Fundamentals of Color Measurement

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Spectrum of Color measurement

Wavelength (nm)

100 206 400 700 1100

Ultraviolett (UV)  Visible Light (VIS)  Near Infrared (NIR)

385 430 550 620 670
Yellow red blue green  = color of liquid
Color Scales and Terms

- APHA - American Public Health Assoc., Hazen Standard
- ASTM – American Society for Testing and Materials, Hazen and SayBolt Standards
- EBC – European Brewery Convention; 430 nm, 1 cm
- Hazen – Unit of the Color Standard Scale for APHA/ASTM. Also know as Pt-Co.
- Saybolt – Color Scale unit for Petroleum Products based upon visual comparison of Optical Filters
Photometry - Principles

Absorption of light:

\[ I_0 \rightarrow I_R \]

Scattering of light:

\[ I_0 \rightarrow I_S, I_D \]
Absorption - Lambert Beer´s Law I

\[ I = I_0 \cdot \exp[-\varepsilon \cdot c \cdot d] \]

\[ T = \frac{I}{I_0} \]

\[ A = -\log T = \varepsilon \cdot c \cdot d \]

- **A**: Absorbance
- **T**: Transmission
- **\( \varepsilon \)**: Molar decaying coefficient of absorption \( (l / \text{mol} \cdot \text{cm}) \)
- **c**: Concentration of absorbing substance \( (\text{mol} / l) \)
- **d**: Optical path length (OPL) \( (\text{cm}) \)
Absorption - Lambert Beer’s Law II

Units of Absorption:

\[ A = -\log T = \varepsilon \cdot c \cdot d \]

\[ \text{OD} = \frac{A}{\text{OPL}^{\text{cm}}} \]

A: Absorbance
E: Extinction (Europe)
AU: Absorbance Units
CU: Concentration Units (competitor)

OD: Optical Density
Absorption - Lambert Beer’s Law III

- Absorbance
- % Transmission
- Concentration
Absorption - Lambert Beer’s Law IV

\[ A = -\log T \]

<table>
<thead>
<tr>
<th>Absorbance (CU)</th>
<th>Transmission (%)</th>
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<tbody>
<tr>
<td>0</td>
<td>100</td>
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<tr>
<td>0,5</td>
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<tr>
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<td>0,1</td>
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<td>4</td>
<td>0,01</td>
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Absorption - Different Colors

![Absorption - Different Colors](image-url)
Color Analysis, e.g. APHA

500 APHA
5 cm cuvette

50 APHA
5 cm cuvette
Color Analysis

Single Beam Absorption:

\[ A = \varepsilon \cdot c \cdot d \]

Dual Beam Absorption:

\[ A = A_{\text{meas}} - A_{\text{ref}} \]
Color Analysis - Comparison Single and Dual Beam

Single Beam Absorption:
- No Turbidity
- No Bubbles
- Significant color changes

Dual Beam Absorption:
- Compensation of turbidity
- Compensation of bubbles
- High sensitivity
- Compensation of lamp aging
Color Analysis - Typical Apps Single and Dual Beam

- Phase separation:
  - Beer / Water
  - Wine / Water
  - Juice / Water
  - Hemoglobin concentration in blood

- Color dosage
- Quality control / Purity (absence of color)
- Decolorization control
- Color scales: APHA, Hazen, EBC, ASBC, ASTM, ICUMSA, Lovibond
- Concentration of inks / colorants
- Residual color in waste water
- Metals in solution: Iron, copper, nickel, chromium
- Huminic matter in drinking water
- Chlorophyll in edible oil
- Bleaching of edible oil, sugar syrup...
- Lignin in hydrosulfuric acid
- Dissolved water in organics
- Phase separation: organic and aqueous phase
- Chlorine / chlorine dioxide / hypochlorite
Color Analyzer Manufacturers

- Ametek Process Instruments Model 4000
- Galvanic Applied Sciences Monitek Monispec AD
- Optek Model AF26
- Sigrist ColorPlus
- Wedgewood Analytical Model AF21, AF22
Ametek Model 4000
GAS Monitek Monispec AD
Optek Control 4000/AF26
Sigrist ColorPlus
Wedgewood Analytical
980/AF21, AF22