

ELEMENTS OF MODERN PHYSICS LABORATORY

Course Code- PHY259
Practical-9



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List of Practicals

- To study The Photo Electric Effect using Planck's Constant Set.
- Determine the Planck's constant using LEDs of at least 4 different colors.
- Determine work function of material of filament of directly heated vacuum diode.
- Determine the wavelength of H-alpha emission line of Hydrogen atom.
- Determine the charge of an electron with the help of Millikan oil drop Set.
- Show the tunneling effect in tunnel diode using I-V characteristics.
- Determine the wavelength of laser source using diffraction of single slit.
- Determine the wavelength of laser source using diffraction of double slits.
- Determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
- Determine the absorption lines in the rotational spectrum of Iodine vapor



Objective: Determine the absorption lines in the rotational spectrum of Iodine vapor.

Basic Understandings

Basic Understandings

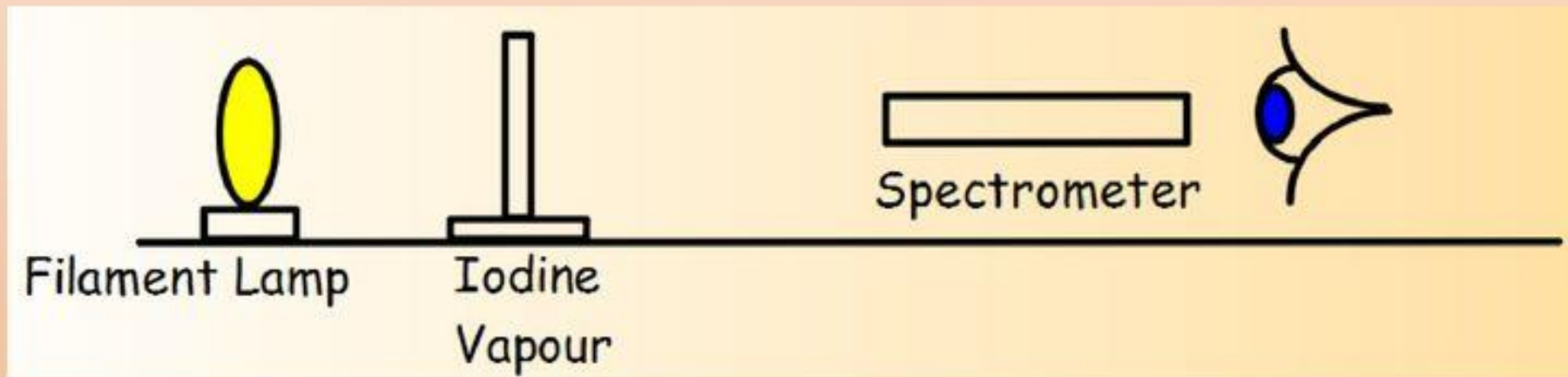
Introduction to Experiment

- Determining the absorption spectrum of iodine is a classic experiment in Physical Chemistry.
- Study of this spectrum clearly shows the relationship between vibrational and electronic energy levels.
- According to Schrödinger equation every bound system of particles can have only discrete energy levels and any transition between two such levels results in absorption or emission of a photon with energy equal to energy difference of the two levels.
- In this experiment, a white light source with a continuous spectrum is used to excite the molecules of iodine vapour. When the spectrum of light after passing through the iodine vapour is analysed by a spectrometer, it is observed that specific wavelengths are absorbed.
- Each absorbed wavelength will appear as a dark line in the spectrum corresponding to the difference of different energy states of iodine molecule.
- The characteristics of the iodine molecule can be determined from this spectrum.

- **Objective:** To study the absorption spectrum of iodine vapour with Constant Deviation spectrometer and then to determine:
 - (a) the energy level diagram of iodine molecule
 - (b) the electronic energy gap and vibrational energies
 - (c) bond dissociation limit.
 - (d) force constant for the excited state
- **Apparatus Required:**
 - (1) Constant deviation spectrometer with the special prism (Pellin-Broca),
 - (2) a mercury lamp for calibration,
 - (3) an incandescent bulb of 60 to 100 watts,
 - (4) a long glass tube with plane windows to hold the iodine vapour.

Absorption Spectra

- When white light such as a filament lamp is viewed through a spectrometer, a continuous spectra is viewed (all frequencies of visible light).
- An absorption spectrum is produced when white light is passed through a vapour e.g. iodine vapour.



- The absorption spectrum is a continuous spectrum with a series of dark lines on it. The position of the dark lines corresponds to the lines of the emission spectrum for iodine.

Theory

- In atoms and molecules different electronic energy levels exist corresponding to particular quantum states.
- The lowest energy level is called the ground state, all higher energy states are called excited states.
- The potential energy experienced by the electrons in a molecule in any "bound state" is described by the anharmonic Morse potential [Fundamentals of Molecular Spectroscopy, Text book by C. N. Banwell]

Theory

- **Vibronic transition in iodine:** Molecular iodine is purple in colour because it absorbs light in the visible (yellow) region of the electromagnetic spectrum.
- The absorption involves the following transition $(X, \nu'') \rightarrow (B, \nu')$
- where X represents the **ground state** and B is the **first excited electronic energy state**.
- ν'' (=0, 1, 2 etc) and ν' (=0,1,2, etc) represent the vibrational quantum numbers in the ground and excited electronic states, respectively.

Energy level diagram of iodine

Figure 1 shows a schematic energy level diagram of iodine with ground and first excited electronic state along with the vibrational states. At room temperature most of the molecules of iodine reside in ground state $v'' = 0$. When a beam of light having continuous spectrum is made to pass through the iodine vapour the first transition corresponds to $v'' = 0$ to $v' = 0$ which is labelled as $0 \leftarrow 0$ absorption line. The next peak corresponds to the $1 \leftarrow 0$ transition, the third, $2 \leftarrow 0$ and so on.

