Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2017

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 6 – Atomic Physics

Student Number: In figures

In words

Mark: $\overline{}$ 50

Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: sixty minutes

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	-	-	-	-	-
Section Two: Problem-solving	8	8	60	50	100
Section Three: Comprehension	-	-	-	-	-
				Total	100

Instructions to candidates

1. The rules for the conduct of examinations at Holy Cross College are detailed in the College Examination Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

6. Answers to questions involving calculations should be ***evaluated and given in decimal form.*** It is suggested that you quote all answers to ***three significant figures***, with the exception of questions for which estimates are required. Despite an incorrect final result, credit may be obtained for method and working, providing these are ***clearly and legibly set out***.

7. Questions containing the instruction "estimate" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

8. Note that when an answer is a vector quantity, it must be given with magnitude and direction.

9. In all calculations, units must be consistent throughout your working.

1. The photoelectric effect experiment supports the particle model of light rather than the wave model of light. The following are observed in a photoelectric effect experiment.

Observation 1: The number of emitted electrons (the photocurrent) depends on the intensity of the incident light.
Observation 2: The energy of emitted electrons depends only on the frequency of the incident light and is independent of the intensity.
Observation 3: The energy of the emitted electrons depends on the metal surface involved.

The particle model can account for all the above three observations. The wave model can explain two of these observations but not a third.

(a) Select the observation that the ***wave model cannot explain***. (1 mark)

Observation number 2 (1)

(b) Explain how the ***particle model*** satisfactorily explains this observation. (2 marks)

- Energy of the incident photons depends on frequency ($E = hf$).
- As each photon interacts with one electron, the energy of the emitted electrons depends on frequency. (1)
- Changing the intensity of light varies the number of electrons, not their energy.
- Energy of the emitted electrons is not affected - only the number emitted. (1)

2. Students set up the following apparatus as shown in Figure 2 to study the photoelectric effect. They have a number of photocells with different metal plates in them.

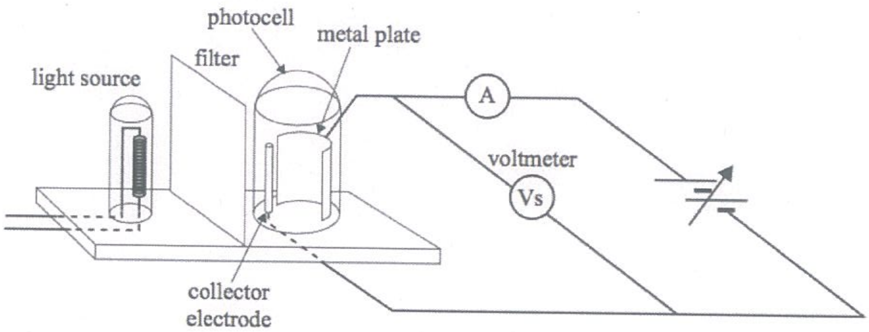


Figure 2

With a selenium plate in place, and using their data, the students draw the graph of maximum kinetic energy of photoelectrons versus frequency of light incident on the selenium plate. This is shown in Figure 3.

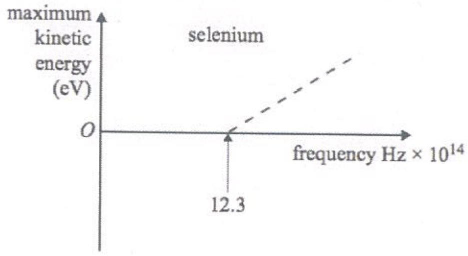
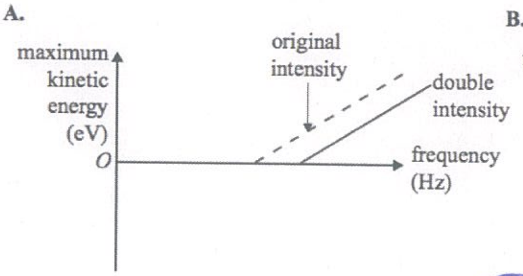


Figure 3

(a) The students double the intensity of the light source and repeat the experiment. Which one of the following graphs will now show their results? (Circle your answer.)

