**Models of the atom from Democritus to Rutherford**

**Levels:** 5-6  
**NoS achievement aims:** Understanding about science, Communicating in science   
**Contextual strands:** Material world   
**Topic:** Atoms, ions, molecules

**Rationale**

The atom is composed of many different kinds of sub-atomic particles which are arranged in particular ways.

Scientific knowledge about the atom has evolved as new evidence has been discovered. The discovery of sub-atomic particles changed how scientists view the atom. This is an area where students can gain an understanding of how science ideas change over time.

**What you need**

* From Democritus to Rutherford - Developing our understanding of atomic structure (a play), p2-6

**Focus**

* How would early scientists have shown that matter was made of units too small to be seen?
* Why do you think scientists’ views of atomic structure have changed over time?
* How do scientists develop ideas about structures that are too small to see with the naked eye?
* Have scientists’ ideas about atoms changed over time only because their instrumentation has become more powerful?
* What might drive scientists to keep looking for new explanations?

**Exploration**

* Get students to read and/or act out the play.

**Reflection**

* Why do we need more than one type of model for complex phenomena? (No one model can represent all the features of a reality. Where something is complex, scientists pick the model that is most relevant to the aspect under investigation.)
* How do scientists use other ideas to develop better understanding? (For example, they build on other ideas either directly or by challenging them.)
* Do scientists have a complete understanding of the structure of atoms and how they act?
* How do models help scientists understand the complexities of subatomic particles?
* If you were going to extend this play to the modern day, whose ideas would you include, and why? (For more on atomic models see [Selecting models of atoms](https://scienceonline.tki.org.nz/Nature-of-science/Nature-of-science-teaching-activities/Selecting-models-of-atoms) .)

# From Democritus to Rutherford: Developing our understanding of atomic structure

Haigh, M. & Ward, G. (2000) From a paper presented at Scicon 2000, Palmerston North.

**Cast:**   
Narrator(s) – could be one actor, or up to 10, depending on the number of students available

Democritus

Aristotle

Lucretius

Lavoisier

Dalton

Madame Curie

J. J. Thomson

Rutherford

**From Democritus to Rutherford: Developing our understanding of atomic structure**

**Narrator 1**

The story of the development of our understanding of atomic structure begins in Greece, a long, long time ago. The Greeks had a sophisticated schooling structure where teachers and their students met to discuss ideas about the world that they lived in. These teachers and their students proposed theories about the nature of the world and would debate them vigorously. Every few years another teacher would propose a new idea and gain a following, but no one seriously believed these ideas could be proved right or wrong, and they never carried out any experiments to test the ideas.

We will start our story about the development of an atomic theory in the fifth century B.C. with Leucippus and his student Democritus, two Greek philosophers and teachers. Here is Democritus.

**Democritus**

I spent a lot of time thinking and asking questions. What would happen if I took a block of gold and kept cutting it up? Large block to lump, lump to powder, powder to what? Maybe I would reach a point where I couldn’t cut it up any more. I would be left with an ‘uncuttable’ particle. I called this particle ‘atomos’ which means unable to be divided. I thought only atoms and empty space existed.

I have also spent some time thinking about how substances change. I suggest that these changes involve the joining and separation of the particles I called atoms.

**Narrator 2**

Not everyone agreed with Democritus. Plato and Aristotle led the debate against his ideas by asking to be shown atoms. Listen to Aristotle.

**Aristotle**

‘Show me an atom.’ I don’t believe they exist. If atoms are meant to explain nature then a universe can exist without a god. I believe that matter consists of four elements – water, fire, air and earth. There is also a fifth element only found in the heavens – ether.

**Narrator 3**

Aristotle challenged Democritus because Democritus made no serious attempt to relate his theories to observations of natural phenomena.

Unfortunately, the writings of Leucippus and Democritus were destroyed or lost. However, we can get some information about their ideas when other scrolls from early ages are found again. A poem about Democritus’s ideas was found in 1417 AD. This poem had been written in the first century BC by the Roman poet Lucretius. Let us listen to Lucretius read some of his poem.

**Lucretius**

On the Nature of Things

Before our very eyes. Do but observe:

Whenever beams make their way in and pour

The sunlight through the dark rooms of a house,

You will see many tiny bodies mingling

In many ways within those beams of light

All through the empty space, and as it were

In never-ending conflict waging war,

Combating and contending troop with troop

Without pause, kept in motion by perpetual

Meetings and separations; so that this

May help you to imagine what it means

That the primordial particles of things

Are always tossing about in the great void.

