PHYA1 Particles & radiation 4

121 min
116 marks

1. (a) (i) Complete the equation that represents the collision between a proton and an antineutrino.

$$\bar{\nu}_e + p \longrightarrow$$

(ii) What fundamental force is responsible for the interaction shown in part (i)?

....

(iii) Name an exchange particle that could be involved in this interaction.

....

(4)

(b) Describe what happens in pair production and give **one** example of this process.

You may be awarded marks for the quality of written communication in your answer.

....

....

....

....

....

....

....

(3)

(Total 7 marks)

2. A radioactive isotope of carbon is represented by ${}^{14}_{6}C$.

(a) Using the same notation, give the isotope of carbon that has two fewer neutrons.

....

(1)

(b) Calculate the charge on the ion formed when **two** electrons are removed from an atom of ${}^{14}_{6}C$.

....

....

....

(2)

(c) Calculate the value of $\frac{\text{charge}}{\text{mass}}$ for the nucleus of an atom of $^{14}_{6}\text{C}$.

....

....

....

(2)
(Total 5 marks)

3. (a) (i) Give an example of an exchange particle other than a W^+ or W^- particle, and state the fundamental force involved when it is produced.

exchange particle ....

fundamental force ....

(ii) State what roles exchange particles can play in an interaction.

....

....

....

(4)

(b) From the following list of particles,

$p \quad \bar{n} \quad \nu_e \quad e^+ \quad \mu^- \quad \pi^0$

identify **all** the examples of

(i) hadrons, ...

(ii) leptons, ...

(iii) antiparticles, ...

(iv) charged particles. ....

(4)
(Total 8 marks)

4. (a) An ion of plutonium $^{239}_{94}Pu$ has an overall charge of $+1.6 \times 10^{-19}$C.

For this ion state the number of

(i) protons ....

(ii) neutrons ....

(iii) electrons ....

(3)

(b) Plutonium has several *isotopes*.

Explain the meaning of the word isotopes.

....

....

....

(2)
(Total 5 marks)

5. Under certain conditions a γ photon may be converted into an electron and a positron.

(a) What is this process called?

....

(1)

(b) (i) Explain why there is a minimum energy of the γ photon for this conversion to take place and what happens when a γ photon has slightly more energy than this value.

....

....

....

....

....

(ii) Using values from the data sheet calculate this minimum energy in MeV.

....

....

(3)

(c) Under suitable conditions, a γ photon may be converted into two other particles rather than an electron and positron.
Give an example of the two other particles it could create.

....

(1)
(Total 5 marks)

6. (a) Complete the following equations

$$p + e^- \longrightarrow \_\_\_\_ + \_\_\_\_$$

$$n + \nu_\mu \longrightarrow p + \_\_\_\_$$

$$p + p \longrightarrow p + p + K^- + \_\_\_\_$$

(4)

(b) Give an equation that represents β^- decay, using quarks in the equation rather than nucleons.

....

....

(2)

(c) (i) Which fundamental force is responsible for electron capture?

....

(ii) What type of particle is an electron?

....

(iii) State the other fundamental forces that electrons may experience.

....

(3)
(Total 9 marks)

7. (a) How many protons, neutrons and electrons are there in an atom of caesium, $^{133}_{55}\mathrm{Cs}$, which is the most abundant and stable *isotope* of caesium.

.... protons

.... neutrons

.... electrons

(2)

(b) (i) Explain what is meant by isotopes.

....

....

(ii) Write down an isotope $^{133}_{55}\mathrm{Cs}$ that is likely to be a beta minus emitter.

....

(3)

(c) Determine the specific charge of a nucleus of ${}^{133}_{55}\text{Cs}$.

specific charge = ...

(3)

(Total 8 marks)

8. The quark model was developed to help understand hadrons. Quarks cannot exist separately, they form combinations.

(a) (i) List the **three** combinations that quarks can form.

....

(ii) Give the quark combination for a positive pion, Π^+ and an antiproton, $\bar{p}$.

Π^+ ....

$\bar{p}$ ....

(4)

(b) The event represented by, $K^- + p \rightarrow K^0 + K^+ + X$, is a strong interaction.

The K^- has strangeness –1 and the kaons K^+ and K^0 both have strangeness +1.

(i) Use the conservation laws to deduce the strangeness, charge, baryon number and lepton number of the particle represented by X.

Strangeness ....

Charge ....

Baryon number ....

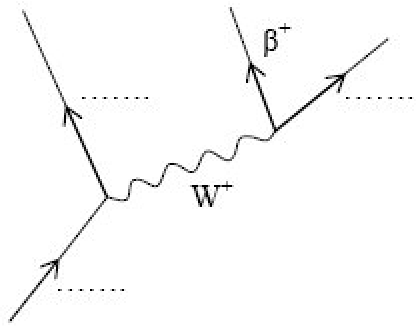
Lepton number ....

(ii) What will particle X eventually decay into?

....

(4)
(Total 8 marks)

9. (a) Complete the labelling of the Feynman diagram below representing positron emission from an individual nucleon.



(3)

(b) (i) What is the virtual exchange particle used by electromotive force?

....

(ii) State **two** differences between the exchange particles used by the weak interaction and used by the electromagnetic force.

....

....

....

(3)

(c) The theoretical work of Dirac suggested that for every particle there should exist a corresponding antiparticle. The first to be antiparticle to be discovered was the positron.

