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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

National Certificate of Educational Achievement
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Level 3 Physics, 2006

90522 Demonstrate understanding of atoms, photons and nuclei

Credits: Three
9.30 am Monday 20 November 2006

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, and the answer must be rounded to the correct number of significant figures and given with an SI unit.

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 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) M		

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

Assessor's use only

You may find the following formulae useful.

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

QUESTION ONE: NUCLEAR REACTIONS

Mass of nuclei:

- neutron: 1.67492×10^{-27} kg
- proton: 1.67353×10^{-27} kg
- deuterium: 3.34449×10^{-27} kg
- tritium: 5.00827×10^{-27} kg
- helium-4: 6.64648×10^{-27} kg
- lithium-6: 9.98835×10^{-27} kg

Speed of light = 3.00×10^8 m s^{-1}

Three bottles of water and some rocks can provide, in theory, enough energy for a family for one year. The water and rocks can be used to obtain the raw materials for a thermonuclear reaction that can take place between deuterium and tritium.

Tritium can be made from lithium $^6_3$Li, which can be extracted from the rocks.

(a) Show that the mass deficit of a lithium nucleus is 5.700×10^{-29} kg.

$3p + 3n = 3 \times 1.673 + 3 \times 1.674 = 1.004535 \times 10^{-26}$

$3p + 3n -$ lithium 6 $= 1.004535 \times 10^{-26} - 9.98835 \times 10^{-2}$

$\Delta m = 5.7 \times 10^{-29}$

A2

(b) Calculate the binding energy per nucleon for the lithium nucleus.

$E = mc^2$ $\quad E = 5.7 \times 10^{-29} \times (3 \times 10^8)^2$ $\quad E = \frac{5.13 \times 10^{-12}\ J}{6}$

M2

binding energy per nucleon = 8.55×10^{-13} J

Assessor's use only

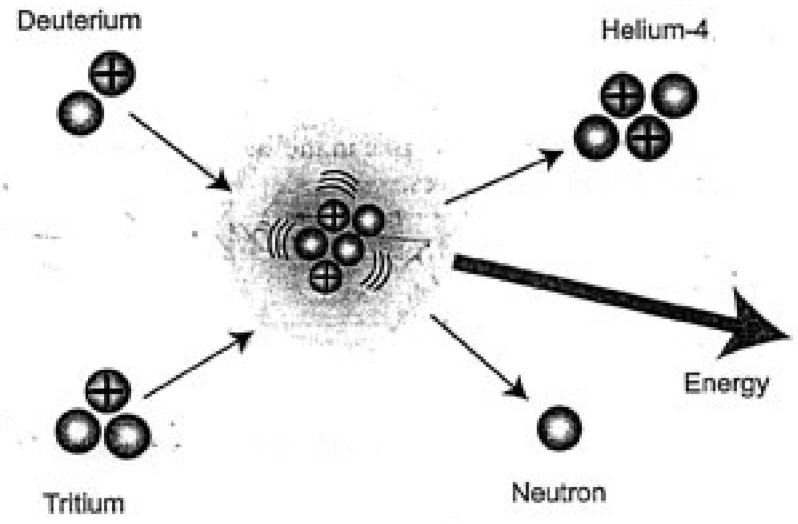
(c) State how the binding energy per nucleon can indicate the **stability** of a nucleus.

The greater the binding energy, the more energy required to split the nucleus apart.

No mention of how this relates to stability.

NA

Deuterium (hydrogen–2) can be extracted from the water. Thermonuclear reactors heat a mixture of deuterium and tritium to 100 million degrees Celsius to produce the reaction illustrated below.



Source www.iter.org

The nuclear equation for this reaction is: ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$

(d) Calculate the amount of energy produced in this reaction.

$3.34449 \times 10^{-27} + 5.00827 \times 10^{-27} = 6.64648 \times 10^{-27} + 1.67492 \times 10^{-27}$

$\Delta m = 3.136 \times 10^{-29}$

$E = \Delta m c^2$

$E = 3.136 \times 10^{-29} \times (3 \times 10^8)^2$

energy = 2.82×10^{-12} J

M2

(e) Explain why it is necessary for the temperature to be so **high** for this reaction to occur.

