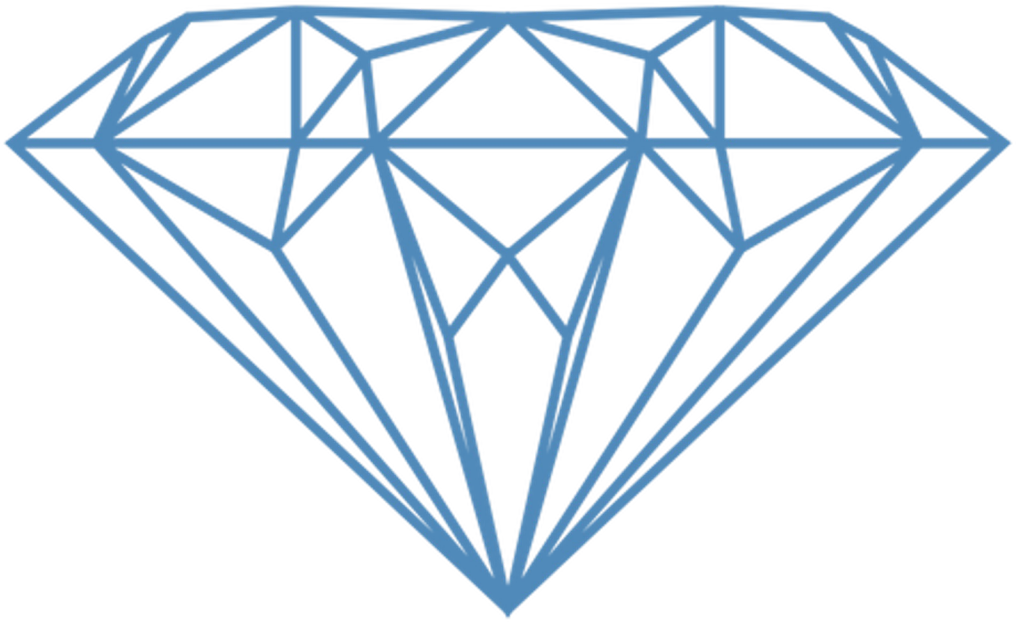
Gemstones

The Precious, the Semi-Precious, and the Ugly



Catherine Barrie

Dogbone of the Week

April 11, 2022

JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

Gemstones

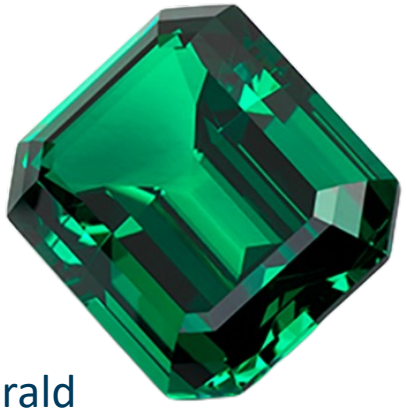
a mineral or petrified material that when cut and polished can be used as jewelry – Merriam Webster

- Measured in Carats (200 mg)

- Classification:
  - Precious
  - Semi-Precious

Ruby

Sapphire



Emerald

Diamond

Gemstones

a mineral or petrified material that when cut and polished can be used as jewelry

- Measured in Carats (200 mg)
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  - Precious
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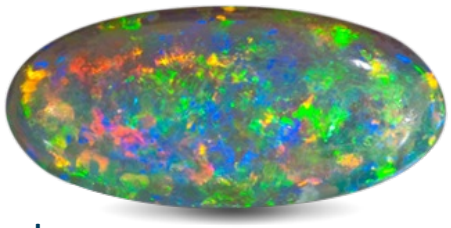


