Western Australian Certificate of Education
ATAR course examination, 2019

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 5 – Atomic Physics

Student Number: In figures

In words ______________________________

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Mark: $\frac{\quad}{41}$

Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: fifty 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	5	5	15	11	-
Section Two: Problem-solving	3	3	35	30	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. Photons of wavelength 290 nm are incident on a metal plate. The work function of the metal is 4.10 eV. Calculate the maximum kinetic energy of the emitted electrons. [3 marks]

$$E = hf = \frac{hc}{\lambda} = \phi + E_k(max)$$

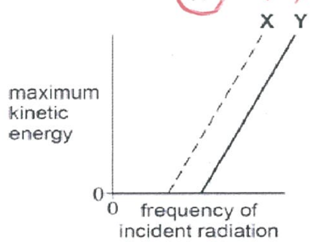
$$\Rightarrow E_k(max) = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(290\times10^{-9})} \;(1)\; + (4.10)(1.60\times10^{-19}) \;(1)$$

$$= \underline{2.99\times10^{-20}\ \text{J}} \;(1)$$

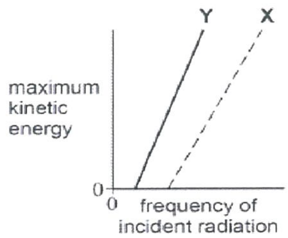
2. Line **X** on the graphs below shows how the maximum kinetic energy of emitted photoelectrons varies with the frequency of incident radiation for a particular metal.

(a) Which graph shows the results for a metal **Y** that has a higher work function than **X**? (Circle the correct answer.) [1 mark]

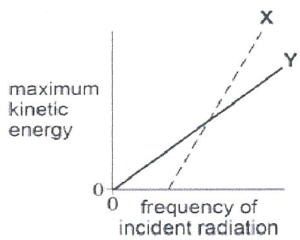
A (1)



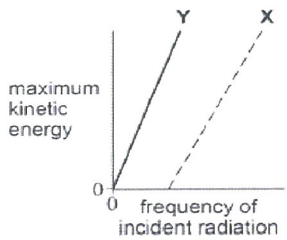
B



C



D



(b) Explain your choice. Include a sketch of a graph if this helps your explanation. [2 marks]

$$E = hf = \phi + E_k(max)$$

$$\Rightarrow E_k(max) = hf - \phi$$

- Plotting E_k vs f gives a gradient $= h$.
- $\therefore$ Gradient of X and Y must be the same. (1)
- Cut-off frequency must be greater for Y. (1)

3. A line emission and a line absorption spectrum of a particular gas were observed. Describe the differences observed between these two spectra. [3 marks]

- LINE EMISSION - bright lines on a dark background. (1)
- LINE ABSORPTION - dark lines on a continuous colour spectrum. (1)
- More lines in the emission spectra than the absorption spectra. (1)

4. Which statement suggests that electrons have wave properties? (Circle the correct answer.) [1 mark]

(a) Electrons are emitted in photoelectric effect experiments.
(b) Electrons are released when atoms are ionised.
(1) (c) Electrons produce dark rings in diffraction experiments.
(d) Electron transitions in atoms produce line spectra.

5. In an experiment to demonstrate the photoelectric effect, a charged metal plate is illuminated with light from different sources. The plate loses its charge when an ultraviolet light source is used but not when a red light source is used. What is the reason for this? (Circle the correct answer.) [1 mark]

(a) The intensity of the red light is too low.
(b) The wavelength of the red light is too short.
(c) The frequency of the red light is too high.
(1) (d) The energy of red light photons is too small.

6. (a) Light has a dual wave-particle nature. State and outline a piece of evidence for the wave nature of light and a piece of evidence for its particle nature. For each piece of evidence, outline a characteristic feature that has been observed or measured and give a short explanation of its relevance. [6 marks]

WAVE-LIKE
- light shows diffraction and interference patterns. (1)
- Young's double-slit experiment produced interference patterns. (1)
- Particle theory would predict 2 single bright images. (1)

PARTICLE-LIKE
- Photoelectric effect. (1)
- Need to be above threshold frequency for it to occur. (1)
- Wave theory predicts emission at all frequencies. (1)

(b) For a proton of kinetic energy 5.00 MeV:

