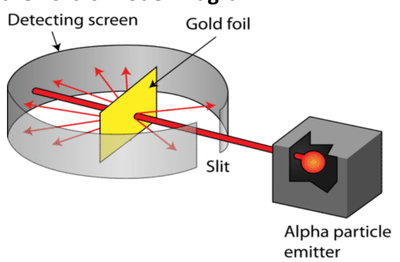
SP6 Radioactivity

Kettering Science Academy

1. Atomic Models

Atom	Smallest particle of an element.
Size of Atoms	2.5 x10^{-10} m in diameter
Element	Pure substance made of a single type of atom.
Plum-Pudding Model	Atoms as a sphere of positively charged matter with negative electrons scattered throughout it. Rutherford's experiment disproves this
Rutherford's Experiment	Fired alpha particles at very thin gold leaf and used a special screen to record where they went.
Rutherford's Results	Most alpha particles went straight through, some scattered (changed path).
Rutherford's Explanation	See diagram. Most α went through the empty space. The scattered ones must have bounced off the **nucleus**
Rutherford's Model	A positive **nucleus** with electrons going round it

Rutherford's Model Diagram

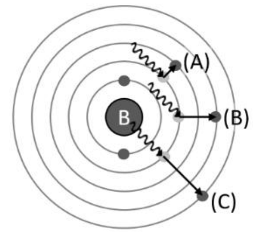


Nucleus	The central part of an atom; very small and dense, positively charged. **Rutherford's experiment** proves its existence. (Made of protons and neutrons)
Bohr's Model	Same as Rutherford's, but the electrons can only be in certain **orbits / shells**

2. Inside Atoms

Subatomic Particle	Any particle smaller than atoms: protons, neutrons and electrons.
Protons	+1 charge, mass = 1, located in the nucleus
Neutrons	0 charge, mass = 1, located in the nucleus
Electrons	-1 charge, mass = 1/1835, located around nucleus in shells
Relative Mass	Not the actual mass because no units. Protons and neutrons have same relative mass: their mass is 1.
Nucleons	The particles in the nucleus: protons and neutrons.
Determining the Element	The number of protons determines which element an atom is.
Atomic Number	The number of protons in an atom.
Mass Number	The number of nucleons (protons and neutrons) in an atom.
Number of Neutrons	Mass number – atomic number
Isotopes	Versions of an element with the same number of protons, but different number of neutrons.
Naming Isotopes	Carbon-13, or ^{13}C, where 13 is the mass number

3. Electrons and Orbits

Orbits	The shells of electrons around an atom.
Orbits and Energy	Higher orbit = higher energy
Excited Electrons	When an electron has absorbed energy and jumped to a higher orbit.
How to Excite Electrons	- When atoms absorb light - When electricity is passed through gases - Strongly heating a material
Absorbing Light	When electron absorbs light and jumps up to a higher shell.
Emitting Light	When electrons drop down to a lower shell and emit light.
Emission Spectrum	Pattern of bands of light at specific wavelengths caused by exciting a gaseous element with electricity.
Absorption Spectrum	Pattern of dark band in a 'rainbow' spectrum caused by a gas absorbing some of the light
Forming Ions	When an electron is given so much energy it leaves the atom entirely creating a positive ion.
Ionising Radiation	Radiation that causes ionisation: (high energy) UV, x-rays, gamma rays.
Diagram	

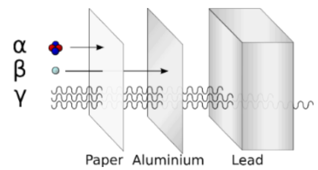
4. Background Radiation

Background Radiation	Low levels of ionising radiation that we are constantly exposed to; mainly natural causes.
Radon Gas	The biggest source of background radiation: a radioactive gas produced by some rocks in the ground
Other Natural Sources	Background radiation also comes from food and space (cosmic rays)
Artificial Sources	Hospitals, nuclear industry
Geiger-Müller (GM) Tube	Used to measure radioactivity, produce a click each time radiation passes through it.
Count-rate	The number of time a GM tube detects radiation each second.
Measuring Background Radiation	Use a GM tube to take several readings and then calculate the average (mean).
Corrected Count Rate	Measure the source, subtract the background radiation.
Dosimeter	A badge that changes colour in response to radiation exposure.
Dose	The amount of radiation received by a person.

