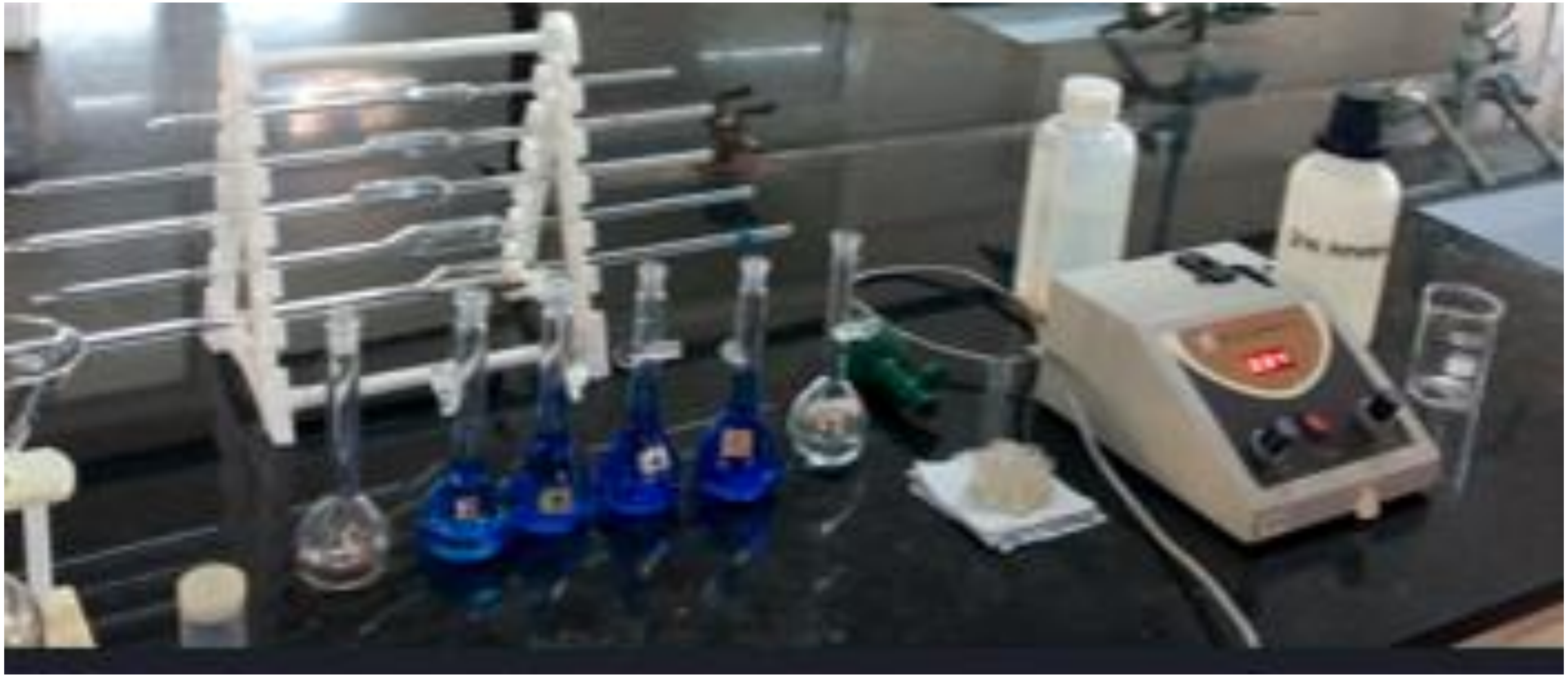
Colorimetric Estimation of Copper

Aim of the experiment:

To determine the concentration of copper in 50 mL of the given solution using photoelectric colorimeter.



