**AQA Questions from 2004 to 2006**

# Particle Physics

**1.** (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.

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**(2)**

**(Total 5 marks)**

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

(a) What is this process called?

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**(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.

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

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**(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.

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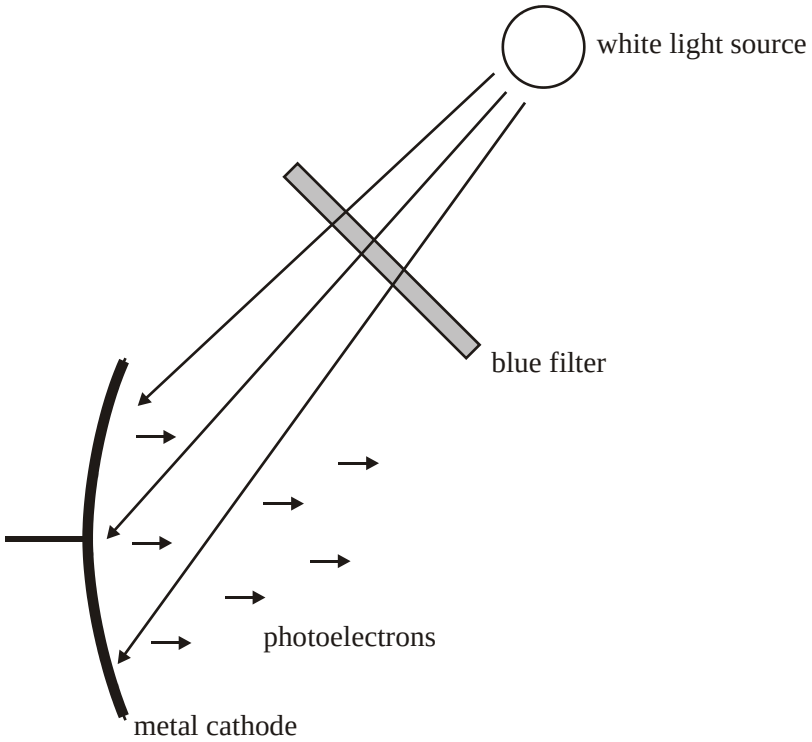
**(1)**
**(Total 5 marks)**

**3.** The apparatus shown in the figure below can be used to demonstrate the photoelectric effect. Photoelectrons are emitted from the metal cathode when it is illuminated with white light which has passed through a blue filter.



You may be awarded additional marks to those shown in brackets for the quality of written communication in your answers to parts (a) and (b).

(a) The intensity of the light source is reduced. State and explain the effect of this on the emitted photoelectrons.

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**(3)**

(b) Explain why no photoelectrons are emitted when the blue filter is replaced by a red filter.

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**(3)**

(c) When a metal of work function $2.30 \times 10^{-19}$ J is illuminated with ultraviolet radiation of wavelength 200 nm, photoelectrons are emitted.

Calculate

(i) the frequency of the ultraviolet radiation,

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(ii) the threshold frequency of the metal,

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(iii) the maximum kinetic energy of the photoelectrons, in J.

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**(5)**

**(Total 11 marks)**

**4.** **Figure 1** shows the energy level diagram of a hydrogen atom. Its associated spectrum is shown in **Figure 2**.

The transition labelled **A** in **Figure 1** gives the spectral line labelled **B** in **Figure 2**.