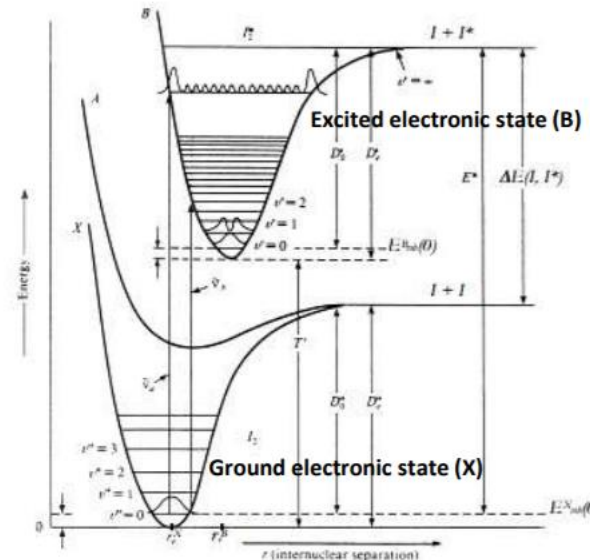


Fig. 1: Schematic energy level diagram of iodine

Rotational / Vibrational spectroscopy

- It is concerned with the measurement of the energies of transitions between quantized rotational states of molecules in the gas phase.
- The spectra of polar molecules can be measured in absorption or emission by microwave spectroscopy or by far infrared spectroscopy.
- The rotational spectra of non-polar molecules cannot be observed by those methods, but can be observed and measured by Raman spectroscopy.
- Rotational spectroscopy is sometimes referred to as *pure* rotational spectroscopy to distinguish it from rotational-vibrational spectroscopy where changes in rotational energy occur together with changes in vibrational energy, and also from ro-vibronic spectroscopy (or just vibronic spectroscopy) where rotational, vibrational and electronic energy changes occur simultaneously.

https://www.youtube.com/watch?v=2A_Ir--NWyw

Set Up of Experiment

Useful conversions/calculations:

1. Convert the wavelengths of the absorption band into the wave number by using: $\bar{\nu}_e (cm^{-1}) = 1/\lambda$.
2. $1eV = 8068cm^{-1}$
3. $E(eV) = hc / \lambda_{max} = hc\bar{\nu}_{e min}$

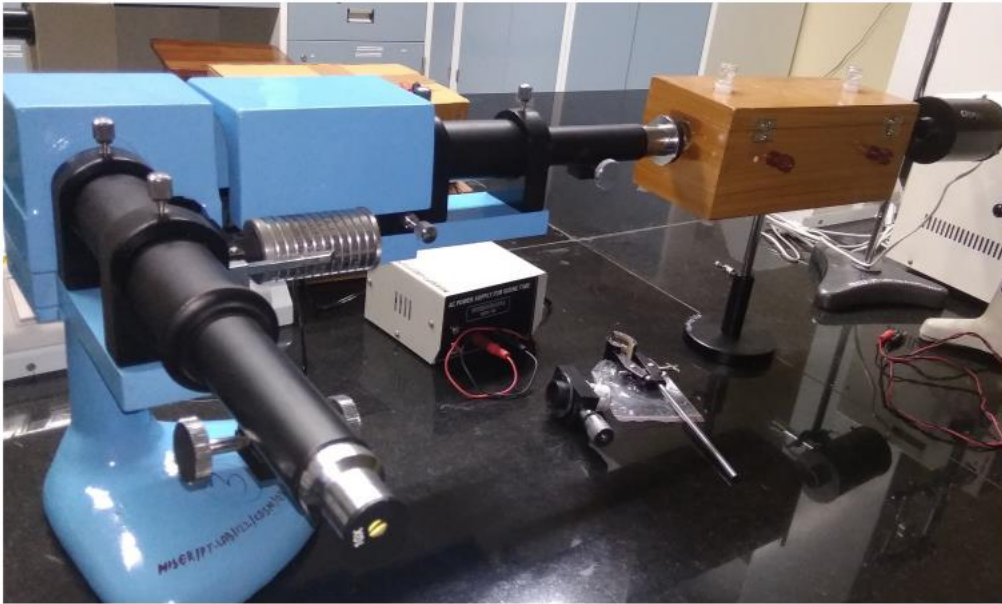
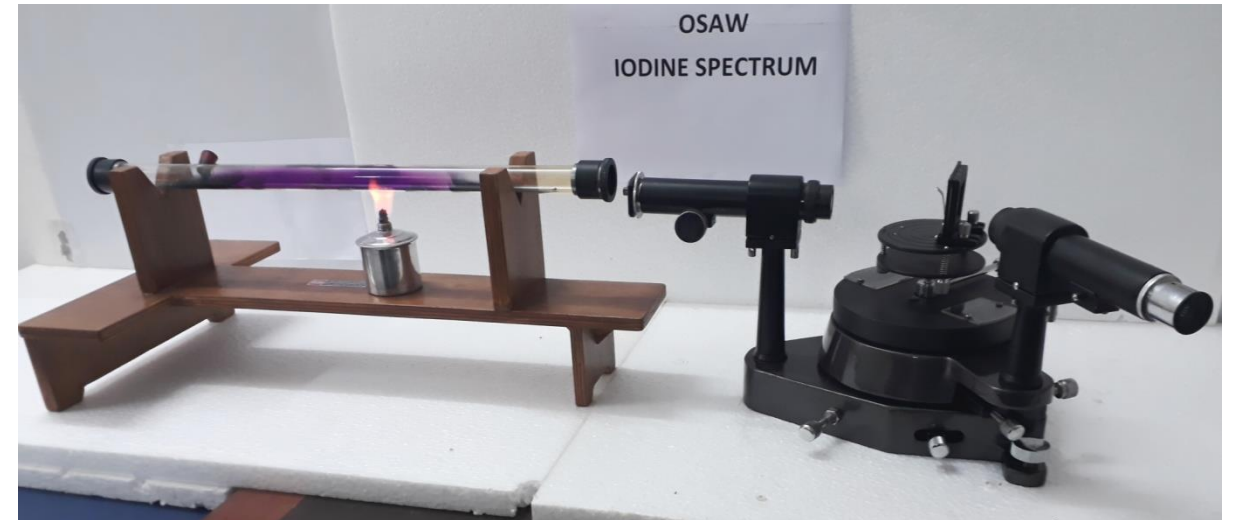


Figure 2: Set up for absorption spectrum of Iodine



Procedure of Experiment

- (I) **Calibration of constant deviation spectrometer:** Using the mercury lamp calibrate the constant deviation spectrometer as already described in the experiment “Emission spectra of metals”.
- (II) Obtain the calibration parameters from appropriate plot.

(II) Observation of Iodine spectrum

1. After calibration of spectrometer remove the mercury lamp and place the incandescent lamp (60 or 100 watts) as the source. Observe the continuous spectrum (see Fig. 3).

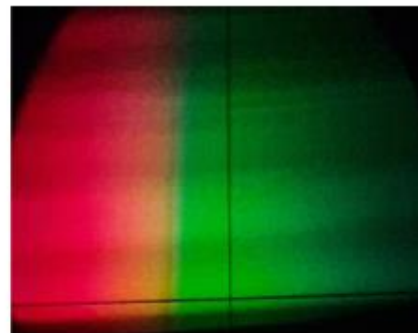


Fig. 3: Continuous spectrum

2. Now place the tube filled with iodine specks in between the incandescent lamp and the slit of the collimator. Wait till the tube becomes filled with iodine vapour which will look purple in colour.