Principle

Lambert's law:

When a ray of monochromatic light passes through an absorbing medium, its intensity decreases exponentially as the length of the medium absorbing increases.

$$-\frac{dI}{dt} = kI \qquad (1)$$

Where I = intensity of the incident light of wavelength, λ; t = thickness of the medium;

k = proportionality constant

Integrating eq. 1, and putting $I = I_0$ when t = 0

$$-\int \frac{dI}{dt} = \int kI$$

$$-\int \frac{dI}{I} = k \int dt$$

$$\ln \frac{I_0}{I_t} = kt$$

$$I_t = I_0\, e^{-kt} \qquad (2)$$

Where I_0 = intensity of the incident light falling upon the absorbing medium of thickness, t

It = intensity of the transmitted light

k = constant for the wavelength and the absorbing medium we can write the eq. 2 as

$$\frac{I_t}{I_0} = e^{-kt} = 10^{\frac{-k}{2.3036}t} = 10^{-0.4343kt}$$

$$I_t = I_0\, 10^{-Kt} \qquad (3)$$

Where ‘K’ is called as absorption coefficient.

The absorption coefficient (K) is generally defined as the reciprocal of the thickness (t, cm) required to reduce the light to 1/10th of its intensity.

i.e., in eq. 3, $\frac{I_t}{I_0} = 10^{-Kt}$

or Kt = 1 and K = 1/t

The ratio, $\frac{I_t}{I_0}$ is the fraction of the incident light transmitted by a thickness ‘t’ of the medium and is termed as the transmittance (T). The reciprocal of transmittance i.e., $\frac{I_o}{I_t}$ is opacity. The absorbance (A) of the medium is given by A = log $\left(\frac{I_0}{I_t}\right)$ (4)

Beer's law:

When a monochromatic light passes through an absorbing medium, its intensity decreases exponentially as the concentration of the medium absorbing increases.

$I_t = I_0 e^{-k'C}$

$= I_0\, 10^{-0.4343k`C} = I_0\, 10^{-KC}$ (5)

Where 'C' is the concentration, k` and K are constants.

Combining eq. (3) and eq. (5),

$$\frac{I_t}{I_0} = 10^{-aCt}$$

$$\log\left(\frac{I_t}{I_0}\right) = aCt \qquad (6)$$

This **(eq. 6) is the mathematical expression for Beer-Lambert's law**.

The value 'a' depend upon the method of expression of the concentration of the solution. If 'C' is expressed in mol/l and 't' in cm; then 'a' is given the symbol, ε and is called the molar absorption coefficient or molar absorptivity.

It is clear that, there is a relationship between the absorbance (A), the transmittance (T) and the molar absorption coefficient.

$$A = \log\left(\frac{I_0}{I_t}\right) = \log(1/T) = -\log T \qquad (7)$$

$$\therefore A = -\log(T)$$

$$A = \varepsilon C t$$

Procedure

Preparation of Blank:

- Take a 3N ammonia solution in a cuvette.
- Place the cuvette in the colorimeter in the correct position.
- Select a suitable filter.
- Adjust the transmittance to 100% (zero absorbance) – this is the ‘blank setting’.

Preparation of Standard Copper Sulfate Solution:

- Weigh approximately 1 g of $CuSO_4 \cdot 5H_2O$ crystals.
- Transfer into a 250 mL standard flask.
- Dissolve in dilute H_2SO_4 and dilute to the mark with distilled water.
- Calculate the concentration of copper per mL.

Preparation of Standard Copper Sulfate Solutions for calibration curve:

- Pipette 5, 10, 15, 20, and 25 mL of the standard copper sulfate solution into 50 mL standard flasks.
- Add 3N ammonia to each flask to make it up to the 50 mL mark and shake well.

Measurement of Absorbance:

