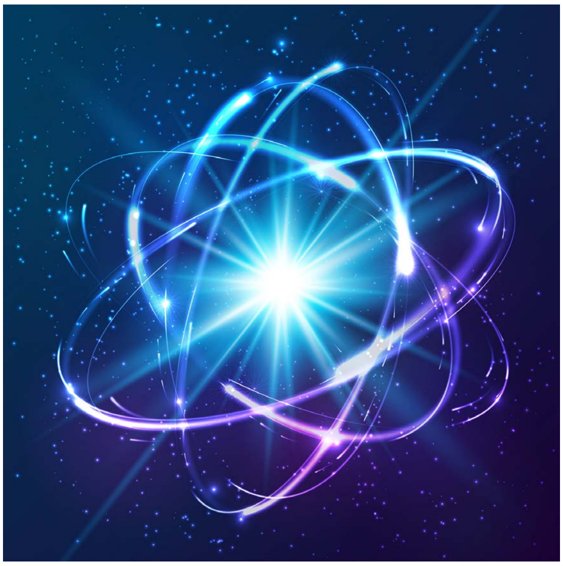
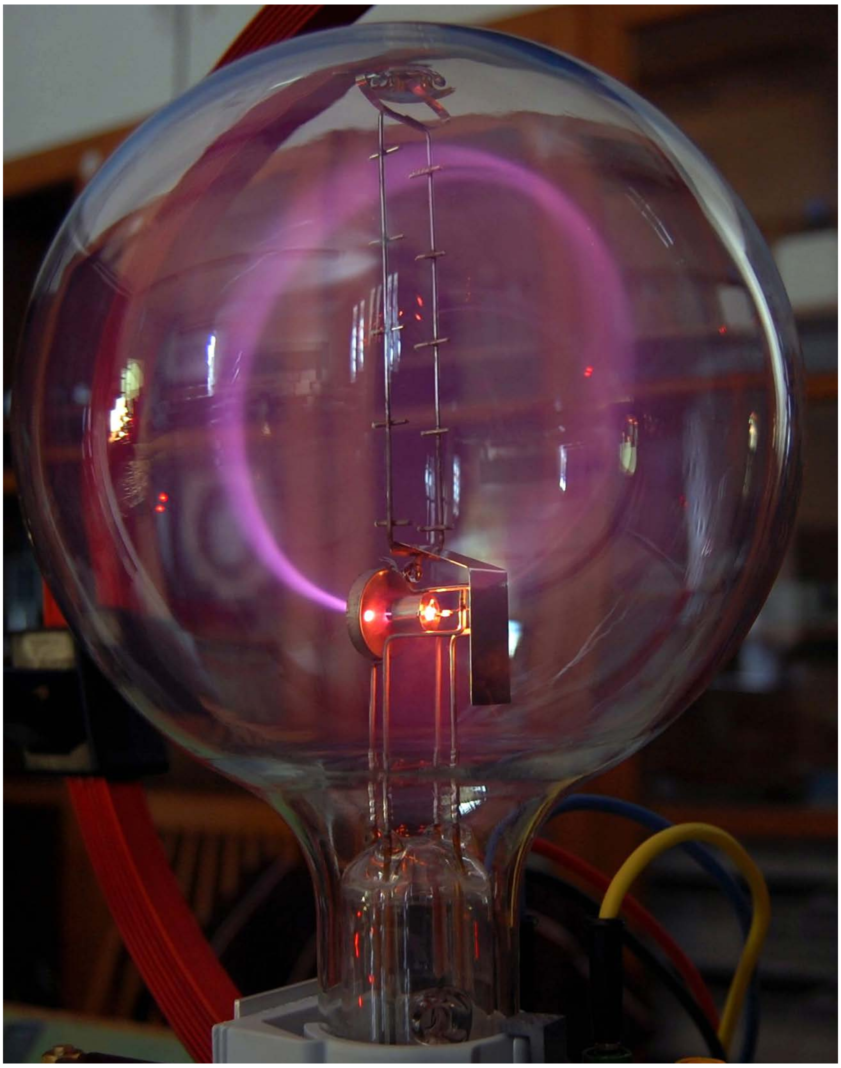
David Sang

Models of the atom

Today we are very familiar with the picture of the atom as a particle with a tiny nucleus at its centre and a cloud of electrons orbiting around the nucleus. But where did this model come from? What were scientists trying to explain using their models of the atom? To find out, we have to go back to the early years of the twentieth century.



