MYP 5 - Atomic physics

Content notes

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Source of information :

-*What are radioactive substances*. Anjung Sains Makmal 3. (2013, October 4). https://anjungsainssmkss.wordpress.com/2013/09/30/what-are-radioactive-substances/

-Cambridge - IGCSE - Physics coursebook - David Sang

-MYP - Physics - concept based learning - Oxford

-Cambridge - IGCSE - Physics - Tom Duncan - Heather Kennett.

- Science quest 9 - Jacaranda - Victorian Curriculum

Guiding question

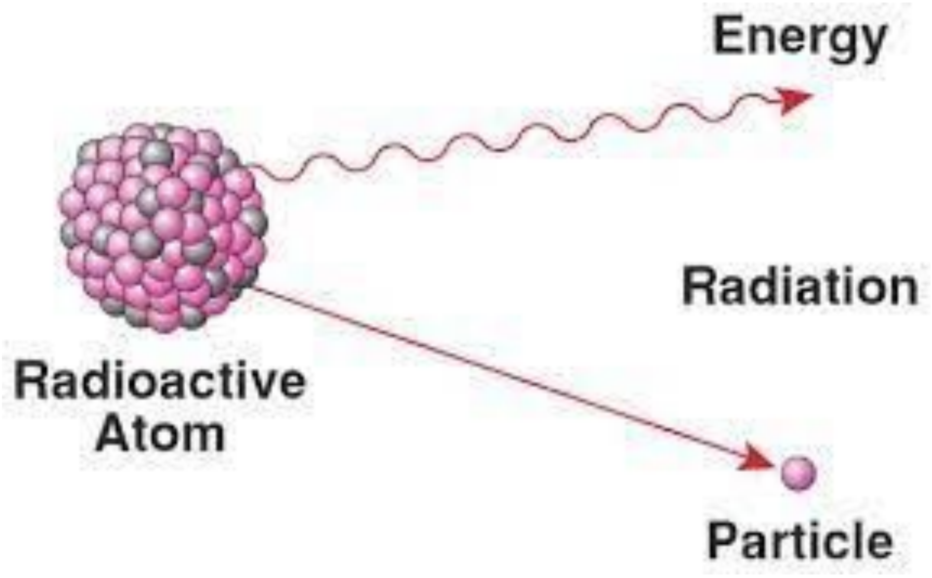
- What leads to nuclear instability ?
- What are isotopes ?
- What causes radioactivity ?
- What is the difference between alpha and beta emissions ?
- What is the main source of background radiation ?
- Why are radioisotopes kept in a lead box in labs ?
- Why it is important to know the half life of a radioactive isotope ?

Isotopes - Atoms of the same element with different mass numbers are called isotopes.
Isotopes of the element have same proton number, but different neutron number.

In stable nucleus, the protons and neutrons in the nuclei are held together very strongly.
In unstable nucleus, the protons and neutrons in the nuclei are not held together strongly.
Unstable nucleus decays to form more stable nuclei.

Natural radioactivity - This is the radioactivity emitted from matter without energy being supplied to the atoms. There are about 50 isotopes that emit radioactivity naturally. They exist in air, water, in living things and in ground.

Most radioactive isotopes (about 2000 in total) are made radioactive artificially by bombarding their atoms with subatomic particles like protons and neutrons.



Substances that emits radiations and particles.

