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ATOMS AND RADIOACTIVITY

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Specification

Radioactivity and particles

Radioactivity

describe the structure of an atom in terms of protons, neutrons and electrons and use symbols such as $^{14}_{6}C$ to describe particular nuclei

understand the terms atomic (proton) number, mass (nucleon) number and isotope

understand that alpha and beta particles and gamma rays are ionising radiations emitted from unstable nuclei in a random process

describe the nature of alpha and beta particles and gamma rays and recall that they may be distinguished in terms of penetrating power

describe the effects on the atomic and mass numbers of a nucleus of the emission of each of the three main types of radiation

understand how to complete balanced nuclear equations

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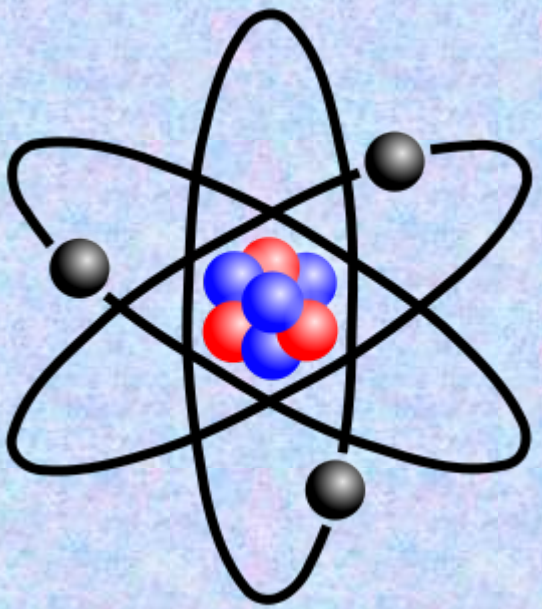
Atomic structure

An atom consists of a small central nucleus composed of protons and neutrons surrounded by electrons.

An atom will always have the same number of electrons as protons.



A Lithium atom

- **protons**
- **neutrons**
- **electrons**

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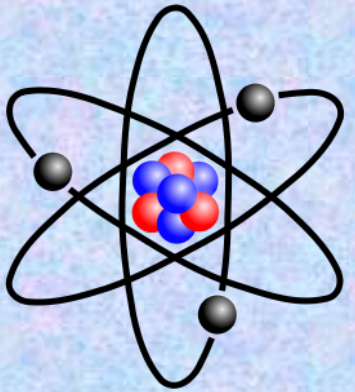
Atomic and mass number

The **atomic number** (or proton number) of an atom is equal to the number of **protons** in its nucleus.

The **mass number** (or nucleon number) of an atom is equal to the number of **protons plus neutrons** in its nucleus.



protons = 3

neutrons = 4

electrons = 3

This Lithium atom has:

atomic number = 3

mass number = 7

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Properties of protons, neutrons and electrons

	Position in the atom	*Relative mass*	*Relative electric charge*
PROTON	**nucleus**	**1**	**+ 1**
NEUTRON	**nucleus**	**1**	**0**
ELECTRON	**outside nucleus**	**0.005**	**- 1**

