Access Tuition

A-Level Physics

Radionuclide Imaging

Mark Scheme

Time available: 70 minutes
Marks available: 40 marks

Mark schemes

1. (a) Half-life of 6 hours ✓

Condone several hours

*Do **NOT** allow couple / few hours*

Long enough to allow scan to take place ✓

Short enough not to expose the patient to excessive radiation / patient is not left with an active source for too long ✓

Too short to keep stored / transport with enough activity / enough undecayed nuclei to be useful ✓

4

(b) Other radiation causes damage to tissue without being detectable ✓

Pass through the body (tissue) so that it can be detected (outside) ✓

Least ionising so that it causes least damage to tissue ✓

Reference to least ionising without reason not enough

Energy / frequency of gamma is similar to medical X-rays so that an X-ray camera can be used for detection ✓

4

(c) Photocathode emits an electron ✓

Electrons accelerated to (positive) dynodes ✓

Each electron collides with dynode to releases more (4) electrons✓

*Do **NOT** allow suggestion that 1 photon leads to the release of more than 1 electron at photocathode*

3

(d) Calculation of effective half life or justification for ignoring biological half-life ✓

Calculation of decay constant ✓

Substitution or rearrangement of $A = A_0 e^{-\lambda t}$ ✓

Ecf available for incorrect calculation of effective half-life or use of one of the half-lives and for decay constant.

eg $T_E = (8.0^{-1} + 66^{-1})^{-1} = 7.1$

$\lambda = \frac{\ln 2}{7.1} = 0.097$ *days*$^{-1}$ $(1.12 \times 10^{-6}\ s^{-1})$

$T = -\frac{\ln\left(\frac{1100}{3200}\right)}{0.097} = 11$ *days* $(9.50 \times 10^{5}\ s)$

or $A = 3.2e^{-0.097 \times 10} = 1.2$ *GBq*

Ignoring biological half life gives

$\lambda = \frac{\ln 2}{7.1} = 0.0867$ *days*$^{-1}$ $(1.00 \times 10^{-6}\ s^{-1})$

$T = -\frac{\ln\left(\frac{1100}{3200}\right)}{0.097} = 12$ *days* $(1.04 \times 10^{6}\ s)$

or $A = 3.2e^{-0.0867 \times 10} = 1.3$ *GBq*

Conclusion consistent with calculation based on effective half-life ✓

Condone conclusion based on physical half-life

4

[15]

2. Correct identification of all three
A: CT scanner, B: MR scanner, C: Ultrasound scanner ✓

A: good picture of bone / bright picture of bone / lacking detail on soft tissue (eg eyes, brain) ✓

B: highest resolution / good (detailed/bright) image of soft tissue (eg eyes, brain) / dim picture of bone ✓

C: low resolution / image shows external boundaries (eg uterus) / lack of detail inside skull ✓

Allow CAT for CT and MRI for MR

[4]

3. (a) Material with nuclei which are unstable / will decay / emits ionising / radiation. ✓

At least two of the descriptors

1

(b) Calc with answer showing T_E = 68.98 or 69 ✓

$$\frac{1}{T_E} = \frac{1}{110} + \frac{1}{185}$$

1

(c) Mention of time between 10 to 70 minutes with reference to effective half life / time for a scan ✓

and to allow the **<u>blood</u>** to carry the isotope around the body ✓

and to allow the isotope to be taken in by the body part to be investigated ✓

3

(d) Positron (collides with an) electron and results in annihilation ✓

All the mass of positron and electron is converted to energy in gamma photons ✓

Must be two photons travelling in opposite directions to conserve momentum ✓

MAX 2

(e) Use of 0.18 to 0.2 m and 3×10^8 m/s for speed of em waves through the head to get a time between 0.6 and 0.7×10^{-9} s for time to travel across head ✓

then explanation of difference in trig times from a minimum of 0 s at centre of head to a maximum of their calculated answer at edge of head. ✓

2

[9]

4. **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.**

Mark	Criteria	QoWC
6	All three aspects covered: An comparison of patient safety in terms of ionising radiation exposure. An appreciation of convenience in terms of pre treatment, scan time, patient movement and discomfort. There may also be a discussion of comparative cost and equipment partability. A discussion of the types of information available in terms of uses and limitations.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
5	Two of the three aspects fully covered, with some detail missing from the third.	
4	One aspect fully covered, with some detail missing from the other two Or Two aspects fully covered, with little or no relevant information about the third.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
3	All three aspects partially covered, with some detail missing from each Or One aspect fully covered, with little or no relevant information about the other two	
2	Two aspects partially covered, with little or no relevant information about the third.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g

1	One aspect partially covered, with little or no relevant information about the other two.	allow meaning to be derived although errors are sometimes obstructive.
0	Little or no relevant information about any of the three aspects.	The student's presentation, spelling punctuation and grammar seriously obstruct understanding.

The following comparisons are likely to be present:

		PET	u / s
Patient Safety	*Ionising radiation exposure*	*Mod to high*	*None (no tracer)*
Convenience	*Scan time*	*2-4 h*	*10 -15 min*
	equipment	*Large, bulky*	*portable*
	cost	*expensive*	*relatively cheap*
	Pre-treatment	*Needs tracer injection*	*No injection*
	Patient movement	*Must lie still*	*Movement tolerated*
	discomfort	*Not good if claustrophobic*	*Requires cold gel*
Information		*Chemical and physiological changes related to metabolism*	*Size position movement (of foetus, organs etc.)*
		Useful for detecting brain activity	*Cannot penetrate bone – cannot examine brain*
			Good for imaging soft tissues
			Cannot pass through air spaces / lungs

		Can provide info re malignancy and tumour spreading	*Cannot distinguish between benign and malignant solid masses*

[6]

5. (a) Gamma photon travels through collimator grid, E, ensuring that the point of emission of the gamma photon is directly below the point where the photon interacts with the scintillation crystal, D. ✓

Gamma photon is converted to many light photons in scintillation event in crystal. ✓

The light photons produced travel to photomultiplier tubes, C, where signal is produced and amplified. ✓

The amplified signals are passed to processing unit, B, which compares the strengths of the signals, deduces the position of the scintillation and displays this on a screen. ✓

The lead shield, A, protects the crystal and photomultipliers from random background signals. ✓

Any 4 relevant points.

Allow marks to be awarded for clear labelled diagram.

MAX 4

(b) Image in diagnostic X-ray is a shadow photograph. ✓

Image produced by gamma camera is image of actual emission points which can be used to monitor rapidly changing situations. ✓

2

[6]