(2 marks)

A.



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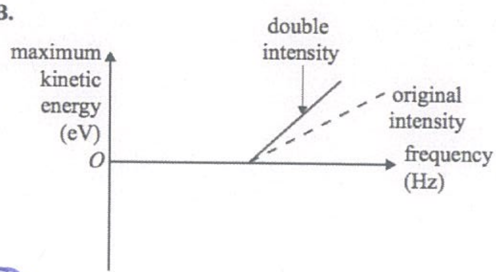

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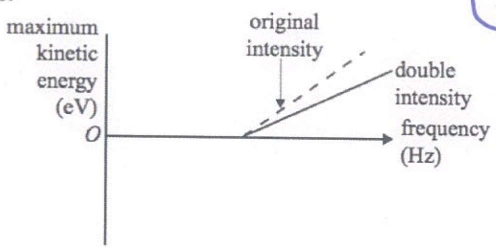
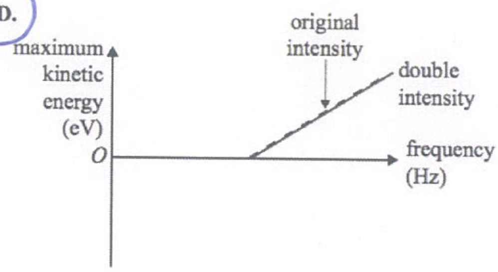


D.

(2)

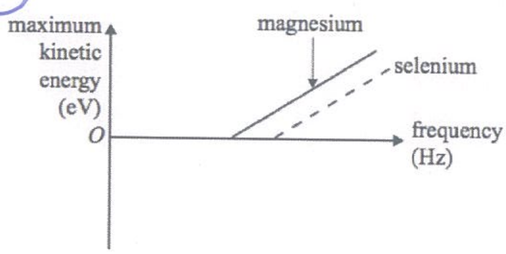


(b) The students now use a photocell with a magnesium plate. The work function of magnesium (3.7 eV) metal is less than that of selenium (5.1 eV).
The dotted line on each graph shows the original graph for selenium.

(i) Which one of the following graphs will now show their results? (Circle your answer.)

(1 mark)

(1) **A.**



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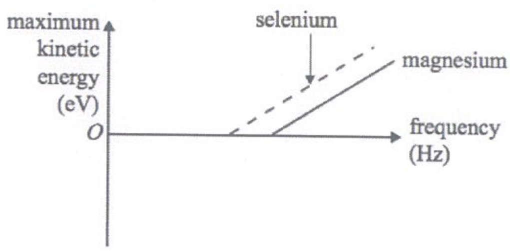

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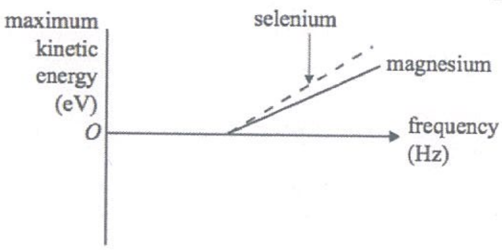
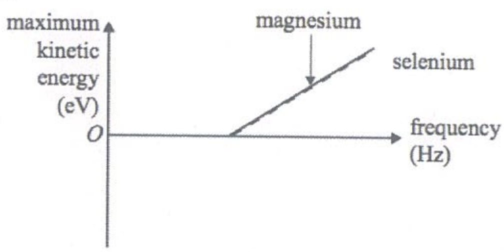


D.