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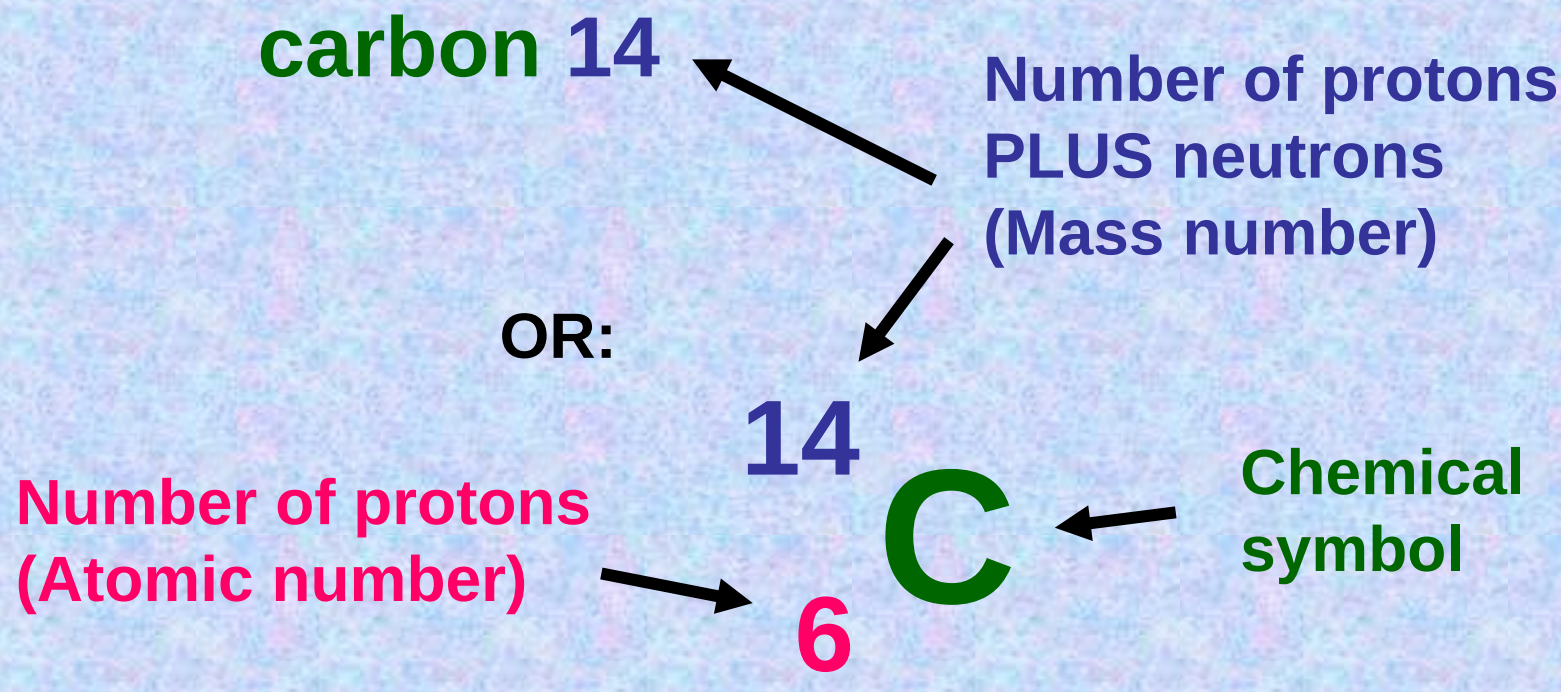
Nuclear notation

An isotope of carbon consists of 6 protons and 8 neutrons.
This can be written as:



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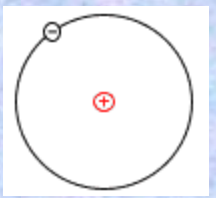
Isotopes

The atoms of an element always have the same number of protons.

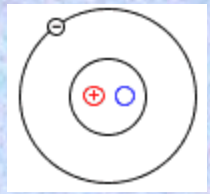
Isotopes are atoms of the same element with different numbers of neutrons.

The three isotopes of hydrogen

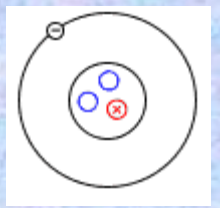
○ neutrons



hydrogen 1



hydrogen 2
(deuterium)



hydrogen 3
(tritium)

Note: The number after ‘hydrogen’ is the mass number of the isotope.

