The Atom

All substances are made of atoms. They're really tiny — too small to see, even with a microscope.

Atoms Contain Protons, Neutrons and Electrons

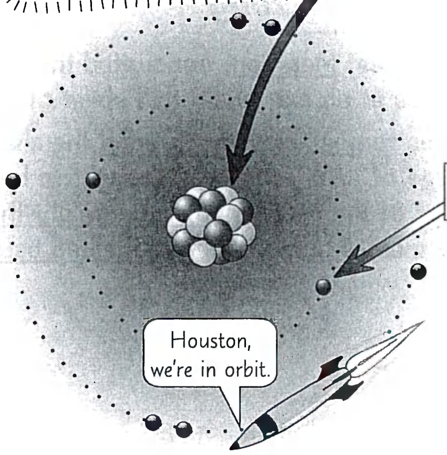
The atom is made up of three subatomic particles — protons, neutrons and electrons.

- Protons are heavy and positively charged.
- Neutrons are heavy and neutral.
- Electrons have hardly any mass and are negatively charged.

Particle	Relative mass	Relative charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	–1

Relative mass (measured in atomic mass units) measures mass on a scale where the mass of a proton or neutron is 1.

Protons and neutrons are still teeny tiny — they're just heavy compared to electrons.



The Nucleus

1) It's in the middle of the atom.
2) It contains protons and neutrons.
3) It has a positive charge because of the protons.
4) Almost the whole mass of the atom is concentrated in the nucl
5) Compared to the overall size of the atom, the nucleus is tiny.

The Electrons

1) Electrons move around the nucleus in electron shells.
2) They're negatively charged.
3) They're tiny, but their orbitals cover a lot of space.
4) The size of their orbitals determines the size of the atom. Atom have a radius (known as the atomic radius) of about 10^{-10} m.
5) Electrons have a tiny mass (so small that it's sometimes given as zero).

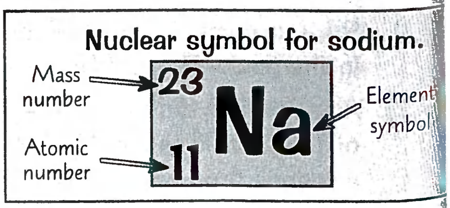
In an Atom the Number of Protons Equals the Number of Electrons

1) Atoms are neutral — they have no charge overall (unlike ions).
2) This is because they have the same number of protons as electrons.
3) The charge on the electrons is the same size as the charge on the protons, but opposite — so the charges cancel out.
4) In an ion, the number of protons doesn't equal the number of electrons. This means it has an overall charge. For example, an ion with a 2– charge, has two more electrons than protons.

An ion is an atom or group of atoms that has lost or gained electrons.

Atomic Number and Mass Number Describe an Atom

1) The nuclear symbol of an atom tells you its atomic (proton) number and mass number.
2) The atomic number tells you how many protons an atom has. Every atom of an element has the same number of protons.
3) For a neutral atom, the number of protons equals the number of electrons, so the number of electrons equals the atomic number.
4) The mass number tells you the total number of protons and neutrons in the atom.
5) To work out the number of neutrons in an atom, just subtract the atomic number from the mass numbe



Don't trust atoms — they make up everything...

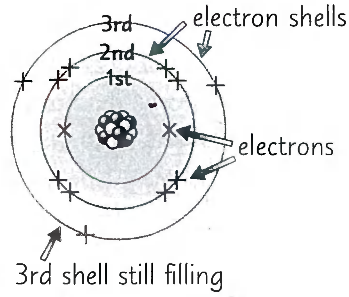
You need to learn what's in that table with the relative masses and relative charges of the different parts of the atom.

Q1 A certain neutral atom of potassium has an atomic number of 19 and a mass number of 39. Give the number of electrons, protons and neutrons in the atom. [3 marks]

Electronic Configurations

Like snails, electrons live in shells. Unlike snails, electrons won't nibble on your petunias...