**Figure 1**

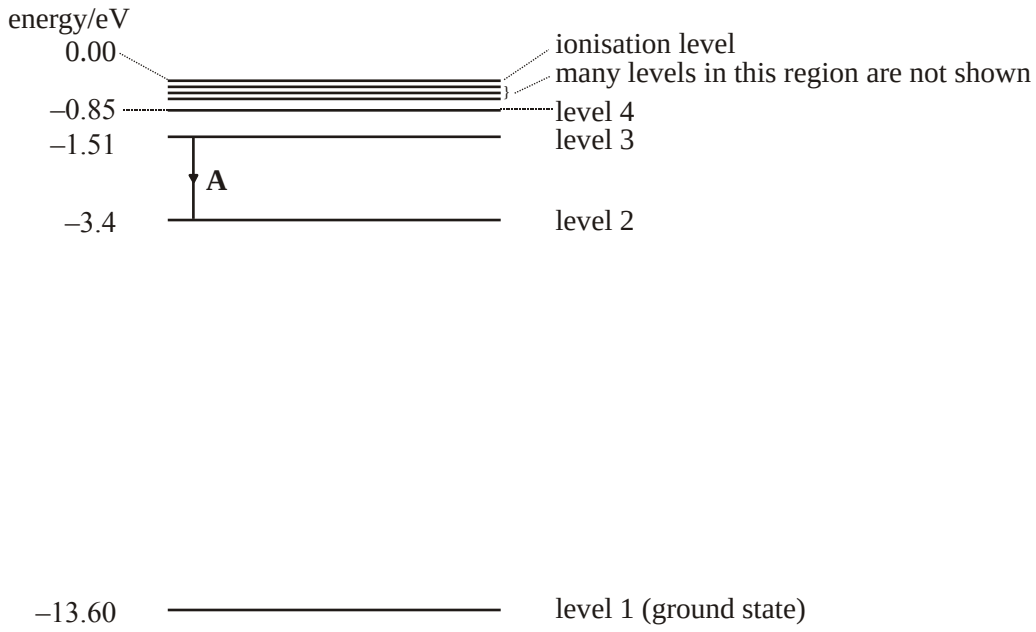
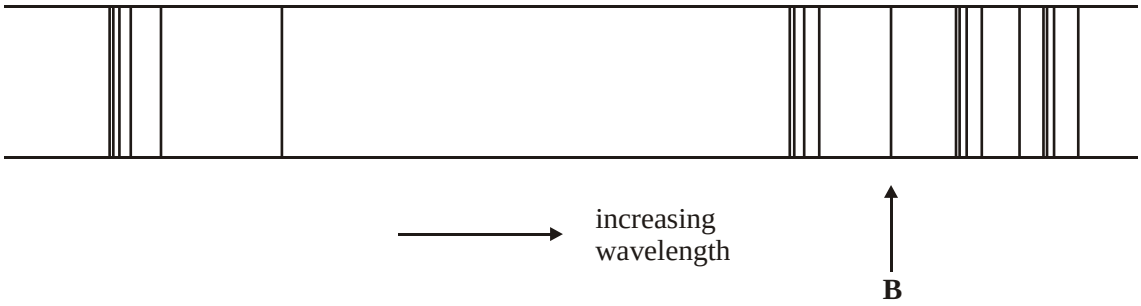


**Figure 2**

hydrogen spectrum showing some of the main spectral lines




(a) (i) Show that the frequency of spectral line B is about $4.6 \times 10^{14}$ Hz.

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(ii) Calculate the wavelength represented by line B.

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**(3)**

(b) The hydrogen atom is excited and its electron moves to level 4.

(i) How many different wavelengths of electromagnetic radiation may be emitted as the atom returns to its ground state?

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(ii) Calculate the energy, in eV, of the longest wavelength of electromagnetic radiation emitted during this process.

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**(2)**

(c) In a fluorescent tube, explain how the mercury vapour and the coating of its inner surface contribute to the production of visible light. You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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**(3)**

**(Total 8 marks)**

**5.** (a) Complete the following equations

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

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

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

**(4)**

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

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**(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)**

**6.** 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.

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**(1)**

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

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**(2)**

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

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**(2)**

**(Total 5 marks)**

**7.** (a) One quantity in the photoelectric equation is a characteristic property of the metal that emits photoelectrons. Name and define this quantity.

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**(2)**

(b) A metal is illuminated with monochromatic light. Explain why the kinetic energy of the photoelectrons emitted has a range of values up to a certain maximum.

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

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**(3)**

(c) A gold surface is illuminated with monochromatic ultraviolet light of frequency $1.8 \times 10^{1}$ Hz. The maximum kinetic energy of the emitted photoelectrons is $4.2 \times 10^{-19}$ J.
Calculate, for gold,

(i) the work function, in J,

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(ii) the threshold frequency.

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**(5)**
**(Total 10 marks)**

**8.** (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.

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**(4)**

(b) From the following list of particles,

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

identify **all** the examples of

(i) hadrons,

.....

(ii) leptons,

.....

(iii) antiparticles,

.....

(iv) charged particles.

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**(4)**
**(Total 8 marks)**

**9.** (i) A negative muon, $\mu^-$, is 207 times more massive than an electron.
Calculate the de Broglie wavelength of a negative muon travelling at $3.0 \times 10^6$ m $s^{-1}$.

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(ii) Using values from the data sheet calculate the ratio $\frac{\text{rest mass of } \pi^0}{\text{rest mass of } \mu^-}$ where $\pi^0$ is a neutral pion.