A model of the atom. But does the nucleus glow like this? No. And are electrons blue? No.



In this photo, an electron beam is bent along a circular path by a magnetic field. The beam is produced at the bottom in an 'electron gun' and follows a clockwise path inside the evacuated tube. A small amount of gas has been left in the tube; this glows to show up the path of the beam.

Discovering radioactivity and the electron

By the 1890s, most physicists were convinced that matter was made up of atoms. The idea of vast numbers of tiny, moving particles could explain many things, including the behaviour of gases and the differences between the chemical elements.

Then, in 1896, Henri Becquerel discovered radioactivity. He was investigating uranium salts, many of which glow in the dark. To his surprise, he found that all the uranium-containing substances that he tested produced invisible radiation that could blacken photographic paper. What's more, the radiation was constant – there was nothing he could do to speed up or slow down the process.

The next year, J J Thomson discovered the electron. He was studying 'cathode rays', glowing beams which streamed out of the negatively-charged cathode in a vacuum tube. These beams could be deflected by a magnetic field. And, because the beam didn't split up into many thinner beams, Thomson deduced that it was made up of particles of only one type, with negative charge, and all travelling at the same speed.

The importance of these two discoveries was that they suggested that atoms were not indestructible. Atoms are tiny but they are made of still smaller particles.

Positive and negative

Electrons are negatively charged. However, atoms are neutral, so it seemed that there must also be positively-charged particles in an atom. So the question was, how are the positive and negative particles arranged in an atom?

Several scientists came up with suggestions, which we now describe as **models** of the atom. The next two pages show five different models. Then, on page 12, we consider why the nuclear model was successful.

Key words

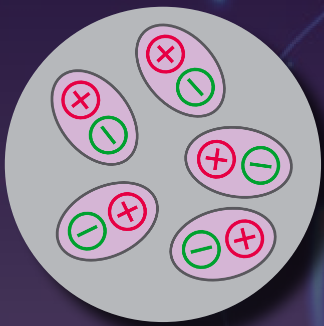
model

atomic structure

electron

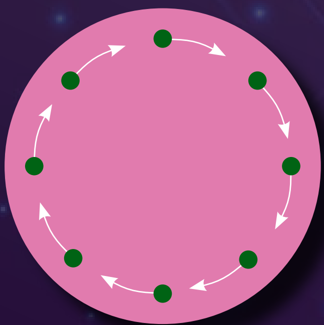
nucleus

ATOMIC MOD



THE DYNAMID MODEL (1903)

Who? Philipp Lenard (Hungarian-German)
Structure: 'Dynamids' each made of an electron bound to a positive charge. Atoms of different elements would be formed of different numbers of dynamids stuck together – one for hydrogen, four for helium, 12 for carbon.
Explains: Different elements have different atomic masses.
Problem: How do the dynamids stick together to form an atom?



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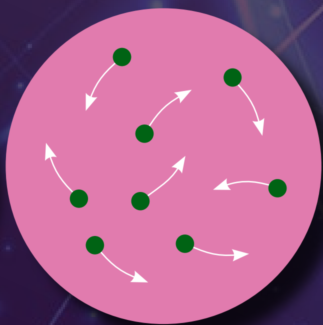
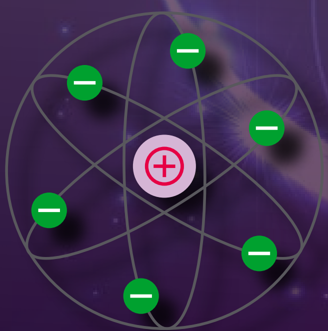


later version

THE PLUM PUDDING M

Who? J J Thomson (British)
Structure: Electrons equally spaced a
charge. Later version: the electrons ar
like the dried fruit in a Christmas pudd
Explains: Atoms are neutral because p
Problem: Alpha scattering (see p12) sh
charge were concentrated in a small fra



THE NUCLEAR MODEL (1911)

Who? Ernest Rutherford (New Zealand) but originally suggested by Jean Perrin (France)
Structure: All of the positive charge of the atom and most of its mass are concentrated at the centre with the electrons orbiting around it.
Explains: Alpha particle scattering results (see p12).
Problem: What holds the nucleus together?
And why don't electrons spiral into the nucleus?

