HL Paper 3

This question is about the standard model.

a. State what is meant by the standard model. [3]

b. Use the conservation of lepton number and charge to deduce the nature of the particle *x* in the following reaction. [1]

$$v_{\mathrm{e}} + \mu^{-} \rightarrow e^{-} + x$$

c. State what is meant by deep inelastic scattering. [1]

Markscheme

a. the theory that describes the electromagnetic and weak (and strong) interaction of quarks and electrons/particles;

b. v_{μ} / muon neutrino;

c. scattering (of leptons by hadrons) in which large amounts of energy is transferred (to the hadrons);

Examiners report

a. A significant number of candidates left the question unanswered. Of those candidates who did attempt the question very few knew anything about deep inelastic scattering.

b. A significant number of candidates left the question unanswered. Of those candidates who did attempt the question very few knew anything about deep inelastic scattering.

c. A significant number of candidates left the question unanswered. Of those candidates who did attempt the question very few knew anything about deep inelastic scattering.

This question is about linear accelerators.

b. A moving proton is incident on a stationary pion, producing a kaon (*K* meson) and an unknown hadron X according to the reaction given below. [2]

$$p+\pi^{-} \rightarrow X+K^{-}$$

(i) State, with a reason, the electric charge of X.

(ii) State, with a reason, if X is a baryon **or** a meson.

c. In a deep inelastic scattering experiment, protons of momentum 2.70 $\times 10^{-18}$ N s are scattered by gold nuclei. [3]

Given that the diameter of nucleons is of the order 10^{-15} m and the diameter of quarks is less than 10^{-18} m, determine if these protons will be able to resolve

(i) nucleons within the gold nuclei.

(ii) quarks within the gold nuclei.

d. Outline how deep inelastic scattering experiments led to the conclusion that gluons exist. [2]

Markscheme

b. (i) positive in order to satisfy electric charge conservation;

(ii) baryon in order to satisfy baryon number conservation/contains 3 quarks;

c. (i) the de Broglie wavelength is $\lambda = \frac{6.63 \times 10^{-34}}{2.7 \times 10^{-18}} = 2.5 \times 10^{-16} \text{m}$;

this is less than the nucleon size so nucleons can be resolved;

Argument required for second mark.

(ii) but it is greater than the quark size so quarks cannot be resolved;

d. deep inelastic scattering experiments measure the (fraction of) momentum carried by electrically charged constituents of hadrons;

this is less than the total momentum of the hadron indicating the presence of neutral constituents;

Examiners report

b.

c.

d.