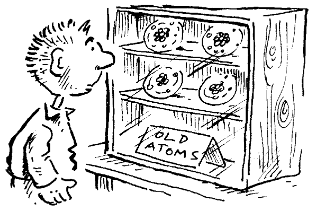
A brief history of atoms



UNIT 5

This unit focuses on the history and development of the theory of atoms.

Using this unit

This unit primarily focuses on the historical development of the theory of atoms from the ancient Greeks up to modern ideas about quarks. History should have an important part to play in science teaching because:

- It provides insight into how science is linked to the worldviews of its practitioners.
- It helps to expose the myth of the neutrality of science. Science is shaped by philosophical and cultural, as well as scientific considerations.
- Research has revealed parallels between student misconceptions in science and historical conceptions. Studying how scientific ideas have developed may help to remove some misconceptions.

It is assumed that students will be familiar with the idea that matter is composed of particles.

The work covered is suitable for Higher Level students.

Links with GCSE

Sc3 Materials and their properties

- Solids, liquids and gases are all composed of particles.
- Atoms consist of nuclei and electrons.
- The charges and relative masses of protons, neutrons and electrons; and the way electrons are arranged in atoms.

Sc0 The nature of science

- An understanding of how scientific ideas are accepted and rejected on the basis of empirical evidence, and how scientific controversies can arise from different ways of interpreting such evidence.
- Consideration of the ways in which scientific ideas may be affected by the social and historical contexts in which they develop, and how these contexts may affect whether or not the ideas are accepted.

Moral and spiritual aims

- To show that scientific knowledge of reality is limited and can be flawed - science is not infallible.

TEACHER'S NOTES

Additional resources

John D. Barrow, *The World Within the World* (Oxford: Oxford University Press, 1988)

Notes on the activities

Activity 1: What do you think an atom is like?

This is an opportunity to assess students' ideas about atoms.

Activity 2: A history of atoms from the ancient Greeks to Ernest Rutherford

1. In part it was the need for the development of experimental apparatus. That, however, is not the whole story. It was largely due to a Platonic and Aristotelian worldview that thwarted scientific development. It was Newton and Galileo who exposed the erroneous nature of the Aristotelian worldview and this resulted in the flourishing of scientific development.

   Atomism, in the seventeenth century, was thought to be synonymous with materialism and atheism (see Richard S. Westfall, *Science and Religion in Seventeenth Century England*, Michigan: University of Michigan Press, 1973). The re-emergence of atomism was due largely to a change in the philosophical climate. The switch from a Greek view of nature as an organism to an Enlightenment view of nature as a mechanism meant that seeing nature as being composed of discrete particles was advantageous for the Enlightenment scientists. Thus, its acceptance was based on philosophical, rather than scientific, beliefs.

4. Is science concerned with discovery or invention? Some radical sociologists and philosophers of science have suggested that electrons etc. are invented rather than discovered! Most others believe that electrons are discovered. One philosopher of science puts it into perspective:

   "... while electrons have always existed and the laws concerning them have always been valid, an electronic theory *and the* fact *of the existence of electrons did not appear until 1896. Prior to that year the existence of an electron was not a fact. Theories, hypotheses, models and facts, though bound to the creation order, are human inventions. But laws and sub-human subjects (e.g. animals, plants, rocks, cells, electrons) exist independently of human knowledge."*
   Marinus Dirk Stafleu, *Time and Again* (Toronto: Wedge, 1980) pp. 8-9

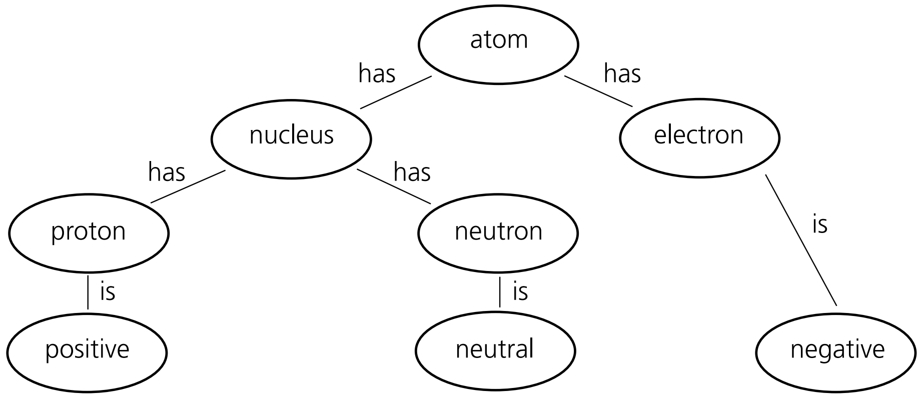
Activity 3: A history of atoms from Ernest Rutherford to the present day

5.

