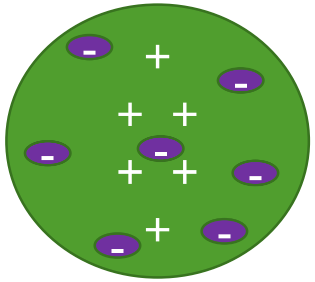
Radioactivity

GCSE overview

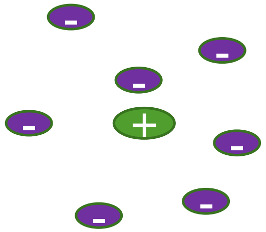
isaacphysics.org
https://isaacphysics.org/pages/remote_learning

Atomic models

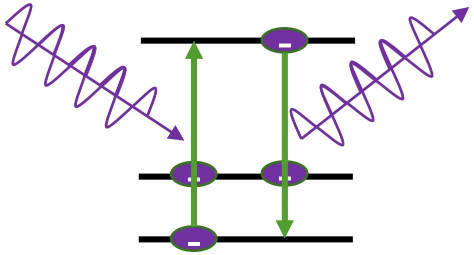
Plum pudding



Nuclear



Energy levels



Scattering

Alpha particles fired at the atom usually did not deflect. A small number were bounced back.

Spectra

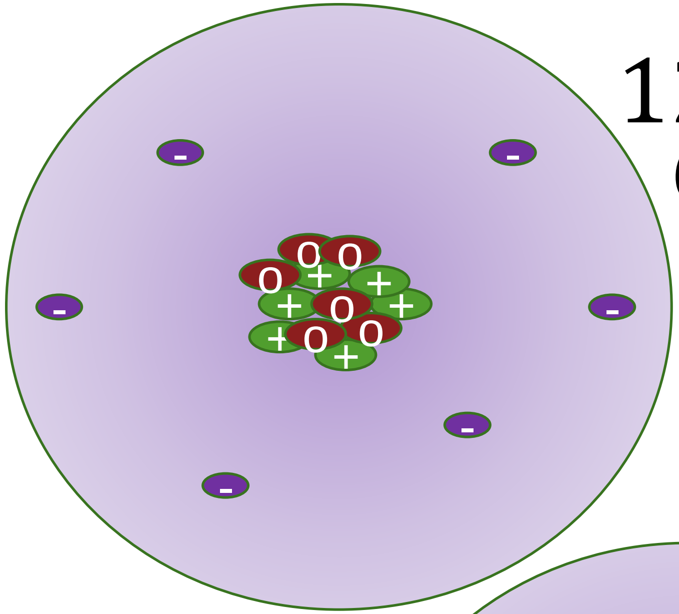
Light absorbed or emitted by atoms was at specific frequencies.

Neutrons

Neutral particles of similar mass to the proton were discovered in nuclei

Meet the atom

Particle	Charge	Mass
Proton	+1	1
Neutron	0	≈1
Electron	-1	0.0005



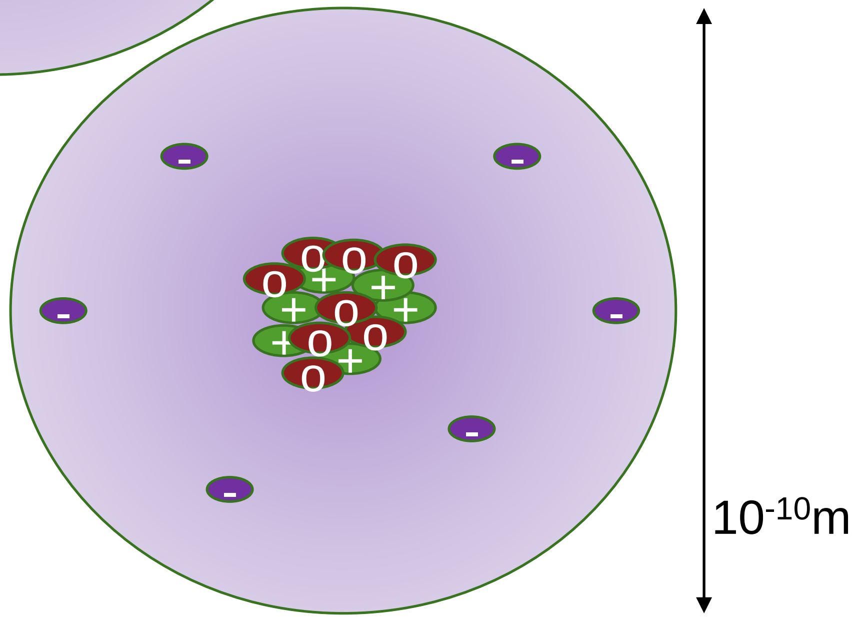
${}^{12}_{6}C$

Same element
Different mass
ISOTOPES

Mass of nucleus (or atom) approx. proportional to number of neutrons and protons (mass number)

