



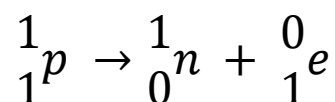
Production and use of PET radioisotopes

Teacher resource

Positron Emission Tomography (PET) Scans

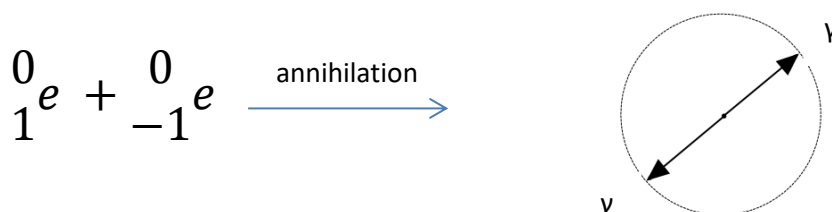
PET scans are very useful diagnostic scans and are obtained through the use of neutron deficient (see Note 1) radioisotopes. These radioisotopes can decay by three different modes (see Note 2) but the one of interest here is **positron emission**. A positron is also called a **positive beta** (β^+) or an **anti-electron**.

A positron is emitted when a proton in the nucleus decays according to the equation:



Proton \rightarrow neutron + electron

A positron is the anti-particle of an electron and therefore it is **antimatter**. When a positron collides with an electron a very short lived particle called a **positronium** is formed which then undergoes **annihilation**. In annihilation two gamma (γ) emissions of equal energy (511 keV) are produced and they travel in opposite directions. The two gamma emissions are called a **coincident pair** and each pair is detected by a circle of detectors or PET cameras.



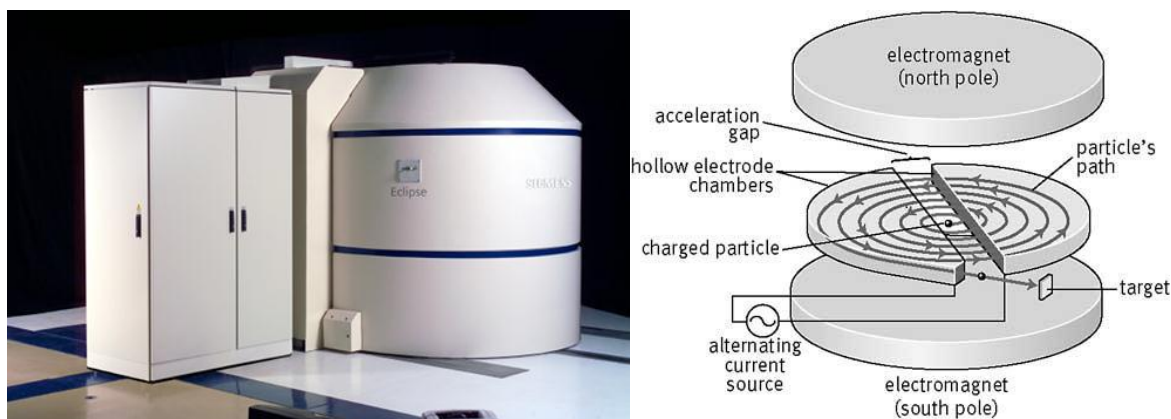
In a PET scan the patient is given a dose of medicine containing a positron emitting neutron deficient isotope. The resultant coincident pairs of gammas from the annihilation are detected by PET cameras. The cameras are arranged in a ring through which the patient is moved. From this process a series of 'slice' images are obtained and these can then be combined to give a 3-dimensional picture.



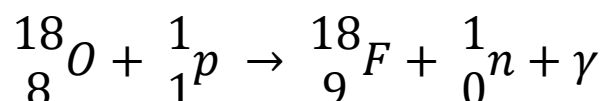
Carrying out a PET scan

Production of the PET radioisotope, Fluorine-18

PET radioisotopes are produced in **cyclotrons**. A cyclotron is a particle accelerator (see Note 3). It is an electrically powered machine which produces charged particles in an ion chamber in the centre of the machine. As the name suggests, a cyclotron accelerates the beam of charged particles in a spiral path. These particles are then focused onto a 'target' or starting material and the bombardment causes the production of the desired radioisotope.