5. Types of Radiation

Unstable Atom	An atom whose nucleus contains too much energy becomes unstable.
Decay	When an unstable atom releases its excess energy; this releases ionising radiation.
Alpha Radiation	Made of alpha particles: two protons and two neutrons. Symbol: α or $^{4}_{2}He$. Blocked by air/paper
Beta-minus Radiation	**Beta-** particles are fast-moving **electrons**. Symbol: β^- or $^{0}_{-1}e$. Blocked by aluminium
Beta-plus Radiation	**Beta+** particles are **positrons**: particles with same mass as electrons but a positive charge. Symbol: β^+ or $^{0}_{1}e$.
Gamma Radiation	Electromagnetic radiation. Extremely short wavelength / high frequency / high energy Symbol: γ. Blocked by lead/concrete
Neutron Radiation	Fast-moving neutrons. Symbol: n.
Ionising Power	Alpha is most ionising, gamma least.
Penetrating Power	Gamma is most penetrating, alpha least

Penetrating Power Diagram



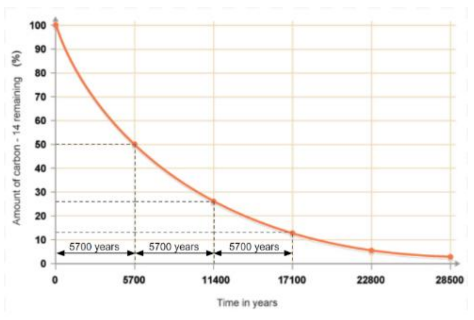
6. Radioactive Decay

Alpha Decay	Atomic number decreases by two, mass number decreases by four.
Beta- Decay	Atomic number increases by one, mass number stays the same.
Beta+ Decay	Atomic number decreases by one, mass number stays the same.
Gamma Decay	Atomic number and mass number unchanged.
Neutron Decay	Atomic number stays the same, mass number decreases by one.

7. Half-Life

Half-life	The time taken for half of the undecayed atoms in a sample to decay.
Stability, Half-life and Activity of Isotopes: Low stability = short half-life = high activity; High stability = long half-life = low activity	
Becquerel's, Bq	The unit of radioactivity: 1 Bq = one decay per second.
Half-life Graph	x-axis = time, y-axis = radioactivity. The line curves downwards but never touches the x-axis.

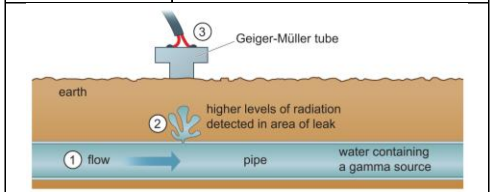
Half-life Graph



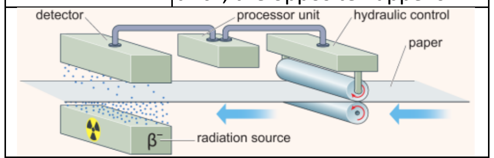
8. Using radioactivity

Irradiate	To expose something to ionising radiation (e.g. in order to sterilise food or medical equipment with gamma rays).
Sterilise	To destroy microorganisms (e.g. bacteria, viruses and fungi) in or on an object. It can be carried out using radioactive sources.
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.

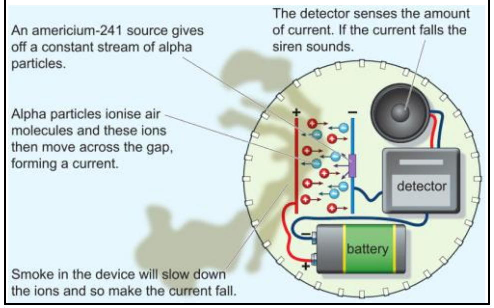
Killing microorganisms	Food can be irradiated with gamma rays to kill bacteria. It does not make the food radioactive or more radioactive.
Surgical instruments	Need to be sterilised to kill microorganisms. They are sealed into bags and irradiated with gamma rays, which can penetrate the bags and the equipment.
Leaks in water pipes	Radioactive isotopes can be used as tracers. A gamma source added to water is used to detect leaks in water pipes buried underground. A Geiger-Muller tube following the path of the pipe will detect higher levels of radiation where there is a leak.



Cancer	- to diagnose cancer using tracers in the body - to treat cancer
Checking thickness	There is a source of beta particles. When the paper is too thin, more beta particles penetrate the paper and the detector records a higher count rate. A computer senses that the count rate has risen and reduces the force applied to the rollers to make the paper thicker. When the paper is too thick, the opposite happens.



Smoke alarms



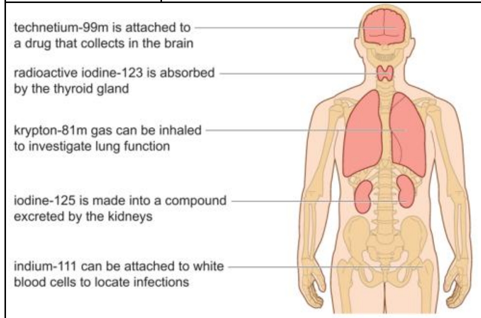
9. Dangers of Radioactivity

Mutations	DNA damage caused by ionising radiation, can lead to cancer.
Repairing Damage	Cells contain proteins that can repair DNA damage as long as the radiation dose is low enough.
Minimising Radiation Risk	- Wear protective clothing - Handle with tongs - Don't point at people - Limit time - Use protective shielding Wear dosimeter badges
Nuclear Power Risks	There is a small chance of accidents causing radioactive sources to escape
Irradiation	Exposure to radiation, stops when the source of radiation is removed.
Contamination	When particles of radioactive substances are on or in the body.
Risks in Perspective	Using radioactivity carries serious risks, but so do many other things, so it is safe to use as long as it is treated with caution.