Date	Discovery	Discoverer
1896	Discovery of radioactivity	Antoine Henri Becquerel
1897	Discovery of the electron	J. J. Thompson
1911	Proposal of "nuclear" atom	Ernest Rutherford
1932	Discovery of the neutron	James Chadwick

TEACHER'S NOTES

6. On concept mapping see: J. D. Novak and D. B. Gowin, *Learning How to Learn* (New York: CUP, 1984).



7.

Particle	Relative Mass	Charge
Proton	1	positive
Neutron	1	neutral
Electron	1/1840	negative

Activity 4: Nothing buttery

A useful book on "nothing buttery" (for teachers) is Rodney Holder's *Nothing But Atoms and Molecules?* (Tunbridge Wells: Monarch, 1995).

There is an opportunity here, through discussion, to expose the fallacy of reductionism.

Extension ideas

Students could research other scientific theories that have changed over time, for example:

- The shape of the earth
- The composition of the moon's surface
- Ptolemaic versus Copernican solar system
- The phlogiston theory
- The idea of the ether.

TEACHER'S NOTES

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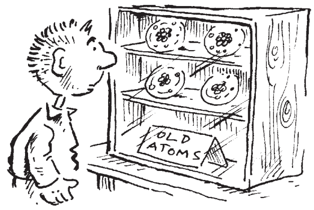
A brief history of atoms



UNIT 5

Scientific theories change through history. This unit will show how theories about atoms have changed and developed.

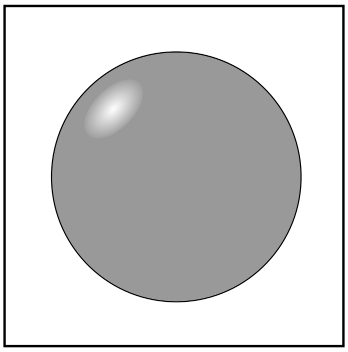
1 What do you think an atom is like?

Have you ever stopped to think what an atom might be like?

Below are some drawings of how scientists throughout the ages have thought of atoms.

Try to put them into date order. Check your answers by reading the sections that follow this.

A



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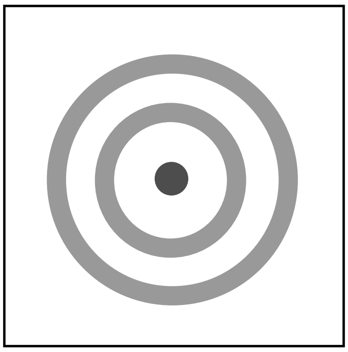

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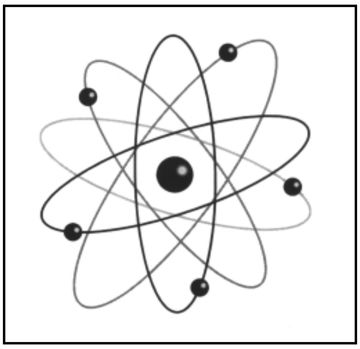

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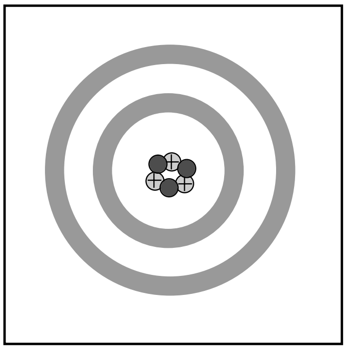

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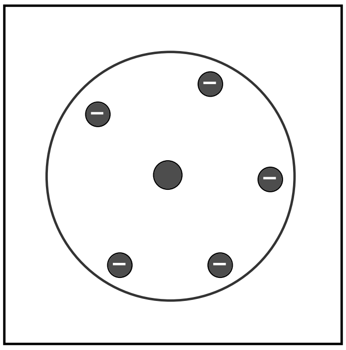

