

Metrics and Measurement

Measuring Light and Matter

What do we usually measure?

- Weight
- Height
- Volume
- Distance
- Temperature

The “English” System

mass or weight

Pounds, ounces, tons

length or distance

Inches, feet, yards, miles

volume

Quarts, gallons

temperature

degrees Fahrenheit

The “Metric” System

- Used everywhere except for
 - Liberia
 - Myanmar (formerly Burma)
 - **United States**
- Based on three BASE UNITS
- **Powers of Ten** system

Metric BASE UNITS

- Length METER m
- Mass GRAM g
- Volume LITER L
- Temperature °Celsius °C

Important Metric PREFIXES

- Kilo k 1000x or 10^3 x the base
- Centi c 1/100x or 10^{-2} x the base
- Milli m 1/1000x or 10^{-3} x the base
- Micro μ 1/1000000 or 10^{-6} x the base
- Nano n 1/10000000000 or 10^{-9} x the base

Why Metrics and Not English?

- Powers of ten can easily represent

- very large numbers

$$6.02 \times 10^{23} = \# \text{ atoms in a mole}$$

- very small numbers

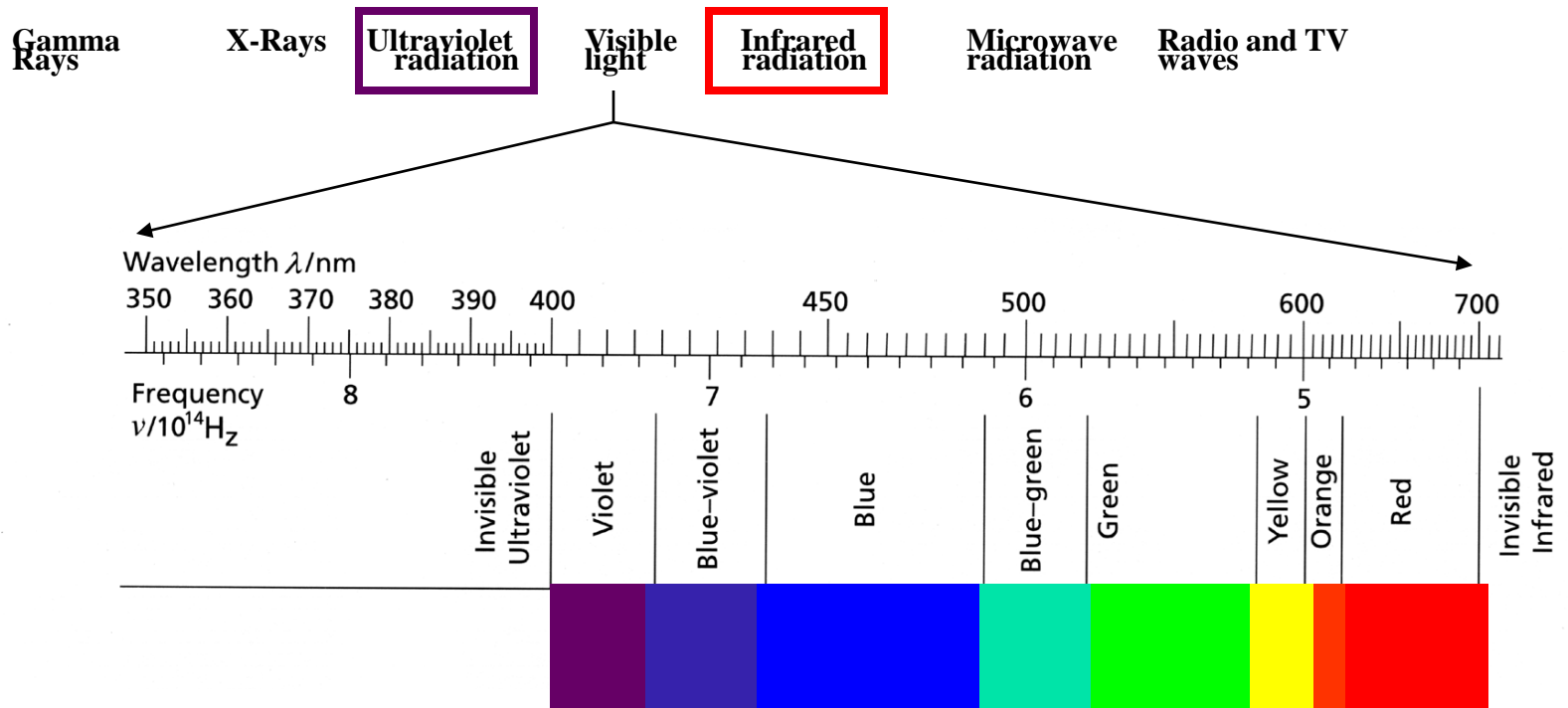
$$1.0 \times 10^{-7} = \# \text{ H}^+ \text{ ions in water}$$