Energy released

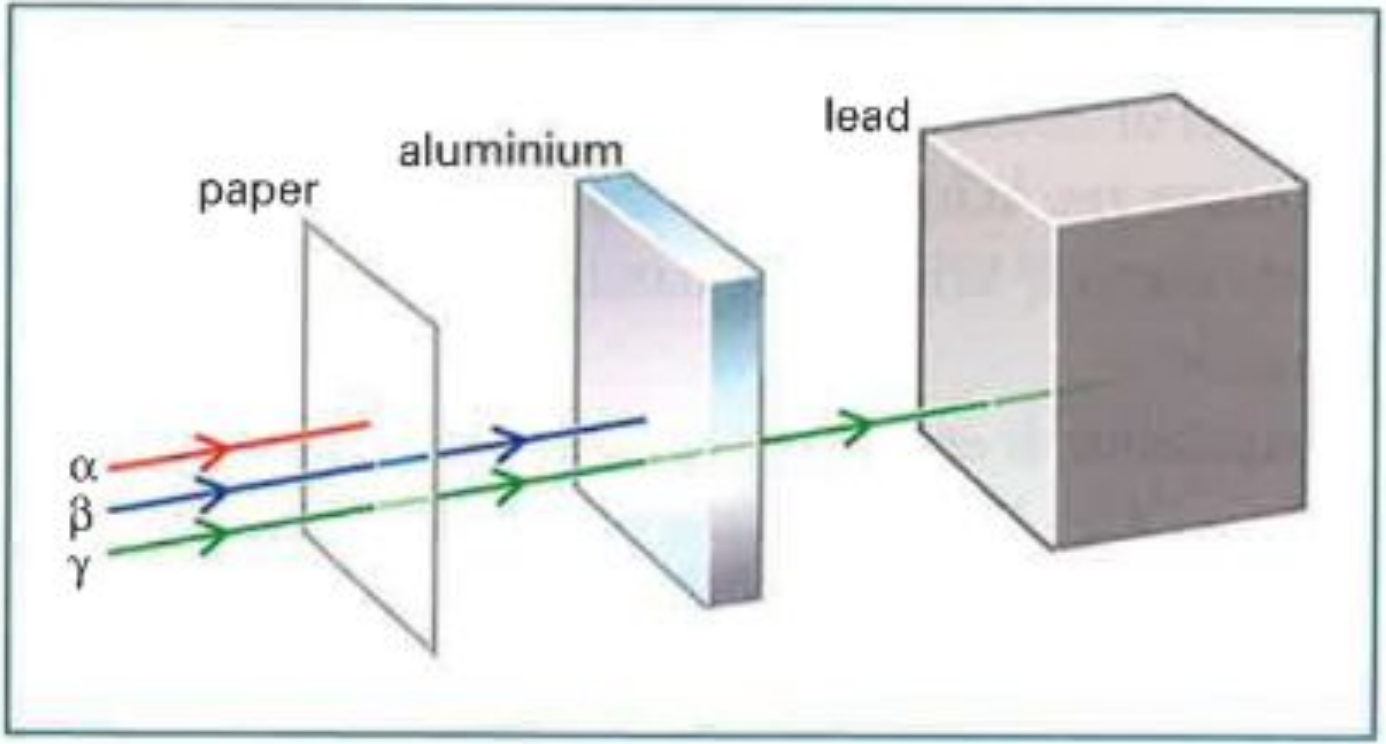
Radioactive substances release energy when they decay. Before they decay, this energy is stored in the nucleus of the atom. When it is released, it is in two forms:

- An alpha or beta particle is fast-moving. The nucleus that has emitted it recoils. Both particles have **kinetic energy**.
- A gamma ray transfers energy as **electromagnetic radiation**.

Name	Symbol	Made of	Mass	Charge	Speed / m/s
alpha	α or ^4_2He	2 protons + 2 neutrons	approx. (mass of proton) × 4	+2	$\sim 3 \times 10^7$
beta	β or $^{0}_{-1}e$	an electron	$\frac{\text{approx. (mass of proton)}}{1840}$	−1	$\sim 2.9 \times 10^8$
gamma	γ	photon of electromagnetic radiation	0	0	3×10^8

- Alpha particles are the most easily absorbed. They can travel about 5 cm in air before they are absorbed. They are absorbed by a thin sheet of paper.
- Beta particles can travel fairly easily through air or paper. But they are absorbed by a few millimetres of metal.
- Gamma radiation is the most penetrating. It takes several centimetres of a dense metal like lead, or several metres of concrete, to absorb most of the gamma radiation.

These ideas about **penetrating power** are represented in


lead
aluminium
paper
α
β
γ

Ionisation

When radiation passes through air, it may interact with air molecules, knocking electrons from them, so that the air molecules become charged. We say that the air molecules have become ionised. The relative ionising effects are as follows:

- alpha particles are the most ionising
- gamma radiation is the least ionising.

Because the radiation from radioactive substances causes **ionisation** of the materials that absorb it, it is often known as **ionising radiation**.

