Lees Brook Community School

Science Autumn Term 2 – Separate Physics P6 Radioactivity

Section A: Vocabulary

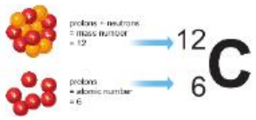
Tier 3 Vocabulary

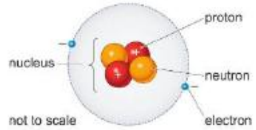
alpha particle	A particle made of two protons and two neutrons, emitted as ionising radiation.
atom	The smallest neutral part of an element that can take part in chemical reactions.
nucleus	The central part of an atom or ion.
subatomic particle	A particle that is smaller than an atom, such as a proton, neutron or electron.
atomic number	The number of protons in the nucleus of an atom. It is also known as the proton number.
isotope	Atoms of an element with the same number of protons (atomic number) but different mass numbers due to different numbers of neutrons.
mass number	The total number of protons and neutrons in the nucleus of an atom. It is also known as the nucleon number.
beta particle	A particle of radiation emitted from the nucleus of a radioactive atom when it decays. It is an electron.
gamma ray	A high-frequency electromagnetic wave emitted from the nucleus of a radioactive atom.

Section B: Atomic structure and Radiation

Structure of an atom

Subatomic particle	Location in atom	Relative charge	Relative mass
proton	nucleus	+1 (positive)	1
neutron	nucleus	0	1
electron	around nucleus	−1 (negative)	$\frac{1}{1835}$ (negligible)



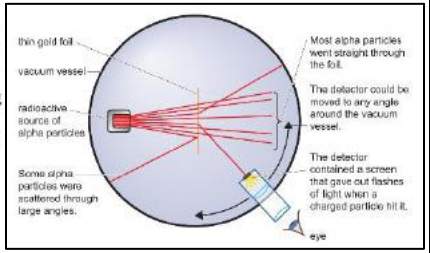


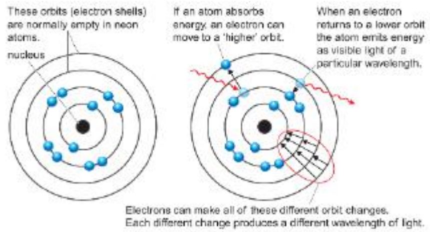
Atomic Models

J.J. Thomson (1856–1940) carried out some experiments that showed that atoms contain much smaller **subatomic particles** called **electrons**. These had a negative **charge** and hardly any mass.

In the 1900s, Thomson supported using a new model for atoms that could explain this new evidence. This new model described the atom as a 'pudding' made of positively charged material, with negatively charged electrons (the 'plums') scattered through it.

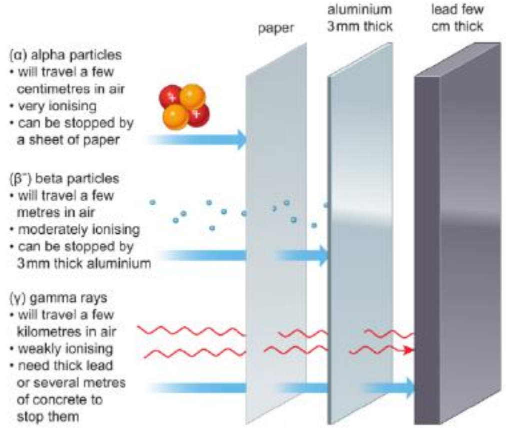
Between 1909 and 1913, a team of scientists led by Ernest Rutherford (1871–1937) carried out a series of experiments that involved studying what happened when positively charged subatomic particles, called **alpha particles**, passed through various substances (such as gold foil).





