Radioactivity

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PPT-1

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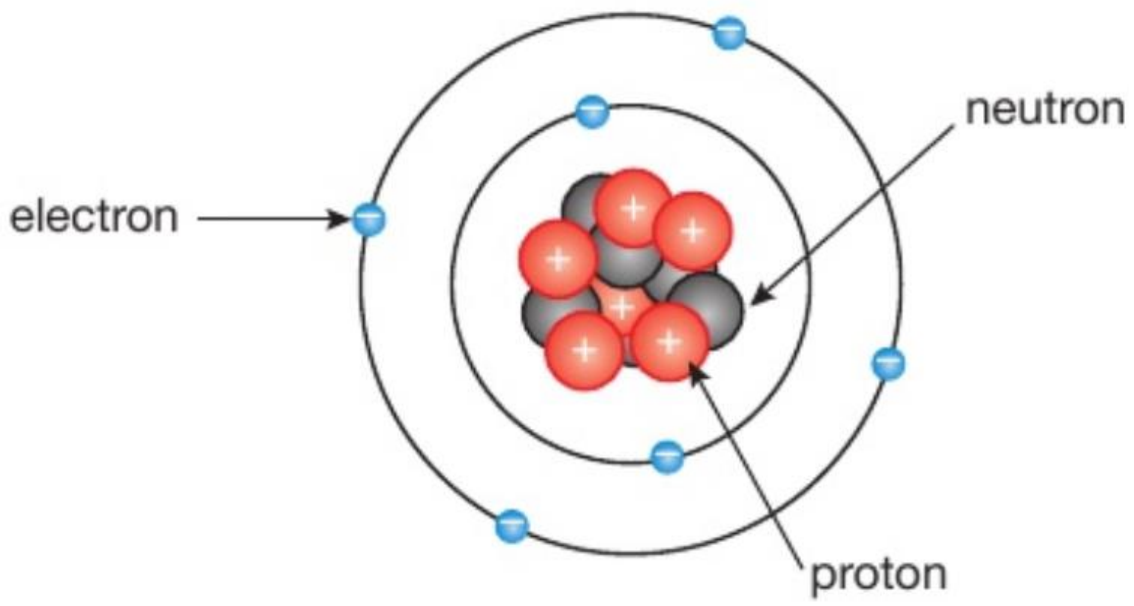
(b)	**Radioactivity**
Students should:	
7.2	describe the structure of an atom in terms of protons, neutrons and electrons and use symbols such as ${}^{14}_{6}C$ to describe particular nuclei
7.3	know the terms atomic (proton) number, mass (nucleon) number and isotope
7.4	know that alpha (α) particles, beta (β^-) particles, and gamma (γ) rays are ionising radiations emitted from unstable nuclei in a random process
7.5	describe the nature of alpha (α) particles, beta (β^-) particles, and gamma (γ) rays, and recall that they may be distinguished in terms of penetrating power and ability to ionise
7.6	*practical: investigate the penetration powers of different types of radiation using either radioactive sources or simulations*
7.7	describe the effects on the atomic and mass numbers of a nucleus of the emission of each of the four main types of radiation (alpha, beta, gamma and neutron radiation)
7.8	understand how to balance nuclear equations in terms of mass and charge
7.9	know that photographic film or a Geiger–Müller detector can detect ionising radiations
7.10	explain the sources of background (ionising) radiation from Earth and space
7.11	know that the activity of a radioactive source decreases over a period of time and is measured in becquerels
7.12	know the definition of the term half-life and understand that it is different for different radioactive isotopes
7.13	use the concept of the half-life to carry out simple calculations on activity, including graphical methods
7.14	describe uses of radioactivity in industry and medicine
7.15	describe the difference between contamination and irradiation

Structure of an atom.



Protons, neutrons and electrons

- **Atoms** are very small; they have a radius of around 1×10^{-10} metres.

- The modern view of the atom is of a positively charged **nucleus** containing **protons** and **neutrons** with smaller **electrons** orbiting outside the nucleus.

Relative Mass & Relative Charge

Atomic particle	Relative mass of particle	Relative charge of particle
electron	1	–1
proton	2000	+1
neutron	2000	0

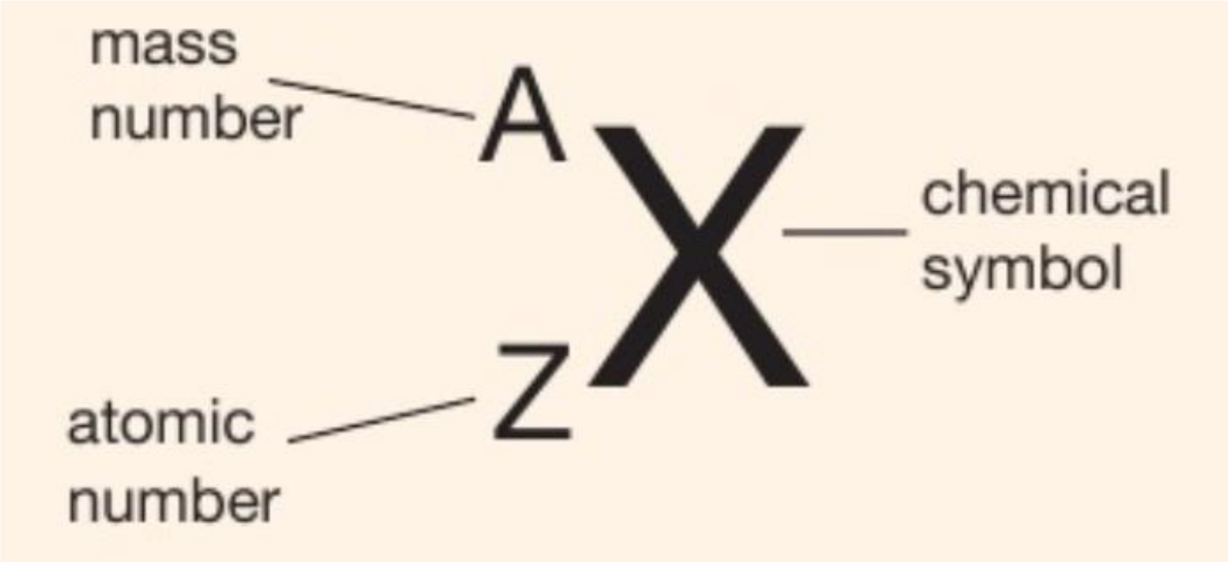
Atomic Number

- The number of protons in the nucleus of an element is called the atomic number(proton number)

