Radiation Notes

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For GCSE we need to know about Alpha, Beta, Gamma and background radiation. **But what is radiation?**

Radiation: describes anything that is given out by a source.

That does sounds a bit vague, but it needs to be to make sure that it covers all of the things that emit radiation. Radiation isn't necessarily a bad thing. You are **radiating** out heat right now.
Before we get into the different types of radiation, here are a few definitions of terms that will be used a lot.

Radioactive: describes a material that contains unstable nuclei that emit radiation.

What is an unstable nucleus? An unstable nucleus is a nucleus that can spilt into two smaller nuclei.

Radioactive decay: this is the process in which an unstable nucleus breaks down randomly and emits ionising radiation.

Ionising radiation: radiation that carries enough energy to knock electrons out of atoms, turning them into ions.

This is the radiation that is the bad radiation. Our cells don't like to be charged as this can cause damage to our cells, this can also cause our cells to keep making more of themselves, this is a cancer.

Penetration power: the ability of radiation to pass through or penetrate a material.

Let's start with background radiation 😊

Background Radiation

What is background radiation? Background radiation is the radiation all around us.

What produces background radiation? Everything really. The floor you're standing on, the walls, rocks, even the food you eat. All of these produce back ground radiation. For the AQA GCSE we need to place sources of background radiation into two categories. They're either man made or natural. We know some natural ones so let's look at some man made ones.

Man made sources: the fallout from nuclear weapons testing, nuclear accidents (like Chernobyl) or medical x-rays.

Alpha Radiation

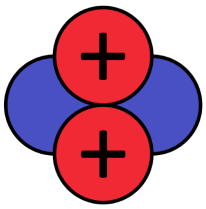
What is it? Alpha radiation is a particle. It is made of 2 protons and 2 neutrons.

What is its mass? 4	**What is its charge?** +2

Is it ionising? Very! Alpha particles are the most ionising form of radiation.

Range in air: alpha radiation travels only a few centimetres in air.

What is its penetration power? Low. It can be stopped by a few cm of air or a single sheet of paper.



An Alpha Particle

Is it affected by a magnetic field? Yes. But as its mass is so high it is only weakly affected. Think of it as throwing a brick into strong wind, the wind will change the direction of the brick but only a little.

What is it used for? It is used in smoke detectors.

How does this work? Smoke detectors that use alpha particles work on the penetration power of alpha particles. There is an emitter in the smoke detector, this gives out alpha particles and also a detector which can detect them. When smoke rises to the detector it blocks the particles from reaching the detecting plate (as the penetration power is low) and the alarm sounds.

Beta Radiation

What is it? Beta radiation is a particle, it's a high speed electron that has been ejected from the nucleus as a neutron turns into a proton

What is its mass? $\frac{1}{2000}$	**What is its charge?** –1 or just –

Is it ionising? It is not very ionising. So, it is not very capable of passing on its charge.

Range in air: beta travels a moderate distance in air. It can travel about a metre in air.

What is its penetration power? It can be stopped by a few millimetres of aluminium.

A Beta Particle

Is it affected by a magnetic field? Yes, it is strongly deflected. This is because it has such a low mass compared to its charge. Think of it as throwing a paper ball into strong wind, the wind would change the direction of the paper ball very easily.

What is it used for? One use of beta radiation is to ensure paper thickness in a paper mill.
How does this work? Paper mills use beta particle emitters to ensure that the paper they make is the right thickness or it could get jammed in a printer later.

The beta particle emitter gives out particles above the paper and the detector below the paper will detect them. When the correct amount of beta particles is detected on the other side of the paper the thickness is correct 😊 If too little is detected the paper is too thick, if too much is detected the paper is too thin. We could not use alpha particles for this as they would all be stopped by the paper.

Gamma Radiation

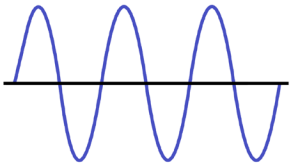
What is it? Gamma radiation is very high frequency electromagnetic waves.

What is its mass? 0	**What is its charge?** 0

Is it ionising? It is very weakly ionising.

Range in air: gamma radiation travels very long distances in air.

What is its penetration power? Gamma radiation is the most penetrative form of radiation. It can be reduced by a few centimetres of lead or a few metres of concrete. We would need quite a few centimetres of lead to stop it fully.