Opal

Topaz

Alexandrite

Color

- Structure
- Impurities
- Radiation
- Light Source

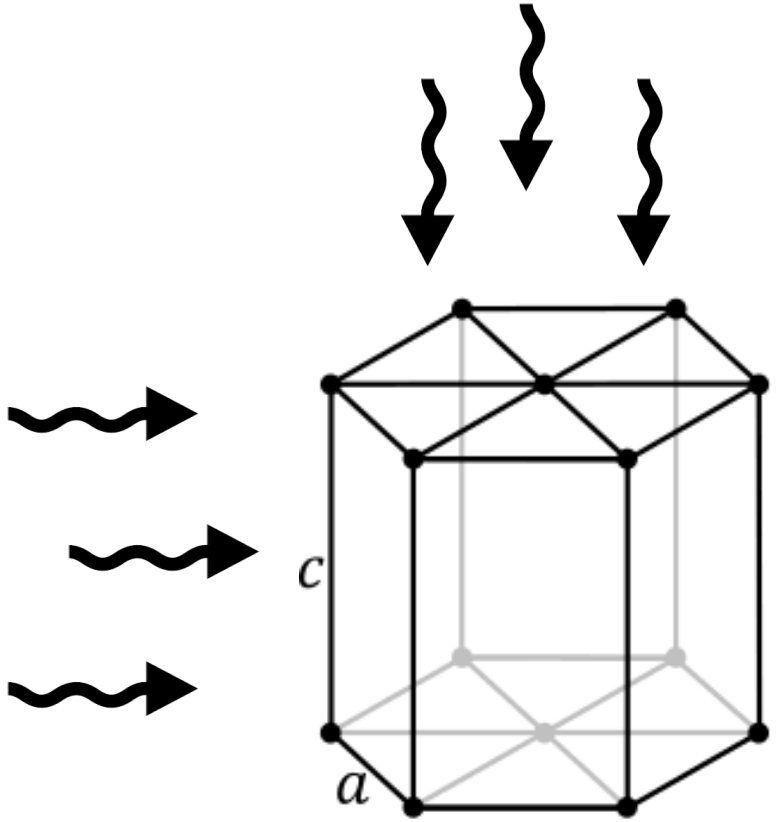
ELECTRON TRAVEL

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

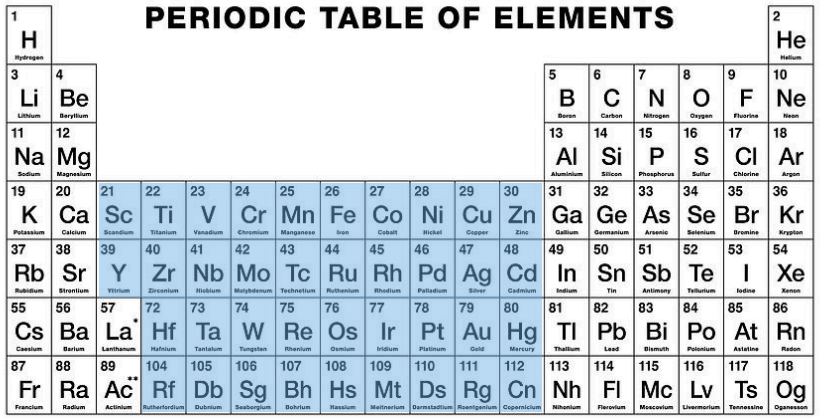
Structure

- Anisotropy → Pleochroism



Impurities

- Transition Elements



Gem	Formula	Color	Origin of color
Ruby	Al_2O_3	Red	Cr^{3+} replacing Al^{3+} in octahedral sites
Emerald	$Be_3Al_2(SiO_3)_6$	Green	Cr^{3+} replacing Al^{3+} in octahedral site
Alexandrite	Al_2BeO_4	Red/Green	Cr^{3+} replacing Al^{3+} in octahedral site
Garnet	$Mg_3Al_2(SiO_4)_3$	Red	Fe^{2+} replacing Mg^{2+} in 8-coordinate site

