Optical and Electrochemical properties of herbal materials

M.Sc. Thesis

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DEPARTMENT OF PHYSICS
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JUNE, 2022

Optical and Electrochemical properties of herbal materials

A THESIS

Submitted in partial fulfillment of the
requirements for the award of the degree
of
Master of Science

by
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Optical and Electrochemical properties of herbal materials**, in the partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE** and submitted in the **DEPARTMENT OF PHYSICS, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from June 2021 to June 2022 under the supervision of **Prof. Rajesh Kumar**, Professor, IIT Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Bhumika 26/05/22

Signature of the student with date
BHUMIKA SAHU

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

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Bhumika Sahu

Master of Science

Discipline of Physics

Indian Institute of Technology, Indore

DEDICATION

Dedicated to My Parents

Abstract

Medicinal plants, also called as Indian Ayurveda has many health benefits. Other than the medicinal benefits they are also believed to show applications like luminescence, electronic properties etc. We studied the Optical and Electrochemical properties of some natural materials. The characterization techniques used are UV-Vis spectroscopy, Photo Luminescence (PL) spectroscopy and Cyclic Voltammetry (CV). Most of the natural material are good UV absorber and are found to show good luminescence. Aparajita, Paras Pipal, Neem, Henna shows red luminescence; Turmeric shows green luminescence; Beetroot, Carrot, Pomegranate shows blue luminescence. They are good antioxidants due to their reducing properties.

Also, we mixed Turmeric and Henna in equal proportion to obtain yellow light from blue/UV LED. UV LED shows yellow and orangish color under the extract while, BLUE LED shows only yellow color. The difference seen in two LED glow is explained on the basis of PL curve.

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NOMENCLATURE

E	Energy
λ	Wavelength
υ	Frequency
h	Planck's constant
c	Speed of light
T	Transmittance
A	Absorbance
I	Intensity of incident photons
I_o	Intensity of transmitted photons
λex	Excitation wavelength

ACRONYMS

EM	Electromagnetic
UV	Ultra
UV-Vis	Ultraviolet-Visible
HOMO	Highest Occupied Molecular Orbital
LUMO	Lowest Unoccupied Molecular Orbital
PL	Photo Luminescence
PLQY	Photo Luminescence Quantum Yield
i.e.	That is
CV	Cyclic Voltammetry
WE	Working Electrode
CE	Counter Electrode
RE	Reference Electrode
V	Volts
Theo.	Theoretical
Exp.	Experimental
LED	Light Emitting Diode

Chapter 1

INTRODUCTION

INDIAN AYURVEDA

Indian medicinal plants[1], also called as Indian Ayurveda is made up of two words – 'Ayu' means life and 'Veda' means science/knowledge. So, Ayurveda[2] means science of life. The five essential constituents and tri doshas are central to Ayurveda's philosophy. The universe, according to Ayurveda, is made up of five basic elements (Panchamahabuthas). In India, there are over 45,000 medicinal plant species[3]. India is the world's largest producer of medicinal herbs and is known as the "botanical garden". Plants have long been used as a source of medicine, and they constitute an important part of India's health-care system. Most practitioners in Indian medical systems design and deliver their own formulas, necessitating meticulous documentation and research. We have proof of more than 3000 years of traditional use of medicinal plants in the Atharva Veda[4].

The five elements combine to form "Tri Doshas[5]" i.e. Vata, Pitta, and Kapha. They are the "Basic Forces'' and also known as the "Pillars of Life".

1. Vata (Air principle)- The elements ether and air.
2. Pitta (Fire principle)- The elements fire and water.
3. Kapha (Water principle)- The elements earth and water.

According to the Ayurveda, sickness is due to the imbalance of any one or more of the three doshas.

Indian Ayurveda[6] have their own medicinal properties. We all are aware about its medicinal properties, but nowadays they are used to study their electronic properties. By studying their electronic properties, they are used to make electronic devices[7,8]. Researchers are more interested towards the

naturals materials as they are harmless, easily available and free of cost as it is present on the earth.

Some of the natural materials are used here to study their electronic properties like optical and electrochemical. They are:-

1.1 Aparajita flower

Figure 1.1: Aparajita flower.

Its botanical name is “Clitoria ternatea”. Its herbal tea has a variety of therapeutic properties. It increases blood flow to the capillaries, which enhances vision. Treatment for ophthalmitis, hair nourishment, and skin tone improvement. Additionally, it provides antioxidants to help the body's immunity.

1.2 Paras pipal flower

Figure 1.2: Paras pipal flower.

Its botanical name is “Thespesia populnea”. Cholera, fevers, herpes, urinary tract problems, abdominal swellings, coughs, headaches, skin diseases, are all treated with the bark, root, leaves, flowers, and fruits of the paras[9] pipal tree.

1.3 Palash flower

Figure 1.3: Palash flower.

Its botanical name is "Butea monosperma". Its anthelmintic action makes it ideal for removing worms from the stomach. It has antibacterial and astringent characteristics, therefore it can be used to treat diarrhoea. Its antioxidant[10] capabilities can aid in the treatment of liver problems.

1.4 Neem

Figure 1.4: Neem.

Its botanical name is "Azadirachta indica". Eye disorders, bloody nose, intestinal worms, stomach distress, skin ulcers, heart and blood vessel ailments, fever, diabetes, gum disease, and liver problems are all treated with neem[11] leaf.

1.5 Henna

Figure 1.5: Henna.

Its botanical name is “Lawsonia inermis”. It is a well-known medicinal herb used as a natural hair color. Its leaves have anti-kapha and anti-pitta capabilities. It can also help with fever, burning sensations, skin problems, and liver problems. Wounds, swellings, and fungal infections benefit from its external use. Henna leaves[12] are used to cleanse wounds, boils, and skin diseases because they are astringent and antimicrobial.

1.6 Turmeric

Figure 1.6: Turmeric.

Its botanical name is “Curcuma longa”. Turmeric[13] contains the active component curcumin, which has potent biological activities. Turmeric is used to cure coughs, diarrhoea, abdominal pain, respiratory problems, and dental problems. During eye infections, burns, and bites, turmeric paste is administered to the skin. Turmeric aids in platelet aggregation reduction, which improves blood circulation. It has a powerful antibacterial function, therefore it can aid with any bacterial skin issue.

1.7 Beet Root

Figure 1.7: Beet Root.

Its botanical name is “Beta vulgaris”. Beetroot[14] has a variety of health benefits, including lowering blood pressure, aiding digestion, and lowering diabetes risk. Alpha-lipoic acid is an antioxidant found in it, which may help reduce blood sugar levels and improve insulin sensitivity. Beetroots[15] have a high nutritional value, with numerous vital vitamins, minerals, and antioxidants.

1.8 Carrot

Figure 1.8: Carrot.

Its botanical name is “Daucus carota”. Carrots[16] include vitamin C, which aids in the formation of antibodies that protect your immune system. They can aid with constipation relief. Carrots' fibre can help keep blood sugar levels in check. They're also high in vitamin A. Carrots include calcium and vitamin K, which are beneficial to bone health.

1.9 Pomegranate

Figure 1.9: Pomegranate.

Its botanical name is “Punica granatum”. Pomegranates[17] have three times the amount of antioxidants as green tea or red wine. Antioxidants protect cells from harm, help to prevent diseases like cancer, and reduce inflammation and ageing. It is helpful in lowering blood pressure and lowering blood sugar. It is also high in fiber, which can help with weight loss, cholesterol reduction, and constipation relief.

1.10 Antioxidant properties of natural materials

When we work out or your body transforms food into energy, free radicals are generated. Free radicals[18] can also enter our body from a range of environmental factors, including cigarette smoke, air pollution, and sunlight. Free radicals can induce "oxidative stress," which can result in cell damage. Antioxidant-rich foods may lower the risk of a variety of diseases (including heart disease and certain cancers). Antioxidants scavenge free radicals from bodily cells, preventing or reducing oxidative damage.

Antioxidants[19] are those who has the property to reduce. Our body produces excess electron, which are harmful for our health. So, to neutralize that electron we need antioxidants. Antioxidants gains that extra electron, thus neutralizes our body and protect it from cell damage and many other diseases.

1.11 Motivation

Motivation to use the natural materials is that it is not harmful for our environment and also for our health.

1. Recetly, Johnson & Johnson was told to pay 2.1 billion dollars, as it was found that the talc powder produced by them have chemical which can cause cancer, see fig 2.1(a).
2. We all use sunscreen in our daily life to protect our skin from harmful UV rays. Sunscreens are also harmful as many companies are making it with very harmful chemicals, see fig 2.1(b), which can affect our skin severely. Sunscreens can be made from natural materials, as there are many good UV absorber. Using chemical free natural material are not only beneficial for our skin but also for our planet.
3. Also, recently the research team of IIT Indore made UV protective device from natural material, Hibiscus flower, see fig 2.1(c). The flower has electrochromic property which changes its color with change in the current.

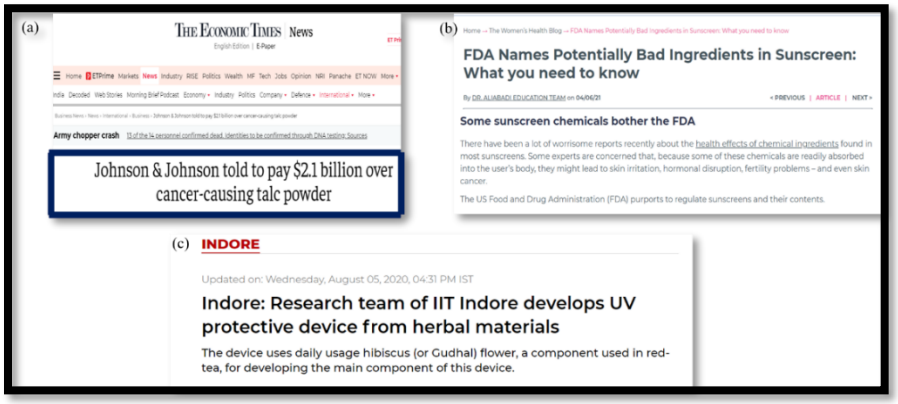

Figure 1.10: Some News articles.

Chapter 2

EXPERIMENTAL TECHNIQUES

2.1 Spectroscopy

Spectroscopy[20] is the measure of how light interact with the matter. Light is a form of energy/ EM radiations. The interaction between EM radiation[21] and matter is a quantum phenomenon. It depends on properties of EM radiation and the samples that is been used. EM radiation spectrum[22] with increasing wavelength and decreasing energy is shown is fig. 2.1, from left to right.