Charge of nucleus proportional to number of protons (atomic number)

${}^{14}_{6}C$

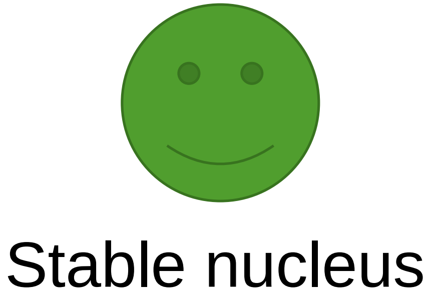


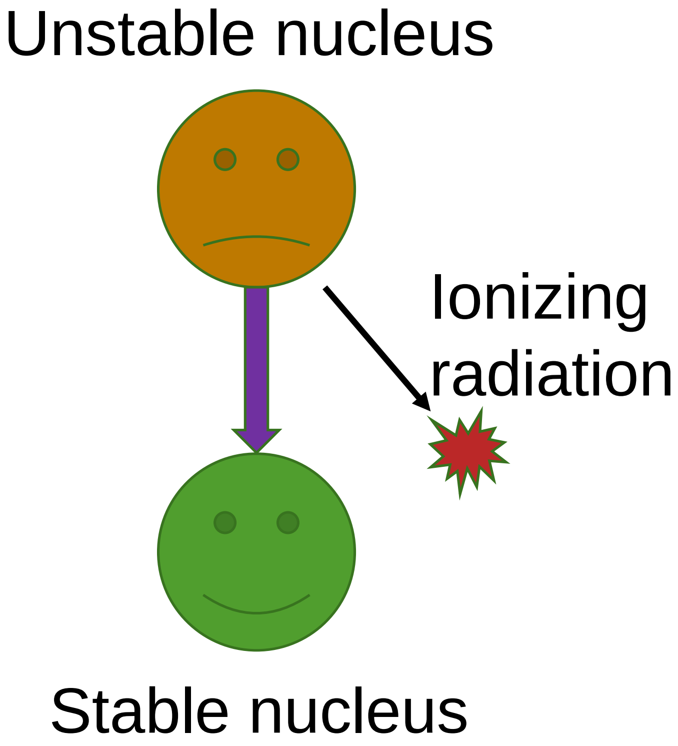
Nuclide practice

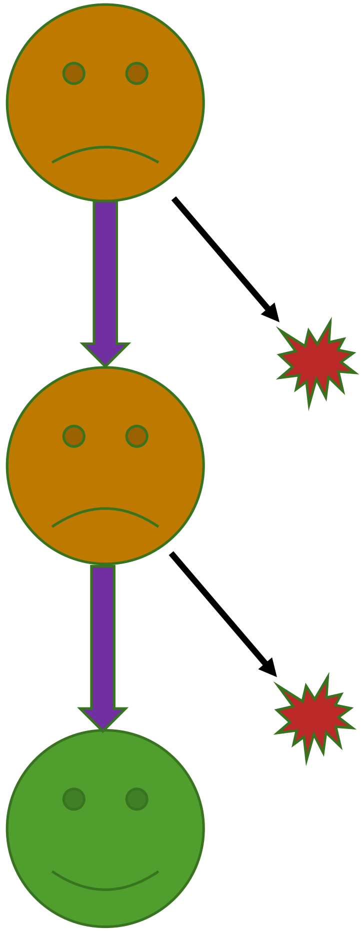
1. How many protons, neutrons and electrons are there in these nuclides? ${}^{2}_{1}H,\ {}^{3}_{1}H,\ {}^{15}_{8}O,\ {}^{56}_{26}Fe,\ {}^{238}_{92}U$

2. Write the symbol for the isotope of...
   a) carbon (6) with 7 neutrons
   b) hydrogen (1) with no neutrons
   c) neon (10) with mass number of 21

Ionizing radiation







When ionizing radiation passes another atom, it will take out electrons. The atom's chemistry will be altered.

