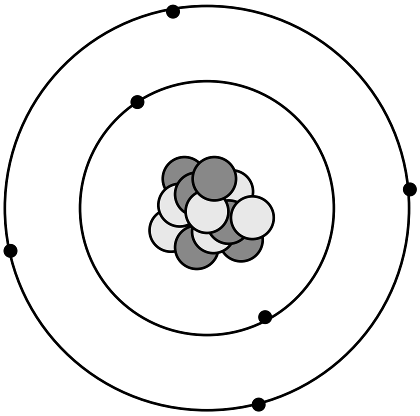
How to represent the nucleus of an atom



In 1911 Ernest Rutherford discovered the nucleus of an atom. He proposed that the atom had a central nucleus made up of protons, which were positively charged and neutrons with no charge.

Around the nucleus were very light negative particles called electrons.

Rutherford

When studying the atomic nucleus the electrons are ignored and we concentrate on the nucleus.

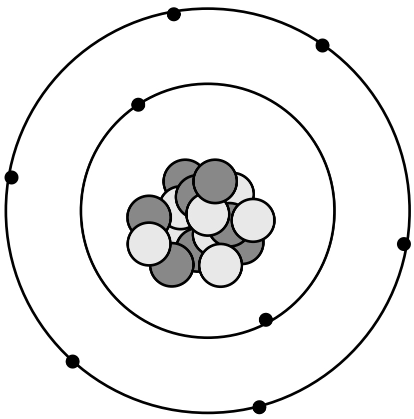
The atom`s nucleus shown above is carbon. It can be written as:

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

12 ◄ ....

C ◄ ....

6 ◄ ....



$$^{16}_{8}\mathrm{O}$$

In general a nucleus can be represented as

$$^{A}_{Z}\mathrm{X}$$

A ....

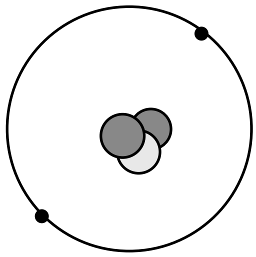
Z ....

....

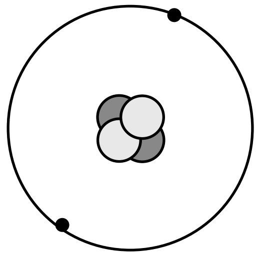
Isotopes

These are atoms of the same element having the same number of protons but a different number of neutrons.

The pictures below show the isotopes of helium.



He



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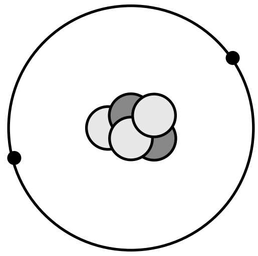


He

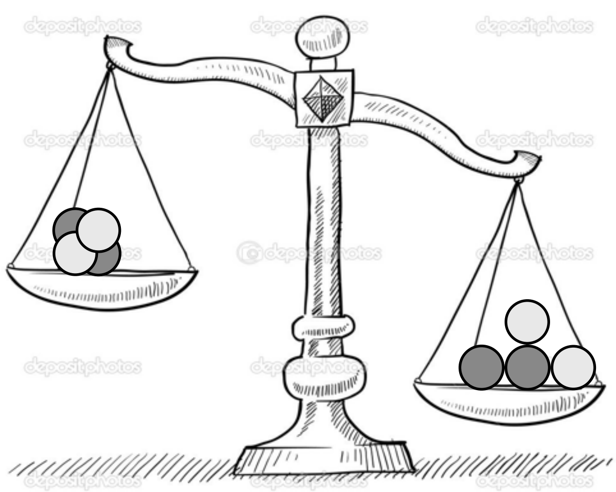
It doesn't`t add up

Here is a table showing the masses of the proton, neutron and electron

Particle	Symbol	Mass in kg
Proton	$^{1}_{1}p$	1.6726×10^{-27}
Neutron	$^{1}_{0}n$	1.6749×10^{-27}
Electron	$^{0}_{-1}e$	9.11×10^{-31}

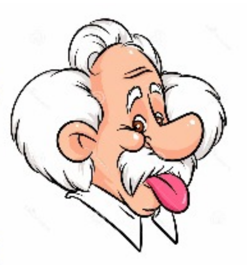
He

The helium nucleus has a mass of 6.6465×10^{-27} kg



The total mass of all the nucleons if the nucleus was broken apart is:

The mass of the nucleus is less than its parts!!!!!!!



