INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

PHYSICS DEPT.

NO. 19B030033 CLASS CHEMISTRY BATCH P17/8

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EXPT. No. 3 LABORATORY

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PHOTOELECTRIC EFFECT

Aim :

To show the particle behaviour of the light and find the Planck's constant 'h' using photoelectric effect.

Apparatus :

Halogen Tungsten lamp (12 V/35W), phototube inside a box (vacuum conditions), voltage power supply, current meter (nanometer), optical bench as marked with a scale marking, and a set of color filters.

Theory :

Electrons are emitted from a metal surface when light (visible or ultraviolet) of right frequency is shone on a metal. This is known as photoelectric effect. The classical wave theory predicts that energy of the electrons should increase as the intensity of light increases. In contrast to this popular belief, it was found that energy of the emitted electron was dependent upon the frequency of the incident light and electrons will not be emitted if frequency was not above a certain threshold. It was observed that higher energy electrons will be emitted when higher frequency light was incident on a metal and low energy electron will be seen when a lower frequency light is incident on the metal.

$$h\nu = W + KE_{max},$$

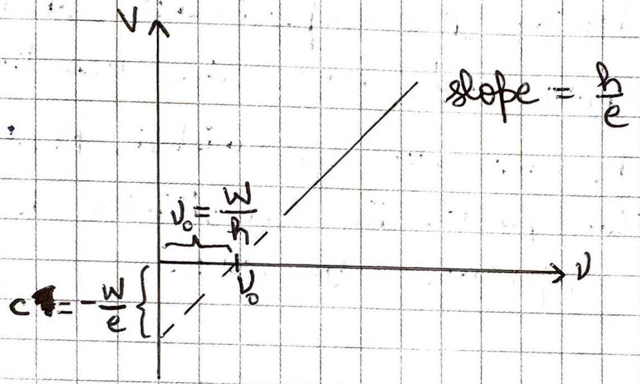
where $h\nu$ is the energy of photons, W is the work function of a given metal plate and KE_{max} is the maximum kinetic energy attained by the photoelectrons.

In a given experiment, a collector plate is charged negatively by applying a negative potential (so called 'stopping' potential) so that electrons do not reach to the collector plate and then photocurrent is noted to be zero. KE_{max} will be equivalent to eV where V is the stopping potential and e is the charge of the electron (1.6×10^{-19} C).

$$eV = h\nu - W$$

$$\Rightarrow \quad V = \frac{h}{e}\nu - \frac{W}{e}$$

Calculation and error analysis:



1. Use the least square fitting of a straight line method to find the slope "m" and its uncertainty in slope 'Δm'.

$$m = \frac{N \sum x_i y_i - \sum x_i \sum y_i}{N \sum x_i^2 - \left(\sum x_i\right)^2} \; ; \quad \bar{x} = \sum x_i / N \; ; \; D = \sum (x_i - \bar{x})^2$$

$$c = \bar{y} - m\bar{x} \; ; \quad \bar{y} = \sum y_i / N$$

$$(\Delta m)^2 \approx \left[\frac{1}{D} \frac{\sum d_i^2}{(N-2)}\right] \; ; \quad (\Delta c)^2 \approx \left[\frac{1}{N} + \frac{\bar{x}^2}{D}\right] \frac{\sum d_i^2}{(N-2)} ,$$

$$\text{where } d_i = y_i - m x_i - c$$

2. Find the y intercept 'c' and the corresponding error 'Δc'
3. Using this method, determine Planck's constant h and the work function W of the metal used. Tabulate error calculations of these two parameters.

Precautions:

1) The instrument needs careful gentle handling while during the working operation.
2) Drawtube shall not be kept open. After finishing the experiment cap it with the given black cap.
3) Filters' screens should not be touched while changing the filter. If found dirty a cotton swab with alcohol is a good way to clean.
4) After finishing the experiment switch off the power supply and cover the drawtube with the black lens cover provided. Phototube is a sensitive part. The sensitivity decreases with an exposure to light.

Observations:

(A) Constant frequency and different intensity experiment:

S. No.	Voltage (V) (in volt)	Photocurrent (i) (in nA)		
		for $I_1 = I_{max}$	for $I_2 = \frac{I_{max}}{2}$	for $I_3 = \frac{I_{max}}{4}$

S.No.	Voltage (V) (in volt)	Photocurrent (i) (in nA) for $I_1 = I_{max}$	for $I_2 = \frac{I_{max}}{2}$	for $I_3 = \frac{I_{max}}{4}$

(B) Different frequency and constant intensity experiment :

S.No.	Voltage (V) (in volt)	Photocurrent (i) (in nA) for $\lambda_1 = 635nm$	for $\lambda_2 = 570nm$	for $\lambda_3 = 540nm$	for $\lambda_4 = 500nm$	for $\lambda_5 = 460nm$

S.No.	Voltage (V) (in volt)	Photocurrent (i) (in nA) for $\lambda_1 = 635$ nm	for $\lambda_2 = 570$ nm	for $\lambda_3 = 540$ nm	for $\lambda_4 = 500$ nm	for $\lambda_5 = 460$ nm

(c)

S.No.	wavelength (λ) (in nm)	frequency (ν) ($\times 10^{14}$ Hz) (x_i)	Stopping potential (V_s) (in volt) (y_i)	x_i^2	$x_i y_i$
1.					
2.					
3.					
4.					
5.					
		$\Sigma x_i =$	$\Sigma y_i =$	$\Sigma x_i^2 =$	$\Sigma x_i y_i =$

Calculations :

$$m = \frac{N \sum x_i y_i - \sum x_i \sum y_i}{N \sum x_i^2 - (\sum x_i)^2}$$

$$=$$

$$\bar{x} = \frac{\sum x_i}{N} =$$

$$\bar{y} = \frac{\sum y_i}{N} =$$

$$c = \bar{y} - m\bar{x} =$$

S.No.	x_i	y_i	$\bar{x} - x_i$	$(\bar{x} - x_i)^2$	$d_i = y_i - mx_i - c$	d_i^2
1.						
2.						
3.						
4.						
5.						
				$\sum(\bar{x}-x_i)^2 =$		$\sum d_i^2 =$

$$D = \sum(\bar{x} - x_i)^2 =$$

$$(\Delta m)^2 \approx \frac{1}{D} \frac{\sum d_i^2}{(N-2)} =$$

$$(\Delta c)^2 \approx \left[\frac{1}{N} + \frac{\bar{x}^2}{D}\right] \frac{\sum d_i^2}{(N-2)} =$$

Planck's constant, $h = m \times e =$

Work function, $W = -c \times e =$

Uncertainty in calculation:

$$\Delta h = \Delta m \times e =$$

$$\Delta W = \Delta c \times e =$$

Result and discussion:

Parameter	Value	Uncertainty
Planck's constant (h)		$\Delta h =$
Work function(W)		$\Delta W =$