This makes ionizing radiation harmful to life

Irradiation and Contamination

- Irradiation is when you receive ionizing radiation from a source. In general, this will not make you radioactive, and your dose will end once the source is not near you.
- Contamination is when a part of the source sticks to you, or is inhaled, consumed or otherwise becomes part of you. If this happens, you do become radioactive.

Background radiation

Radiation in the environment which is not related to the experiment we are doing. Dose is measured in sieverts (Sv)

Sources of background radiation (with typical annual doses) for a person in the UK include

- **1.3mSv - radon (radioactive gas coming up through rocks)**
- **0.4mSv - rocks (especially igneous rocks like granite)**
- **0.4mSv - medical uses of radioactivity**
- **0.3mSv – food and drink**
- **0.3mSv - the Sun, and cosmic radiation (from outside the solar system)**
- **0.01mSv - fallout from the testing of nuclear weapons & nuclear accidents**

Sources: Nuclear Industry Association and UK Radioactive Waste Inventory for fractions, gov.uk for totals.

Background correction

The number of decays each second is the activity.

Activity is measured in becquerel (Bq).

Example: Before an experiment is done, the background radiation gives 30 counts in 120s. During an experiment, 120 counts are measured in one minute

Types of radiation

$$^{241}_{95}\mathrm{Am} \rightarrow \mathrm{Np} + {}^{4}_{2}\alpha$$

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

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

	What it is	Range in air	Stopped by	Ionizing?
Alpha	helium nucleus (2p+2n)	5cm	paper skin	very
Beta	high energy electron	1m	1cm Al	moderately
Gamma	high freq. electromag. wave	far	few cm Pb	weakly

Nuclear equation practice

Write the equations for the following decays

1. **Beta decay of $^{3}_{1}\mathrm{H}$ to helium (He)**

2. **Alpha decay of $^{238}_{92}\mathrm{U}$ to thorium (Th)**

3. **Gamma decay of $^{60}_{27}\mathrm{Co}$**

Uses of radiation

- Smoke alarm
  - alpha particles ionize air, enabling it to conduct electricity
  - smoke from a fire stops the current, triggering the alarm
- Medical diagnosis (investigation)
  - usually a small quantity of a gamma emitter is injected into the patient, attached to a suitable molecule
  - ideal half life is about 6 hours
  - special cameras can monitor where it goes in the body
- Medical therapy (treatment)
  - cancerous cells have higher metabolic rate than healthy ones
  - targeting beams of gamma rays kills them more easily (radiotherapy)

Half life

Radioactive decay is a random process

You can not predict when a nucleus will decay

With many billions of nuclei in a sample, you can predict when half of them will have decayed – the half life.

The number of nuclei (and the activity) halves with each half life.

Start
120 Bq

12 years
60 Bq

24 years
30 Bq

36 years
15 Bq

Half life practice

1. The half life of tritium ($^{3}_{1}H$) is 12 years. If the background corrected count is 360 counts/min today, what would you expect it to be in 24 years time?

2. The half life of $^{99}_{43}Tc$ is 6.0 hours. With background of 10counts/min, and current count of 60counts/min, what will count be in 6.0 hours time?