3. Now observe the spectrum through the telescope adjusting the focus. You will observe narrow dark bands in the continuous spectrum as shown in Fig. 4.

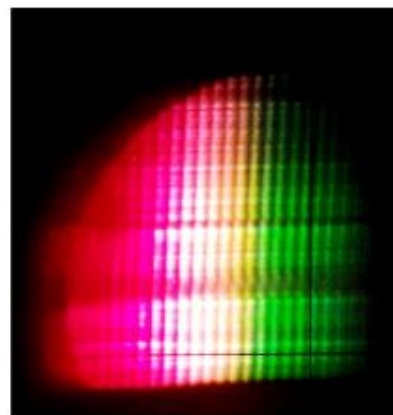


Fig. 4: Absorption spectrum of Iodine

4. Note down the wavelength readings ($\lambda_{\text{observed}}$) of each dark band from the spectrometer and calculate the corrected value (λ_{corr}) using the calibration parameters.

5. Calculate the wave numbers corresponding to dark bands.

6. Draw the energy level diagram in terms of wavenumbers starting from the lowest to highest energy level.

7. The approximate energy gap is determined from the highest wavelength.

Observation:**(I) Table for calibration using mercury lamp**

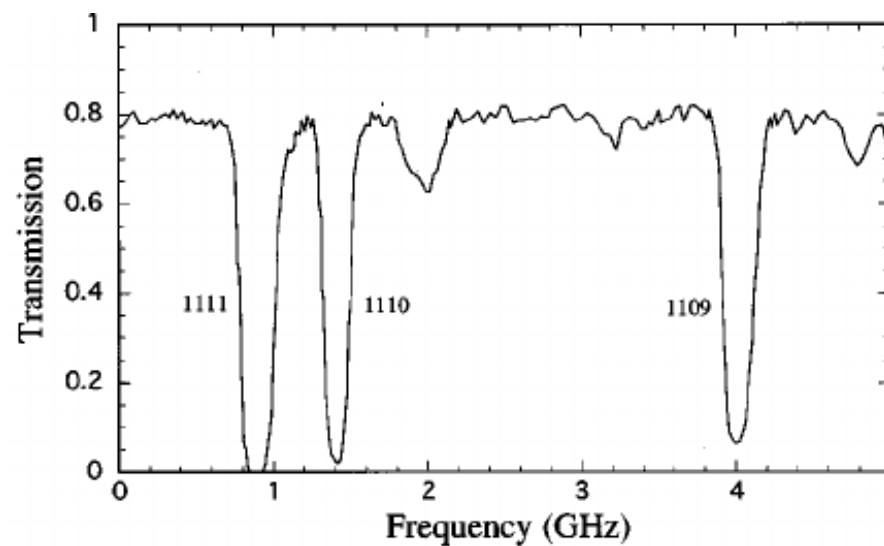
| Sl. No. | λ_{given} | $\lambda_{\text{observed}}$ |
|---------|--------------------------|-----------------------------|
| | | |
| | | |
| | | |

(II) Table for absorption spectrum of iodine

| Sl. No. | $\lambda_{\text{observed}}$ | λ_{corr} | Wave number $\bar{\nu}_e$ (cm^{-1}) | Difference in wave number $\Delta\bar{\nu}_e$ (cm^{-1}) |
|---------|-----------------------------|-------------------------|---|---|
| | | | | |
| | | | | |
| | | | | |

Graph/Calculations: Plot $\lambda_{\text{given}} \sim \lambda_{\text{observed}}$ and obtain the calibration parameters from list square fit.

Conclusions:



How to calculate optical band gap of a material

- By plotting the graph between $(\alpha h\nu)^S$ versus photon energy $(h\nu)$.
- $S = 2$ or $\frac{1}{2}$ for direct or indirect band gap
- where, α (alpha) is the **absorbance calculated** from **UV** .
- $(h\nu)$ can be **calculated** from wavelength using: $(h\nu = 1240/\text{wavelength})$;
- Extrapolating the straight line portion of the curves to zero **absorption** coefficient value gives the energy **band gap** value.

$$1\text{eV} = 1.6 \times 10^{-19} \text{ J}$$

Using the values of h , Planck's constant and c , the speed of light¹

$$h = 6.62606957 \times 10^{-34} \text{ J.s}, c = 2.99792458 \times 10^8 \text{ m/s}$$

we have in this new system:

$$\begin{aligned} hc &= 1.9864457 \times 10^{-25} \text{ J} \cdot \text{m} \\ &= 1.2415 \times 10^{-5} \text{ eV} \cdot \text{m} \\ &= 1241.5 \text{ eV} \cdot \text{nm} \end{aligned}$$



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FORMULAS

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VIEW



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Calibri

11

A⁺A⁻**B** *I* U**A**

Font



Alignment



Wrap Text



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General



%

,

0.00

0.00

Number



Conditional Formatting



Format as Table

Styles

B1



fx

A

B

C

D

E

F

G

H

I

J

1

2

3

wavelength(nm)

Absorbance (a)

4

1500

0.10546

5

1498

0.10559

6

1496

0.10575

7

1494

0.10624

8

1492

0.10686

9

1490

0.10762

10

1488

0.10845

11

1486

0.1092

12

1484

0.10996

13

1482

0.11041

14

1480

0.11077

15

1478

0.11116

16

1476

0.11154

17

1474

0.11199

Microsoft Excel ribbon showing the Font, Alignment, Number, Styles, Cells, and Editing tabs. The Font tab is active, displaying options for font face (Calibri), size (11), bold (B), italic (I), underline (U), color (A), and background color (A). The Alignment tab shows options for text alignment (left, center, right, justified), orientation (horizontal, vertical), and text wrapping. The Number tab shows options for number format (General, Percentage, etc.). The Styles tab shows options for conditional formatting, format as table, and cell styles. The Cells tab shows options for insert, delete, and format. The Editing tab shows options for sorting, finding, and filtering.

