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**Abstract**

While doing this summer project on dyes industries I learn that Dye is a colored substance that has an affinity to the substrate to which it is being applied. The dye is generally applied in an aqueous solution, and requires a mordant. Both dyes and pigments appear to be colored because they absorb some wavelengths of  more than others. In contrast with a dye, a pigment generally is insoluble, and has no affinity for the substance. Dyeing  is the process of adding color to textile products like fibers, yarns and fabrics. Dyes are not completely beneficial as they are time consuming to extract from the raw materials, some fibers such as silk and wool can be dyed by simply dipping them in the dye but cotton requires a mordant. The discharge of highly colored synthetic dye effluents into inland and coastal waters is causing environmental problems. Natural dyes are more eco-friendly than the synthetic dyes, because  natural dyes are also free from carcinogenic components also natural  dyes cause no disposal problems, as they are biodegradable. Dyes are so problematic because the families of chemical compounds that make good dyes are also toxic to humans. Each new synthetic dye developed is a brand new compound, and because it’s new no one knows it’s risks to humans and the environment. Many dyes like Amaranth have entered the market, then have subsequently been discovered to be carcinogenic and withdrawn.

**Introduction :**

A substance may be called dye if it must have a suitable colour,capable of being fixed to the fabric directly or When fixed ,it must not be fugitive,i.e. the colour must be fast to light and resistant to soap and water ,and to a certain extent to dilute n alkalies.

Unlike most organic compounds, dyes possess colour because they absorb light in the visible spectrum (400–700 nm), have at least one chromophore (colour-bearing group), have a conjugated system, i.e. a structure with alternating double and single bonds, and exhibit resonance of electrons, which is a stabilizing force in organic compounds . When any one of these features is lacking from the molecular structure the colour is lost. In addition to chromophores, most dyes also contain groups known as auxochromes , examples are carboxylic acid, sulfonic acid, amino, and hydroxyl groups. While these are not responsible for colour, their presence can shift the colour of a colourant and they are most often used to influence dye solubility.[Reference 1]

**Sensation of Colour:**

Light is electromagnetic radiation (that is, it has both electrical and magnetic components) vibrating in transverse wave packets, or quanta. The vibration may occur in all planes or in one only (plane polarized light), each plane having right and left

circular vector components. We may measure the amplitude of the wave quantum (intensity of the light), its frequency, ***u,*** and/or wavelength, **X** , and its velocity in a given medium, ***v.*** The last is mainly of interest in differential refraction or separation of vibrations of different frequencies for spectral determinations. There are other important characteristics of light spectral distribution or purity, brightness and variation , reflection and absorption of specific light frequencies , refraction or the "rainbow" effect, and scattering, or the Tyndall effect. The latter, for example, has been used to explain why the sky is blue-Rayleigh's Law states that the intensity of the scattering varies inversely with the fourth power of the wavelength-that is, because the atmosphere scatters the shorter wavelengths to us more efficiently. This effect is also founds more efficiently. This effect is also found in the blue color of lakes and in the blue color of the rump of a species of chimpanzee that possesses no colored compounds in that region of its anatomy. Light is composed of waves of varying wavelengths, not all of which are visible to the human eye. We can see those having wavelengths between 4000 A0and 8000 A0, approximately. In general, an object appears colored when it transmits or reflects light of the visible region non-uniformly. The band of waves having a wavelength of about 4250A0appears violet; waves from 5450 A0 to about 5850 A0appear yellow; and those longer than about 6200A0are red. Light is absorbed selectively by all organic materials, but most of them appear colorless because they absorb in the ultraviolet region of the spectrum. Molecules which contain conjugated double bonds in certain arrangements, or which contain specific systems of delocalized electron wave quanta, however, absorb some of the frequencies of visible light. If they absorb all the wavelengths except those in the red region, for instance, the material will appear red in color. If they absorb only the waves of the color completely complementary to red, i.e. blue-green, the material will appear to he red in this case also, but it will usually be of a lighter tint, because of the greater amount of total reflection or transmission.The principles involved in this interaction of the electronic constituents of matter with light have been the subject of careful mathematical scrutiny. It is the purpose of this discussion to present an unsophisticated non-mathematical model-system approximation of these principles and of their useful application.

