Unit 4 Topic 3 Particle physics

1 **(a)** Lots of energy needed **(1)** to produce the extra mass **(1)**

(b) Conservation of charge **(1)**
Conservation of lepton number **(1)**
Conservation of baryon number **(1)**

(c) They annihilate one another **(1)** giving rise to γ-ray/γ photon **(1)**
Energy of γ-ray
$= 2 \times 0.00055 \times 930$ MeV **(1)**
$= 1.0/1.02/1.023$ MeV **(1)**

(Total 9 marks)

2 **(a)** **(i)** n = udd and p = uud **(1)**
β^- and $\overline{\nu}$ have no quarks / are leptons / are fundamental **(1)**
(ii) $p \rightarrow n$ **(1)** + $\beta^+ + \nu$ [allow e^+] **(1)**

(b) Baryon and hadron **(1)**
Lepton **(1)**

(c) **(i)** Antiproton [or anti-up quark, anti-down quark] and positron **(1)**
(ii) $\overline{p} = -1$ and $e^+ = +1$ [accept correct $\overline{u}$, $\overline{d}$ charges for $\overline{p}$] **(1)**
$\overline{u}\,\overline{u}\,\overline{d}$ (e^+ fundamental / no quarks) [e.c.f. from **(b)**, credit if in **(i)**] **(1)**
(iii) Zero / neutral **(1)**
(iv) Annihilates **(2)** [on contact with matter / container / protons / H]
OR Not charged: not affected by magnetic fields **(2)**

(Total 12 marks)

3 **Charge on strange quark:**
$-1/3$ **(1)**

Conservation law:
Charge $-(-1) + (+1) \rightarrow (0)$ + X/by charge conservation **(1)**
X is neutral **(1)**

Meson or baryon:
Particle X is a meson **(1)**
Baryon number conservation $(0) + (+1) \rightarrow (+1) + (0)$ **(1)**
OR Discussion in terms of total number of $q + \overline{q} = 5$ OR $\Sigma q - \overline{q} = 3$

Composition of X
Is $s\overline{d}$ [0/3 if not $q\overline{q}$]**(1)**
Justify S quark: This is not a weak interaction/only a weak interaction can change quark type/this is a strong interaction/strangeness is conserved/ quark flavour cannot change **(1)**
Justify $\overline{d}$ quark: X neutral; $s - 1/3$; $\overline{d} + 1/3$. [e.c.f. if $s = -1/3$ in first line.]
For the third mark accept any $q\,\overline{q}$ pair that creates a meson of the charge deduced for X above. **(1)** [The justification for both q and $\overline{q}$ can be done also by tracking individual quarks]

Unit 4 Topic 3 Particle physics (cont.)

4 Similarity

Any 1 from:

- both nuclear decay products
- both charged/ionise/damage tissue
- both have momentum
- both deflected by electric fields
- by magnetic fields **(1)**

Differences

Any 2 from:

- β fundamental, α not
- mass $\alpha \gg$ mass β
- α positive, β either
- β a lepton, α composed of hadrons
- α is He^{2+}, β is e^+ or e^- **(2)**

[A difference must mention BOTH particles]

[If discussing spectrum shape needs 'given source' idea]

(Total 3 marks)

5 Meson or bayron:

Ω^- is a baryon [no mark]

p is a baryon/need to conserve baryon number **(1)**

Strangeness – 3 needs three quarks **(1)**

Composition

p is uud

Ω^- is sss

All Ks quark-antiquark pairs

K^- is $\bar{u}s$; K^+ is $u\bar{s}$; K^0 is $d\bar{s}$ [all correct, **4**]

(Total 6 marks)

6 Explanation:

Diffraction **(1)**

Molecular/atomic separation ≅1 nm/de Broglie wavelength **(1)**

Kinetic energy:

Use of $\lambda = h/mv$ **(1)**

Use of KE = $\frac{1}{2} mv^2$ OR $p^2/2m$ **(1)**

KE = 9.1–9.2 × 10^{-23} J [no e.c.f.] **(1)**

Wave–particle duality:

Quality of written communication **(1)**

When a wave/particle behaves like / has properties / has characteristics of a particle/wave **(1)**

Neutron is a particle in the (α) nucleus / it has momentum / mass / can collide **(1)**

Neutrons diffract/interfere, a wave-like property. **(1)**

(Total 9 marks)