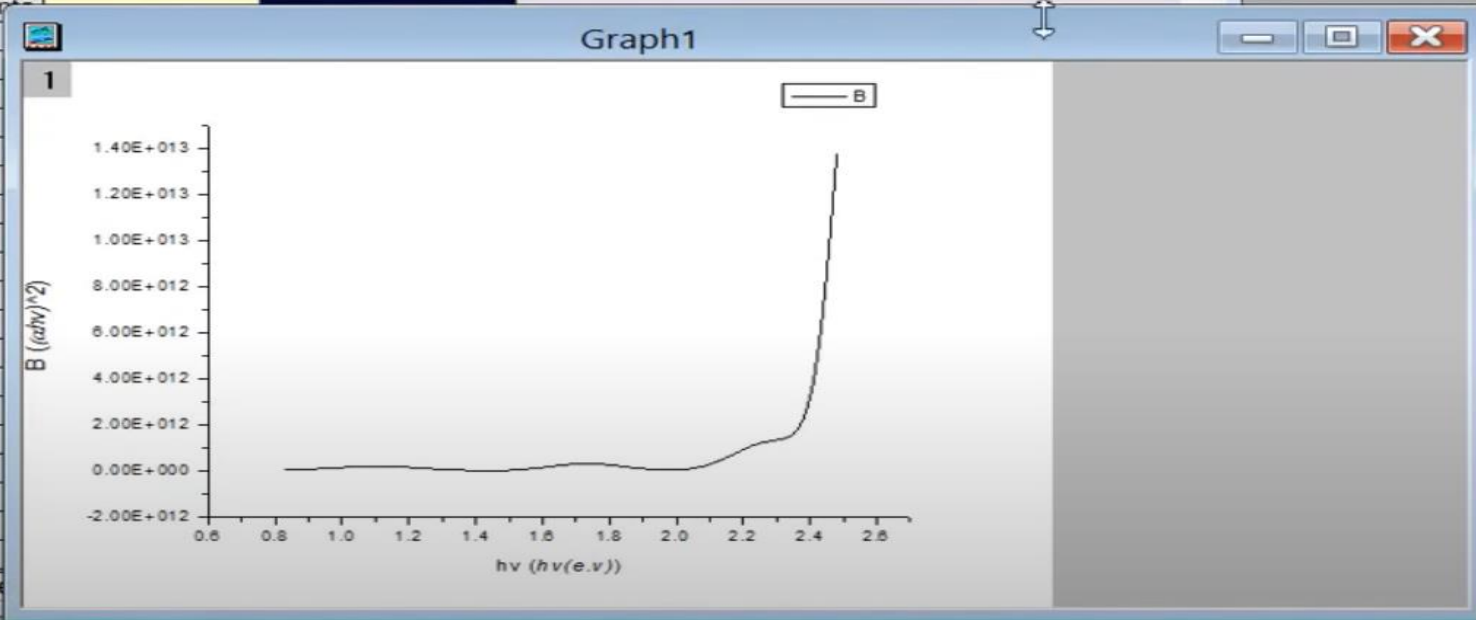
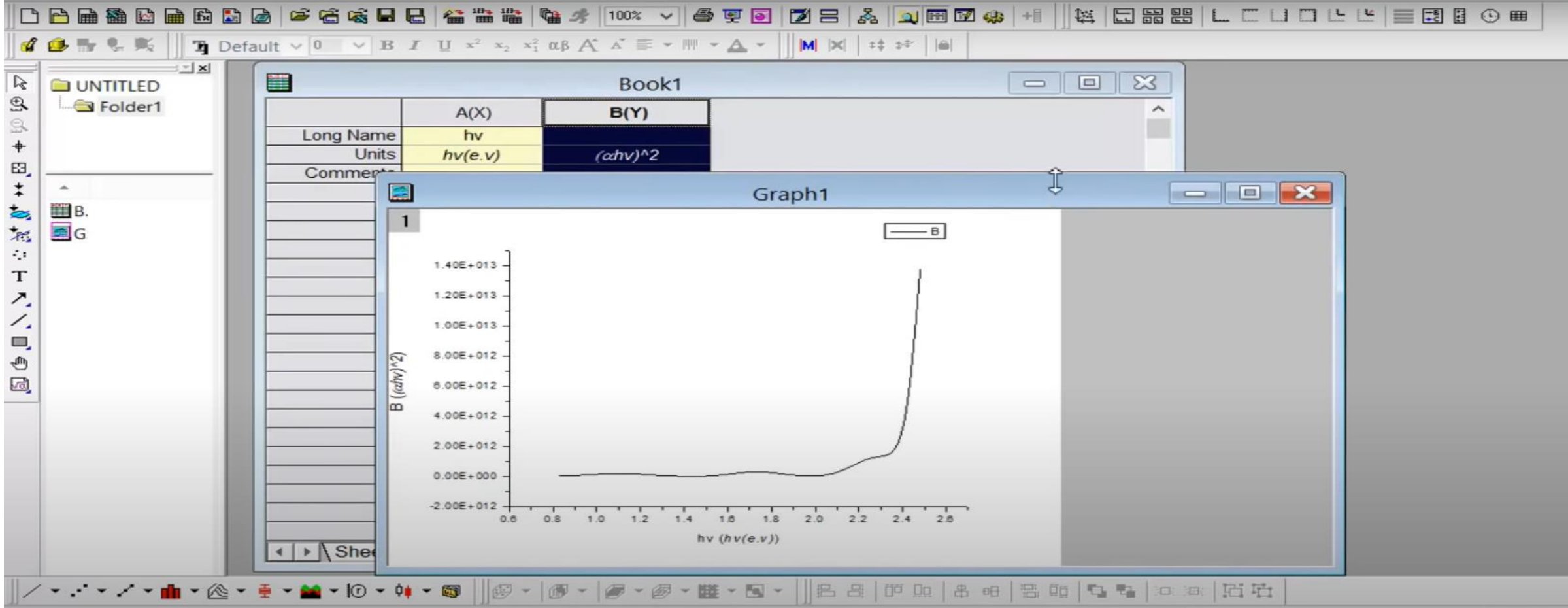
| =F4^2 | | | | | | |
|----------------|---|---|-------------|-------------|---|---|
| B | C | D | E | F | G | H |
| | | Thickness=500*10 ⁻⁹ | E=hc/lambda | | | |
| Absorbance (a) | | Absorption coe alpha = absorbance/Thickness | Energy hv | (alpha hv) | (alpha hv) ² for direct band | |
| 0.10546 | | 210920 | 0.826666667 | 174360.5333 | 30401595584 | |
| 0.10559 | | 211180 | 0.82777036 | 174808.5447 | 30558027309 | |
| 0.10575 | | 211500 | 0.828877005 | 175307.4866 | 30732714869 | |
| 0.10624 | | 212480 | 0.829986613 | 176355.5556 | 31101281975 | |
| 0.10686 | | 213720 | 0.831099196 | 177622.5201 | 31549759649 | |
| 0.10762 | | 215240 | 0.832214765 | 179125.906 | 32086090215 | |
| 0.10845 | | 216900 | 0.833333333 | 180750 | 32670562500 | |
| 0.1092 | | 218400 | 0.834454913 | 182244.9529 | 33213222855 | |
| 0.10996 | | 219920 | 0.835579515 | 183760.6469 | 33767975349 | |
| 0.11041 | | 220820 | 0.836707152 | 184761.6734 | 34136875963 | |
| 0.11077 | | 221540 | 0.837837838 | 185614.5946 | 34452777727 | |
| 0.11116 | | 222320 | 0.838971583 | 186520.1624 | 34789770975 | |
| 0.11154 | | 223080 | 0.840108401 | 187411.3821 | 35123026146 | |
| 0.11199 | | 223980 | 0.841248304 | 188422.7951 | 35503149719 | |