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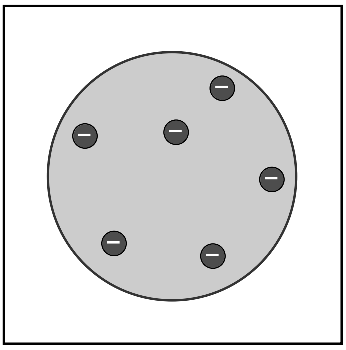
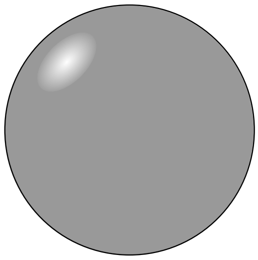


2 A history of atoms from the ancient Greeks to Ernest Rutherford

Greek views of the atom



One group of Greeks known as the Atomists believed that all things were made up of invisible particles that could not be divided up. The Greek word *atomos* means indivisible.

One such atomist was **Democritus** who lived around 400 BC.

To the Greeks, atoms were rather like very small billiard balls. They existed in a variety of shapes and sizes but one atom could not be changed into another.

Not all Greeks thought that matter was made up of particles. Some thought it was composed of Earth, Air, Water and Fire. The idea that all things were made up of atoms was disregarded. There was no evidence for or against it.

The idea of atoms had to wait until people's thinking about the world changed. About 2000 years after Democritus, the thought that the world was a giant machine became popular. The idea of atoms fitted well with this, because it was helpful to see nature as being made up of separate building blocks. So John Dalton developed a similar atomic theory to the Atomists.

John Dalton (1766-1844)

John Dalton, a Quaker school teacher, developed an atomic theory in 1808. He thought that:

- All matter consists of tiny particles, called atoms.
- Atoms of one element cannot be split or changed.
- Atoms can neither be created nor destroyed.
- All atoms of the same element are the same in mass, size and other properties.
- Atoms of one element differ from atoms of another element.

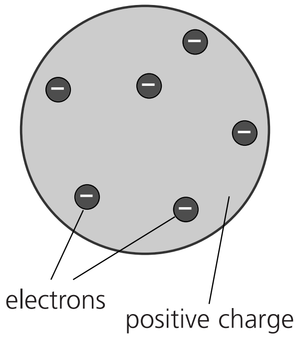
This was very similar to the Greek Atomists' picture of the atom.

The discovery of radioactivity in 1896 by the Frenchman **Antoine Henri Becquerel** (1852-1908) caused problems for the "billiard ball" model of the atom. It showed that atoms could break up.

Sir John Joseph Thompson (1856-1940)

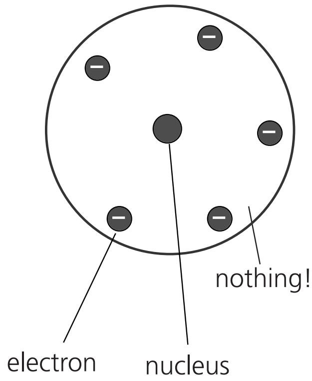
The next major step in the development of the atom was the 'discovery' of the electron in the late 1890s by J. J. Thompson in Cambridge.

Thompson's model of the atom differed from the billiard ball model because he saw the atom as a plum pudding. The main part of the atom was positive, with negatively charged electrons scattered throughout it.



Ernest Rutherford (1871-1937)

H. W. Geiger (1882-1945) and E. Marsden were two research students working for Rutherford. In 1908 they started to bombard the atoms in a thin film of solid gold with a form of ionising radiation called alpha particles. These alpha particles are positively charged. What happened seemed unbelievable: "It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you," Rutherford remarked. Some of the massive alpha particles were being deflected rather than travelling straight through the atom!



It seemed that the atom had a concentrated positive charge which was responsible for deflecting the alpha particles. This concentrated positive charge was called the nucleus. This nucleus was very dense, about 3,000,000,000,000 times more dense than lead!

Rutherford realised that, though some alpha particles were being deflected, most of them went straight through, so the atom must be mainly empty space!

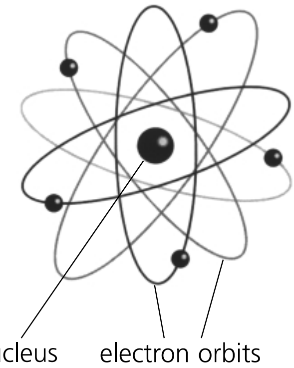
Now try these questions:

1. Why do you think that the theory of the atom remained undeveloped for such a long time?
2. In what ways were Dalton's atomic ideas similar to Democritus's?
3. Why did the discovery of radioactivity mean that the idea of atoms as billiard balls had to change?
4. Did the electron exist before Thompson 'discovered' it? Try to give reasons for your answer.
5. Why was Rutherford so surprised at some alpha particles bouncing back off the atom? Why did this mean that Thompson's plum-pudding model of the atom had to change?

