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90522

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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

For Supervisor's use only

Level 3 Physics, 2008

90522 Demonstrate understanding of atoms, photons and nuclei

Credits: Three
9.30 am Tuesday 25 November 2008

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

For all numerical answers, full working must be shown. The answer should be given with an SI unit to an appropriate number of significant figures.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

For Assessor's use only — **Achievement Criteria**

Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and / or relationships.	Give explanations that show clear understanding in terms of phenomena, concepts, principles and / or relationships.
Solve straightforward problems.	Solve problems.	Solve complex problems.

Overall Level of Performance (all criteria within a column are met)

You are advised to spend 35 minutes answering the questions in this booklet.

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You may find the following formulae useful.

$E = \mathrm{h}f$	$\mathrm{h}f = \phi + E_K$	$E = \Delta mc^2$	$E_n = -\frac{\mathrm{hcR}}{n^2}$
$\frac{1}{\lambda} = \mathrm{R}(\frac{1}{S^2} - \frac{1}{L^2})$	$E_\mathrm{P} = qV$	$v = f\lambda$	

QUESTION ONE: NUCLEAR REACTIONS

Nuclear rest mass data

Electron:	$9.11\,939 \times 10^{-31}$ kg
Proton:	$1.672\,623 \times 10^{-27}$ kg
Neutron:	$1.674\,929 \times 10^{-27}$ kg
Promethium-147:	$243.906\,111 \times 10^{-27}$ kg
Neodymium-146:	$242.243\,122 \times 10^{-27}$ kg
Neodymium-147:	$243.908\,613 \times 10^{-27}$ kg
Speed of light	3.00×10^{8} m s^{-1}
Charge on an electron	1.602×10^{-19} C

The radiated energy of the substance promethium-147 can be used on the hands of luminous watches to produce light. Promethium-147 is not a naturally occurring substance. It is made by bombarding neodymium-146 with neutrons to produce neodymium-147, which then decays to promethium-147.

(a) Show that the binding energy per nucleon of promethium-147 ($^{147}_{61}\mathrm{Pm}$) is 1.3×10^{-12} J.

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The nuclear equation for the bombardment of a neodymium-146 nucleus with a neutron is:

$$^{146}_{60}\text{Nd} + {}^{1}_{0}n \rightarrow {}^{147}_{60}\text{Nd}$$

(b) The mass of a nucleus of Nd-147 is less than the total mass of a Nd-146 nucleus plus a neutron.

State the term to describe this apparent loss of mass.

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(c) Show that the 'missing mass' in this reaction is 9.438×10^{-30} kg.

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The second reaction is the radioactive decay of $^{147}_{60}\text{Nd}$ (neodymium-147) to $^{147}_{61}\text{Pm}$ (promethium-147).

$$^{147}_{60}\text{Nd} \rightarrow {}^{147}_{61}\text{Pm} + {}^{0}_{-1}e$$

(d) Calculate the energy released during this reaction.
Express your answer in electron volts.

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energy = ___ eV

(e) By considering both energy **and** binding energy per nucleon of Nd-147 and Pm-147, explain why a neodymium-147 nucleus has more mass than its decay products.

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QUESTION TWO: ENERGY LEVELS

Planck's constant = 6.63×10^{-34} J s
Speed of light = 3.00×10^{8} m s^{-1}

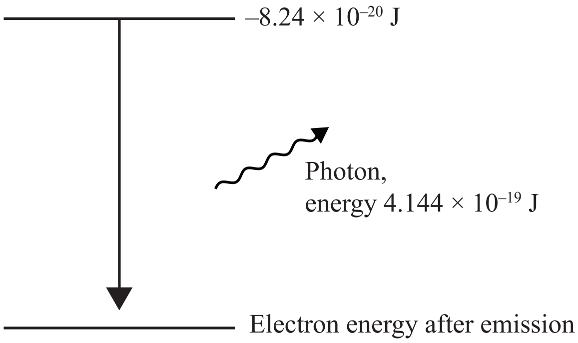
A 'black' lamp produces photons that are in the ultraviolet (UV) part of the electromagnetic spectrum. When UV is absorbed by some materials, it makes them glow in the dark. These materials are called *phosphors*. The white T-shirt in the photo glows because the detergent it was washed in contains phosphors that remain in the fabric after laundering. When an electron in a phosphor is excited by a UV photon, it comes down from its excited state by emitting a visible photon. Some of the original UV energy is retained in the phosphor as thermal energy.

An electron is excited by a UV photon, causing a visible photon of frequency 6.250×10^{14} Hz and energy 4.144×10^{-19} J to be emitted.

(a) Calculate the wavelength of the light photon. Round your answer to the correct number of significant figures.

wavelength = ______________

(b) Suggest a reason why the photons **emitted** from the phosphor are in the visible region of the electromagnetic spectrum but not in the X-ray region.



(c) The visible photon is emitted when the excited electron drops to a lower energy level.

If the excited electron has an energy of -8.24×10^{-20} J, calculate the energy of the electron **after** the photon has been emitted.

energy = ____________

(d) The UV photon whose energy was used to excite the electron has a frequency of 3.86×10^{15} Hz.

Calculate the amount of heat energy gained by the phosphor after one absorption-emission event.

heat energy = ____________

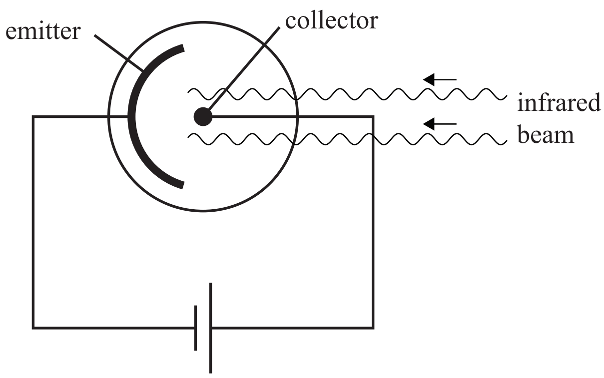
(e) The **colour** of the T-shirt under the 'black lamp' light is **white**. White light is seen when light of many different wavelengths is present.

Explain what this tells you about the energy levels in the phosphor material.

QUESTION THREE: PHOTOELECTRIC EFFECT

Planck's constant = 6.63×10^{-34} J s

One way in which automatic doors operate is to have a beam of infrared radiation directed on to a photocell. The beam is arranged so that it is broken if someone approaches the door and stops the radiation hitting the photocell. A simple model of the operation of the system is shown in the diagram below. A sensor sends a signal to the door opener when the current in the circuit stops.



The infrared radiation has frequency 1.32×10^{13} Hz.

(a) Calculate the energy of the infrared photons.

energy = ______________

(b) Explain how the infrared photons cause current in the circuit.

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(c) One of the materials considered for the emitter plate has a work function energy of 8.94×10^{-21} J.

Explain whether this material would be suitable.

(d) The material that is finally chosen for the emitter plate has a threshold frequency of 9.85×10^{12} Hz.

Calculate the maximum energy of the photoelectrons released.

energy = ______________

Extra paper for continuation of answers if required.
Clearly number the question.

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