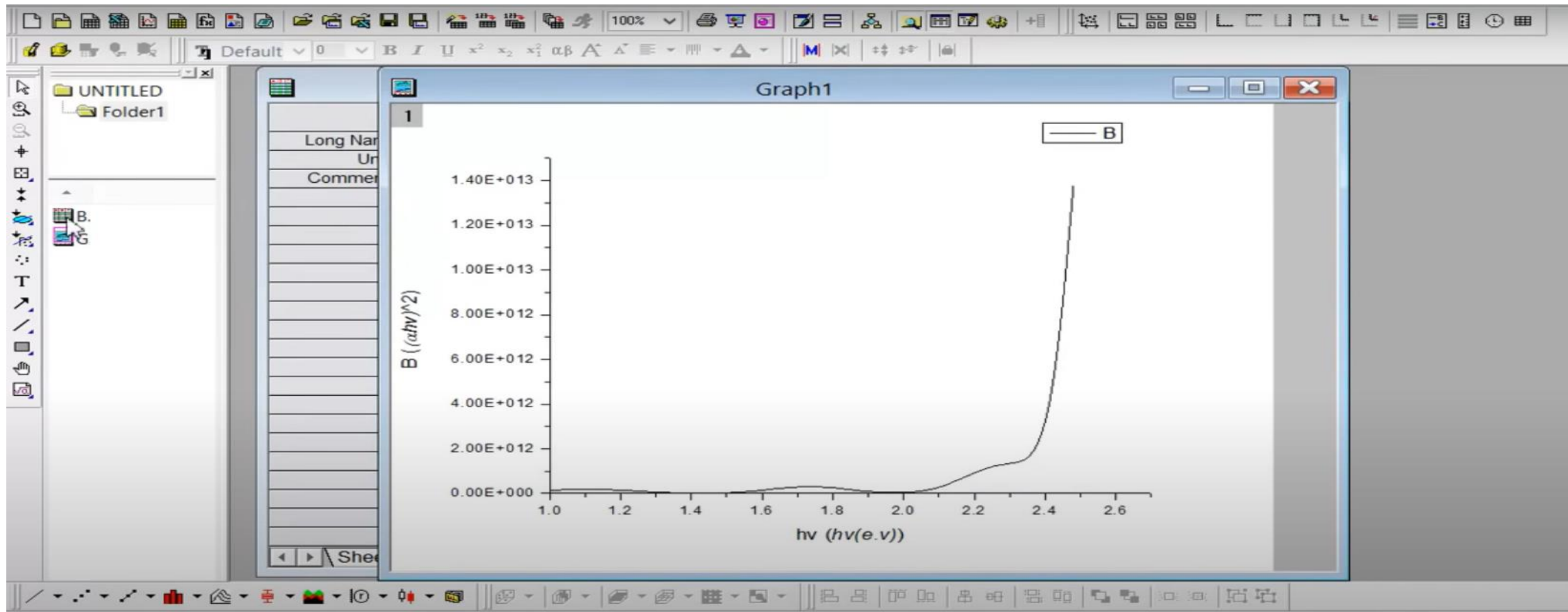
Book1

| | A(X) | B(Y) |
|-----------|----------------|--|
| Long Name | h ν | |
| Units | h ν (e.v) | ($\alpha h\nu$) ² |
| Comments | Energy h ν | (alpha h ν) ² for dire |
| 1 | 0.82667 | 3.04016E10 |
| 2 | 0.82777 | 3.0558E10 |
| 3 | 0.82888 | 3.07327E10 |
| 4 | 0.82999 | 3.11013E10 |
| 5 | 0.8311 | 3.15498E10 |
| 6 | 0.83221 | 3.20861E10 |
| 7 | 0.83333 | 3.26706E10 |
| 8 | 0.83445 | 3.32132E10 |
| 9 | 0.83558 | 3.3768E10 |
| 10 | 0.83671 | 3.41369E10 |
| 11 | 0.83784 | 3.44528E10 |
| 12 | 0.83897 | 3.47898E10 |
| 13 | 0.84011 | 3.5123E10 |
| 14 | 0.84125 | 3.55031E10 |
| 15 | 0.84239 | 3.61037E10 |
| 16 | 0.84354 | 3.68987E10 |
| 17 | 0.84469 | 3.74556E10 |
| 18 | 0.84584 | 3.8157E10 |
| 19 | 0.84699 | 3.87599E10 |