Mass Number

- The total number of protons and neutrons in the nucleus of an element is called the mass number(nucleon number)

Atomic Notation



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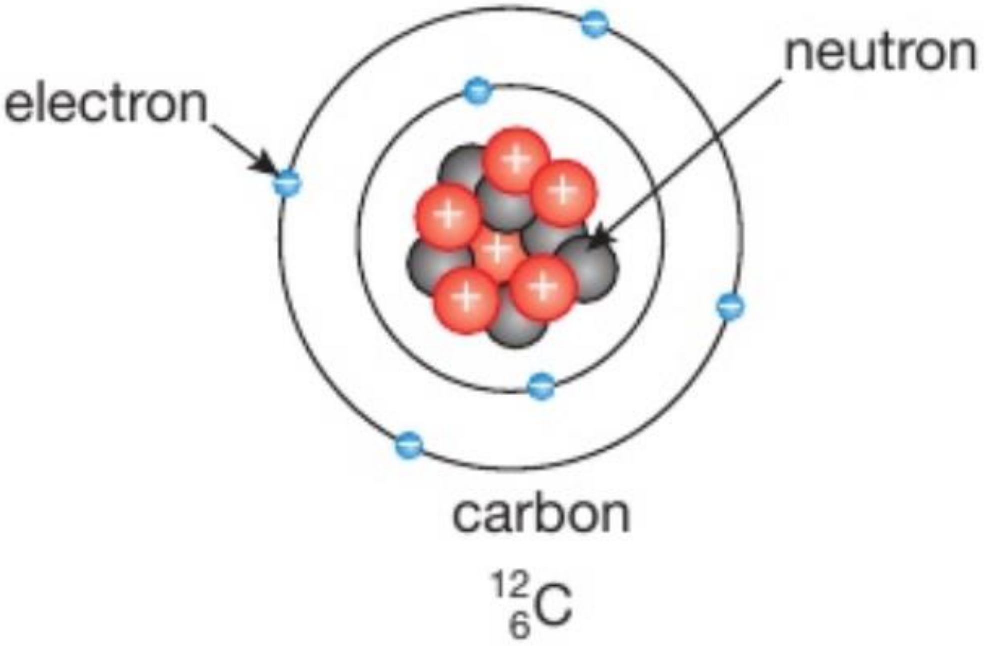

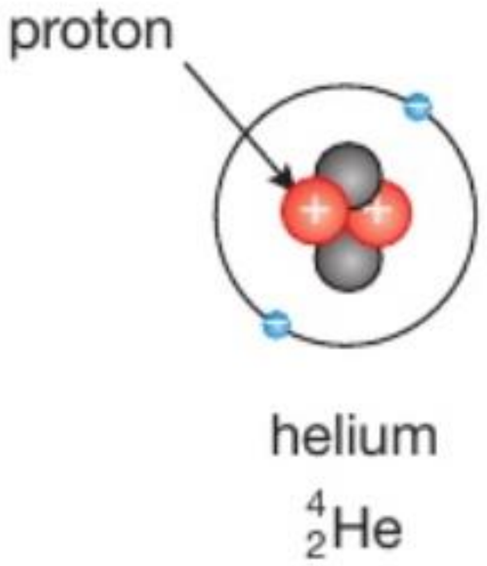

Mass Number(A) =12

Atomic Number(Z) = 6

Mass Number(A) =4

Atomic Number(Z) = 2

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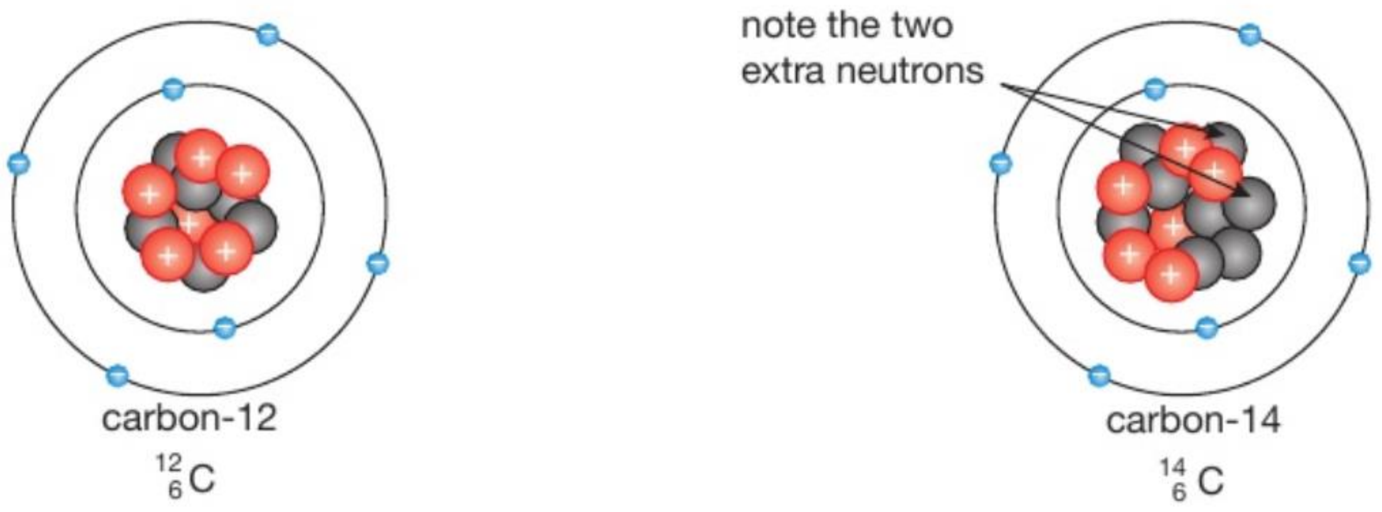
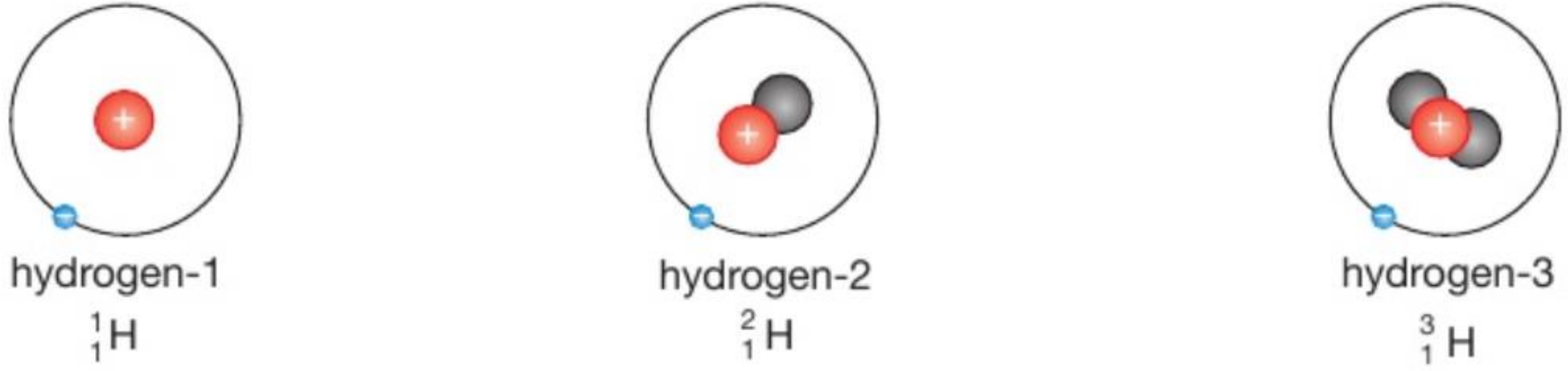
Isotopes

