Access Tuition

A-Level Physics

Particles

Mark Scheme

Time available: 74 minutes
Marks available: 52 marks

Mark schemes

1. (a) d quark changes to u quark ✓

1

(b) (Assume that energy released in decay is discrete) Distribution of (kinetic) energies of beta up to a max ✓
Suggests another particle must be released due to conservation of energy. ✓

Allow discussion in terms of conservation of momentum provided link to KE is made (eg reference to $p^2/2m$)

2

(c) neutron ✓

1

(d) Calculation of minimum energy produced in annihilation (from rest mass energy ×2)

= 2 × 0.51 MeV = 1.6×10^{-13} J ✓

2 photons produced so energy per photon = 8.0×10^{-14} J ✓

Only G3 has sufficient energy to have been made in annihilation. ✓

Allow 1 max if ×2 ignored both times.

3

[7]

2. (a) ${}^{4}_{2}\alpha$ ✓ + ${}^{234}_{90}\mathrm{Th}$ ✓

Either 1 mark each for alpha and Th

If no other mark is given, one mark can be awarded for A correct and/or Z correct.

Condone He for alpha

Ignore symbol for Thorium

2

(b) Idea that a proton changes to neutron/beta minus decay ✓

This is a weak interaction/involves the weak force

So particle is W^- to conserve charge. ✓

Evidence can be found in the form of equations or diagrams.

Second mark requires some explanation of why particle is negative.

2

(c) FOR

Lines A and C could be mistaken for hydrogen

OR Line E could be mistaken for sodium ✓

AGAINST

Line D has no counterpart in other spectra ✓

Treat references to B and F in FOR or AGAINST as neutral.

2

(d) Wavelength = 5.8×10^{-7} m ✓

Use of $E = hc$/wavelength

To give 3.46×10^{-19} J ✓

Conversion of their E in J to eV (= 2.1 eV) ✓

Allow 5.8 to 5.9

Allow 1 mark for demonstrating idea of which equation to use if no other mark awarded

3

(e) Reference to $\Delta E = hf$ and several discrete energy transitions ✓

Emission – as atoms/electrons decrease energy by ΔE, light of frequency f produced ✓

Absorption – as atoms/electrons increase energy by ΔE, light of frequency f removed (from spectrum) ✓

3

[12]

3. (a) 2 rows correct ✓

3 rows correct ✓✓

π^+	p	Σ^+	Y	
B	0	1	1	0
Q	+1	+1	+1	+1
S	0	0	−1	+1

2

(b) Tick 3rd box only - Σ^+ ✓

1

(c) **Y** has a greater rest energy than a pion / **Y** has greater mass than a pion ✓

Y is a kaon ✓

Pion has greater specific charge because it has the same charge as **Y** but less mass than **Y** ✓

Accept for mp2:

***Y** contains an s quark which is more massive than u or d quarks in the pion / Pion is 1st generation while **Y** is 2nd generation*

*Error carried forward for charge on **Y** from **(a)** **Y** will have a greater specific charge where **Y** has charge greater than +4*

3

[6]

4. (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.

2

(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 ✓

<u>gamma photon**s**</u> are produced ✓

<u>Two</u> (gamma) <u>photons</u> 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]

5. (a) MP1 is for evidence of determining the charge on the nucleus. ✓

Charge = $4.39 \times 10^{7} \times 8.02 \times 10^{-26}$ kg

(= 3.52×10^{-18} C)

MP2 is for evidence of determining either the number of protons OR the number of nucleons. ✓

Number of protons = charge/1.6×10^{-19} (= 22)

OR

Number of nucleons

= $8.02 \times 10^{-26} / 1.67 \times 10^{-27}$ (= 48)

MP3 is for determining number of neutrons. ✓

Number of neutrons = 48 – 22 = 26

Note use of 1.7 gives 27 neutrons and loses MP3

3

(b) Evidence of conversion of MeV to J ✓

Energy $= 2.15 \times 10^{8} \times 1.6 \times 10^{-19}$ *(*$= 3.44 \times 10^{-11}$ *J) - allow POT error in MP1*

Substitution into KE equation ✓

$v^2 = 2E/m = 8.58 \times 10^{14}$

Correct final answer ✓

$v = 2.9(3) \times 10^{7}\ m\ s^{-1}$

3

(c) $\pi^+ \rightarrow e^+ + v_e$
OR
charge: 1 = 1 + 0✓

B: 0 = 0 + 0
AND
L: 0 = –1 + 1✓
(S: 0 = 0 + 0)

2

(d) $(K^+ \rightarrow \mu^+ + v_\mu)$

Correct strangeness

+1 = 0 + 0 ✓

Weak interaction so strangeness can change (by 0, +1 or –1) ✓

2

(e) Decay consistent with Q B L conservation✓

Equation involving pions ✓

e.g.

$K^+ \rightarrow \pi^+ + \pi^+ + \pi^-$

$K^+ \rightarrow \pi^+ + \pi^0$

2

[12]