Mass Defect.

It was Albert Einstein who came up with the answer.

Yes mass was missing indeed! It was changed into energy. More precisely into **binding energy** to keep the nucleus from flying apart,

Why should the nucleus fly apart?

....

What keeps the nucleus from flying apart?

....

Where does this energy come from?

....

....

$$E = mc^2$$

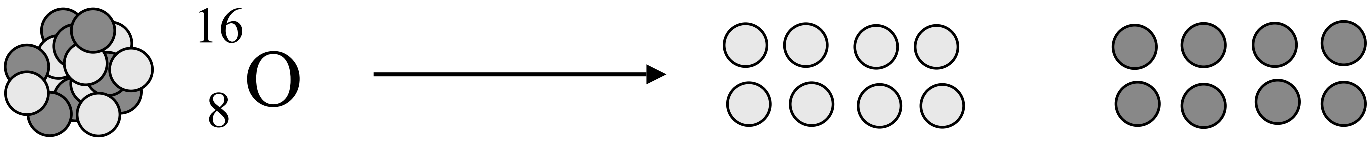
The mass defect of the helium 4 nucleus compared to its constituent nucleons is

Total mass of nucleons = ...

Mass of nucleus = ...

Mass defect = ...

Binding energy =



The mass defect of the oxygen nucleus compared to its constituent nucleons is

Total mass of nucleons = ...

Mass of nucleus = 2.6559×10^{-26} kg

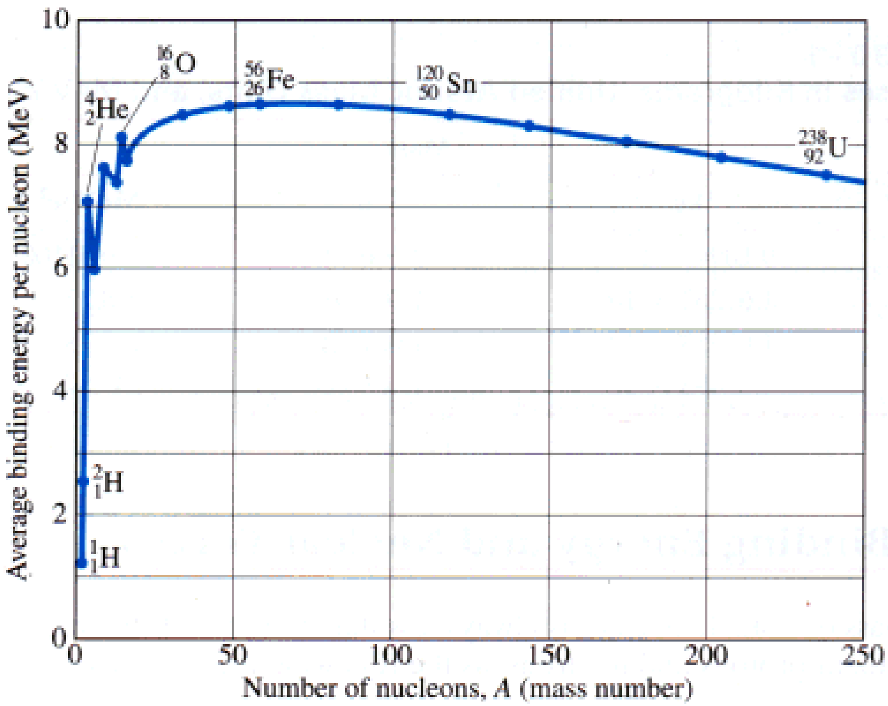
Mass defect = ...

Binding energy =

The binding energy is the energy needed to break apart a nucleus into its constituent nucleons.

The bigger the binding energy the more stable the nucleus.

Every nucleus has a different binding energy. The graph below shows the binding energy for nuclei from hydrogen to helium to iron to uranium.



All nuclei want to become as stable as possible. In other words they want to get to get to the peak of that curve.

That is as close to iron as they can get.

Alpha beta and gamma radiation.

If a nuclei is unstable it will emit radiation. The nucleus gives off either an alpha particle, beta particle or a flash of gamma radiation.