Isotopes are forms of an element that have the same number of protons but different numbers of neutrons.

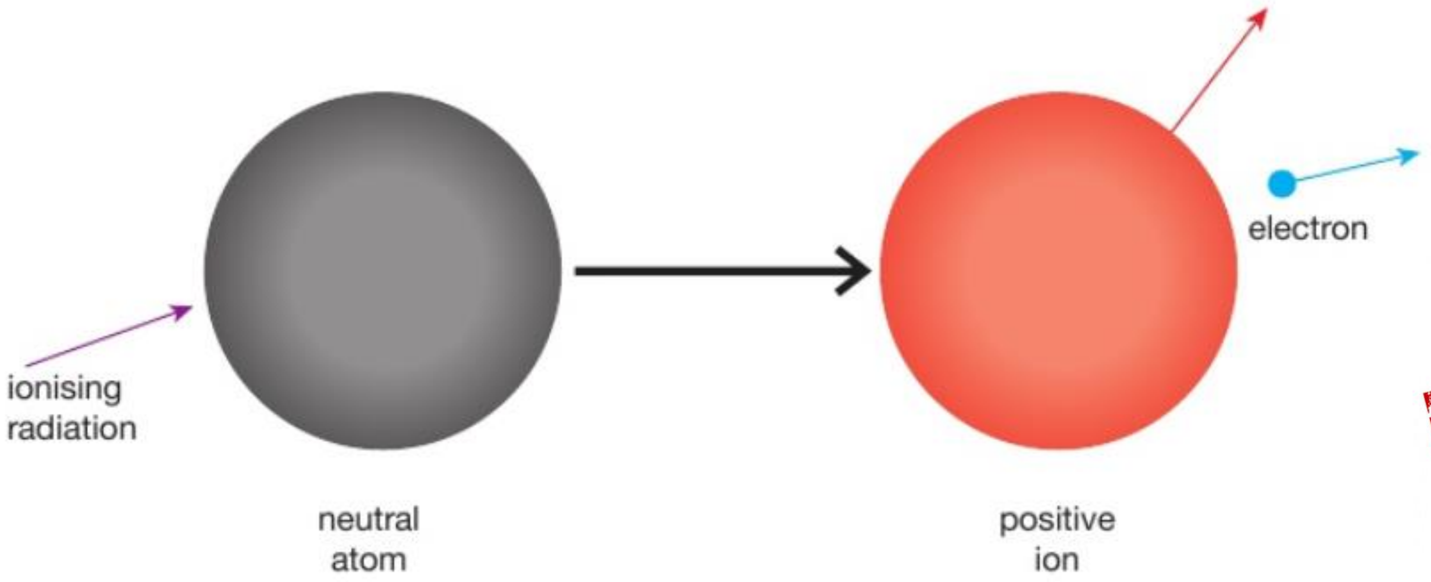


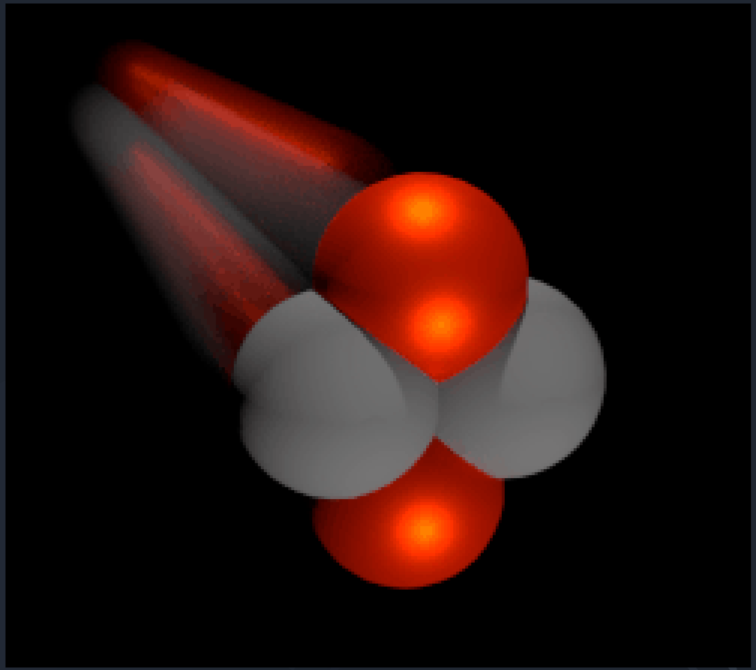


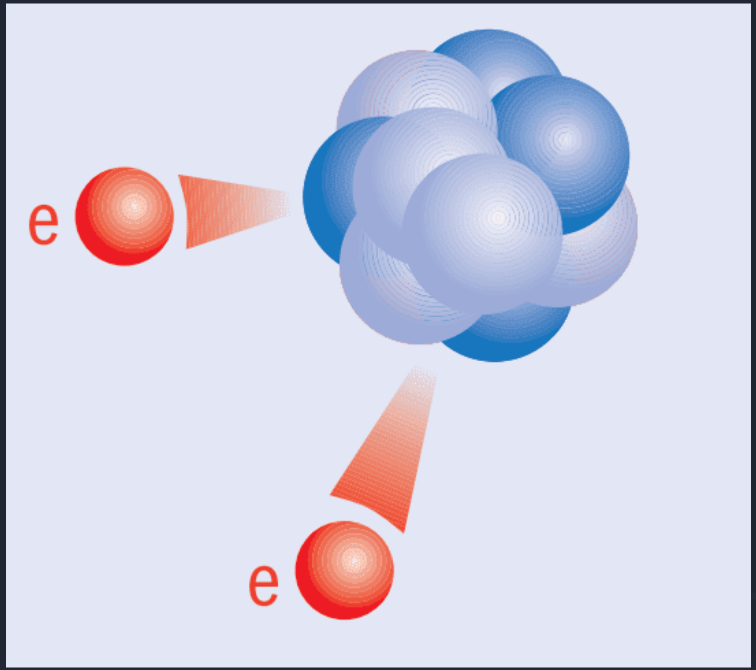
Ionising Radiation

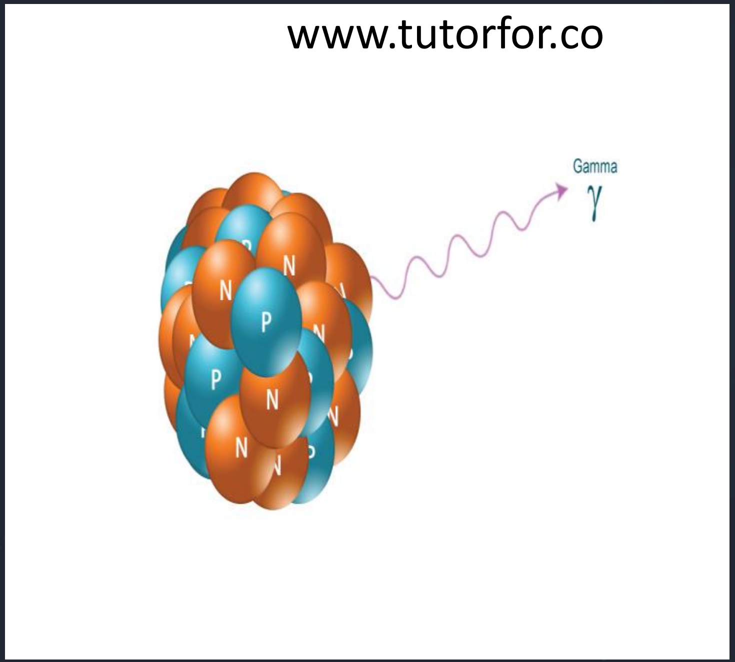
- The protons are held together in the nucleus by **strong nuclear forces**. The presence of too many neutrons or too less neutrons affects the stability of the nucleus.

- When unstable nuclei decay it gives out **ionising radiation.**









There are three basic types of ionizing radiation.

- Alpha radiation
- Beta radiation
- Gamma radiation