A Gamma Ray

Is it affected by a magnetic field? No, as it has no mass and no charge. Think of a laser beam being fired through wind. The wind would have no effect on the laser beam.

What is it used for? Gamma radiation has many uses. Here are just a few of the best-known examples.

1. Radiotherapy.
2. Sterilising food.
3. Sterilising medical equipment.
4. Detecting leaks in underground pipes.

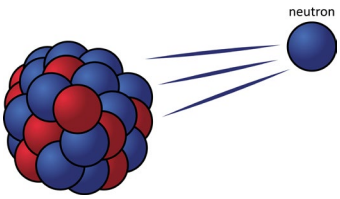
Neutron Radiation

What is it? It's simply a single neutron (n) that is ejected from an unstable nucleus.

What is its mass? 1	**What is its charge?** 0

Is it ionising? No, it is not ionising.

Why does it happen? Sometimes a nucleus is unstable simply because it has too many neutrons. To become more stable, it just throws one out!



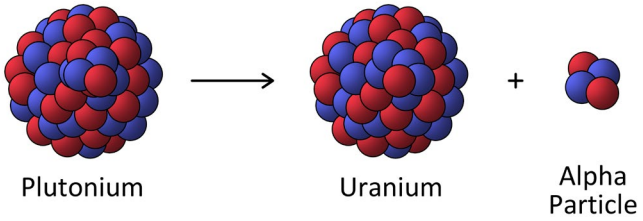
A neutron is emitted

Is it affected by a magnetic field? No, because a neutron has absolutely no electrical charge, it will pass straight through a magnetic or electric field without being deflected at all.

As we mentioned already radioactive decay is the process in which an unstable nucleus breaks down randomly and emits ionising radiation. For the exams we must know about **alpha**, **beta** and **gamma decay**.

Alpha Decay

What is alpha decay? Alpha decay occurs when an unstable nucleus breaks down to produce a smaller nucleus and an alpha particle. The figure below shows alpha decay of an atom of Plutonium.



Exam note: how do the exams ask questions about alpha decay? Most questions have problems involving nuclear equations 😊

What is a nuclear equation? A nuclear equation represents the reactants and products in radioactive decay, nuclear fission, or nuclear fusion. It's very similar to a chemical equation that we meet in chemistry.

The nuclear equation below shows the alpha decay of plutonium.

$$^{239}_{94}Pu \longrightarrow ^{235}_{92}U + ^{4}_{2}He$$

We can tell that this is alpha decay right away because of **three** features 😊

$$^{239}_{94}Pu \longrightarrow ^{235}_{92}U + ^{4}_{2}He$$

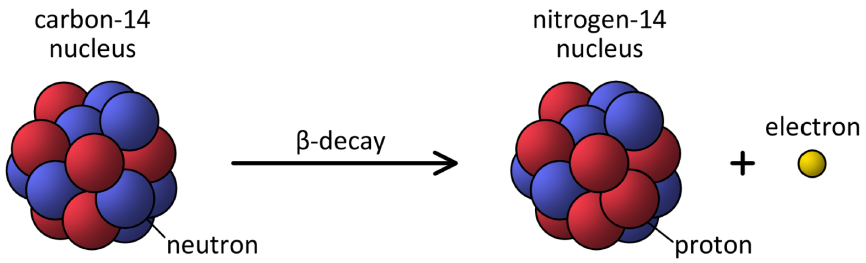
1 2 3

1. The mass number of the product has decreased by 4.
2. The atomic number has decreased by 2.
3. A **helium nucleus** has been produced. This will always have a mass of 4 and an atomic number of 2.

Note: any <u>one</u> of these features can be used to identify alpha decay 😊

Beta Decay

What is beta decay? Beta decay occurs when an unstable nucleus emits a high energy electron.
The figure below shows beta decay of an atom of Carbon-14.



The nuclear equation below shows the beta decay of carbon.

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

We can tell that this is beta decay right away because of **two** features 😊

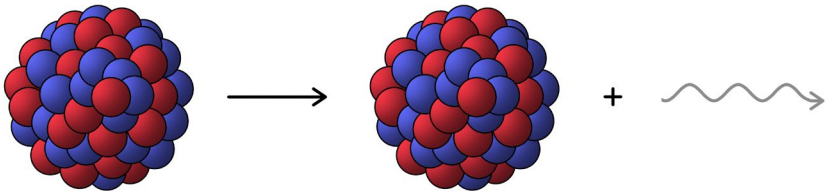
$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

1 2

1. The atomic number increases by 1. In this case it increases from 6 to 7.
2. An electron has been produced, it has a mass of 0 and a charge of – 1.