Electron Shell Rules:



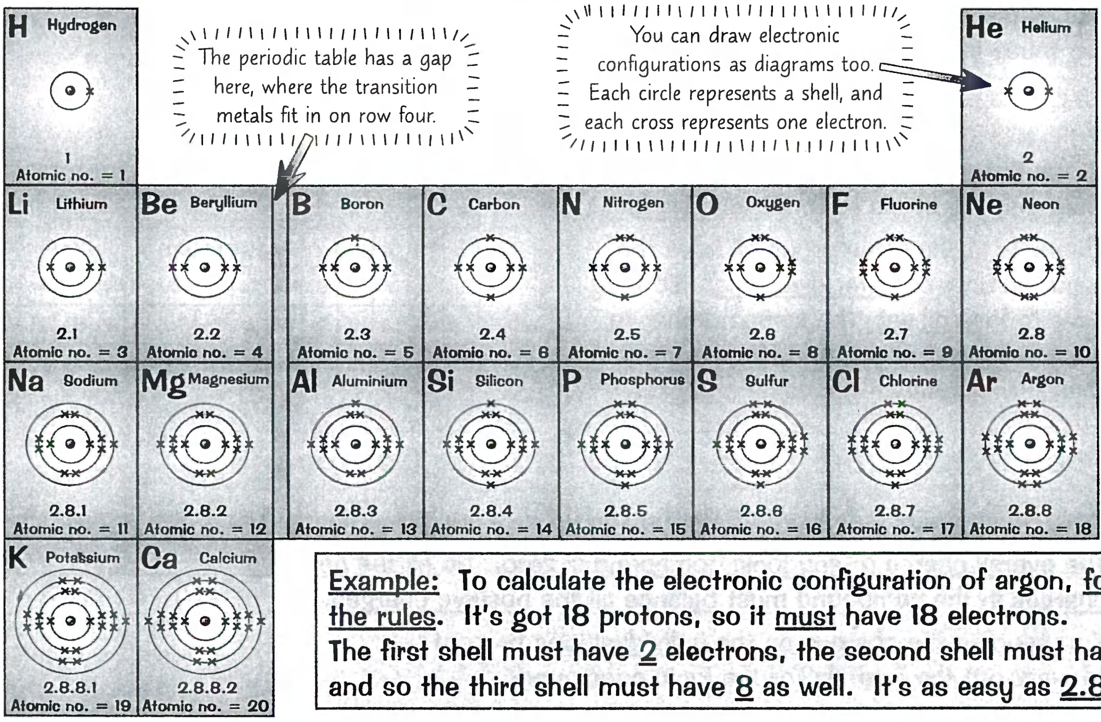
1) Electrons always occupy shells (sometimes called energy levels).
2) The lowest energy levels are always filled first.
3) Only a certain number of electrons are allowed in each shell:

1st shell	2nd shell	3rd shell
2 electrons	8 electrons	8 electrons

Working Out Electronic Configurations

The electronic configurations of the first 20 elements are shown in the diagram below. They're not hard to work out. For a quick example, take nitrogen:

1) The periodic table tells you that the atomic number of nitrogen is seven. That means nitrogen has seven protons, so it must have seven electrons.
2) Follow the 'Electron Shell Rules' above. The first shell can only take 2 electrons and the second shell can take a maximum of 8 electrons. So the electronic configuration of nitrogen must be 2.5.



Example: To calculate the electronic configuration of argon, follow the rules. It's got 18 protons, so it must have 18 electrons. The first shell must have 2 electrons, the second shell must have 8, and so the third shell must have 8 as well. It's as easy as 2.8.8.

You can also work out the electronic configuration of an element from its period and group.

- The number of shells which contain electrons is the same as the period of the element.
- The group number tells you how many electrons occupy the outer shell of the element.

Example: Sodium is in period 3, so it has 3 shells occupied. The first two shells must be full (2.8). It's in Group 1, so it has 1 electron in its outer shell. So its electronic configuration is 2.8.1.

