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PHOTOELECTRIC EFFECT**LESSON OVERVIEW**

1. Introduction – 15 minutes
2. Typical exam questions – 20 minutes
3. Review/solutions/memo – 25 minutes

SECTION A: TYPICAL EXAM QUESTIONS**Question 1: 15 minutes** (*Taken from the DoE Additional Exemplar P1 2008*)

A learner wants to demonstrate the photoelectric effect. He uses a disk of zinc placed on an electroscope. The work function of zinc is $6,9 \times 10^{-19} \text{ J}$.

- 1.1 Define the concept *work function*. (2)
 - 1.2 Calculate the maximum wavelength of light that will eject electrons from the zinc. (4)
 - 1.3 The electroscope is negatively charged and then exposed to ultraviolet light from a mercury discharge lamp. One of the wavelengths of the light is 260 nm. Calculate the kinetic energy of an electron emitted from the zinc disk by a photon of this light. (4)
 - 1.4 When the student attempts the experiment with a positively charged electroscope, he finds that the ultraviolet light has no apparent effect. Explain this observation. (2)
- [12]**

Question 2: 15 minutes (*Taken from DoE Physical Sciences P1 Nov 2008*)

A fully automatic camera has a built-in light meter. When light enters the light meter, it strikes a metal object that releases electrons and creates a current.

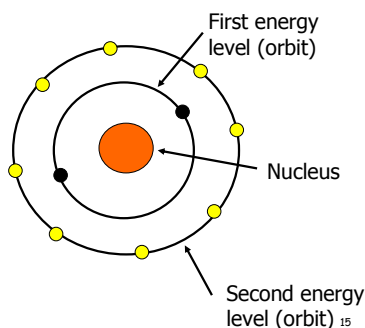
- 2.1 What phenomenon is described by the underlined sentence? (1)
 - 2.2 A metal plate is irradiated with electromagnetic radiation of wavelength 200 nm. The metal has a work function of $7,57 \times 10^{-19} \text{ J}$. Show by calculation that the metal plate will emit photo-electrons when irradiated with radiation of this wavelength. (6)
 - 2.3 The intensity of the incident radiation on the metal plate is increased whilst maintaining a constant wavelength of 200 nm. State and explain what effect this change has on the following:
 - 2.3.1 Energy of the emitted photo-electrons (2)
 - 2.3.2 Number of emitted photo-electrons (2)
- [11]**

SECTION B: SOLUTIONS AND HINTS**Question 1:**

- 1.1 Minimum energy needed to eject electrons from a certain material/metal. ✓✓ (2)
- 1.2 $E = hc/\lambda$ ✓
 $\therefore 6,9 \times 10^{-19} \text{ J} = (6,63 \times 10^{-34} \text{ Js})(3 \times 10^8 \text{ m/s})/\lambda$ ✓
 $\therefore \lambda = 288,26 \times 10^{-9} \text{ m} = 288,26 \text{ nm}$ ✓ (4)
- 1.3 $E_k = \frac{hc}{\lambda} - W$ ✓
 $= \frac{(6,63 \times 10^{-34} \text{ Js})(3 \times 10^8 \text{ m/s})}{260 \times 10^{-9} \text{ m}} - 6,9 \times 10^{-19} \text{ J}$ ✓
 $= 7,65 \times 10^{-19} \text{ J} - 6,9 \times 10^{-19} \text{ J}$
 $= 7,5 \times 10^{-20} \text{ J}$ ✓ (4)
- 1.4 The positively charged zinc plate will attract electrons ✓ preventing them from being emitted. ✓ (2)

Question 2:

- 2.1 Photo-electric effect ✓ (1)
- 2.2 $c = f\lambda$ ✓
 $\therefore 3 \times 10^8 \text{ m/s} = f(200 \times 10^{-9} \text{ m})$ ✓
 $\therefore f = 1,5 \times 10^{15} \text{ Hz}$
- $f_0 = W_0/h$ ✓
 $= \frac{7,57 \times 10^{-19} \text{ J}}{6,63 \times 10^{-34} \text{ Js}} = 1,14 \times 10^{15} \text{ Hz}$ ✓
 Frequency ($1,5 \times 10^{15} \text{ Hz}$) greater than threshold frequency ($1,14 \times 10^{15} \text{ Hz}$) ✓ (6)
- 2.3.1 The energy of the photo-electrons remains unchanged ✓ as the frequency / wavelength of the photons did not change. ✓ (2)
- 2.3.2 Number of photo-electrons (per second) is increased ✓. When the intensity is increased the number of photons will increase, releasing an increased number of electrons. ✓ (2)

SECTION C: ADDITIONAL NOTES**The Photoelectric Effect**

In order to understand the photoelectric effect and spectra, we need to remind ourselves of Bohr's atomic model. He believed that more than 1 electron could move in each orbit. Electrons release and absorb energy as they move between energy levels. Electrons move as waves within the orbitals.