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Question 1

*An isotope of uranium (chemical symbol **U**) consists of 92 protons and 143 neutrons. Give the two different ways of notating this isotope.*

The mass number of the Uranium isotope:

= 92 + 143 = 235

uranium 235 **AND** $^{235}_{92}U$

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Question 2

Determine the number of protons and neutrons in the isotopes notated below:

(a) $^{13}_{7}N$ protons = 7 neutrons = 6

(b) $^{60}_{27}Co$ p = 27 n = 33

(c) $^{197}_{79}Au$ p = 79 n = 118

(d) $^{239}_{94}Pu$ p = 94 n = 145

Note: Apart from the smallest atoms, most nuclei have more neutrons than protons.

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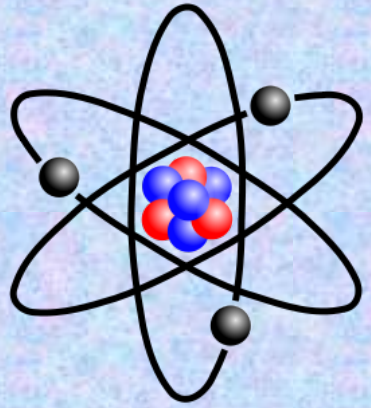
Ionisation

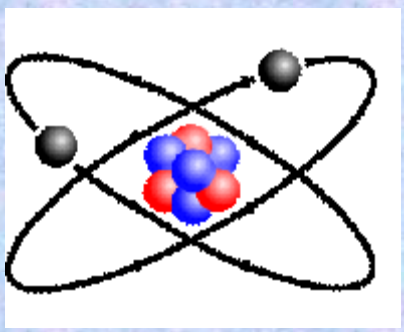
Ionisation occurs when an atom loses or gains one or more electrons.



Lithium atom (uncharged)

When an atom loses electrons it becomes a **positive ion**.

When an atom gains electrons it becomes a **negative ion**.



Lithium ion (positively charged)

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Radioactivity and Ionising Radiation

The nuclei of some isotopes are unstable and when they decay they give of radiation that causes ionisation.

This phenomena is called **radioactivity** and the radiation produced is called **ionising radiation**

Radioactivity is a **random** process. When a particular nucleus decays cannot be predicted.

Henri Becquerel discovered radioactivity in 1896

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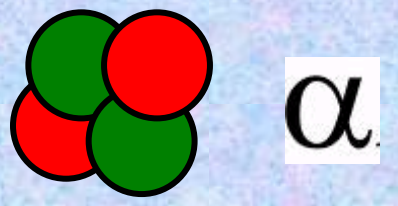
Alpha, beta and gamma radiation

An alpha particle consists of two protons and two neutrons.

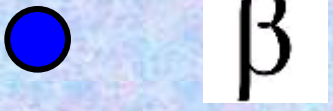
It is strongly ionising.



A beta particle is a high speed electron.

It is produced when a neutron has decays into an electron and proton.

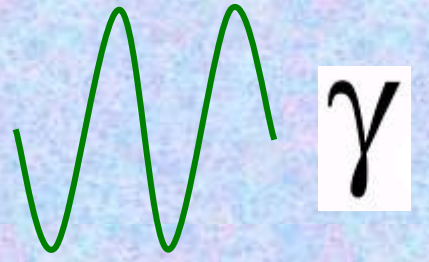
It is moderately ionising.



Gamma rays are very high frequency electromagnetic waves.

They are produced when an unstable nucleus loses energy..

They are weakly ionising.