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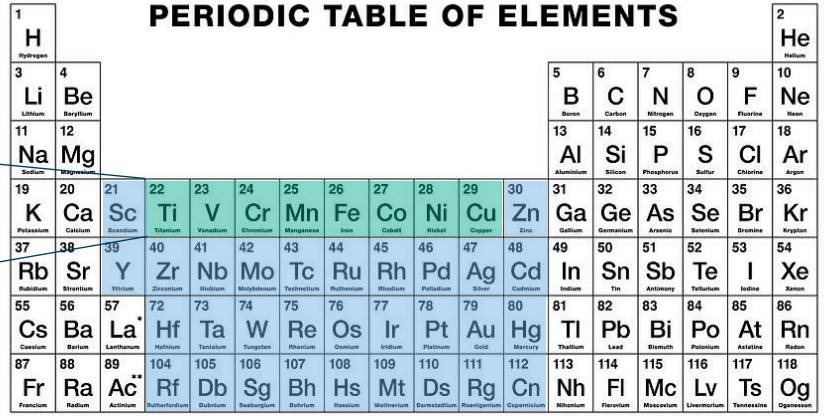
Impurities

- Transition Elements



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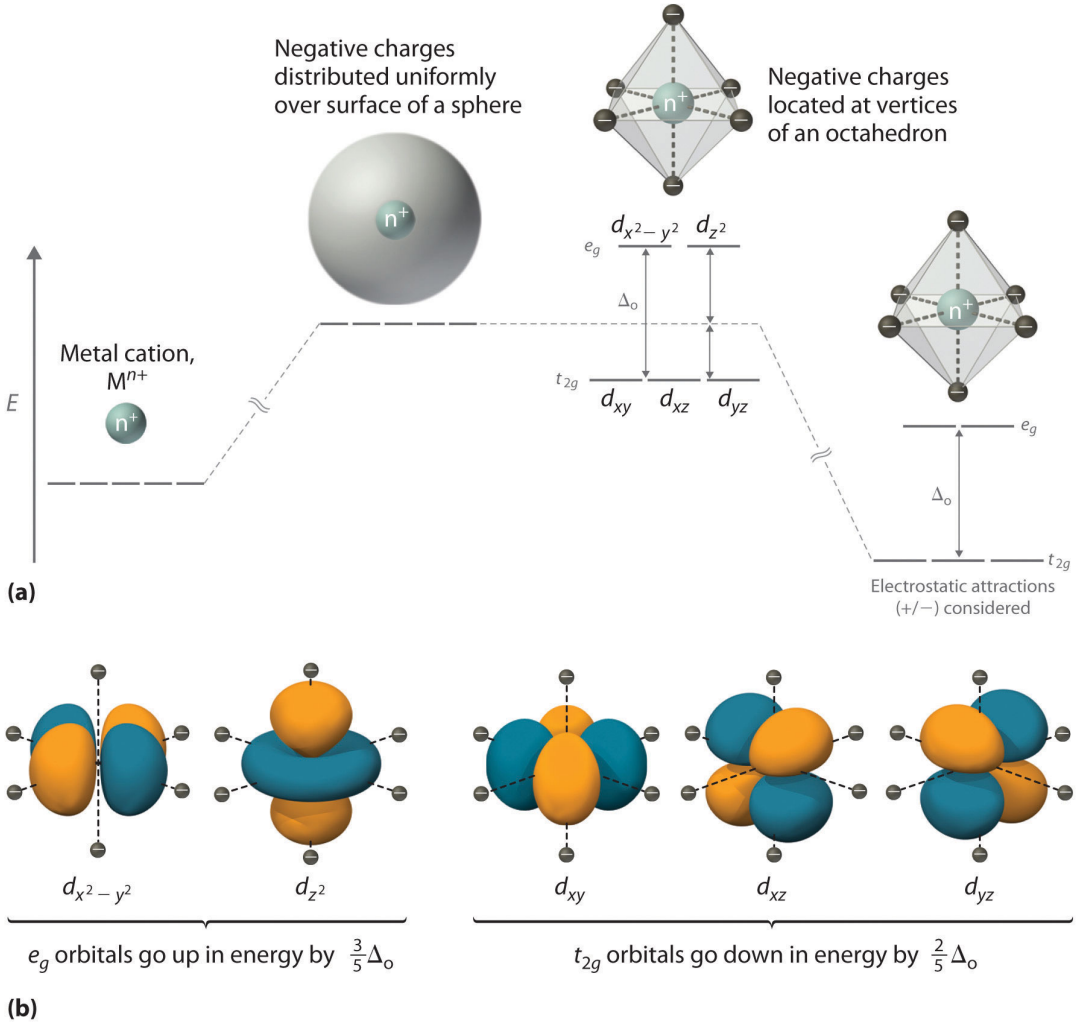
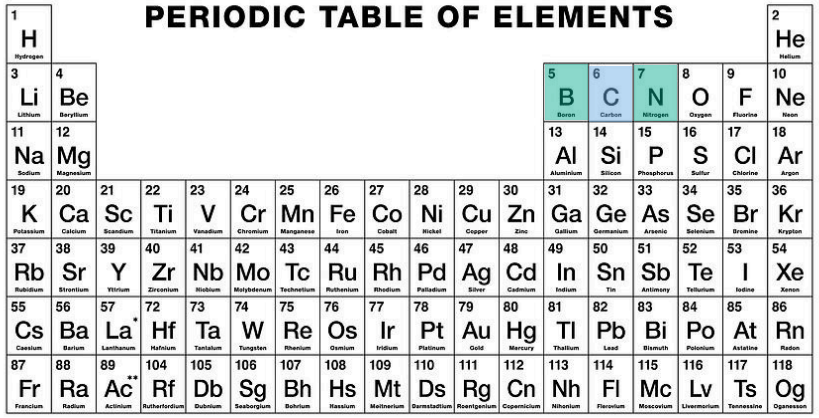
Crystal Field Theory



