Nuclear Physics

Q1. (a) Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons quoting suitable values for separation.

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(3)

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

(i) State the nature of an alpha particle.

.....

.....

(1)

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

$$^{238}_{92}U \rightarrow \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\text{Th} + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\alpha$$

(2)

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

(i) State what is meant by isotopes.

.....

.....

(2)

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

answer = ...

(3)

(Total 11 marks)

Q2. (a) The nucleus of a particular atom has a *nucleon number* of 14 and a *proton number* of 6.

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

nucleon number .....

.....

.....

proton number .....

.....

.....

(1)

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

answer = ...

(1)

(iii) Calculate the specific charge of the nucleus.

answer = ... Ckg^{-1}

(3)

(b) The specific charge of the nucleus of another isotope of the element is 4.8×10^7 Ckg^{-1}.

(i) State what is meant by an isotope.

.....

.....

.....

(2)

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

answer = ...

(3)

(Total 10 marks)

Q3. (a) What are isotopes?

.....

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.....

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.....

(2)

(b) One of the isotopes of nitrogen may be represented by $^{15}_{7}\text{N}$.

(i) State the number of each type of particle in its nucleus.

.....

.....

(ii) Determine the ratio $\frac{\text{charge}}{\text{mass}}$, in C kg^{-1}, of its nucleus.

.....

.....

.....

.....

(4)

(c) (i) What is the charge, in C, of an atom of $^{15}_{7}N$ from which a single electron has been removed?

.....

(ii) What name is used to describe an atom from which an electron has been removed?

.....

(2)

(Total 8 marks)

Q4. (a) State what is meant by the specific charge of a nucleus and give an appropriate unit for this quantity.

.....

.....

.....

.....

unit: .....

(2)

(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.

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

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.....

(2)

(ii) Nucleus X is $^{10}_{5}\mathrm{B}$. Deduce the number of protons and the number of neutrons in nucleus Y.

number of protons .....

number of neutrons .....

(4)

(Total 8 marks)

Q5. (a) A stable atom contains 28 nucleons.

Write down a possible number of protons, neutrons and electrons contained in the atom.

..... protons

..... neutrons

..... electrons

(2)

(b) An unstable *isotope* of uranium may split into a caesium nucleus, a rubidium nucleus and four neutrons in the following process.

$$^{236}_{92}\mathrm{U} \Rightarrow {}^{137}_{55}\mathrm{Cs} + {}^{X}_{37}\mathrm{Rb} + 4\,{}^{1}_{0}\mathrm{n}$$

(i) Explain what is meant by isotopes.

.....

.....

.....

(ii) How many neutrons are there in the $^{137}_{55}\mathrm{Cs}$ nucleus?

.....

(iii) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$, in C kg^{-1}, for the $^{236}_{92}U$ nucleus.

.....

.....

.....

(iv) Determine the value of X for the rubidium nucleus.

.....

X = ...

(6)
(Total 8 marks)

Q6. (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)

Q7. Alpha decay is a process by which an unstable *isotope* of an element may decay.

(i) State what is meant by isotopes.

.....

.....

.....

.....

(2)

(ii) Complete this equation for alpha decay.

$$^{A}_{Z}\mathrm{X} \rightarrow {}^{\ldots\ldots}_{\ldots\ldots}\mathrm{Y} + {}^{4}_{2}\alpha$$

(2)

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

answer = ...

(4)

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

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(2)
(Total 10 marks)

Q8. (a) (i) Determine the charge, in C, of a $^{239}_{92}\mathrm{U}$ nucleus.

.....

.....

(ii) A positive ion with a $^{239}_{92}U$ nucleus has a charge of 4.80×10^{-19} C.
Determine how many electrons are in this ion.

.....

.....

.....

(4)

(b) A $^{239}_{92}U$ nucleus may decay by emitting **two** β^- particles to form a plutonium nucleus $^{X}_{Y}Pu$.
State what X and Y represent and give the numerical value of each.

X .....

.....

Y .....

.....

(4)
(Total 8 marks)

Q9. A neutral atom of a radium isotope may be represented by $^{228}_{88}Ra$.

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

.....

.....

.....

(3)

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

.....

(1)

(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)

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

A: .....

Z: .....

(2)

(Total 10 marks)

Q10. 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)

Q11. In a radioactive decay of a nucleus, a β^+ particle is emitted followed by a γ photon of wavelength 8.30×10^{-13} m.

(a) (i) State the rest mass, in kg, of the β^+ particle.

.....

(ii) Calculate the energy of the γ photon.

.....

.....

.....

.....

(iii) Determine the energy of the γ photon in MeV.

.....

.....

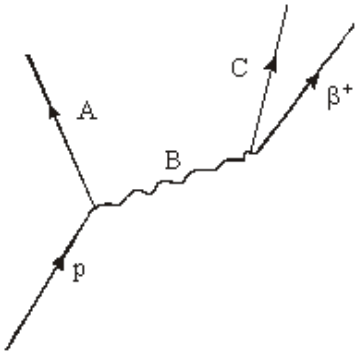
(6)

(b) Name the fundamental interaction or force responsible for β^+ decay.

.....

(1)

(c) β^+ decay may be represented by the Feynman diagram.



Name the particles represented by A, B and C.

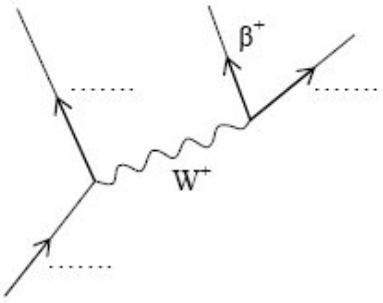
A .....

B .....

C .....

(3)
(Total 10 marks)

Q12. (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.

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.....

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(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)

Q13. The isotope of potassium $^{40}_{19}K$ can decay by positron emission to form an isotope of argon, Ar.

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

$$^{40}_{19}K \rightarrow \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix} \cdots\cdots + \cdots\cdots + \cdots\cdots$$

(4)

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

$$^{40}_{19}K + ^{0}_{-1}e \rightarrow ^{40}_{18}Ar + \nu_e$$

(i) What is this type of decay called?

.....

(1)

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

.....

(1)

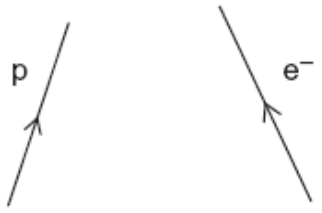
(iii) Explain why this reaction has to produce a neutrino rather than an antineutrino.

.....

.....

(1)

(iv) Complete the Feynman diagram shown in the figure below that represents this decay.



(3)
(Total 10 marks)