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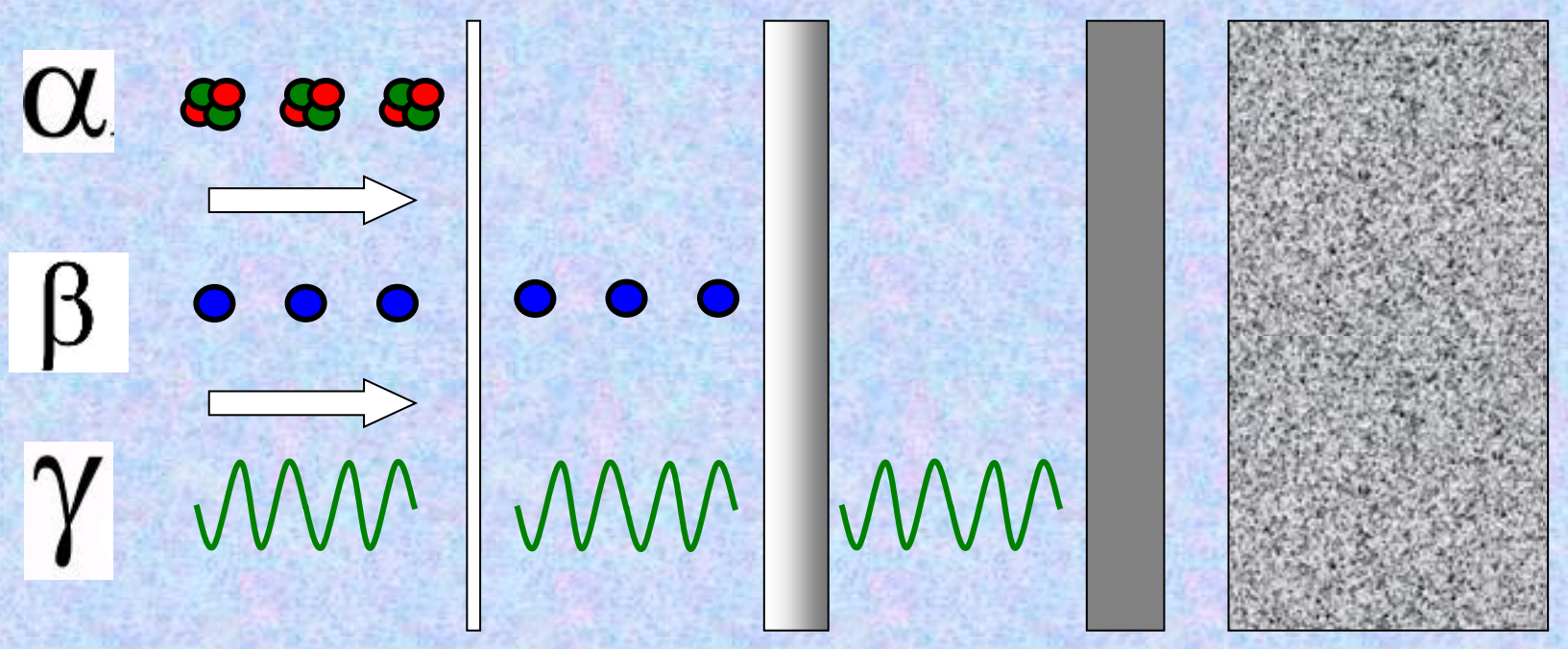
The penetrating power of alpha, beta and gamma radiation



Paper or a few cm of air stops alpha particles

1cm or 1m of air of aluminium stops beta particles

Several cm of lead or 1m of concrete is needed to stop gamma rays

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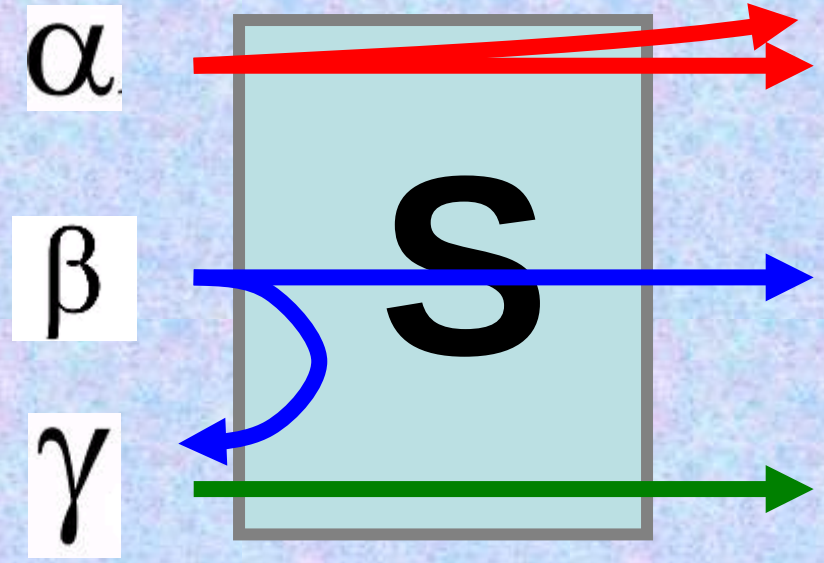
Deflection by magnetic fields