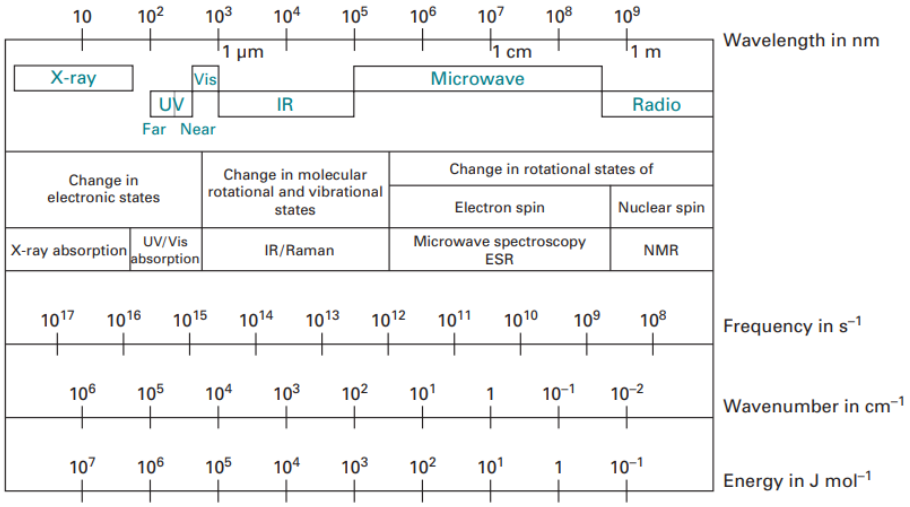

Figure 2.1: EM spectrum.

Different matters interact with various rays in different ways. Human eye is sensitive to very small part of the band i.e. visible region[23] (350nm to 750nm). To study the interaction between matter and radiation for which the human eye cannot observe, we need different instruments to study these interactions.

2.1.1 UV- VIS SPECTROSCOPY

The machine used to perform the experiment is PerkinElmer.

Figure: 2.2: UV-Vis Spectroscopy.

The study of interaction of light and matter in the UV and Visible region is called as UV-Vis spectroscopy[24]. It measures the amount of light absorbed or transmitted in the UV-Vis region[25] by the sample. Different molecules absorb different frequencies. Electrons are bounded differently in different molecules, therefore requires different energies to get excited from ground state to the excited state. That is why different samples have different absorption wavelength.

This technique relies only on the light. Light[26] is a form of energy, inversely proportional to the wavelength, $E=hc/\lambda$, as the wavelength increases energy decreases or vice versa. The total energy of the molecule is the sum of electronic, vibrational and rotational energy. Energy possessed by the molecule is in the form of discrete energy levels. UV radiation possess sufficient energy to cause the electronic transition[27] in the molecular orbitals (ΔE). This is the energy difference between the HOMO and LUMO. Smaller the value of ΔE, lesser the energy required for the electron to make the transition. According to the participation of

molecule in the molecular orbitals, the electronic transition[28] can be classified into four transitions:

- n ⟹ π*
- π ⟹ π*
- n ⟹ σ*
- σ ⟹ σ*

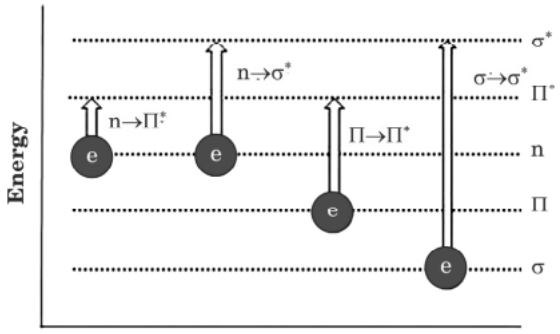

Figure 2.3: Electronic transition of n, π and σ electrons.

Transmittance[29]- It is the ratio of the intensity of incident photon to the intensity of transmitted photon.

$$T = \frac{I}{I_o}$$

Absorbance[30]**-** It is defined as the log of the ratio of the intensity of transmitted photon to the intensity of incident photon.

$$A = \log\left(\frac{I}{I_o}\right)$$

$$A = \log\frac{1}{T}$$

$$A = -\log T$$

Instrumentation

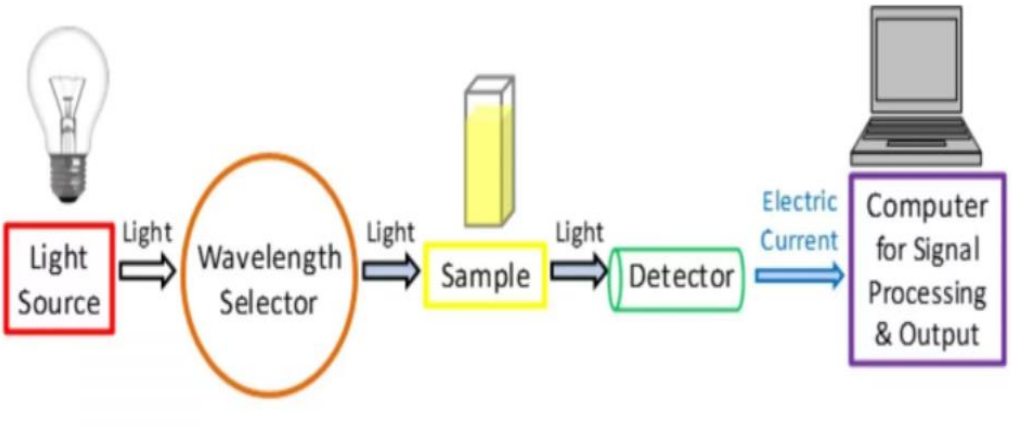

Figure 2.4: Instrumentation of UV-Vis Spectroscopy.

1. **Light source –** It generates the radiations. It must provide sufficient radiation to excite the molecule over the given wavelength region. The light source is the tungsten lamp for the visible region (320nm to 2400nm) and the deuterium lamp for the UV region (160nm to 380nm). Other source to generate the radiation is shown in table 2.1.

Source	*Wavelength region*
Hydrogen and deuterium lamp	160 nm to 380 nm
Tungsten lamp	320 nm to 2400 nm
Xenon arc lamp	200 nm to 1000 nm
Nernst glower	0.4 μm to 20 μm
Globar	1 μm – 40 μm
Nichrome wire	0.75 μm – 20 μm
Hollow cathode lamp	Line source in UV and Visible depending upon cathode material
Mercury vapor lamp	Line source in UV and Visible
Laser	Line source in UV, Visible, IR region depending upon lasing medium
X-ray tube	Wavelength depends upon target material

Table 2.1: Different source to generate radiation.

2. Selector- It selects the different wavelength from the band of light to reach the sample. We generally use monochromatic light i.e. single wavelength.

3. Sample- Prepared sample is putted in the cuvette, which is made up of quartz, has a dimension of $1\times1\times4.5$ cm ^{3}, whose two faces are transparent and other two are opaque. The cuvette is placed in the sample compartment. The radiation enters the sample and exits from the other end.

4. Detector-It is a device which can convert EM radiation energy into the electric signals. A list of commonly used detectors are shown in table 2.2.

Transducer	***Wavelength range***
Photon detector	
Photo-tube	200 to 1000 nm
Photomultiplier	110 to 1000 nm
Silicon photodiode	250 to 1100 nm
Photoconductor	750 to 6000 nm
Photovoltaic cell	400 to 5000 nm
Thermal detectors	
Thermocouple	0.8 to 40 μm
Thermistor	0.8 to 40 μm
Pneumatic	0.8 to 1000 μm
Pyroelectric	0.3 to 1000 μm
X-ray detectors	
Geiger counter	
Proportional counter	
Semiconductor detector Si(Li) or Ge(Li)	
Scintillator detector	

Table 2.2: Commonly used detectors.

4. **Output-** Signals coming out from detector is get amplified and recorder records it, which is then displayed in the readout device. Spectrometer is not complete without the processing and control. The useful information is provided in the computer screen.

2.1.2 PHOTOLUMINESCENCE SPECTROSCOPY

The machine used to perform the PL spectroscopy is PerkinElmer.

Figure 2.5: PL Spectroscopy.

Photoluminescence[31] (PL) is a light emission phenomenon, where transition of energy takes place from higher energy level to the lower energy level. For emission phenomenon to occur, electron must be in the excited state. It works in contactless mode and is nondestructive method to check the material's electronic structure. When lights fall on the sample, some energy get absorbed. The electrons present in the material get excited and moves to the higher energy level. This process is called photo-excitation. When electrons come back to the equilibrium state from the excited state, it dissipates the excess energy in the form of light emission i.e., luminescence. This whole process of photo-excitation and luminescence is called as photoluminescence. PL[32] is the process of absorption of photon to stimulates the emission of photon. When electrons return back to the equilibrium state, the emission of photon may be radiative or non-radiative. The emitted energy is related with the energy difference between the two electronic states that has taken part in the transition.

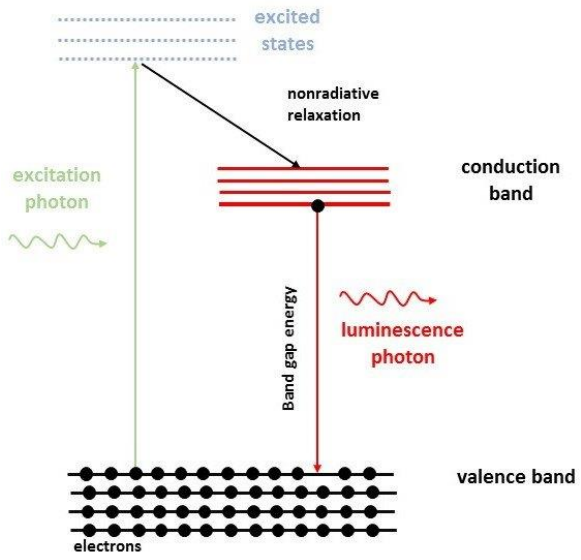

Figure 2.6: Schematic representation of the photoluminescence excitation.

Different modes of PL

1. **Fluorescence**[33]**-** A pair of electron having opposite spins occupies the same ground state, called singlet spin state. When they absorb light, one of its electrons get excited and move to the excited state. The emission of light from singlet excited state to singlet ground state is called fluorescence. It has short lifetime of 10^{-5} -10^{-8} seconds. Therefore, it gets decayed easily once the source of excitation is ben removed.

2. **Phosphorescence-** The electron in singlet excited state modifies to the triplet excited state, such that spin is not get paired with the ground state spin. The emission of light from triplet excited state to the singlet excited state, is called as phosphorescence. It has larger lifetime than fluorescence of about 10^{-4}-10^{-2} seconds. Therefore, it

may continue for some time even when the excited source has been removed.