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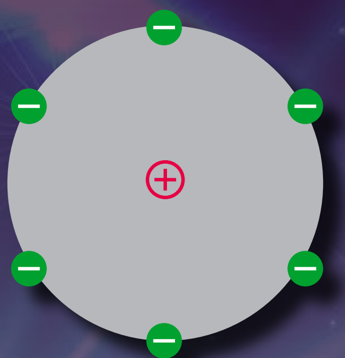
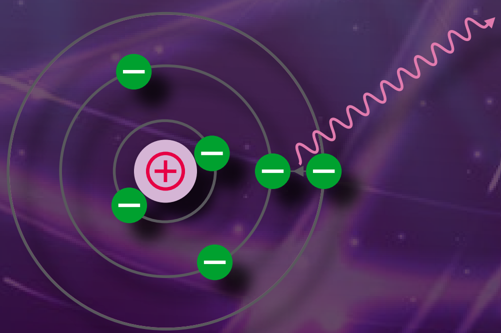


THE SATURNIAN MODEL (1904)

Who? Hantaro Nagaoka (Japanese)
Structure: Electrons form rings around a central positively-charged 'planet' like Saturn. The attraction between opposite charges keeps the electrons in their orbits.
Explains: Different elements have rings with different energies, so they have different colours in their spectra.
Problem: Not enough supporting evidence at the time.

MODEL (1904)

around a ring, orbiting inside a sphere of positive
e scattered about inside the positive charge, rather
ing.
positive and negative charges are balanced.
howed that most of the mass and all of the positive
action of the atom.



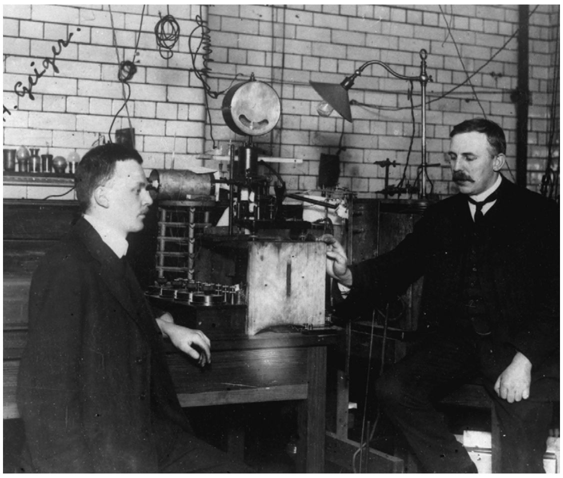
THE BOHR MODEL (1913)

Who? Niels Bohr (Denmark)
Structure: Electrons only in orbits with fixed energies around the central nucleus. They can jump from one orbit to another, emitting or absorbing energy.
Explains: The wavelengths of light emitted by hydrogen atoms.
Problem: Breaks several laws of classical Physics, paving the way for Quantum Physics to be developed.