(i) Explain your answer. (2 marks)

- A lower work function gives a lower threshold frequency. (1)
- Gradient should be the same. (1)

3. Sodium metal has a work function of 2.30 eV.

(a) What is the wavelength of light that will just eject an electron from a sodium surface? (3 marks)

$$W = hf_0 = \frac{hc}{\lambda_0}$$

$$\Rightarrow \lambda_0 = \frac{hc}{W} \quad (1)$$

$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(2.30)(1.60\times10^{-19})} \quad (1)$$

$$= \underline{5.40\times10^{-7}\ m} \quad (1)$$

(b) Light of wavelength 122 nm is incident on a sodium photocell.

(i) Calculate the maximum energy (in eV) of the emitted photoelectrons? (4 marks)

$$E_K(max) = hf - W$$

$$= \frac{hc}{\lambda} - W \quad (1)$$

$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(122\times10^{-9})} - (2.30)(1.60\times10^{-19}) \quad (1)$$

$$= 1.26\times10^{-18}\ J \quad (1)$$

$$= \underline{7.89\ eV} \quad (1)$$

(ii) Determine the maximum speed of the emitted photoelectrons? (3 marks)

$$E_K(max) = \frac{1}{2}mv^2$$

$$\Rightarrow \quad v = \sqrt{\frac{2E_K(max)}{m}} \quad (1)$$

$$= \sqrt{\frac{2(1.26\times10^{-18})}{(9.11\times10^{-31})}} \quad (1)$$

$$= \underline{1.66\times10^{6}\ ms^{-1}} \quad (1)$$

(iii) What is the cut-off (stopping) voltage of the photocell? (3 marks)

$$W = V_0 q = E_K(max)$$

$$\Rightarrow V_0 = \frac{E_K(max)}{q} \quad (1)$$

$$= \frac{1.26\times10^{-18}}{1.60\times10^{-19}} \quad (1)$$

$$= \underline{7.89\ V} \quad (1)$$

NOTE: Students may give a satisfactory explanation involving $E_K(max) = 7.89\ eV$.

4. A group of students were investigating the dispersion of light from a 1.30 mW red laser operating at 580 nm. If the laser is used for 35.0 s, calculate the number of photons transferred to the slits. (4 marks)

$$E = Pt$$

$$= (1.30\times10^{-3})(35.0) \quad (\tfrac{1}{2})$$

$$= 4.55\times10^{-2}\ J \quad (\tfrac{1}{2})$$

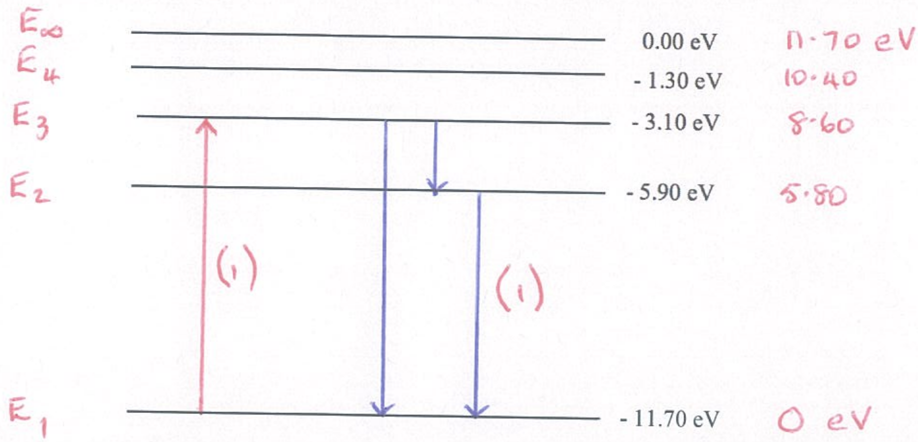
$$E = Nhf = \frac{Nhc}{\lambda} \quad \text{where } N = \#\text{electrons}$$

$$\Rightarrow \quad N = \frac{E\lambda}{hc} \quad (1)$$

$$= \frac{(4.55\times10^{-2})(580\times10^{-9})}{(6.63\times10^{-34})(3.00\times10^{8})} \quad (1)$$

$$= \underline{1.33\times10^{17}\ \text{electrons}} \quad (1)$$

5. A gas sample has the following energy levels in its atoms.



It is contained in a glass tube under normal pressure and bombarded with 8.80 eV electrons.