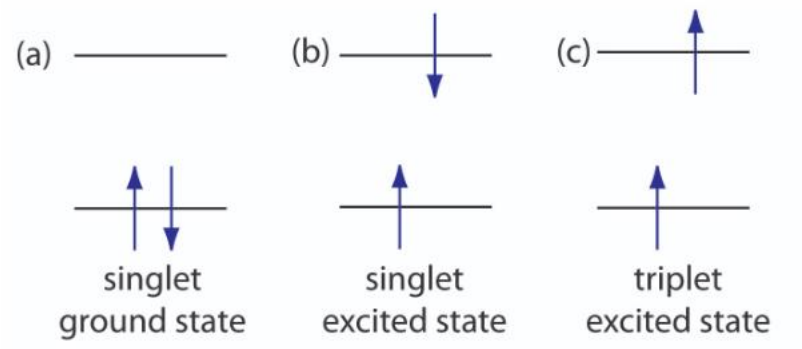

Figure 2.7: (a)Singlet ground state configuration, (b)Singlet excited state configuration, (c)Triplet excited state configuration.

Photo Luminescence Quantum Yield[34] is the ratio of the number of photons absorbed to the number of photons given.

$$PLQY = \frac{no.of\ photons\ absorbed}{no.of\ photons\ given}$$

Instrumentation

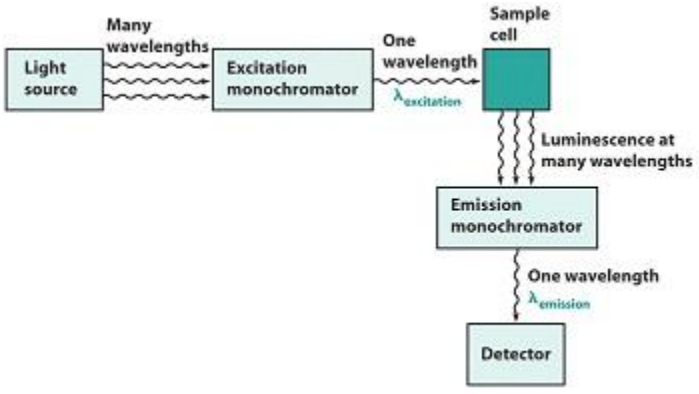

Figure 2.8: Instrumentation of PL.

1. **Light Source-** It is an excitation source, which generates the photoluminescence. In PL spectroscopy, LASER is the source to generate photoluminescence from the sample, because of its excellent source of beam. LASER stands for Light Amplification by Stimulated Emission of Radiation. The LASER which is used here is Helium-Cadmium (He-Cd) laser. Cadmium is the lasing component, which is a metal. Evaporation of metal is important for the lasing action to take place; the distribution of vapor should be uniformly.
2. **Excitation monochromator-** It selects the specific monochromatic light i.e., of particular wavelength from the spectrum of excitation source. We need this monochromator to filter out some unnecessary light source, as we need only one particular wavelength at a time. The light source gives us the whole spectrum which depends upon the instruments.
3. **Sample cell-** It is a sample holder. We used cuvette made up of quartz, having dimension of $1\times1\times4.5$ cm^3, with all the faces transparent, to hold the sample. This cuvette is then placed in the sample chamber to examine. The light of specific wavelength falls on the one face of cuvette and get emitted from the other.
4. **Emission monochromator-** The emitted light from the sample enters the emission monochromator. It selects the particular wavelength from the whole spectrum of sample emission. The sample might give us the wide range of light, so to filter the unnecessary light, emission monochromator is used.
5. **Detector-** It is used to detect the number of photons per unit area coming from the sample at a particular wavelength. The spectrum is then shown on the computer screen.

Applications

1. For the determination of band gap.
2. To check material's quality.
3. To check molecular structure and crystallinity.
4. To check impurity level.
5. To detect defects.

2.2 Electrochemistry

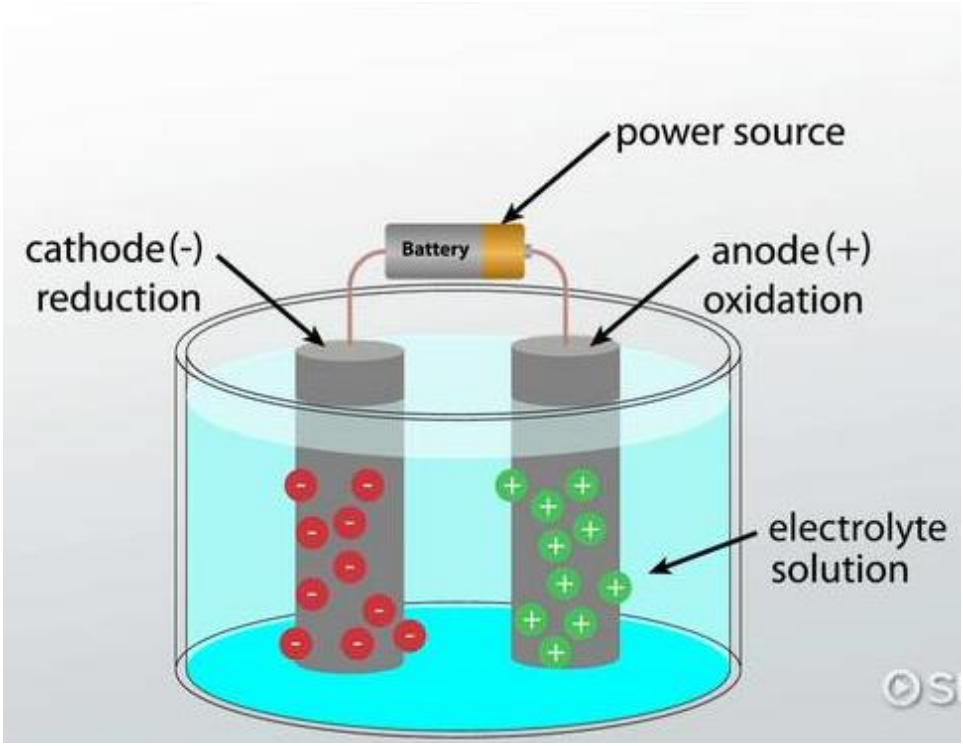

Figure 2.9: Electrochemical Cell.

Electrochemistry[35] is the branch of science. Its basic principle is to convert chemical energy into electrical energy or vice versa. It is the combined phenomena of chemical and electrical effects. It relates the chemical

change and the flow of electron. The cell in which the reactions take place is called electrochemical cell. And the whole process is called electrolysis.

It has two conducting electrodes: -

1. Cathode – It is the negative electrode where reduction takes place, i.e., the gain of electrons.
2. Anode – It is the positive electrode where oxidation takes place, i.e., the loss of electrons.

Electrolyte is the substance added to the electrochemical cell, which has free ions. It helps to conduct electric current after the dissociation of negative and positive ions.

2.2.1 CYCLIC VOLTAMMETRY

"Keithley workstation" is the machine used to perform the cyclic voltammetry.

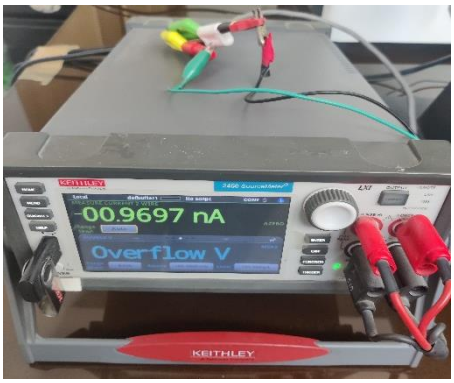

Fig 2.10: Keithley workstation to perform CV.

Cyclic Voltammetry[36,37,38] (CV), is very popular and powerful technique in electrochemical used to investigate the redox reaction of the molecular species. The trace obtained from CV is called voltammogram. By sweeping the potential from negative to positive and from positive to

negative (back and forth) between the limits chosen, current is recorded. The graphical inspection of the CV curve gives the information about the redox peaks. From the graph obtained from CV one can guess the properties of material like resistive, capacitive nature, etc. Cathodic current is the current during reduction and Anodic current is the current during oxidation.

Instrumentation

This is an electrochemical technique which has 3 electrodes: -

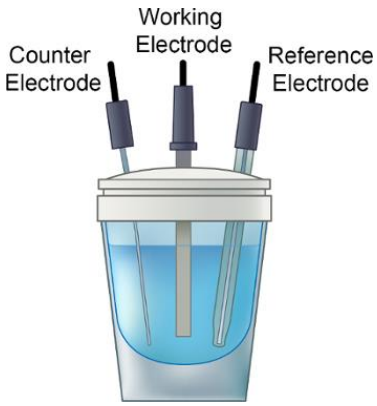

Figure 2.11: Electrodes used in CV.

1. **WORKING ELECTRODE (WE)** – The WE[39] electrode performs the event of our interest. The potential applied on the working electrode is controlled by potentiostat. The type of working electrode chosen may differ from experiment to experiment. The most commonly used working electrodes are glassy carbon, platinum, gold, etc. We have used glassy carbon as the working electrode to perform the experiment.

Figure 2.12: Glassy Carbon.

2. **COUNTER ELECTRODE**[40] **(CE)** – Due to flow of electron between the CE and WE, current gets produced. It is the stable and nonreactive electrode, having high surface area then the WE. It works as the supporting electrode. We have used platinum wire as a counter electrode.

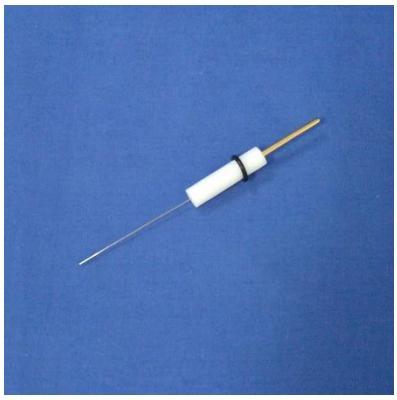

Figure 2.13: Platinum wire.

3. **REFERENCE ELECTRODE (RE)** – RE[41] is well defined electrode with stable potential. It has known electrode potential. We have used Ag/AgCl as a RE, having potential 0.2V.

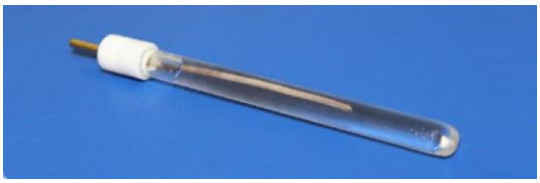

Figure 2.14: Ag/AgCl.

The electrolyte used is sodium acetate (CH_3COONa) as it is fully soluble in methanol/ ethanol.

2.3 Method for preparation of extract.

Approximately 25gms of the material (leaves/flowers) were taken and washed it with the tap water and then with distilled water thoroughly. The material was then dried and chopped/crushed into small pieces. 20ml of methanol is taken in a cleaned beaker and the chopped/crushed material is added to it. They were left for an overnight to get its extract. The extract obtained were filtered using Whatman filter paper. The filtered extract is kept in a separate glass vial and stored in a refrigerator for further use.

Chapter 3

RESULTS AND DISCUSSIONS

Section A. Optical and Electrochemical Analysis.