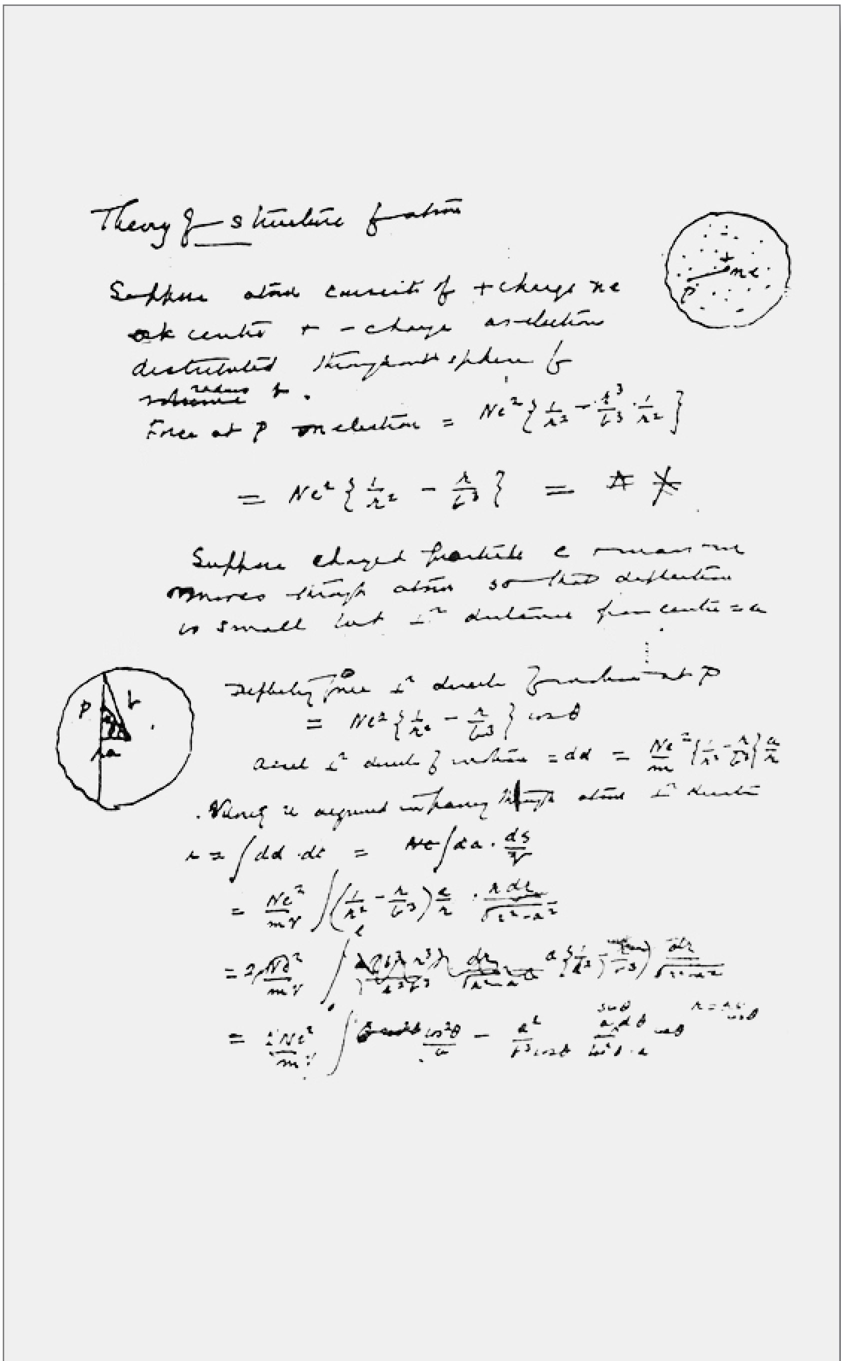
What makes a good scientific model?

Models are used in science to help to explain observations and to develop theories. A good model can explain experimental evidence and lead the way to a theory.

You can see that each of the atomic models shown on pages 10-11 (and there were several others) had some good features. They might be able to explain why atoms are stable, why the atoms of one element differ from another, why different elements emit different colours of light, why some atoms decay and so on. But, in the end, a good model must explain everything we know or it will have to be modified or discarded.



Ernest Rutherford (right) with his colleague Hans Geiger in their lab in 1912.


Theory of structure of atom

Suppose atom consist of + charge Ne at centre & − charge as electrons distributed throughout sphere of radius R.

Rutherford's notes, in which he used the laws of static electricity to work out how a charged particle would move through an atom.

Ernest Rutherford's most famous experiment involved directing alpha radiation (positively-charged particles) at a thin gold foil. Some of the alpha particles were scattered back towards their source; he guessed that gold atoms had a tiny charged nucleus which reflected them.

The nuclear model was rapidly developed by Rutherford and others. A striking feature of Rutherford's thinking is that he realized that it was hard to explain why the nucleus, made only of positive charge, didn't fly apart. Gradually it came to be understood that the nucleus is made up of two types of particle, protons and neutrons, and a new force, the strong nuclear force, was discovered which holds these particles together.

The nuclear model had another problem: when charged particles such as electrons travel round in circular paths, they usually radiate energy, slow down and spiral in towards the centre of their orbit. Niels Bohr developed the idea that this simply doesn't happen in atoms, because they have to be in one or other of a fixed set of orbits around the nucleus. They cannot be somewhere in between, so spiraling is out of the question.

Both Rutherford and Bohr showed that sometimes bold thinking is necessary. They were prepared to discard long-held ideas and move ahead, acknowledging that there were problems still to be solved but optimistic that they could adapt their models and the ideas they represented to give a deeper understanding of the nature of matter at the level of atoms.

David Sang is Physics editor of Catalyst.

Some other scientific models you may know

The lock-and-key model of enzyme action

The kinetic model of a gas

The heliocentric model of the Solar System

The wave model of light