The Deuterium and Tritium molecules must be moving very quickly in order to collide. The small but very positively charge nucleus's repel each other very strongly and an enormous speed, and therefore an enormous energy level, must be reached for the reaction to occur.

M1

QUESTION TWO: SOLAR POWER

Assessor's use only

Rydberg's constant $= 1.097 \times 10^{7}\ m^{-1}$
Planck's constant $= 6.63 \times 10^{-34}$ J s
Speed of light $= 3.00 \times 10^{8}\ m\,s^{-1}$

Nuclear reactions in the Sun produce light. The main element in the Sun is hydrogen. The spectrum of hydrogen can be observed in the laboratory with a hydrogen discharge tube.
The visible lines in the hydrogen spectrum are called the Balmer series and are described by the formula:

$$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$$

where $S = 2$.

(a) Calculate the wavelength of the lowest frequency line in the Balmer series (L = 3). Give the answer to the correct number of significant figures.

$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$ $\frac{1}{\lambda} = 1.097 \times 10^{7}\left(\frac{1}{4} - \frac{1}{9}\right)$

wavelength = 6.6×10^{-7} m

A2

NA

sig figs wrong

(b) Explain how light of **this particular** frequency is produced in the hydrogen atom.

When the electrons of hydrogen drop from an excited state (n=3) to a ground state (n=2) they release energy as electromagnetic radiation. The frequency of the light depends on the energy drop of the electron, and this particular frequency is released by an electron dropping from the 3rd to the 2nd energy level.

M1

(c) An electron in the 6th excited state (L = 7) returns to the ground state in two jumps. It releases one photon with a wavelength of 2.165×10^{-6} m.

Assessor's use only

What is the wavelength of the second photon?

~~$E_6 = \frac{hcR}{n^2} = \frac{6.63\times10^{-34} \times 3\times10^8 \times 1.097\times10^7}{7^2 \cdot 6}$~~

~~$E_6 = 4.45\times10^{-20}$~~ ~~$E = hf = 6.63\times10^{-34} \times 1.39\times10^{14}$~~
~~$= 9.19\times10^{-20}$ J.~~

~~$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{4} - \frac{1}{49}\right)$~~ 1st photon $7 \rightarrow 4$
2nd photon $4 \rightarrow 2$

$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{4} - \frac{1}{16}\right)$ $\frac{1}{\lambda} = 2056875$
$\lambda = 4.86\times10^{-7}$ m

wavelength = 4.86×10^{-7} m.

A₂ Second drop should be 4→1

(d) The Sun emits **all** wavelengths. However, when a solar spectrum is observed on Earth, it contains black lines that correspond to missing wavelengths.

Give an explanation, in terms of energy absorption by electrons, for why some of the wavelengths of light in the solar spectrum are missing when the light reaches Earth.

When the light from the sun strikes the atmosphere some frequencies of light are absorbed by electrons in the molecules that make up the atmosphere. These frequencies therefore are absorbed and so do not make it to Earth's surface where the spectroscope is located, leaving gaps in the spectrum.

no mention of specific frequencies linked to electron energy transitions

M₁

QUESTION THREE: NIGHT VISION CAMERA

Planck's constant = 6.63×10^{-34} J s

A night vision camera, like the one shown below, detects low levels of light on the photo-cathode, which releases a few electrons. A photomultiplier increases the number of electrons, which then hit the screen to produce an image.

(a) Name the **effect** that causes electrons to be released by the photo-cathode.

Photo-electric effect.

A

(b) The photo-cathode material of this night vision camera prevents it detecting infrared radiation. State **why** this is so.

The work-function of the photo-cathode is higher than the frequency of infra-red, so no IR registered

NA

The photo-cathode is made of a material that has a work function of 2.58×10^{-19} J.

(c) Calculate the lowest frequency of light that could release a photoelectron.

$hf = \phi \qquad \frac{2.58 \times 10^{-19}}{6.63 \times 10^{-34}} = f = 3.89 \times 10^{14}$ Hz

frequency = 3.89×10^{14} Hz

A2