**Wavelength of light absorption versus colour in organic dyes**

|  |  |  |
| --- | --- | --- |
| Wavelength Absorbed (nm) | Colour Absorbed | Colour Observed |
| 400–435 | Violet | Yellow-Green |
| 435–480 | Blue | Yellow |
| 480–490 | Green-Blue | Orange |
| 490–500 | Blue-Green | Red |
| 500–560 | Green | Purple |
| 560–580 | Yellow-Green | Violet |
| 580–595 | Yellow | Blue |
| 595–605 | Orange | Green-Blue |
| 605–700 | Red | Blue-Green |

[Reference 2]

**Colour and Constitution:**

Various theories have been put forward to establish a relation between colour and constitution .Some of the important theories are Witt's theory, quinonoid theory, resonance theory and molecular orbital theory. In short, a certain amount of unsaturation in the dye molecule,with part of it at least in the form of aromatic rings combined with the quinonoid structure of a minimum complexity,usually lays the foundation for dyes.

According to Graebe and Libermann, unsaturation is essential for light absorption.Usually all the coloured compounds known at that time were decolourised on reduction and the colour was restored on oxidation.They concluded that colour was due to unsaturation and conjugation of alternative double and single bond deepens the colour.

When a molecule absorbs light ,its electron are excited to vibration the more firmly the electrons are bound ,the greater the light energy required to excite them. In unsaturated organic compounds ,the pi-electrons associated with double and triple bonds are less firmly bound than those in the saturated organic compounds in which sigma electrons form single covalent bonds. In other words, it is most easy to excite pi-electrons than sigma electrons .Saturated compounds usually appear colourless because of the fact that they absorb ultraviolet and infrared light. Practically one or more of these unsaturated groups are always present in all synthetic dyes.

O.N.Witt pointed out that all coloured organic compounds contain certain unsaturated groups which are responsible for colour and he called these groups as chromophores.In other words groups responsible for selective absorption of light of wavelength 2500-10,000 Å are called chromophores.A compound containing a chromophore,is called chromogen.If a chromogen has one or more auxochromes,the resulting substance is called a dye.

In other words.

Dye=Chromogen+Auxochrome [Reference 3]

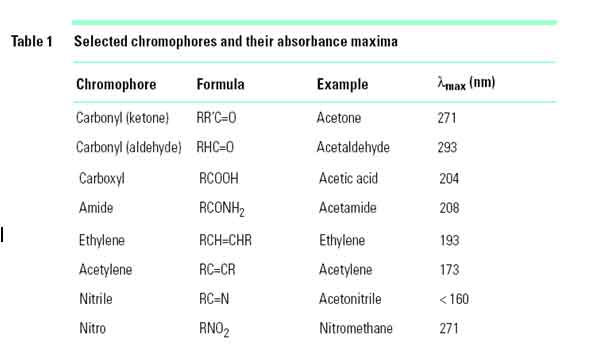


Table 1

**Nomenclature:**

Dyes are named either by their commercial trade name or by their Colour Index (C.I.) name. In the Colour Index these are cross-referenced. The commercial names of dyes are usually made up of three parts. The first is a trademark used by the particular manufacturer to designate both the manufacturer and the class of dye, the second is the color, and the third is a series of letters and numbers used as a code by the manufacturer to define more precisely and also to indicate important properties of the dye. The code letters used by different manufacturers are not standardized. The most common letters used are R for reddish, B for bluish, and G for greenish shades. Some of the more important letters used to denote the dyeings and fastness properties of dyes are W for washfastness and E for exhaust dyes. For solvent and disperse dyes, the heatfastness of the dye is denoted by letters A, B, C, or D, A being the lowest level of heatfastness, and D the highest. In reactive dyes for cotton, M denotes a warm (40 °C) dyeing dye, and H a hot-dyeing (800). dye. There are instances in which one manufacturer may designate a bluish red dye as Red 4B and another manufacturer uses Violet 2R for the same dye. To resolve such a problem the manufacturers’ pattern leaflets should be consulted. These show actual dyed pieces of cloth (or other substrate) so the colors of the dyes in question can be compared directly in the actual application. Alternatively, colors can be specified in terms of color space coordinates. In the CIELAB system, which is is becoming the standard, the color of a dye is defined by *L* , *a*, and *b* coordinates. The C.I. name for a dye is derived from the application class to which the dye belongs, the color or hue of the dye and a sequential number.

