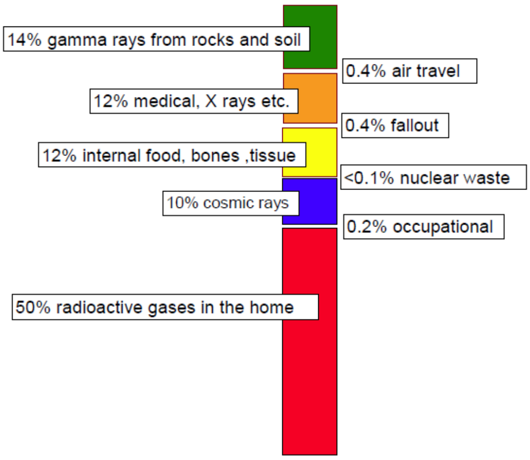
Detection and measurement of Radioactivity:

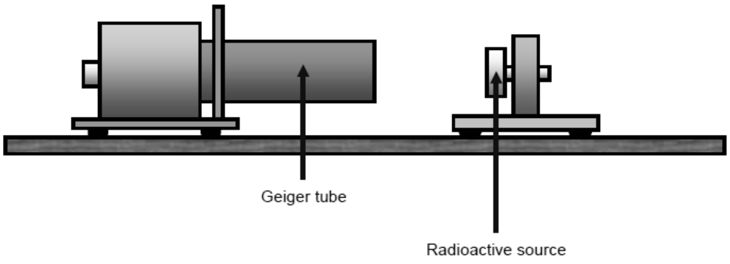
A Geiger counter set up anywhere will register a low level of natural radioactivity, known as the background radiation.



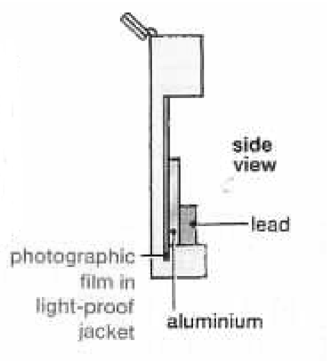
Natural sources include: radiation from space (cosmic rays from Sun), from naturally occurring radioisotopes in rocks e.g. granite, and radiation due to human activity - atomic weapons testing & emissions from nuclear power stations.

To detect this and additional radioactivity, we use detectors such as Geiger-Muller tubes and photographic film.

- Geiger-Muller (GM) tube and counter electronically amplifies the ionising effect of the radiation.

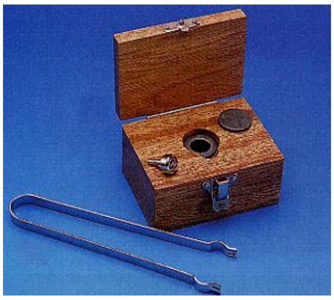


- Photographic film badges (for workers in nuclear industry and hospitals) monitor how much radiation they are exposed to.



Dangers of radioactivity:

Any radioactivity is dangerous to living organisms.



When radioactivity hits living cells, alpha, beta and gamma radiation collides with neutral atoms or molecules, knocking off electrons and turning them into charged/ionised particles (ions). These may be very reactive and cause other chemical changes in the cell molecules. Ionisation can kill cells directly or cause genetic damage (damages DNA).

High doses of radiation cause burn effects and can kill cells. Doses too low to kill cells can still genetically damage them & if they replicate, the mutations can lead to the formation of cancerous cells / tumours. The 3 radiations have different capacities to cause cell damage. Inside the body the 'danger' order is alpha > beta > gamma. The bigger the mass or charge of the particle, the bigger its ionising impact on atoms or molecules.

Outside the body, the order danger is gamma > beta > alpha because it depends on the pattern of penetrating power. The smaller the mass and charge the more penetrating the radiation. Gamma and beta are the most penetrating and will reach vital organs in the body and be absorbed. Most gamma passes through soft tissue but some is absorbed by cells. Since alpha radiation would not penetrate clothing its unlikely to reach living cells.

The Uses of Radioactive Isotopes:

Uses depend on their penetrating power & their half-life.

Alpha: easily stopped and used in some smoke detectors. Americium-241 (half-life 458 years) emits alpha particles which collide with the oxygen and nitrogen in air in the detector's ionisation chamber to produce ions. A low-level electric voltage applied across the chamber is used to collect these ions, causing a steady small electric current to flow between two electrodes. When smoke enters the space between the electrodes, the alpha radiation is absorbed by smoke particles. This causes the rate of ionisation of the air to decrease and therefore the electric current to fall, which sets off an alarm. The alpha particles from the smoke detector do not themselves pose a health hazard, as they are absorbed in a few centimetres of air or by the structure of the detector.