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(iii) Calculate the speed necessary for a $\pi^0$ to have the same de Broglie wavelength as that of the $\mu^-$ in part (i).

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**(Total 6 marks)**

**10.** Some of the energy levels of an atom are shown below. The atom may be *ionised* by electron impact.

energy/$10^{-17}$ J

0.00 _____ ionisation level

–1.97 _____ level E

–2.20 _____ level D

–2.32 _____ level C

–2.43 _____ level B

–4.11 _____ level A (ground state)

(a) (i) State what is meant by the ionisation of an atom.

.....

.....

(ii) Calculate the minimum kinetic energy, in eV, of an incident electron that could ionise the atom from its ground state.

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**(2)**

(b) You may be awarded marks for the quality of written communication in your answer to parts (b)(i) and (b)(ii).

The atom in the ground state is given $5.00 \times 10^{-17}$ J of energy by electron impact.

(i) State what happens to this energy.

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(ii) Describe and explain what could happen subsequently to the electrons in the higher energy levels.

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**(4)**

(c) Identify **two** transitions between energy levels that would give off electromagnetic radiation of the same frequency.

_____ to _____

and

_____ to _____

**(2)**
**(Total 8 marks)**

**11.** (a) What are isotopes?

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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.

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

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**(4)**

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

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

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**(2) (Total 8 marks)**

**12.** Some energy levels of an atom of a gas are shown in **Figure 1**.

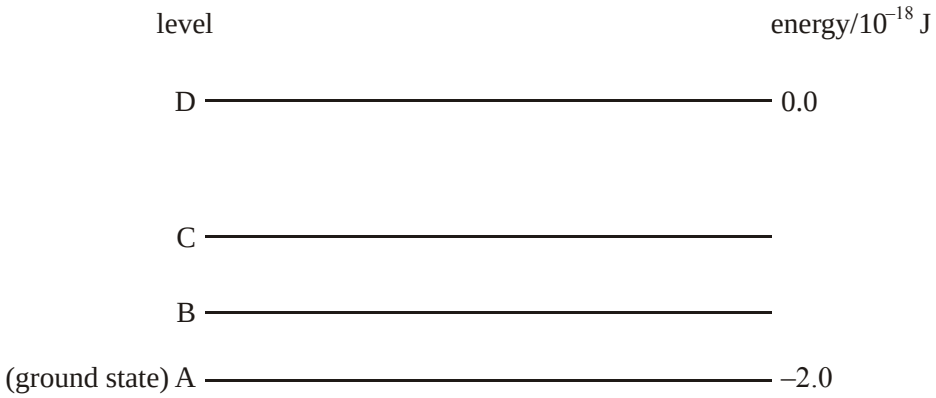


**Figure 1**

When a current is passed through the gas at low pressure, a line spectrum is produced. Two of these lines, which correspond to transitions from levels B and C respectively to the ground state, are shown in **Figure 2**.

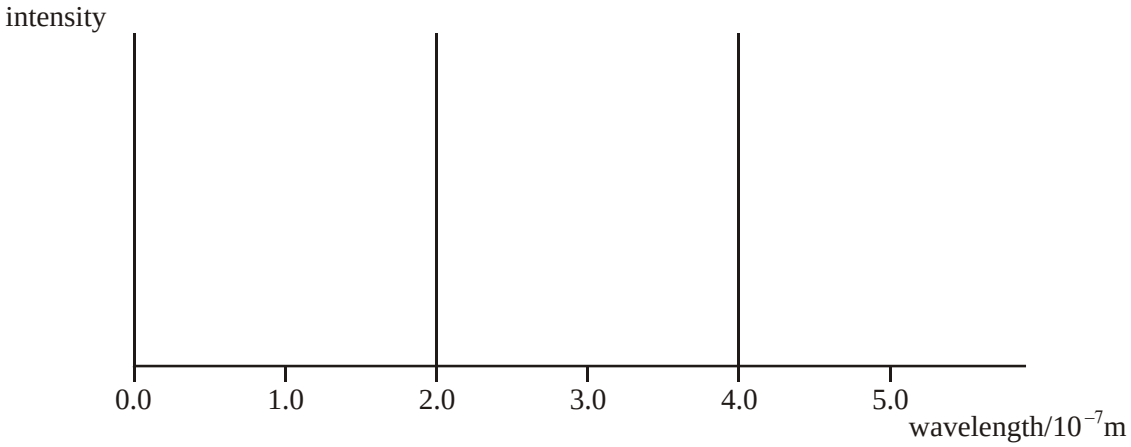


**Figure 2**

(a) Describe what happens to an electron in an atom in the ground state in order for the atom to emit light of wavelength $4.0 \times 10^{-7}$ m.