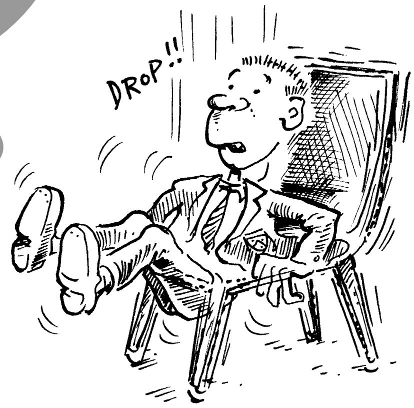
3 A history of atoms from Ernest Rutherford to the present day

Niels Bohr (1885-1962)

The Danish physicist Bohr suggested that the atoms were more like a minature solar system, with negatively charged electrons (planets) orbiting a positively charged nucleus (the Sun).



If the atom is mainly space then, the chair you are sitting on, and the ground you are standing on, are mainly nothing!



Rutherford began to wonder what the nucleus might be like. He carried on experiments to try to "split" the atom, by firing alpha particles at different targets. He found that the nucleus had a structure to it. It contained particles that were positively charged. We now call these positively charged particles protons.

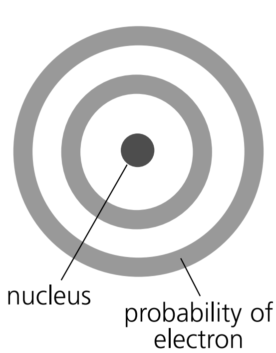
The protons couldn't account for all the mass of the atom. This led Rutherford, in 1911, to propose that the nucleus was made up of protons and other particles he called neutrons. If neutrons exist they must be as heavy as protons but carry no charge.

So the search was on to see if Rutherford's idea about the neutron was right.

Prince Louis de Broglie (1892-1987)

In the meantime, in 1924, de Broglie suggested that particles could act like waves. The electron could no longer be thought of as spinning around a nucleus in a certain path; there was no way of knowing where it was at any time. He thought that electrons were like the ripples on the pond, rather than the stone that made the ripples.

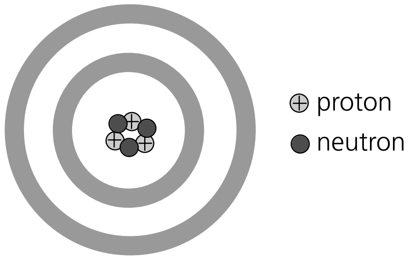
The grey areas represent the probability of the presence of an electron.



James Chadwick (1891-1974)

Eventually, in 1932, neutrons were discovered by James Chadwick, confirming Rutherford's hypothesis made 1 year earlier.

In 1935 Chadwick won a Nobel Prize for his discovery of the neutron.



Comparative size of an atom

There are more atoms in a cup of water than there are cups of water in all the oceans of the world.

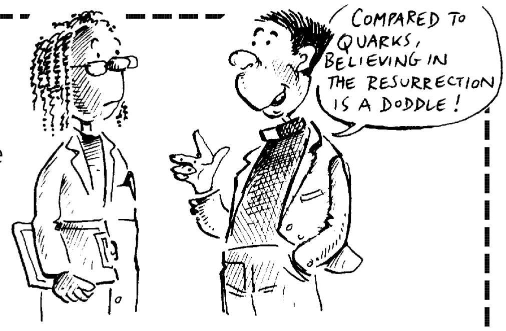
A single drop of water is made up of more than 1, 000, 000, 000, 000, 000, 000, 000 atoms.

If an atom was the size of Wembley Stadium, then the nucleus would be the size of a walnut on the centre spot of the pitch.

If the nucleus was the size of a full stop, the whole atom would be the size of a house.

Ten million atoms would fit across the tip of a needle.

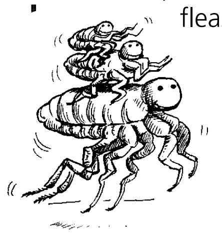
Even more complicated models of atoms



So far our idea of the atom has changed from seeing it as a solid unbreakable ball, to seeing it composed of different particles. We now think that these particles are also made up of even more fundamental particles called quarks. Scientists also think that there are "antiquarks".

