Radioactivity

History of Radioactivity

Discovered by: Becquerel
Marie and Pierre Curie

Alpha Radiation (nature and penetration ability)

- α-particles are made of two protons and two neutrons (a helium nuclei)
- α-particles are therefore positive (+2)
- move relatively slowly
- are stopped quite easily (human skin, paper)
- strongly ionising
- hazardous if they get into the body (mouth, nose)
  - molecules in living cells are damaged / destroyed, possibly leading to cancer if penetrated by ionising radiation
- defected by electrical and magnetic fields

Example: α-emitter

- Americium-241
  - used in smoke detectors - no health hazard due to poor penetrating ability, long half-life
- $^{241}_{95}Am \longrightarrow {}^{237}_{93}N + {}^{4}_{2}He + energy$

Beta Radiation

- a neutron disintegrates into a proton and emits an electron (a β-particle)
- β-particles are negative (-1)
- move quickly
- penetrate more deeply than α-particles - stopped by 5mm of aluminium
- penetrate deeply into the body - damaging - possibly cancer
- no change in mass number, atomic number increases by 1.
- defected by electrical and magnetic fields

Example: β-emitter

- Carbon-14
  - when alive, the carbon-12 to carbon-14 ratio is constant
  - when the plant / animal dies, the carbon-14 starts to decay (β) and the ratio changes
  - the ratio is evaluated and the age can be determined due to the knowledge that carbon-14 has a half-life of 5700 years
- $^{14}_{7}C \longrightarrow {}^{14}_{6}N + {}^{0}_{-1}e + energy$

Gamma Radiation

- γ rays are not particles - no mass or charge
- γ rays are neutral
- move very quickly
- much greater penetrating ability - thick shields of concrete / lead can stop them
- very damaging - cancer
- not defected by electrical and magnetic fields

Example: γ-emitter

- Cobalt-60
    - used in cancer treatment and food irradiation
- $^{60}_{27}Co \longrightarrow {}^{60}_{27}Co + \text{energy}$

Note: a Geiger-Müller tube may be used to detect radioactivity. A gas is ionised by alpha, beta or gamma radiation resulting in an electric current which is amplified and detected.

Note: in an electric field, beta radiation is attracted to the positive plate, alpha to the negative and gamma is not attracted to either.

Note: transmutation is when an element changes into another element (eg: by the emission of α and β particles).

Widespread Occurrence of Radioactivity

- background radiation is the low level of ionising radiation that surrounds us at all times
- 90% comes from natural sources
- >50% is caused by radon gas which is formed from the decay of radioisotopes found in rocks
- all isotopes of radon are radioactive (emitting α particles)
- potential damage to health means that radon barriers are incorporated into new buildings
- artificial sources are mostly medical
- include cobalt-60 (cancer treatment and x-rays)
- small amount from fallout of weapons tests and from nuclear waste

Distinction Between Chemical Reaction and Nuclear Reaction (& equations)

- nuclear reactions involve a change in the nucleus involving protons and neutrons
- nuclear reactions involve transmutation
- chemical reactions only involve changes in the distribution of electrons
- chemical reactions never involve transmutation

Radioisotopes and their uses

- radioisotopes are unstable radioactive isotopes
- all isotopes of atomic no. greater than 83 are radioactive

Archaeology

- carbon dating
- when alive, the ^{12}C to ^{14}C ratio is constant
- after death, the ^{14}C begins to decay (β) while the ^{12}C remains stable, changing the ratio
- by measuring the ratio and knowing the half-life of ^{14}C, the age of the specimen can be estimated

Medicine

- cobalt-60 (γ) is used in the treatment of cancer - radiotherapy
- the gamma rays are directed onto the tumour
- ionising radiation damages the more susceptible cancerous cells

Food Preservation

- cobalt-60 is used in food irradiation
- the gamma rays kill micro-organisms and insects which could cause the food to deteriorate quickly

Smoke Alarms

- americium-241 (α)
- safe: radiation is not very penetrating
- does not have to be replaced: long half-life

Half-life

- the half-life of a sample is the interval of time after which half of the sample has decayed
- nuclear power is seen unfavorably due to the long half-lives and difficulty of disposing of nuclear waste