Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2018

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 6 – Atomic Physics

Student Number: In figures

Mark: $\overline{59}$

In words ______________________

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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	59	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. Physicists use the expression 'wave-particle duality' because light sometimes behaves like a particle and electrons sometimes behave like waves.

(a) What evidence do we have that light can behave like a particle? Explain how this evidence supports a particle model of light. [2 marks]

- Photoelectric effect. (1)
- Effect occurs above a threshold frequency - wave theory would allow energy to build up.
- Effect is immediate - there would be a delay as wave energy builds up.

EITHER (1)

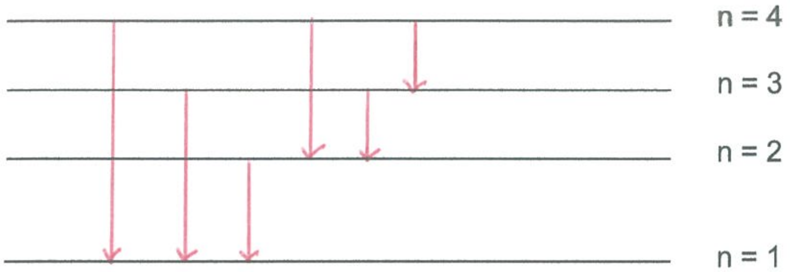
[Students could mention reflection - will need to give a good explanation]

(b) What evidence do we have that electrons can behave like waves? Explain how this evidence supports a wave model of electrons. [2 marks]

- Electron diffraction. (1)
- Electrons moving through a double-slit produce interference patterns like waves.
- Electrons diffract when reflected from a metal surface or passed through thin metal.

EITHER (1)

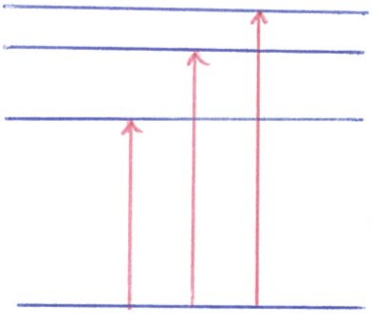
2. Argon gas is excited with sufficient energy to reach the n = 4 energy level as shown in the diagram below.



[$\frac{1}{2}$ mark each]

(a) On the diagram above, clearly label each of the possible transitions that would give rise to the ***emission spectra*** of the gas. [3 marks]

(b) How many lines would be seen in the ***absorption spectra*** for argon gas? Explain your answer. A simple diagram may help your explanation. [3 marks]



(1)

- 3 lines (1)
- Only energy from ground state up to each higher level is absorbed. (1)

(c) If ΔE (n=3 → n=1) is 6.70 eV, what would be wavelength of an emitted photon arising from this transition? [4 marks]

$$E_{3\to1} = hf = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{E_{3\to1}} \quad (1)$$

$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(6.70)(1.60\times10^{-19})} \quad (1)$$

Conversion (1)

$$= \underline{1.86\times10^{-7}\ \text{m}} \quad (1)$$

3. Taylah and Steven investigated the photoelectric effect by shining an ultraviolet light with a wavelength of 380 nm onto a clean metal surface. The stopping voltage was measured to be 1.50 V.

(a) Calculate the energy of the incident photons. [3 marks]

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

$$= \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{(380 \times 10^{-9})} \quad (1)$$

$$= \underline{5.23 \times 10^{-19}\ J} \quad (1)$$

(b) Determine the maximum kinetic energy of the resulting photoelectrons. [3 marks]

$$W = V_{co}q = E_K(max) \quad (1)$$

$$\Rightarrow E_K(max) = (1.50)(1.60 \times 10^{-19}) \quad (1)$$

$$= \underline{2.40 \times 10^{-19}\ J} \quad (1)$$

(c) Explain why no photocurrent is produced when the stopping voltage is applied between the cathode and the anode. [2 marks]

- The potential difference does work on the most energetic electrons. (1)
- Pushes the electrons back onto the cathode so they don't reach the anode. (1)

