Chapter 2 The Atom

1. Introduction

The scientific name for materials is *matter*.
The idea that materials are made up of small particles is often referred to as the *particulate nature of matter*.

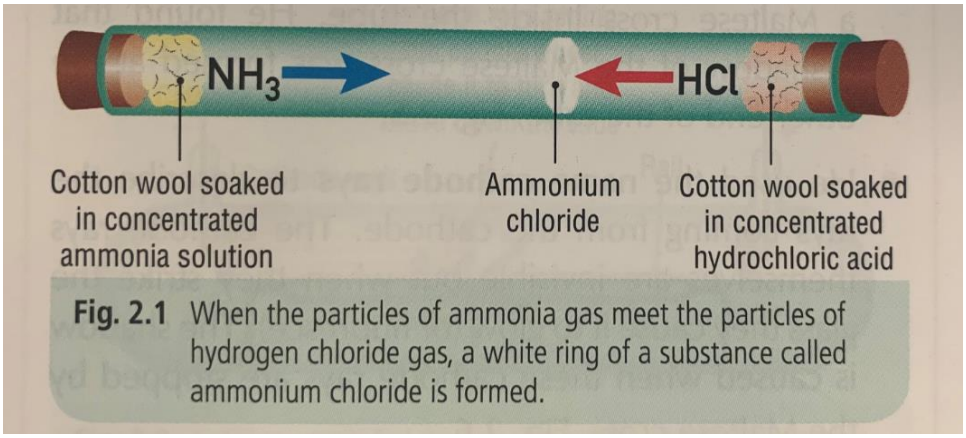


Fig. 2.1 When the particles of ammonia gas meet the particles of hydrogen chloride gas, a white ring of a substance called ammonium chloride is formed.

In the above experiment:

- Particles of the ammonia gas moving from left to right meet up with particles of hydrogen chloride gas moving from right to left.
- A white cloudy substance is formed where the particles of hydrogen chloride and ammonia meet.

The spreading of gases is called *diffusion*.

2. History of the Atom

Greek philosophers were the first to propose that matter was composed of small particles. They believed that those particles could not be broken down into smaller particles. They called these small particles *atoms*.

Later, in 1808 John Dalton (English chemist) came forward with an atomic theory.
His theory may be summarised as follows:

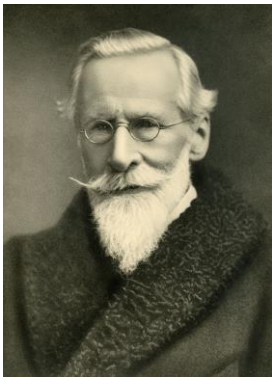
1. All matter is made up of very small particles called atoms.
2. All atoms are indivisible. They cannot be broken down into simpler particles.

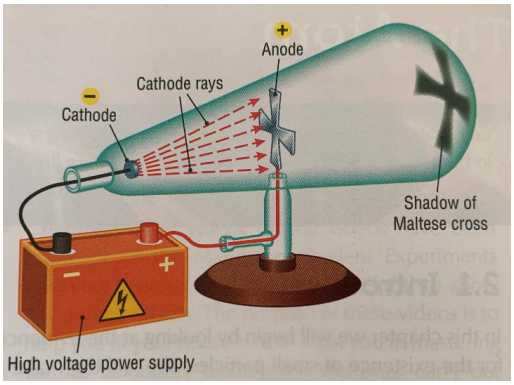
However, his theory started to be questioned towards the end of the XIX century as a result of a series of experiments.

John Dalton:

3. Discovery of the Electron

In 1875 William Crookes (English chemist)

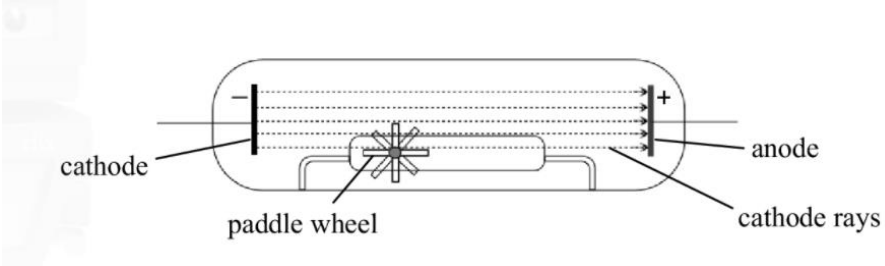




- Crookes used a *vacuum tube* - long glass tube with an electrode at each end, inside the tube there was gas at low pressure
- Rays travelled from cathode to anode these rays were called cathode rays
- They travelled in straight lines – to show the presence of radiation he placed a Maltese cross inside the tube – a sharp shadow in glow formed at end of tube

