the mass of a proton; that is, 2000 electrons would have about the same mass as a single proton. Electrons carry a negative charge and are often given the symbol e^-.

Electrons spin around the nucleus at very high speeds. The region in which electrons spin is vast compared to the size of the nucleus. Only electrons inhabit that vast region.

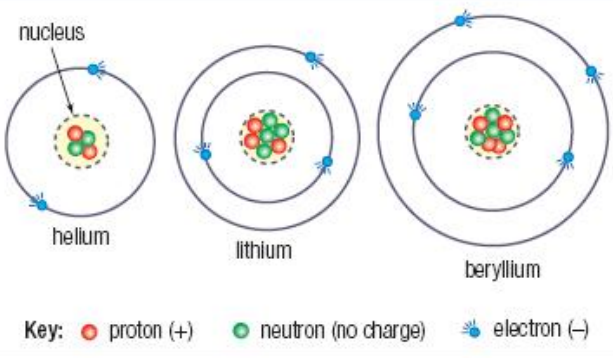
Atoms and numbers

All atoms are electrically neutral: they have no charge. This means that the charge of every proton must be cancelled out by the charge of an electron. So, for every type of atom:

the number of protons in an atom = the number of electrons in an atom

The simplest atom is the hydrogen atom: it has a single proton in its nucleus and has no neutrons. Only one electron spins around its nucleus. The next three simplest atoms are helium, lithium and beryllium.

9.3.2 Helium, lithium and beryllium atoms



Atomic number

The number of protons in an atom is called its **atomic number**. So:

Atomic number = number of protons
= number of electrons in an atom

Mass number

The **mass number** of an atom is the total number of particles in its nucleus.

Mass number = number of protons + neutrons

To find out how many protons, neutrons and electrons there are in an atom:

- protons = atomic number
- neutrons = mass number – atomic number
- electrons = protons = atomic number

The periodic table

The **periodic table** shows all the known types of atoms from the common (e.g. oxygen and nitrogen) to the rare (e.g. rutherfordium). The atomic number of an atom gives its place in the periodic table. The higher the atomic number, the more protons an atom has. This also makes the atom heavier.

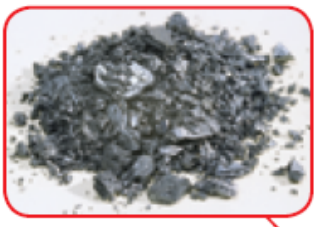
The vertical columns in the periodic table are called **groups**. Groups are numbered using the Roman numerals I, II, III, IV, V, VI, VII and VIII. Atoms in the same group have similar properties. For example, all of the noble gases are in Group VIII. All are gases and none of them react easily with other elements. Likewise, all the elements of Group II are reactive metals.

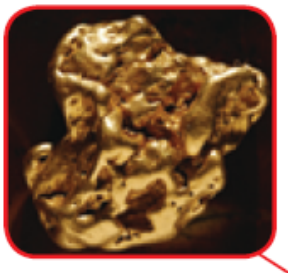
The horizontal rows in the periodic table are called **periods** (which is also where the name of the table comes from).

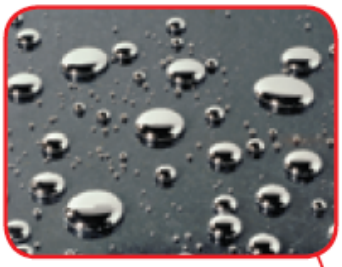
Weird particles

Scientists believe that there exist other subatomic particles besides protons, neutrons and electrons. These other particles, some of which have yet to be discovered, include quarks, leptons, neutrinos, gravitons, bosons, photons and gluons.

