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CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

12 ATAR Physics

Quantum Physics & Light Test 2016 (5%)

Student name: SOLN

1. The colour of a star depends on its surface temperature. Which of these colours indicates the highest temperature? **[1 mark]**

a) Blue
b) Green
c) Yellow
d) White

2. White light is shone through a glass bottle containing a solution of nickel chloride. The colour of the light that emerges out of the other side is a green-blue mixture. If this light is dispersed through a prism the type of spectrum that results is classified as: **[1 mark]**

a) Band emission
b) Band absorption
c) Line emission
d) Line absorption

3. Which of the following can occur when a photon strikes an atom: **[1 mark]**

a) It can lose all of its energy (or), it can lose part of its energy
b) It can lose part of its energy (or), it can lose none of its energy
c) It can lose all of its energy (or), it can lose none of its energy
d) It can lose all of its energy, it can lose part of its energy (or), it can lose none of its energy

4. What is the energy of a photon of green light with a wavelength of 535 nm? **[1 mark]**

a) 3.72×10^{-19} J
b) 3.54×10^{-40} J
c) 1.06×10^{-22} J
d) 3.54×10^{-31} J

4

5. Which of the following transitions in a hydrogen atom will emit a photon with the longest wavelength of light? **[1 mark]**

a) n = 3 to n = 4
b) n = 5 to n = 4
c) n = 2 to n = 1
d) n = 3 to n = 2

(1)

6. Covalent bonds in a molecule absorb radiation in the IR region and vibrate at certain frequencies. The HCl bond has a frequency of 8.652×10^{13} Hz. What wavelength corresponds to this frequency? **[1 mark]**

a) 3.467 nm
b) 3467 nm
c) 5733 nm
d) 3.733 nm

(1)

7. An office worker wants to heat a cup of coffee. She uses a 750W microwave oven, with a frequency of 2.5GHz, to heat 600mL of water in a jug. The water heats up but the jug remains cool during this time.

a) What is the wavelength of the microwave radiation? **[2 marks]**

(2)

$V = f\lambda \quad \therefore \quad \lambda = \frac{V}{f} = \frac{3 \times 10^8}{2.5 \times 10^9} = 0.12\ m.$

b) How much energy **(J & eV)** does one microwave photon possess? **[2 marks]**

(2)

$E = hf = (6.63 \times 10^{-34})(2.5 \times 10^9)$

$= 1.66 \times 10^{-24}\ J = 1.04 \times 10^{-5}\ eV.$

c) Given that it took 2.75 minutes to heat the water to an acceptable drinking temperature, how many photons were used to heat the water? **[4 marks]**

(4)

$(2.75)(60) = 165\ secs.$

$ENERGY = (750)(165) = 123750\ J.$

$\therefore \#\gamma's = \frac{123750}{1.66 \times 10^{-24}} = 7.46 \times 10^{29}\ \gamma's$

(10)

8. The element Mercury (Hg) has a work function of 4.50 eV.

a) Determine the threshold frequency for Mercury. **[4 marks]**

$E_K = hf - \phi$, but at f_0 $E_K = 0$.

$\therefore hf = \phi$, so $f = \frac{\phi}{h} = \frac{(4.5)(1.6 \times 10^{-19})}{(6.63 \times 10^{-34})}$. (4)

$\therefore f = 1.09 \times 10^{15}$ Hz.

b) When 250nm light is incident on the sample of Mercury, photoelectrons are emitted. Calculate the maximum speed of the photoelectrons that are emitted. **[5 marks]**

$E_{K(max)} = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(250 \times 10^{-9})} - (7.2 \times 10^{-19})$

$= 7.56 \times 10^{-20}$ J. (5)

$v^2 = \frac{2E}{m} = \frac{2(7.56 \times 10^{-20})}{9.11 \times 10^{-31}}$ $\therefore v = 4.07 \times 10^5$ ms^{-1}.

c) The photoelectric effect marked a major departure from the theories of light established in classical physics. Explain what is meant by the classical nature of light. **[1 mark]**

- LIGHT IS A WAVE. (1)

d) How can the classical nature of light be shown to be true? **[1 mark]**

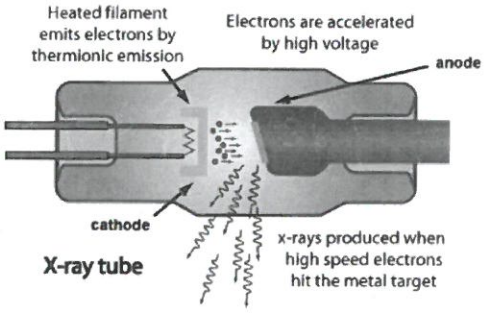
- INTERFERENCE OF WAVES BY YOUNG'S SLITS. (1)