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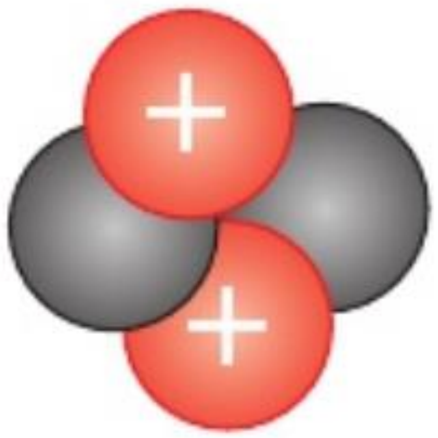
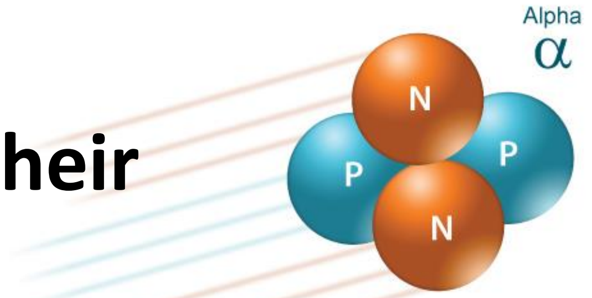
Alpha Particle

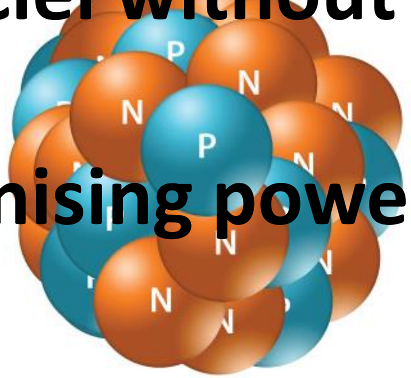


$^{4}_{2}He$

- ❑ **Helium nucleus = Alpha particle**
- ❑ **Four nucleons -> Mass Number =4**
- ❑ **Two protons -> Atomic Number =2**
- **-> Relative Charge = +2**

Alpha radiation



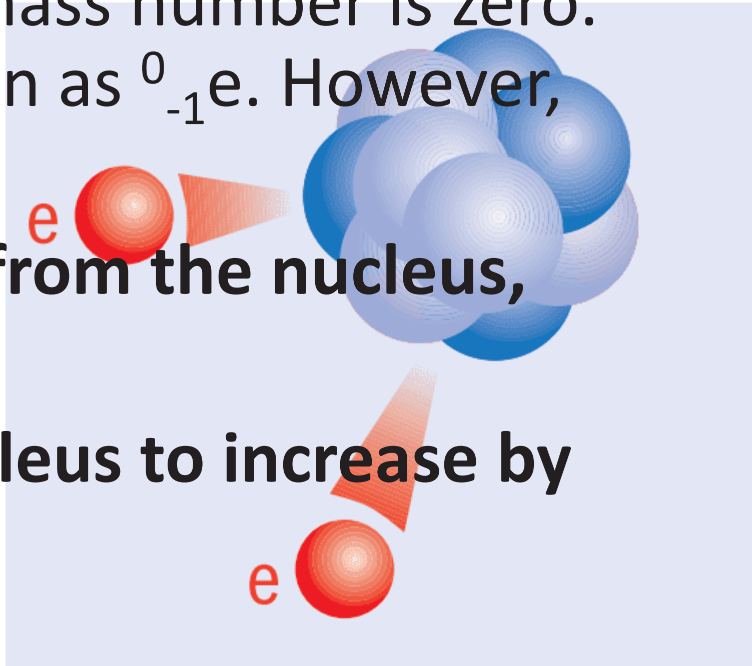


- Alpha particles are Helium nuclei without their orbiting electrons.
- Alpha particles have a high ionising power due to the +2 relative charge.
- Lower Range:

  -Alpha particles travel less distance through matters because they lose their energy by interacting with the atoms along the path and causing ions.