9.3.3 The periodic table of elements







I	II											III	IV	V	VI	VII	VIII
H hydrogen 1																	He helium 2
Li lithium 3	Be beryllium 4											B boron 5	C carbon 6	N nitrogen 7	O oxygen 8	F fluorine 9	Ne neon 10
Na sodium 11	Mg magnesium 12											Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18
K potassium 19	Ca calcium 20	Sc scandium 21	Ti titanium 22	V vanadium 23	Cr chromium 24	Mn manganese 25	Fe iron 26	Co cobalt 27	Ni nickel 28	Cu copper 29	Zn zinc 30	Ga gallium 31	Ge germanium 32	As arsenic 33	Se selenium 34	Br bromine 35	Kr krypton 36
Rb rubidium 37	Sr strontium 38	Y yttrium 39	Zr zirconium 40	Nb niobium 41	Mo molybdenum 42	Tc technetium 43	Ru ruthenium 44	Rh rhodium 45	Pd palladium 46	Ag silver 47	Cd cadmium 48	In indium 49	Sn tin 50	Sb antimony 51	Te tellurium 52	I iodine 53	Xe xenon 54
Cs cesium 55	Ba barium 56	La* lanthanum 57	Hf hafnium 72	Ta tantalum 73	W tungsten 74	Re rhenium 75	Os osmium 76	Ir iridium 77	Pt platinum 78	Au gold 79	Hg mercury 80	Tl thallium 81	Pb lead 82	Bi bismuth 83	Po polonium 84	At astatine 85	Rn radon 86
Fr francium 87	Ra radium 88	Ac** actinium 89	Rf rutherfordium 104	Db dubnium 105	Sg seaborgium 106	Bh bohrium 107	Hs hassium 108	Mt meitnerium 109	Ds darmstadtium 110	Rg roentgenium 111	Uub ununbium 112						

*Lanthanides 58–71	Ce cerium 58	Pr praseodymium 59	Nd neodymium 60	Pm promethium 61	Sm samarium 62	Eu europium 63	Gd gadolinium 64	Tb terbium 65	Dy dysprosium 66	Ho holmium 67	Er ersium 68	Tm thulium 69	Yb ytterbium 70	Lu lutetium 71
**Actinides 90–103	Th thorium 90	Pa protactinium 91	U uranium 92	Np neptunium 93	Pu plutonium 94	Am americium 95	Cm curium 96	Bk berkelium 97	Cf californium 98	Es einsteinium 99	Fm fermium 100	Md mendelevium 101	No nobelium 102	Lr lawrencium 103

Elements

Chemical **elements** are made up of atoms that are all basically the same. A block of copper, for example, is made up entirely of copper atoms while diamond (a form of carbon) is made up entirely of carbon atoms. The periodic table is a list of all the different types of atoms and is also a list of all the different elements that exist. Each box in the periodic table represents a different element which is made from a different type of atom.

Element symbols

Each element has its own abbreviation or **symbol**. Symbols always have one or two letters, the first always being a capital.

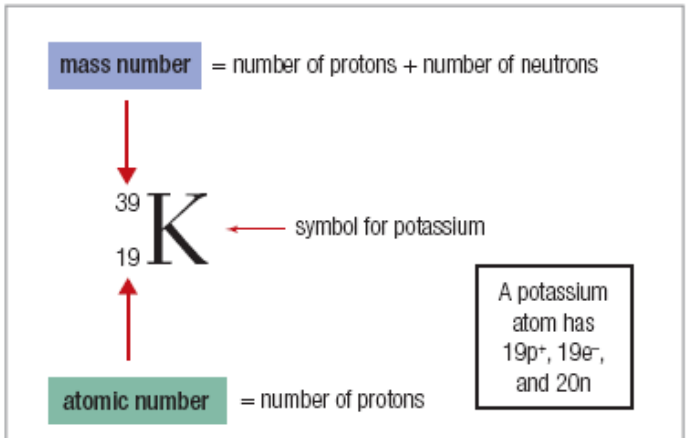
Some symbols:

- use just the first letter of the element's name
  e.g. O = oxygen, C = carbon, F = fluorine
- use the first two letters of the name
  e.g. Si = silicon, Al = aluminium, Ca = calcium
- use the first letter of the name and another letter in it
  e.g. Mg = magnesium, Cl = chlorine, Pt = platinum
- use symbols based on their older, Latin names
  e.g. Na = sodium (natrium), Cu = copper (cuprum), Au = gold (aurum).

Symbols make it quicker to write an element's name and make it possible to write chemical reactions as equations.

Symbols for atoms

Atoms of a particular element all have the same number of protons, but may have different numbers of neutrons. Scientists use a shorthand way of writing all this information about an atom.