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

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**(3)**

(b) Determine the energy, in J, of

(i) the photons responsible for each of the two lines shown in **Figure 2**,

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(ii) levels B and C in **Figure 1.**

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energy of level B =

.....

energy of level C =

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**(5)**

**(Total 8 marks)**

**13.** The equation represents the collision of a neutral kaon with a proton, resulting in the production of a neutron and a positive pion.

$$K^\circ + p \longrightarrow n + \pi^+$$

(a) Show that this collision obeys **three** conservation laws in addition to energy and momentum.

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**(3)**

(b) The neutral kaon has a strangeness of +1.
Write down the quark structure of the following particles.

$K^\circ$ .....

$\pi^+$ .....

p .....

**(4)**
**(Total 7 marks)**

**14.** (a) Explain what is meant by the term *work function* of a metal.

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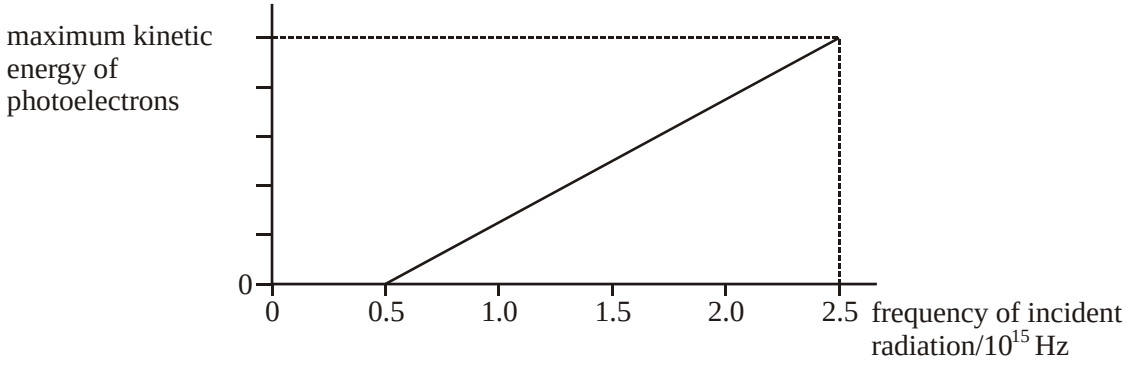
**(2)**

(b) In an experiment on the photoelectric effect, the maximum kinetic energy of the emitted photoelectrons is measured over a range of incident light frequencies. The results obtained are shown in the figure below.




(i) A metal of work function $\varphi$ is illuminated with light of frequency $f$. Write down the equation giving the maximum kinetic energy, $E_K$, of the photoelectrons emitted in terms of $\varphi$ and $f$.

$E_K$ =

(ii) Use the data in the figure to determine the work function of the metal.

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(iii) Determine the maximum kinetic energy of the photoelectrons when the frequency of the incident radiation is $2.5 \times 10^{15}$ Hz.

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**(6)**

(c) The experiment is repeated but with the light incident on a metal of lower work function. Draw a new line on the figure that results from this change.

**(2)**
**(Total 10 marks)**

**15.** (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)?

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

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**(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.

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**(3)**
**(Total 7 marks)**

**16.** (a) Name the constituent of an atom which

(i) has zero charge,

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(ii) has the largest charge to mass ratio,

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

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**(3)**

(b) An $\alpha$ particle is the same as a nucleus of helium, $^{4}_{2}He$.

The equation

$$^{229}_{90}Th \longrightarrow {}^{X}_{Y}Ra + \alpha$$

represents the decay of thorium by the emission of an $\alpha$ particle.

Determine

(i) the values of X and Y, shown in the equation,

X = .....

Y = .....