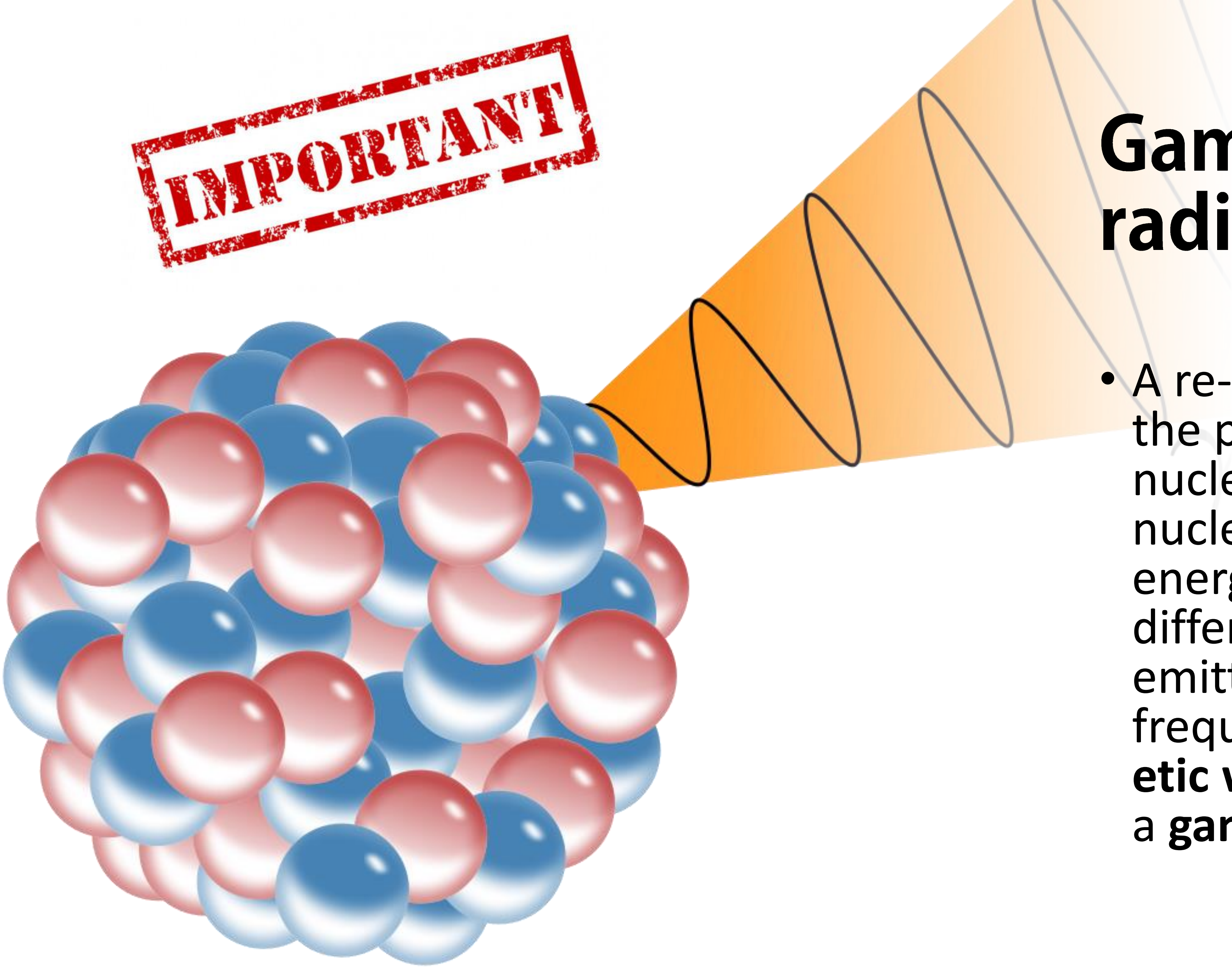
Beta(β-) Radiation

- If the nucleus has too many neutrons, a neutron will turn into a proton and emit a fast-moving **electron**. This electron is called a beta minus (β-) particle - this process is known as **beta radiation**.
- A beta particle has a relative mass of zero, so its mass number is zero. As the beta particle is an electron, it can be written as ${}^{0}_{-1}e$. However, sometimes it is also written as ${}^{0}_{-1}\beta$.
- **The beta particle is an electron, but it has come from the nucleus, not the outside of the atom.**
- **Beta decay causes the atomic number of the nucleus to increase by one and the mass number remains the same.**



Positron (ß+) emission

- If the nucleus has too few neutrons, a proton will turn into a neutron and emit a fast-moving positron. This positron can be called a beta plus (β+) particle - this process is known as positron emission.
- A positron is the antimatter version of an electron. It has the same relative mass of zero, so its mass number is zero, but a +1 relative charge. It can be written as ${}^{0}_{+1}e$, however sometimes it is also written as ${}^{0}_{+1}\beta$.
- **Beta plus decay - positron emission - causes the atomic number of the nucleus to decrease by one and the mass number remains the same.**