- Use of logarithms easier

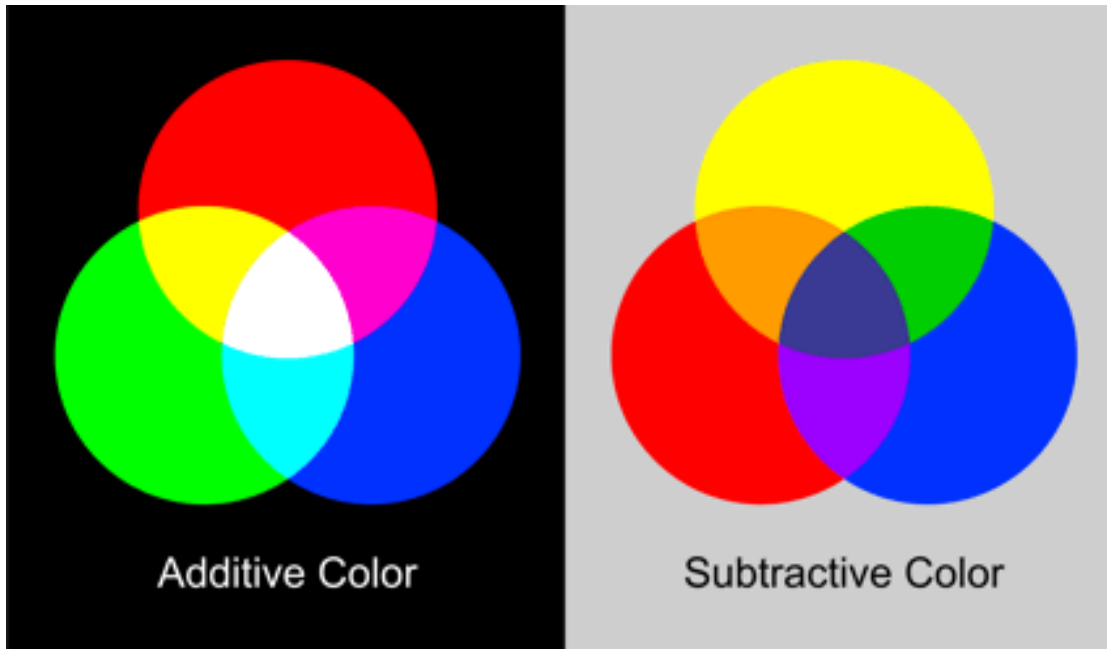
Measuring EM Radiation

- **Infrared radiation** micrometers 10^{-6}m
- **Visible radiation** nanometers 10^{-9}m
- **Ultraviolet radiation** nm 10^{-9}m
- X-rays and gamma rays Angstrom Å 10^{-10}m

