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# Relationship between Wavelengths of Lights, Chemical Structure of Different Compounds and Colours

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**ABSTRACT:** Colours play very significant roles in individual life. Everything has unusual colours than each other. Likes carrots are orange, leafs are green. In addition to this, colours of materials are differs as their compounds differs. Over and above that water is transparent, means devoid of colours. Absorption wavelength of lights also straightforwardly depends on double bond of structure. In addition to that A photon will be absorb, when the photon energy match with the energy between the ground electronic state and exited electronic state. But questions arise is that why same material has different colours, when its compound differs. But one can never hold back from the fact that, colours of compounds are directly in relation with chemical arrangement of compounds, energy of photons and wavelengths of lights. Because  $\pi$  conjugation chain of electron play imperative role for colours conjugation. Moreover, it's chief to know the connection between chemical structures of materials, absorption wavelengths, energy of lights and colours of lights. Also photon plays significant function to colours of compounds. Colours are directly depends on absorption of the different range of wavelengths of lights with chemical compounds and as wavelength differs and chemical arrangement of complex differ colours also differs. Also it does indicate the absorbed photons energy levels.

**KEYWORDS:** colours of materials, colours of compound, wavelengths of colours, energy of photons, absorption spectrum, energy of lights, colours of lights.

### I. INTRODUCTION

The individual eye is responsive to electromagnetic radiation with wavelengths involving about 380 and 700 nanometers. This emission is acknowledged as light. The visible spectrum is illustrated on the right. The eye has three module of color-sensitive light receptors called cones that counter roughly to red, blue and green light (approximately 650, 530 and 460 nm, respectively). Electromagnetic radiation is fabricated of waves that convey energy. These energy movements in miniature packets recognized as photons. There are many different types of electromagnetic emission, and mutually they structure the electromagnetic spectrum, which includes: GAMMA RAYS, X-RAYS, ULTRAVIOLET WAVES, VISIBLE LIGHT WAVES, INFRARED WAVES, MICROWAVES, and RADIO WAVES. Waves can be calculated by their wavelength (the amount of the wave) and frequency (how many waves overtake a point throughout a time intermission). All of the energy surrounded by a photon has its own wavelength and frequency.

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## II. ORIGIN OF COLOURS

This paper is about the affiliation between colours, frequency of photon absorb by colour, and Chemical chain. We are surrounded by colour. For example: leaves, colour of the clothes we wear. Every object has different colours and as per that colour we can conclude different things like frequency of photon which are not absorbed by that type of chemical composition of the material.

**A. CARROT:** Why carrot is orange? In carrot they are plenty of molecules whose name is beta-carotene. It is the structure of beta-carotene.

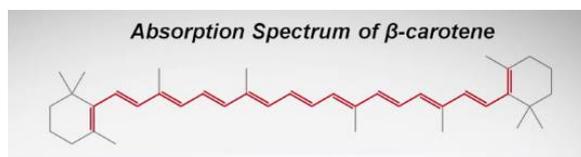


Figure 1: Structure of Beta- Carotene

In beta-carotene, in middle unit there are double bond and single bond. In this case there are total 11 double bonds. Length of the chain plays is very important role in determines the colour of molecule.

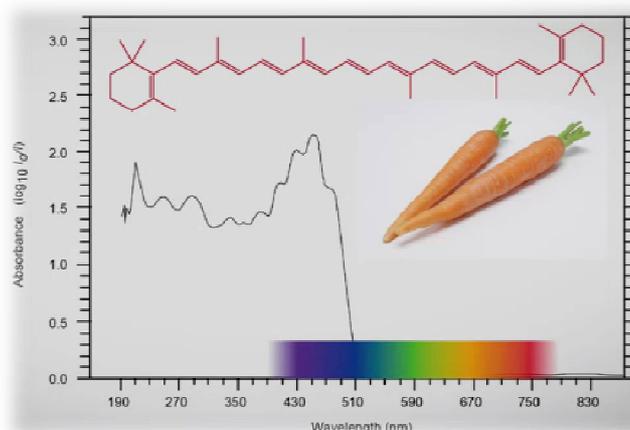


Figure 2: Absorbance Spectrum

The center of wavelength of this absorption band is 450 nanometers. This comes in array of blue. The absorbance band is situated at 450 nanometers, around that wavelength region photon are absorbed but in yellow region and red region photon is could not be absorbed, is the reason that why carrot is orange! Because red and yellow colours are reflects.