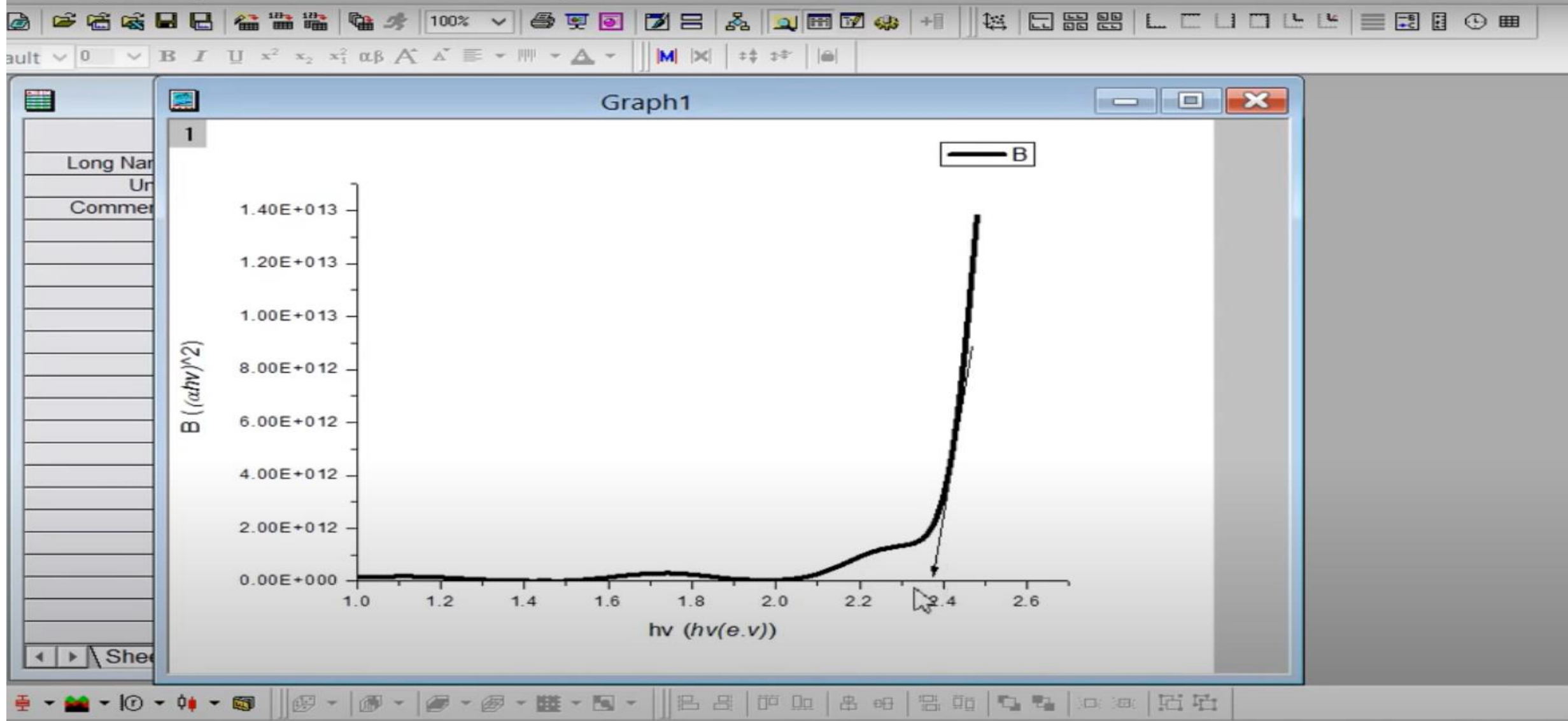
Sheet1 Sheet2

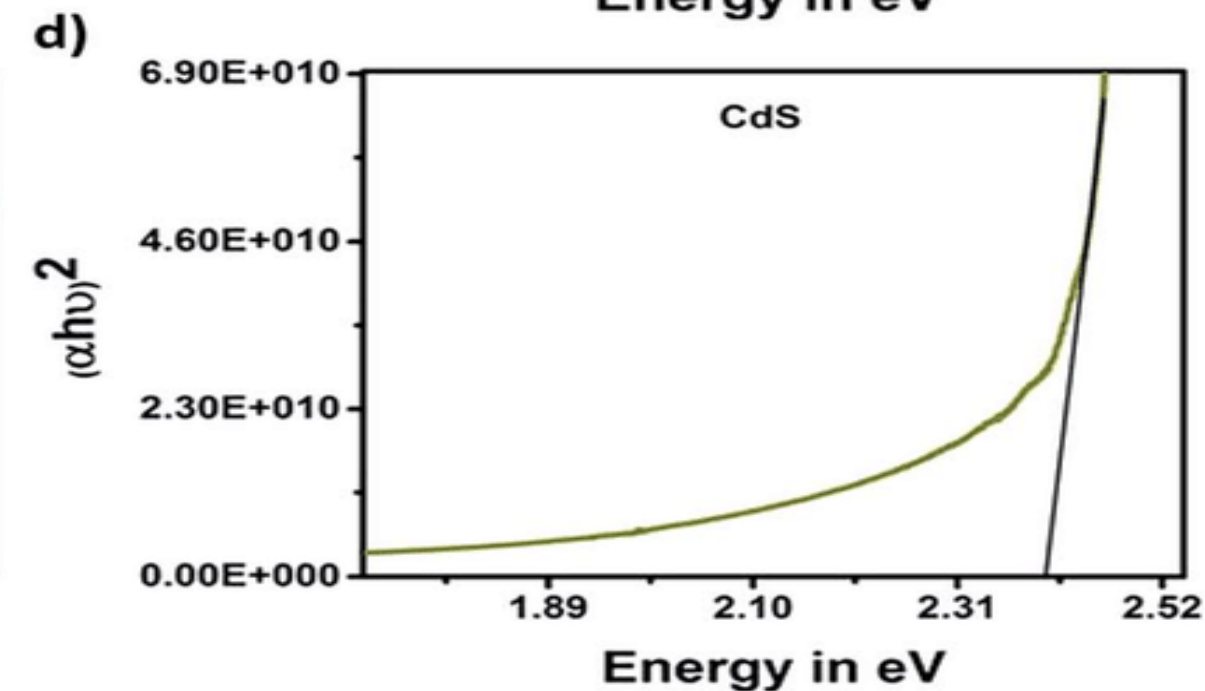
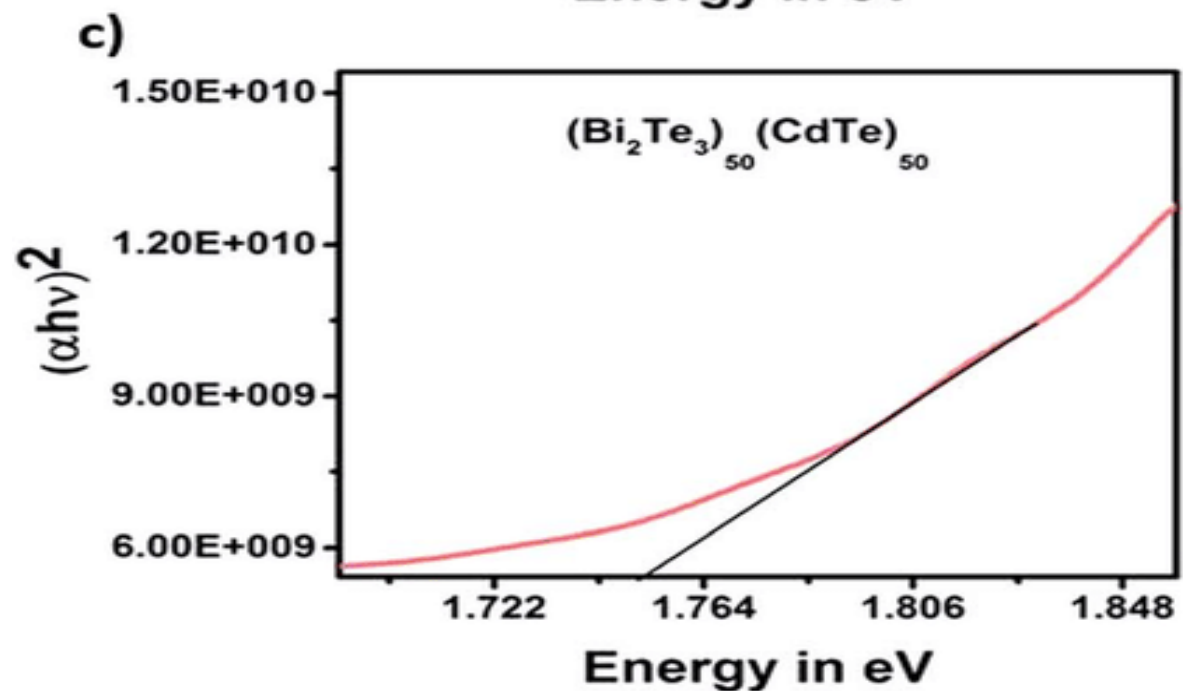