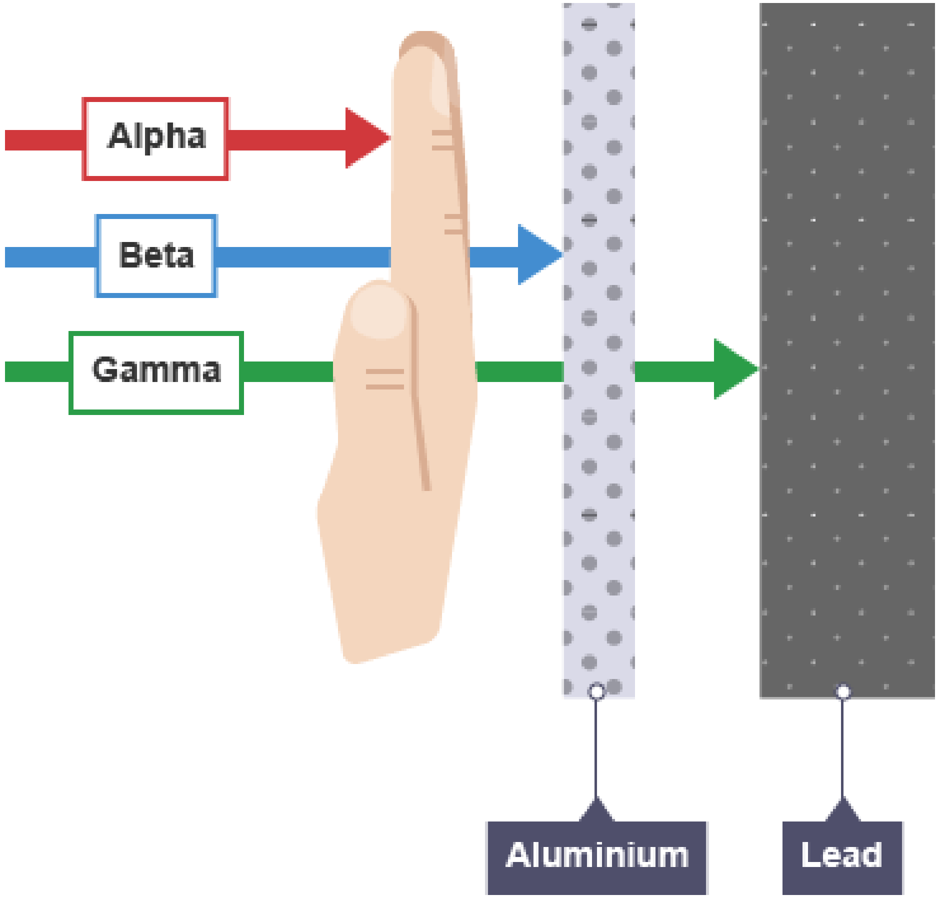


Gamma radiation

- A re-arrangement of the particles in a nucleus can move the nucleus to a lower energy state. The difference in energy is emitted as a very high frequency **electromagnetic wave** called a **gamma ray**.

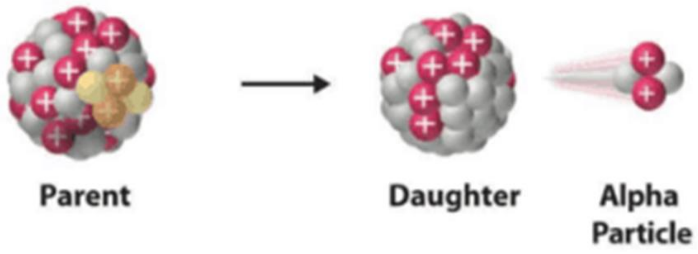
Penetrating Power

Symbol	Penetrating power	Ionising power	Range in air
Alpha	Skin/paper	High	< 5 centimetre
Beta	3 mm aluminium foil	Low	≈ 1 metre (m)
Gamma	Few cm thick lead/ 1 m thick concrete	Very low	> 1 kilometre (km)



Nuclear equations for alpha decay:

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$



- ❑The mass number decreases by 4
- ❑The atomic number decreases by 2
- ❑The nuclear charge decreases by 2

Example:

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

GM-Tube

Detecting radioactivity

All types of radioactive decay can be detected by

- ❑ Photographic film,
- ❑ Geiger-Muller tube (G-M tube).

- ❖ The photographic film is chemically changed by the radiations so it can be developed to see if there has been exposure.

- ❖ In a G-M tube, the radiations ionise the gas inside and the resulting charged particles move across the chamber and get counted as charges rather like an ammeter.

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The Geiger-Muller tube

The Geiger-Muller tube is a device that detects radiation. It gives an electrical signal each time radiation is detected. These signals can be converted into clicking sounds, giving a **count rate** in clicks per second or per minute.

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Nuclear equations for beta decay:

- ❑The mass number stays the same
- ❑The atomic number increases by 1
- ❑The nuclear charge increases by 1

Example:

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

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Concept Learning Questions

a. $^{235}_{\square}\mathrm{U} \rightarrow {}^{4}_{2}\alpha + {}^{\square}_{90}\mathrm{Th}$

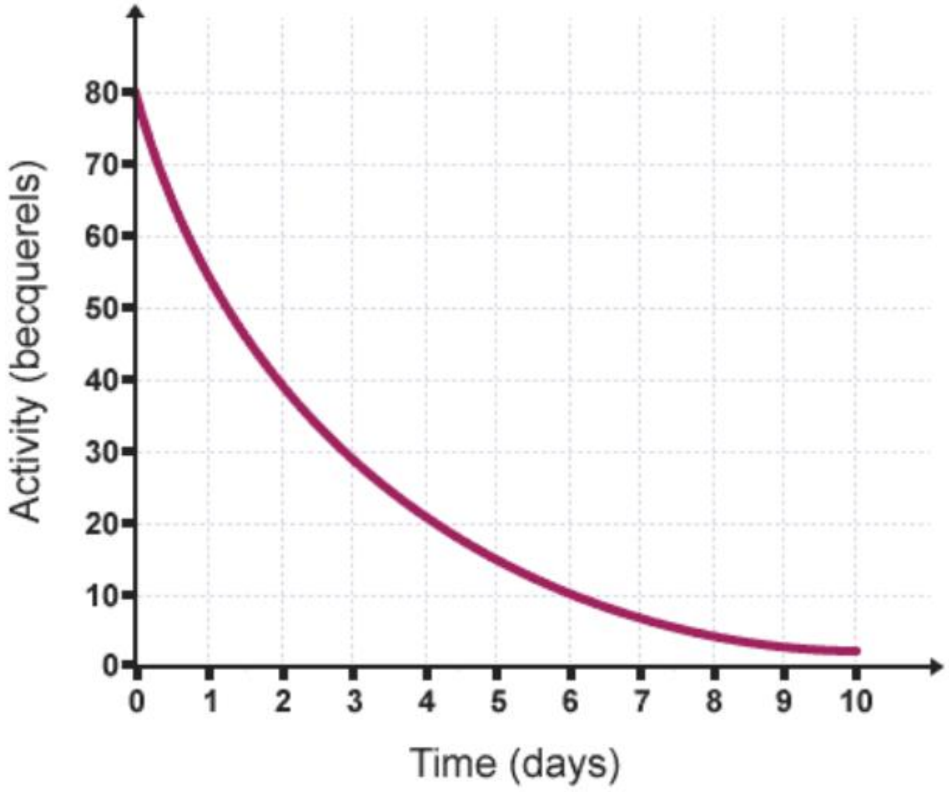
b. $^{87}_{37}\mathrm{Rb} \rightarrow {}^{0}_{-1}\beta + {}^{87}_{\square}\mathrm{Sr}$

c. $^{\square}_{19}\mathrm{K} \rightarrow {}^{0}_{+1}\beta + {}^{38}_{18}\mathrm{Ar}$