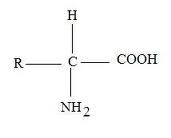
**Fibres To Be Dyed:**

There are three types of fibres to be dyed:

(1) Products of vegetable origin. Examples are cotton, linen and paper. These essentially consist of cellulose. They contain -OH groups and can not be dyed directly. Animals fibres like wool, silk etc..are proteinous in nature possesing both -COOH and -NH2 groups. These fibres can be dyed directly by both basic as well as acid dyes.

(2) Products of animal origin. Examples are silk, wool, feather, fur and leather. All these are very reactive. Silk is wetted by water and then dyed with acid or basic dyes through the formation of salt linkages.

(3 )Products of synthetic origin. Examples are nylon, dacron ,orlon etc.



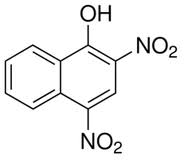
Amino acid in wool fibre [Reference 4]

**Dyeing:**

**Dyeing** is the process of adding colour to [textile](http://en.wikipedia.org/wiki/Textile) products like [fibres](http://en.wikipedia.org/wiki/Fibre), [yarns](http://en.wikipedia.org/wiki/Yarn), and [fabrics](http://en.wikipedia.org/wiki/Fabric). Dyeing is normally done in a special [solution](http://en.wikipedia.org/wiki/Solution) containing [dyes](http://en.wikipedia.org/wiki/Dye) and particular [chemical material](http://en.wikipedia.org/wiki/Material). After dyeing, dye [molecules](http://en.wikipedia.org/wiki/Molecules) have uncut [chemical bond](http://en.wikipedia.org/wiki/Chemical_bond) with fiber molecules. The [temperature](http://en.wikipedia.org/wiki/Temperature) and time controlling are two key factors in dyeing. Wool and silk may be regarded as amphorteric proteins and they have a natural affinity for substance containing acidic and basic groups with which they react as result of salt information.

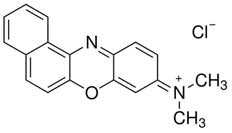
Some importants dyes used for proteinic fibres include the following acidic and basic dyes.

**Acidic:**

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**Martius Yellow**

**Basic:**

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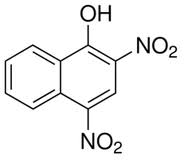
**Meldolas blue**

Cotton, linen are composed of natural cellulose molecules and do not show any affinity for many dyes and known as substantive dyes.

**Classification of Dyes:**

**Acid dyes:**

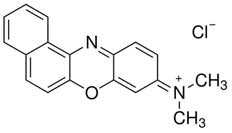
**Acid dyes** are water soluble anionic dyes that are applied to  fibres such as silk, wool, nylon and modified acrylic fibres using neutral to acid dye baths. Attachment to the fiber is attributed, at least partly, to salt formation between anionic groups in the dyes and cationic groups in the fiber. Acid dyes are not substantive to cellulosic fibers. Most synthetic food colors fall in this category.

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**Martius yellow**

**Basic dyes:**

**Basic dyes** are water-soluble cationic dyes that are mainly applied to acrylic , but find some use for wool and silk. Usually acetic acid is added to the dyebath to help the uptake of the dye onto the fiber. Basic dyes are also used in the coloration of paper.



**Meldolas blue**

**Direct dyes:**

**Direct**  or  **substantive dyeing**  is normally carried out in a neutral or slightly alkaline dyebath, at or near boiling point with the addition of either  NaCl or Na2CO3 Direct dyes are used on cotton, paper, leather wool, silk and nylon. They are also used as pH indicators and as biological stains.