Electromagnetic Spectrum



Basic color definitions



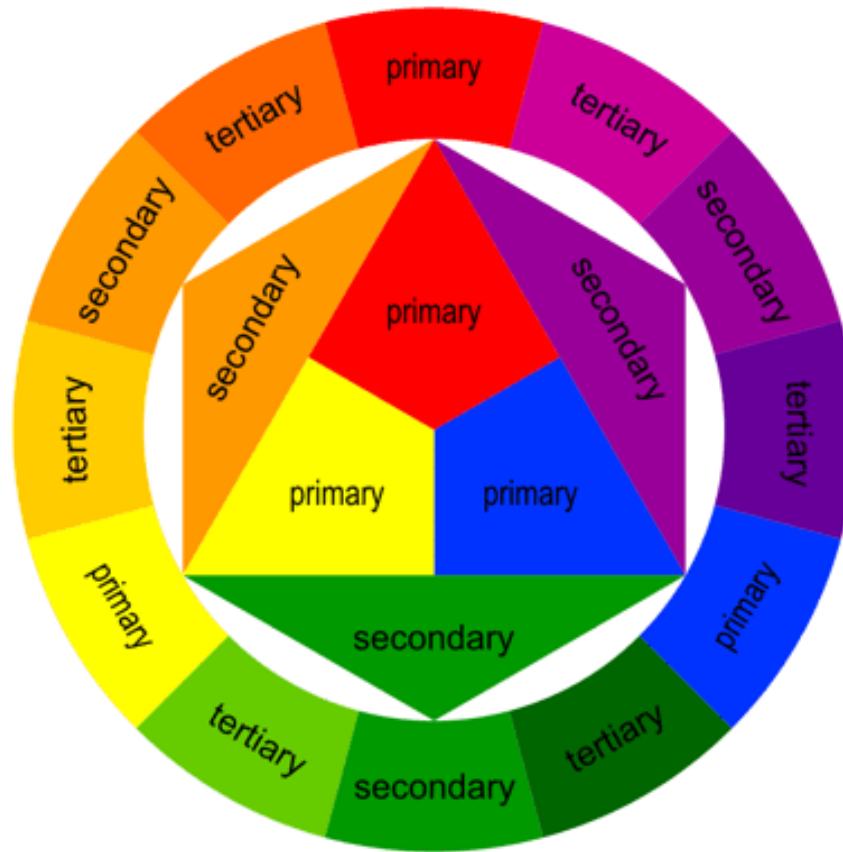
Additive Color

Subtractive Color

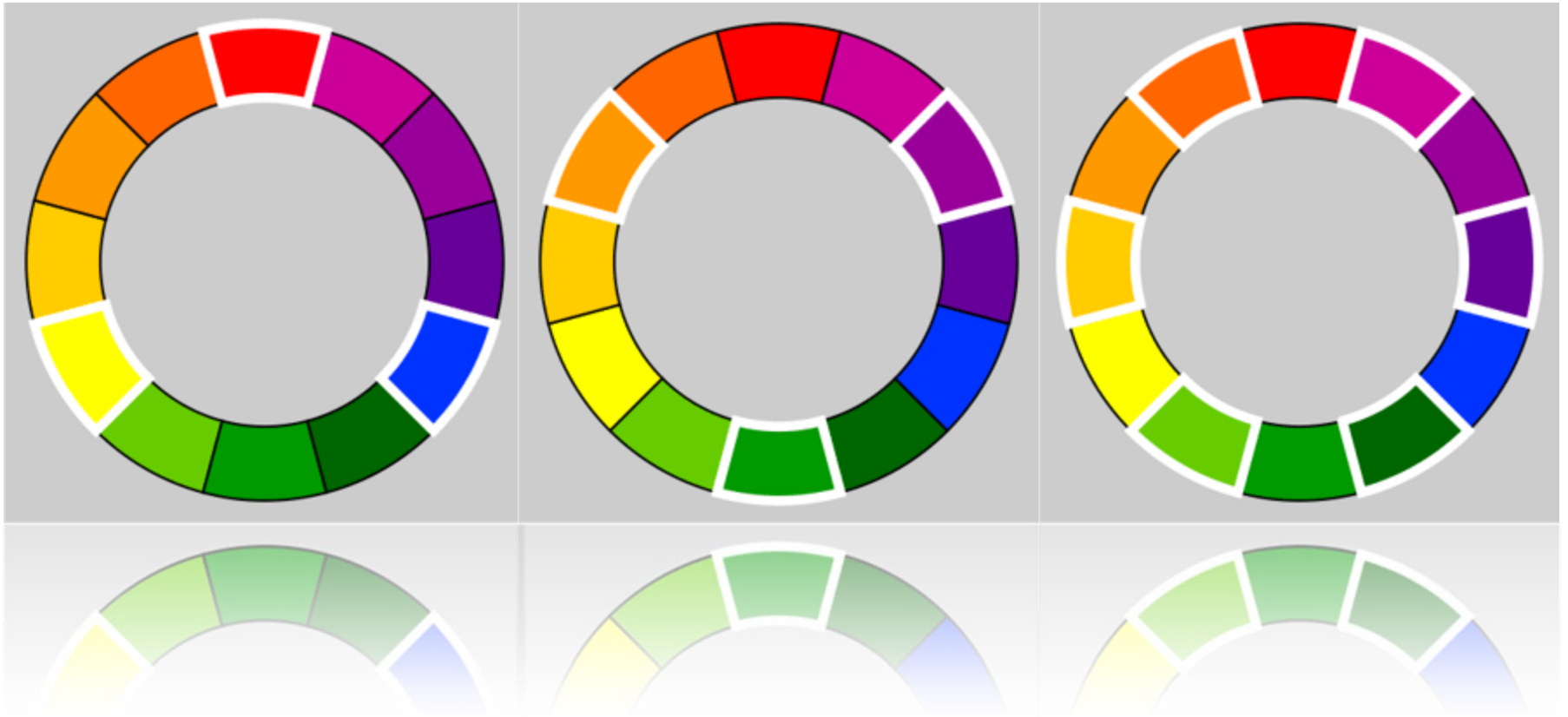
Your TV

Your paints

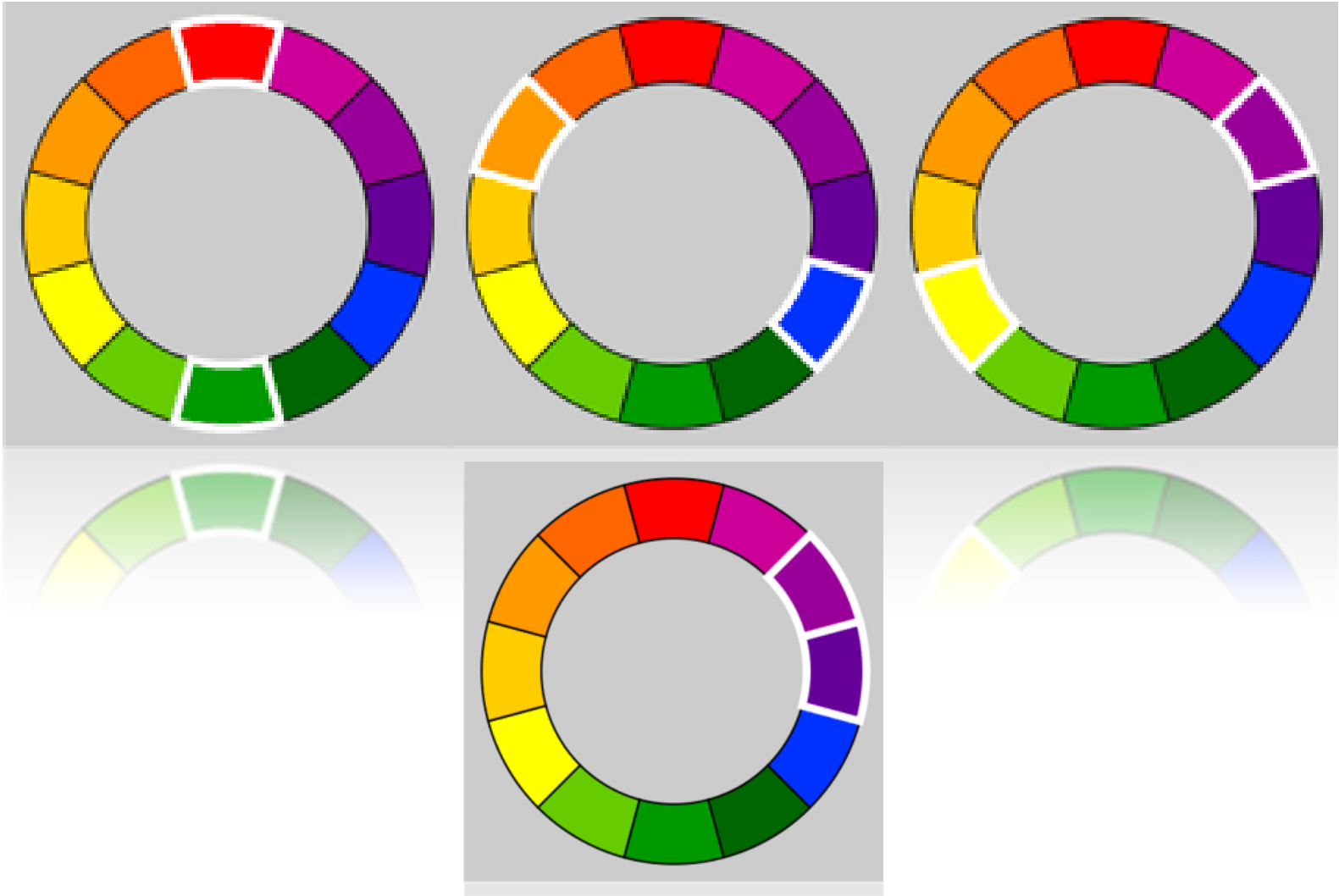
Color wheel



Primary, secondary, tertiary?



Complementary, analogous ?





Monochromatic Complementary



Analogous

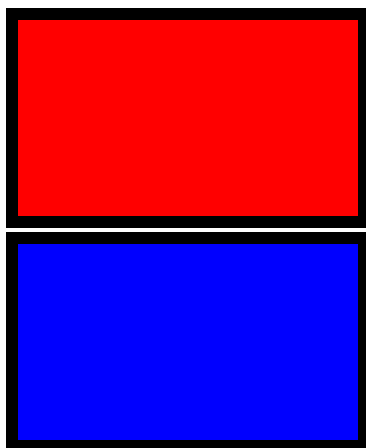


Triadic