(ii) the ratio $\dfrac{\text{mass of } {}^{X}_{Y}\text{Ra nucleus}}{\text{mass of } \alpha \text{ particle}}$

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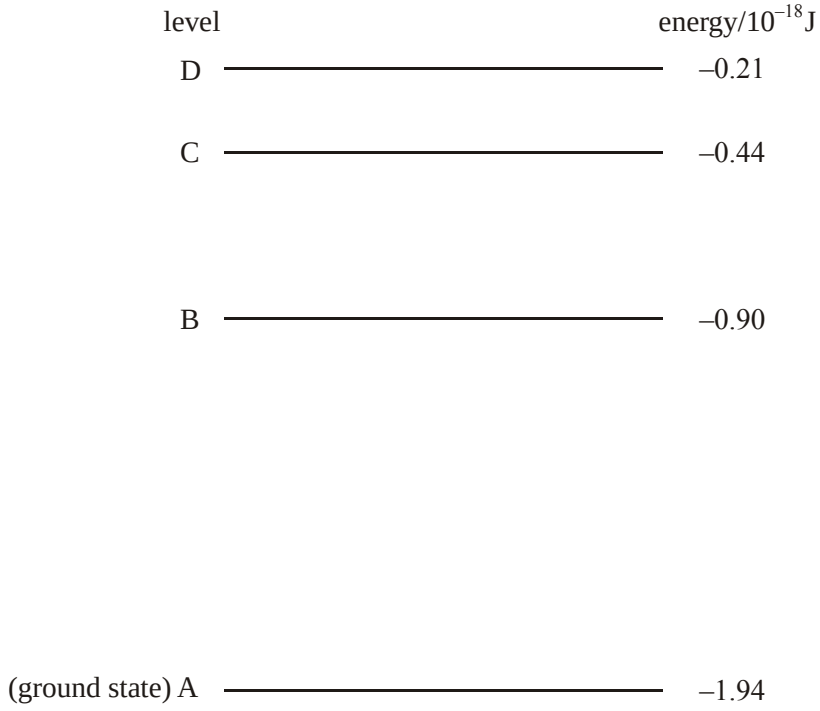
**(3)**

**(Total 6 marks)**

**17.** The diagram shows some of the electron energy levels of an atom.




An incident electron of kinetic energy $4.1 \times 10^{-18}$ J and speed $3.0 \times 10^{6}$ m $s^{-1}$ collides with the atom represented in the diagram and excites an electron in the atom from level B to level D.

(a) For the incident electron, calculate

(i) the kinetic energy in eV,

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(ii) the de Broglie wavelength.

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**(4)**

(b) When the excited electron returns directly from level D to level B it emits a photon.
Calculate the wavelength of this photon.

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**(3)**
**(Total 7 marks)**

**18.** (a) (i) Name a force which acts between an up quark, u, and an electron. Explain, with reference to an exchange particle, how this force operates.

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

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(ii) With what particle must a proton collide to be annihilated?

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**(4)**

(b) A sigma plus particle, $\Sigma^+$, is a baryon.

(i) How many quarks does the $\Sigma^+$ contain?

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(ii) If one of these quarks is an s quark, by what interaction will it decay?

.....

(iii) Which baryon will the $\Sigma^+$ eventually decay into?

.....

**(3)**

**(Total 7marks)**

**19.** The equation

$$p \longrightarrow n + \beta^+ + \nu_e$$

represents the emission of a positron from a proton.

(a) Energy and momentum are conserved in this emission.
What other quantities are conserved in this emission?

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**(3)**

(b) Draw the Feynman diagram that corresponds to the positron emission represented in the equation.

**(4)**

(c) Complete the following table using ticks ✓ and crosses ✗.

| **particle** | **fundamental particle** | **meson** | **baryon** | **lepton** |
|---|---|---|---|---|
| p | | | | |
| n | | | | |
| $\beta^+$ | | | | |
| $\nu_e$ | | | | |

**(4)**
**(Total 11 marks)**

**20.** (a) The photoelectric effect is represented by the equation

$$hf = \phi + E_k.$$

What does $E_k$ represent?

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**(2)**

(b) A metal plate is illuminated with electromagnetic radiation of wavelength 190 nm. The metal has a work function of $7.9 \times 10^{-19}$ J.

(i) Calculate the frequency of the incident electromagnetic radiation.

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(ii) Show that the metal plate will emit photoelectrons when illuminated with radiation of this wavelength.

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(iii) The radiation incident on the metal plate remains at a constant wavelength of
190 nm but its intensity is now doubled.
State and explain the effect this has on the emitted photoelectrons.

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

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**(6)**
**(Total 8 marks)**

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

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

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**(4)**

(b) A $^{239}_{92}U$ nucleus may decay by emitting **two** $\beta^-$ 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)**

**22.** In a radioactive decay of a nucleus, a $\beta^+$ particle is emitted followed by a $\gamma$ photon of wavelength $8.30 \times 10^{-13}$ m.