Magnetic south pole placed behind the rays

Alpha and beta particles are deflected in opposite directions due to their opposite charges.

Due to their much larger mass alpha particles are deflected far less than beta.

Gamma rays are not deflected because they are not charged.

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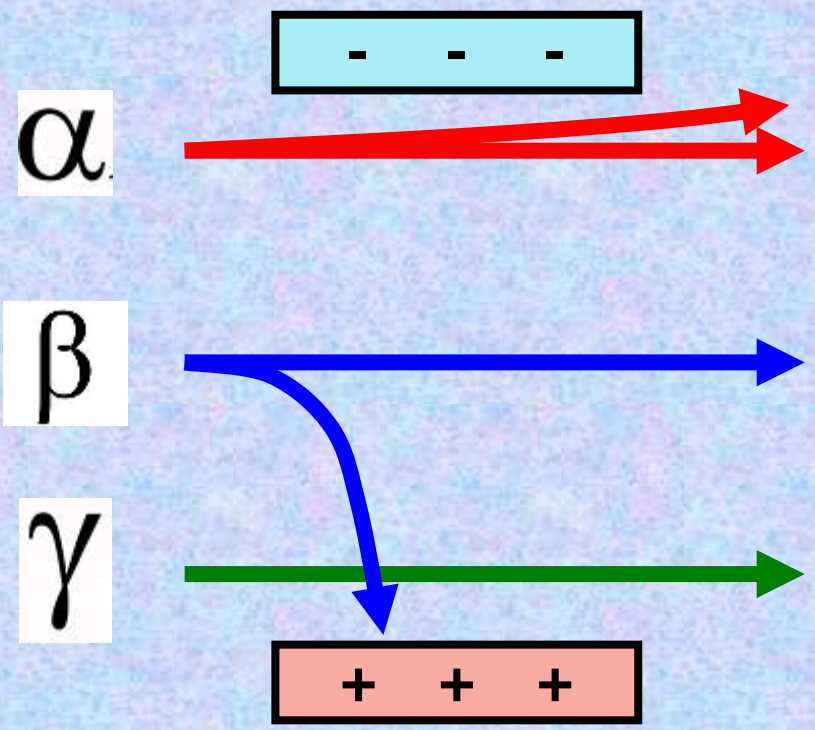
Deflection by electric fields



Electric field produced by positively and negatively charged plates

Alpha and beta particles are deflected in opposite directions due to their opposite charges.

Due to their much larger mass alpha particles are deflected far less than beta.

Gamma rays are not deflected because they are not charged.

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Choose appropriate words to fill in the gaps below:

Atoms consist of a very small _____, containing protons and neutrons, surrounded by _____. Atoms of the same element will always have the same number of _____ but different _____ of the same element will have different numbers of _____.

The atoms of some substances are unstable and _____. They may give off alpha or _____ particles or gamma rays.

Gamma rays are the most penetrating type of radiation, _____ is the least.