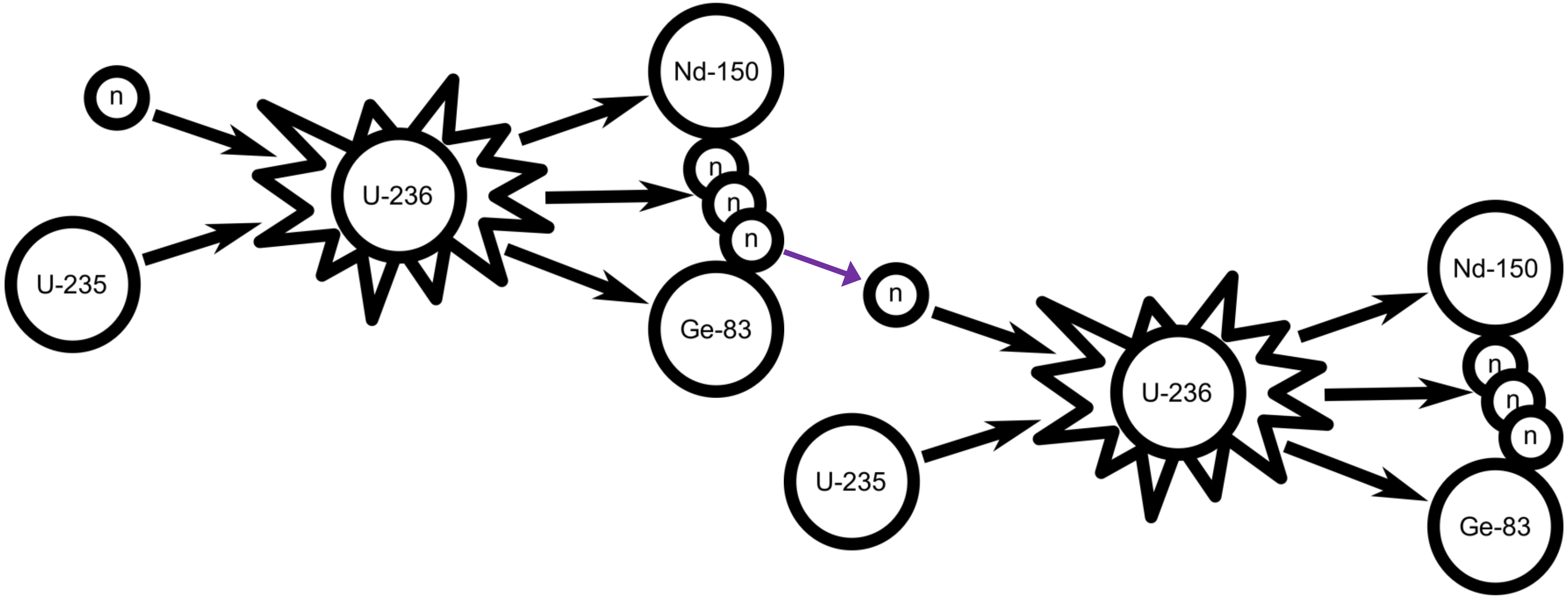
Count rate = Starting rate x $0.5^{\text{number of half lives}}$

Fission

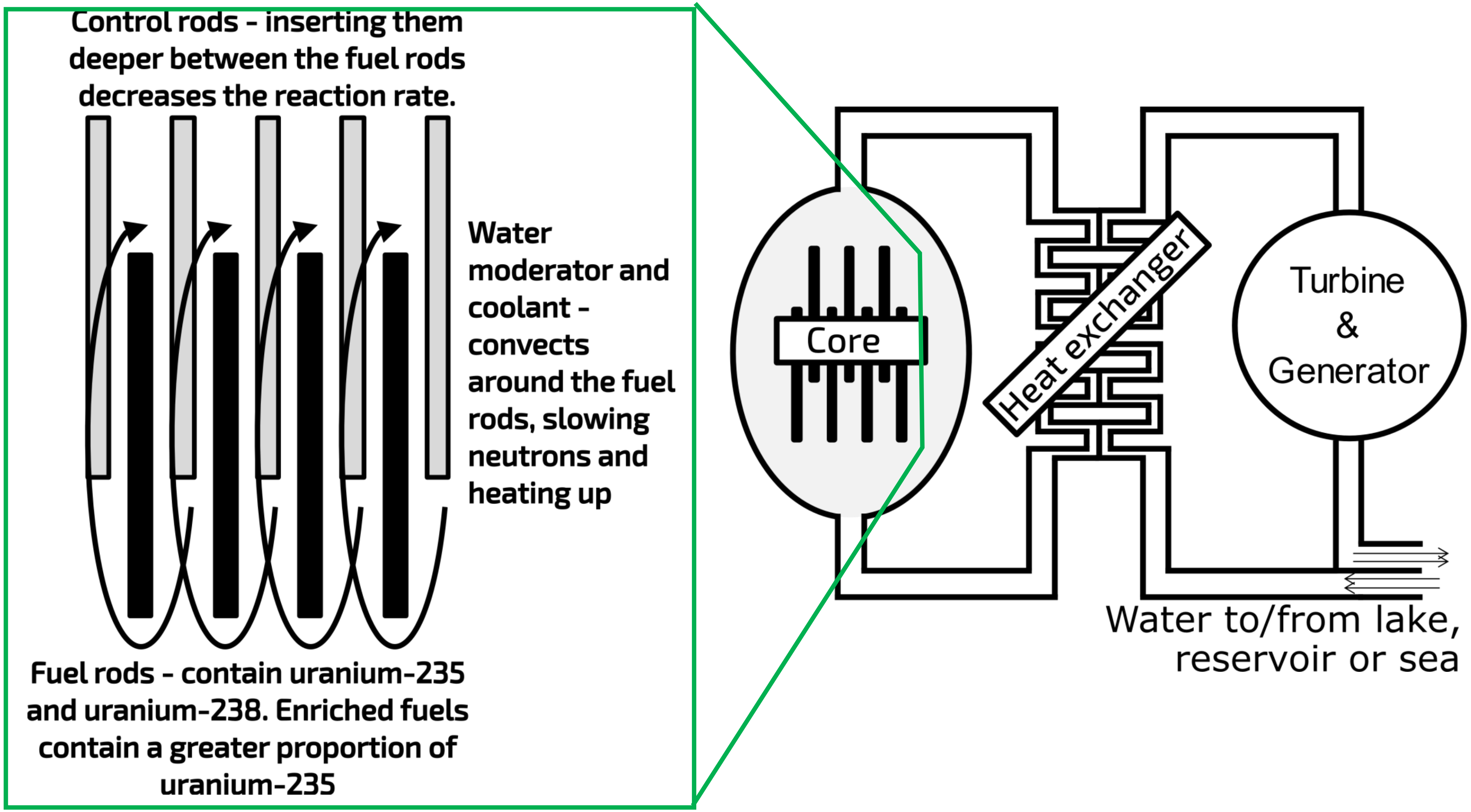
Some nuclei, such as uranium, split after absorbing a neutron

