PHYS 30121 NUCLEAR AND PARTICLE PHYSICS EXAMPLES 5

Question 1 asks you to determine the interactions responsible for different processes. Questions 2 and 6 are on the flavour quantum numbers of hadrons. Questions 3 to 5 are on processes involving particles beyond the first generation.

1. Indicate which of the following processes are allowed, and classify them as strong, electromagnetic or weak.

   (a) $K^- + p \to \Lambda + \pi^0$

   (b) $\nu_e + p \to p + \pi^+ + e^-$

   (c) $\gamma + p \to p + K^+ + K^-$

   (d) $\nu_e + p \to n + K^+ + K^- + e^+$

   (e) $p + \overline{p} \to \pi^+ + \pi^- + \pi^0$

   (f) $p \to \pi^0 + e^+$

   (g) $\Sigma^0 \to \Lambda + e^+ + e^-$

   (h) $\Xi^- \to \Lambda + \pi^-$

2. Identify the quark constituents of hadrons with the following values for the flavour quantum numbers (Q, B, S, C, $\tilde{B}$):
   (a) (+1, 0, 0, +1, 0), (b) (0, 0, −1, 0, +1), (c) (+2, +1, 0, 0, 0),
   (d) (+1, −1, +1, 0, 0), (e) (−1, +1, −1, 0, −1).
   Determine also the value of I_3 for each.

   For each of the particles (a)–(d), list its isospin partners and give the value of I for the resulting multiplet.

3. Muon and τ neutrinos can be distinguished from electron neutrinos by their interactions with electrons. Explain this by drawing the lowest-order Feynman diagrams for $\nu_e + e^-$ and $\nu_\mu + e^-$ scattering.

4. (a) The $N^+(1900)$ baryon is a nonstrange, charmless excited state of the proton. It has been observed to decay by the process

   $$N^+ \to K^0 + \Sigma^+.$$

   Draw a quark-level diagram for this.

   (b) Draw quark-level diagrams for the process

   $$\gamma + p \to K^0 + \Sigma^+,$$

   and for the subsequent decays,

   $$K^0 \to \pi^+ + \pi^-, \quad \text{and} \quad \Sigma^+ \to p + \pi^0.$$

5. Draw quark-level diagrams for the decays $D^0 \to K^- + \pi^+$ and $D^0 \to K^+ + \pi^-$. (The D^0 meson has charm $C = +1$ and $I_3 = -\frac{1}{2}$.) Which of these decays do you expect to occur at the higher rate?

6. From time to time (most recently by the LEPS Collaboration in 2008), claims are made of evidence for a new particle, the Θ^+. This evidence comes from photoproduction experiments using deuterium $(p + n)$,

$$\gamma + d \to \Theta^+ + K^- + p,$$

followed by the decay

$$\Theta^+ \to n + K^+.$$

The production rate is consistent with an electromagnetic process, and the decay with a strong one.

Determine the flavour quantum numbers, I_3, B, and S, for this particle. Deduce the minimum quark content that could explain these and comment on how the Θ^+ would fit into the usual quark model.