**B. CHLOROPHY II:** Chlorophy II absorbance band located at a yellow and blue region so those colours are not absorbed. That why colour of leaves are green. The absorption wavelengths have different chemical compound and structures.

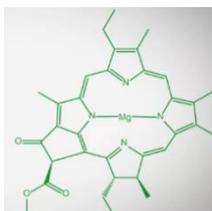


Figure 3: Structure of Chlorophy II

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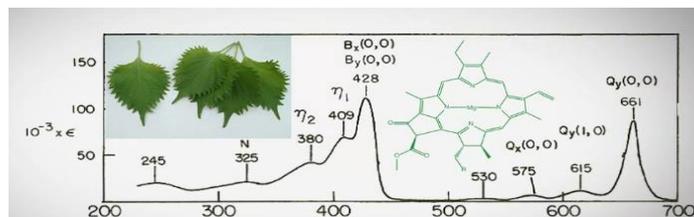


Figure 4: Spectrum of Chlorophyll II

### C. QUANTIZATION OF ENERGY LEVELS:

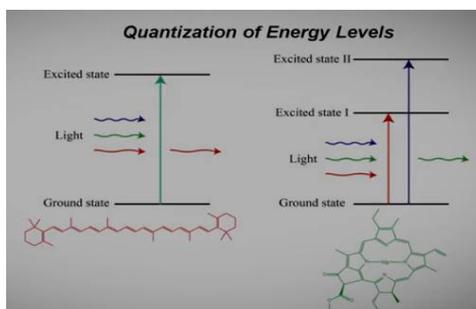


Figure 5: Energy diagram

A specific chemical compound has a specific absorption band having different wavelength of region from other compounds, which can show in terms of quantum mechanics. A photon will be absorbed, when the photon energy matches with the energy between the ground electronic state and excited electronic state.

The wavelength of photon in the case of carrot is 450nm, which is the reason for the orange colours of carrot. In Chlorophyll II, it has two excited stages. From excited state 1 to ground state region photon is in the red region and the wavelength for the transitions to excite the particle from ground state to the excited state number 2 is the blue region. That's the colours of the leaves are green.

### D. ABSORPTION SPECTRUMS FOR DIFFERENT COLOURS:

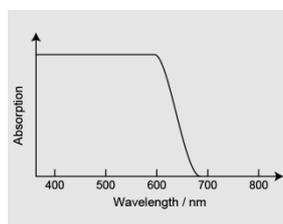


Figure 6: Absorbance spectrum for red colour

The reflection of light with a wavelength, longer than 600nm, is red. So red colour is reflected.

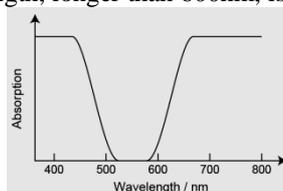


Figure 7: Absorbance spectrum for green colour

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The transmission of light is 550nm so the green colour is reflected.

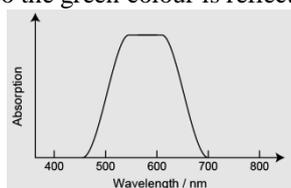


Figure 8: Absorbance spectrum for violet colour

The transmission of light wavelength is roughly 550nm, in words BLUE + RED = VIOLET. So violet colour is reflected.

### III. COLOURS OF LIGHT AND ENERGY OF LIGHT

When the lights have the wavelength in visible region than colours are noticeable but if the wavelengths are shorter than visible region then they are not visible. Those wavelength regions are called ultraviolet wavelength, vacuum ultraviolet wavelength. A shorter one may be called as soft X-ray and much shorter is called X-ray. Wavelengths longer than visible range are called infrared. Much longer wavelength is called micro-wave and much longer wavelengths are called radio wave.

