Lecture 8

Measuring Refractive Index
Refractive Index

Refractive index (n)

# of samples

1.55 biologicals
1.66 minerals

# of samples

Refractive index (n)
Becke Line Test

1. The indices of refraction of the particle and surrounding medium are different.
2. The microscope is defocused (on the sample).

Becke line
Refraction of Light

Air $n_1 = 1.00$

Glass $n_2 = 1.52$

Light bends toward (or away) from surface normal.
Can be used to find refractive index of unknown materials using standard liquids.
How to Check Becke Line

1. Prepare a series of samples in media with different refractive indices

2. High contrast > close down condenser aperture

3. Control wavelength > yellow is best > use orange filter

4. Raise the focus > lower the stage > rotate toward you

5. Decide the refractive index depending on the position of Becke line
Refractive Index Measurements via Becke Line Test

1. One unknown sample

2. Choose standard refractive index liquids (1.4 and 1.8)

3. Decide whether refractive index is equal, greater, or less than refractive index you choose
Recrystallization of Inorganic/Organic Salts

1. Sublimation

2. Evaporation
   • 10X Objective
   • Supersaturation

3. Transfer saturated solution “Huffing”
Detection of Lead

KI \rightarrow \text{Pb(NO}_3\text{)}_2 \rightarrow \text{KI} \rightarrow \text{Pb(NO}_3\text{)}_2

Red Lead
PbI\textsubscript{2} formed

PbI\textsubscript{2}

Pigment
Test for Lead with Potassium Iodide (KI)

Method II
Exercise 5: Fiber Sample Preparation (see handout)

1. Three samples (hair and two fibers)

2. Your hair (cut one or two hair of ~ 1”)

3. Choose your sample in the list

4. Label your samples with marker (initial and sample name) on the slide glass

5. Cure them for a week

6. Place them in your assigned positions in a sample box by next week
Exercise 6: Mineral Sample Preparation (see handout)

1. DO NOT contaminate your sample
2. Use very small portion of your sample
3. Evaporation
4. Transfer saturated solution “Huffing”
Isotropic vs Anisotropic

Refractive index: interaction between electromagnetic light and materials (ions and molecules)

Isotropic: Equal refractive index in all directions (one n)

Anisotropic: Not equal refractive index in all directions (two or three n)
Cubic (Isotropic) Indicatrix

- Same refractive index in all directions
- Light travelling in all directions has same speed
- Cross sections are always circle (radius n)
- Cubic crystal system only

\[ n = n_a = n_b = n_c \]
Two rows of dots, with each row corresponding to one of the two light rays formed as the light is split upon entering the calcite.
Two refractive indices

\[ n_a = n_b (\omega) \neq n_c (\varepsilon) \]

Light travels in different speed depending on directions

Hexagonal and tetragonal crystal systems

\[ n_a = n_b (\omega) \neq n_c (\varepsilon) \]

\[ \omega < \varepsilon \text{ or } \omega > \varepsilon \]
Uniaxial Indicatrix (Positive)

If $\omega < \varepsilon$ (positive)

$Z = \text{optic axis} = c$-axis

- Circular Section
  - Radius = $n_\omega$

- Principle Sections
  - Radii = $n_\lambda$ and $n_\omega$

Uniaxial Positive Indicatrix
- Elongated along the optic axis
  - $c$-axis = optic axis
  - $c$-axis = $Z$ indicatrix axis

$n_\omega > n_c$
Uniaxial Indicatrix (Negative)

If $\omega > \varepsilon$ (negative)

$X = \text{optic axis} = c$-axis

$n_c < n_\pi$

Uniaxial Negative Indicatrix
Flattened along the optic axis
$c$-axis = optic axis
$c$-axis = $X$ indicatrix axis
Uniaxial Crystal: Orientation-Dependence

isotropic

anisotropic
Calcite Double Refraction

Extraordinary Ray ($\varepsilon$)

Ordinary Ray ($\omega$)

$\omega < \varepsilon' < \varepsilon$
Birefringence: Double Refraction

Materials with two (or more) refractive indices

For calcite,

\[ n_{\omega} = 1.658 \] (parallel to c axis, ordinary ray, regardless of the direction).
\[ n_{\epsilon} = 1.486 \text{ to } 1.658 \] (perpendicular to c axis, extraordinary ray, dependant on the direction)

Calcite, \( \Delta n = 0.172 \) (two images with very large separation)
Quartz, \( \Delta n = 0.009 \) (two images with very little separation)

<table>
<thead>
<tr>
<th>Crystal name</th>
<th>( \omega )</th>
<th>( \epsilon )</th>
</tr>
</thead>
<tbody>
<tr>
<td>rock crystal (quartz)</td>
<td>1.5443</td>
<td>1.5534</td>
</tr>
<tr>
<td>calcite</td>
<td>1.6584</td>
<td>1.4864</td>
</tr>
<tr>
<td>sapphire</td>
<td>1.768</td>
<td>1.760</td>
</tr>
</tbody>
</table>
• Three refractive indices
• \( n_a(\alpha) \neq n_b(\beta) \neq n_c(\gamma) \)
• Light travels in different speed depending on directions
• Orthorhombic, monoclinic, and triclinic crystal systems

• by definition, \( \gamma > \beta > \alpha \)
• \( \gamma - \beta > \beta - \alpha \) (+): positive
• \( \gamma - \beta < \beta - \alpha \) (-): negative
Biaxial minerals have three indices of refraction, \(n_\alpha, n_\beta, n_\gamma\) each of which is measured along an indicatrix axis as shown on the left, such that the following relationship holds: \(n_\kappa < n_\beta < n_\gamma\).

- **XZ** plane with axes \(n_\alpha\) and \(n_\gamma\)
- **YZ** plane with axes \(n_\beta\) and \(n_\gamma\)
- **XY** plane with axes \(n_\alpha\) and \(n_\gamma\)
Biaxial Crystal: Orientation-Dependence

- $\gamma$ and $\beta$ for YZ plan
- $\gamma$ and $\alpha$ for XZ plan
- $\alpha$ and $\beta$ for XY plan

Random orientation
- $\gamma$, $\gamma'$, $\beta$, $\beta'$, $\alpha$, and $\alpha'$ depending on the orientation
Biaxial Crystal: Orientation-Dependence