**Mordant dyes:**

**Mordant dyes** require a mordant, which improves the fastness of the dye against water, light and perspiration. The choice of mordant is very important as different mordants can change the final color significantly. Most natural dyes are mordant dyes and there is therefore a large literature base describing dyeing techniques. The most important mordant dyes are the synthetic mordant dyes, or chrome dyes, used for wool , these comprise some 30% of dyes used for wool, and are especially useful for black and navy shades. The mordant potassium dichromate is applied as an after-treatment. It is important to note that many mordants, particularly those in the heavy metal category, can be hazardous to health and extreme care must be taken in using them.

**Vat dyes:**

**Vat dyes** are essentially insoluble in water and incapable of dyeing fibres directly. However, reduction in alkaline liquor produces the water soluble alkali metal slat of the dye, which in this leuco form, has an affinity for the textile fibre. Subsequent oxidation reforms the original insoluble dye. The color of denim is due to indigo, the original vat dye.

**Reactive Dyes:**

**Reactive Dyes** utilize a chromophore attached to a substituent that is capable of directly reacting with the fibre substrate. The covalent bonds that attach reactive dye to natural fibers make them among the most permanent of dyes. "Cold" reactive dyes, such as MX, are very easy to use because the dye can be applied at room temperature. Reactive dyes are by far the best choice for dyeing  cotton and other cellulose fibers at home or in the art studio.

**Disperse Dyes:**

**Disperse dyes** were originally developed for the dyeing of cellulose acetate and are water insoluble. The dyes are finely ground in the presence of a dispersing agent and sold as a paste, or spray-dried and sold as a powder. Their main use is to dye polyester  but they can also be used to dye nylon, cellulose triacetate , and acrylic fibres. In some cases, a dyeing  temprature of 130 °C is required, and a pressurised dyebath is used. The very fine particle size gives a large surface area that aids dissolution to allow uptake by the fibre. The dyeing rate can be significantly influenced by the choice of dispersing agent used during the grinding.

**Sulphur Dyes:**

Sulphur dyes are used to dye cotton from sodium sulphide bath in dull shades. [Reference 5]

**Methods of dyeing:**

Direct dyeing may be depend on the following factors:

(a)Absorptive power of the fibre.

(b)Nature of the fibre.

(c)Dyeing conditions.

**Vat dyeing:**

Vat dyes are an ancient class of dyes based on natural dyes. Vat dyes, which include indigo and anthraquinone based dyes, are chemically complex dyes which are insoluble in water. They must first be reduced to the leuco form in an alkaline solution of sodium hydrosulfite before application to the cotton or rayon fiber. Air oxidation fixes the dye strongly on the fiber, resulting in excellent wash-fastness and light-fastness. The vat dyes were one of the most significant textile dye inventions in the

20th century.

Indanthrene blue was the first anthraquinone vat dye, synthesized by René Bohn at BASF in Germany in 1901. He used the synthetic indigo reaction conditions with 2- aminoanthraquinone, fusing it with caustic potash, to obtain the colorant. By 1906, Bayer had introduced the first vat red and marketed a range of colors under the Algol brand. The United States imported vats from Germany because domestic production was by German patent protection, the lack of sufficient anthracene (the source of anthraquinone), inadequate technical expertise of American chemists, and the large Vat dyes, which include indigo and anthraquinone-based dyes, are chemically complex dyes which are insoluble in water. They must first be reduced to the leuco form in an alkaline solution of sodium hydrosulfite before application to the cotton or rayon fiber. Air oxidation fixes the dye strongly on the fiber, resulting in excellent wash-fastness and light-fastness. The vat dyes were one of the most significant textile dye inventions in the 20th century.