Impurities

- Color Centers - Wrong Valence
- Radiation also creates this same color phenomenon



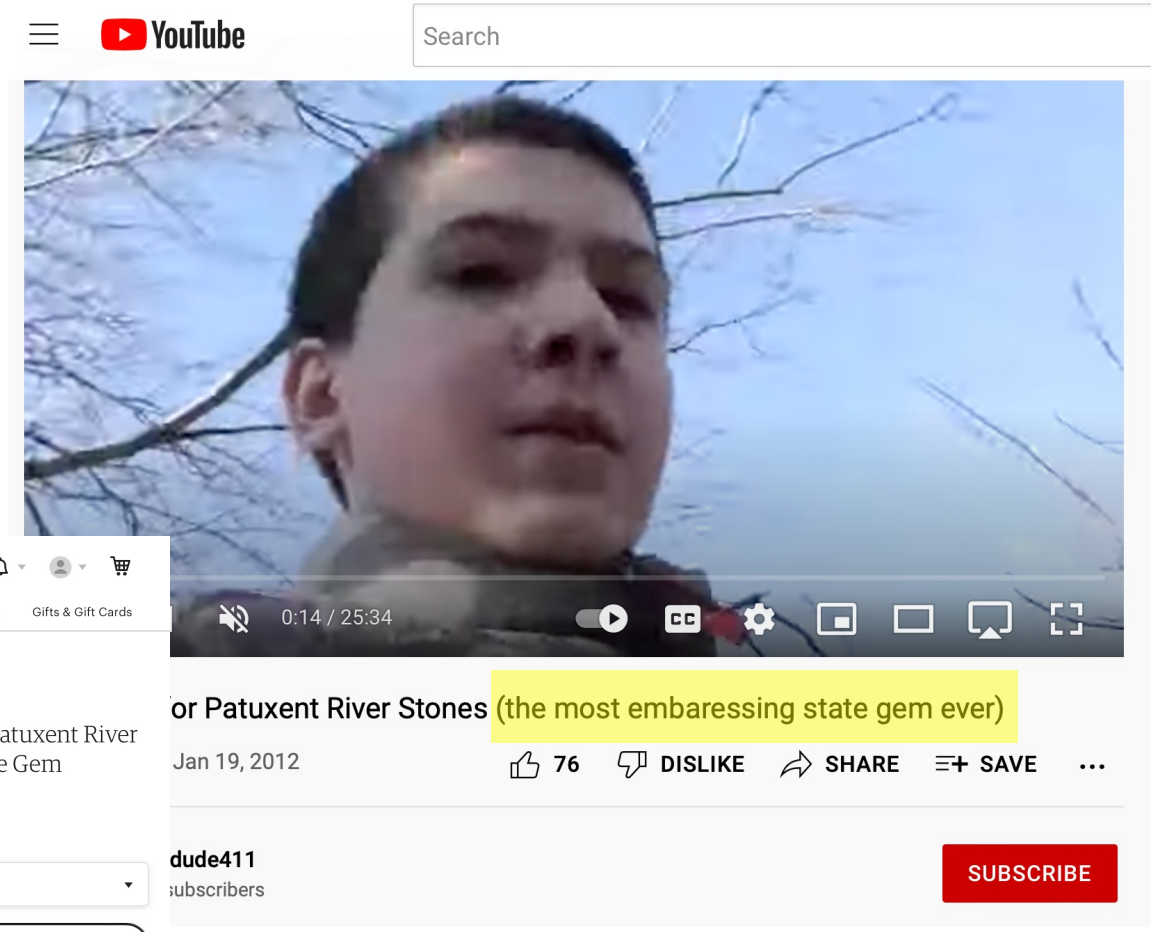
The Hope Diamond

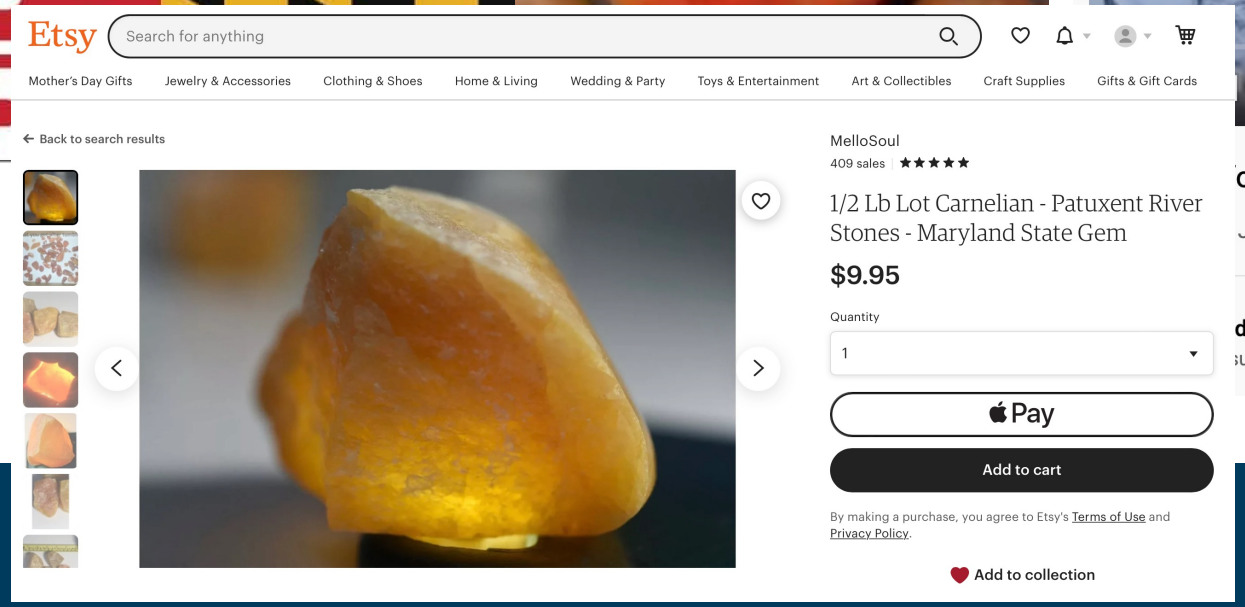
- 45.52 carat blue diamond
  - Surprisingly light
- Owned by prominent figures such as King Louis XIV, XV, XVI
- Cursed
  - Suicide
  - Hanged
  - Thrown from precipice
  - Murdered by lover
  - Torn to pieces by wild dogs
  - Torn to pieces by French mob