WORD SELECTION:

alpha protons electrons isotopes

beta nucleus neutrons radioactive

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Choose appropriate words to fill in the gaps below:

Atoms consist of a very small _nucleus_, containing protons and neutrons, surrounded by _electrons_. Atoms of the same element will always have the same number of _protons_ but different _isotopes_ of the same element will have different numbers of _neutrons_.

The atoms of some substances are unstable and _radioactive_. They may give off alpha or _beta_ particles or gamma rays.

Gamma rays are the most penetrating type of radiation, _alpha_ is the least.

WORD SELECTION:

alpha protons electrons isotopes

beta nucleus neutrons radioactive

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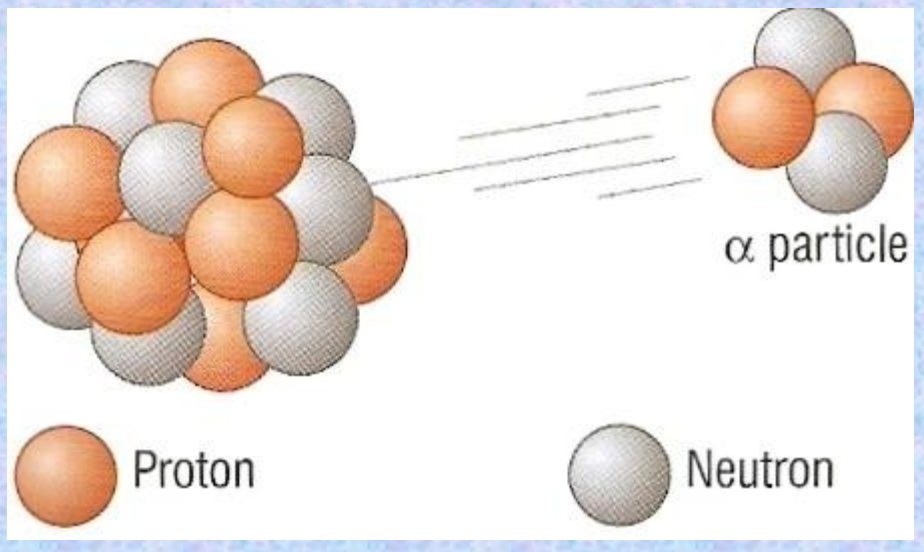
Alpha decay

Alpha particles consist of two protons plus two neutrons.

They are emitted by some of the isotopes of the heaviest elements.



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Example: The decay of Uranium 238

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$$

Uranium 238 decays to **Thorium 234** plus an **alpha particle**.

Notes:

1. The mass and atomic numbers must balance on each side of the equation: (238 = 234 + 4 AND 92 = 90 +2)

2. The alpha particle can also be notated as: $^{4}_{2}He$

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Question

*Show the equation for Plutonium 239 (**Pu**) decaying by alpha emission to Uranium (atomic number 92).*

$$^{239}_{94}\mathrm{Pu} \rightarrow {}^{235}_{92}\mathrm{U} + {}^{4}_{2}\alpha$$

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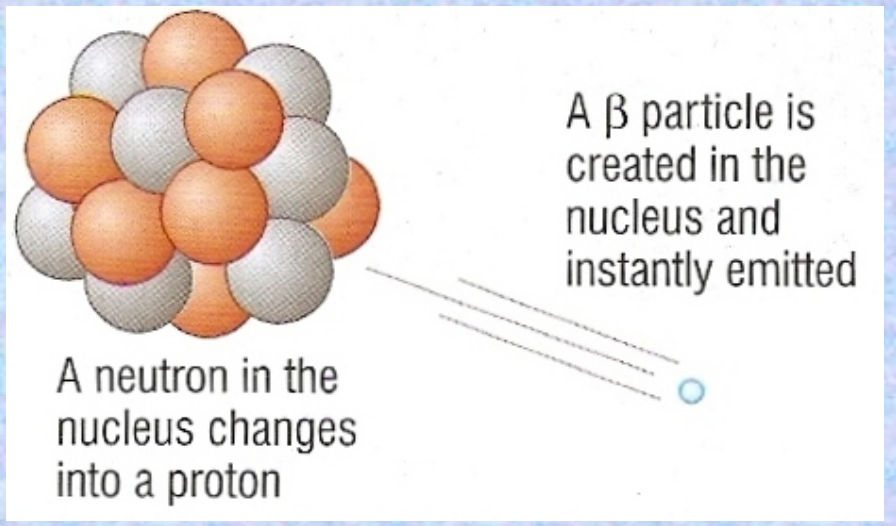
Beta decay