A breakthrough occurred in 1917 when government chemists in Washington, DC developed a process to manufacture Indanthrene blue was the first anthraquinone vat dye, synthesized by René Bohn at BASF in Germany in 1901. He used the synthetic indigo reaction conditions with 2- aminoanthraquinone, fusing it with caustic potash, to obtain the colorant. By 1906, Bayer had introduced the first vat red and marketed a range of colors under the Algol brand. The United States imported vats from Germany because domestic production was hindered by German patent protection, the lack of sufficient anthracene (the source of anthraquinone), inadequate technical expertise of American chemists, and the large investment needed for organic solvent operations, specialized equipment, and explosion proof manufacturing buildings.re anthraquinone from readily available coal-tar naphthalene and benzene. Vapor-phase oxidation of naphthalene gave phthalic anhydride, which was condensed with benzene to form 2-benzoyl benzoic acid (Friedel-Crafts reaction), followed by ring closure with sulfuric acid to afford anthraquinone. Sulfonation of anthraquinone gave 2-anthraquinonesulfonic acid, named silver salt because of the silvery sheen of its crystals. Reaction of silver salt with ammonia in an autoclave at 200 ºC and pressures of up to 1000 psi yielded 2-aminoanthraquinone, a source of several vat dyes. The use of toluene instead of benzene gave 2- methylanthraquinone, the starting material for vat orange dyes. Far more significant, however, was the versatile 1-aminoanthraquinone. This required mercury-catalyzed sulfonation of anthraquinone, to afford 1-anthraquinonesulfonic acid (known as diamond salt), followed by arsenic-catalyzed amination. Diamond salt was a source of olive greens, browns, grays, etc. This often involved many chemical synthesis steps, apart from the physical steps of separating, drying, and finishing. Vat dye processes included the production of other intermediates, such as benzanthrones, in which an additional aromatic ring was added on to anthraquinone.

**Mordant dyeing:**

 The choice of mordant is very important as different mordants can change the final color significantly. Most natural dyes are mordant dyes and there is therefore a large literature base describing dyeing techniques. The most important mordant dyes are the synthetic mordant dyes, or chrome dyes, used for wool these comprise some 30% of dyes used for wool, and are especially useful for black and navy shades. The mordant, potassium dichromate , is applied as an after-treatment. It is important to note that many mordants, particularly those in the heavy metal category, can be hazardous to health and extreme care must be taken in using them.

**Substantive Dyeing:**

 Substantive dyeing is normally carried out in a neutral or slightly alkaline dye bath, at or near  boiling point, with the addition of either NaCl or  Na2SO4 or Na2CO3. Direct dyes are used on cotton, paper,  wool, silk and nylon. They are also used as pH indicators  and as biological stains.

**Disperse Dyeing:**

 This process of dyeing is finely ground in the presence of a dispersing agent and sold as a paste, or spray-dried and sold as a powder. Their main use is to dye polyester but they can also be used to dye nylon, cellulose triacetate , and acrylic fibres. In some cases, a dyeing temprature of 130 °C is required, and a pressurised dye bath is used. The very fine particle size gives a large surface area that aids dissolution to allow uptake by the fibre. The dyeing rate can be significantly influenced by the choice of dispersing agent used during the grinding.

**Cross Dyeing:**

Cross dyeing is a method of dyeing blend or combination fabrics to two or more shades by the use of dyes with different affinities for the different fibers. The cross dyeing process can be used to create heather effects, and plaid, check, or striped fabrics. Cross dyed fabrics may be mistaken for fiber or yarn dyed materials as the fabric is not a solid color, a characteristic considered typical of piece dyed fabrics. It is not possible to visually differentiate between cross dyed fabrics and those dyed at the fiber or yarn stage. An interesting example is cross dyeing blue worsted wool fabric with polyester pin stripes.   
 Cross dyeing is commonly used with piece or fabric dyed materials. However, the same concept is applicable to yarn and product dyeing. For example, silk fabric embroidered with white yarn can be embroidered prior to dyeing and product dyed when an order is placed. [Reference 6]

**APPLICATIONS:**

**For cotton fabric (for dyeing)**

The most important reaction of indigo is its reduction to soluble indigo white by alkaline Na2 S2 O4 .