3.1 Extracts under room light and UV lamp.

The extracts are seen under room light and the UV light. Some of the natural materials shows luminescence[42] under the UV lamp and some does not show any luminescence property.

3.1.1 Aparajita flower

The color of extract under room light is blue in color as shown in fig 3.1(a). When the extract is seen under UV lamp it shows red luminescence as shown in fig 3.1(b).

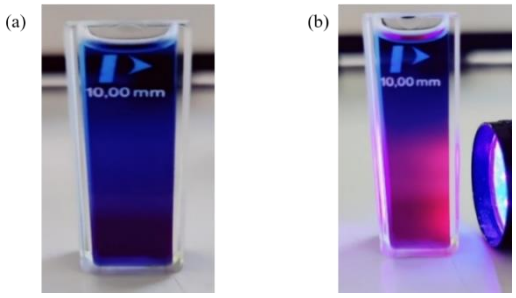

Figure 3.1: Aparajita (a) under room light. (b) under UV light.

3.1.2 Paras pipal flower

The color of extract under room light is orange in color as shown in fig 3.2(a). When the extract is seen under UV lamp it shows red luminescence as shown in fig 3.2(b).

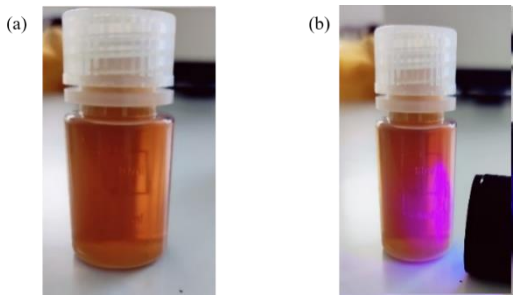

Figure 3.2: Paras Pipal (a) under room light. (b) under UV light.

3.1.3 Palash flower

The color of extract under room light is orange in color as shown in fig 3.3(a). When the extract is seen under UV lamp it does not shows any luminescence as shown in fig 3.3(b).

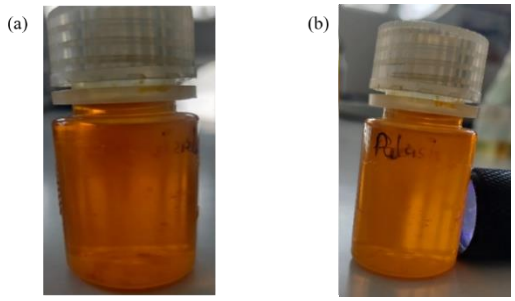

Figure 3.3: Palash (a) under room light. (b) under UV light.

3.1.4 Neem

The color of extract under room light is green in color as shown in fig 3.4(a). When the extract is seen under UV lamp it shows red luminescence as shown in fig 3.4(b).

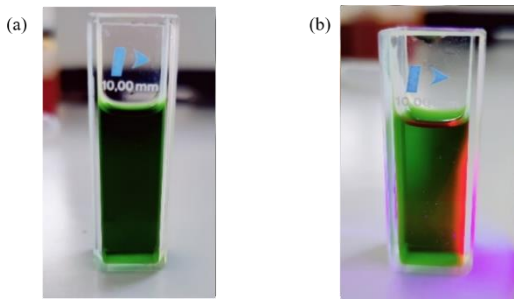

Figure 3.4: Neem (a) under room light. (b) under UV light.

3.1.5 Henna

The color of extract under room light is brown in color as shown in fig 3.5(a). When the extract is seen under UV lamp it shows red luminescence as shown in fig 3.5(b).

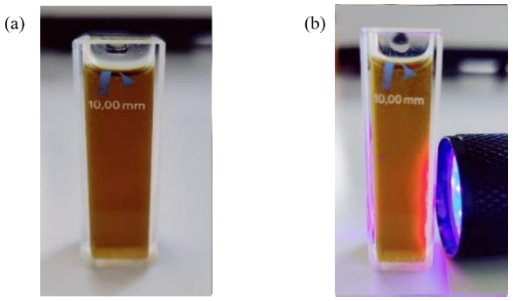

Figure 3.5: Henna (a) under room light. (b) under UV light.

3.1.6 Turmeric

The color of extract under room light is yellow in color as shown in fig 3.6(a). When the extract is seen under UV lamp it shows green luminescence as shown in fig 3.6(b).

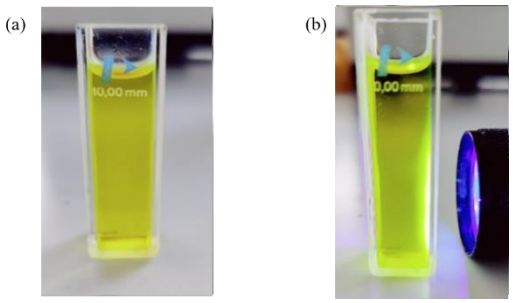

Figure 3.6: Turmeric (a) under room light. (b) under UV light.

3.1.7 Beet Root

The color of extract under room light is red in color as shown in fig 3.7(a). When the extract is seen under UV lamp it shows some blue luminescence as shown in fig 3.7(b).

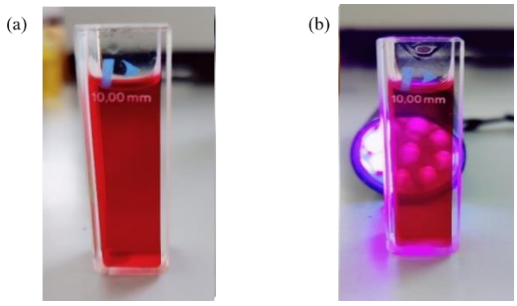

Figure 3.7: Beet root (a) under room light. (b) under UV light.

3.1.8 Carrot

The color of extract under room light is yellowish in color as shown in fig 3.8(a). When the extract is seen under UV lamp it shows some blue luminescence as shown in fig 3.8(b).

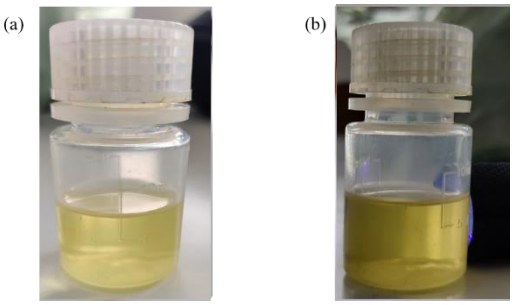

Figure 3.8: Carrot (a) under room light. (b) under UV light.

3.1.9 Pomegranate

The color of extract under room light is transparent/pinkish in color as shown in fig 3.9(a). When the extract is seen under UV lamp it shows some blue luminescence as shown in fig 3.9(b).

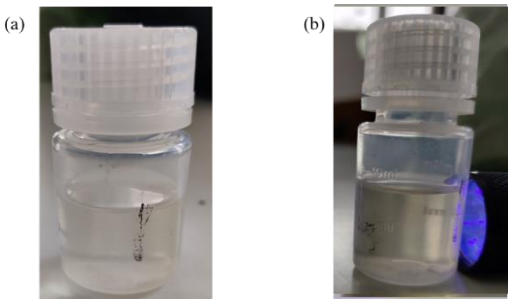

Figure 3.9: Pomegranate (a) under room light. (b) under UV light.

3.2 UV-Vis Analysis.

Cuvette is filled with 3ml of methanol and 1-2 drop of extract is added to the cuvette. If the graph gets saturated then the solution is diluted to get the graph of our interest. Methanol curve was recorded as a baseline.

3.2.1 Aparajita flower

The extract of Aparajita flower is absorbing the wavelength of 575nm and 621nm mostly as shown in the fig 3.10. From the absorbance spectra, it is evident that the extract is absorbing the yellow and orange color and transmitting the blue/violet color. That is why, we see the color of flower as blue color. It is also a good UV absorber.

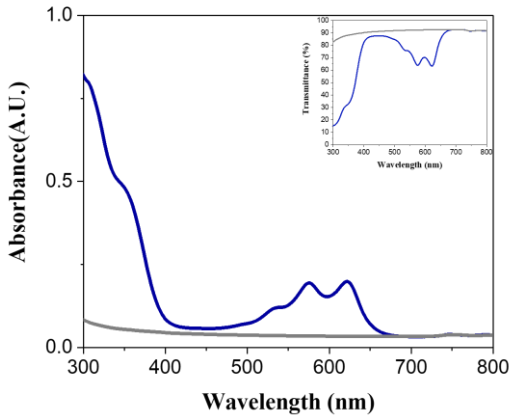

Figure 3.10: UV-VIS Spectra of Aparajita.

3.2.2 Paras pipal flower

The color of paras pipal flower is yellow in color. The absorbance and the transmittance spectra are shown in fig 3.13. From the absorbance spectra, it is seen that there is a peak in the violet region, absorbing violet color and transmitting yellow/oranges color. That is why, we see the color of flower as yellow/orange. It is a good UV absorber.

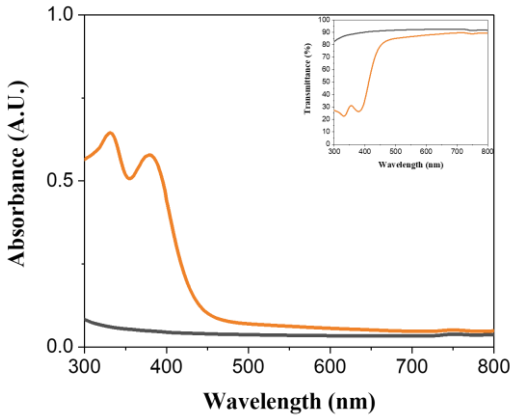

Figure 3.11: UV-VIS Spectra of Paras Pipal.

3.2.3 Palash flower

The color of flower is bright orange. It is a good UV absorber. Fig 3.12, shows absorbance and transmittance spectra. From the absorbance spectra, we can see that since it has peak in blue region; it is absorbing blue color and transmitting orange color. That is why, we see the color of flower as orange.

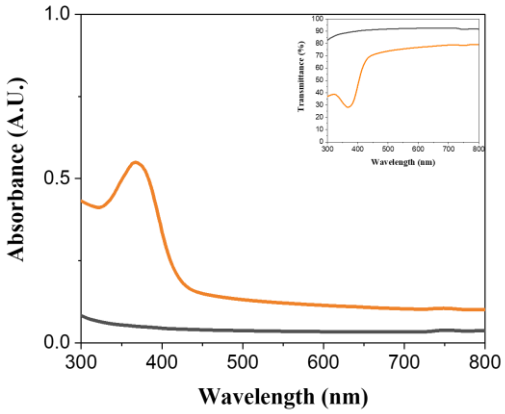

Figure 3.12: UV-VIS Spectra of Palash.

3.2.4 Neem

The leaves of neem are green in color. The extract is a good UV absorber. The absorbance and the transmittance spectra of neem is shown

in fig 3.13. It is transmitting the green color. That is why, we see the color of leaf as green.