Neutrons are given out, which can trigger more reactions

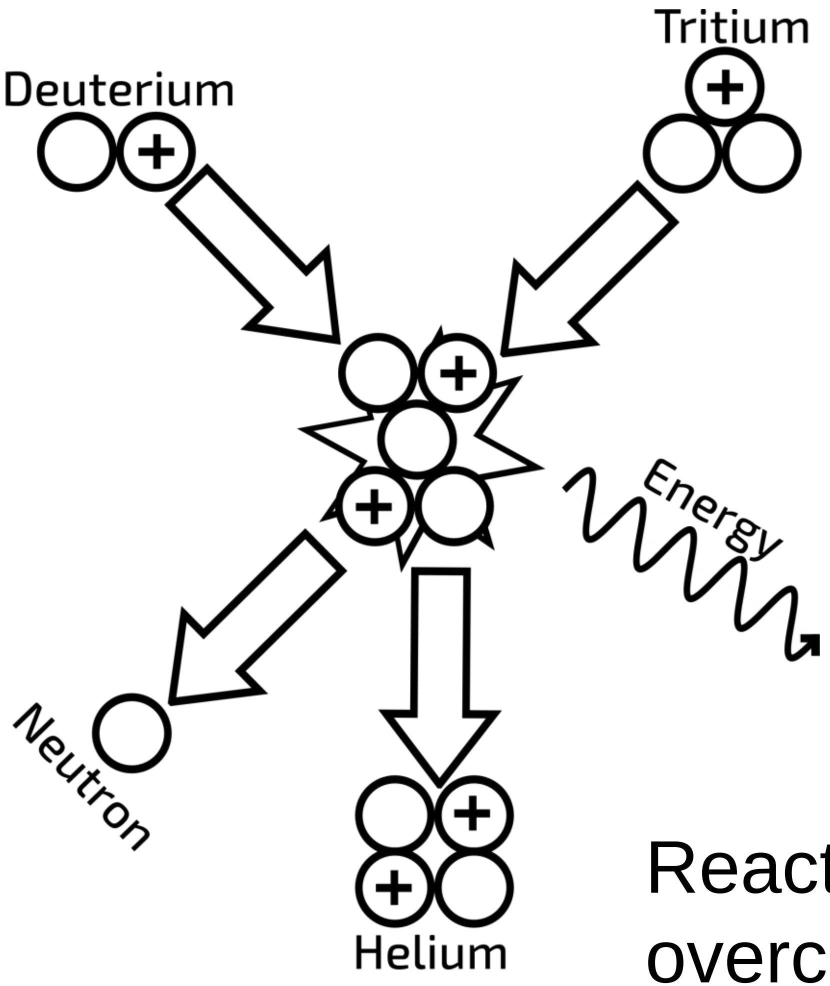
All particles given out have high kinetic energy



Nuclear reactor



Fusion



Two small nuclei (hydrogen) join to make a larger nucleus

Particles come out with high kinetic energy

Once stationary, products have less mass than reactants

Reaction requires high temperatures to overcome repulsion of reactants

Links

GCSE Topic Revision

https://isaacphysics.org/pages/gcse_topic_index#gcse_revision

Consolidation Programme

https://isaacphysics.org/pages/summer_programmes_2021