Gamma Decay

What is gamma decay? Gamma decay occurs when an unstable nucleus emits high energy electromagnetic waves. The figure below shows the gamma decay of Technetium (Tc).



The nuclear equation below shows the gamma decay of Technetium (Tc).

$$^{99}_{43}Tc \longrightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

We can tell that this is gamma decay right away because of **three** features 😊

$$^{99}_{43}Tc \longrightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

1. The mass number does not change.
2. The atomic number does not change.
3. A gamma ray is emitted, this is given the symbol ***γ***.

Exam note: gamma decay can also be given out <u>at the same time as either alpha decay or beta decay</u>.

With this in mind let's look at the nuclear equation below.

$$^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{234}_{90}Th + {}^{0}_{0}\gamma$$

As we can see here in the equation above an alpha particle has been given out as well as some gamma radiation.

Q. How could this combination style decay question come up in an exam question?

A. It could be a question where they <u>ask you to fill in the missing values</u> for either the alpha particle (He) or the Thorium (Th). In addition, you could be asked to complete the gamma radiation gap in full.

Check out the example below of what we could see in an exam. 😊

$$^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{\square}_{\square}e + {}^{\square}_{\square}\text{----}$$

$$^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e + {}^{0}_{0}\text{--}\gamma\text{--}$$

Let's have a look at another example while we're here.

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{\square}_{\square}He + {}^{\square}_{\square}\text{----}$$

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\text{--}\gamma\text{--}$$

Half Life

Nuclear half-life is one of those topics that some students are a bit put off by. But it's a lot easier than it looks, just practise, then practise some more and you'll be fine 😊

Half-life: is the time that it takes for **number of unstable nuclei in a sample to halve** we could also say that it's the time it takes for the **count rate** (or activity) from a sample to fall to half its initial level.

What's count rate? It's the rate at which a source of unstable nuclei decays. So, how quickly the radioactive source is giving out radiation. It is measured in becquerels (Bq). 1 Bq = 1 decay per second.

So, half-life is a **time** problem 😊

Take the following as an example.

Example 1: Caesium-134 has a half-life of 2 years. If the sample contained 120g of Caesium, what mass of caesium would remain after 8 years?

Step 1: find out how many half-lives have happened in the time that you are given.

- In this case we are given 8 years as the time. The half-life of caesium is 2 years.
- Therefore, caesium will have had 4 half-lives in that time.

Step 2: So, we would now half 120 four times 😊

$120 \div 2 = 60$ $\quad$ $60 \div 2 = 30$ $\quad$ $30 \div 2 = 15$ $\quad$ $15 \div 2 = 7.5$

Answer: After 8 years (which is 4 half-lives) we would be left with **7.5 g of caesium**.

Alternative method: as we need to halve 120 four times, we could do the following 😊

$$120 \div 2^4 = 7.5 \text{ g}$$

Check out this example as well.

Example 2: Tritium is radioactive. After 36 years, only 10 g of tritium remains from an original sample of 80 g. Calculate the half-life of tritium. Show clearly how you work out your answer.

Step 1: find out how many times that we would need to halve 80 to get to 10.

$80 \div 2 = 40$ $\quad$ $40 \div 2 = 20$ $\quad$ $20 \div 2 = 10$

Step 2: each time that we can half if we have a half-life. So, we have **three half-lives**. So, let's divide 36 by 3.

$$36 \div 3 = 12$$

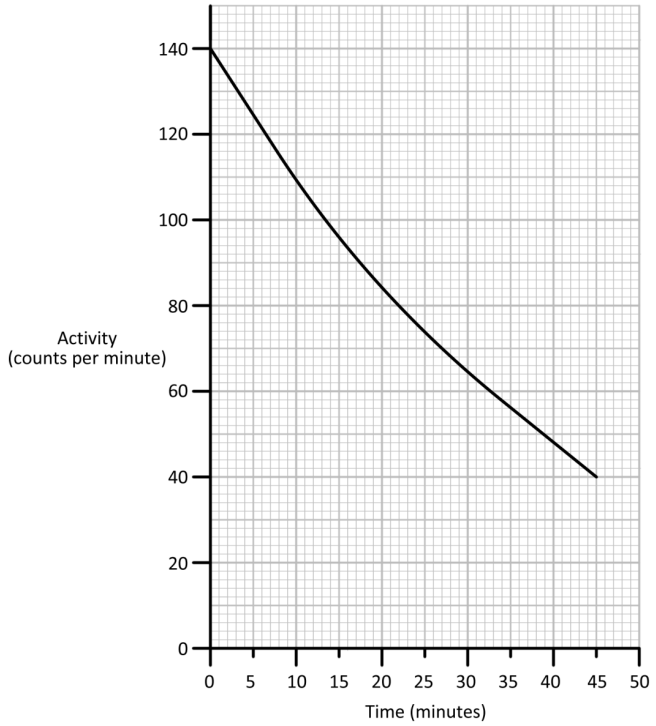
Answer: the half-life of Tritium is **12 years**.