**Narrator 4**

For almost 2000 years after Democritus, ideas about atoms were sometimes talked about but were not considered to be important. Some of the reasons for this were the influence of the alchemists and the early Christian church. Over this time people thought that what Aristotle was saying sounded most reasonable and the words of Democritus were forgotten.

However, Democritus’ ideas about atoms were revived in the early 1800s by John Dalton, an English school teacher. Dalton was particularly influenced by the experiments of two Frenchmen, Lavoisier and Proust.

Meet Monsieur Antoine Lavoisier.

**Lavoisier**

My wife and I enjoyed entertaining the chemists from England and Europe in our home. Much of the discussion was about what happens when elements are burned in air. Some of my colleagues believed that something was lost when a substance was burned in air and they called this phlogiston. But my experiments indicated that the total mass does not change during chemical reactions, and in 1789 I published a textbook in which I stated the law of conservation of mass.

I could not have done without the help of my wife, Marie Anne. She was a meticulous record keeper, helped with my experiments and translated the writings of other chemists, often finding scientific errors in their works.

I worked in a magnificent private laboratory that I had financed through my investments in a tax collection firm.

**Narrator 5**

Although Lavoisier was not actually involved in tax collecting he was accused of being a ‘tax farmer’ and brought to trial during the French Revolution. He was guillotined in 1794 just two months before the end of the French Revolution.

It is interesting to note that Lavoisier was brought to trial by one of the leaders of the French Revolution, Jean Paul Marat. Marat’s admission to the Academy of Sciences had been blocked by Lavoisier in 1780 because he thought Marat ’s work was nonsense.

The other Frenchman influencing Dalton was Proust. He saved his head during the French Revolution by escaping to Spain where he worked as a chemist under the sponsorship of the Spanish King.

Let’s look at the work of Dalton, the English schoolteacher who is considered to be the father of modern atomic theory.

Here is Dr Dalton, an old man reflecting on his life.

**Dalton**

I had a very busy life. I began teaching in a Quaker school at the age of 12. As well as teaching I liked to carry out experiments in the chemistry laboratory. When I was 37 I proposed my atomic theory which I published in 1808.

The key ideas in my theory are:

* All elements are composed of atoms.
* Atoms of the same element have the same properties but differ in properties from the atoms of other elements.
* Every chemical change consists of the combination or separation of whole atoms.
* Atoms do not subdivide during a chemical change.

I was very careful in my measurements and record keeping and wrote convincingly about my findings.

I became quite popular and people wanted to meet me to discuss my work. However, as a Quaker, I wasn’t very happy about being in the public eye. Some friends wanted to present me to King William IV. This required me to wear my doctorate robes but I was worried about this because being a Quaker I couldn’t wear scarlet, which is the colour of my doctorate robes. Fortunately because I am totally colour blind, I could imagine I was being presented in grey!

**Narrator 6**

However, Dalton and the Greeks were wrong. Atoms are divisible. At the turn of the twentieth century, Roentgen, Bequerel, the Curies, Rutherford and Villard were all working with radioactive substances. Natural radioactive substances give off radiations. The scientists interpreted this as indicating that atoms have an internal structure. The Curies and Bequerel received the Nobel Prize in physics for this work in 1902.

Meet Madame Skowdoska-Curie.

**Madame Curie**

I was only 36 when I received that Nobel Prize. Originally it was only my husband who was nominated. At that time women were considered to not be capable of doing science of any importance. However, my husband, Pierre wrote to the organisers and said that if they were considering him they should also consider me.

When my husband was tragically killed in a traffic accident in 1906, I was appointed to the position that he had held at the University of Paris, continuing our work with radioactive substances. Although, very ill in later life with leukaemia, no doubt brought on by exposure to radioactive substances, looking back I would still say:

“It isn’t really necessary to live such a peculiar life as I have, but you see I so love science.”

**Narrator 7**

Despite Curie’s contribution and success in science, she was refused membership to the French Academy of Science. In fact it wasn’t until 1979 that the first woman was accepted into the Academy. The Royal Society in Britain did not accept her as a member either.

J.J. Thomson and Rutherford, working at the same time as Curie were dismissive of her work. Curie was particularly interested in what the rays from radioactive substances did, but Thomson and Rutherford were interested in how the rays might help them explain the structure of the atom. This followed on from the work of Becquerel who in 1896, discovered an unusual form of radiation coming from a uranium compound. Madame Curie had hypothesised that this radiation was a property of uranium atoms. Meantime J.J. Thomson was thinking about the meaning of his experiments on radioactive substances.