There are thought to be six "flavours" of quark: discovered so far are Up, Down, Charm, Strange and Bottom; yet to be discovered is Top. Each "flavour" of quark comes in three"colours": red, blue and green! Though, of course, quarks don't really have a taste or a colour!

Perhaps quarks in turn are made up of other smaller particles, and perhaps these even smaller particles are made up of even smaller particles ... perhaps this is like fleas having tiny fleas on them?



"So, naturalists observe, a flea
Hath smaller fleas that on them prey;
And these have smaller fleas to bite 'em,
And so proceed ad infinitum."

Jonathan Swift (1667-1745)

How many different kinds of atom are there?

Atoms are composed of neutrons, protons and electrons. Those particles do not change. But what is different is the number of the particles that make up individual atoms.

There are over 90 different kinds of atoms that occur naturally. These different atoms make up the different elements in the Periodic Table. All materials in the Universe are made up of them. There are also a number of new atoms that can be made in the laboratory.

Having read this brief history of atoms, try these questions:

1. Why do we think that the atom is mainly empty space?

2. Imagine you have access to a time machine. In it you are able to travel back to the time of the Greek philosopher Democritus. How would you persuade his fellow Greeks that his idea of the atom was largely correct, although not perfect?

3. In your time machine go back to the time of J. J. Thompson. Write a letter to him explaining how his concept of the atom will have to change.

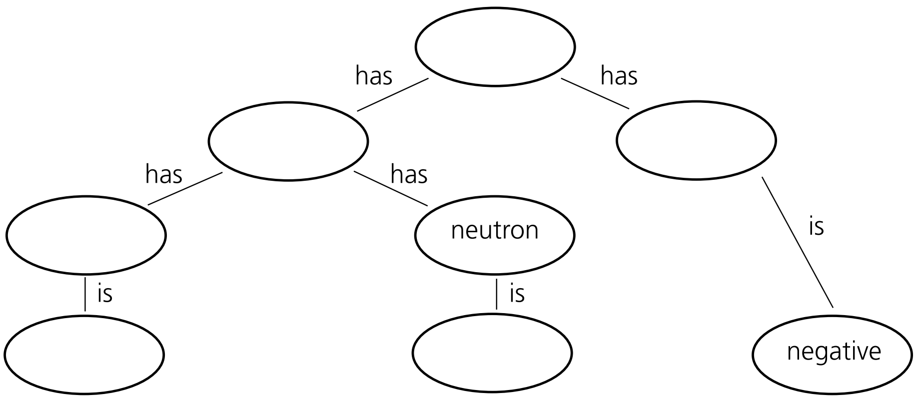
4. Look back at Dalton’s atomic theory. Which of his ideas have had to change over the years and which continue to be accepted?

5. Copy the following table into your books, but make sure the date corresponds to the right discovery and discoverer(s).

Date	**Discovery**	**Discoverer(s)**
1896	Discovery of the neutron	Ernest Rutherford
1897	Proposal of “nuclear” atom	Antoine Henri Becquerel
1911	Discovery of the electron	J. J. Thompson
1932	Discovery of radioactivity	James Chadwick

6. Copy the concept map and fill in the blanks with the following concepts:

atom electron neutral nucleus positive proton



7. Copy and complete this table:

Particle	Relative Mass	Charge
Proton	1	
Neutron		
Electron	1/1840	

4 Nothing buttery

If humans are just a collection of atoms, then what is justice? What is love? What is music?

Is the Mona Lisa more than just a set of atoms?

Is a poem just a set of atoms making up the ink on the page?

Or perhaps there is something more ...?

Try to make up some amusing 'nothing buttery' statements. For example, 'a kiss is *nothing but* the touching of lips', or 'a novel is *nothing but* words on pages'!

The idea that things can be "nothing but" something else has been called "nothing buttery", or "reductionism". The poem below characterises a reductionist view of the world:

"Nature, it seems, is the popular name
For milliards and milliards and milliards
Of particles playing their infinite game
Of billiards and billiards and billiards"

Piet Hein

An electron is 1/1840 times less massive than a proton or neutron. This is an important property to maintain the structure of the Universe. If the electron had a similar mass to protons or neutrons, then they would rotate around each other and all matter would be fluid.

Why is it that the charge on the proton and electron is numerically exactly the same? Is this merely an incredible coincidence?