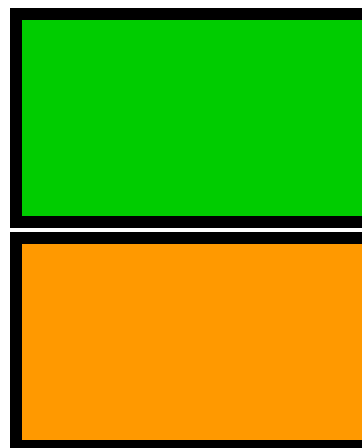


Complementary Colors

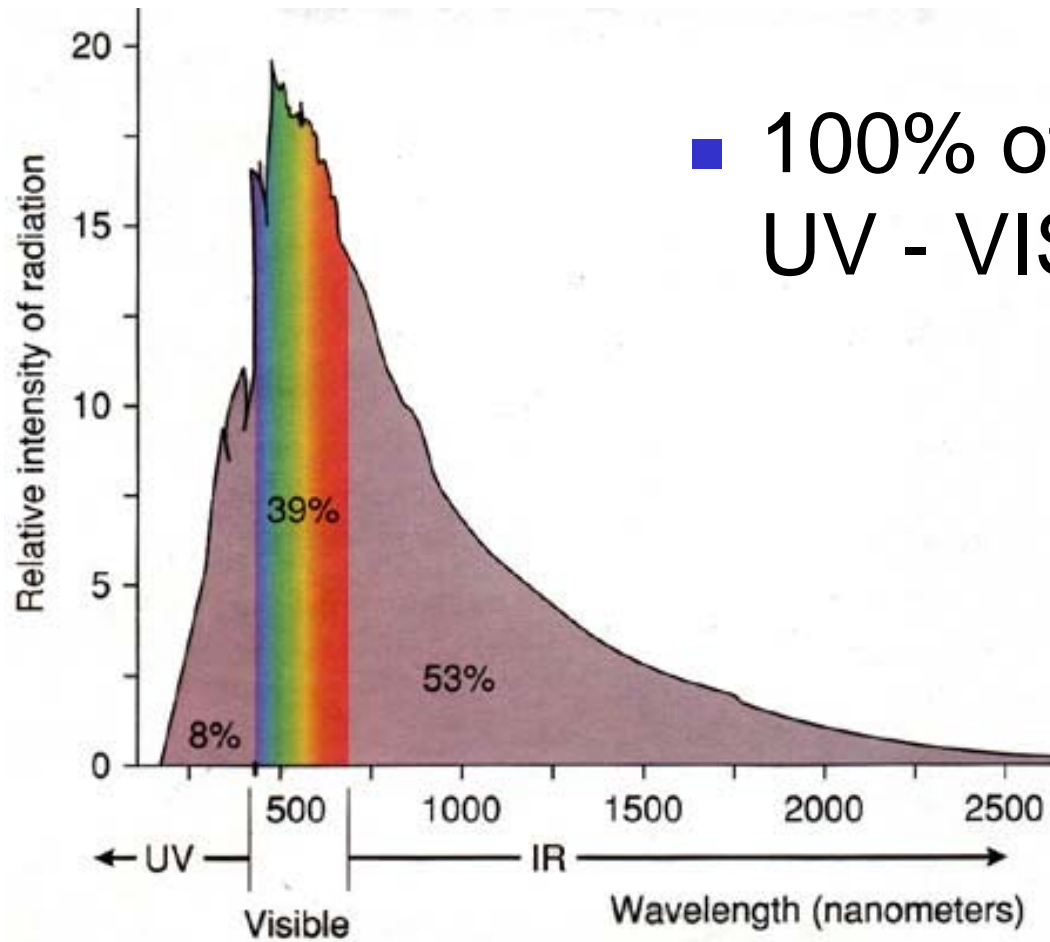
Absorbed



Observed



Three Important Regions of EM



- 100% of sunlight is UV - VIS - IR

Three Important Regions of EM

- UV - VIS - IR cause changes in matter

Models or Theories of Light

- The **Wave Theory**

Explains transmission, reflection and scattering, refraction, diffraction, polarization, and interference of light.