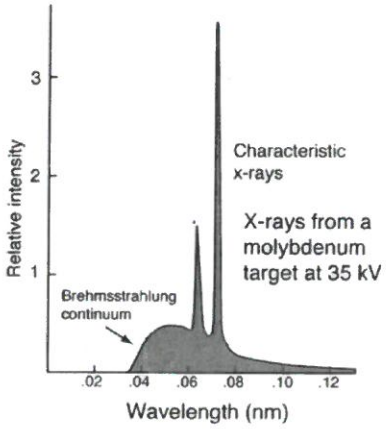
e) How does the photoelectric effect deviate from that described in part (d)? **[1 mark]**

PE SHOWS THAT LIGHT IS A PACKET (QUANTUM) OF ENERGY KNOWN AS A PHOTON. (1)

(12)

9. The following diagrams show a 30 kV X-ray tube and a graph of the X-ray energy range produced.





a) Why is a range of X-ray energies produced? **[2 marks]**

e⁻s UNDERGO SEVERAL COLLISIONS WITH THE TARGET METAL. e⁻s LOSE SOME OF THEIR ENERGY RESULTING IN PHOTONS OF THAT ENERGY. THIS RESULTS IN PHOTONS OF DIFF ENERGIES. (2)

b) How are the peak energy X-rays produced? **[2 marks]**

+ K_α : L → K TRANSITION.
+ K_β : M → K — " —

(2)

c) What is the wavelength of the most energetic X-ray produced? **[3 marks]**

$$E = Vq$$
$$= (30{,}000)(1.6 \times 10^{-19})$$
$$= 4.8 \times 10^{-15}\ J.$$

(3)

$$f = \frac{E}{h} = \frac{4.8 \times 10^{-15}}{6.6 \times 10^{-34}} = 7.24 \times 10^{18}\ Hz.$$

(7)

d) How fast are the electrons travelling when they strike the metal target?
[3 marks]

$E_K = \frac{1}{2}mv^2 = Vq = 4.8 \times 10^{-15}\ J.$

$\therefore v^2 = \frac{2E_K}{m} = \frac{(2)(4.8 \times 10^{-15})}{9.11 \times 10^{-31}}$

$v = 1.03 \times 10^8\ ms^{-1}$

(3)

e) The tube voltage can be varied. On the graph below draw:

i) The graph showing the range and intensity of the X-rays produced if a higher accelerating voltage (40 kV) is used. **[2 marks]**

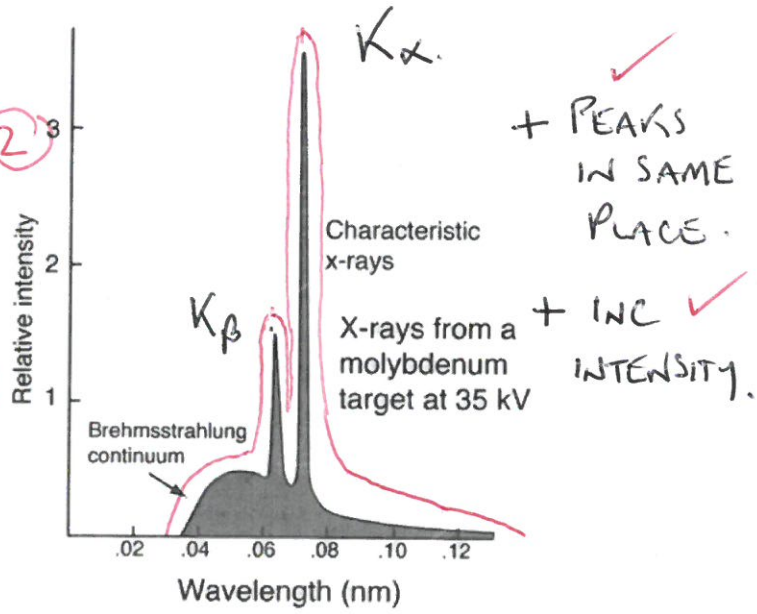
(2)

+ PEAKS IN SAME PLACE.

ii) The Kα and Kβ peaks for this sample **[1 mark]**

(1)

+ INC INTENSITY.



10. NOVA 93.7 FM is a popular Perth radio station. Calculate the energy of a typical radio wave photon emitted during a daily radio show. Give your answer in electron volts. **[3 marks]**

$93.7\ MHz = 93.7 \times 10^6\ Hz$

(3)

