MEDICAL PHYSICS

6-1 Radionuclide imaging

1\. (a) (i) The 'biological half-life' is the time it takes for half of a substance to be removed from the body.

(ii) T_p = 8.0 h, T_b = 24 h

$$\frac{1}{T_{eff}} = \frac{1}{T_b} + \frac{1}{T_p} = \frac{1}{24} + \frac{1}{8.0} = 0.04166... + 0.125 \quad = 0.1666.....h^{-1}$$

T_{eff} = 6.0 h or 6.0 hours

2\. ${}^{99}_{43}\mathrm{Tc}^{m}$ has $t_{1/2}$ = 6.0 hours

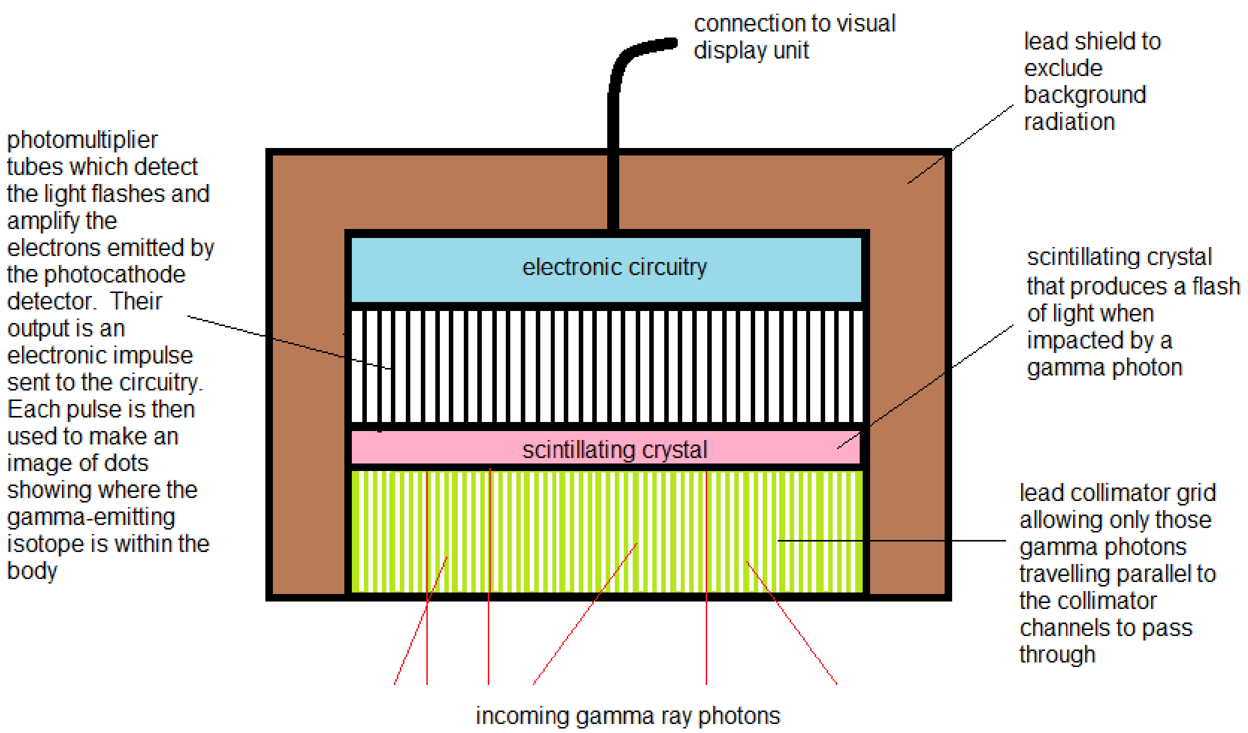
(a) In radioactive decay, the nucleus produced by alpha, beta-minus or beta-plus decay is often excited. In most cases the excess energy is released very soon afterwards as gamma rays. In some cases like the decay of molybdenum-99 to produce technetium-99, there is a significant delay in the production of the gamma rays. The metastable state is the one formed after the beta-minus emission. E.g.