Radiation emitted	What it is.	Symbol
Alpha particle	Basically a helium nucleus. The nucleus` mass number goes down by 4 and its atomic number goes down by 2	α $\quad {}^{4}_{2}He$
Beta particle	A fast moving electron emitted from nucleus. Really a neutron decays into a proton and emits an anti neutrino and an electron. The nucleus mass number remains unchanged but the atomic number goes up by 1	${}^{0}_{-1}\beta$
Gamma radiation	This is when an electromagnetic wave is emitted in the form of a photon . The mass and atomic numbers of the nucleus remain unchanged. This radioactive emission usually comes after an alpha decay.	γ

$${}^{234}_{92}U \longrightarrow {}^{230}_{90}Th + {}^{4}_{2}\alpha$$

$${}^{234}_{91}Pa \longrightarrow {}^{234}_{92}U + {}^{0}_{-1}\beta$$

Alpha beta and gamma radiation examples.

Determine the radioactive particle given off in the following nuclear decays.

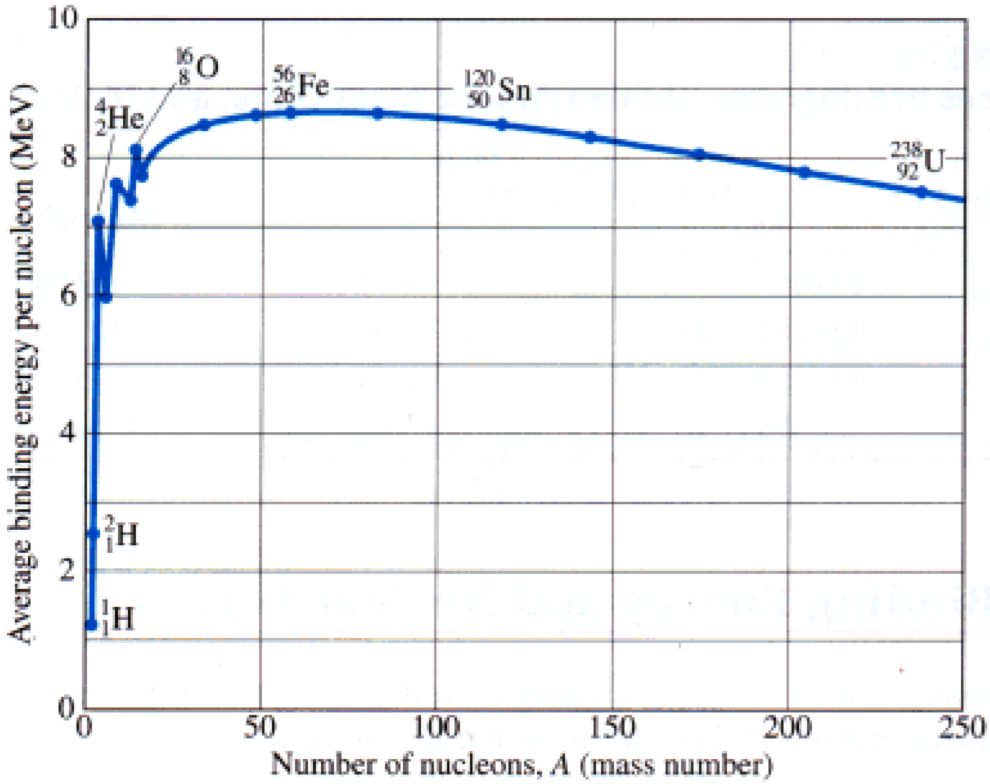
$$^{228}_{90}Th \longrightarrow \, ^{224}_{88}Ra + \, ^{A}_{Z}X$$