Beta: stopped by a few mm or cm of solid materials. The thicker the layer the more beta radiation is absorbed. A beta source is placed on one side of a sheet of material. A detector (eg a Geiger counter) is put on the other side and can monitor how much radiation gets through. The signal size depends on thickness of the sheet and it gets smaller as the sheet gets thicker. Therefore the signal can be used to monitor the sheet thickness.

Gamma: Gamma radiation is highly penetrating and so gamma sources are used where the radiation must be detected after passing through an appreciable thickness of material. This is used in various tracer situations eg monitoring pipes for leaks, medical tracers, radiotherapy (A beam of gamma radiation is directed onto the tumour site to kill the cancer cells), testing structure of materials (eg welds), and to sterilise surgical equipment or packaged food.

Isotopes:

If you look at the pictures you will see that there are two 'versions' of hydrogen. One of them has a nucleus containing a proton but the other has a nucleus with both a proton and a neutron. These two 'versions' of hydrogen are called **ISOTOPES** of hydrogen.

Isotopes are nuclei with the same number of protons (proton number) but with a different number of neutrons. This means that they will have a different mass number (nucleon number).

The chemical properties of all the isotopes of an element will be the same but their physical properties will be different because of their different masses. This means that properties like the boiling point and density of isotopes of an element will be different. For example 'heavy water' containing the isotope of hydrogen ${}^{2}_{1}H$ (called deuterium) has a boiling point of 104 ^{o}C.

Carbon 14 (6 protons and 8 neutrons) and carbon 12 (6 protons and 6 neutrons) are two isotopes of carbon.

Uses of Radioactive Isotopes:

Radioactivity can be used in a number of ways. Because the radioactive half-life of a given radioisotope is not affected by temperature, physical or chemical state, or any other influence of the environment outside the nucleus save direct particle interactions with the nucleus, then radioactive samples continue to decay at a predictable rate. Some of these are described below.

1. Radioactive dating

(a) CARBON 14 - for dating material that has been alive or has been made from once living material. This is used for dating wood, bones, Egyptian mummies, the Dead Sea scrolls, old paintings etc.

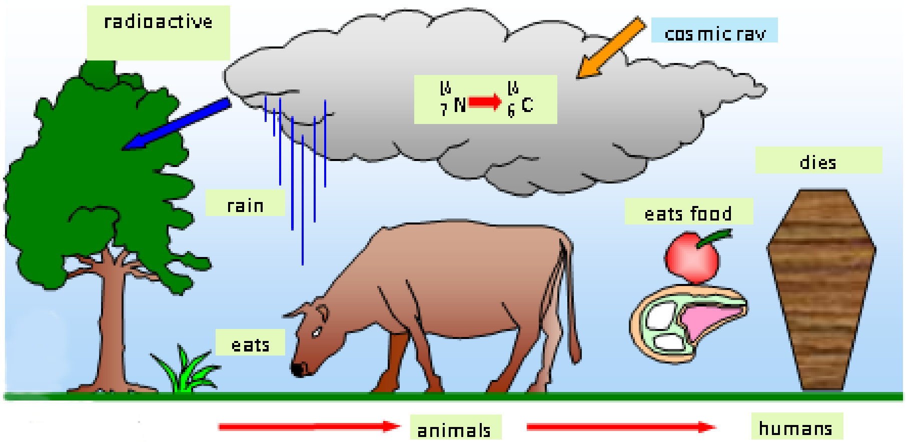
One radioactive isotope which is present in the air we breathe is carbon-14. This is formed when cosmic rays interact with nitrogen in the upper atmosphere.