(i) calculate its speed. [2 marks]

$$E_K = \frac{1}{2} m v^2$$

$$\Rightarrow \quad v = \sqrt{\frac{2E_K}{m}}$$

$$= \sqrt{\frac{2(5.00\times10^{6})(1.60\times10^{-19})}{(1.67\times10^{-27})}} \quad (1)$$

$$= \underline{3.09\times10^{7}\ \mathrm{ms^{-1}}} \quad (1)$$

(ii) calculate its de Broglie wavelength. [2 marks]

$$\lambda = \frac{h}{mv} = \frac{(6.63\times10^{-34})}{(1.67\times10^{-27})(3.09\times10^{7})} \quad (1)$$

$$= \underline{1.28\times10^{-14}\ \mathrm{m}} \quad (1)$$

7. When a clean metal surface in a vacuum is irradiated with ultraviolet radiation, electrons are emitted from the metal. The following equation relates the frequency of the incident radiation to the kinetic energy of the emitted electrons.

$$hf = \phi + E_k$$

(a) Briefly state what each of the following terms represents in the above equation. [3 marks]

(i) hf The energy of the bombarding photons. (1)

Must mention minimum and maximum.

(ii) ϕ The minimum energy required to remove an electron (1) from the surface.

(iii) E_k Maximum kinetic energy of the emitted electron. (1)

(b) (i) State what would happen to the number of photoelectrons ejected per second if the ultraviolet source were replaced by a source of red light of the same intensity but of frequency less than ϕ/h. [1 mark]

- No photoelectrons are emitted. (1)

(ii) What would the ***wave theory of light*** predict about the effect of using the red light source instead of an ultraviolet source? [1 mark]

- Energy from the waves builds up until a photoelectron is emitted.
- There is a time delay in emitting a photoelectron.

Either (1)

(iii) Use the ***quantum theory of light*** to explain the effect of using the red light source instead of an ultraviolet source. [3 marks]

- Each electron absorbs one photon.
- If $E = hf > \phi$, a photoelectron is emitted.
- Red light energy $< \phi$, so no photoelectron is emitted.

8.

$2{\cdot}18 \times 10^{-18}$ $E = 0$ ionisation level

$1{\cdot}94 \times 10^{-18}$ $E_2 = -2.42 \times 10^{-19}$ J level 2

$1{\cdot}63 \times 10^{-18}$ $E_1 = -5.48 \times 10^{-19}$ J level 1

0 $E_0 = -2.18 \times 10^{-18}$ J ground state

The diagram represents some of the energy levels of an isolated atom. An electron with a kinetic energy of 2.00×10^{-18} J makes an inelastic collision with an atom in the ground state.

(a) Calculate the speed of the electron just before the collision. [2 marks]

$$E_K = \frac{1}{2} m v^2$$

$$\Rightarrow \quad v = \sqrt{\frac{2E_K}{m}}$$

$$= \sqrt{\frac{2(2{\cdot}00 \times 10^{-18})}{(9{\cdot}11 \times 10^{-31})}}$$

$$= \underline{2{\cdot}09 \times 10^{6}\ \text{ms}^{-1}}$$

(b) (i) Show that the bombarding electron can excite the electron in the atom to excitation level 2. [2 marks]

$$E_2 - E_0 = -2{\cdot}42 \times 10^{-19} - (-2{\cdot}18 \times 10^{-18}) \quad (1)$$

$$= 1{\cdot}94 \times 10^{-18}\ \text{J} \quad < 2{\cdot}00 \times 10^{-18}\ \text{J}. \quad (1)$$

$\therefore$ Excited electron can reach E_2.

(ii) Calculate the wavelength of the radiation that will result when an atom in level 2 falls to level 1 and state the region of the spectrum to which this radiation belongs. [3 marks]

$$E_2 - E_1 = \frac{hc}{\lambda}$$

$$\Rightarrow \quad \lambda = \frac{hc}{E_2 - E_1}$$

$$= \frac{(6{\cdot}63 \times 10^{-34})(3{\cdot}00 \times 10^{8})}{-2{\cdot}42 \times 10^{-19} - (-5{\cdot}48 \times 10^{-19})} \quad (1)$$

$$= 6{\cdot}50 \times 10^{-7}\ \text{m} \quad (1)$$ $\therefore$ red light (1)

[visible light OK]

(c) Calculate the minimum potential difference through which an electron must be accelerated from rest in order to be able to ionise an atom in its ground state with the above energy level structure. [2 marks]

$$E = W = Vq$$

$$\Rightarrow 2.18 \times 10^{-18} = V(1.60 \times 10^{-19}) \quad (1)$$

$$\Rightarrow \underline{V = 13.6\,V} \quad (1)$$

(d) An atom can be excited by bombardment by electrons or by bombardment by photons. Explain why, for a particular transition, the photon must have an exact amount of energy whereas the free electron only needs a minimum amount of energy.

[3 marks]

- Transition upwards from ground state is an exact amount. (1)
- All of a photon's energy is absorbed and must equal the exact amount. (1)
- A bombarding electron can transfer part of its energy during the collision so it must have at least this exact amount of energy. (1)