(CNAP – cathode negative, anode positive)

<u>Crookes carried out a second experiment to investigate the properties of cathode rays (Crookes Paddle Wheel Experiment)</u>



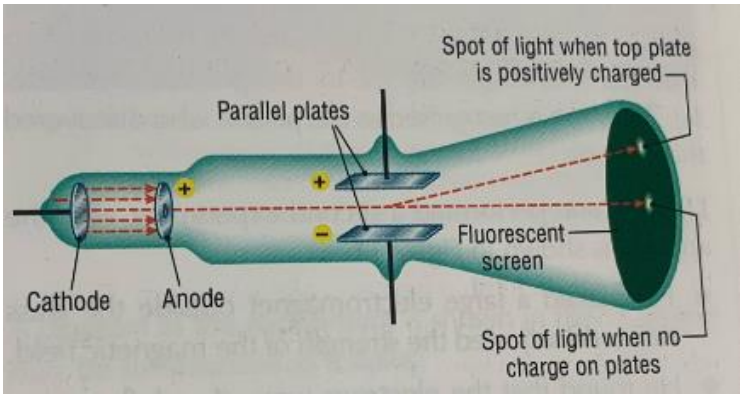
- Consisted of a light paddle wheel mounted on rails in front of the cathode.
- When current on – paddle wheel rotated and travelled down the tube.

- Vanes always turned away from the cathode (concluded: they were struck by particles from the cathode)

Crookes deducted properties of the cathode:

- Cathode rays travel in straight lines
- Cathode rays cause glass to fluorescence when they stroke it
- Cathode rays possess enough energy to move a paddle wheel

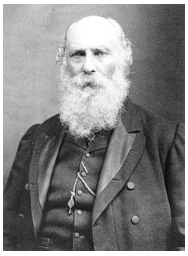
In 1897, *J. J. Thomson* (English scientist) - Nobel Prize in 1906 for the discovery of the electron



He obtained a narrow beam of cathode rays by passing them through a small hole in the positive electrode. The narrow beam then passed between two parallel metal plates (that could be given a charge) and then struck a fluorescent screen at the far end of the tube. This caused the fluorescent screen to glow.

- Showed cathode rays were attracted to positive plate – therefore they were negative
- Measured e/m ratio using the fact that they are deflected by magnetic fields
- Same e/m no matter what gas/electrode materials – therefore in all matter
- e/m is charge of electron over mass of electron which is equal to 1.76×10^{11} coulombs per kg.

Cathode rays were called *electrons* – name proposed by George Stoney (professor of physics) to describe particles in an electric current.



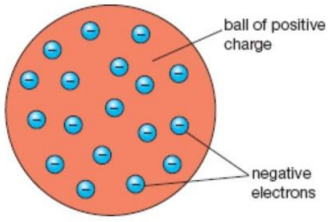
<u>Definition (learn off)</u>

Cathode rays are streams of negatively charged particles called electrons. They travel in straight lines from the cathode (-) to the anode (+), are deflected by electric and magnetic fields, and have sufficient energy to move small objects such as a paddle wheel.

4. Thomson's Plum Pudding Model for Atom

In 1898 J. J. Thomson proposed a very simple Plum Pudding model for the Atom:

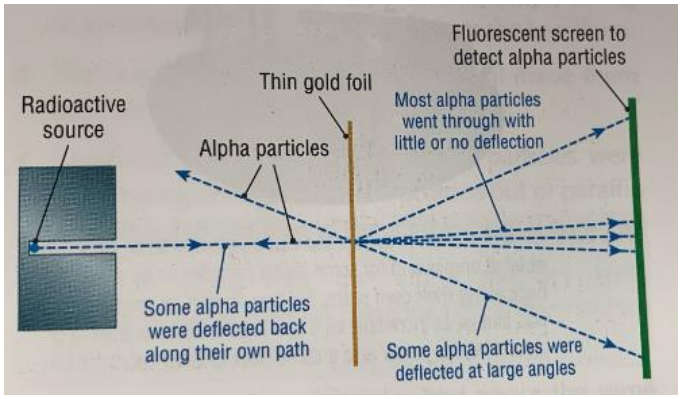
- An atom is like a sphere of positive charge
- Electrons are embedded in the sphere at random