#### 1) LIGHTS AND WAVELENGTHS:

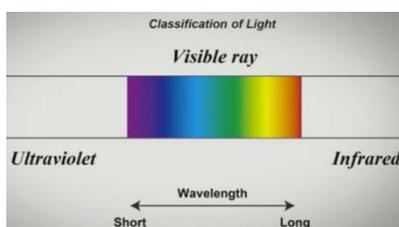


Figure 9: Classification of Light

#### 2) WAVELENGTH OF LIGHT:

Table 1: Rays and Wavelengths

X-ray	1 A	X-ray photography.
Soft x-ray	100 nm	-
Vacuum ultra violet	100-200 nm	Black light.
Ultra violet	200-400 nm	Sunlight has lots of ultra violet rays.
Visible ray	500 nm	Beta carotene absorbs light at the 400 nm. This is the visible range.
Infrared	10 μm	Molecular vibration motion can be excited. Infrared used in Heater.
Micro wave	1 cm	In microwave, molecular rotation can be excited by absorption of micro wave.
Radio wave	1 m	Radio receiver detects the radio wave

#### 3) RELATIONSHIP BETWEEN THE FREQUENCY OF LIGHT AND WAVELENGTH OF LIGHT:

Light is a wave with velocity cm/s. 'c' is the speed of light.

$$c = \lambda \cdot \nu$$

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$$\lambda = \frac{c}{\nu} = \frac{\left(\frac{m}{s}\right)}{s^{-1}}$$

So  $\lambda = (m)$

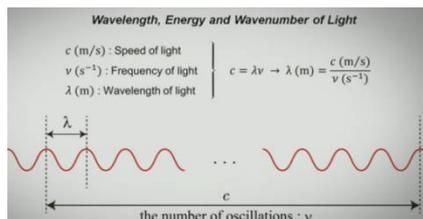


Figure 10: No. of Oscillations

$$E = h \cdot \nu$$

In infrared spectroscopy, quite often functional unit is  $cm^{-1}$ .  $cm^{-1}$  unit is for the wavelengths. Wave number is represented by  $\tilde{\nu}$  with the symbol of tilde on top of fit ( $\tilde{\nu}$ ).

$$\text{Wave number} = \frac{1}{\lambda(cm)} = \frac{\nu(s^{-1})}{c(\frac{cm}{s})}$$

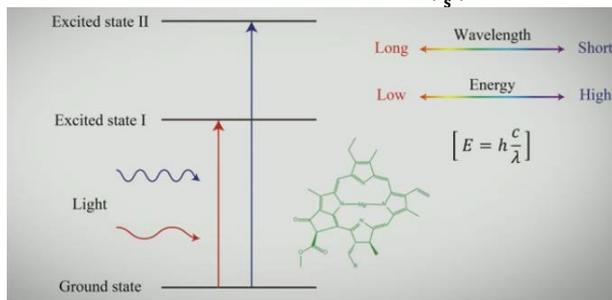


Figure 11: Excitation of Molecule by Light

Molecules are excited between first or second excited state and ground state. If wavelength of colour is long than in the red region the excited state will be reached. If wavelengths be converted into shorter, the higher energy state can be reached. Longer wavelengths of light have a lower energy. Higher energy of photons are having a shorter wavelength. It can motivate the molecule to higher excited states.

Table 2: Equipment & Wavelength

SR. NO.	EQUIPMENT	WAVELENGTH
1	X-ray	Computer tomography (CT SCANE)
2	Black light	Ultra violate
3	Traffic signals	Visible light
4	Remote control of T.V.	Infrared
5	Wi-fi	Microwave
6	Magnetic resonance imaging(MRI)	Radio wave and Magnetic wave

## IV. CONJUGATION AND ABSORPTION

Different colours of molecules can be interrupted by the motions of electron with in the molecules. Here are three different kind of molecule.