=

State Gemstones - Maryland

Patuxent River Stone





State Gemstones - California

- Benitoite - $BaTi(Si_3O_9)$
- Found in San Benito, California
  - Only mine to produce gemstone quality
    - ~$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

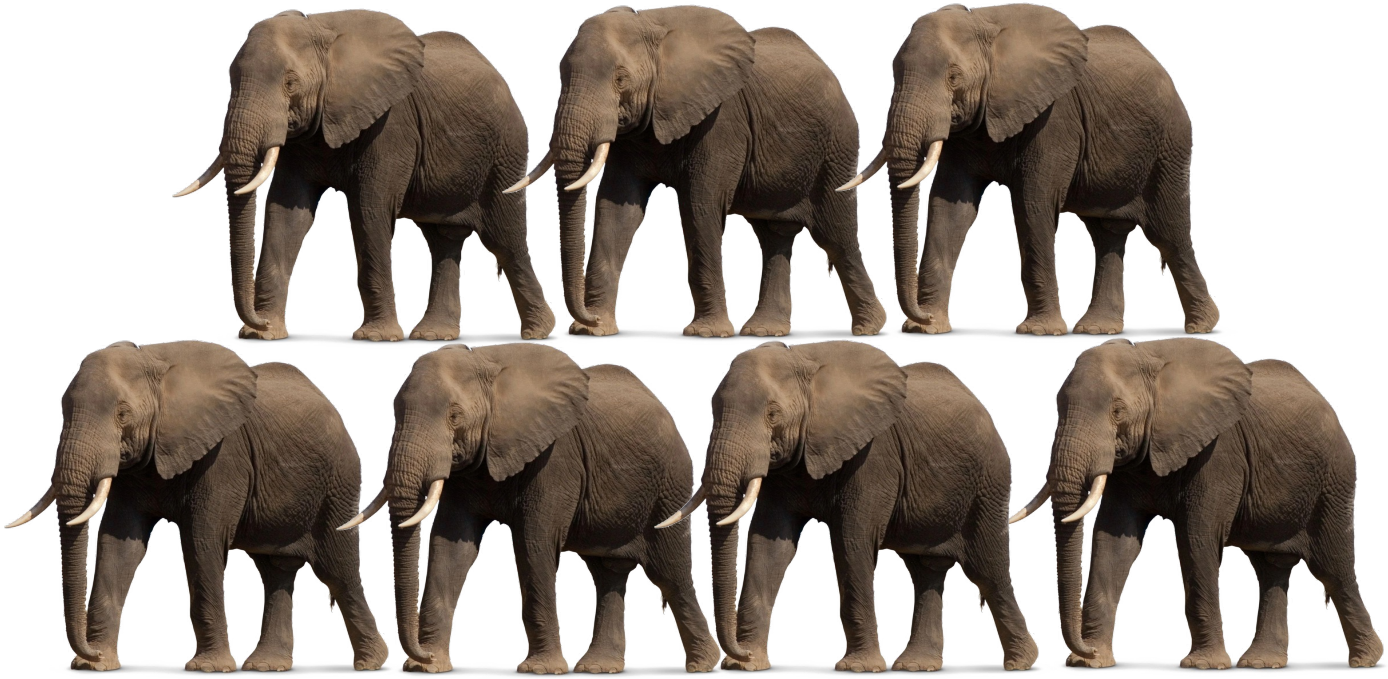
Can we increase monetary value?

- Of *quartz* we can!
- Almost all gems go though “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 C + 50,000 atm – turns the diamond from brown to clear!



+ 180,465 more

Heat Treatments

- Diamonds are more valuable colorless!
  - Nitrogen is often an unwanted impurity
  - GE: 1800 C + 50,000 atm – turns the diamond from brown to clear!
- 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 photoluminecesce

Chemical and Engineering News

Conclusions

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