(d) What is the work function of this metal? [2 marks]

$$E = hf = W + E_K(max)$$

$$\Rightarrow W = hf - E_K(max) \quad (1)$$

$$= 5.23 \times 10^{-19} - 2.40 \times 10^{-19}$$

$$= \underline{2.83 \times 10^{-19} \text{ J}} \quad (1)$$

(e) Calculate the threshold frequency of this metal? [2 marks]

$$W = hf_0$$

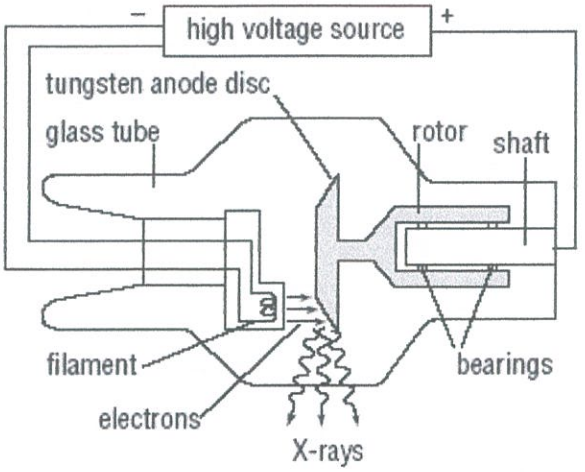
$$\Rightarrow f_0 = \frac{2.83 \times 10^{-19}}{6.63 \times 10^{-34}} \quad (1)$$

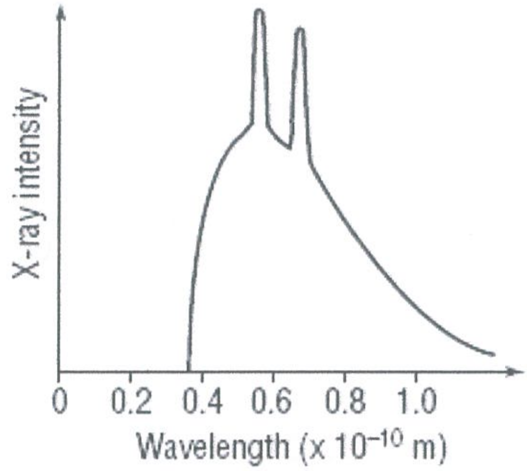
$$= \underline{4.27 \times 10^{14} \text{ Hz}} \quad (1)$$

(f) Explain why no photocurrent is produced when light of frequencies below the threshold frequency in part (e) is used, even at high intensities. [2 marks]

- For $f < f_0$, the energy of the photons is insufficient to remove an electron from the metal surface. (1)
- Electrons can only absorb one photon at a time, so intensity (number of photons) makes no difference. (1)

4. The diagrams below show a typical X-ray machine and the type of spectra it produces.





(a) During operation, the tungsten anode disc is rotated. Suggest reasons why they have to rotate the disk. [2 marks]

- most of the energy from the decelerating electrons is converted to heat. (1)
- Rotating the disk disperses heat over a larger area, which reduces the temperature rise and prevents damage or melting. (1)

(b) What is the frequency of the shortest wavelength X-ray produced by this machine? [3 marks]

From the graph: $\lambda = 0.35 \times 10^{-10}$ m (1)

$c = f\lambda$

$\Rightarrow f = \dfrac{3.00 \times 10^{8}}{0.35 \times 10^{-10}}$ (1)

$= 8.6 \times 10^{18}$ Hz (1)

(c) What ***high voltage*** (in kV) is being used to produce this spectrum? [3 marks]

$W = Vq = hf_{max}$

$\Rightarrow V = \dfrac{hf_{max}}{q}$ (1)

$= \dfrac{(6.63 \times 10^{-34})(8.6 \times 10^{18})}{(1.60 \times 10^{-19})}$ (1)

$= 3.6 \times 10^{4}$ V (1)

(d) Briefly explain the origin of the "spikes" in the intensity versus wavelength graph. [2 marks]

- Line emission spectra of the metal anode. (1)
- Inner electrons have been "knocked out" of the atom and outer electrons transition down to fill them, releasing characteristic wavelengths of light. (1)

(e) How would the intensity versus wavelength graph change if:

(i) you used a different metal element for the anode. [1 mark]

- Position of the spikes would change. (1)

(ii) you used a slightly higher voltage to accelerate the electrons. [1 mark]

- λ_{min} would decrease slightly
- Intensity of the spectrum would decrease slightly.