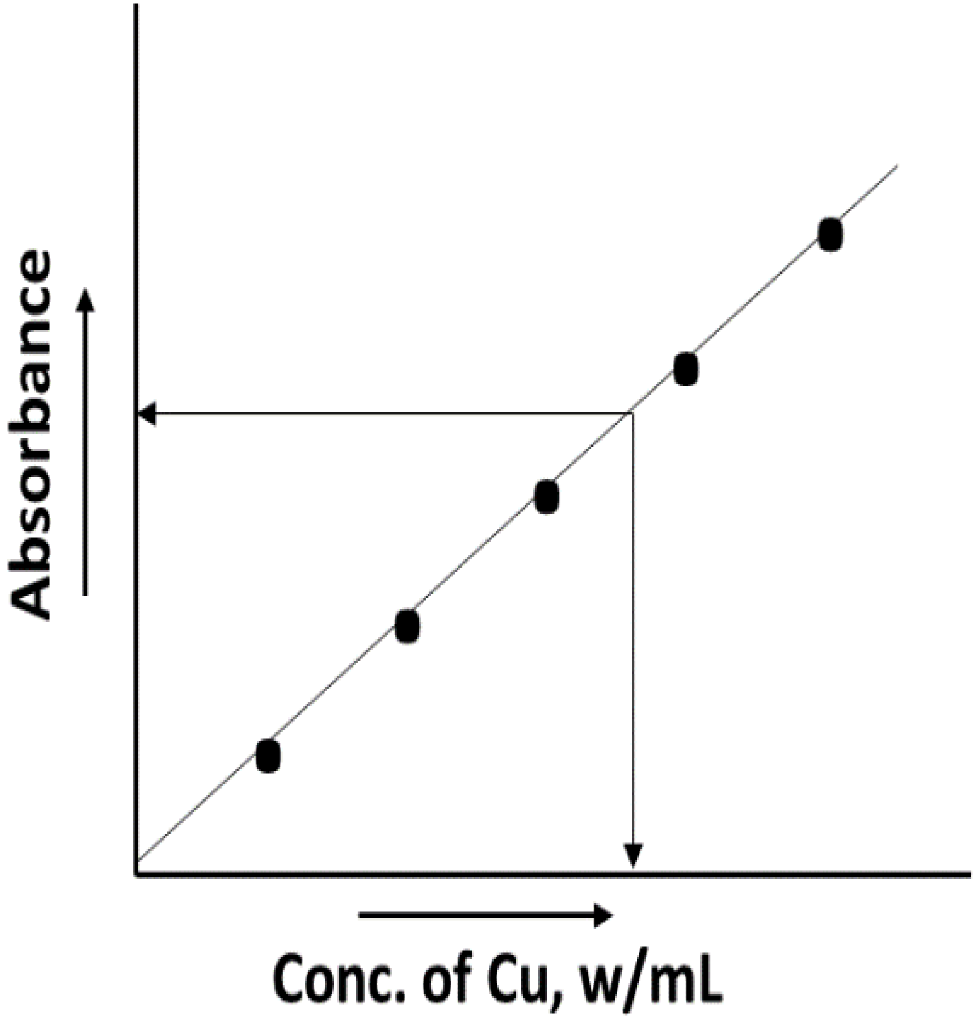
- Take each prepared solution in the cuvette.
- Measure the absorbance using the colorimeter.

Unknown Sample Analysis:

- Dilute the unknown copper solution in a 50 mL standard flask with 3N ammonia solution up to the mark.
- Measure the absorbance of this solution.

Graph and Calculation:

- Plot a graph of absorbance vs. copper concentration for the standard solutions.
- Use the graph to determine the concentration of copper in the unknown solution.




1
2
3
4
5
2

Sl. No.	Volume of standard copper solution pipetted in 50 mL standard flask V mL	Weight of copper in 1 mL of diluted solution in mg ($Z \times V/50$)	Absorbance
1	5		
2	10		
3	15		
4	20		
5	25		
6	30		
7	Unknown	Unknown	

Observation and calculations:

Weight of weighing bottle + copper sulphate crystals, W_1 = g.

Weight of empty weighing bottle, W_2 = g.

Weight of copper sulphate crystals, $W = W_1 - W_2$ = g

Weight of $CuSO_4.5H_2O$ in one mL of the standard solution prepared, W/250 = y = g

Weight of copper present in 1 mL of the standard solution prepared, $z = 63.54 \times y \times 1000/249.7$