Alpha particles These are stopped by a thick sheet of paper and have a range in air of only a few centimetres since they cause intense ionisation in a gas due to frequent collisions with gas molecules. They are deflected by electric and strong magnetic fields in a direction and by an amount which suggests they are helium atoms minus two electrons, i.e. helium ions with a double positive charge. From a particular substance, they are all emitted with the same speed (about 1/20th of that of light). Americium (Am-241) is a pure α source

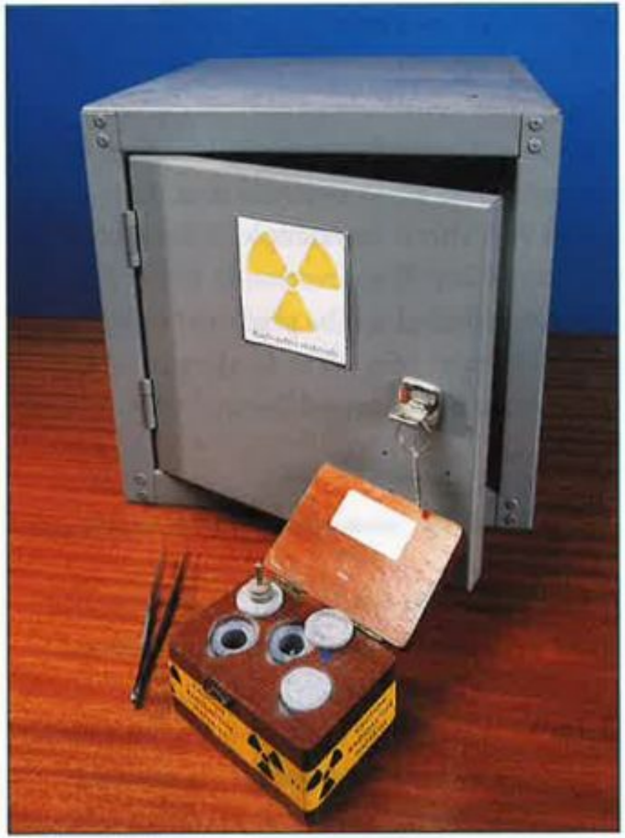
Beta particles : These are stopped by a few millimetres of aluminium and some have a range in air of several metres. Their ionising power is much less than that of α-particles. As well as being deflected by electric fields, they are more easily deflected by magnetic fields. Measurements show that β^--particles are streams of high-energy electrons, like cathode rays, emitted with a range of speeds up to that of light. Strontium (Sr-90) emits β^--particles only

Gamma rays These are the most penetrating and are stopped only by many centimetres of lead. They ionise a gas even less than β-particles and are not deflected by electric and magnetic fields. They give interference and diffraction effects and are electromagnetic radiation travelling at the speed of light. Their wavelengths are those of very short X-rays, from which they differ only because they arise in atomic nuclei whereas X-rays come from energy changes in the electrons outside the nucleus. Cobalt (Co-60) emits γ-rays and β^--particles but can be covered with aluminium to provide pure γ-rays.

Comparing alpha, beta and gamma radiation In a collision, α-particles, with their relatively large mass and charge, have more of a chance of knocking an electron from an atom and causing ionisation than the lighter β-particles; γ-rays, which have no charge, are even less likely than β-particles to produce ionisation

Safe handling

Knowing about the radiation produced by radioactive materials tells us how to handle them as safely as possible. Radioactive sources should be stored in a container that will absorb as much as possible of the radiation coming from them. Lead is a good material for this, as it is a strong absorber of all three types of radiation.



Tongs should be used so that the person handling is not in direct contact with the source. Also during any experiment, the user should stand at a safe distance from the source.

Half lives of radioisotopes - It is the time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay.

Half life can vary from microseconds to billions of years.

Few examples -
The half life of strontium - 90 is about 28 years
The half life of uranium isotope is about billion years
The half life of francium - 223 is 22 minutes

Background radiation - We are all exposed to background radiation everyday but fortunately it is quite safe.

- Most of it comes from naturally occurring radioactive elements in the Earth's crust and atmosphere.
- Most of it is from radon, which is produced during the breakdown of other radioisotopes like uranium and thorium.
- A smaller amount comes from outer space in the form of cosmic radiations from Sun and stars. The Earth's atmosphere protects us from dangers of cosmic radiations.
- There are even small amount of radioisotopes in the human body including hydrogen 3, carbon 14, and potassium 40.