24.3 PET scanning

Name: ____________ Class: ________ Date: __________ **Total: 13 marks**

KEY WORDS positron 正电子 • tracer 示踪剂 • antiparticle 反粒子 • photon 光子 • momentum 动量

Objective

Build the skills to answer exam questions on **PET scanning**.

You must be able to:

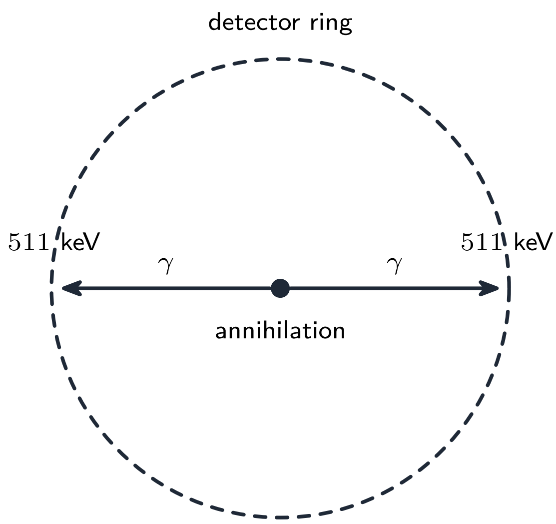
- explain the **tracer** and **annihilation**
- calculate the **annihilation photon energy**
- explain how the photons locate the event

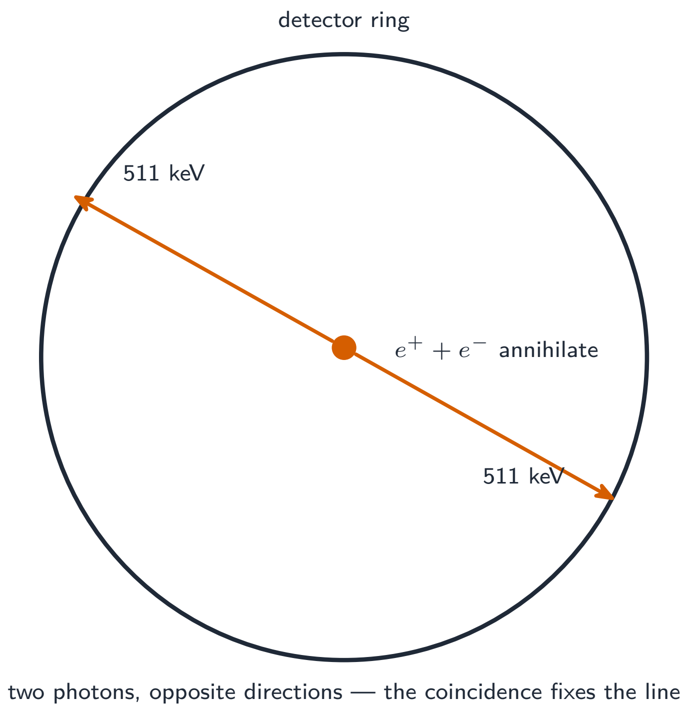
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Tracer and annihilation

A **tracer** is a radioactive substance put into the body and taken up by the tissue studied. In **PET** it is a β^+ **(positron) emitter**. The positron meets an **electron** and they **annihilate**:





PET detects annihilation photons

Mass-energy and **momentum** are conserved. Since the total momentum is ~zero, **two** γ photons go in **opposite directions**, each of energy $m_e c^2 = 511$ keV.

Detecting **both** photons (and their arrival times) lets the scanner work out the **line** they came from, building an image of tracer concentration.

2 Practice

Now apply the methods above.

2.1 State what a **tracer** is. [1]

2.2 State the type of **decay** a PET tracer undergoes. [1]

2.3 Explain what **annihilation** is. [2]

2.4 State the **energy** of each annihilation photon. [1]

3 Exam-style questions

3.1 In PET, the two γ photons from an annihilation travel: [1]

- **A** in the same direction
- **B** in opposite directions
- **C** at right angles
- **D** in random directions

3.2 Calculate the **energy** of each γ photon produced when an electron and positron annihilate. ($m_e = 9.11 \times 10^{-31}$ kg.) [3]

3.3 Explain why **two** photons are produced (not one), travelling in opposite directions. [2]

3.4 Explain how detecting the two photons helps locate the **annihilation** event. [2]

Solutions

2.1 A substance containing **radioactive nuclei** introduced into the body and **taken up** by the tissue being studied.

2.2 β^+ **(positron)** decay.

2.3 When a particle meets its **antiparticle**, they are destroyed and their **mass becomes energy** (electromagnetic radiation).

2.4 511 keV ($= m_e c^2$).

3.1 **B** — in opposite directions.

3.2 Total rest energy $= 2m_e c^2$, shared by two photons, so each $E = m_e c^2 = (9.11 \times 10^{-31})(3.0 \times 10^8)^2 = 8.2 \times 10^{-14}$ J ($=$ 511 keV).

3.3 Momentum must be **conserved**; the pair's total momentum is ~zero, so the photons must go in **opposite directions** with equal momentum (a single photon could not conserve momentum).

3.4 Both photons are detected (almost simultaneously) on **opposite sides** of the ring; the annihilation lies on the **straight line** joining the two detectors — combining many such lines builds the image.