The Atom

Dalton's Atom

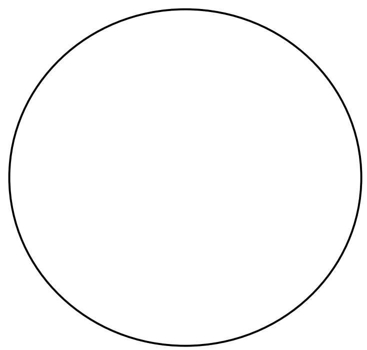
- In 1808 John Dalton proposed that:
  - all matter is made up of atoms which cannot be sub-divided
  - atoms of the same element are identical
  - atoms of different elements have different masses
  - atoms combine together in fixed whole number ratios to form compounds
  - in a chemical reaction, atoms are not created or destroyed, they are rearranged to form new substances.

Dalton's Atom

- These ideas were based on Dalton's estimates of the relative atomic masses of various elements.
- Although his assumptions were not correct in every way, Dalton's theory revived interest in the idea of atoms.
- He was able to explain many chemical reactions and the Law of Conservation of Mass.

Dalton's Atom

- Of course, he was unaware of the existence of isotopes and the underlying structure of the atom.
- Diagram of Dalton's atom



How well does Dalton's Theory fit Modern Atomic Theory

- All matter is made up of atoms as Dalton suggested, but it can be subdivided into protons, neutrons and electrons.
- Atoms of the same element are not identical.
- Each atom of the same element has the same number of protons, but not necessarily the same number of neutrons.
- Dalton was unaware of the existence of isotopes.

How well does Dalton's Theory fit Modern Atomic Theory

- He was correct in his assumption that atoms of different elements have different masses and that they combine together in fixed whole number ratios.
- Atoms are not created or destroyed during chemical reactions - they are rearranged.

Mendeleev and the Periodic Table (1869)

- Mendeleev's work indicated there had to be some underlying characteristics within atoms themselves to account for:
  - the regular (periodic) nature of the properties of the elements
  - the existence of families (groups) of elements with similar properties.

Radioactivity and atomic structure (1896 onwards)

- Radioactivity is the spontaneous disintegration of the atomic nuclei of some elements, such as uranium and radium, into other elements accompanied by the emission of radiation.
- After Henri Becquerel's discovery of radioactivity in 1896 and subsequent investigations by the Curies and Rutherford, it was shown that there are three types of radioactive emissions which are known to have the following characteristics:

Types of Radioactivity

Type of Radiation	Description	Penetrating Power	Symbol	Charge
Alpha (a) particles	Helium nuclei	low	$^{4}_{2}He$	+ 2
Beta (ß) particles	electrons	medium	$^{0}_{-1}e$	– 1
Gamma(?) rays	High energy Electromagnetic radiation	Very high	?	0

Radioactivity and atomic structure (1896 onwards)

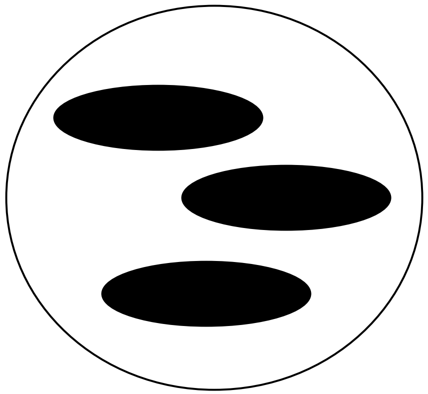
- These findings provided evidence that the atom could in fact consist of smaller particles, that is, it is not indivisible.
- Radioactivity was also a useful tool with which to probe the structure of the atom.
- We now know that the stability of the nucleus depends upon the ratio of protons to neutrons.
- Radioactive elements have unstable nuclei in their atoms and lose energy during radioactive decay by spontaneously emitting radiation.

Thomson's plum-pudding model (1899)

- J. J. Thomson established that all atoms contain negatively charged particles called electrons.
- He proposed a structure for the atom in which rings of electrons were embedded in a sphere of positive charge.
- The positive and negative charges cancelled so that overall the atom was neutral.