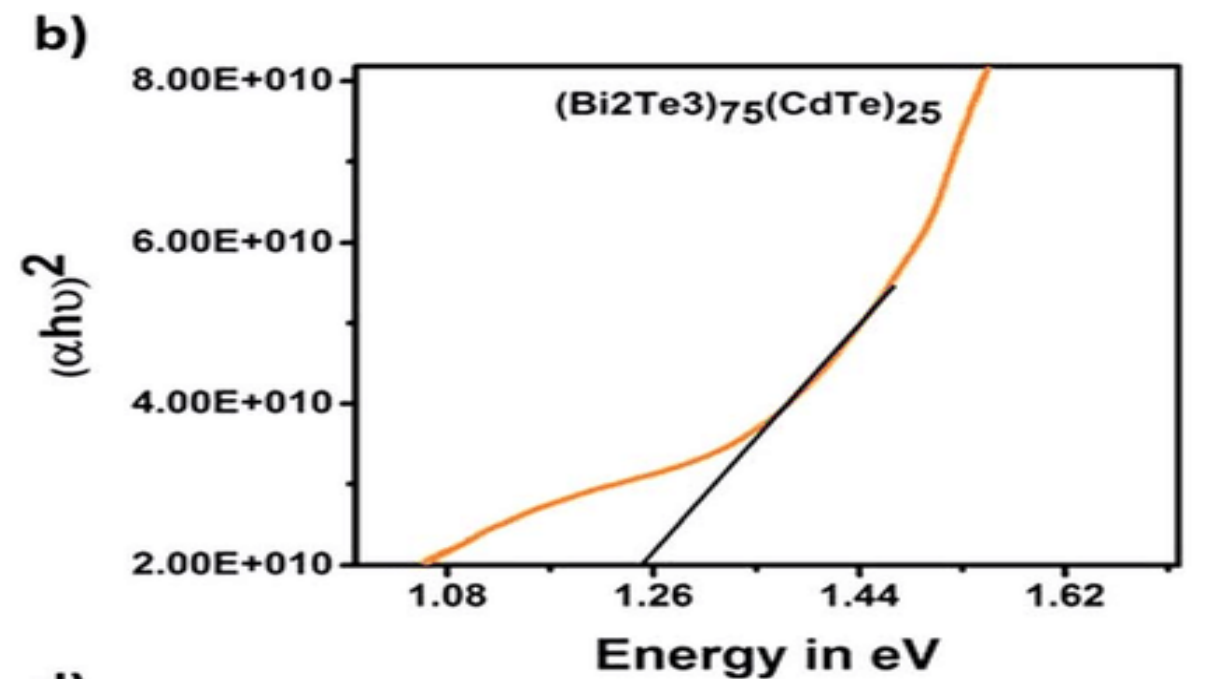
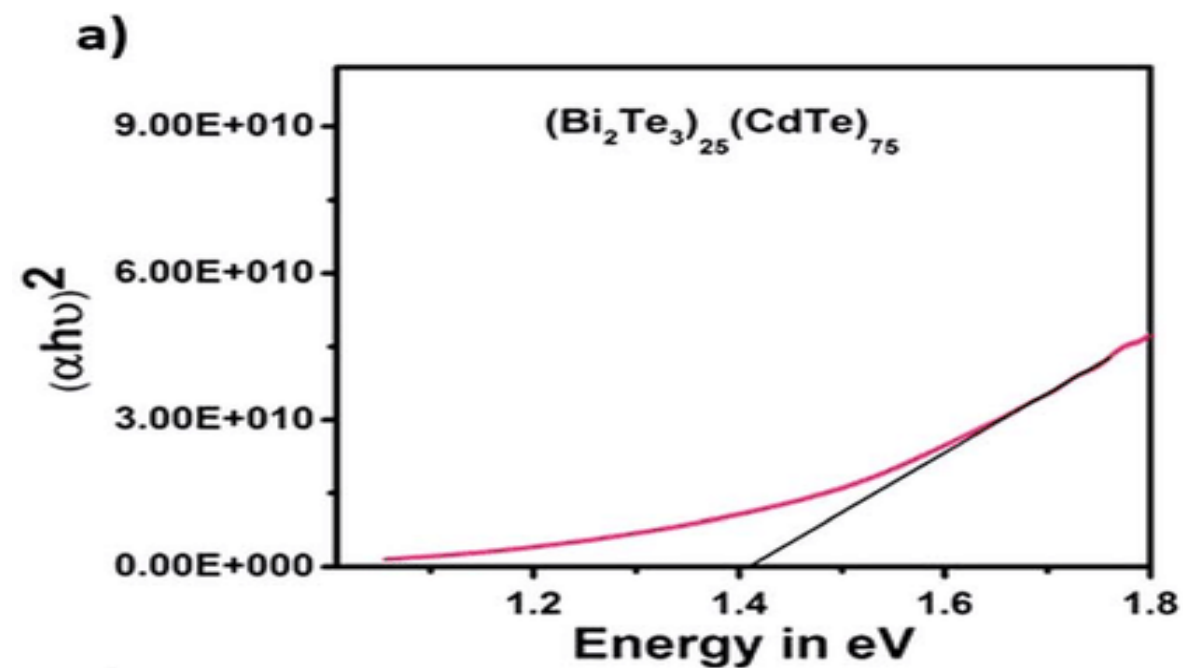
Band gap (E_g) calculation of UV-Vis spectroscopy from absorption spectra

