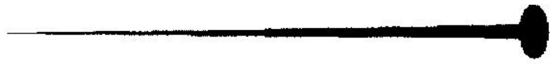
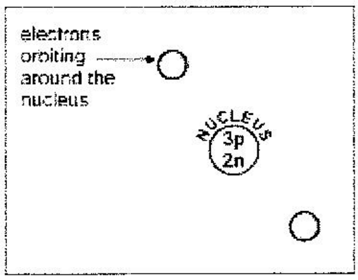
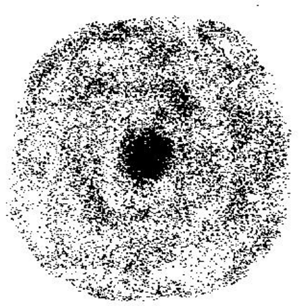
Models of the Atom

Atoms are tiny! A pinhead has a diameter of about 1mm. A line of 5 million million atoms could fit on a pinhead. Also the size of the nucleus in relationship to the whole atoms is very small. If the nucleus had a diameter equal to that of a pinhead, then the atom itself would have a diameter of 10 metres (the height of 5 men).



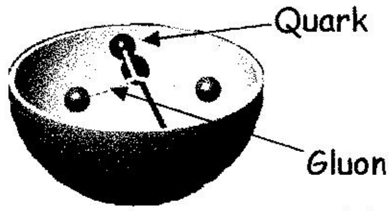
So small that we don't really know what they look like
Over the years there have been many theories of atomic structure. The one that you have probably learnt about at school is the one put forward by Bohr in 1913. He said that the atom consisted of a central nucleus (positive charge) which was surrounded by negatively charged electrons which orbited the nucleus in shells.



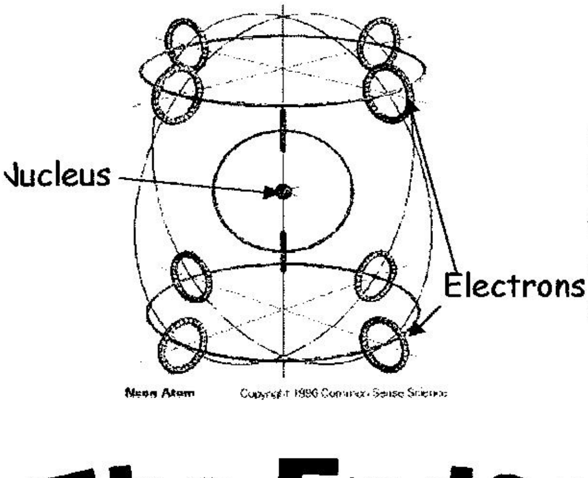


Clouds of mystery Bohr's sharply defined electron shells have been superseded by fuzzy electron 'clouds' which can be seen with an electron microscope. It is now known that electrons behave as waves, as well as like particles. An electron is most likely to be found where the electron 'cloud' is dense. But there is always a definite, if small, chance of finding it closer to, or farther from, the nucleus.

Not just protons, neutrons and electrons
Recently it has been discovered that protons and neutrons are made up of smaller particles called quarks and gluons.



A picture of a neutron cut in half (remember we cannot really cut open a neutron and peer inside!)



A modern theory of atomic structure (David Bergman, 1990). This is a neon atom. The nucleus and the shells are visible but the electrons spin in a circular motion whilst orbiting the nucleus. The electrons exist as both waves and particles.

The End?

Have we finally worked out the mystery of the atom or is there still more discoveries?

Learning Objectives:

- Know that early models of atomic structure predicted that atoms and ions with noble gas electron arrangements should be stable.
- Appreciate that there are various models to illustrate atomic structure.

Specification Reference 3.1.1

2. Atomic Models

The model of the atom is useful for understanding loads of ideas in chemistry. But it's just a model, and the accepted model of the atom has changed throughout history.

Dalton's and Thomson's models

The model of the atom you're expected to know (the one on page 5) is one of the currently accepted ones. But in the past, completely different models were accepted, because they fitted the evidence available at the time. As scientists did more experiments, new evidence was found and the models were modified to fit it.

At the start of the 19th century John Dalton described atoms as solid spheres (see Figure 1) and said that different spheres made up the different elements. In 1897 J J Thomson concluded from his experiments that atoms weren't solid and indivisible. His measurements of charge and mass showed that an atom must contain even smaller, negatively charged particles — electrons. The 'solid sphere' idea of atomic structure had to be changed. The new model was known as the 'plum pudding model' — see Figure 2.