$$^{60}_{27}Co \longrightarrow \, ^{60}_{28}Ni + \, ^{A}_{Z}X$$

$$^{214}_{84}Po \longrightarrow \, ^{p}_{q}X + \, ^{4}_{2}\alpha$$

$$^{210}_{83}Bi \longrightarrow \, ^{p}_{q}X + \, ^{0}_{-1}\beta$$

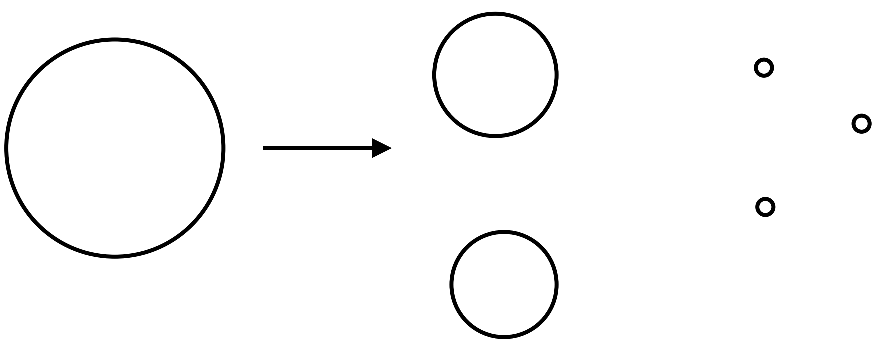
Fission and Fusion.



The binding energy graph indicates that atomic nuclei such as uranium - 238 is unstable and in order to become stable it would have to reduce the number of nucleons in its nucleus.

It does this by splitting into two smaller nuclei. This process is called **FISSION.**

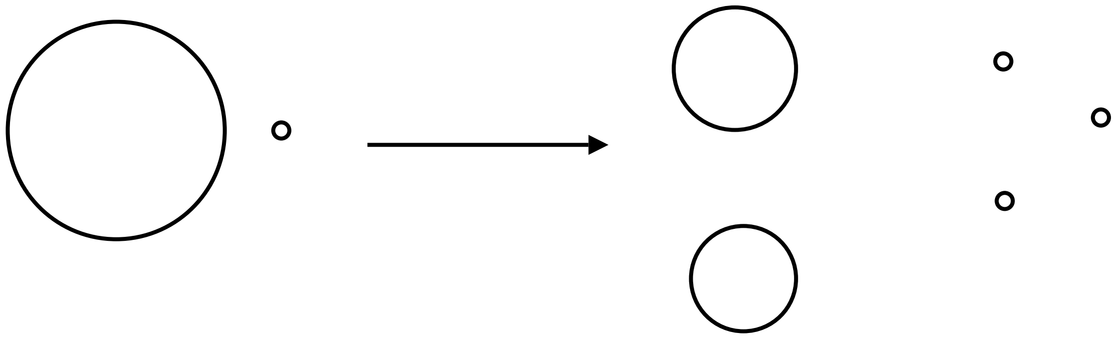
$$^{236}_{92}U \longrightarrow \, ^{144}_{56}Ba + \, ^{89}_{36}Kr + 3n$$



Heavy nuclei can be made to ***undergo*** fission. The large heavy nucleus captures a neutron and then splits into two smaller nuclei.

This is called induced fission.

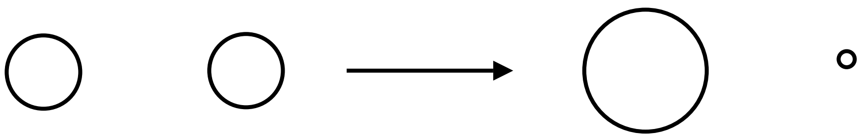
$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$$



Two very light nuclei can also come together to make a larger nucleus.

This is called fusion

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$



In both fission and fusion the mass of the product nuclei will be less than the mass of the nuclei before the reaction. Once again we have a mass defect.

$$E = mc^2$$

Calculating the mass defect in nuclear reactions

Nuclear Fusion

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

Nucleus	Mass in kg
$^{2}_{1}H$	3.349 x 10^{-27} kg
$^{3}_{2}He$	5.007 x 10^{-27} kg
$^{1}_{0}n$	1. 675 x 10^{-27} kg

Total mass on left hand side of equation

....

....

= ....

Total mass on right hand side of equation

....

....

= ....

Mass defect = ...

Energy released = ...

Nuclear Fission

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{137}_{56}Ba + ^{97}_{42}Mo + 2^{1}_{0}n$$

Nucleus	Mass in kg
$^{235}_{92}U$	390.2 x 10^{-27} kg
$^{1}_{0}n$	1.675 x 10^{-27} kg
$^{137}_{56}Ba$	227.3 x 10^{27} kg
$^{97}_{42}Mo$	160.9 x 10^{-27} kg

Total mass on left hand side of equation

....

....

= ....

Total mass on right hand side of equation

....

....

....

= ....

Mass defect = ...

Energy released = ...