Light has a wave nature and a particle nature. The particles in light are called photons. When a photon of high enough energy collides with an electron near the surface of a metal, it transfers all its energy to the electron. If there is enough energy for that particular metal, then the electron that was collided with is knocked out of the metal.

If there is not quite enough energy to remove the electron from the metal, then the energy excites electrons into the next energy level, which then fall back emitting energy (shiny). Metal energy levels are close together and metal electrons are delocalised and can therefore be relatively easily removed from the lattice.

Non metals have large gaps between energy levels so some frequencies are absorbed and others reflected, giving the object its colour .

Work is done in removing an electron from the surface of a metal. The minimum amount of energy needed to remove an electron from the metal is called the Work Function.

$$\text{Work function} = h \times \text{threshold frequency}$$

Where h is Planck's constant

The Threshold Frequency is the minimum frequency of the light that can eject an electron from a certain metal. The kinetic energy of an electron that has been ejected can be found using the following equation:

$$\text{energy of the photon} = \text{work function} + \text{kinetic energy}$$

$$\text{Energy of the photon} = hf$$

- where f is the actual frequency of the light shone on the metal.

SECTION D: HOMEWORK**Question 1: 10 minutes** (Taken from DoE Feb/March Physical Sciences P1 2009)

The work function of three metals is shown in the table below.

Metal	Work function (W_0) in J
Aluminium	$6,54 \times 10^{-19}$
Zinc	$6,89 \times 10^{-19}$
Silver	$7,58 \times 10^{-19}$

- 1.1 Give a reason why different metals have different work functions. (1)
- 1.2 Light of wavelength $2,3 \times 10^{-7}$ m is shone onto a metal X. The average speed of the emitted electrons is $4,78 \times 10^5$ m·s⁻¹. Identify metal X by performing a relevant calculation. (6)
- 1.3 What conclusion about the nature of light is drawn from the photo-electric effect? (1)

Question 2: 10 minutes (Taken from the GDE Preliminary Examination 2009)

The light reaching the earth from the sun is regarded as white light. The sky however appears to be blue during the day.

- 2.1 Using scientific terminology explain why the sky appears to be blue during the day. (3)
- 2.2 The photoelectric work function of potassium is 3.204×10^{-19} J. Light with a wavelength of 360 nm falls onto the surface of the potassium.
 - 2.2.1 Calculate the energy of the photons (3)
 - 2.2.2 Calculate the velocity of the electrons ejected from the surface of the potassium under these circumstances. (4)

[10]

SECTION E: SOLUTIONS TO SESSION 17 HOMEWORK

Question 1:

$$W = F \cdot \Delta x \cdot \cos \theta \quad \checkmark$$

$$= 100 \times 10 \times \cos 0^\circ \quad \checkmark$$

$$= 1000 \text{ J} \quad \checkmark$$

(3)

Question 2:

$$\cos 20^\circ = \frac{F_x}{60} \quad \checkmark$$

$$F_x = (\cos 20^\circ)(60) \quad \checkmark$$

$$F_x = 56,38 \text{ N} \quad \checkmark$$

$$W = F_x \cdot \Delta x \cdot \cos \theta \quad \checkmark$$

$$W = (56,38)(20) \cos 0^\circ \quad \checkmark$$

$$W = 1127,63 \text{ J} \quad \checkmark$$

(6)

Question 3:

$$(E_{\text{mech}}) \text{ at A} = (E_{\text{mech}}) \text{ at B} \quad \checkmark$$

$$(E_p + E_k) \text{ at A} = (E_p + E_k) \text{ at B}$$

$$(mgh + \frac{1}{2}mv^2) \text{ at A} = (mgh + \frac{1}{2}mv^2) \text{ at B} \quad \checkmark$$

$$(40)(9,8)(4) \quad \checkmark + \frac{1}{2}(40)(0) \quad \checkmark = (40)(9,8)(0,4) \quad \checkmark + \frac{1}{2}(40)(v^2) \quad \checkmark$$

$$1568 + 0 = 156,8 + 20v^2$$

$$1568 - 156,8 = 20v^2$$

$$1411,2 = 20v^2$$

$$v^2 = 70,58 \quad \checkmark$$

$$v = \sqrt{70,58}$$

$$v = 8,4 \text{ m} \cdot \text{s}^{-1} \quad \checkmark$$

(8)