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

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(ii) Calculate the energy of the $\gamma$ photon.

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

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**(6)**

(b) Name the fundamental interaction or force responsible for $\beta^+$ decay.

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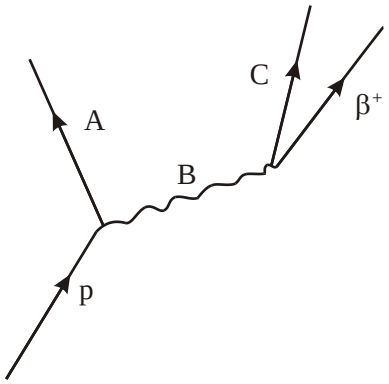
**(1)**

(c) $\beta^+$ decay may be represented by the Feynman diagram.




Name the particles represented by A, B and C.

A .....

B .....

C .....

**(3)**

**(Total 10 marks)**

**23.** Some subatomic particles are classified as *hadrons.*

(a) What distinguishes a hadron from other subatomic particles?

.....

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**(1)**

(b) Hadrons fall into two subgroups. Name each subgroup and describe the general structure of each.

subgroup 1 .....

.....

subgroup 2 .....

.....

**(3)**

(c) The following equation represents an event in which a positive muon collides with a neutron to produce a proton and an antineutrino.

$$n + \mu^{+} \Rightarrow p + \bar{\nu}_{\mu} .$$

Show that this equation obeys the conservation laws of charge, lepton number and baryon number.

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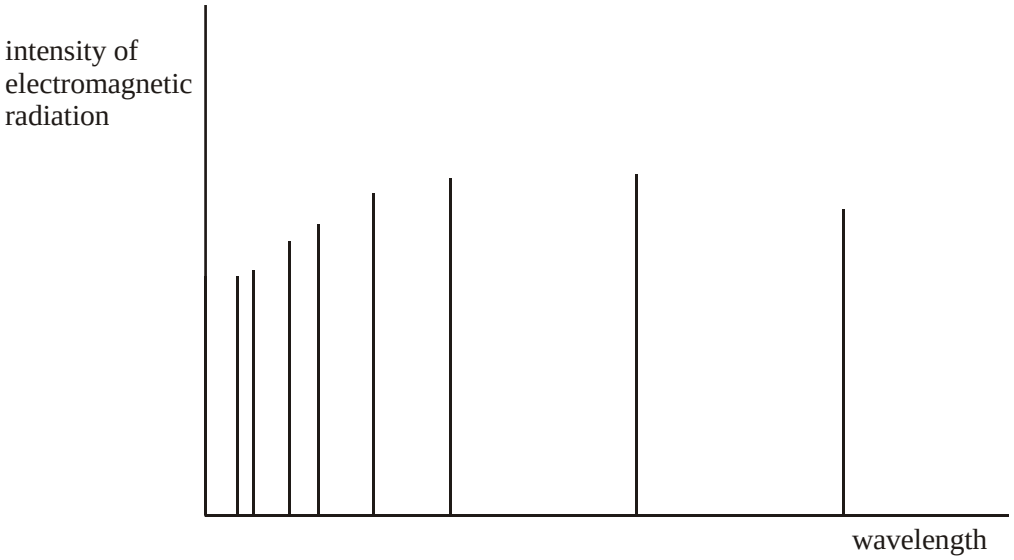
**(3)**

**(Total 7 marks)**

**24.** (a) Explain what happens to electrons in hydrogen atoms when a spectrum, such as that represented below, is produced.

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

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**(4)**

(b) A fluorescent tube is normally coated on the inside with a powder. The tube is then filled with mercury vapour at low pressure. When the tube is switched on, the mercury vapour emits ultraviolet electromagnetic radiation.

Explain how this ultraviolet radiation causes the powder to emit electromagnetic radiation as well. State the difference between the radiations emitted by the mercury vapour and the powder.

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

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**(4)**
**(Total 8 marks)**

**25.** A proton and an electron have the same velocity. The de Boglie wavelength of the electron is $3.2 \times 10^{-8}$ m.

(a) Calculate,

(i) the velocity of the electron,

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.....

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.....

(ii) the de Broglie wavelength of the proton.

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**(4)**

(b) (i) State what kind of experiment would confirm that electrons have a wave-like nature. Experimental details are not required.

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(ii) State why it is easier to demonstrate the wave properties of electrons than to demonstrate wave properties of protons.

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**(2)**

**(Total 6 marks)**