Positron Emission Tomography

Contents

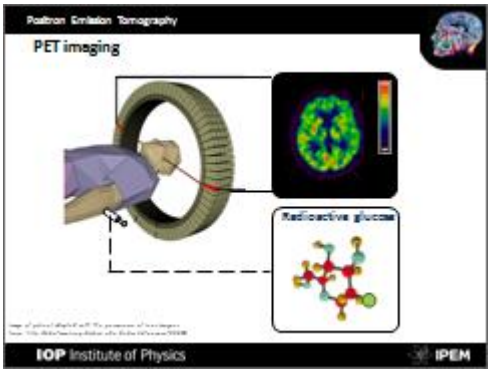
Curriculum links:

- Stable and unstable isotopes
- Beta decay

Introduction

Positron emission tomography (PET) is a gamma imaging technique that uses radiotracers that emit positrons, the antimatter counterparts of electrons. In PET the gamma rays used for imaging are produced when a positron meets an electron inside the patient's body, an encounter that annihilates both electron and positron and produces two gamma rays travelling in opposite directions. By mapping gamma rays that arrive at the same time the PET system is able to produce an image with high spatial resolution. Another advantage of PET over procedures that employ gamma emitting tracers is the greater availability of suitable isotopes. Positron emitting isotopes of biologically active elements such as fluorine, carbon and oxygen are all available. Fluorine-18 in particular, can be used to make a radioactive analogue of glucose which is preferentially taken up by brain and cancer cells making an ideal tool for detecting tumours. PET can also be used to map brain function and the diagnosis of conditions such as Alzheimer's disease.

Lesson notes

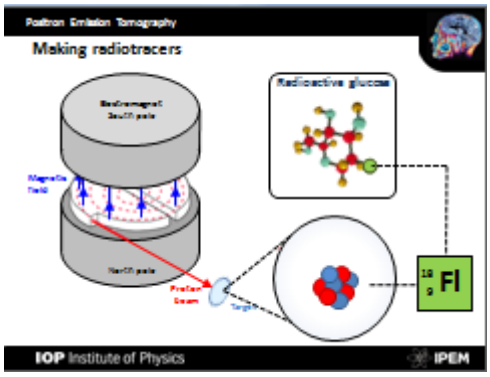


PET imaging

PET imaging carried out by injecting patient with a tracer that produces gamma rays (indirectly).

Gamma rays detected using ring of detectors around patient. Signal from detectors used by computer to build a functional image of organs such as the brain.

Positron Emission Tomography

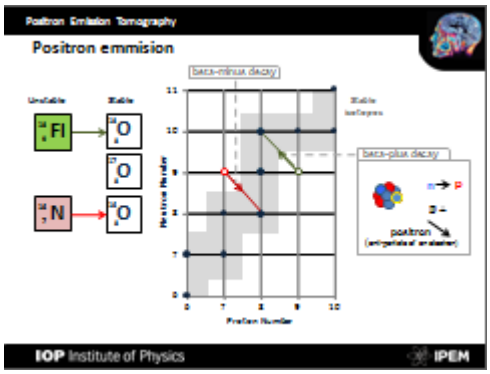


Making radiotracers

The radiotracer fluorine-18 is made using a particle accelerator (cyclotron).

- **CLICK**: *production of fluorine-18 by proton bombardment of oxygen-18 (in heavy water).*

Protons must be accelerated to very high speed in order to overcome repulsion of positively charged target nuclei. Fluorine-18 can be used to make radioactive glucose, which is preferentially taken up by brain and cancer cells.



Positron emission

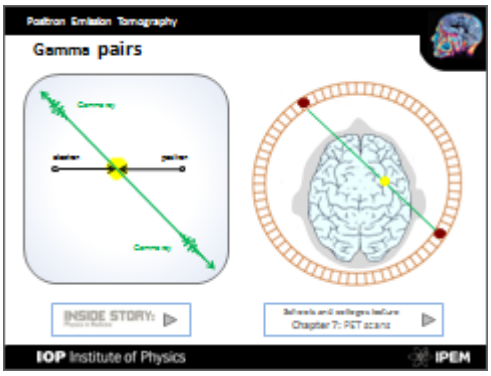
Isotopes are atoms/nuclei with same number of protons but different number of neutrons.

- **CLICK**: *examples of unstable isotopes, and beta-plus decay*

Unstable (light) nuclei have either too many protons or too many neutrons to be stable.

Neutron-rich Isotopes undergo beta -minus decay; neutron changes to a proton inside the nucleus and a negatively charged electron emitted.

Proton-rich Isotopes can undergo beta-plus decay; proton changes to a neutron inside the nucleus and positively charged antimatter counterpart of electron (positron) emitted.



Gamma pairs

After being emitted positron slows down (after travelling about 1 mm) and interacts with an electron inside patient's body. Annihilation of electron and positron produces two gamma rays.

- **CLICK**: *electron-positron annihilation and detection of resulting gamma rays*

PET offers detailed imaging because:

- Gamma rays that do not arrive in pairs are ignored
- Computer works out position of source by "drawing lines" between gamma rays that arrive at the same time (within nanoseconds of each other).

Gamma rays produced must travel in opposite directions to conserve momentum (both electron and positron have negligible momentum before annihilation)

- **Chapter 7**: *launch chapter 7 of schools lecture on PET*
- **Inside story**: *launch interactive; investigate PET brain scans*

Worksheet mark-scheme

1.

(a) (nuclides with) same number of protons, but different number of neutrons ✓

(b) (can used to make radioactive) glucose/FDG ✓

(c) fluorine-19 is stable/does not emit radiation/is not radioactive ✓

fluorine-20 is neutron-rich/ will undergo beta-minus decay/emits electrons ✓

2.

(a) (because target nucleus) has a positive charge/repels proton ✓

(b) using a voltage/electric field/in a cyclotron/particle accelerator ✓

(c) alpha particle/helium (nucleus) ✓

3.

(a) B ✓

(b) annihilation/when positron meets electron ✓

(c) to conserve momentum/so that total momentum is zero
(*accept*: so momentum cancels out) ✓

TOTAL: 10 Marks