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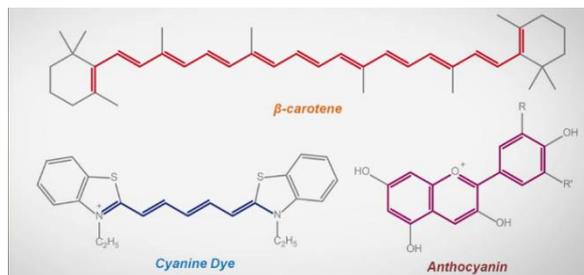
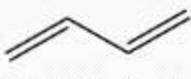
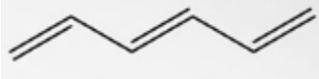
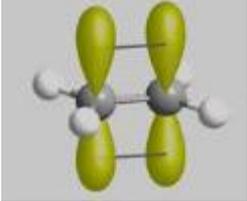
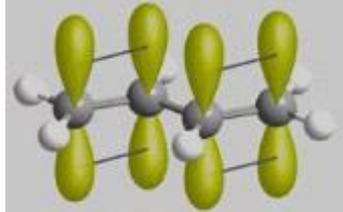
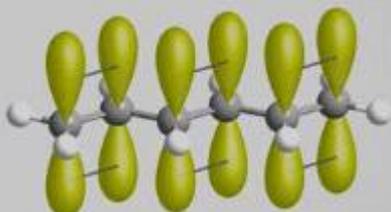


Figure 12: Beta- carotene, Cyanine dye & Anthocyanine

An ordinary feature in this molecule is the alternating single bond and double bond. This is very important structure to determine the colours of molecule.

Table 3: Conjugation

ETHYLENE	BUTADIENE	HEXATRIENE
	 (buta-1,3-diene)	 ((3E)-hexa-1,3,5-triene)
		

In this table ethylene, butadiene and hexatriene are given. These compounds have double bonds. In case of ethylene has only one double bond but butadiene has two double bonds. Hexatriene has three double bonds. And double bond means it having a  $\pi$  bonding in count to a single bond connecting the neighboring carbon atoms. The shape of the molecular orbital can be seen as below.

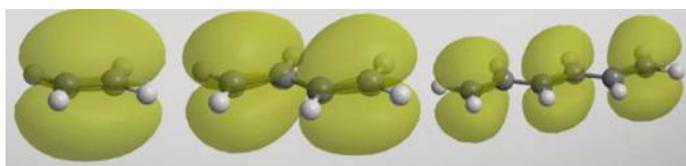


Figure 13: Ethylene, Butadiene and Hexatriene respectively

### V. DELOCALIZATION OF ELECTRON

The alternating  $\pi$  bond and single bond have a very attractive feature. Electron moves from double bond to single bond to construct single bond a double bond. If these electrons relocate action occurs concertedly, single bond and double bond may be reversed.

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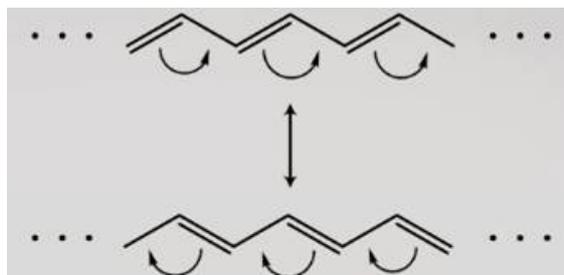


Figure 14: Delocalization of electron

Because the construction of this configuration is almost identical, energy of this complex should be same. This means electrons can move liberally from the left side to the right side by the complimentary action of electron and this means that molecular orbital can be cover entire array of molecules.

This is the delocalization of  $\pi$  electron within the conjugated  $\pi$  bond. These kinds of  $\pi$  bonding have the iso-energetic and dissimilar configuration like  $\pi$  conjugation. Through the  $\pi$  conjugation, electron in specific  $\pi$  bond can move around the molecule like this is a very extensive range with in the molecule. By expressive these conjugations of  $\pi$  bond, understandings of different colours of different molecules become easy.