- The **Particle Theory** — Planck, Einstein
Explains **emission** and **absorption** of light

Particle or Quantum Theory

- What's the relationship between energy (E), frequency (ν), and wavelength (λ) of light?

$$E = h\nu = \frac{hc}{\lambda}$$

frequency

wavelength

h = Planck's constant

Light is composed of a stream of packets of energy called **Quanta** or **Photons**.

Emission of Light

- Emission spectrum of Helium gas



↪
Energy of
blue light

↑
Energy of
green light

↶
Energy of
yellow light

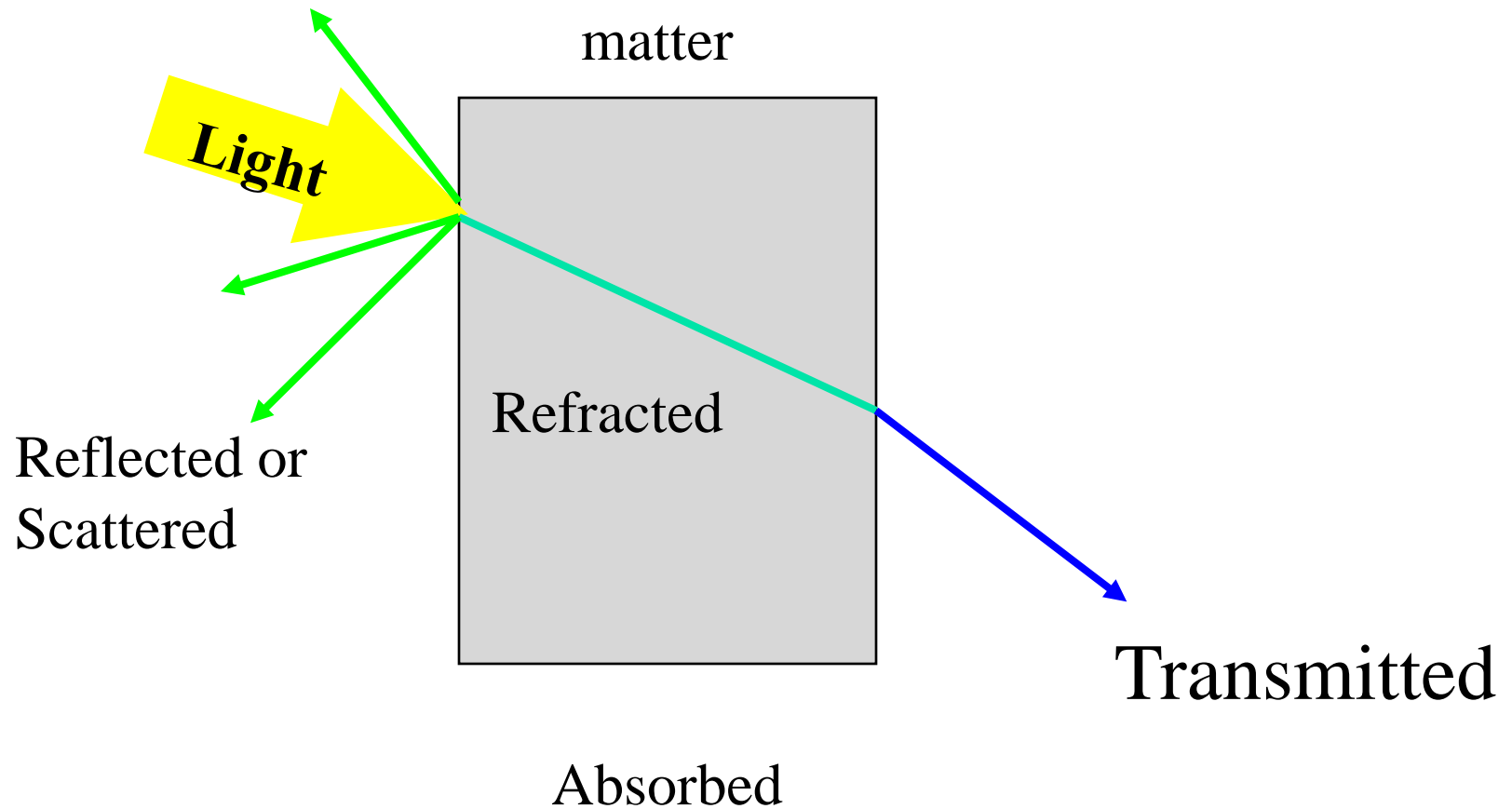
Absorption of Light by Matter

- Absorption spectrum of Sodium gas



) ()
Dark lines = light energy absorbed

Interaction of Light With Matter



Seven Types of Matter

Transparent and colorless

Transparent and **colored**

Translucent and colorless

Translucent and **colored**

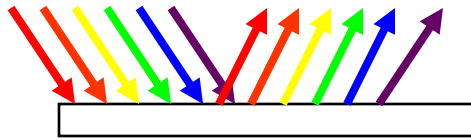
Opaque and white

Opaque and black

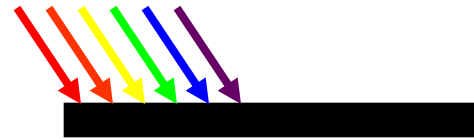
Opaque and colored

Absorption and Transmission

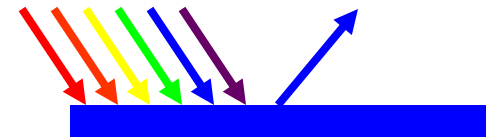
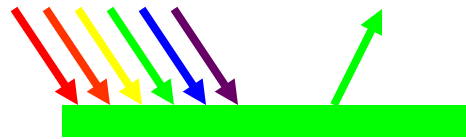
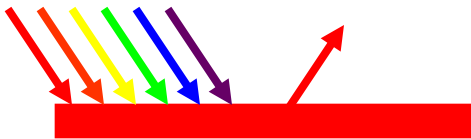
White light — composed of all wavelengths



White opaque object
transmits all wavelengths



Black opaque object
absorbs all wavelengths.