(a) On the diagram above, indicate the maximum upward transition of electrons possible from the ground state.

(1 mark)

(b) How many emission photons can be produced from this transition? Show these on the diagram.

(2 marks)

3 (1)

(c) Calculate the ***largest possible wavelength*** produced by these photons. (4 marks)

$E = \frac{hc}{\lambda}$ $\Rightarrow$ Longest λ has smallest E

$\therefore E_3 \rightarrow E_2$ (1 mark - uses correct levels)

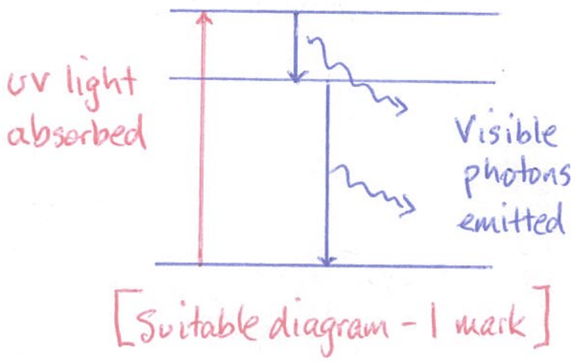
$E_3 - E_2 = \frac{hc}{\lambda}$ (1)

$\Rightarrow [(-3.10 - (-5.90)](1.60 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda}$ (1)

$\Rightarrow \lambda = 4.44 \times 10^{-7}$ m (1)

6. Some substances will ***fluoresce*** by photon absorption, while others will ***phosphoresce***.

(a) Explain how fluorescence occurs for an atom. ***Include a simple energy level diagram*** in your explanation. (3 marks)



- UV light is absorbed, causing an electron to transition to a higher level. (1)
- The electron returns to ground state in smaller energy steps, releasing photons of visible light. (1)

(b) In terms of electron transition, how is phosphorescence different to fluorescence? (1 mark)

- In phosphorescence, the excited electrons remain in a metastable state for an extended period of time. (1)

(c) "Optical whiteners" are added to laundry detergents to make fabric colours "brighter" and true in colour when viewed under sunlight. Explain how they achieve this. (2 marks)

- Optical whiteners fluoresce by absorbing UV light. (1)
- They emit mainly blue light, which when combined with the mainly yellow light of the sun, makes the colours appear brighter and normal in appearance. (1)

7. Fraunhofer lines are used by astrophysicists to study the elemental structures of stars, finding they are mainly composed of hydrogen gas. They appear as dark lines on a continuous colour spectrum.

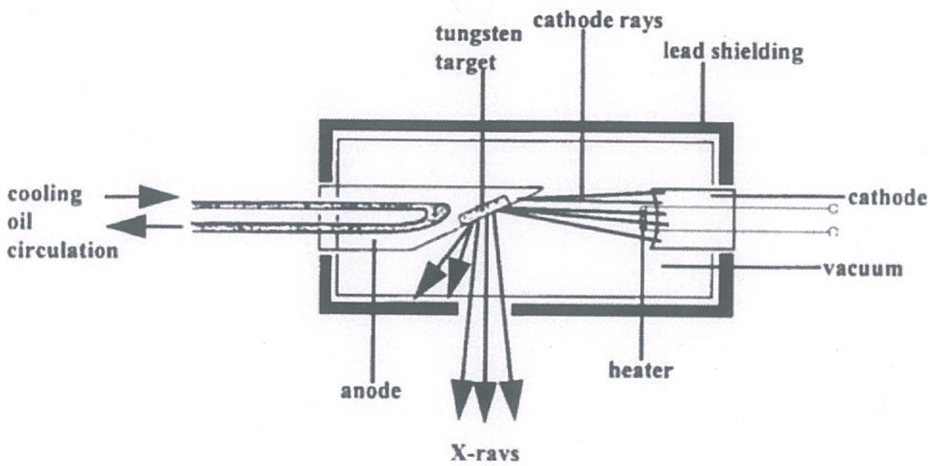
(a) What type of spectra is this? (1 mark)

line absorption spectra. (1)

(b) Explain how Fraunhofer lines are formed. (2 marks)

- light from the interior of a star passes through the relatively cool gases of its atmosphere (corona). (1)
- Certain frequencies of light are absorbed and re-emitted in all directions by the atoms of the atmosphere, causing dark lines to appear on the spectrum. (1)

8. An X-ray tube is shown in the following figure.



(a) Briefly answer the following questions.