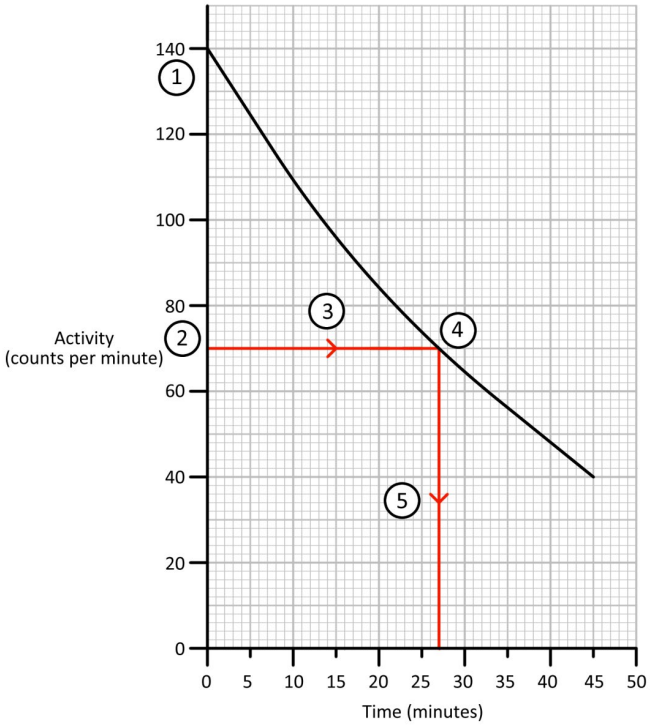
Exam note: the majority of half-life questions also involve a graph. They typically involve reading off of the graph and interpreting that data. They are quite nice and straightforward. They are typically worth 2 marks but this can vary.

Let's have a look at a half-life problem involving a graph 😊

Example 3: The figure below shows how the radioactivity of an isotope of plutonium–238 changes over time.

Use the graph below to determine the half-life for Pu-238. You must show your working on the graph.





Step 1: find out what the maximum value is on the y axis in this case that is 140.

Step 2: halve this value. We find that this is 70.

Step 3: draw a horizontal line from 70 on the y axis to the curve.

Step 4: where the horizontal line from step 3 hits the curve draw a vertical line straight down to the x axis.

Step 5: find out what value the vertical line hits on the x axis. This is your answer.

Answer: the half-life of Pu-238 is 27 minutes 😊

Contamination and Irradiation

These two words sound very similar, we hear them a lot in movies, TV shows or gaming, and they both involve radiation, but they mean two completely different things in physics. Let's look at each…

Exam note: we are regularly asked to compare contamination and irradiation in paper 1.

Irradiation: the process of exposing an object to nuclear radiation, alpha, beta, or gamma.

Does the object become radioactive? No! The object is just getting hit by the radiation (the waves or particles), not the radioactive atoms themselves. As soon as you remove the source, the radiation stops.

Where do we use irradiation? We irradiate medical equipment with gamma rays to kill bacteria and sterilise them. The equipment does not become radioactive.

How do we protect ourselves from the harmful effects? Shielding (lead), distance (space away from it) and time (don't spend too much time near the radioactive substance).

Contamination: the unwanted presence of radioactive atoms on or inside an object.

Does the object become radioactive? Yes! Because the actual radioactive atoms are physically stuck to the object (or inside your body), they will continue to decay and emit ionising radiation.

How can this happen? If radioactive dust lands on our skin, or if we breathe in radioactive gas, we are contaminated.

How do we protect against it? We can wear protective suits, gloves, and breathing masks to stop the radioactive atoms from touching our skin or entering our lungs.