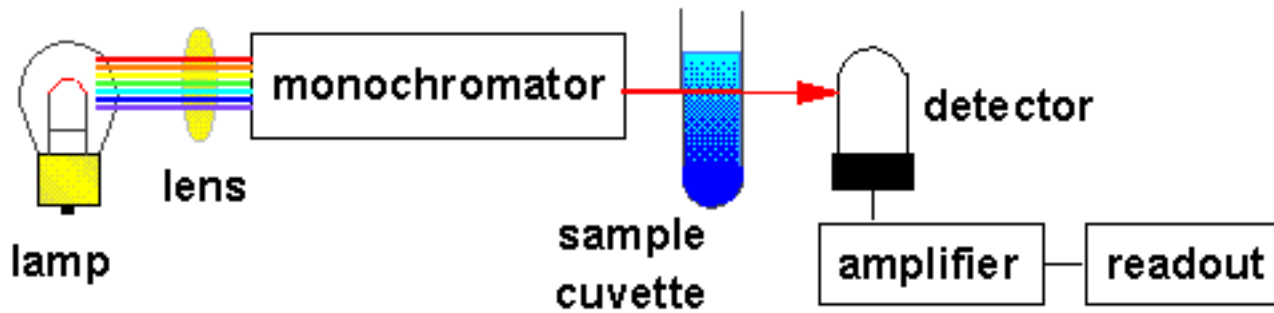
Colored opaque objects

selectively absorb and **transmit** (or reflect) light.

Absorption of Light by Matter

- Matter consists of **atoms** and **molecules**
- Atoms contain **electrons**
- Molecules contain **chemical bonds** which form by exchange or sharing of electrons between atoms
- Light interacts with matter through electrons

Measuring Light Absorption



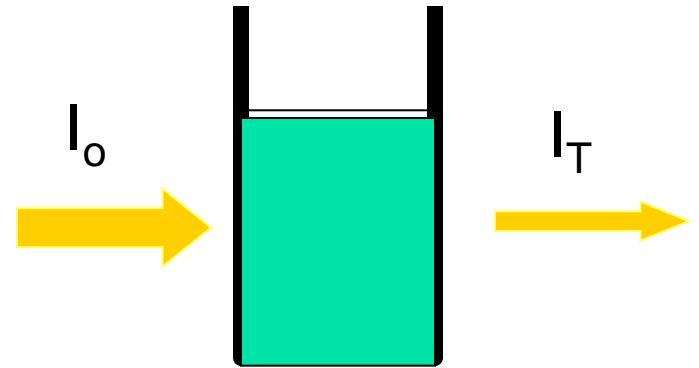
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Single Beam Spectrophotometer

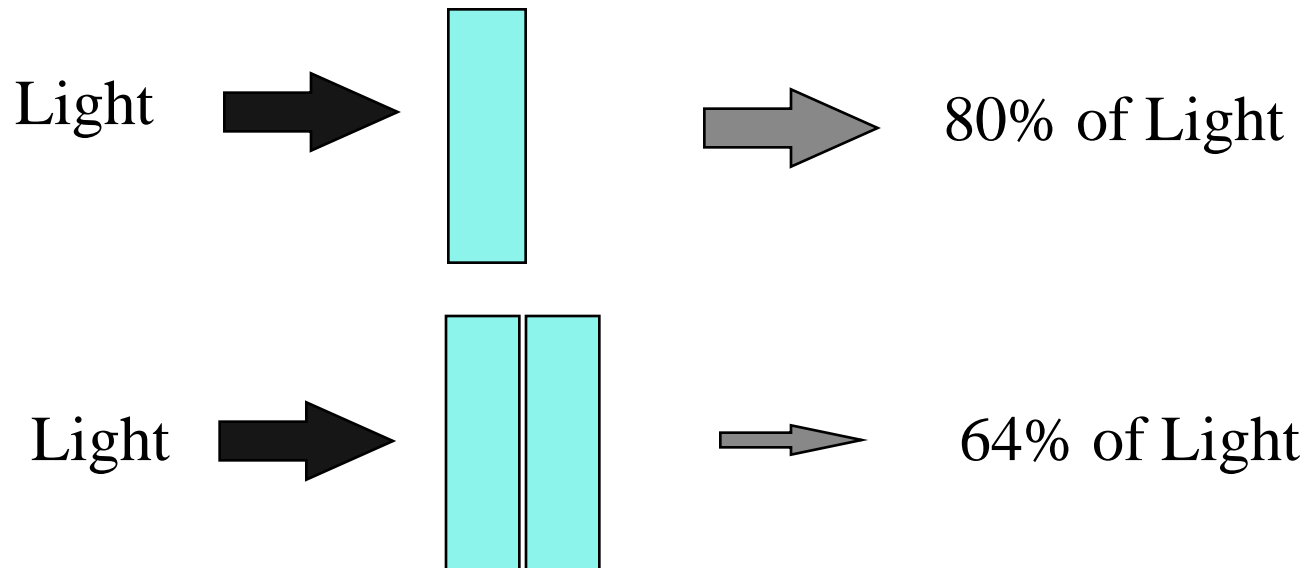
Laws of Light Absorption

- I_o = intensity of light through blank
- I_T = intensity of light through sample
- Absorption = $I_o - I_T$
- Transmittance = I_T/I_o
- Absorbance = $\log(I_o/I_T)$