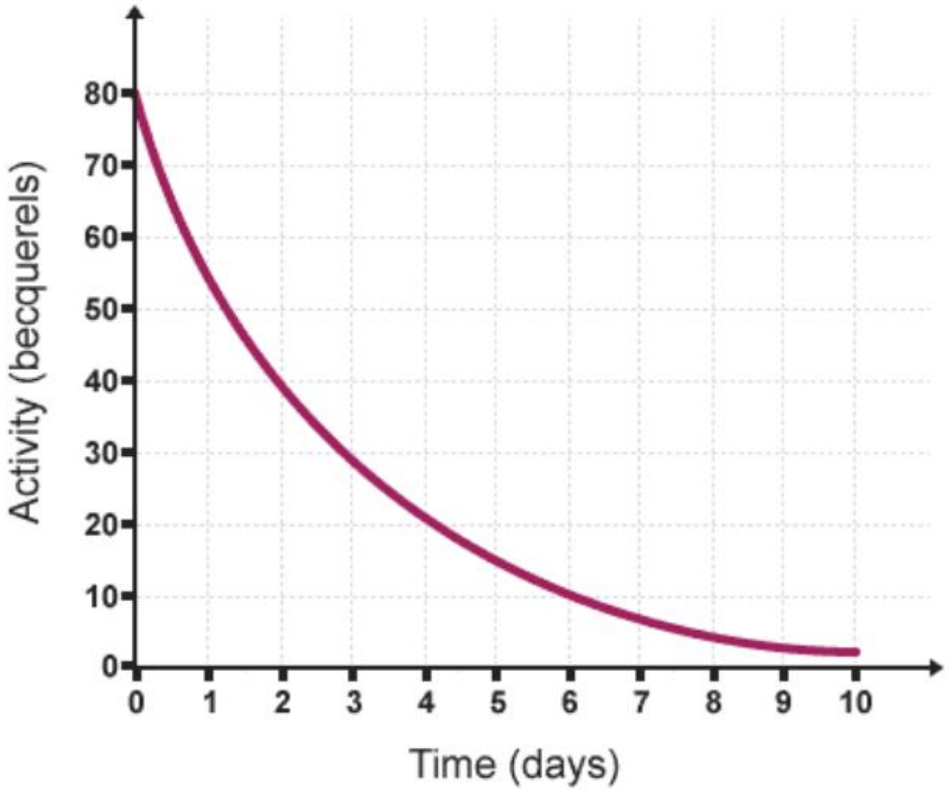
d. $^{55}_{\square}\mathrm{Fe} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{55}_{25}\mathrm{Mn}$

Half-life

Half-life is the time it takes for half of the unstable nuclei in a sample to decay or for the activity of the sample to halve or for the count rate to halve.



The activity of a radioactive substance is measured in **Becquerel** (**Bq**). One Becquerel is equal to one nuclear decay per second.



From the start of timing it takes two days for the activity to halve from 80 Bq down to 40 Bq. It takes another two days for the activity to halve again, this time from 40 Bq to 20 Bq.

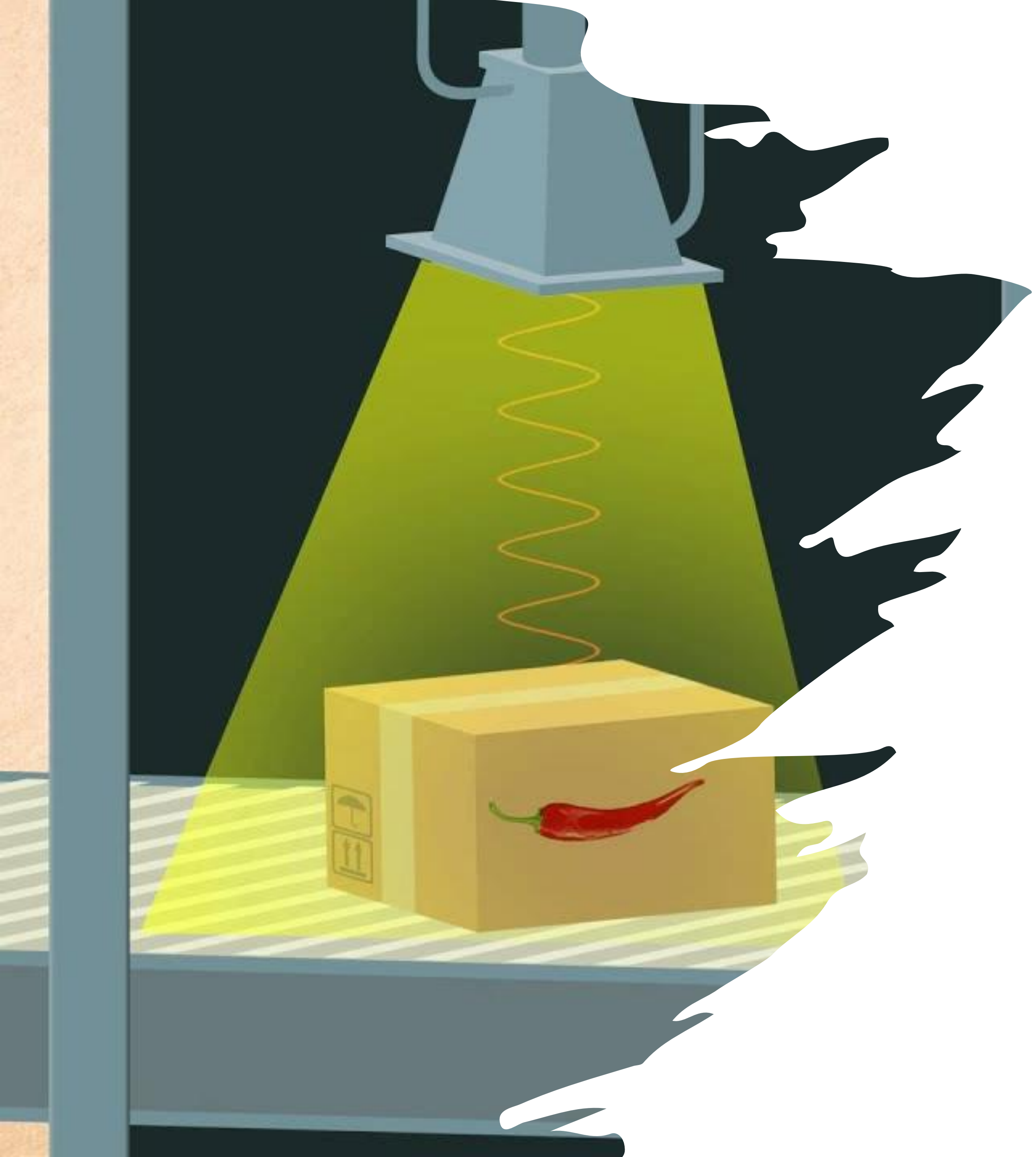
Example

The half-life of cobalt-60 is 5 years. If there are 100 g of cobalt-60 in a sample, how much will be left after 15 years?