The electronic configuration of the fifth element — it's a bit boron...

Electronic configurations may seem a bit complicated at first but once you learn the rules, it's a piece of cake.

Q1 Give the electronic configuration of aluminium (atomic number = 13). [1 mark]

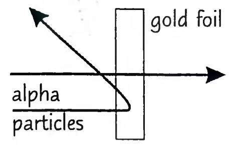
Q2 In which group and period of the periodic table would you expect to find the element with the electronic configuration 2.8.8.2? [2 marks]

The Model of the Atom

We used to think atoms were tiny solid spheres (like ball-bearings), but they're much more complex than that...

The Theory of Atomic Structure Has Changed Over Time

1) In 1897 J. J. Thomson discovered that electrons could be removed from atoms, so atoms must be made up of smaller bits. He suggested the 'plum-pudding' model — that atoms were spheres of positive charge with tiny negative electrons stuck in them like fruit in a plum pudding.
2) That "plum pudding" theory didn't last very long though. In 1909, Rutherford and Marsden tried firing a beam of alpha particles (see p.51) at thin gold foil. From the plum-pudding model, they expected the particles to pass straight through the gold sheet, or only be slightly deflected.
3) But although most of the particles did go straight through the sheet, some were deflected more than they had expected, and a few were deflected back the way they had come — something the plum-pudding model couldn't explain.



4) Being a pretty clued-up guy, Rutherford realised this meant that most of the mass of the atom was concentrated at the centre in a tiny nucleus.
5) He also realised that most of an atom is just empty space, and that the nucleus must have a positive charge, since it repelled the positive alpha particles.
6) This led to the creation of the nuclear model of the atom.
7) Niels Bohr tweaked Rutherford's idea a few years later by proposing a model where the electrons were in fixed orbits at set distances from the nucleus. These distances were called energy levels (p.50).
8) He suggested that electrons can only exist in these fixed orbits (or shells), and not anywhere inbetween.
9) This model is known as the Bohr model and is pretty close to our currently accepted model of the atom.

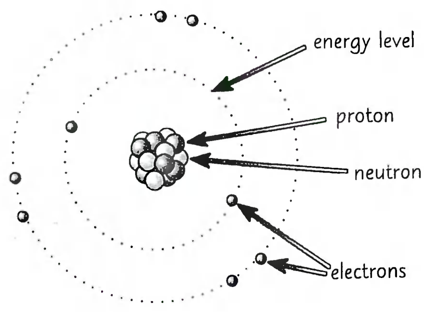
The Current Model of the Atom — Protons, Neutrons and Electrons

The quantities to do with atoms are really tiny, so they're written in standard form: $A \times 10^n$

where A is a number between 1 and 10 and n is the number of places the decimal point would move if you wrote the number out in decimal form.

According to our current model of the atom:

1) An atom is a positively-charged nucleus surrounded by negatively-charged electrons.
2) Virtually all the mass of the atom is in the nucleus. The nucleus is tiny — about 10 000 times smaller than the whole atom. It contains protons (which are positively charged) and neutrons (which are neutral). The rest of the atom is mostly empty space.
3) The negative electrons whizz round outside the nucleus in fixed orbits called energy levels or shells. They give the atom its overall size of around 1×10^{-10} m.



4) Atoms are neutral, so the number of protons = the number of electrons. This is because protons and electrons have an equal but opposite relative charge.
5) If an atom loses an electron it becomes a positive ion. If it gains an electron it becomes a negative ion (p.50).
6) Atoms can join together to form molecules — e.g. molecules of oxygen gas are made up of two oxygen atoms bonded together. Small molecules like this have a typical size of 10^{-10} m — the same sort of scale as the size of an atom.

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	–1

These models don't have anything on my miniature trains...

That's a whole lot of history, considering this is a book about physics. It's all good, educational fun though.

Q1 a) Describe the current model of the atom. [4 marks]
b) Describe how the radius of an atom compares to the size of its nucleus. [1 mark]