Laws of Light Absorption

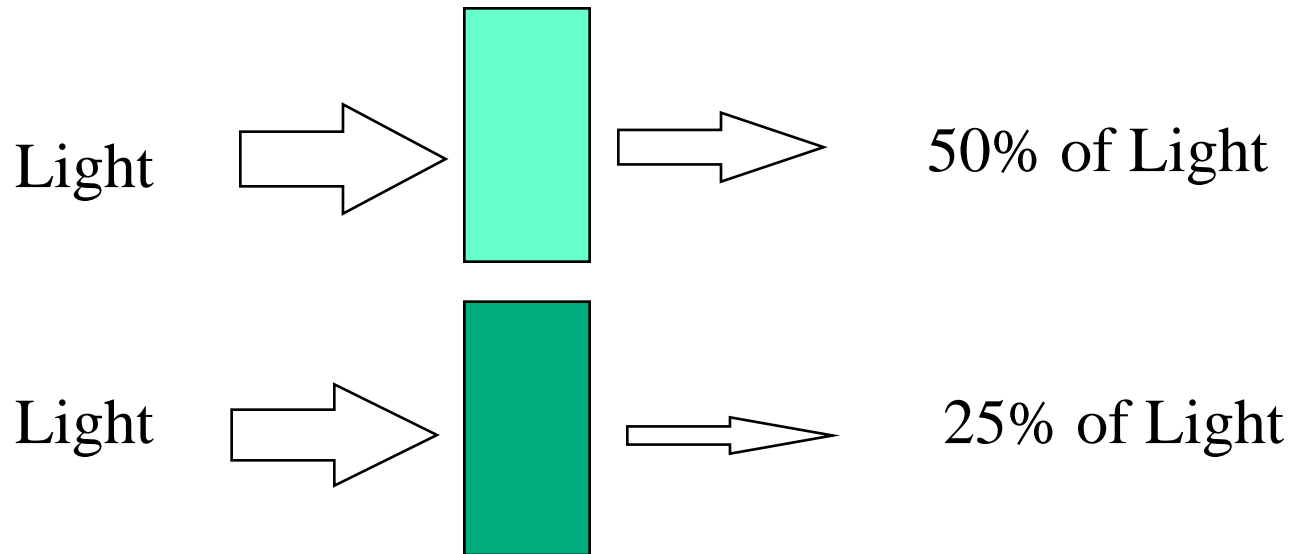
- Lambert's Law



Thicker matter absorbs more light

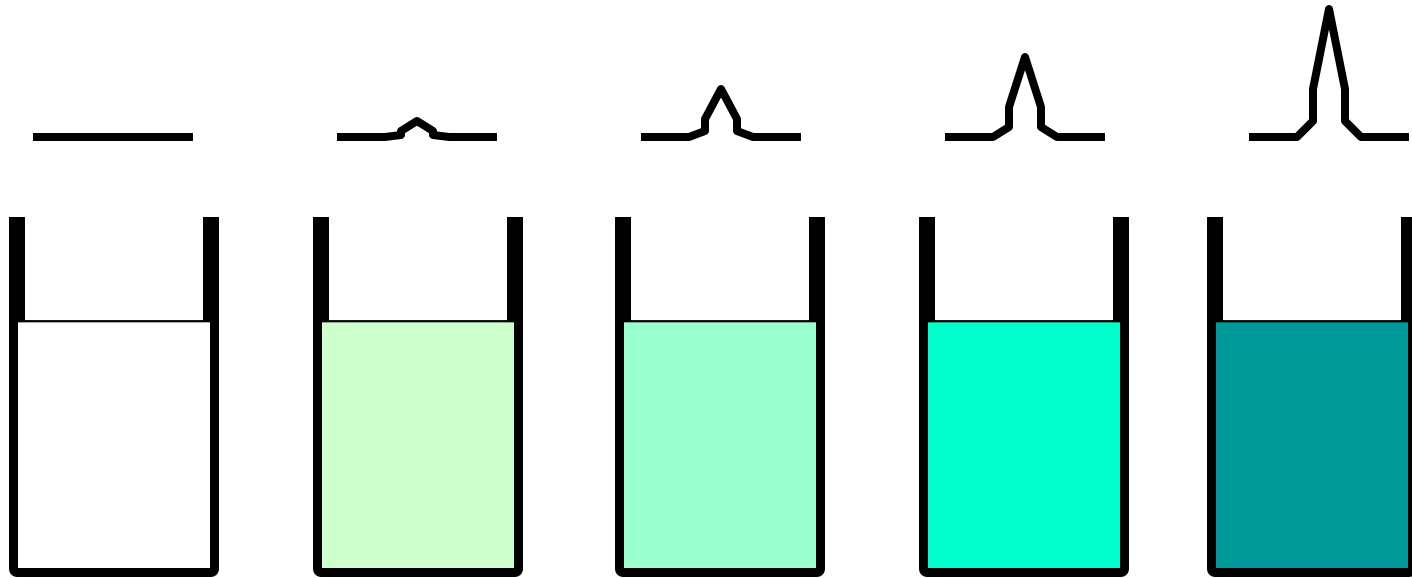
Laws of Light Absorption

- Beer's Law



Absorption depends upon **concentration** of absorbing matter

Absorbance & Beer's Law



Increasing absorbance

Laws of Light Absorption

- Beer-Lambert Law

$$A = abc$$

A = absorption

b = path length (thickness of matter)

c = concentration of matter

a = absorptivity constant (fudge factor)

Beers Law: $A = abc$

What is the relationship between Absorption (A) and concentration (c)?