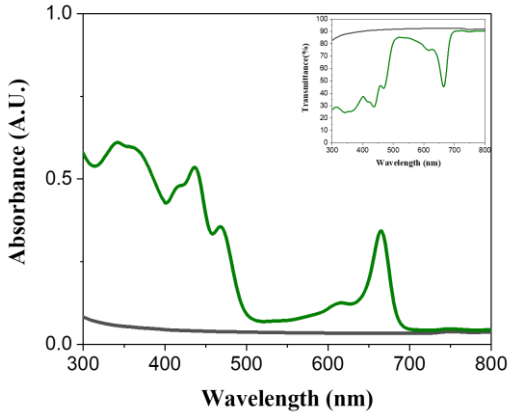

Figure 3.13: UV-VIS Spectra of Neem.

3.2.5 Henna

The prepared extract of Henna is yellowish-brown in color. Fig 3.14 shows the absorbance and transmittance spectra of the Henna. It is a good UV absorber. It is transmitting the green color; therefore, we see the color of leaf as green color.

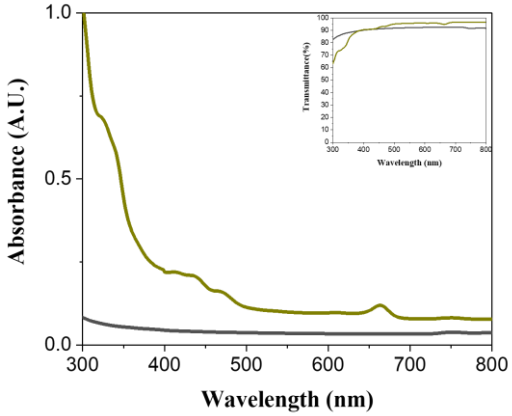

Figure 3.14: UV-VIS Spectra of Henna.

3.2.6 Turmeric

The color of extract is yellow. The absorbance and the transmittance are shown in fig 3.15, it is absorbing the wavelength of 419nm mostly.

Turmeric is also a good UV absorber. It is absorbing the blue color, transmitting the yellow color. Therefore, color of Turmeric is yellow.

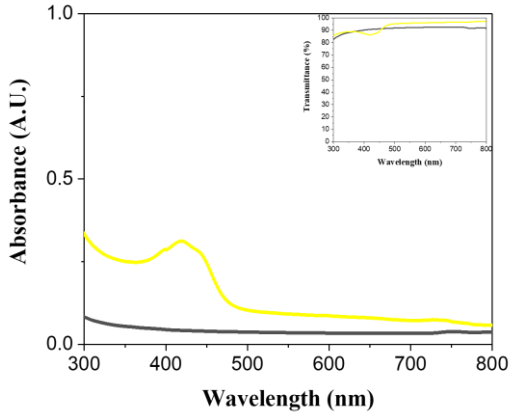

Figure 3.15: UV-VIS Spectra of Turmeric.

3.2.7 Beetroot

The color of extract is red. Beetroot is a good UV absorber. Fig 3.16 shows the absorbance and the transmittance spectra of the beetroot. It is absorbing the wavelength 477nm and 534nm mostly. It is absorbing green color and transmitting red color. Therefore, we see the color of Beetroot as red.

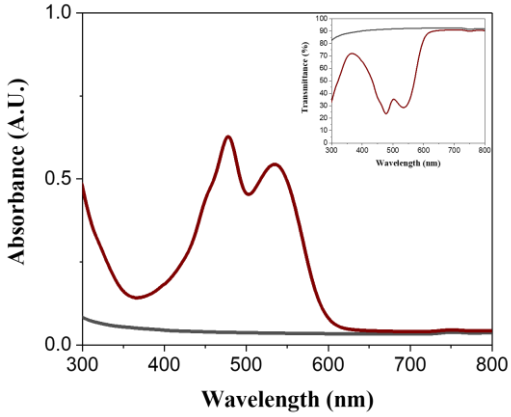

Figure 3.16: UV-VIS Spectra of Beetroot.

3.2.8 Carrot

The color of extract is yellowish. It is a good UV absorber. The absorbance and the transmittance spectra are shown in fig 3.17. The absorbance curve doesn't specifically contain any peak meaning the all of the light is almost transmitted probably because of the dilute nature of the extract.

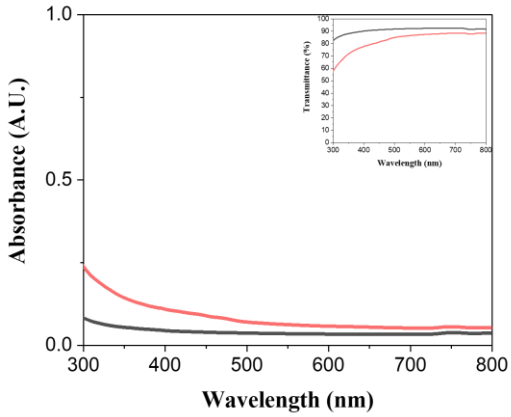

Figure 3.17: UV-VIS Spectra of Carrot.

3.2.9 Pomegranate

The extract is pinkish/transparent. Fig 3.18 shows absorbance and transmittance spectra of pomegranate. It is also a UV absorber.

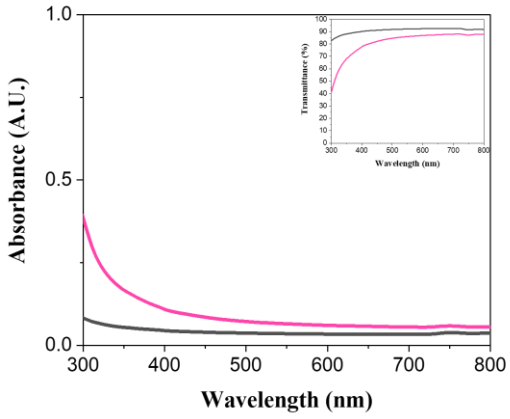

Figure 3.18: UV-VIS Spectra of Pomegranate.

3.3 PL Analysis.

Cuvette is filled with 3ml of methanol and 1 drop of extract is added to it. Dilute it according to the need to get the perfect graph without any saturation.

3.3.1 Aparajita flower

The PL curve of Aparajita is shown in fig 3.19. It has peaks at 673nm when excited with 350nm and 400nm, which is a red color region. That is why, we see red luminescence under UV lamp, shown in fig 3.1(b).

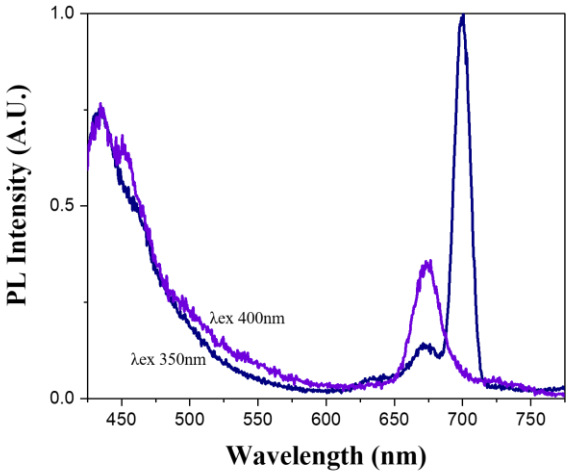

Figure 3.19: PL spectra of Aparajita.

3.3.2 Paras pipal flower

The PL curve of Paras pipal is shown in fig 3.20. It has peaks at 670nm when excited with 350nm and 400nm, which is a red color region. That is why, we see red luminescence under UV lamp, shown in fig 3.2(b).

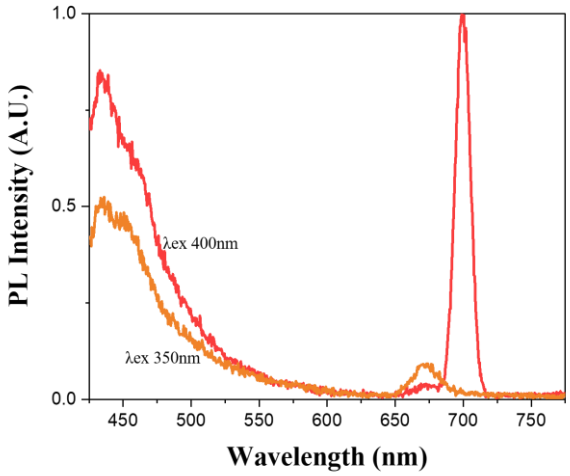

Figure 3.20: PL spectra of Paras pipal.

3.3.3 Palash flower

The PL curve of Palash is shown in fig 3.21. It has peaks at 671nm when excited with 350nm and 400nm, which is a red color region. Since the intensity of luminescence is very low, it does not show any luminescence under UV light, as in fig 3.3(b).

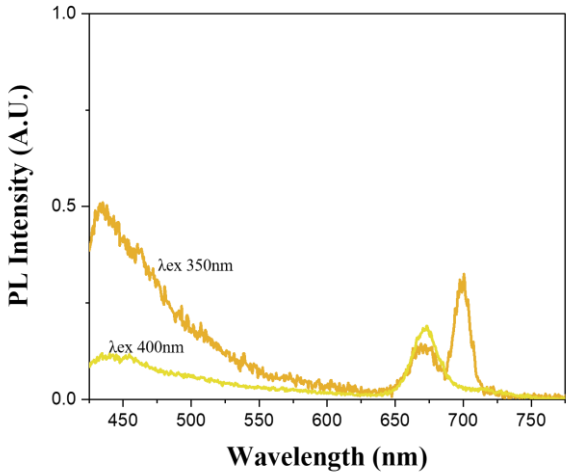

Figure 3.21: PL spectra of Palash.

3.3.4 Neem

The PL curve of Neem is shown in fig 3.22. It has peaks at 674nm when excited with 350nm and 400nm, which is a red color region. That is why, we see red luminescence under UV lamp, shown in fig 3.4(b).

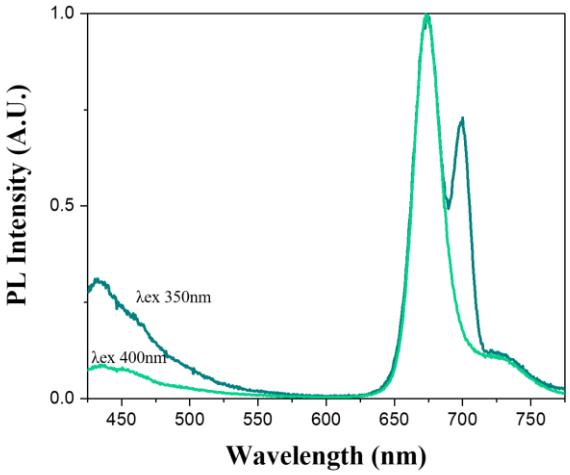

Figure 3.22: PL spectra of Neem.