10. Radioactivity in medicine

External radiotherapy	Treatment of cancer by sending radiation into the body from outside.
Internal radiotherapy	Treatment of cancer by putting a radioactive source inside the body.

Gamma camera	A camera that detects gamma rays.
Tracers	Tracers often contain a radioactive isotope attached to molecules that will be taken up by particular organs in the body. The tracer is usually **injected** into the bloodstream, but it may be **swallowed**, **inhaled** or **injected directly** into an organ.



PET scanner	A medical scanning technique that detects gamma rays caused by the interaction of a positron from a radioactive source with an electron.
Tumour	A lump formed of cancer cells.

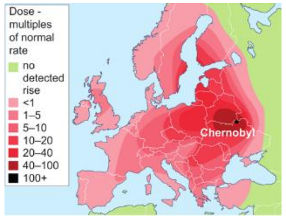
11. Nuclear energy

Climate change	Changes that will happen to the weather as a result of global warming, which is caused by the increase in the amount of carbon dioxide in the atmosphere.
Decommission	To dismantle safely.
Fossil fuel	A fuel formed from the dead remains of organisms over millions of years (e.g. coal, oil or natural gas).
Non-renewable	Any energy resource that will run out because it cannot be renewed, such as oil.
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.

Nuclear accidents

Chernobyl - 1986

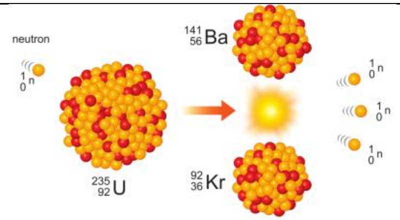


Ukraine, 1986.The accident was the result of a flawed reactor design that was operated with inadequately trained personnel.

Fukushima - 2011	The disaster was a 2011 nuclear accident at the Fukushima Daiichi Nuclear Power Plant in Ōkuma, Fukushima Prefecture, Japan. The event was caused by the 2011 Tōhoku earthquake and tsunami.
Three Mile Island - 1979	The Three Mile Island accident was a partial meltdown of reactor number 2 of Three Mile Island Nuclear Generating Station in Dauphin County, Pennsylvania, near Harrisburg, and subsequent radiation leak that occurred on March 28, 1979.
Windscale - 1957	The fire which occurred the 10th of October 1957 on the Windscale site along the Irish Sea in England is an accident of the British military nuclear program at its beginnings. This accident happened on one of the reactors (referred as atomic «piles» at that time) supplying in plutonium the United Kingdom arsenal of atomic bombs.

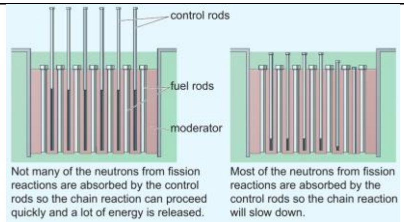
12. Nuclear fission

Nuclear fission	The reaction in which the nucleus of a large atom, such as uranium, splits into two smaller nuclei.



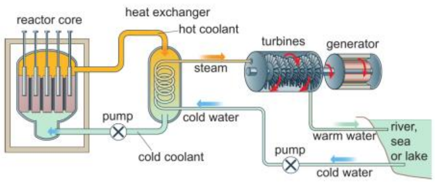
Chain reaction	The sequence of reactions produced when a nuclear fission reaction triggers one or more further fissions.

Nuclear reactor



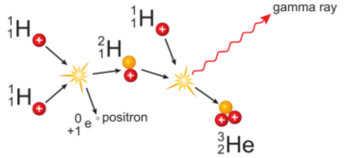
control rod	A rod that can be lowered into the core of a nuclear reactor to absorb neutrons and slow down the nuclear chain reaction.
core	The innermost part of something.
daughter nucleus	A nucleus produced when the nucleus of an unstable atom splits into two during fission or when a radioactive nucleus decays by emitting an alpha or beta particle.
fuel rod	A rod containing the nuclear fuel for a nuclear reactor.
moderator	A substance in a nuclear reactor that slows down neutrons, so that the nuclear fuel can absorb them more easily.

Generating electricity

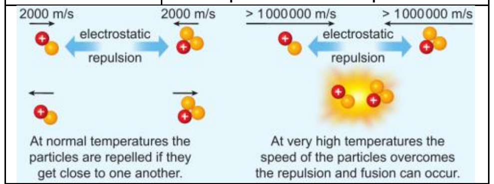


13. Nuclear fusion

Nuclear fusion	The reaction in which nuclei of light atoms, such as hydrogen, combine to make the nucleus of a heavier atom.



Electrostatic repulsion	A force between two electrical charges that have the same sign, which pushes them apart.



Lesson	Memorised?
1. Atomic Models	
2. Inside Atoms	
3. Electrons and Orbits	
4. Background Radiation	
5. Types of Radiation	
6. Radioactive Decay	
7. Half-Life	
8. Using radioactivity	
9. Dangers of Radioactivity	
10. Radioactivity in medicine	
11. Nuclear energy	
12. Nuclear fission	
13. Nuclear fusion	