# ATOMIC STRUCTURE

## model of the atom

### DEVELOPMENT

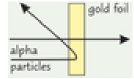
1804 - John Dalton agreed with Democritus that matter was made up of tiny spheres that could not be broken up, but he believed that each element was made up of different types of atoms

1897 - J.J. Thomson discovered particles called electrons that could be removed from atoms, and he suggested that atoms were spheres of positive charge with tiny negative electrons stuck in them -> PLUM PUDDING MODEL

1909 - Scientists in Rutherford's lab fired a beam of alpha particles at thin gold foil -> ALPHA SCATTERING EXPERIMENT

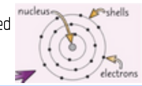
1932 - James Chadwick proved the existence of the neutron

Expectations:
- Particles will pass straight through gold sheet, or be slightly deflected




Results:
- Most particles went straight through -> most of the atom is empty space
- Some deflected by small angles -> tiny positive nucleus
- Some deflected by large angles -> strong positive nucleus

Alpha scattering experiment resulted in this nuclear model:
- Positively charged nucleus surrounded by a cloud of negative electrons




- Neils Bohr said that electrons orbiting the nucleus do so at certain distances called energy levels and his theoretical calculations agreed with experimental data
- Evidence from further experiments changed the model to have a nucleus made up of a group of particles (protons) which all had the same positive charge that added up to the overall charge of the nucleus
- About 20 years later the neutron was discovered by Chadwick which explained the imbalance between the atomic and mass numbers

Current Model:
- Tiny nucleus makes up most of atom's mass contains protons & neutrons
- Rest of atom is mostly empty space
- Electrons orbit nucleus very fast and give atom its overall size
- Number of protons = number of electrons
- Electrons in energy levels can move within/leave the atom
- Electrons gain energy (absorbing EM radiation) -> move to higher energy level (further from nucleus)
- Electrons lose energy (release EM radiation) -> move to lower energy level (closer to nucleus)
- Electrons leave atom -> atom becomes +ve ion
- Atom gains electrons -> atom becomes -ve ion

| SUBATOMIC PARTICLE | LOCATION | MASS | CHARGE |
|---|---|---|---|
| PROTON | nucleus | 1 | +1 |
| NEUTRON | nucleus | 1 | none |
| ELECTRON | shells | 0 | -1 |

- All atoms of each element have a set number of protons -> atomic number
- Mass number = proton number + neutron number

### ISOTOPES

- Isotopes are atoms with same proton number but different neutron number
- All elements have different isotopes but usually only have one or two stable isotopes
- Unstable isotopes tend to decay into other elements and give out radiation to become more stable (radioactive decay)
- Radioactive substances release one or more types of ionising radiation from their nucleus (alpha, beta or gamma) and they can also release neutrons
- Ionising radiation knocks electrons off atoms, creating +ve ions

## radioactive decay

Alpha particles (α):
- Two neutrons, two protons (helium nucleus)
- Low penetration power
- Stopped by paper
- Very ionising

Beta particles (β):
- Electron released by nucleus
- Moderate penetration power
- Stopped by aluminium
- Moderatley ionising
- For every beta particle emitted, a neutron in the nucleus has turned into a proton

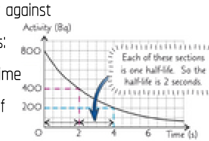
Gamma rays (γ):
- EM radiation released by nucleus
- High penetration power
- Stopped by lead
- Weakly ionising

### HALF-LIFE

- Radioactive substances give out radiation from the nuclei of their atoms
- This radiation can be measured with a Geiger-Muller tube and counter, which records the count-rate (number of radiation counts per second)
- Radioactive decay is random so it is impossible to predict which nucleus in a sample will decay
- You can find out the time it takes for the amount of radiation emitted by a source to halve (half-life), and this can be used to make predictions
- Half-life can be used to find the rate of decay of a source -> its ACTIVITY (measured in Bq)

- Each time a radioactive nucleus decays to become a stable one, the activity as a whole will decrease -> older sources emit less radiation
- Activity never reaches zero
- Half life is the time taken for the number of radioactive nuclei in an isotope to halve
- Short half life: activity falls quickly, nuclei are very unstable, dangerous due to high amount of radiation emitted at the start
- Long half life: activity falls slowly, small amounts of radiation emitted for a long time which is dangerous because nearby areas will be exposed to radiation for many years