$${}^{99}_{42}\mathrm{Mo} \rightarrow {}^{99}_{43}\mathrm{Tc}^{m} + {}^{0}_{-1}\mathrm{e} + \bar{\nu} \quad \text{(half-life 66 hours)}$$

$${}^{99}_{43}\mathrm{Tc}^{m} \rightarrow {}^{99}_{43}\mathrm{Tc} + \gamma \quad \text{(half-life 6 hours)}$$

(b) The half-life of the molybdenum needs to be significantly longer than that of the technetium-99m so that it can be transported to the hospital where it will produce the technetium 99m.

3\. (a)



(b) $^{111}_{49}\mathrm{In}$ has $t_{1/2}$ = 67 hours, decays through electron capture:

$$^{111}_{49}\mathrm{In} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{111}_{48}\mathrm{Cd} + \nu + \gamma \text{ (stable product)}$$

$^{110}_{49}\mathrm{In}$ has $t_{1/2}$ = 65 minutes, decays through positron emission and γ emission to give $^{109}_{48}\mathrm{Cd}$ (radioactive)

$$^{110}_{49}\mathrm{In} \rightarrow {}^{109}_{48}\mathrm{Cd} + {}^{0}_{+1}\mathrm{e} + \gamma \text{ (product is radioactive)}$$

$^{109}_{48}\mathrm{Cd}$ has $t_{1/2}$ = 330 days, decays through positron emission and γ emission to give $^{109}_{48}\mathrm{Cd}$

$$^{109}_{48}\mathrm{Cd} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{109}_{47}\mathrm{Ag} + \gamma$$

- The radioactive isotope for use needs to be a gamma emitter so that it can be detected outside the body. Although $^{110}_{49}\mathrm{In}$ produces gamma radiation in the second decay, the first emits beta+ radiation which is undesirable because it is not easy to detect outside the body and would cause unnecessary radiation exposure.
- $^{110}_{49}\mathrm{In}$ is also not suitable because the first product of decay is not a stable isotope.
- $^{110}_{49}\mathrm{In}$ is also not suitable because the half-life of the gamma emitting stage is too long. Making the necessary measurements would require too long a time-scale and would expose the body to unnecessary levels of radiation. (330 years for the half-life is also longer than someone's life expectancy).

4. (a)

PET scanner	**CT X-ray scanner**
Suitable radioactive substance introduced to organ/body structure to be investigated	Radiation sent into the body to be scattered and/or absorbed
Resolution is poorer than a CT X-ray scanner	Resolution is better than a CT X-ray scanner
Show where the radioisotope is used	Not as good at showing where the radioisotope is used

(b) $^{18}_{9}\mathrm{F}$ emits positrons and has a half-life of 110 minutes

$$^{18}_{9}\mathrm{F} \rightarrow {}^{18}_{8}\mathrm{O} + {}^{0}_{+1}\mathrm{e}\ (+\gamma)$$

The emission of the positron may be accompanied by the emission of gamma photons if the daughter nucleus produced after positron emission is be excited. The excited nucleus would then emit its excess energy as gamma photon(s).

$^{18}_{9}\mathrm{F}$ is used in PET scans. The $^{18}_{9}\mathrm{F}$ is in a drink given to the patient. The patient lies in a ring of detectors connected to a computer.

When a positron is emitted, it annihilates with an electron inside 1mm of travel. The annihilation produces 2 gamma ray photons travelling in opposite directions:

$$^{0}_{+1}\mathrm{e} + {}^{0}_{-1}\mathrm{e} \rightarrow 2\gamma$$

The detectors register the positron emission when two opposite detectors detect a gamma photon at the same time. As the gamma photons are created simultaneously and travel at the same speed in opposite directions, the position of the emission must be midway between the two detectors. The computer is programmed with the information about the positions of the detectors and uses the detection information to map where the positron emissions occur. This will give the location of the positron-emitting fluorine within the body.