Meet Sir Joseph John Thomson.

**J.J. Thomson**

A colleague of mine, William Crookes, who was working with cathode rays found that they could be deflected by magnetic fields in ways that suggested that they are negatively charged. I continued with the development of this idea and found that these particles had a mass approximately 2000 times smaller than the atom. Following George Stoney’s suggestion, I called these particles ‘electrons’. After much consideration, in 1904 I proposed a model linking the ideas of the time. This was called the ‘plum pudding model’ in which the negatively charged electrons were embedded in a positively charged sphere or ‘pudding’. The overall effect is a neutrally charged atom.

**Narrator 8**

At the same time that Thomson was working, other scientists around the world were also proposing models for the internal structure of the atom.

Philipp Lenard suggested that atoms were mostly empty space and that a negative particle paired with a positive particle and whizzed around in this space.

Nagoaka in Japan suggested that atoms looked like the planet Saturn, with rings of electrons circling a positive core.

By 1911 Rutherford and his associates had good experimental evidence that Nagaoka had come closest to describing actuality but that there were not thousands of electrons as Nagaoka had suggested. Rutherford’s model was more like a solar system than the rings around Saturn.

Listen to Rutherford

**Rutherford**

I was brought up at Havelock in the Marlborough Sounds in New Zealand and went to Nelson College. I wasn’t top of my class and was not accepted at teachers’ college. I went to Canterbury College instead, where I studied physics. My work on magnetism won me a scholarship to Europe, where I became one of J.J. Thomson’s students. I discovered that radioactive uranium emits two different kinds of ‘rays’ – alpha and beta.

**Narrator 9**

A year later Curie suggested that the alpha rays were in fact particles ejected by the radioactive substance – a hypothesis which we now know to be true. Back to Rutherford.

**Rutherford**

This really fascinated me. The atom was no longer considered to be indivisible … but what was its structure?

When my students, Geiger and Marsden, and I fired alpha particles at gold foil we came up with an unexpected result. Some of the particles went through the gold foil, some were reflected back at angles and a small number came straight back to the alpha ray source. “It was quite the most incredible event that has happened to me in my life. It was almost as incredible as if you had fired a 15-inch shell at a piece of tissue paper and it came back to hit you.” We spent the next three years investigating this result and testing our ideas with other experiments. Since most of the alpha particles went through the gold undisturbed we decided that almost all of the space occupied by an atom must be empty.

A very small number of the alpha particles came straight back which we believed indicated that the centre of the atom was very dense, small and having a strong positive charge.

In 1911 we proposed our solar system model of the atom. If the nucleus is the size of a baseball, the edges of the atom are about 600 metres away.

**Narrator 10**

People from many different countries were working on the atom. There were Geiger from Germany, Bohr from Denmark, Rutherford from New Zealand and Mosely who was British.

Rutherford’s work suggested the existence of the positive proton in 1914 but its existence wasn‘t detected until 1918 when advances in technology allowed the scientists to study the nature of the atom in more detail. Other technological advances allowed the scientists to search for other subatomic particles. One machine in particular, a mass spectrometer, allowed the scientists to analyse an element that has more than one atomic mass. Once the scientists knew the mass of a proton and the charge on any nucleus they realised that something else must exist in the nucleus to stop the protons from flying apart. By 1920 scientists were using the name neutron for this other particle in the nucleus but no one was sure just what it was. However, they continued their search and, in 1935, James Chadwick received the Nobel Prize for his discovery of the neutron, the existence of which had been predicted by Rutherford.

The story of our understanding about the structure of the atom is much more complicated than has been presented.

There were lots of other scientists working in this area over a long period of time. I haven’t been able to present many of them to you. There are also some scientists that can’t be found easily in the literature.

Anderson, Aston, Avogadro, Berzelius, Bohr, Cannizzaro, Curie, de Broglie, Fermi, Gay-Lussac, Hahn, Heisenberg, Heitler, Irene Joliot-Curie, Landolt, London, Newton, Marley, Meitner, Mendeleef, Mosely, Pauli, Planck, Priestley, Proust, Schrodinger were all working within or close to the period of time covered by this reading. There are many contemporary scientists working in this area.

There will be many more to come, maybe even one of you.

This reading is dedicated to all of these scientists.

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