The Nucleus

We have spent some time on the revolution in physics that led to an understanding of the nature of the atom and its interaction with radiation.

This also led to the realisation that atoms are organised around *nuclei*.

Lets take a closer look at the nucleus.

Some Properties of Nuclei

Composition

Size

and

Mass

Some Properties of Nuclei

Size - how *big* is a nucleus?

On the basis of many scattering *experiments*, it is found that most nuclei are approximately spherical and have an average radius given by: $r = r_0 A^{1/3}$

where A is the mass number and r_0 is a constant equal to 1.2 x 10^{-15} m.

This suggests that the density of nuclei is approximately constant (*Why*?).

A *drop of liquid* also has a constant density and this has lead to the liquid drop model of the nucleus, which we will treat in some detail later.

Some Properties of Nuclei

Composition:

All nuclei appear to contain two kinds of particles bound together. These are *protons* and *neutrons*.

Protons have a charge of +*e*.

Neutrons are neutral

The ***atomic number***, *Z*, of a nucleus is just the number of protons that it contains. This is sometimes called the *charge number*.

The ***neutron number***, *N*, is the number of neutrons.

The ***mass number***, *A*, is equal to the total number of particles, neutrons and protons, present in the nucleus: $A = Z + N$.

For an element with symbol, X we use the notation ${}^{A}_{Z}X$. For example iron is the 26th element in the periodic table. Any nucleus of iron has 26 protons. The stable isotope of iron, Fe-56, contains 56 particles, 26 protons and 30 neutrons, we write: ${}^{56}_{26}Fe$ or often just ${}^{56}Fe$.

How many neutrons are there in ${}^{56}Fe$?

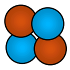
***Composition*:**

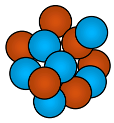
This gave the following picture of a nucleus made of:

protons

and **bound together.**

neutrons

e.g.  **α particle or** ${}^{4}_{2}\mathrm{He}$ **nucleus**

 ${}^{12}_{6}\mathrm{C}$ **nucleus**

The particles are bound together by the so-called *strong nuclear force*.

Some Properties of Nuclei

***Masses*:**

Particle	Masses in different units		
	kg	Atomic mass units u	MeV/c^2
proton	1.67262×10^{-27}	1.007276	938.28
neutron	1.67493×10^{-27}	1.008665	939.57
electron	9.10939×10^{-31}	5.486×10^{-4}	0.511
${}^{1}_{1}\mathrm{H}$ atom	1.67353×10^{-27}	1.007825	938.783
${}^{12}_{6}\mathrm{C}$ atom	1.99265×10^{-26}	12 by definition	11 177.9

$$1\ \mathrm{u} = 931.494\ \mathrm{MeV}/c^2$$

Some Properties of Nuclei

Size - how big is a nucleus?

Say that this were a nucleus. Its diameter is about 2 mm on the computer screen

The size of an atom can be about 10 000 bigger, i.e it would be about 20 m on the same scale.

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Exercise 16

1. Use the relation: $r = r_0 A^{1/3}$ to calculate the size (diameter) of the nuclei ^{12}C, ^{140}La, ^{235}U and ^{238}U. What are the ratios of the diameters of the others to the diameter of ^{12}C?

2. Do the same for the nucleus ^{197}Au and compare the answer with the one you obtained previously by Rutherford scattering.

3. After a supernova explosion the core of the star that remains can consist of pure nuclear material. This is known as a neutron star. Calculate the mass of a volume of 10 cm^3 of a neutron star.

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