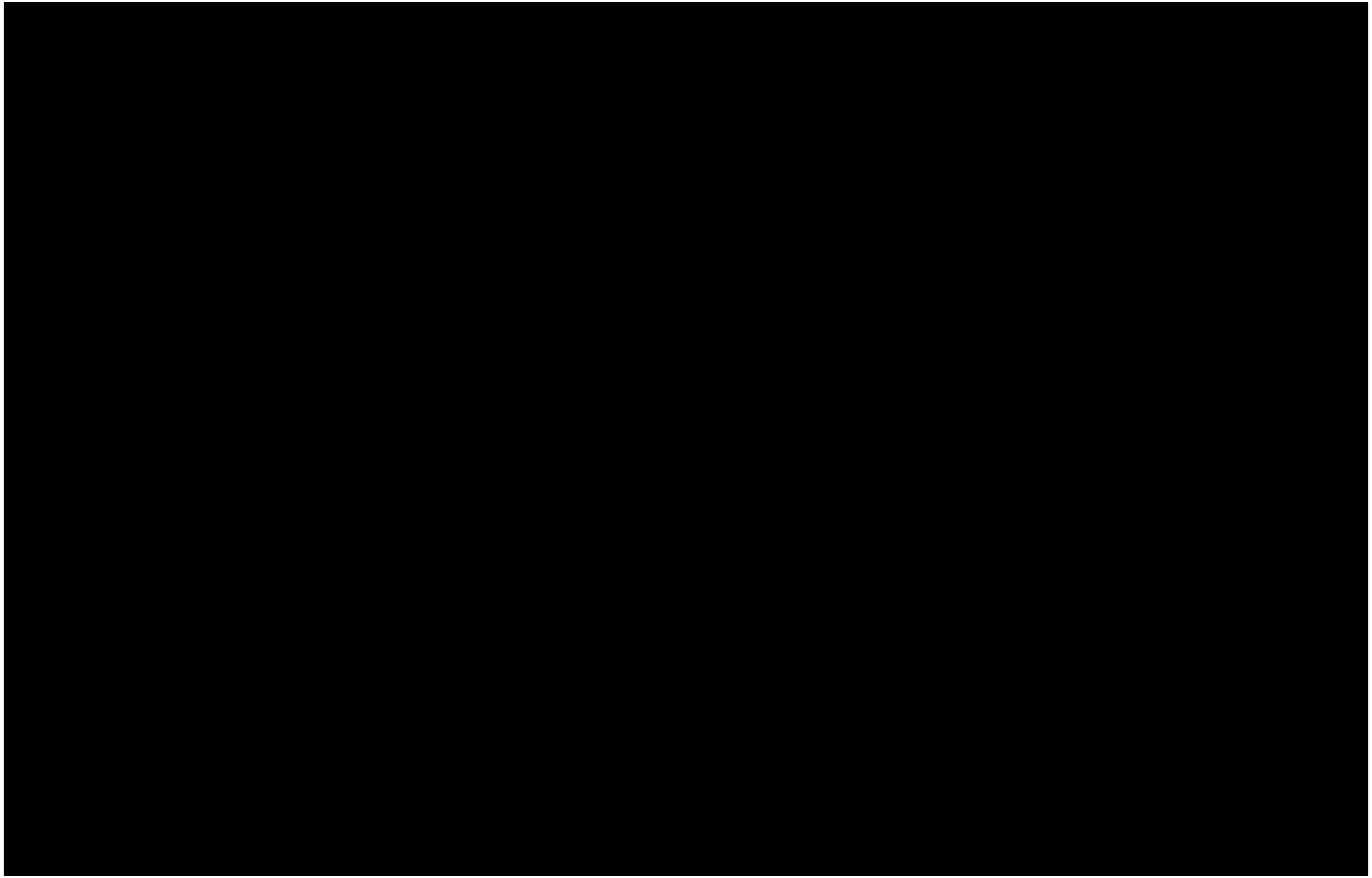
= mg

From the graph, weight of copper in one mL of the solution = mg

Hence weight of copper in 50 mL of given solution = × 50 = mg

Limitations of the Beer-Lambert law:

- Chemical and instrumental factors limit the linearity of the Beer-Lambert law. The probable causes of nonlinearity are:
- Deviations in absorptivity coefficients at *high concentrations (>0.01M)* due to electrostatic interactions between molecules nearby
- Scattering of light due to particulates in the sample
- Fluorescence or phosphorescence of the sample
- Changes in refractive index at a high analyte concentration
- Shifts in chemical equilibria as a function of concentration
- Non-monochromatic radiation, deviations can be minimized by using a relatively flat part of the absorption spectrum such as the maximum of an absorption band
- Stray light



https://www.youtube.com/watch?v=_i_JjW_rNHM