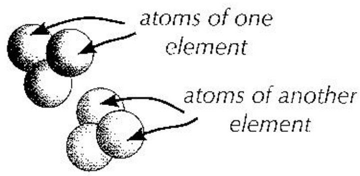


Figure 1: *Dalton's model of the atom.*

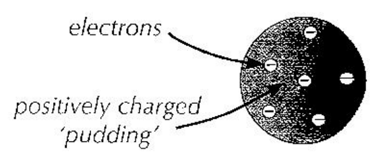


Figure 2: *Thomson's model of the atom.*

Rutherford's model

In 1909 Ernest Rutherford and his students Hans Geiger and Ernest Marsden conducted the famous gold foil experiment. They fired alpha particles (which are positively charged) at an extremely thin sheet of gold. From the plum pudding model, they were expecting most of the alpha particles to be deflected very slightly by the positive 'pudding' that made up most of an atom. In fact, most of the alpha particles passed straight through the gold atoms, and a very small number were deflected backwards. So the plum pudding model couldn't be right. So Rutherford came up with a model that could explain this new evidence — the nuclear model of the atom. In this, there's a tiny, positively charged nucleus at the centre, surrounded by a 'cloud' of negative electrons — most of the atom is empty space.

Figure 3: *Rutherford and Thomson worked together at Cambridge University.*

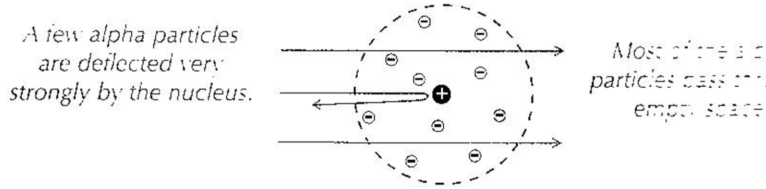


Figure 4: *Rutherford's model of the atom.*

This is nearly always the way scientific knowledge develops — new evidence prompts people to come up with new, improved ideas. Then other people go through each new, improved idea with a fine-tooth comb as well — modern 'peer review' (see page 2) is part of this process.

Bohr's model

HOW SCIENCE WORKS

There were quite a few other modifications to the model before we got to our currently accepted versions. Niels Bohr got pretty close though. Scientists realised that electrons in a 'cloud' around the nucleus of an atom, as Rutherford described, would quickly spiral down into the nucleus, causing the atom to collapse. Niels Bohr proposed a new model of the atom with four basic principles:

- Electrons only exist in fixed orbits (shells) and not anywhere in between.
- Each shell has a fixed energy.
- When an electron moves between shells electromagnetic radiation is emitted or absorbed.
- Because the energy of shells is fixed, the radiation will have a fixed frequency.

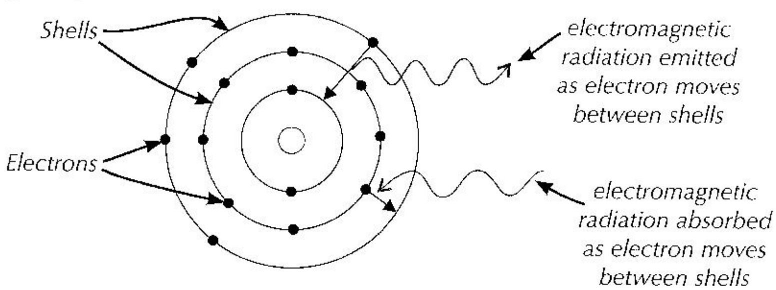


Figure 5: *Bohr's model of the atom.*

Figure 6: *Rutherford and Bohr worked together at the University of Manchester.*

The frequencies of radiation emitted and absorbed by atoms were already known from experiments. The Bohr model fitted these observations — it looked good.

The refined Bohr model

HOW SCIENCE WORKS

One of the things that makes a theory scientific is that it's 'falsifiable' — if you can make predictions using the theory, then if you test the predictions and they turn out to be wrong, you know that the theory's wrong. Scientists discovered that not all the electrons in a shell had the same energy. This meant that the Bohr model wasn't quite right. So, they refined it to include sub-shells. The Bohr model also explained why some elements (the noble gases) are inert. Bohr said that the shells of an atom can only hold fixed numbers of electrons, and that an element's reactivity is due to its electrons. When an atom has full shells of electrons it's stable and does not react.

Examples

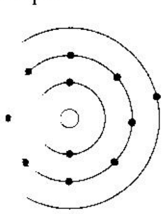


Figure 7: *Atomic structure of sodium (Bohr model).*

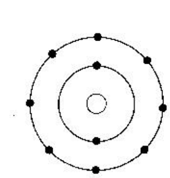


Figure 8: *Atomic structure of neon (Bohr model).*

Sodium only has 1 electron in its outer shell. This shell isn't full, so sodium is unstable and will react.

Neon (a noble gas) has full shells of electrons. This means the atom is stable, so neon will not react.

Figure 9: *Sodium reacts vigorously with water as it is unstable.*

Lots of observations fitted in with the Bohr model, and the refined Bohr model was even better.