

1)

A neutral atom of a radium isotope may be represented by ${}_{88}^{228}\text{Ra}$.

(a) (i) Name the constituents of this atom and state how many of each are present.

.....
.....
.....
(3 marks)

(a) (ii) Which constituent of an atom has the largest specific charge?

.....
(1 mark)

(a) (iii) This isotope of radium decays by β^- decay to form an element with symbol, Ac.
Write down an equation that represents this decay.

(4 marks)

(b) ${}^A_Z\text{Ra}$ is a neutral atom of a different isotope of radium. State a possible value for A and for Z.

A:
Z:
(2 marks)

2)

(a) State what is meant by the specific charge of a nucleus and give an appropriate unit for this quantity.

.....
.....
.....
.....

unit:
(2 marks)

(b) Nucleus X has the same nucleon number as nucleus Y. The specific charge of X is 1.25 times greater than that of Y.

(b) (i) Explain, in terms of protons and neutrons, why the specific charge of X is greater than that of Y.

.....
.....
.....
.....

(2 marks)

(b) (ii) Nucleus X is $^{10}_5\text{B}$. Deduce the number of protons and the number of neutrons in nucleus Y.

number of protons

number of neutrons

(4 marks)

3)

(a) Name the constituent of an atom which

(a) (i) has zero charge,

.....
(1 mark)

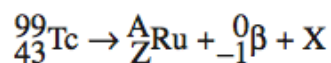
(a) (ii) has the largest specific charge,

.....
(1 mark)

(a) (iii) when removed leaves a different isotope of the element.

.....
(1 mark)

(b) The equation



represents the decay of technetium-99 by the emission of a β^- particle.

(b) (i) Identify the particle X.

.....
(1 mark)

(b) (ii) Determine the values of A and Z.

A =

Z =

(2 marks)

(b) (iii) Calculate the specific charge of the technetium-99 (${}_{43}^{99}\text{Tc}$) nucleus. State an appropriate unit for your answer.

specific charge = unit
(4 marks)

4)

(a) Explain what is meant by an isotope.

.....

.....

.....

.....

(2 marks)

(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

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

(1 mark)

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

(1 mark)

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

.....
.....
.....
.....

(3 marks)

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

.....
.....
.....
.....
.....

(3 marks)

5)

(a) An unstable nucleus, ${}^A_Z\text{X}$, can decay by emitting a β^- particle.

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

.....
(1 mark)

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

change in A

change in Z

(2 marks)

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

(b) (i) Give an equation for this decay.

.....
(1 mark)

(b) (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 marks)

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

.....

.....

.....

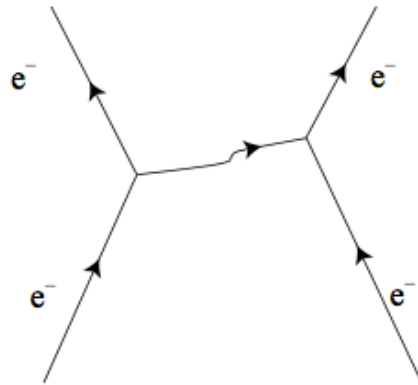
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(2 marks)

6)

(a) **Figure 2** shows the Feynman diagram for a particular interaction.

Figure 2



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

.....

 (2 marks)

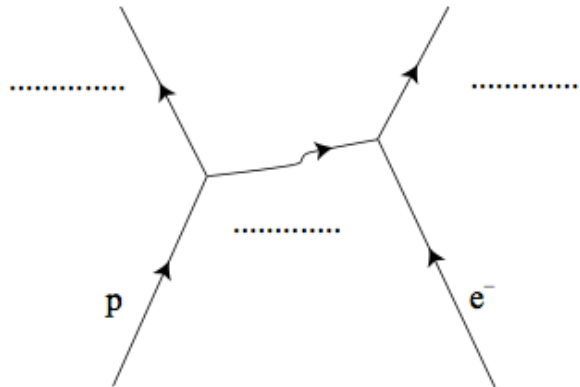
(a) (ii) State **two** quantities other than energy and momentum, that are conserved in this interaction.

