Mark schemes

1. (a) 126 ✓

1

(b) A neutron decays into a proton

Or

$n \rightarrow p + e^{(-)} + \bar{\nu}_e$ ✓

Allow a neutron changes to a proton. (owtte) Accept the decay equation of a neutron / bismuth

- *Statement that neutron converts to proton* ✓
- *all numbers correct and context* ✓

$^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e + ({}^{0}_{0}\bar{\nu}_e)$

Proton number **increases by one** when Bi-210 decays and describes beta minus

Condone missing (or incorrect) neutrino or symbol for bismuth

OR

Bi-210 has **one fewer proton** (than Po-210) and describes beta minus in words

OR

Po-210 has **one more proton** (than Bi-210) and describes beta minus in words

Or

Proton number **increases from 83 to 84** and describes beta minus in words ✓

Allow proton number increases where there is a clear statement that a neutron has decayed into a proton.

2

(c) (Missing) energy carried off by third particle

Or

(A third particle must be produced) for conservation of energy✓

Accept energy is converted into mass of third particle.

Where third particle is named must be a neutrino or an antineutrino.

There is missing energy (When) a beta (particle) has less than 1.2 MeV (of kinetic energy).

Or

The law of conservation of energy appears to be violated when beta (particle) has less than 1.2 MeV ✓

Identify there is difference between 1.2 MeV and E_k.

(d) (It must be an electron antineutrino to) conserve lepton number✓

An electron and (electron) antineutrino have lepton numbers of opposite signs.

Or

An electron and (electron) antineutrino have a (total) lepton number of zero. ✓

Alternative for 2nd Marking point:

Appropriate particle equation seen annotated with correct lepton numbers.

Alternative:

Producing an (electron) neutrino wouldn't conserve lepton number ✓

An electron and (electron) neutrino have lepton numbers of the same sign.

Or

An electron and (electron) neutrino have a (total) lepton number equal to 2. ✓

Alternative 2nd marking point:

Appropriate particle equation seen annotated with correct lepton numbers.

2

(e) (**X** =) W-minus (boson) / W^- (boson) ✓

(**Y** =) neutron / n ✓

2

(f) Lepton (in the water molecule) is an electron ✓

Must state that lepton (in the water) is an electron for all 3 marks

and

Max 2 from

annihilation ✓

gamma photon**s** are produced ✓

Two (gamma) photons are produced (that travel) in opposite directions. ✓

Penalise answers that list other products in MP3 and MP4

3

(g) **Max 3**

The positron because:

positron is charged and the (electron) antineutrino ($\bar{\nu}_{(e)}$) is neutral ✓

The antineutrino only interacts via the weak interaction / The positron interacts via the electromagnetic interaction (and weak interaction)✓

The antineutrino's (weak) interaction is shorter range / the antineutrino is less likely to get close enough to interact (with particles in the water so will travel further) / the antineutrino will interact with fewer particles✓

The positron's (electromagnetic) interaction has a longer range / the positron does not have to be so close to interact (with particles in the water so will travel a shorter distance) / the positron will interact with more particles✓

Must have the correct conclusion for 3 marks.

3

[15]

2. A

−1.3 × 10⁷ C kg⁻¹

[1]

3. D

W^+

[1]

4. A

$\Lambda^0 + \pi^-$

[1]

5. B

1.2 × 10⁻¹⁴ m

[1]

6. D

repulsive attractive negligible

[1]

7. C

$p + e^- + \bar{\nu}_e$

[1]

8. C

using monochromatic light of higher frequency

[1]

Or

10^9 times smaller in number but more than 10^9 times smaller mass ✓
(Therefore) sample 2 must have a lower mean mass (than sample 1) ✓
Sample 2 has a greater percentage of **Y because Y** has less mass than X ✓

Mean mass of a nucleon sample 1=

1.8×10^{-26} kg

Mean mass of a nucleon sample 2 =

1.77×10^{-26} kg

Specific charge of sample 1 = 8.8×10^6 (C kg^{-1})

Specific charge of sample 2 = 9.0×10^6 (C kg^{-1})

Conclusion must be supported by at least one relevant, correct calculation

Condone one power of ten error in one calculation.

Accept converse statements.

Condone incorrect units

3

[10]

17. **A**

[1]

18. **C**

[1]

19. **B**

[1]

20. **D**

[1]

21. (a) Award each mark independently

Lepton number not conserved therefore not possible ✓

Lepton numbers for particles correct ✓

Any incorrect quantum number equation (for Q, B or S) loses MP2.

Eg 0 = 1 −1 −1 (for lepton number)

OR 0 = 0 −1 +0 (for muon lepton number)

Alternative for MP2

reference to missing muon neutrino in order to balance/conserve (muon) lepton number.

2

(b) up anti-up

AND

down anti-down ✓

Either order

Credit symbols

But do not condone any use of capital letter

1

(c) Identification of quarks in either neutral kaon correct, ie kaon d $\overline{s}$

OR anti-kaon $\overline{d}$ s ✓

Identification of quarks in other kaon correct, with statement that they are not the same. ✓

Alternative:

Kaon has strangeness +1 ✓

Anti-kaon has strangeness –1 and is therefore not the same. ✓

Allow max 1 if

- *quark configurations wrong way round.*
- *value of strangeness is wrong way round*
- *statement that strangeness is different without reference to value.*
- *strangeness and quarks given but one of them is incorrect.*

2

(d) Award each mark independently

Links hadrons to strong nuclear force (snf)

OR identifies snf as forcing holding nucleus together ✓

OR

(only) pion and muon have correct rest energy with no mention of kaon.

Reason why it cannot be the kaon ✓

For MP2: kaon rest energy is not between those of electron and half that of nucleon. (values quoted from data booklet)

Reason why it cannot be the muon ✓

For MP3: muon is a lepton (and does not experience snf)

pion is the particle as it (has mass in range and) is a hadron (and therefore experiences snf) ✓

An incorrect statement amount a particle negates the mark for that particle.

Rest energies/MeV:

kaon 493.821 or 497.762

pion 139.576 or 134.972

muon 105.659

nucleon 938.257 or 939.551

4

[9]

22. **B** **[1]**

23. **B** **[1]**

24. **B** **[1]**

25. **D** **[1]**

26. **A** **[1]**

27. **B** **[1]**

28. **C** **[1]**

29. **B**