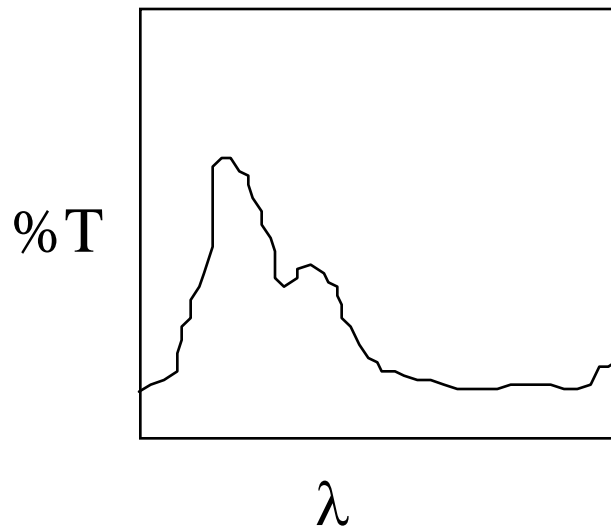
1. As “c” gets smaller “A” gets bigger.
2. As “c” gets larger “A” gets larger.
3. There is no relationship.
4. As “A” gets smaller “c” gets bigger.



Spectral Curves

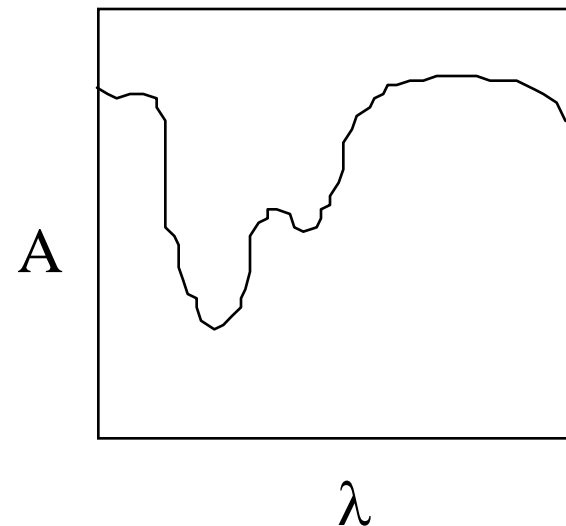
Transmission Curve

%T vs λ



Absorption Curve

A vs λ

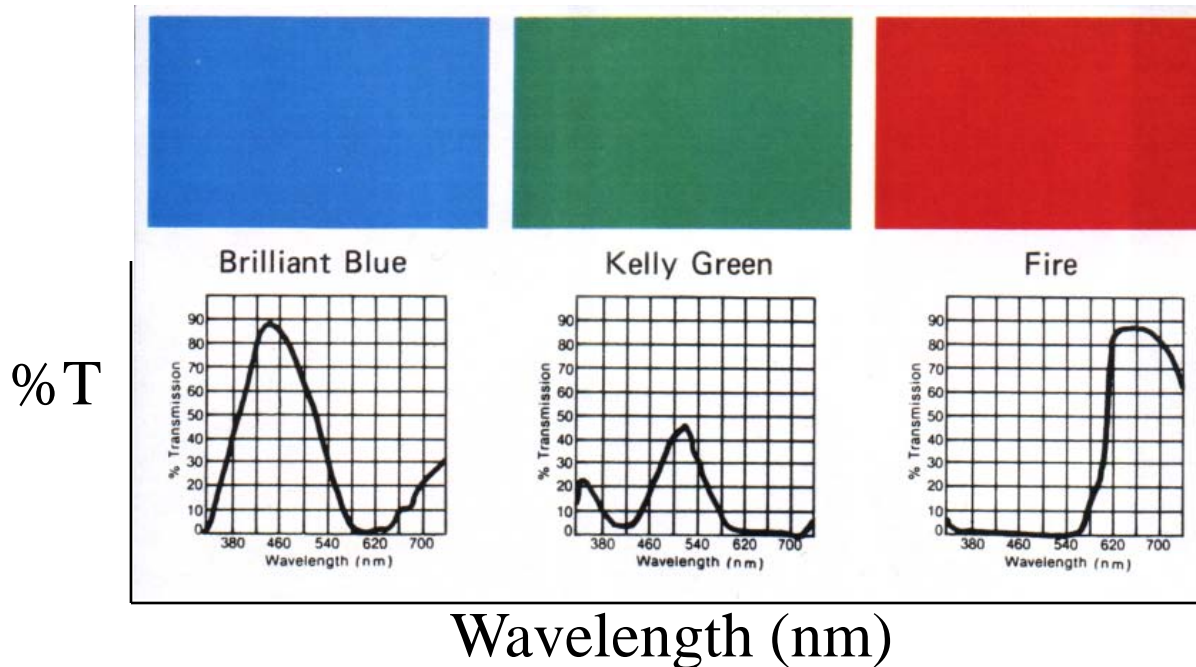


Can be used to help identify colored matter

Measuring Light Absorption

Qualitative analysis...

- Plot absorbance or %transmittance versus wavelength to get **spectral curves**



Measuring Light Absorption

Quantitative analysis...

- Green colored Chlorophyll leaf extract
- 4 chlorophyll standard solutions

Concentrations Absorbances (A)

5%	0.100
10%	0.200
15%	0.300
20%	0.400

- Unknown chlorophyll solution $A = 0.250$

Graphing the Data