(i) State what is meant by an antiparticle.

....

....

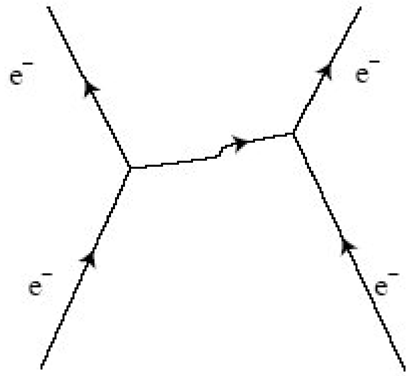
(ii) Write down the corresponding antiparticle for each of the particles listed in the following table.

Particle	antiparticle
β^-	β^+
π^o	
K^o	
γ	

(5)
(Total 11 marks)

10. (a) **Figure 1** shows the Feynman diagram for a particular interaction.

Figure 1



(i) State the type of interaction involved and name the exchange particle.

....

....

(2)

(ii) State **two** quantities other than energy and momentum, that are conserved in this interaction.

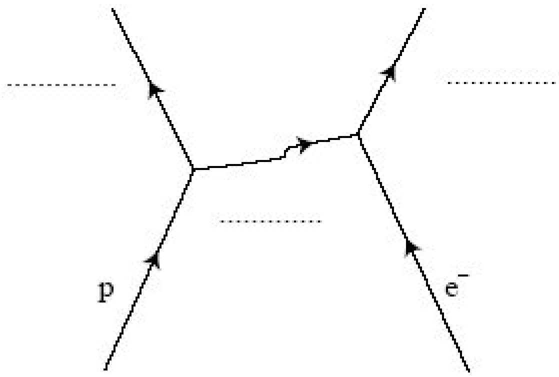
....

....

(2)

(b) **Figure 2** shows the Feynman diagram for another type of interaction.

Figure 2



(i) Complete the diagram to show the two particles formed in the interaction and the exchange particle.

(3)

(ii) Name the type of interaction responsible for this exchange particle.

....

(1)

(iii) Energy and momentum are conserved in this interaction.
State **two** other quantities that must be conserved and show that they are conserved in this interaction.

....

....

....

(4)

(iv) The exchange particle in this interaction was discovered by experiment with a rest mass that had been predicted. Why is it important to test by experiment the prediction of a scientific theory?

....

....

....

....

(2)
(Total 14 marks)

11. (a) Explain what is meant by an isotope.

....

....

....

....

(2)

(b) The incomplete table shows information for two isotopes of uranium.

	number of protons	number of neutrons	specific charge of nucleus/..................
first isotope	92	143	
second isotope			3.7×10^7

(i) Write the unit for the specific charge in the heading of the last column of the table.

(1)

(ii) In the above table write down the number of protons in the second isotope in the table.

(1)

(iii) Calculate the specific charge of the first isotope and write this in the table.

....

....

....

....

(3)

(iv) Calculate the number of neutrons in the second isotope and put this number in the table

....

....

....

....

....

(3)
(Total 10 marks)

12. (a) The Σ^+ particle is a baryon with strangeness –1.

(i) How many quarks does the Σ^+ particle contain?

....

....

answer ....

(1)

(ii) How many of the quarks are strange?

....

....

answer ....

(1)

(b) The Σ^+ decays in the following reaction

$$\Sigma^+ \rightarrow \pi^+ + n$$

(i) State **two** quantities that are conserved in this reaction.

....

....

(2)

(ii) State a quantity that is not conserved in this reaction.

....

(1)

(iii) What interaction is responsible for this reaction?

....

(1)

(iv) Into what particle will the neutron formed in this reaction eventually decay?

....

(1)
(Total 7 marks)

13. (a) *Hadrons* are a group of particles composed of quarks. Hadrons can either be baryons or mesons.

(i) What property defines a hadron?

....

(1)

(ii) What is the quark structure of a baryon?

....

(1)

(iii) What is the quark structure of a meson?

....

(1)

(b) State **one** similarity and **one** difference between a particle and its antiparticle.

similarity ....

....

difference ....

....

(2)

(c) Complete the table below which lists properties of the antiproton.

	charge / C	**baryon number**	**quark structure**
antiproton			

(2)

(d) The K^- is an example of a meson with strangeness –1. The K^- decays in the following way:

$$K^- \rightarrow \mu^- + \overline{\nu_u}$$

(i) State, with a reason, what interaction is responsible for this decay.

....

....

....

....

(2)

(ii) State **two** properties, other than energy and momentum, that are conserved in this decay.

....

....

....

....

(2)
(Total 11 marks)

14. (a) An unstable nucleus, ${}^{A}_{Z}X$, can decay by emitting a β^- particle.

(i) What part of the atom is the same as a β^- particle?

....

(1)

(ii) State the changes, if any, in A and Z when X decays.

change in A ....

change in Z ....

(2)

(b) In the process of β^- decay an *anti-neutrino* is also released.

(i) Give an equation for this decay.

....

(1)

(ii) State and explain which conservation law may be used to show that it is an *anti-neutrino* rather than a *neutrino* that is released.

....

....

....

....

(2)

(iii) What must be done to validate the predictions of an unconfirmed scientific theory?

....

....

....

....

....

(2)
(Total 8 marks)