9.3.4 The number of protons, neutrons and electrons in an atom can be worked out from its atomic number and mass number.

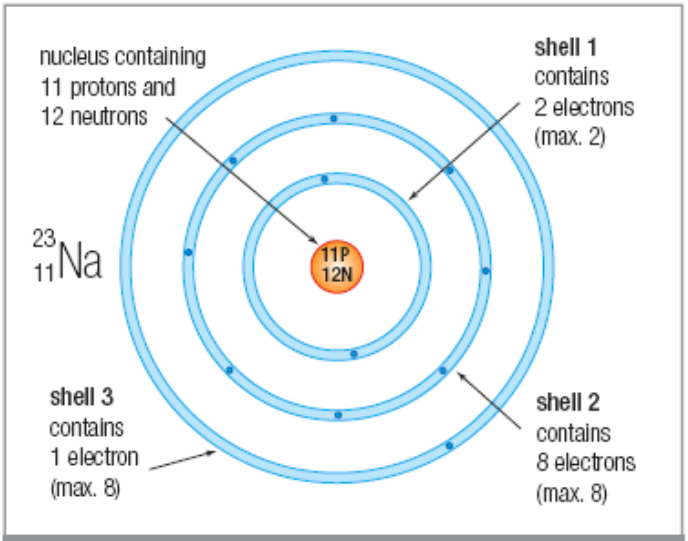
Radioactive atoms

Positive charges repel other positive charges. This means that a proton in the nucleus is constantly trying to escape its proton neighbours. What stops the nucleus from breaking apart? Nuclear force holds all these protons together and it is thought that the neutrons have something to do with it. In small atoms, the number of neutrons is roughly the same as the number of protons. This is enough to hold it all together. As atoms get bigger, more and more neutrons are needed. Heavy radioactive atoms usually have many more neutrons than protons. Even then the nuclear force sometimes allows part of the nucleus to break away. The bit of nucleus that flies off is a nuclear particle. Emitting nuclear particles is what makes an atom radioactive.

More about electrons

Electrons do not just spin anywhere around the nucleus. They spin in special regions called **electron shells** or **energy levels**. The first and innermost shell can only hold two electrons. The next shells are bigger and each can hold up to eight electrons. The innermost shells are used and filled first. When a shell is filled, electrons begin to fill the next shell.

For example, sodium (Na) has eleven electrons. Two electrons spin in the inner shell and eight in the next. This leaves one to spin in the third shell. This is shown in 9.3.5 below.



9.3.5 A sodium atom has three electron shells — the inner two shells are filled to capacity and a solitary electron spins around in the third shell.

Revision questions

Subatomic particles

1 Copy and complete this table for the three types of subatomic particles.

Subatomic particle	Symbol	Charge	Mass	Location
			2000 times heavier than an electron	
			little heavier than a proton	nucleus
electron		none		

2 Draw a labelled diagram of a hydrogen atom.

Atoms and numbers

3 True or false?
- a An atom has the same number of protons as it does electrons.
- b The atomic number is the number of protons in an atom.
- c An atom always has the same number of neutrons as it does protons.
- d The mass number is the number of neutrons in an atom.
- e The mass number is the number of particles in the nucleus.

The periodic table

4 Use the periodic table to find the name of the element that has the symbol:
- a Ag
- b Cl
- c K
- d W
- e Zn.

5 Use the periodic table to find the name of the element:
- a Fe
- b with an atomic number of 33
- c in Group VII, Period 2
- d which is the smallest of all atoms.

Elements

6 A chlorine atom (Cl) has 17 protons, 18 neutrons and 17 electrons. What would be its:
- a atomic number
- b mass number
- c symbol?

7 A boron atom has the symbol $^{11}_{5}B$.
- a What is its atomic number?
- b What is its mass number?

More about electrons

8 What is another name for an electron shell?

9 In an atom, what number of electrons fit in the:
- a innermost shell
- b second shell?

10 How are the eleven electrons of the sodium atom arranged?

Thinking questions

11 Hydrogen is an unusual atom. Identify why.

Analysis questions

12 Lithium (Li) has a mass number of 7 and an atomic number of 3. How many of each of the following does one atom of lithium contain?
- a protons
- b neutrons
- c electrons.

13 A uranium atom has the symbol $^{235}_{92}U$. In a single atom of uranium, how many of these particles are there?
- a protons
- b neutrons
- c electrons.

14 Use the periodic table to find the atomic numbers of each of these atoms:
- a Ca
- b mercury
- c nitrogen
- d Fe.

15 How many protons would be in each of these atoms?
- a atomic number = 25
- b carbon
- c K.