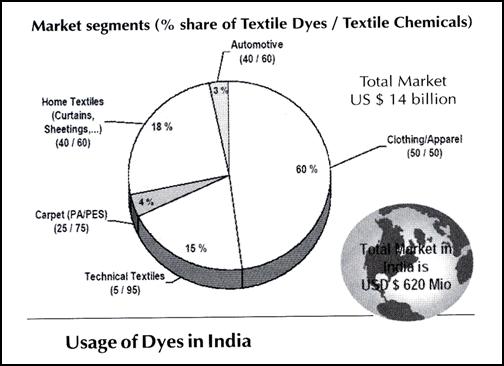
Indigo white is soluble in hot water and alcohol. It dissolves in alkali with yellow colouration . The material to be dyed is soaked in this alkaline solution and then exposed to air, as a result of which the original blue dye is regenerated on the cloth. It is firmly held by the fabric and is fast to washing and light.



**For printing purposes-**

Generally three methods are employed for this purpose

* **Glucose process-** The fabric is treated with glucose solution and then printed with a paste of indigo and NaOH. The steam is now passed over the fabric, the dye is reduced and fixed by the fibre, subsequently being oxidised.
* **Rongalite process-** In this process, the reducing agent Na2 S2 O4is replaced by its compound sodium formaldehyde sulphoxylate. Now it is applied to the fibre together with the dye in form of a paste, in presence of alkali. The colour is finally developed locally by means of oxidising agent.
* **Indigosol process-** Indigo white is not sufficient to be used in textile printing as it is readily oxidised. The indigosol O, thus formed is readily applied to animal or vegetable fibre by soaking the fabric by soaking fabric in the solution then oxidising it to the original insoluble vat dye.



* Dyes are used in CT scan
* Dyes are used in MRI scan
* Dyes are used in different types of industries.These are used in textile, leather,wood and food industries. In food industries natural dyes are genrally used But now federal agency has allowed the use of synthetic dyes. Variety of petroleum based item such as lubricating oils, waxes ,gasoline and polishes used these types of colour .

Natural dyes are more eco-friendly than the synthetic dyes, because  natural dyes are also free from carcinogenic components also natural  dyes cause no disposal problems, as they are biodegradable. [Reference 7]

**Harmful effects of dyes:**

Dyes are not completely beneficial as they are time consuming to extract from the raw materials, some fibers such as silk and wool can be dyed by simply dipping them in the dye but cotton requires a mordant, synthetic fibers, which are becoming widely popular can not be dyed with natural dyes

* The discharge of highly coloured synthetic dye effluents into inland and coastal waters is an environmental problem of growing concern. The Azosynthetic dyes are extensively used in textile, paper printing, photography, pharmaceutical, food, cosmetics and other industries Approximately, 10,000 different dyes and pigments are used industrially and over 0.7 million tons of synthetic dyes are produced worldwide. Azodyes consist of diazotised amine coupled to an amine or a phenol and contain one or more azolinkages Azodyes constitute 70% of synthetic dyes produced (ETAD, 1997) and they are second only to polymers in terms of new compounds submitted for registration in the US under the Toxic Substance Control Act.
* Dyes are so problematic because the families of chemical compounds that make good dyes are also toxic to humans. Each new synthetic dye developed is a brand new compound, and because it’s new,no‐one knows it’s risks to humans and the environment.Many dyes like Amaranth have entered the market, then have subsequently been discovered to be carcinogenic and withdrawn. The European Union in particular has been pro‐active in banning dangerous dyes and dyes formulated from toxic chemicals. But it’s backwards to create a dye, see if it’s hazardous, then ban it if so. Especially since so many dyes are known to be dangerous and carcinogenic.

**Respiratory sensitisation:**

Some people have developed an allergy to certain reactive dyes. Exposure to even small amounts of these dyes causes them to suffer a severe reaction.Usually this affects the airways and is called respiratory sensitisation, but it may affect the skin. People may become sensitised straight away or after years of exposure to reactive dyes. The condition isirreversible.

Early symptoms, which can show up after work each day, can include:

* itching, watering eyes;
* unusual breathlessness or wheezing. [Reference 8]

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Or

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