3.3.5 Henna

The PL curve of Henna is shown in fig 3.23. It has peaks at 673nm when excited with 350nm and 400nm, which is a red color region. We get another peak at 762nm when excited with 350nm wavelength. That is why, we see red luminescence under UV lamp, shown in fig 3.5(b).

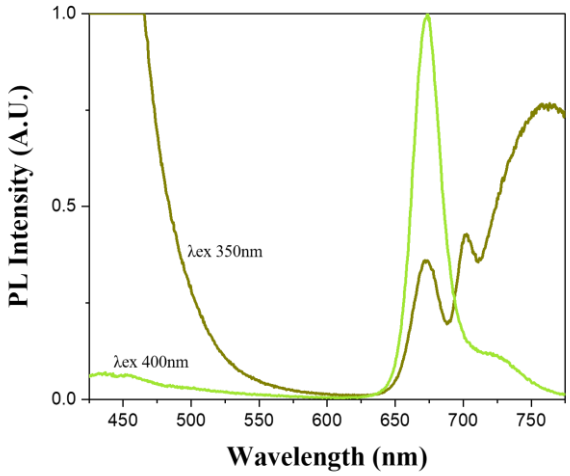

Figure 3.23: PL spectra of Henna.

3.3.6 Turmeric

The PL curve of Henna is shown in fig 3.24. It has a broad peak around 524nm when excited with 350nm and 400nm, which is a green color region. That is why, we see green luminescence under UV lamp, shown in fig 3.6(b).

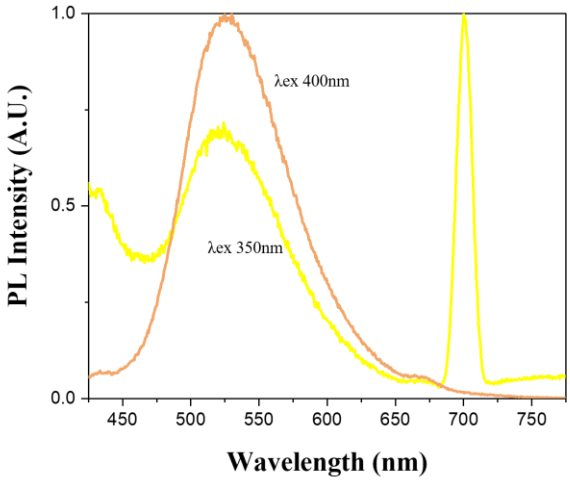

Figure 3.24: PL spectra of Turmeric.

3.3.7 Beetroot

The PL curve of Beetroot is shown in fig 3.25. It has peaks in blue color region when excited with 350nm and 400 nm. That is why, we see some blue luminescence under UV lamp, shown in fig 3.7(b).

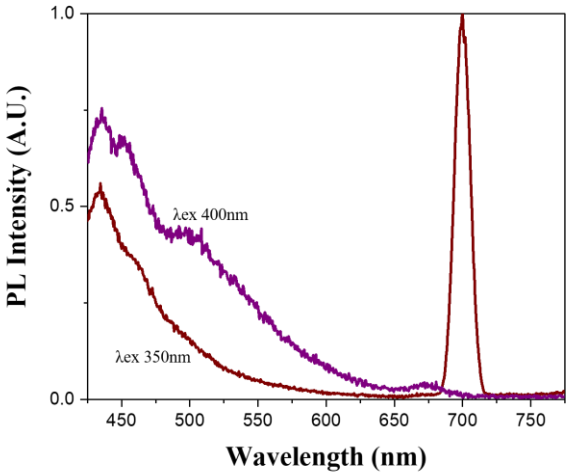

Figure 3.25: PL spectra of Beetroot.

3.3.8 Carrot

The PL curve of Carrot is shown in fig 3.26. It has peaks in blue color region when excited with 350nm and 400 nm. Also, it shows peak at 671nm which is a red region when excited with 400nm. That is why, we see some blue luminescence under UV lamp, shown in fig 3.8(b).

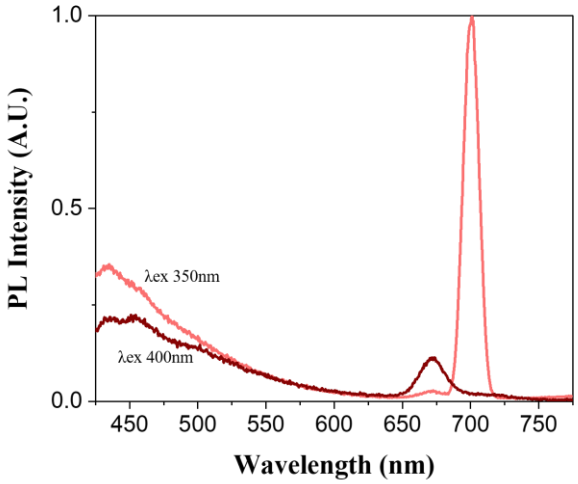

Figure 3.26: PL spectra of Carrot.

3.3.9 Pomegranate

The PL curve of Pomegranate is shown in fig 3.27. It has peaks in blue color region when excited with 350nm and 400nm. That is why, we see some blue luminescence under UV lamp, shown in fig 3.9(b).

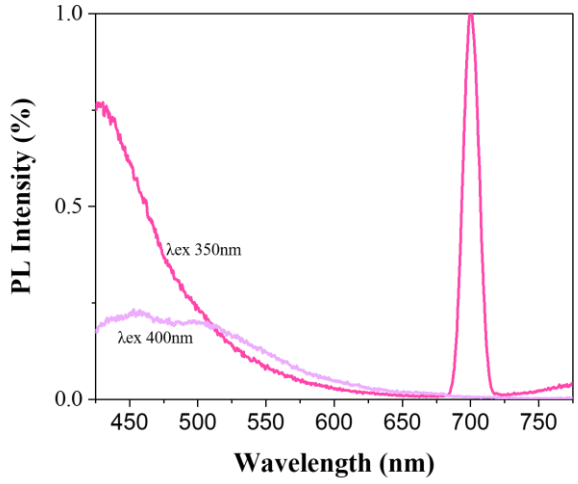

Figure 3.27: PL spectra of Pomegranate.

3.4 Electrochemical Study

To a three neck round bottom flask, we added 10ml of methanol and 5ml of extract to it. The electrolyte used here is sodium acetate (CH_3COONa), and has a reduction peak at -1V. Next, 0.123gm of sodium acetate was weighed and added to the flask. Stirring was done till the electrolyte get fully dissolved. The 3 electrode WE (glassy carbon), CE (platinum wire), RE (Ag/AgCl) was gently dipped in the electrolyte such as to make sure that all the 3 electrodes are not in contact with each other.

3.4.1 Aparajita flower

Aparajita has oxidation peak at around 1.3V and a reduction peak at around -1.1V. However, the reduction peak at around -1V is probably due the electrolyte. The CV curve is shown in fig 3.28.

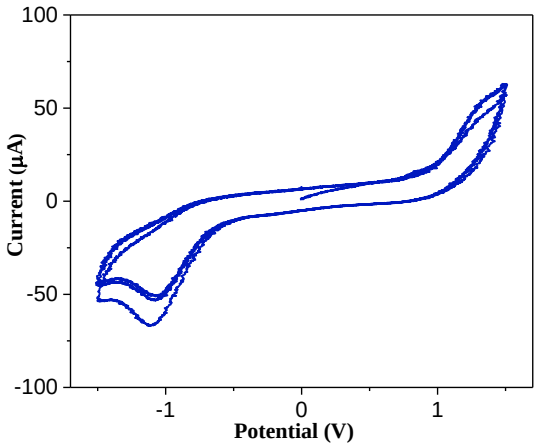

Figure 3.28: CV curve of Aparajita.

3.4.2 Paras pipal flower

Paras pipal has an oxidation peak at around 0.3V and a reduction peak at around -1.2V. The reduction peak at around -1V is due to the electrolyte. The CV curve is shown in fig 3.29.

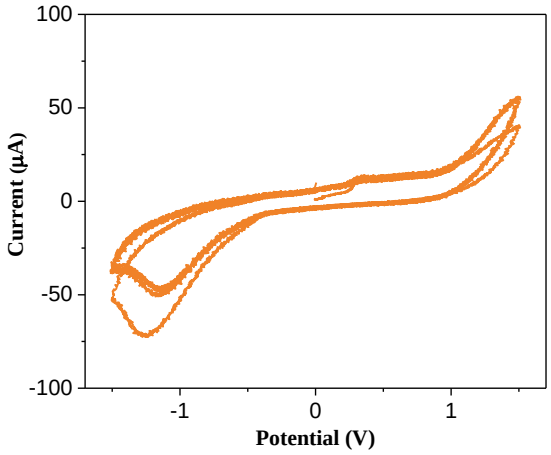

Figure 3.29: CV curve of Paras pipal.

3.4.3 Palash flower

Palash has an oxidation peak at around 1.3V and a reduction peak at around -1.16V. The reduction peak at around -1V is due to the electrolyte. The CV curve is shown in fig 3.30.

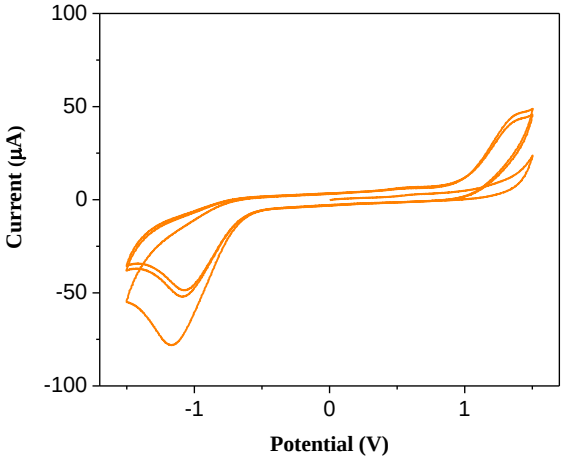

Figure 3.30: CV curve of Palash.

3.4.4 Neem

Neem has an oxidation peak at around 1.3V. The independent reduction peak is not observed. The peak at around -1V is due to the electrolyte. The CV curve is shown in fig 3.31.

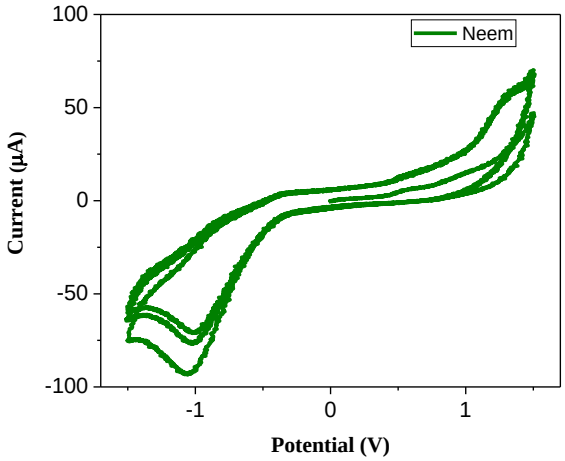

Figure 3.31: CV curve of Neem.