## VI. RELATIONSHIP BETWEEN LIGHT ABSORPTION AND CONJUGATION LENGTH

### A. CYANINE DYES (STREPTOCYANINES):

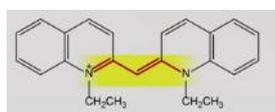


Figure 15: Cyanine (iodide)

If center conjugation is tiny than absorption wavelength is also short, here it is 520 nm.

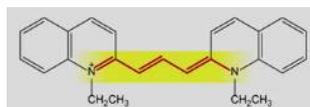


Figure 16: Pinacyanol (Chloride)

It is having longer conjugation series, so absorption wavelength is 600 nm.

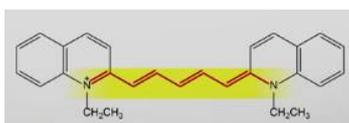


Figure 17: Dicarboyanine

It is longest case, so wave length is 700 nm. This situation can be explained by using energy diagram.

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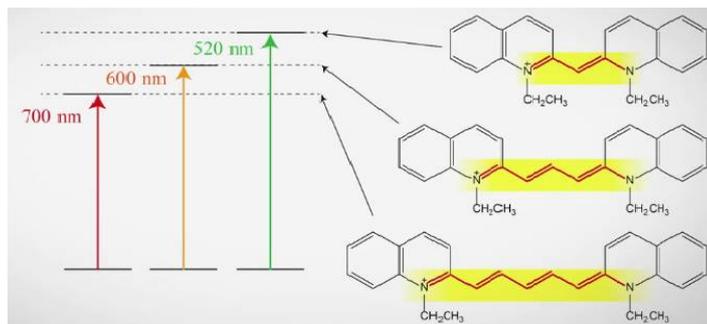


Figure 18: Relationship between light absorption and conjugation length

In the case of short  $\pi$  conjugation system, the absorption wavelengths are as shown here. And shorter wavelength means that the photon's energy is larger. Therefore, the energy of the excited state of this molecule having the shortest conjugation chain has a higher energy like this. Or excited stage of this compound is the highest.

As  $\pi$  conjugation chain becomes longer, the energy of the excited state becomes lower. If conjugation chain becomes longer, electron can move in longer range. If conjugation chain becomes shorter, electron can move in shorter range. This situation can be treated by quantum mechanics.

## B. CONJUGATED $\pi$ ELECTRONS:

1. Lycopene:

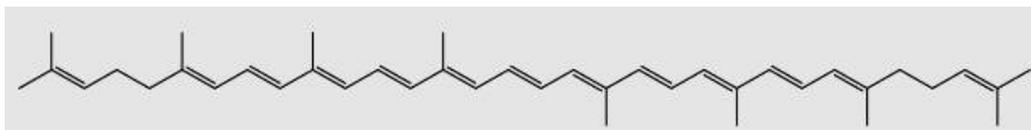


Figure 19: Lycopene

$$11 \times 2 sp = 22\pi \text{ electron}$$

2. Naphthalene:

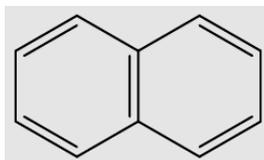


Figure 20: Naphthalene

$$5 \times 2 sp = 10\pi \text{ electron}$$

3. Cyanidin:

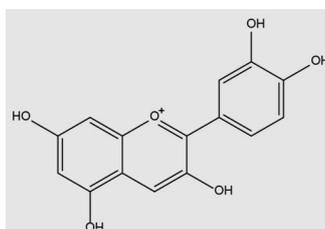


Figure 21: Cyanidin

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8 × 2 sp = 16

## VII. CONCLUSION

Material has dissimilar colours, when its chemical arrangement of composite differs. Absorption wavelength of lights also unswervingly depends on double bond of structure. A photon will be absorb, when the photon energy equivalent to the energy between the ground electronic condition and exited electronic condition. Longer wavelengths of light have a lower energy. Higher energy of photons are having a shorter wavelength. Delocalizations of  $\pi$  electrons are also chief functions for colours of compounds. As  $\pi$  conjugation chain becomes longer, the energy of the excited state become lower. If conjugation chain become longer, electron can move in longer range. If conjugation chain becomes shorter, electron can move in shorter range.

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