1. (a) Identify the number of neutrons in a nucleus of polonium-210 $\left({}^{210}_{84}\mathrm{Po}\right)$.

Tick (✓) **one** box.

84 ☐

126 ☐

210 ☐

294 ☐

(1)

(b) A polonium-210 nucleus is formed when a stationary nucleus of bismuth-210 decays. A beta-minus (β^-) particle is emitted in this decay.

Outline, with reference to β^- decay, why bismuth-210 and polonium-210 have different proton numbers.

_____

_____

_____

_____

_____

_____

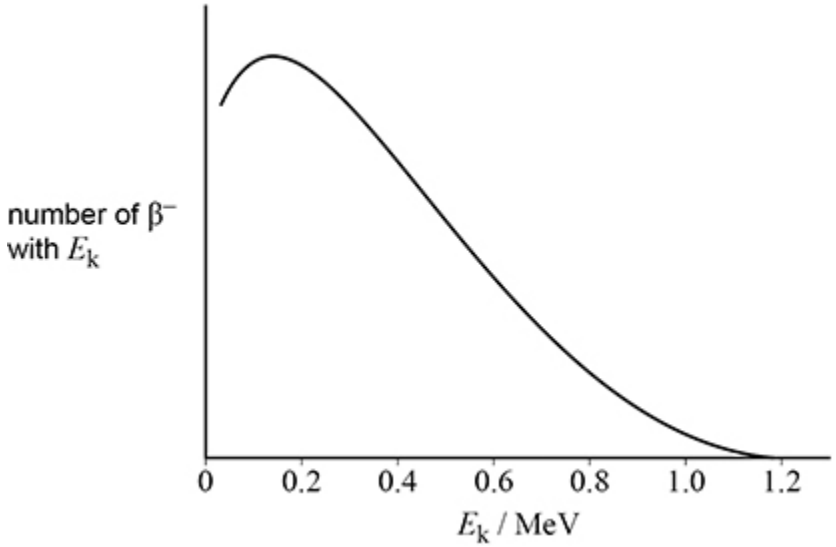
(2)

The kinetic energies of β^- particles emitted from a sample of bismuth-210 are analysed. These β^- particles have a range of kinetic energies.

The total energy released when each nucleus of bismuth-210 decays to a nucleus of polonium-210 is 1.2 MeV.

Figure 1 shows the variation with E_k of the number of β^- particles that have the kinetic energy E_k.

Figure 1



(c) Explain how the data in **Figure 1** support the hypothesis that a third particle is produced during β^- decay.

(2)

(d) This third particle is an electron antineutrino.

Explain why an electron antineutrino, rather than an electron neutrino, is produced during β^- decay.

_____

_____

_____

_____

_____

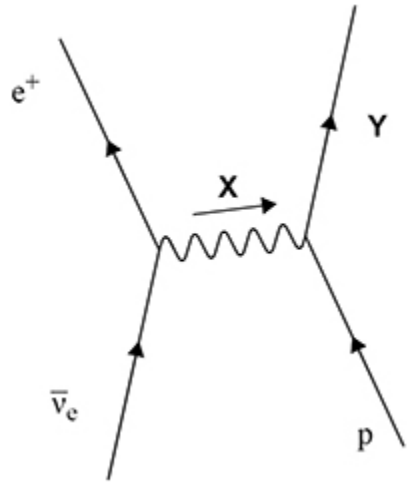
_____

(2)

(e) A large tank of water is used as part of an electron antineutrino detector. An electron antineutrino $\bar{\nu}_e$ enters the tank and interacts with a proton (p).

Figure 2 represents this interaction.

Figure 2



Identify **X** and **Y**.

X = _____

Y = _____

(2)

(f) The positron produced in the interaction in **Figure 2** slows down and collides with a lepton in a molecule of water.

Describe the process that occurs when the positron collides with this lepton. In your answer you should identify the lepton in the molecule of water.

(3)

(g) The range of the electromagnetic interaction is infinite.
The table below gives the range of the strong nuclear interaction and the range of the weak nuclear interaction.

Interaction	Range / m
strong nuclear	10^{-15}
weak nuclear	10^{-18}

Deduce whether the positron or the electron antineutrino is likely to travel the shorter distance in the tank of water before interacting.

(3)

(Total 15 marks)

5. A muon and an antimuon annihilate to produce the minimum number of photons.

What is the maximum wavelength of the photons?

A 5.9×10^{-15} m ⬭

B 1.2×10^{-14} m ⬭

C 5.9×10^{-9} m ⬭

D 1.2×10^{-8} m ⬭

(Total 1 mark)

6. Which row describes the nature of the strong nuclear force between two nucleons at separations of 0.25 fm, 2.0 fm and 8.0 fm?

	At a separation of 0.25 fm	**At a separation of 2.0 fm**	**At a separation of 8.0 fm**	
A	attractive	repulsive	negligible	⬭
B	repulsive	attractive	attractive	⬭
C	negligible	repulsive	attractive	⬭
D	repulsive	attractive	negligible	⬭

(Total 1 mark)

7. What are the products when a free neutron decays?

A $p + e^- + \nu_e$ ⬭

B $p + e^+ + \bar{\nu}_e$ ⬭

C $p + e^- + \bar{\nu}_e$ ⬭

D $p + e^+ + \nu_e$ ⬭

(Total 1 mark)

21. (a) Determine whether the following reaction is a possible decay for the neutral pion π^0.

$$\pi^0 \rightarrow e^- + \mu^+ + \bar{\nu}_e$$

(2)

(b) State the **two** possible quark configurations of a π^0.

1. _____

2. _____

(1)

(c) A student suggests that the kaon K^0 and the anti-kaon $\overline{K^0}$ are the same particle.

Discuss whether this suggestion is correct.

(2)

(d) The nucleus is held together by a force. It was predicted that a particle exists that is responsible for this force. The particle itself must experience this force.

The particle would have a rest energy between that of an electron and half that of a nucleon.

Discuss whether a kaon, a muon and a pion **each** have the properties of the predicted particle.

Information about these three particles is in the Data and Formulae Booklet.

(4)

(Total 9 marks)

22. A deuterium nucleus and a tritium nucleus fuse together to produce a helium nucleus and particle **X**.

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathbf{X}$$

What is **X**?

A an electron ⬭

B a neutron ⬭

C a positron ⬭

D a proton ⬭

(Total 1 mark)