- If you plot a graph of activity against time it will always look like this:
- Half-life is found by finding time interval that corresponds to half the activity

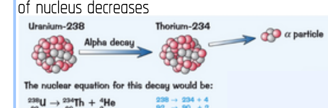



- Gamma rays are a way of getting rid of excess energy from a nucleus
- So there is no change to atomic mass or atomic number

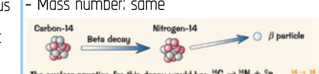
### NUCLEAR EQUATIONS

- Nuclear equations show radioactive decay by using element symbols
- Total mass & atomic numbers must be equal on both sides

Alpha decay:
- Atomic number: -2
- Mass number: -4
- Proton is +ve & neutron is neutral so charge of nucleus decreases



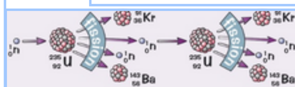

Beta decay:
- Neutron turns into proton and nucleus releases electron (beta particle)
- Atomic number: +1
- Mass number: same




## fission & fusion

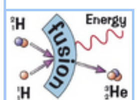
### FISSION

- Nucleus absorbs a neutron then splits, forming two lighter elements that are roughly the same size with some energy in kinetic energy stores
- Two/three neutrons are also released and if any are moving slow enough they can be absorbed by another nucleus causing more fission to occur in a chain reaction




### FUSION

- Two light nuclei collide at high speed and fuse to create larger, heavier nucleus
- Heavier nucleus does not have as much mass as two separate nuclei did as some of the mass of the light nuclei is converted to energy which is released as radiation
- Fusion releases a lot of energy (more than fission)
- Scientists have not found a way of using fusion to generate energy as temperature and pressure needed for fusion is so high that fusion reactors would be really hard and expensive to build




## nuclear radiation

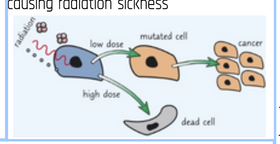
### USES & RISKS

- High doses of radiation can be used to treat cancer cells
- Gamma rays carefully directed to cancer cells or beta-emitting implant can be put next to/inside tumours
- Can make patient feel very ill

- Medical tracers can be used to diagnose life-threatening conditions

- Certain radioactive sources can be injected into people (or swallowed) and their progress around the body can be tracked using a detector which a computer then displays
- Eg, Iodine-123 is absorbed by thyroid gland gives out radiation which is detected to show whether the gland is taking in iodine as it should
- Isotopes which are taken into the body like this are usually gamma as its ionising power is weak
- They should also have a short half-life so radioactivity quickly disappears

- Radiation can enter living cells and ionise atoms and molecules within them -> tissue damage
- Lower dose = minor damage without killing cells, can lead to cancer
- Higher dose = kills cells completely, causing radiation sickness




- If unwanted radioactive atoms get onto/into an object, it is contaminated
- These contaminating atoms may then decay, releasing radiation which could cause harm
- Gloves and tongs should be used when handling sources to prevent contamination

- Contamination and irradiation can cause different amounts of harm depending on radiation type
- Outside body: beta & gamma are most dangerous as they can penetrate the body and damage organs
- Inside body: alpha is most dangerous as it is most ionising and can cause cancer

### BACKGROUND RADIATION

- Background radiation is low-level radiation that is around us all the time which comes from:
  - Radioactivity of naturally occurring unstable isotopes
  - Radiation from space (cosmic rays from the Sun)
  - Radiation due to human activity (nuclear waste)
- Radiation dose tells us the risk of harm to body tissues due to exposure to radiation (measured in Sv)
- The dose from background radiation is very small, but varies depending on location

- Objects near radioactive source are irradiated by it
- Irradiating something does not make it radioactive
- Keeping sources behind lead-lined boxes, standing behind barriers, being in different room reduces effects of irradiation

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## Nuclear reactors

- The energy not transferred to the kinetic energy stores is carried away by gamma rays
- This energy released by fission can be used to heat water, making steam turn turbines and generators
- The amount of energy produced by fission in a nuclear reactor is controlled by changing how quickly chain reactions occur
- This is done by using control rods, which are lowered/raised inside a nuclear reactor to absorb neutrons, slow down the chain reaction and control the amount of energy released
- Uncontrolled chain reactions lead to lots of energy released as an explosion -> this is how nuclear weapons work