3.4.5 Henna

Henna has an interesting CV curve. It has two oxidation peaks at around -0.3V and -0.83V. It has an independent reduction peak at around -0.5V. The reduction peak at around -1V is due to the electrolyte. The CV curve is shown in fig 3.32.

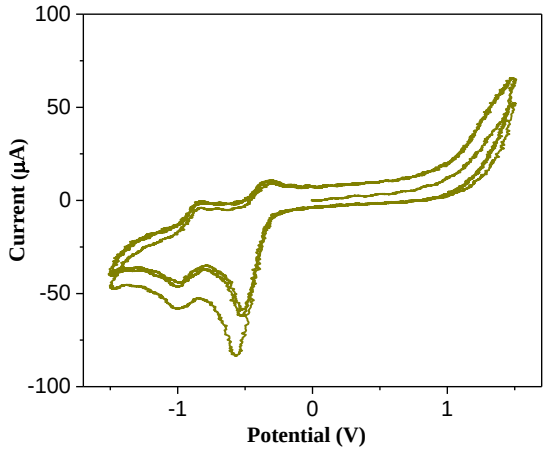

Figure 3.32: CV curve of Henna.

3.4.6 Turmeric

Turmeric has two oxidation peaks at around -0.4V and 1.2V. The reduction peak at around -1V is due to the electrolyte. It does not have its own independent reduction peak. The CV curve is shown in fig 3.33.

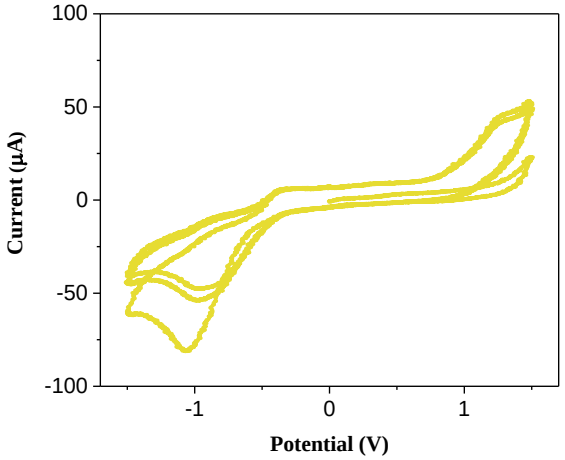

Figure 3.33: CV curve of Turmeric.

3.4.7 Beetroot

Beetroot has an oxidation peak at around -0.3V. The reduction peak at around -1V is due to the electrolyte. It does not have its own independent reduction peak. The CV curve is shown in fig 3.34.

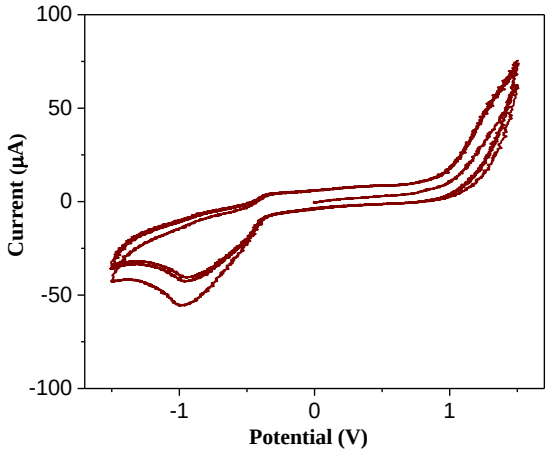

Figure 3.34: CV curve of Beetroot.

3.4.8 Carrot

Carrot has two oxidation peaks at around -0.58V and 0.88V. It has its own independent reduction peak at around -0.83V. The CV curve is shown in fig 3.35.

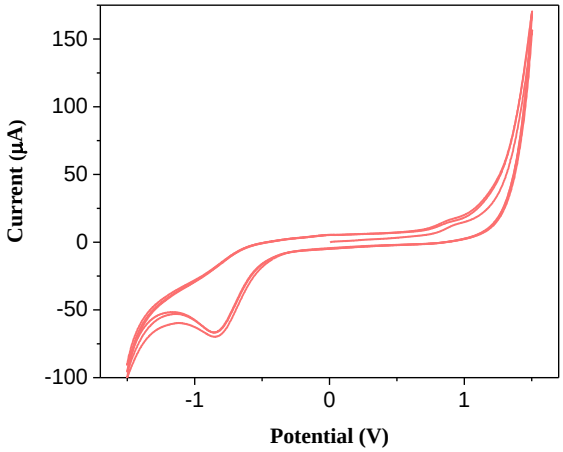

Figure 3.35: CV curve of Carrot.

3.4.9 Pomegranate

Pomegranate has three oxidation peaks at around -0.57V, 0.3V and 1.2V. It has two independent reduction peaks at around -1.2V and -0.8V. The CV curve is shown in fig 3.36.

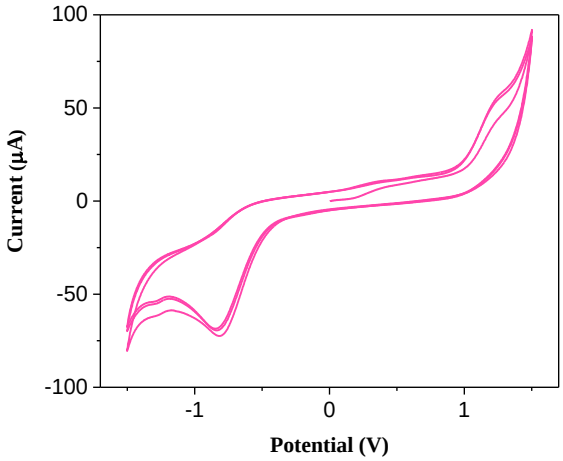

Figure 3.36: CV curve of Pomegranate.

Section B. Mixing of Turmeric and Henna and LED glow

The extract of Turmeric is yellow in color and Henna is brownish in color in methanol as seen in day light. When seen under UV lamp Turmeric shows green luminescence (fig 3.6(b)) and Henna shows red luminescence under UV lamp (fig 3.5(b)). We tried mixing Turmeric and Henna to get yellow color LED glow, because the mixture of green and red luminescence gives yellow luminescence, as per RGB color scheme[43]. Methanol was used as a baseline.

3.5 UV-Vis spectroscopy of the mixture (Turmeric+Henna)

The UV-Vis spectra of individual Turmeric and Henna is shown in fig 3.15 and fig 3.14 respectively. We added the absorption spectrum obtained from the individual Turmeric and Henna, called it as theoretical data, see fig 3.37. From the absorbance spectra, we get the broad peak in blue region means it is absorbing the blue color.

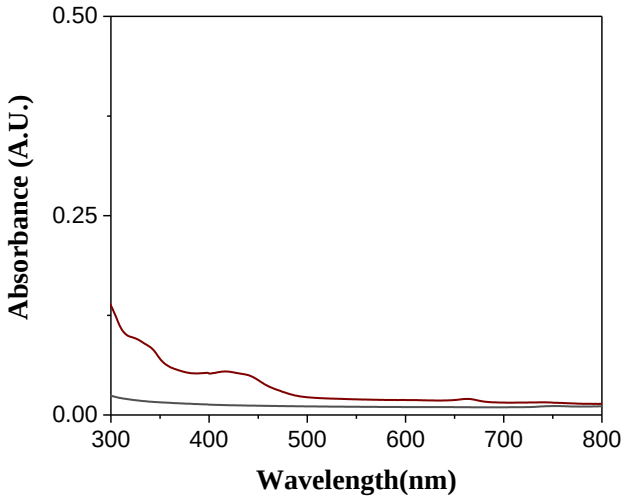

Figure 3.37: Absorbance spectra of theoretical data.

We mixed the Turmeric and Henna in equal proportion i.e., ~5µl of both the extracts taken in 2ml methanol. The absorption spectra were obtained by the UV-Vis spectroscopy, called as experimental data. From the absorbance spectra, shown in fig 3.38, we get the same broad peak in the blue region.

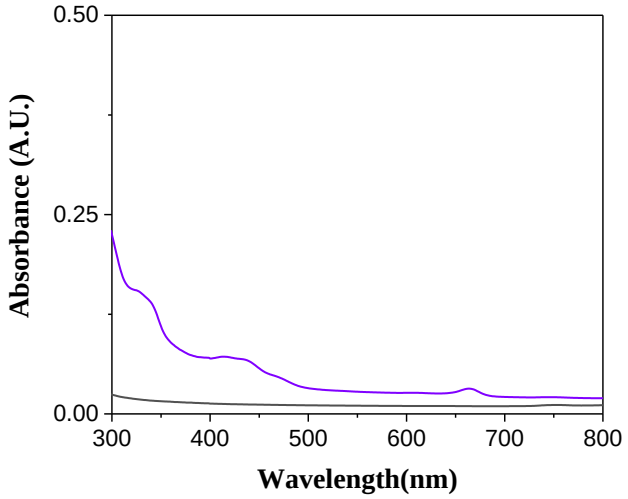

Figure 3.38: Absorbance spectra of experimental data.

Comparison between theoretical and experimental data

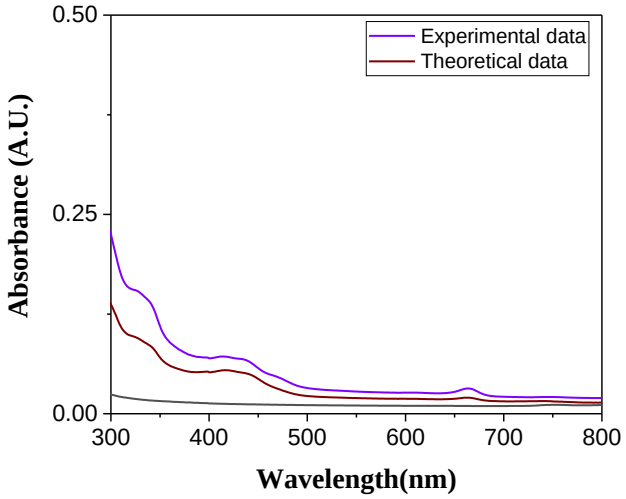

Figure 3.39: Absorbance spectra of Theo. vs exp.

From the fig 3.39, it is showing the same broad peak in the blue region with a little difference in its intensities implying a very good correlation in both experimental and theoretical data.

3.6 PL Spectroscopy of the mixture (Turmeric+Henna)

The PL curve of individual Turmeric and Henna is shown in fig 3.24 and fig 3.23 respectively, excited with two different wavelengths, 350nm and 400nm. PL curve of Turmeric has peak at 524nm which is a green region and PL curve of Henna has peak at 673nm, another peak at 763nm when excited only with 350nm.