.....

 (2 marks)

(b) **Figure 3** shows the Feynman diagram for another type of interaction.

Figure 3



(b) (i) Complete the diagram to show the two particles formed in the interaction and the exchange particle. (3 marks)

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

.....
(1 mark)

(b) (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 marks)

(b) (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 marks)

7)

A ${}_{11}^{22}\text{Na}$ nucleus decays, forming a new nucleus, by releasing a β^+ particle and one other particle which is difficult to detect.

(a) Name the particle which is difficult to detect.

answer =
(1 mark)

(b) Write down the proton number and the nucleon number of the new nucleus.

proton number
nucleon number
(2 marks)

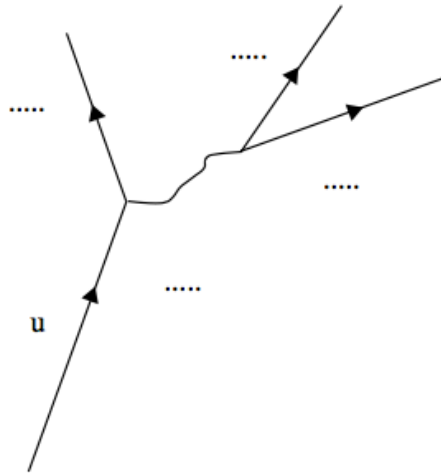
(c) Name the baryon and each of the leptons formed as a result of this decay.

baryon
lepton
lepton
(3 marks)

(d) Give the quark structure for a neutron and a proton.

neutron
proton
(1 mark)

(e) Complete the following Feynman diagram so that it represents β^+ decay.



(3 marks)

8)

(a) Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons quoting suitable values for separation.

.....

.....

.....

.....

.....

.....

(3 marks)

(b) An unstable nucleus can decay by the emission of an *alpha particle*.

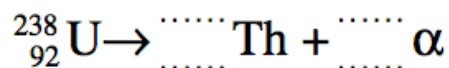
(b) (i) State the nature of an alpha particle.

.....

.....

(1 mark)

(b) (ii) Complete the equation below to represent the emission of an α particle by a ${}_{92}^{238}\text{U}$ nucleus.



(2 marks)

(c) ${}_{92}^{238}\text{U}$ decays in stages by emitting α particles and β^- particles, eventually forming ${}_{82}^{206}\text{Pb}$, a stable *isotope* of lead.

(c) (i) State what is meant by isotopes.

.....
.....

(2 marks)

(c) (ii) If there are eight alpha decays involved in the sequence of decays from ${}_{92}^{238}\text{U}$ to ${}_{82}^{206}\text{Pb}$ deduce how many β^- decays are involved.

answer =
(3 marks)

9)

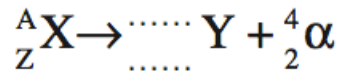
Alpha decay is a process by which an unstable *isotope* of an element may decay.

(i) State what is meant by isotopes.

.....

(2 marks)

(ii) Complete this equation for alpha decay.



(2 marks)

(iii) Calculate the specific charge of an alpha particle, stating an appropriate unit.

answer =

(4 marks)

(iv) Explain why the alpha particle, once outside the nucleus, is unaffected by the strong nuclear force.

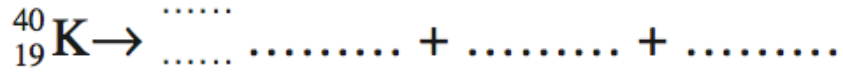
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(2 marks)

10)

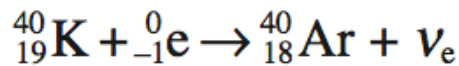
The isotope of potassium ${}^{40}_{19}\text{K}$ can decay by positron emission to form an isotope of argon, Ar.

(a) Complete the following equation which represents this decay.



(4 marks)

(b) The following equation represents another possible decay for ${}^{40}_{19}\text{K}$.



(b) (i) What is this type of decay called?

.....
(1 mark)

(b) (ii) Where does the electron on the left-hand side of the equation come from?