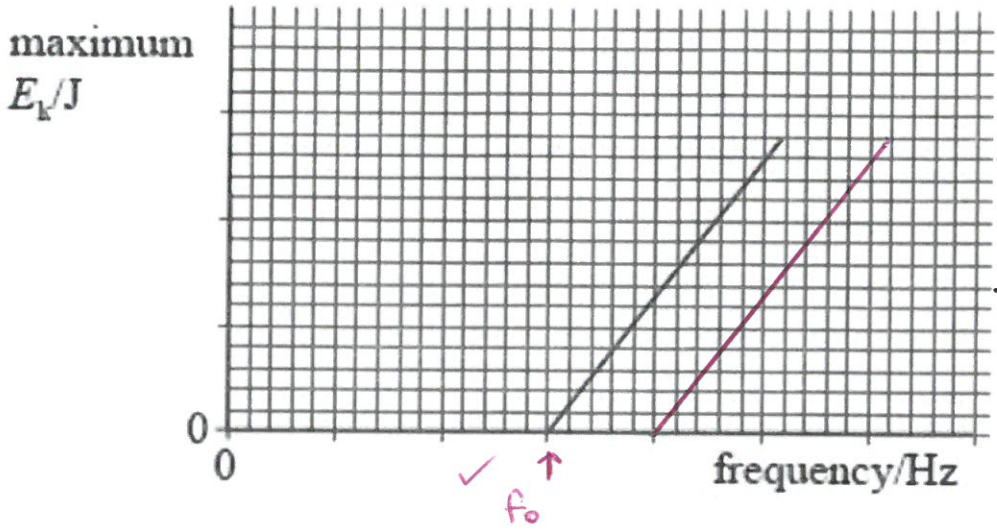
$E = hf = (6.63 \times 10^{-34})(93.7 \times 10^6)$

$= 6.21 \times 10^{-26}\ J.$

$= 3.88 \times 10^{-7}\ eV.$

(9)

11. The graph below shows how the maximum kinetic energy of the electrons varies with the frequency of the light shining on the metal surface.



a) **On the graph** mark the threshold frequency and label it f_o. **[1 mark]** (1)

b) **On the graph** draw the graph for a metal which has a greater work function than the sample shown. **[2 marks]** (2)

12. This figure shows the energy level diagram of a hydrogen atom.

a) Calculate the frequency of the photon emitted when an electron transitions from n=3 to n=2. **[4 marks]**

$n = 3 \rightarrow n = 2$

$3.40 - 1.51 = 1.89\text{ eV}$

$= 3.024 \times 10^{-19}\text{ J}$.

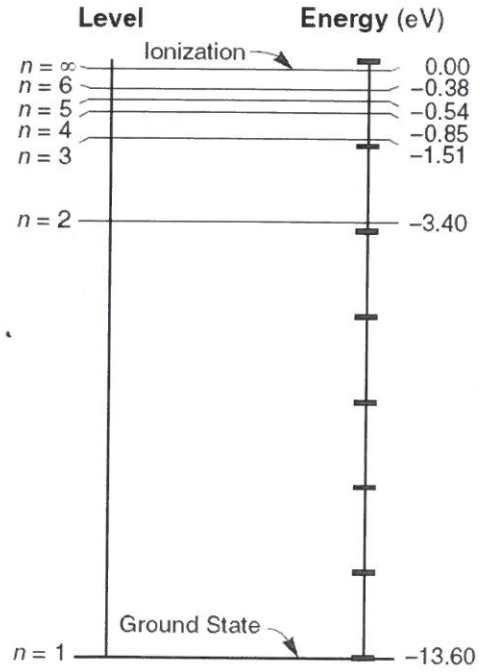
$E = hf$

$\therefore f = \frac{E}{h} = \frac{3.024 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 4.56 \times 10^{14}\text{ Hz}$.

(4)

Hydrogen



Energy Levels for the Hydrogen Atom

(7)

b) What would be detected if the n=2 to n=3 photon was viewed through a spectrometer? **[2 marks]**

+ SINGLE LINE. ✓

+ RED COLOUR. ✓

(2)

c) The hydrogen atom is excited and its electron moves to level n=6. How many different wavelengths of electromagnetic radiation can be emitted as the atom returns to its ground state? **[2 marks]**

$$C(6,2) = \frac{6!}{2!(6-2)!} = \frac{720}{(2)(24)} = \frac{720}{48}$$ ✓ ✓

(2)

Answer: 15 TRANS ✓

(OR CORRECT BY DIAG).

d) Calculate the wavelength of the longest wavelength of electromagnetic radiation emitted during this process. **[3 marks]**

LONGEST λ = LOWEST ENERGY = $0.54 - 0.38$ ✓

$$E = \frac{hc}{\lambda} \quad \therefore \quad \lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(0.54-0.38)(1.6\times10^{-19})}$$ ✓

(3)

$$\therefore \quad \lambda = 7.77\times10^{-6}\ m$$ ✓

13. A neon-filled tube will glow red while a high voltage current is passing through the neon. At night the numbers on a clock may glow in the dark for an hour after the lights have been turned off. How are these two phenomena similar and how are they different?

Similarities **[2 marks]**

+ e^-S EXCITED TO HIGHER STATES BY ABSORPTION OF PHOTONS. ✓

+ e^-S RELAX THROUGH PHOTON EMISSION. ✓

(2)

Differences **[2 marks]**

(NEON): ATOMS RELAX IMMEDIATELY. ✓

(CLOCK): ATOMS TAKE MORE TIME TO RELAX. ✓

(2)

(NEON): EXCITED BY e^- BOMBARDMENT.

(CLOCK): EXCITED BY UV ABSORPTION.

(11)