Beta particles consist of high speed electrons.

They are emitted by isotopes that have too many neutrons.

One of these neutrons decays into a proton and an electron. The proton remains in the nucleus but the electron is emitted as the beta particle.



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Example: The decay of Carbon 14

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta^{-}$$

Carbon 14 decays to **Nitrogen 14** plus a **beta particle**.

Notes:

1. The beta particle, being negatively charged, has an effective atomic number of minus one.

2. The beta particle can also be notated as: $^{0}_{-1}e$

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Question

*Show the equation for Sodium 25 (**Na**), atomic number 11, decaying by beta emission to Magnesium (**Mg**).*

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Question

*Show the equation for Sodium 25 (**Na**), atomic number 11, decaying by beta emission to Magnesium (**Mg**).*

$$^{25}_{11}\mathrm{Na} \rightarrow {}^{25}_{12}\mathrm{Mg} + {}^{0}_{-1}\beta^{-}$$

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Gamma decay

Gamma decay is the emission of electromagnetic radiation from an unstable nucleus

Gamma radiation often occurs after a nucleus has emitted an alpha or beta particle.

Example: Cobalt 60

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{27}\mathrm{Co} + {}^{0}_{0}\gamma$$

Cobalt 60 with excess ENERGY decays to

Cobalt 60 with less ENERGY plus **gamma radiation.**

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Changing elements

Both alpha and beta decay cause the an isotope to change atomic number and therefore element. Alpha decay also causes a change in mass number.

Decay type	Atomic number	Mass number
alpha		
beta		
gamma		

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Complete the decay equations below:

(a) $^{59}_{26}\mathrm{Fe} \rightarrow \; ^{\square}_{\square}\mathrm{Co} + \; ^{0}_{\square}\beta^{-}$

(b) $^{224}_{\square}\mathrm{Ra} \rightarrow \; ^{\square}_{86}\mathrm{Rn} + \; ^{4}_{\square}\alpha$

(c) $^{\square}_{7}\mathrm{N} \rightarrow \; ^{16}_{8}\square + \; ^{0}_{-1}\square$

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Write equations showing how Lead 202 could decay into Gold. (This cannot happen in reality!)

Element	Sym	Z
Platinum	Pt	78
Gold	Au	79
Mercury	Hg	80
Thallium	Tl	81
Lead	Pb	82
Bismuth	Bi	83

$$^{202}_{82}\mathrm{Pb} \rightarrow {}^{198}_{80}\mathrm{Hg} + {}^{4}_{2}\alpha$$

$$^{198}_{80}\mathrm{Hg} \rightarrow {}^{194}_{78}\mathrm{Pt} + {}^{4}_{2}\alpha$$

$$^{194}_{78}\mathrm{Pt} \rightarrow {}^{194}_{79}\mathrm{Au} + {}^{0}_{-1}\beta^{-}$$

There are other correct solutions

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Choose appropriate words to fill in the gaps below:

When an unstable nucleus emits an alpha particle its atomic number falls by _____ and its mass number by _____.

Beta particles are emitted by nuclei with too many _____. In this case the atomic number increases by _____ while the _____ number remains unchanged.

Gamma rays consist of _____ radiation that is emitted from a nucleus when it loses _____, often after undergoing alpha or beta decay.

WORD SELECTION:

four one energy two neutrons mass electromagnetic

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