We added the PL curve obtained in the fig 3.24 and fig 3.23 in origin software, called as theoretical data. Fig 3.40(a) is the addition of PL curve when excited with 350nm wavelength, getting broad peak in green region (524nm), two other peaks at 672nm and 763nm. Fig 3.40(b) is the addition of PL curve when excited with 400nm wavelength, getting peak in green(524nm) and red(673nm) region.

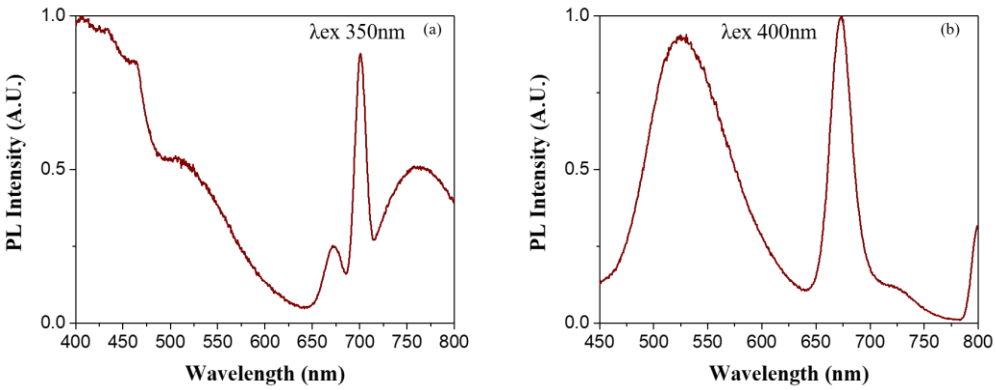

Figure 3.40: PL curve of theoretical data. (a) 350nm excitation. (b) 400nm excitation.

We again mixed Turmeric and Henna in equal proportion (~5µl of both the extracts taken in 2ml methanol). The curve obtained by the PL spectroscopy, called as experimental data. From the experimental data, when excited with 350nm wavelength, we got the broad peak in green region and two other broad peaks in red region at 672nm and 762nm, see fig 3.41(a). When excited with 400nm wavelength, got broad peak in green region and another peak in red region, see fig 3.41(b).

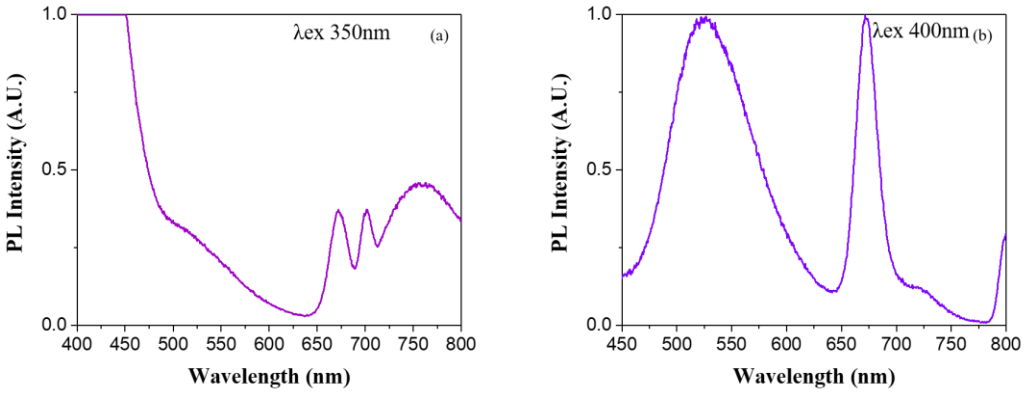

Figure 3.41 PL curve of experimental data. (a) 350nm excitation. (b) 400nm excitation.

Comparison between theoretical and experimental data

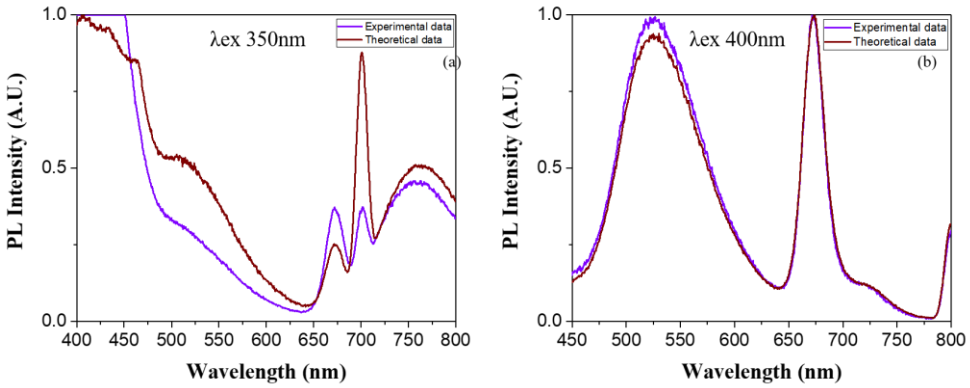

Figure 3.42: PL curve of theo. Vs exp. data. (a) 350nm excitation. (b) 400nm excitation.

From the fig 3.42(a), when excited with 350nm wavelength, we get the broad peak at around 762nm, which is not seen when excited with 400nm, fig 3.42(b). The theoretically and the experimentally obtained data are almost same implying consistency in results.

LED Glow

As observed from the PL spectra, the mixture of the two extracts is seen to give yellow luminescence which can be used to make a blue/UV LED appear yellow. Thus, Turmeric and Henna is mixed in equal proportion i.e., 1.5ml:1.5ml. Two holes are made in an Eppendorf so that led is fitted into it. The mixture obtained is filled in it and an LED is glown by supplying the current. The entire arrangement is shown in shown in Fig 3.43.

UV LED – Fig 3.43 shows the UV LED glow. Here, we can see around the UV LED, the color is yellow, which is a mixture of green and red color. Below the UV LED, orangish color is also seen. The reason behind

the color of UV LED glow can also be understood from the PL curve obtained when excited with 350nm wavelength, fig 3.41(a). Since, we are getting another peak at 762nm, which is the reason for the orangish glow seen in the glowing of UV LED.

Figure 3.43: UV LED glow.

BLUE LED – Fig 3.44 shows the BLUE LED glow.

Here, we can see the glow is only yellow in color. The reason for yellow glow can also be understood from the PL curve of mixture obtained when excited with 400nm wavelength, refer fig 3.41(b). BLUE LED glow is only yellow color because in the PL curve, we are getting peaks in green and red region, which combines to give yellow color. We cannot see the orangish color glow in the BLUE LED as in the previous case. Since we did not get peak at 762nm when excited with 400nm wavelength, that is obtained when excited with 350nm wavelength. That is why, we see only yellow color glow in BLUE LED.

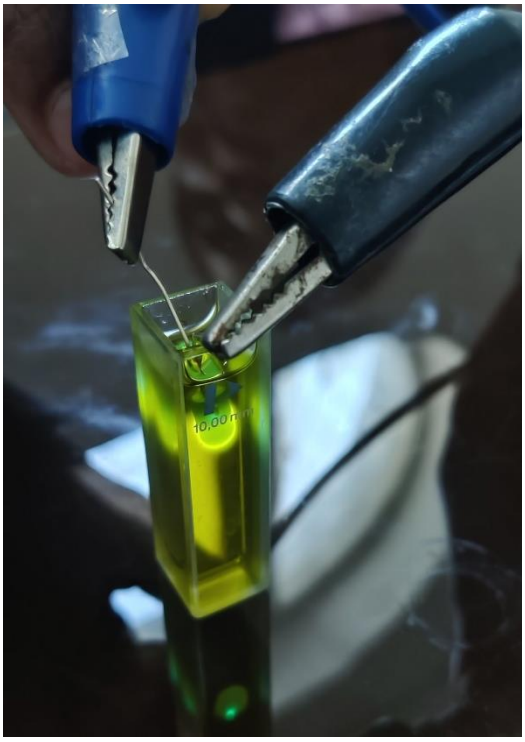

Figure 3.44: BLUE LED glow.

Chapter 4

CONCLUSION AND FUTURE SCOPE

Extracts prepared from natural materials are used to study optical and electrochemical properties. UV-Vis spectroscopy and PL spectroscopy has been done to study optical properties and CV has done to study the electrochemical property. All the materials used are good UV absorber. Some materials show good luminescence when excited with UV and blue wavelength. They are good reducing agents, hence can be used as an antioxidant. Point wise conclusion from individual material is noted down:

1. Aparajita – The color of flower is blue/violet. Since, it is absorbing the yellow/orange color and transmitting the blue/violet color. It shows red luminescence when photoexcited with 350nm and 400nm wavelength.
2. Paras Pipal – The color of flower is yellow/orange in color. Since, it is absorbing the violet color and transmitting the yellow/orange color. It shows red luminescence when photoexcited with 350nm and 400nm wavelength.
3. Palash – The color of flower is bright orange. Since, it is absorbing the blue color, and transmitting the orange color. It has no such luminescence.
4. Neem – The color of leaf is green. Since, it is transmitting more the green color. It has red luminescence when photoexcited with 350nm and 400nm wavelength.
5. Henna – The color of leaf is green. Since, it is transmitting the green color more. It shows red luminescence when photoexcited with 350nm and 400nm wavelength.
6. Turmeric – The color of turmeric is yellow. Since, it is absorbing blue color and transmitting the yellow color. It shows green

luminescence when photoexcited with 350nm and 400nm wavelength.

7. Beetroot – The color of Beetroot is red. Since, it is transmitting the red color more and absorbing the green color. It has very low blue luminescence when photoexcited with 350nm and 400nm wavelength.
8. Carrot – The color is orange, since, it is transmitting the orange color. It shows blue luminescence on photoexcitation with 350nm and 400nm wavelength.
9. Pomegranate – The color is almost transparent/pinkish. Since, it is transmitting all the colors but red color more, therefore its color is pinkish/transparent. It shows blue luminescence when excited with 350nm and 400nm wavelength.

Next, using the mixture of Turmeric and Henna extracts, two types of LED are shown to give yellow luminescence. The UV LED shows yellow and orange both colors, while the BLUE LED only shows yellow light. The reason for the yellow and orange color in UV LED can be understood from the PL curve obtained in fig 4.40. In the PL curve, since we are getting an extra peak in red region at 762nm when excited with 350nm wavelength, which is not seen when excited with 400nm wavelength. That is the reason, that there are two colors (yellow and orange) in UV LED and only one color (yellow) in BLUE LED.

Future scope

1. Natural materials showing luminescence under UV lamp can have application in biomarkers.
2. We will try to mix more extract to make White Light Emitting LED.
3. We will try to make electronic devices from the natural materials, and try to examine whether it works as UV filter.
4. Make electronic device and check its capacitive, resistive or memristive properties.

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