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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 … s the number at the top of this page.

You should answer ALL …

For all numerical answe… …ded to the correct number of significant fig…

For all 'describe' or 'exp… …y with all logic fully explained.

Formulae you may fin…

If you need more space … booklet and clearly number the question.

Check that this booklet … ges is blank.

Overall

→ student knows and can identify correct ideas 1(c) 2(b) 3(a)

But fails to provide correct explanations 2(b) 3(d)

In particular ~~struggles~~ ~~both the photo-electric~~ confuse ideas of photons and electrons (2(b) 3(b)).

Calculations were done well where information was clear or relatively easily extracted 1(c) (d) 2(a) 3(c)

But the student was unable to perform calculations involving more than one concept 2(c) 3(e)

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)		A

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.

$(3 \times 1.67353 \times 10^{-27}) + (3 \times 1.67492 \times 10^{-27})$ ~~5.02476~~ $= 1.004535 \times 10^{-26}$

$1.004535 \times 10^{-26} - 9.98835 \times 10^{-27}$ ~~[crossed out]~~ $= 5.7 \times 10^{-29}$ kg.

A₂

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

$E = mc^2$

$= 5.7 \times 10^{-29} \times 3 \times 10^8$

$= 5.13 \times 10^{-12}$

A₂

binding energy per nucleon = 5.13×10^{-12} J

Correct total binding energy

Correct total binding energy - but failed to change to per nucleon

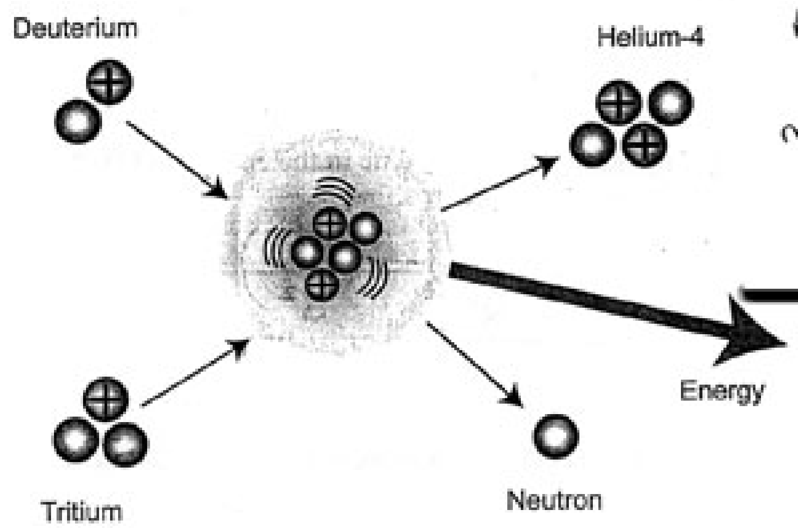
(c) State how the binding energy per nucleon can indicate the **stability** of a nucleus.

if a nucleus has more binding energy then it will be harder to seperate it. so more binding energy means more stable.

Assessor's use only

A1

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.



A good clear statement. more binding energy means more stable. (2nd part of statement)

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.

$(3.34449 \times 10^{-27} + 5.00827 \times 10^{-27}) = 8.35276 \times 10^{-27}$

$6.64648 \times 10^{-27} + 1.67492 \times 10^{-27}) = 8.3214 \times 10^{-27}$

$8.35276 \times 10^{-27} - 8.3214 \times 10^{-27} = 3.136 \times 10^{-29}$

$E = mc^2$

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

$= 2.8224 \times 10^{-12}$

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.

Because to get the electrons moving around and reperating them from the neucleus. The heat excites the electrons. So they jump around and make new connections.//

NA

QUESTION TWO: SOLAR POWER

Assessor's use only

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

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:

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

$v = f\lambda$

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.

$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\frac{1}{\lambda} = 1523611$

$\lambda = 6.56 \times 10^{-7}$

wavelength = 6.56×10^{-7} m

A2

NA

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

a photon of light falls from the 3rd energy level to the 2nd energy level. This particular ~~distance~~ energy drop, produces that frequency.

3 → 2 recognised but photon not electron!

A1

Correct transition BUT should be an electron transition producing a photon.

(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?

$\frac{1}{\lambda} = 1.097\times10^{7}\left(\frac{1}{1^2} - \frac{1}{7^2}\right)$

$\frac{1}{\lambda} = 10746122.45$

$\lambda = 9.31\times10^{-8}$

$9.31\times10^{-8} - 2.165\times10^{-6} = 2.072\times10^{-6}$ m

NA

wavelength =

(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.

Because

NA

Assessor's use only

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.

photoelectric effect. — A1

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

because the metal will only give off light if it is of a particular frequency enfared radiation is not that freqeuncy — 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.

The student identifies emission of light rather than the emission of electrons.

$E = hf$

$\frac{E}{h} = f$

$3.8914 \times 10^{14} = f$

frequency = 3.89×10^{14} Hz — A2

(d) Explain the effect on the number **and** energy of the electrons released when the frequency of the light is decreased.

Assessor's use only

If the frequency is any less than this, then there will be no electrons emitted. This is because then the frequency will be below the threshold frequency, and ~~[illegible]~~ not enough energy is given to ~~[illegible]~~ the electrons, to fly away. Instead the metal will just warm up.//

explain one part – frequency below threshold ~~but~~

~~this is a repeat of the physics to ... so~~

~~also what happens to the energy explained.~~

Identifies that frequency below threshold means no electrons. (line 2-4)

BUT

Needs to link to photon nature of em radiation, that a 1:1 photon to electron interaction.

A

The photo-cathode is replaced with a different material. When it is illuminated [illegible] wavelength 2.80×10^{-7} m, electrons with a maximum kinetic energy of $3.04 \times$ [illegible]

(e) Calculate the threshold frequency for the material.

$hf = \phi + E_k$

$\phi = E_k$

$\frac{3.04 \times 10^{-19}}{6.63 \times 10^{-34}} = f$

4.59×10^{14} Hz =//

threshold frequency = 4.59×10^{14} Hz//

NA