15 years is three half-lives so the fraction remaining will be $(\frac{1}{2})^3 = 1/8 = 12.5$ g.

Concept Learning Questions

What is the half-life of a sample where the activity drops from 1,200 Bq down to 300 Bq in 10 days?



Irradiation

- Exposing objects to beams of radiation is called **irradiation**. The term applies to all types of radiation including radiation from the **nuclei** of **atoms**.

- Irradiation from **radioactive decay** can damage living cells. This can be put to good use as well as being a hazard.

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Irradiation for sterilization

- Irradiation can be used to preserve fruit sold in supermarkets by exposing the fruit to a **radioactive** source - typically cobalt-60.

- The **gamma rays** emitted by the cobalt will destroy any bacteria on the fruit but will not change the fruit in any significant way. The process of irradiation does not cause the irradiated object to become radioactive.

Contamination

- Contamination occurs if an object has a **radioactive** material introduced into it.
- An apple exposed to the **radiation** from cobalt-60 is irradiated but an apple with cobalt-60 injected into it is **contaminated**.
- As with **irradiation**, contamination can be very useful as well as being potentially harmful.

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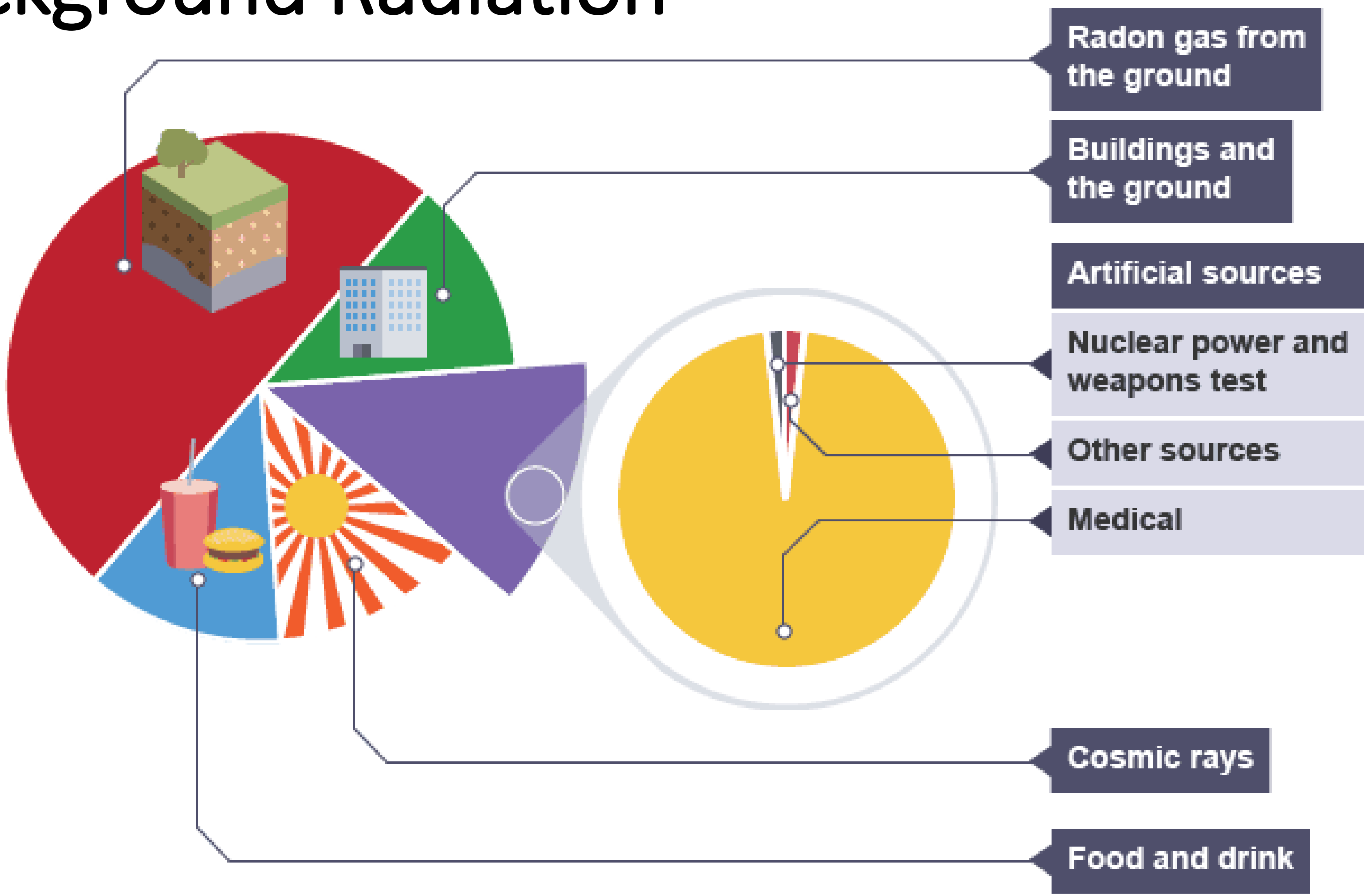
Irradiation	Contamination
Occurs when an object is exposed to a source of radiation outside the object	Occurs if the radioactive source is on or in the object
Doesn't cause the object to become radioactive	A contaminated object will be radioactive for as long as the source is on or in it
Can be blocked with suitable shielding	Once an object is contaminated, the radiation cannot be blocked
Stops as soon as the source is removed	It can be very difficult to remove all of the contamination

Background Radiation



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Background Radiation

Background **radiation** is all around us. Some of it comes from natural sources and some comes from artificial sources.

Natural sources

Natural sources of background radiation include:

- cosmic rays - radiation that reaches the Earth from space
- rocks and soil - some rocks are radioactive and give off radioactive radon gas
- living things - plants absorb radioactive materials from the soil and these pass up the food chain

For most people, natural sources contribute the most to their background radiation dose.

Artificial Sources of Background Radiation

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