$${}^{14}_{6}N + {}^{1}_{0}n \longrightarrow {}^{14}_{6}C + {}^{1}_{1}H$$

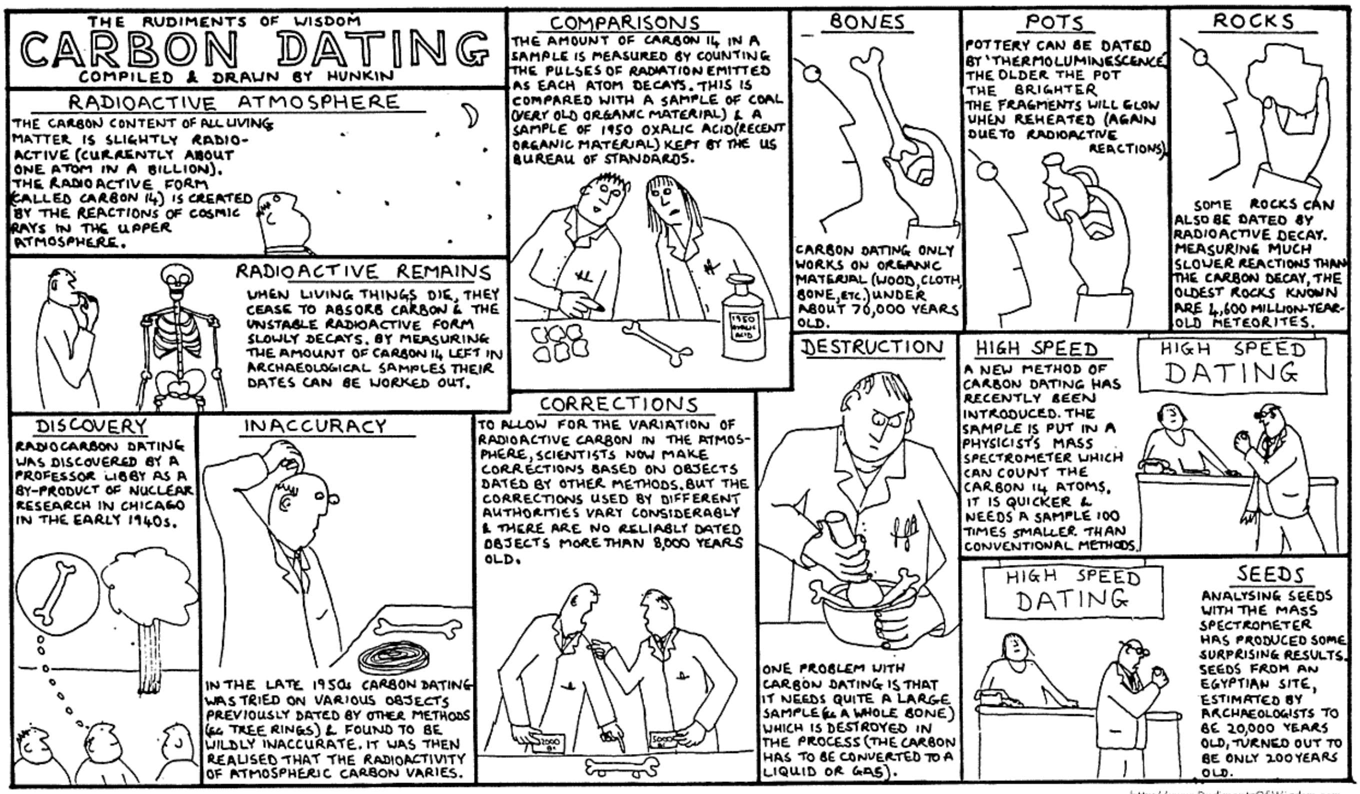
This carbon enters the bodies of living organisms through photosynthesis and the food chain, and while the organism is living the proportion of C-14 to stable C-12 stays constant, decaying and being replaced. The activity of carbon 14 in living tissue is about 250 Bq per kilogram. When the organism dies there is no further intake and the C-14 present goes through its decay cycle with a half-life of 5760 years.

$${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

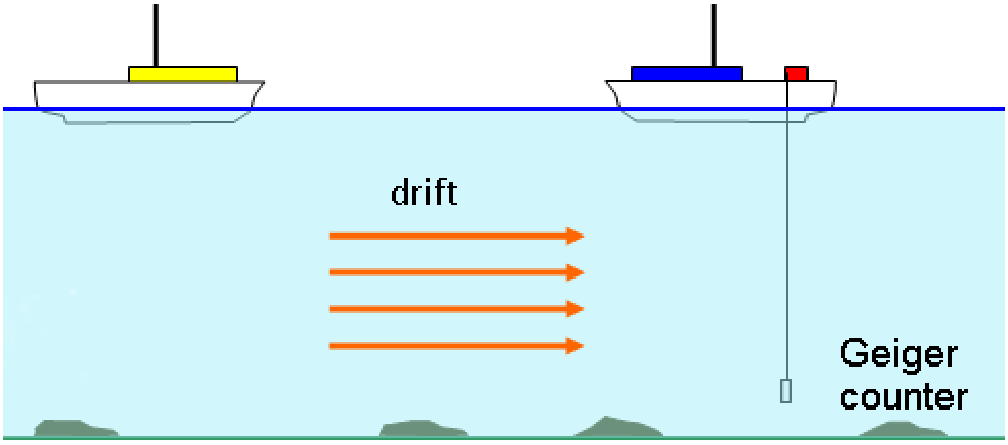
Thus the amount of C-14 remaining in organic remains allows the age of the remains to be calculated.



(b) URANIUM 238 or POTASSIUM 40 for dating rocks. Used because of their very long half lives



2. Radioactive tracers



If a little radioactive material (usually iodine-131 with a half-life of 8.1 days) is put into a moving liquid the path of this liquid can be tracked. Used in testing blood flow, tracking underground streams and following the movement of silt in rivers.