EITHER (1)

5. An industrial process uses a large commercial CO_2 laser for cutting steel plate. The laser has a power of 6.00×10^2 W and produces infra-red radiation of wavelength 10.6 μm.

(a) What is the energy per photon? [3 marks]

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

$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(10.6\times10^{-6})} \quad (1)$$

$$= \underline{1.88\times10^{-20}\ \text{J}} \quad (1)$$

(b) How many photons are released per second? [3 marks]

$$P = \frac{E}{t}$$

$$\Rightarrow E = Pt$$

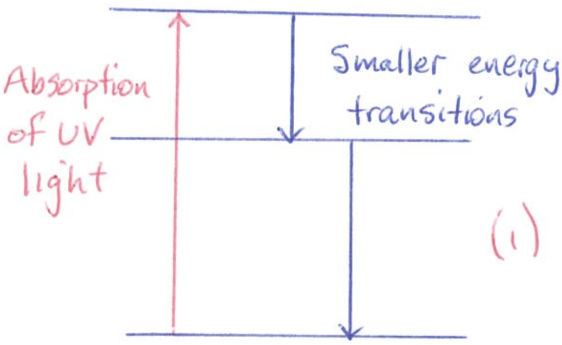
$$= (6.00\times10^{2})(1.00)$$

$$= 6.00\times10^{2}\ \text{J} \quad (1)$$

$$\text{Number } e^- = \frac{6.00\times10^{2}}{1.88\times10^{-20}} \quad (1)$$

$$= \underline{3.19\times10^{22}} \quad (1)$$

6. (a) With the aid of a diagram, explain the mechanism that causes ***fluorescence.*** [3 marks]

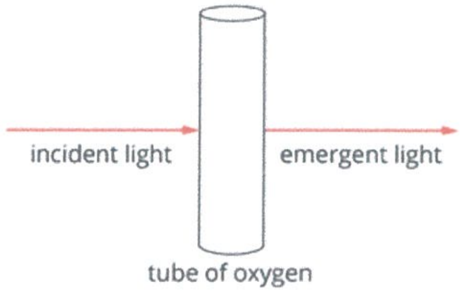


- UV light is absorbed by an electron in the ground state - moves to a higher energy level. (1)
- Electron transitions back to ground state in smaller energy drops, releasing photons in the visible spectrum. (1)

(b) Describe one difference between fluorescence and phosphorescence. [2 marks]

- Phosphorescence - electron stays in the higher energy level for an extended time. (1)
- Fluorescence - electron transitions back to ground state immediately. (1)

7. If a beam of white light is shone through a sample of oxygen gas as illustrated below and the emergent light examined through a spectroscope, rather than a continuous spectrum being observed, there will be a series of dark lines in the spectrum. Explain what causes this series of dark lines. [3 marks]



- The energy of the incident light is absorbed by electrons in the O_2 to excite them to higher levels. (1)
- These energies correspond to transitions of ground state electrons to higher energy levels. (1)
- Each transition absorbs light of specific frequencies, leaving dark lines on the spectrum of the emergent light. (1)

8. Consider a 160 g cricket ball moving at 140 kmh^{-1} and a high-speed electron moving at 0.900 *c*. Using the appropriate mathematical relationship and these two examples, explain why we do not experience or detect the wave-particle duality (wave-like behaviour) for macroscopic objects. [4 marks]

BALL

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$= \frac{(6.63 \times 10^{-34})}{(0.160)(38.9)} \quad (1)$$

$$= 1.06 \times 10^{-34} \text{ m} \quad (1)$$

ELECTRON

$$\lambda = \frac{h}{mv}$$

$$= \frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(0.900 \times 3.00 \times 10^{8})} \quad (1)$$

$$= 2.69 \times 10^{-12} \text{ m} \quad (1)$$

$\therefore$ λ_{BALL} is too small to measure, so it is not detected. (1)