Additional Topic 7 questions

Test yourself

7.1 Discrete energy and radioactivity

1 Calculate the number of neutrons in these nuclei: ${}^{3}_{1}\mathrm{H}$, ${}^{23}_{11}\mathrm{Na}$, ${}^{48}_{22}\mathrm{Ti}$, ${}^{179}_{72}\mathrm{Hf}$.

2 Tritium (${}^{3}_{1}\mathrm{H}$) is a radioactive isotope of hydrogen and decays by beta minus decay. State the equation for the reaction and the names of the products of the decay.

3 Nitrogen (${}^{14}_{7}\mathrm{N}$) is produced in the beta minus decay of a radioactive isotope. State the equation for this reaction and the names of the particles in the reaction.

4 A nucleus (${}^{A}_{Z}\mathrm{X}$) decays by emitting two positrons and one alpha particle. State the atomic and mass numbers of the resulting nucleus.

5 Name the two missing particles in the reaction ${}^{22}_{11}\mathrm{Na} \rightarrow {}^{22}_{10}\mathrm{Ne} + ? + ?$

6 The initial activity of a radioactive sample is 120 Bq. After 24 hours the activity is measured to be 15 Bq. Determine the half-life of the sample.

7 Discuss how you could confirm that a particular element emits:

a positively charged particles

b negatively charged particles

c electrically neutral particles.

8 The track of an alpha particle is measured to be 30 mm. The energy required to produce an ion is about 32 eV, on average. Assuming that alpha particles create 6000 ions per mm along their path, estimate the energy of the alpha particle.

9 Discuss what is meant by the statement that the strong nuclear force has a short range.

10 Compare the gravitational force between two electrons a distance of 10^{-10} m apart with the electrical force between them at the same separation.

11 An unstable nucleus has too many neutrons. Suggest the likely way in which it will decay.

7.2 Nuclear reactions

12 Calculate the energy released in the beta minus decay of a neutron.

13 Calculate the energy released in the alpha decay:

$${}^{234}_{90}\mathrm{Th} \rightarrow {}^{230}_{88}\mathrm{Ra} + {}^{4}_{2}\mathrm{He}$$

(The atomic mass of thorium is 234.043596 u; that of radium is 230.03708 u.)

14 One possible outcome in the fission of a uranium nucleus is the reaction:

$${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{95}_{42}\mathrm{Mo} + {}^{139}_{57}\mathrm{La} + 2{}^{1}_{0}\mathrm{n} + ?$$

a Write down what is missing in this reaction.

b Calculate the energy is released. (Atomic masses: U = 235.043922 u; Mo = 94.905841 u; La = 138.906349 u.)

15 The reaction by which hydrogen in stars is converted into helium is:

$$4{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2{}^{0}_{1}\mathrm{e} + 2\nu_e + {}^{0}_{0}\gamma$$

The reaction releases about 26.7 MeV of energy. The Sun radiates energy at the rate of 3.9×10^{26} W and has a mass of about 1.99×10^{30} kg, of which 75% is hydrogen. Calculate how long it will take the Sun to convert 12% of its hydrogen into helium.

16 Outline the role in nuclear fusion reactions of:

a temperature

b pressure.

7.3 The structure of matter

17 Describe the Rutherford–Geiger–Marsden experiment and explain how its results led to the Rutherford model of the atom.

18 Explain, in terms of quarks, what is meant by the terms **a** hadron, **b** meson and **c** baryon.

19 Discuss whether it is correct that all electrically neutral particles are their own anti-particles. Give examples to support your answer.

20 In the reaction p + p → p + p + X, determine whether X can be a baryon.

21 Write down the charge and strangeness of the baryon λ = (uds).

22 Identify the reactions that conserve lepton number.

a $p^+ \rightarrow e^+ + p^0$

b $p^0 \rightarrow e^+ + \mu^-$

c $\tau^+ \rightarrow \pi^+ + \bar{\nu}_\tau$

d $\pi^- \rightarrow e^- + \bar{\nu}_e$

23 Explain whether the weak force acts:

a on mesons.

b on baryons.

24 Neutrinos are electrically neutral. Are neutrinos identical to anti-neutrinos?

25 **a** The positive pion π^+ has the quark content $(d\bar{u})$ and rest mass 140 MeV c^{-2}. Explain why there exists a different meson (the ρ^+ of rest mass 770 MeV c^{-2}) with the same quark content as the π^+.

b The negative pion π^- has quark content $(d\bar{u})$. Explain how it may be deduced that there exists a meson with the same quark content as the π^- and rest mass 770 MeV c^{-2}.

26 Outline how the exchange of gluons by quarks results in the strong nuclear force between nucleons.

27 Using the weak interaction vertices, draw a Feynman diagram for the reaction $\mu^+ + e^- \rightarrow \bar{\nu}_\mu + \nu_e$.

28 **a** Describe what is meant by a Feynman diagram.

b Draw Feynman diagrams to represent the electromagnetic processes:

i $e^- + e^+ \rightarrow e^- + e^+$

ii $e^- + e^+ \rightarrow \gamma + \gamma$.

29 A meson has quark content $u\bar{u}$.

a State the electric charge of the meson. The meson is at rest and decays into photons.

b Explain why the meson cannot decay into just one photon. The meson in fact decays into two photons.

c Draw the Feynman diagram for this decay.

30 The diagram represents the beta plus (e^+) decay of a proton.

a Identify the quarks making up the neutron.

b State the name of the particle represented by the wavy line.

c Identify the particles denoted by X and Y in the diagram.