(i) What is the function of the cathode? (1 mark)

- Provides electrons (by thermionic emission). (1)

(ii) Is the anode positively or negatively charged in relation to the cathode? (1 mark)

- positive (1)

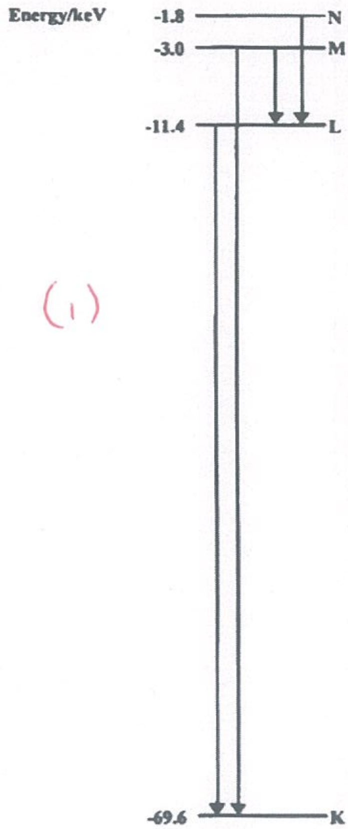
(iii) Why does the anode need to be cooled? (1 mark)

• Huge amount of heat is produced by the decelerating electrons. (1)

(iv) Explain why lead shielding surrounds the X-ray tube. (1 mark)

• Absorbs X-rays - protects the radiographers. (1)

(b) The diagram to the right shows the energy levels (in keV) for tungsten.



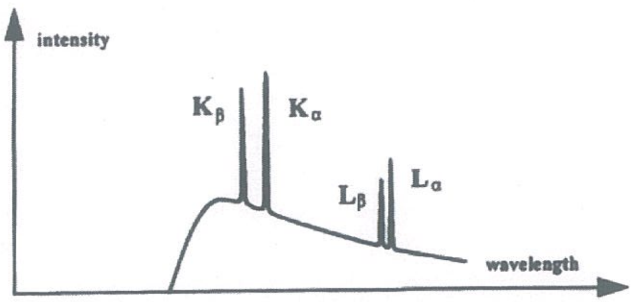
(i) What is the frequency of the transition from -3.00 keV to -69.6 keV? (3 marks)

$E_3 - E_1 = hf$

$\Rightarrow [(-3.0\times10^{3} - (-69.6\times10^{3})](1.60\times10^{-19}) = (6.63\times10^{-34})f$ (1)

[Conversion - 1 mark] $\Rightarrow$ $f = 1.61\times10^{19}$ Hz (1)

(ii) This transition is designated the K_β line in the diagram below showing the x-ray spectrum. What is the ***minimum potential difference*** that must be applied across the X-ray tube to observe the K_β line? Explain your answer. (2 marks)



• 69.6 keV (1)

• The inner electron must be completely knocked out of the atom to allow the downward transition. (1)

(c) Explain why there are characteristic "bumps" on the x-ray spectrum diagram above.

(3 marks)

- An inner electron is totally removed from the atom by a bombarding electron, leaving a "hole" in the inner shell. (1)
- An outer electron moves down to fill the "hole", releasing an X-ray photon of a particular frequency (seen as a "bump"). (1)
- As electrons from different outer shells can transition down to fill the "hole", there are several different frequencies of X-rays produced, leading to several "bumps". (1)