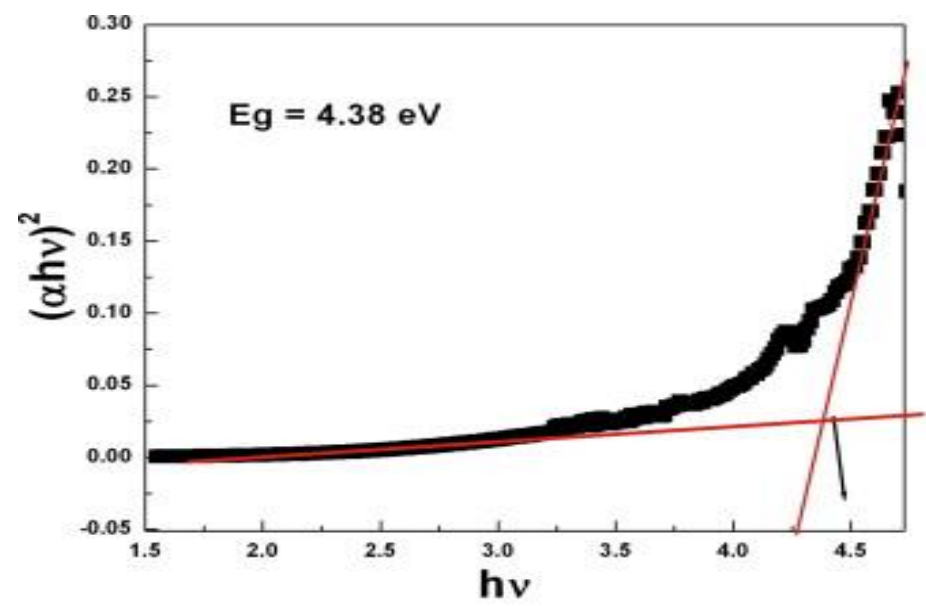




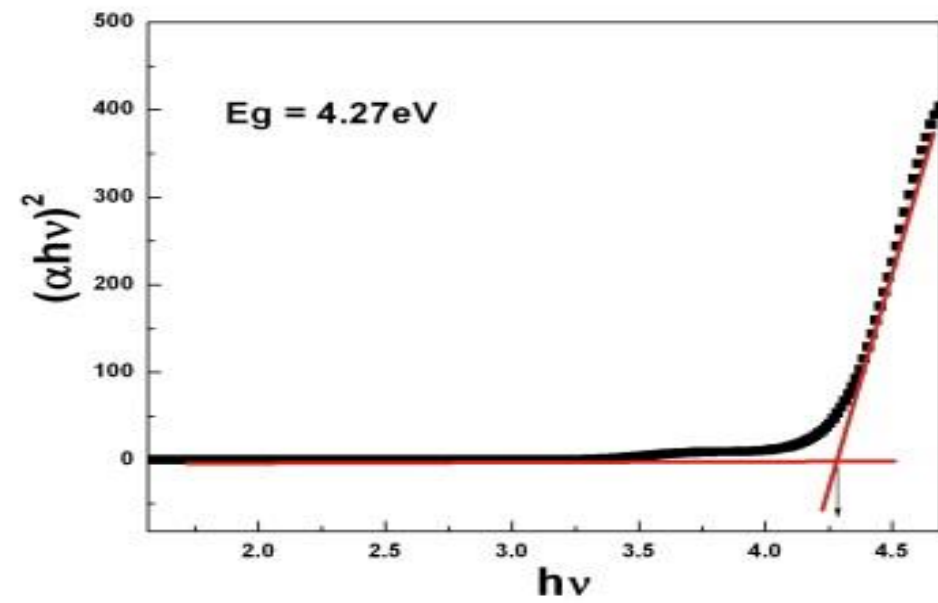
OriginPro 8.5 - D:\85\User Files\UNTITLED * - /Folder1/ ation of UV-Vis spectroscopy from absorption spectra



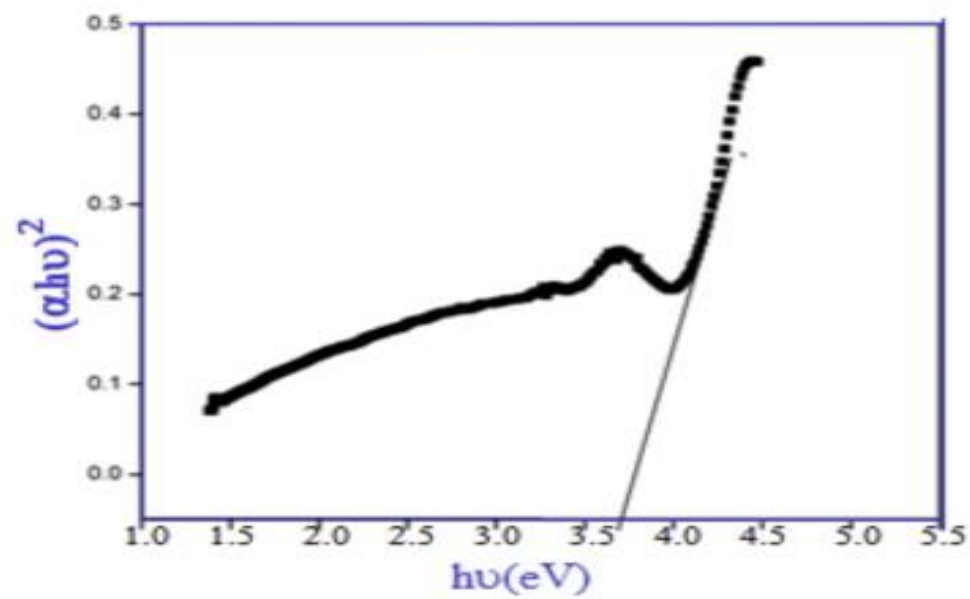




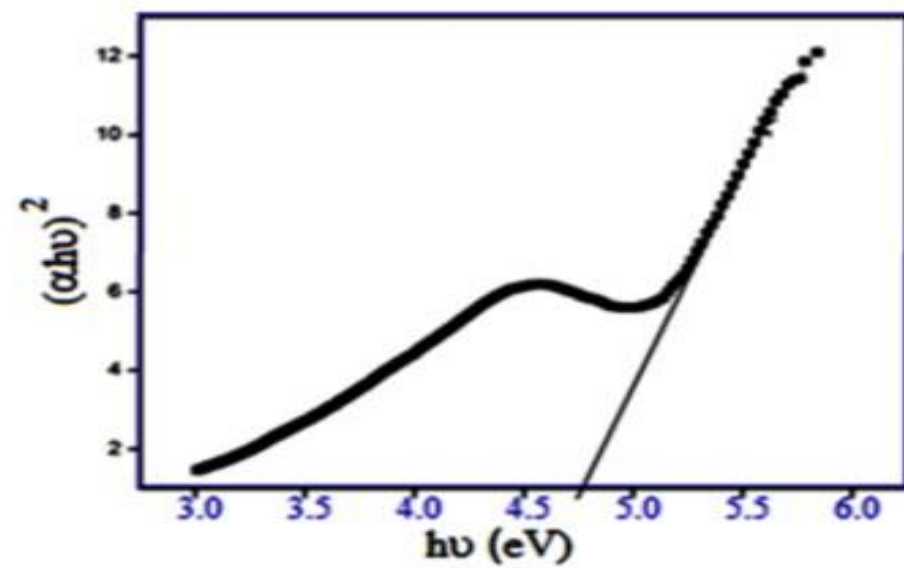
(2)



(3)



(7)



(8)