.....
(1 mark)

(b) (iii) Explain why this reaction has to produce a neutrino rather than an antineutrino.

.....
.....
(1 mark)

(b) (iv) Complete the Feynman diagram shown in **Figure 1** that represents this decay.

Figure 1



(3 marks)

11)

(a) The nucleus of a particular atom has a *nucleon number* of 14 and a *proton number* of 6.

(a) (i) State what is meant by nucleon number and proton number.

nucleon number

.....

.....

proton number

.....

.....

(1 mark)

(a) (ii) Calculate the number of neutrons in the nucleus of this atom.

answer =

(1 mark)

(a) (iii) Calculate the specific charge of the nucleus.

answer = C kg^{-1}

(3 marks)

(b) The specific charge of the nucleus of another isotope of the element is $4.8 \times 10^7 \text{ C kg}^{-1}$.

(b) (i) State what is meant by an isotope.

.....
.....
.....

(2 marks)

(b) (ii) Calculate the number of neutrons in this isotope.

answer =

(3 marks)

12)

An atom of calcium, ${}_{20}^{48}\text{Ca}$, is ionised by removing two electrons.

(i) State the number of protons, neutrons and electrons in the ion formed.

protons

neutrons

electrons

(3 marks)

(ii) Calculate the charge of the ion.

charge C

(1 mark)

(iii) Calculate the specific charge of the ion.

@

specific charge C kg^{-1} or
(2 marks)

13)

(a) **Table 2** contains data for four different nuclei, P, Q, R and S.

Table 2

Nuclei	Number of neutrons	Nucleon number
P	5	11
Q	6	11
R	8	14
S	9	17

(a) (i) Which nucleus contains the fewest protons?

[1 mark]

nucleus

(a) (ii) Which **two** nuclei are isotopes of the same element?

[1 mark]

nuclei and

(a) (iii) State and explain which nucleus has the smallest specific charge.

[2 marks]

.....

.....

.....

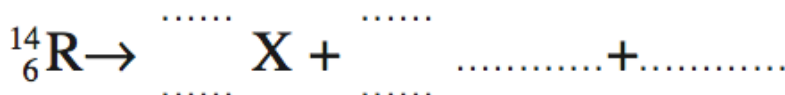
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.....

.....

(a) (iv) Complete the following equation to represent β^- decay of nucleus R to form nucleus X.

[3 marks]



- (b) (i)** The strong nuclear force is responsible for keeping the protons and neutrons bound in a nucleus.
Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons, quoting suitable values for separation.

[3 marks]

.....

.....

.....

.....

.....

.....

- (b) (ii)** Another significant interaction acts between the protons in the nucleus of an atom.
Name the interaction and name the exchange particle responsible for the interaction.

[2 marks]

Interaction

Exchange particle

14)

Table 1 contains five statements that refer to isotopes and some radium isotopes.

Table 1

	$^{223}_{88}\text{Ra}$	$^{224}_{88}\text{Ra}$	$^{225}_{88}\text{Ra}$	$^{226}_{88}\text{Ra}$
Isotope with the smallest mass number	✓			
Isotope with most neutrons in nucleus				
Isotope with nucleus which has the largest specific charge				
Isotope decays by β^- decay to form $^{225}_{89}\text{Ac}$				
Isotope decays by alpha decay to form $^{220}_{86}\text{Rn}$				

- (a) Complete **Table 1** by ticking **one** box in each row to identify the appropriate isotope. The first row has been completed for you.

[4 marks]

- (b) (i) An atom of one of the radium isotopes in **Table 1** is ionised so that it has a charge of $+3.2 \times 10^{-19} \text{ C}$.

State what happens in the process of ionising this radium atom.

[1 mark]

.....

.....

- (b) (ii) The specific charge of the ion formed is $8.57 \times 10^5 \text{ C kg}^{-1}$.

Deduce which isotope in the table has been ionised. Assume that both the mass of a proton and the mass of a neutron in the nucleus is $1.66 \times 10^{-27} \text{ kg}$.

[3 marks]

isotope =