CHAPTER 20

Radioactivity as a diagnostic tool

Answers to revision questions

1. See Chapter 20.

2. (a) and (b)

   (i) Beta (minus): $^{40}_{19}K \rightarrow {}^{40}_{20}Ca + {}^{0}_{-1}e$

   (ii) Alpha: $^{232}_{90}Th \rightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$

   (iii) Alpha: $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

   (iv) Beta (minus): $^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$

   (v) Beta (plus): $^{13}_{7}N \rightarrow {}^{13}_{6}C + {}^{0}_{+1}e$

3. $^{59m}_{26}Fe \rightarrow {}^{59}_{26}Fe + \gamma$

4. (a) $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{31}_{15}P$

   (b) $^{31}_{15}P \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$

5. $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$

6. (a) 39.8 minutes will elapse over two half-lives, therefore:

$$\text{The remaining activity} = 5.84 \times 10^4 \times (\frac{1}{2})^2$$
$$= 1.46 \times 10^4 \text{ Bq}$$

   (b) Two hours – that is, 120 minutes – will elapse over 6.03 half-lives, therefore:

$$\text{The remaining activity} = 5.84 \times 10^4 \times (\frac{1}{2})^{6.03}$$
$$= 8.93 \times 10^2 \text{ Bq}$$

7. First, technetium-99m is a pure gamma emitter. Gamma rays are penetrative enough to pass through the body to reach the detector. Also gamma rays cause the least amount of ionisation compared to both alpha and beta radiations when inside the body, and therefore are relatively safer for injection into the patient. Second, technetium-99m has a short half-life of six hours. A half-life of six hours means that the amount of the injected technetium-99m will be almost non-detectable after about a day.

8. (a) Technetium-99m atoms by themselves will not be taken up by the bones as they will be recognised by the bones as foreign elements. However, bones selectively accumulate (poly)phosphate ions as part their mineralisation process. When technetium-99m atoms are attached to the polyphosphate molecules, they will then be transported to and accumulate in the bones.

   (b) Bones will increase their uptake of technetium-99m labelled polyphosphate molecules when they become more metabolically active. This may happen for many different reasons, including fractures, infections or tumour deposits.

(c) The radiation (gamma rays) emitted can be detected outside the body by using a gamma camera, which is a modified version of a scintillation counter. The gamma camera converts the radiation into flashes of light, which in turn generate electric signals. These signals are used for image formation.

(d) A bone scan can be used to diagnose occult fractures and osteomyelitis and detect the presence of metastasis.

(e) Bone scans can detect fractures that are not shown on plain X-ray films.

9. A thyroid scan is best used to diagnose functional thyroid diseases, whether due to overactivity (hyperthyroidism) or underactivity (hypothyroidism).

10. When positrons collide with electrons, it results in a total annihilation of the mass of the positrons and the electrons and the annihilated masses are converted into energy in the form of paired gamma rays, governed by the equation $E = mc^2$. The pair of gamma rays travel away from each other perpendicular to the initial direction of the motion of the positron and electron.

11. See Chapter 20.

12. Diseases such as epilepsy or Alzheimer's disease might have no associated change or just minimal change in the structure of the brain. This makes their detection difficult using CT scans. PET scans are able to detect the abnormal functional status of the brain associated with these diseases, hence allowing diagnosis.

13. Metastatic cancer may be difficult to see using CT scans, because metastases may be small and embedded in the healthy tissues. However, the cancerous tissues often up-regulate their glucose transporters as a mechanism to increase their nutritional uptake to sustain their rapid growth; consequently, the uptake of FDG will be increased, which allows the cancer tissues to be displayed as 'hot' spots on PET images. This makes their detection easier and more accurate.

14. The main limitations of using radioisotopes scans, in particular PET scans, are:
- possible side effects due to the use of ionising radiation
- poor resolution
- lack of structural detail of the target organ
- cost
- limited availability (especially for PET scans).