An artificial radioisotope that is commonly used for PET scans is fluorine-18, F-18. It is made at the ANSTO site at Lucas Heights in two cyclotrons that started operation in August 2009. To produce F-18, water enriched with oxygen-18 is used as the target. Hydride ions, H⁻, are produced in the ion chamber and are accelerated. Just before the ions are focused onto the target, the hydride ions are passed through an electron stripper which forms protons. The protons then bombard the target to convert the O-18 to F-18 according to the following:

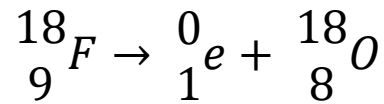


Use of Fluorine-18

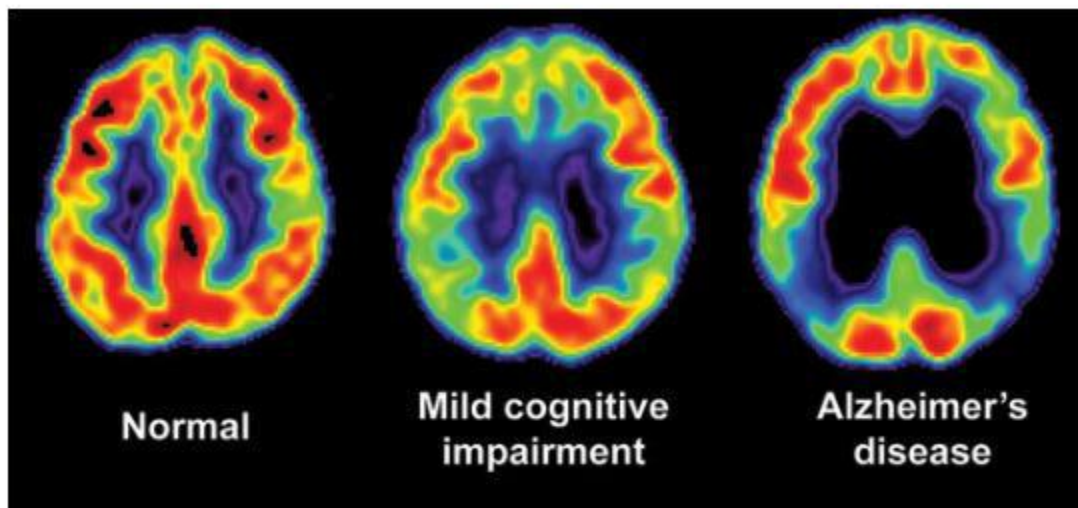
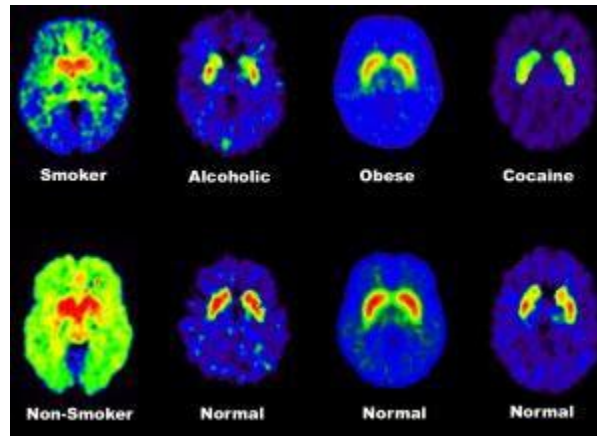
Most of the food we eat converts to glucose in our bodies. Glucose is metabolised in our cells to provide energy for biologic functions. A lot of energy is used in the brain and heart and in any other locations where there is activity so it is to these sites that glucose will be sent. When F-18 is prepared it is attached to a form of glucose called 2-deoxyglucose. This forms a **radiolabelled pharmaceutical** called 2-fluoro-2-deoxyglucose (FDG) and when given to a patient the body assumes it is glucose. The FDG is sent to the brain, heart and other active sites.

At the beginning of the PET scan procedure, the patient receives an injection of a small amount of FDG. The patient then sits quietly for about 60 minutes. During this time he/she must sit and relax and not get up and walk around, talk to friends, or read. This allows the tracer to travel throughout the body while it is in a relaxed state (see Note 4).

When the FDG arrives at the various parts of the body and is absorbed, the F-18 decays according to the equation:



The PET scan is performed and any abnormal glucose metabolism is imaged. The following scans are of the brain and show a variety of conditions in comparison to normal scans:



Advantages of this particular isotope include:

- no γ emission occurs when the positron is first emitted; this means that radiation exposure to the patient is minimised;
- the product of decay is oxygen and therefore there is no toxicity problem;
- the average energy of the emitted positron is quite low (249 keV) and therefore does not travel far before it annihilates leading to very good resolution in the scan images
- F-18 has quite a short half-life ($t_{1/2} = <110$ minutes) meaning the patient's radiation exposure is limited

The short half-life can also be regarded as a disadvantage as it causes some logistical challenges in supplying the radioisotope to facilities located at large distances from the place of production.