Gemstones
The Precious, the Semi-Precious, and the Ugly

Catherine Barrie
Dogbone of the Week
April 11, 2022
Gemstones

*a mineral or petrified material that when cut and polished can be used as jewelry* – Merriam Webster

- Measured in Carats (200 mg)
- Classification:
  - Precious
  - Semi-Precious

![Images of Ruby, Sapphire, Emerald, and Diamond]
Gemstones

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[Images of Opal, Topaz, and Alexandrite gemstones]
Color

- Structure
- Impurities
- Radiation
- Light Source

ELECTRON TRAVEL

1. The Crystal Field Theory
   - Transition metal compounds (malachite, almandine) - idiochromatic
   - Transition metal impurities (ruby, emerald, citrine, jade) - allochromatic
   - Color centers (amethyst, maxixe-beryl)

2. The Molecular Orbital Theory
   - Charge transfer (sapphire, iolite)

3. The Band Theory
   - Insulators (glass)
   - Conductors (metals)
   - Semiconductors (galena)
   - Doped semiconductors (diamond)

4. The Physical Properties Theory
   - Dispersion (Fire in diamond)
   - Scattering (moonstone, cat's eyes, stars)
   - Interference (iridescence, opal)
   - Diffraction (opal)

Sources: Geo.LibreTexts
Structure

• Anisotropy → Pleochroism
## Impurities

- **Transition Elements**

<table>
<thead>
<tr>
<th>Gem</th>
<th>Formula</th>
<th>Color</th>
<th>Origin of color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruby</td>
<td>$\text{Al}_2\text{O}_3$</td>
<td>Red</td>
<td>$\text{Cr}^{3+}$ replacing $\text{Al}^{3+}$ in octahedral sites</td>
</tr>
<tr>
<td>Emerald</td>
<td>$\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$</td>
<td>Green</td>
<td>$\text{Cr}^{3+}$ replacing $\text{Al}^{3+}$ in octahedral site</td>
</tr>
<tr>
<td>Alexandrite</td>
<td>$\text{Al}_2\text{BeO}_4$</td>
<td>Red/Green</td>
<td>$\text{Cr}^{3+}$ replacing $\text{Al}^{3+}$ in octahedral site</td>
</tr>
<tr>
<td>Garnet</td>
<td>$\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3$</td>
<td>Red</td>
<td>$\text{Fe}^{2+}$ replacing $\text{Mg}^{2+}$ in 8-coordinate site</td>
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Crystal Field Theory

Negative charges distributed uniformly over surface of a sphere

Metal cation, \( M^{n+} \)

Electrostatic attractions (+/-) considered

\( e_g \) orbitals go up in energy by \( \frac{3}{2} \Delta_0 \)

\( t_{2g} \) orbitals go down in energy by \( \frac{3}{2} \Delta_0 \)
Impurities

• Color Centers - Wrong Valence
• Radiation also creates this same color phenomenon
The Hope Diamond

- 45.52 carat blue diamond
  - Surprisingly light
- Owned by prominent figures such as King Louis XIV, XV, XVI
- Cursed
  - Suicide
  - Hanged
  - Thrown from precipice
  - Murdered by lover
  - Torn to pieces by wild dogs
  - Torn to pieces by French mob
State Gemstones - Maryland

Patuxent River Stone
State Gemstones - California

- Benitoite - $\text{BaTi}(\text{Si}_3\text{O}_9)$
- Found in San Benito, California
  - Only mine to produce gemstone quality
  - $\sim$7,000/carat

Gems & Gemology Vol XXXIII (1997)
Monetary Value

• Blue Diamonds are the most expensive ($3.93 Million/Carat)

• Painite – 2005 Guinness World Record for “rarest” gemstone on earth
  • Runs for 50 – 60 K PER CARAT
  • Largest stone found is 213.52 Carats
  • THAT’S 10.68 MILLION DOLLARS

x 21

x 42.72 Million
Can we increase monetary value?

- Of *quartz* we can!
- Almost all gems go through “post-processing”

1. Bleaching
2. Surface coating
3. Dyeing
4. Heat Treatment
5. HPHT
6. Irradiation
Heat Treatments

• Diamonds are more valuable colorless!
  • Nitrogen is often an unwanted impurity
  • GE: $1800 \, ^\circ C + 50,000 \, \text{atm}$ – turns the diamond from brown to clear!
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• Corundums are frequently heat treated around ~1500 C
  • There’s been “recent” studies of introducing impurities during treatment to further enhance color

• They can distinguish natural vs treated stones via Raman photoluminesce
Conclusions

• Value of gemstones due to rarity and looks
• Natural isn’t necessarily better
• Maryland’s State Gemstone is “embarrassing”