Section C: Nuclear Radiation

Types of nuclear radiation



Radioactive decay

Particle	Symbol	
alpha	α	$^{4}_{2}He$
beta	β^-	$^{0}_{-1}e$
positron	β^+	$^{0}_{+1}e$
neutron		n

Iodine-131 undergoes β^- decay. What is the other product?

$$^{131}_{53}I \rightarrow ^{0}_{-1}e + ?$$

The mass number stays the same. The atomic number goes up by 1 to 54. This is xenon (Xe). The atomic numbers represent positive charges and the −1 on the beta particle represents a negative charge.

$$^{131}_{53}I \rightarrow ^{0}_{-1}e + ^{131}_{54}Xe$$

Radium-226 emits an alpha particle. What is the other product?

$$^{226}_{88}Ra \rightarrow ^{4}_{2}He + ?$$

On the right of the arrow the nucleus has an atomic number of 88 – 2 = 86. This is radon (Rn). (The atomic numbers also represent the positive charges.)

Mass numbers must also balance. The radon nucleus has a mass number of 226 – 4 = 222.

$$^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn$$

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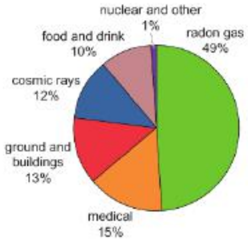
positron	The anti-particle of an electron, having the same mass but opposite charge. Positron emission is a type of beta decay
becquerel (Bq)	The units for the activity of a radioactive object. One becquerel is one radioactive decay per second.
nuclear fission	The reaction in which the nucleus of a large atom, such as uranium, splits into two smaller nuclei.
nuclear fusion	The reaction in which nuclei of light atoms, such as hydrogen, combine to make the nucleus of a heavier atom.
chain reaction	The sequence of reactions produced when a nuclear fission reaction triggers one or more further fissions
PET scanner	A medical scanning technique that detects gamma rays caused by the interaction of a positron from a radioactive source with an electron.
tracer	A radioactive substance that is deliberately injected into the body or into moving water. It allows the movement of the substance to be followed by detecting the ionising radiation emitted.

Background Radiation

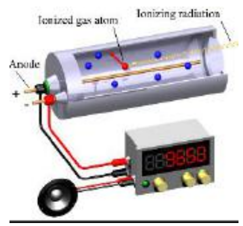


Sources of background radiation in the UK

Measuring radiation

The radioactivity of a source can also be measured using a **Geiger-Müller (GM) tube**. Radiation passing through the tube ionises gas inside it and allows a short pulse of current to flow.

A GM tube can be connected to a counter, to count the pulses of current, or the GM tube may give a click each time radiation is detected. The **count rate** is the number of clicks per second or minute.



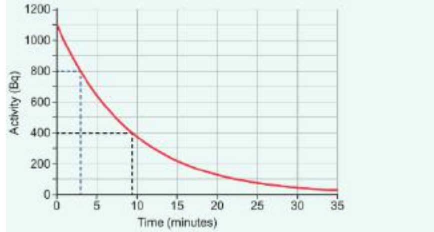
Irradiation	Contamination
Occurs when an object is exposed to a source of radiation outside the object	Occurs if the radioactive source is on or in the object
Doesn't cause the object to become radioactive	A contaminated object will be radioactive for as long as the source is on or in it
Can be blocked 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

Half-life

The **half-life** is the time taken for half the unstable nuclei in a sample of a radioactive isotope to decay. This is shown in diagram B. We cannot predict the decay of an individual nucleus because it is a random process. However, the half-life does allow us to predict the activity of a large number of nuclei. The half-life is the same for any mass of a particular isotope.

In figure D, the activity at 3 minutes is 800 counts per second. After one half-life the count rate will have decreased to 400 counts per second.

This occurs at 9.5 minutes, so the half-life is 9.5 – 3 = 6.5 minutes.



Uses of radiation

Use	Type of radiation	Reason
Smoke Alarm	Alpha	Ionises air, blocked by smoke particles
Thickness gauges	Beta	Passes through certain thickness of materials
Tracers	Gamma	Highly penetrating, will be detected across larger distances
Sterilising medical instruments	Gamma	Highly penetrating, kills micro-organisms
Diagnosing/treating cancer	Gamma	Highly penetrating, ionises cells