InkPhysics

QUESTION WORKBOOK

Radionuclide imaging and PET

Medical physics · Year 13

AQA 3.10.6.1, 3.10.6.2, 3.10.6.3, 3.10.6.4, 3.10.6.5, 3.10.6.6
CIE 24.3.1, 24.3.2, 24.3.3, 24.3.4, 24.3.5, 24.3.6
OCR A 6.5.2(a), 6.5.2(b), 6.5.2(c), 6.5.2(d), 6.5.2(e)

18 questions · 49 marks

PRINT EDITION

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SECTION A · Warm-up

A1 State what is meant by a medical tracer. [2]

A2 Explain why a tracer used with a gamma camera should be a gamma emitter, and why its half-life must be chosen with care. [3]

A3 An X-ray image and a tracer image answer different questions about a patient. State the difference. [2]

A4 Technetium-99m has a half-life of 6.0 hours, so a dose made at a distant factory would decay before reaching the hospital. Explain how hospitals nevertheless have technetium-99m available every morning. [2]

A5 In PET scanning for tumours, the positron emitter fluorine-18 is attached to a glucose analogue. Suggest why a glucose analogue is a good choice of carrier molecule. [2]

SECTION B · Standard

B1 Describe the roles of the collimator and the scintillator crystal in a gamma camera. [3]

B2 Technetium-99m has a half-life of 6.0 hours. Calculate the fraction of a dose's activity remaining 24 hours after preparation. [3]

B3 Describe what happens when a positron emitted by a PET tracer meets an electron, and state the energy of each photon produced. [3]

B4 Show that the rest energy of an electron is about 8×10^{-14} J, and convert it to keV. [3]

B5 Explain why the two annihilation photons travel in opposite directions. [2]

B6 A tracer has a physical half-life of 6.0 hours and is also cleared from the body biologically with a half-life of 12 hours. Calculate the effective half-life of the dose, and explain why it is shorter than either value alone. [3]

B7 Iodine-131 is given to a patient to destroy overactive thyroid tissue. Explain how this treatment uses the same principle as a medical tracer, and how its aim differs from imaging. [3]

SECTION C · Stretch

C1 Explain how a PET scanner uses coincidence detection to locate the tracer. [4]

C2 Calculate the frequency of a 511 keV annihilation photon. [2]

C3 Fluorine-18, used in PET, has a half-life of 110 minutes. A hospital needs at least one eighth of the delivered activity remaining at scan time. Calculate the maximum delay between delivery and scanning. [2]

C4 A patient asks whether a PET scan means being irradiated by the machine. Explain what the scanner actually does, and where the dose really comes from. [3]

C5 A PET detector ring has a radius of 40 cm. An annihilation occurs 4.5 cm from the centre of the ring, on the line joining two opposite detectors. Calculate the difference in the arrival times of the two photons at the detectors ($c = 3.00 \times 10^8$ m s^{-1}), and comment on what this means for the scanner's timing electronics. [3]

C6 Three radionuclides are available for a kidney investigation in which imaging ends 30 minutes after the tracer is administered. Nuclide P emits beta minus particles and has a half-life of 8.0 days. Nuclide Q emits gamma photons and has a half-life of 6.0 hours. Nuclide R emits gamma photons and has a half-life of 90 s. Deduce which nuclide should be chosen, giving a reason for rejecting each of the other two. [4]