Thomson's plum-pudding model (1899)

- This model is now known as the plum-pudding model.



Marie Curie (1867 - 1934)

- Discoverer of radium and polonium
- Radioactivity, a term suggested by Marle Curie, is the spontaneous emission of radiation by the unstable nuclei of atoms of certain elements.

Marie Curie (1867 - 1934)

- This phenomenon was first noticed by Henri Becquerel in 1896. He found that photographic plates darkened when exposed to uranium salts.
- In 1898 Curie examined the radioactivity of pitchblende, a uranium ore (U_30_8).
- She found that far more radiation was emitted than could be accounted for in terms of its uranium content.

Marie Curie (1867 - 1934)

- Marie and her husband Pierre processed several tonnes of uranium ore in 1898 and obtained extremely small amounts of a new radioactive element which she called polonium, after the country of her birth, Poland.
- Its atomic number is 84 and was placed in the same group as tellurium (Group IV, atomic number 52) because of their similar chemical properties.

Marie Curie (1867 - 1934)

- However polonium did not account for all the observed radioactivity
- the Curies subsequently isolated another new, even more powerfully radioactive element called radium (atomic number 88) with similar properties to barium (Group II, atomic number 88).
- In 1901 Curie suggested that radioactivity occurred because of changes taking place **inside** the atom.

Marie Curie (1867 - 1934)

- Polonium and radium have unstable nuclei which break down into smaller nuclei (nuclear fission) with the release of energy.
- The source of these elements is a radioactive isotope of uranium which is at the beginning of a radioactive decay series which ultimately ends in the formation of a stable isotope of lead:

Marie Curie (1867 - 1934)

- 238 U → 234 Th → 234 Pa → 234 U → 230 Th → 226 Ra → 222 Rn → 218 Po → 214 Pb → 206 Pb

- N.B. These reactions occur via a-decay (loss of helium nucleus) and P-decay (loss of an electron) and the release of energy as V-rays (high energy electromagnetic radiation).

Why the elements radium and polonium, always present in uranium ore.

- Uranium ore is the source of radium and polonium.
- A particular isotope of uranium (U-238) is radioactive.
- It undergoes radioactive decay via a series of steps to eventually form a stable isotope of lead (Pb-206).
- Polonium and radium are two of the several radioactive isotopes during this process.

The effect β decay of a radioactive isotope has on

- the mass number of the isotope
  - Mass number of the isotope does not change
  - The loss of a ß-particle (an electron) does not affect the total number of nucleons in the nucleus,
    - e.g. $^{3}_{1}He \rightarrow {}^{3}_{1}He + {}^{0}_{-1}e$

The effect β decay of a radioactive isotope has on

- the atomic number of the isotope
  - The atomic number of the isotope will increase by one because the loss of a negative charge (ß-particle) from the nucleus will increase the positive charge by one.
  - In effect, a neutron has been converted to a proton.

The effect β decay of a radioactive isotope has on

- the position of the isotope in the Periodic Table?
  - The new position of the isotope in the Periodic Table will be one place to the right of its original position, since its atomic number has increased by one.

The effect α decay of a radioactive isotope has on

- the mass number of the isotope

  – The mass number of the isotope will decrease by 4 units since a helium nucleus consists of 4 nucleons (2 protons and 2 neutrons)

The effect α decay of a radioactive isotope has on

- the atomic number of the isotope

  - The atomic number of the isotope will decrease by 2 units since a helium nucleus contains 2 protons.

The effect α decay of a radioactive isotope has on

- the position of the isotope in the Periodic Table

  e.g. $^{226}{}_{88}R \rightarrow {}^{222}{}_{86}R + {}^{4}{}_{2}He$

  An a-particle is a helium nucleus ($^{4}{}_{2}He$)

  – The new position of the isotope will be two places to the left of its original position in the Periodic Table since the atomic number has decreased by 2.