Thomson's 'plum-pudding' model of the atom

5. Discovery of the Nucleus

In 1909, Ernest Rutherford (scientist from New Zealand) performed very important work – led to the discovery of the nucleus – Nobel Prize in Chemistry in 1908 for his work on radioactivity.

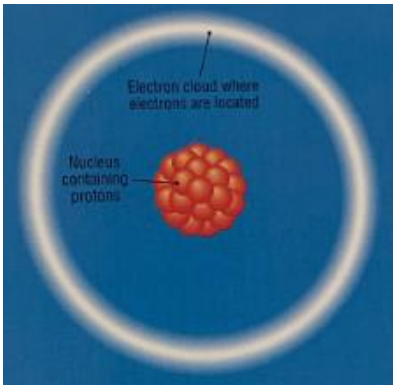


- Rutherford bombarded a thin piece of gold foil with *alpha particles*
- Alpha particles are *positively charged* – 2 neutrons & 2 protons stuck together (nucleus of Helium atom)
- If Thomsons model was right, then you would expect that some alpha particles would be deflected by small amounts.
- Most alpha particles pass straight through the gold foil – most of the atom is empty space.
- Some alpha particles are deflected at large angles – the alpha particles are repelled when they pass near the small positive nucleus.
- A small number of alpha particles are reflected back along their own paths – a small number of alpha particles collide head on with the nucleus.
- He concluded that the positive charge and the mass of the atoms of the metal foil were concentrated in a small dense positive core called the *nucleus* of the atom.
  Watch: https://tinyurl.com/7zy5652f

6. Discovery of the Proton

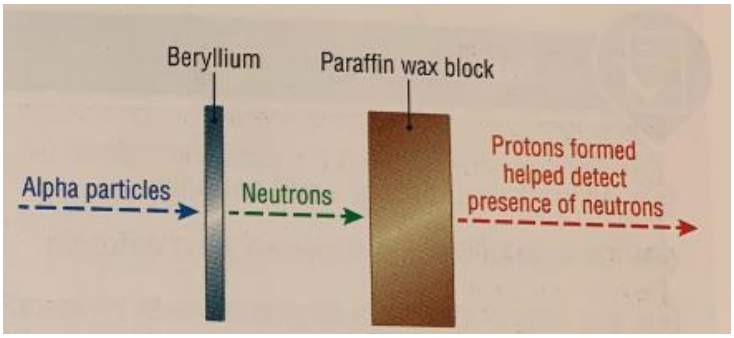
Rutherford continued bombarding elements with alpha particles:

- Light atoms such as O, N – small positively charged particles given off. This did not occur with heavier metals such as Au.
- They concluded that in the case of light atoms, the alpha particles were breaking up their nuclei
- Didn't occur for Au as large positive nuclear charge repelled the alpha particles before they had a chance to break up the nucleus.
- He called the small positive particles – *protons*.
- He discovered that protons were located in the nucleus.
- He proposed a new structure of the atom – it consisted of a nucleus and that the electrons were in some sort of 'electron cloud' surrounding the nucleus.



7. Discovery of the Neutron

In 1932, James Chadwick carried out the following experiment – Nobel Prize in physics in 1935 for discovering the neutron.



- He bombarded a sample of beryllium with alpha particles.
- Some type of radiation with no charge came from beryllium.
- Particles neutral – hard to detect
- These particles were penetrating enough to knock protons out of paraffin wax
- Concluded that the alpha particles were knocking these neutral particles out of the nucleus of the beryllium atom.
- Found that they had same mass as the proton and called them *neutrons*.

If only protons existed in the nucleus, it would fall apart because of the repulsive forces of the proton for each other.

8. Properties of the Sub-Atomic Particles

Sub-Atomic Particle	Relative Charge	Relative Mass	Location
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus
Electron	-1	$\frac{1}{1838}$	Outside nucleus