3. Radiotherapy

Gamma radiation from Cobalt 60 (with a half-life of 5.3 years) has been found to be very useful in the treatment of some types of cancer.

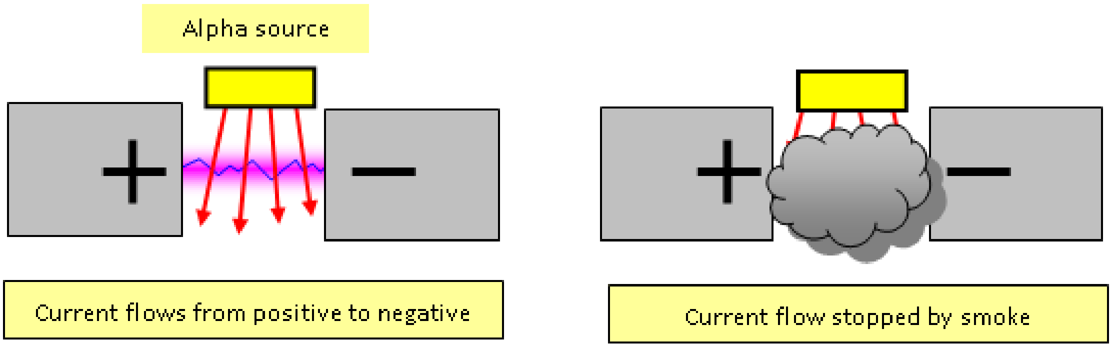
4. Thickness gauge

A beta source is put on one side of a sheet of material and a Geiger counter on the other. The amount of beta radiation that gets through the sheet will give you an idea of its thickness.

5. Smoke alarms

Many houses have a smoke alarm using a weak alpha source.

A typical smoke detector uses a small amount of radioactive americium-241 which decays by alpha decay to neptunium with a half-life of 460 years. When smoke gets into the detector the alpha particles cannot get through to the sensor and the alarm goes off.

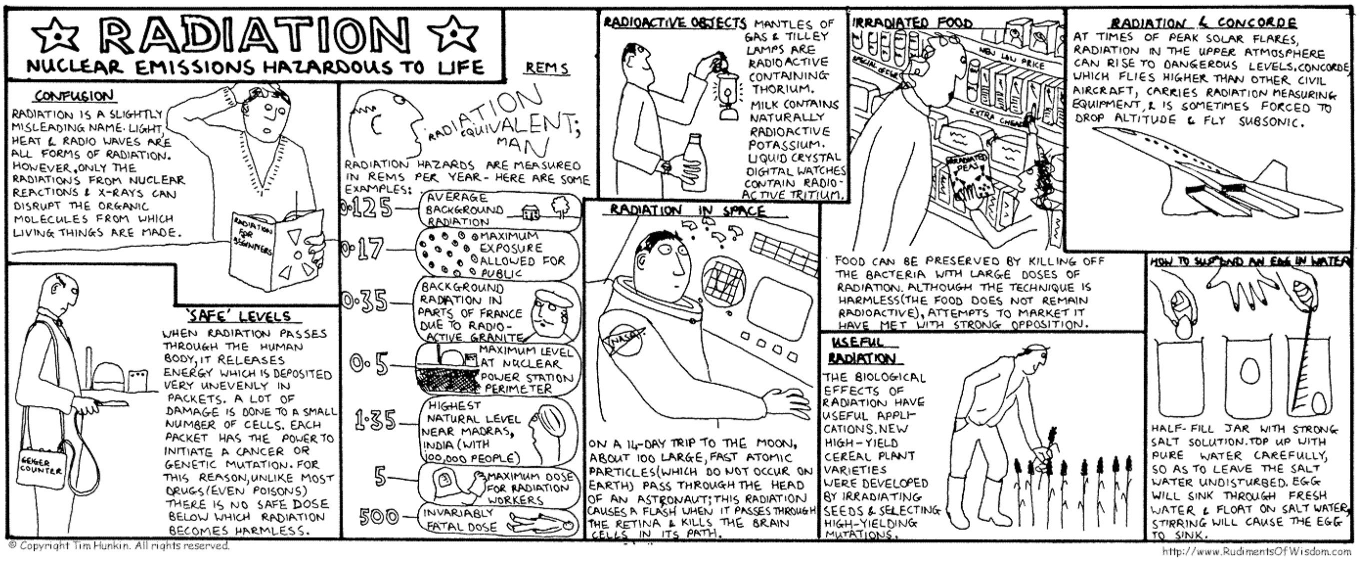


6. Cracks in castings

A gamma source is placed in a metal casting and a Geiger counter moved over its surface. If there are any cracks in the metal gamma radiation can get through and be detected.

7. Sterilisation of food

Bacteria in food can be killed if exposed to gamma radiation.



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