Indium

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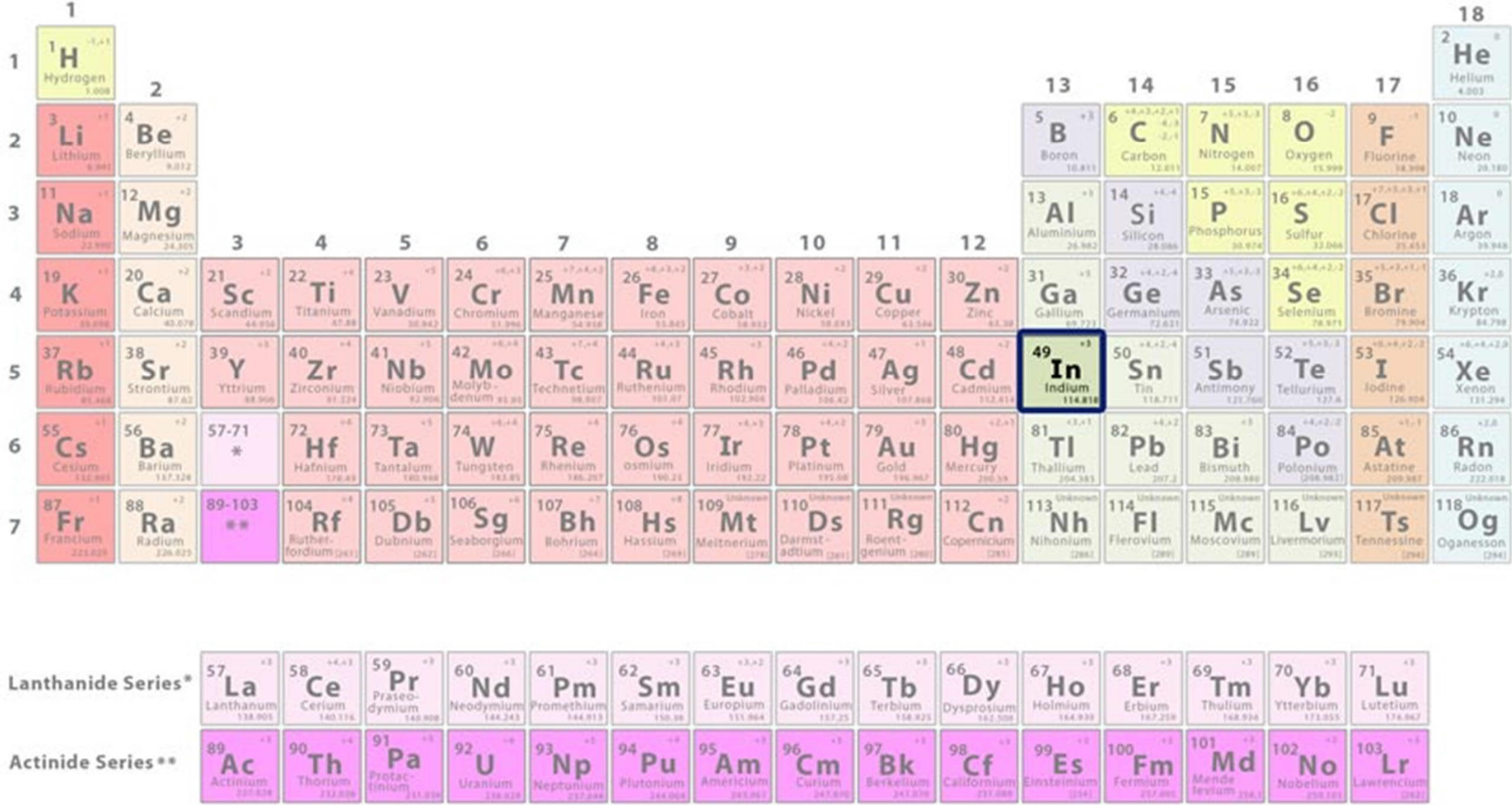
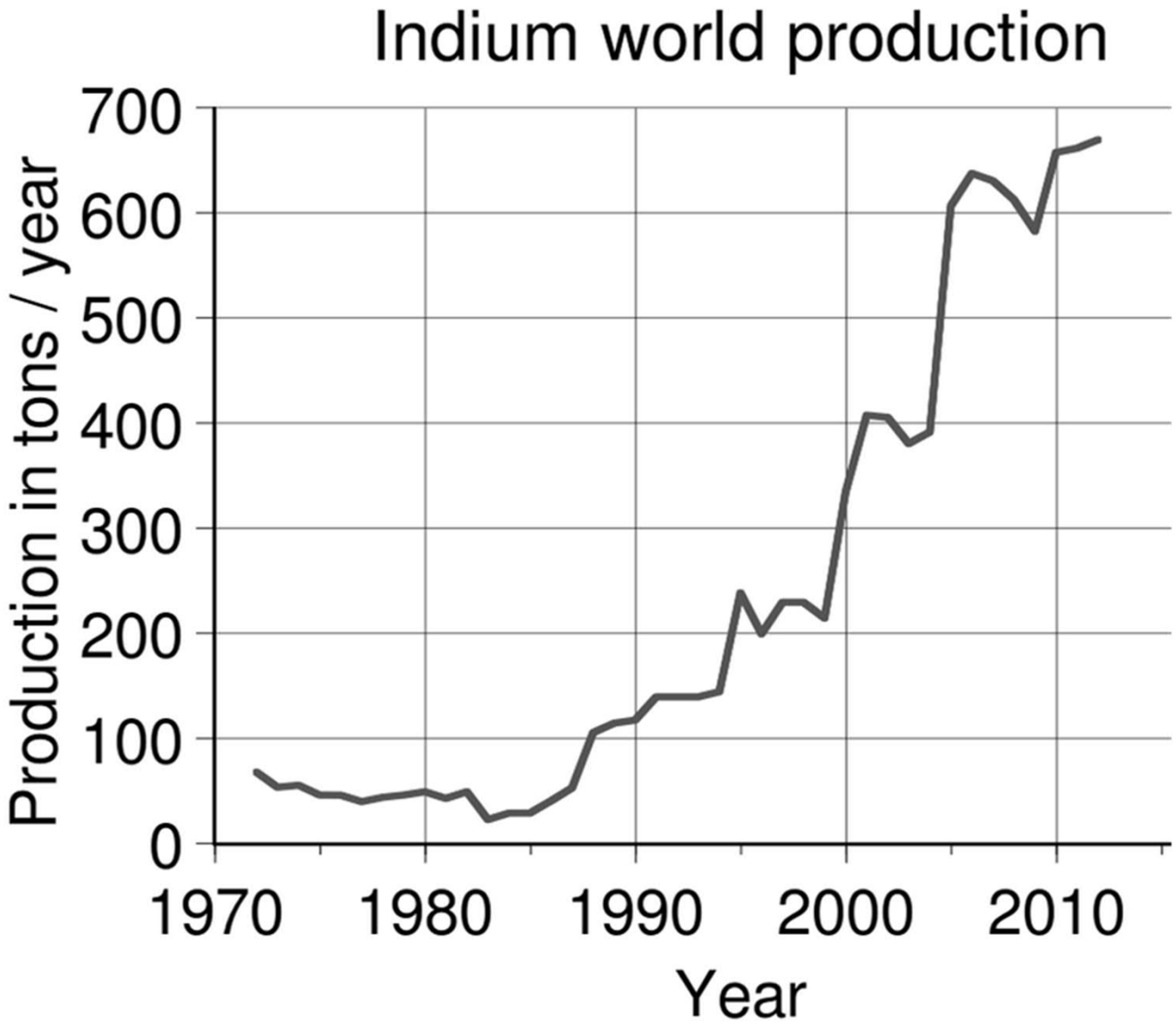
Location of Indium in the Periodic Table



ChemistryLearner.com

Overview

- [Element symbol In, element number 49, Group 13 post-transition p-block metal
- Discovered in 1863 by Richter and Reich in Germany from a mineral sample of sphalerite
- Named after the indigo blue color of the flame
- Relatively rare: abundance of about 50 ppb
- Price of 210€/kg



General properties

- Extremely soft (Mohs hardness 1,2)
- Low melting point (156,6 degrees C)
- Density 7.31 g/cm^3
- No major role in biology, low tocixity; compounds very toxic

http://www.chemistryexplained.com/Hy-Kr/Indium.html

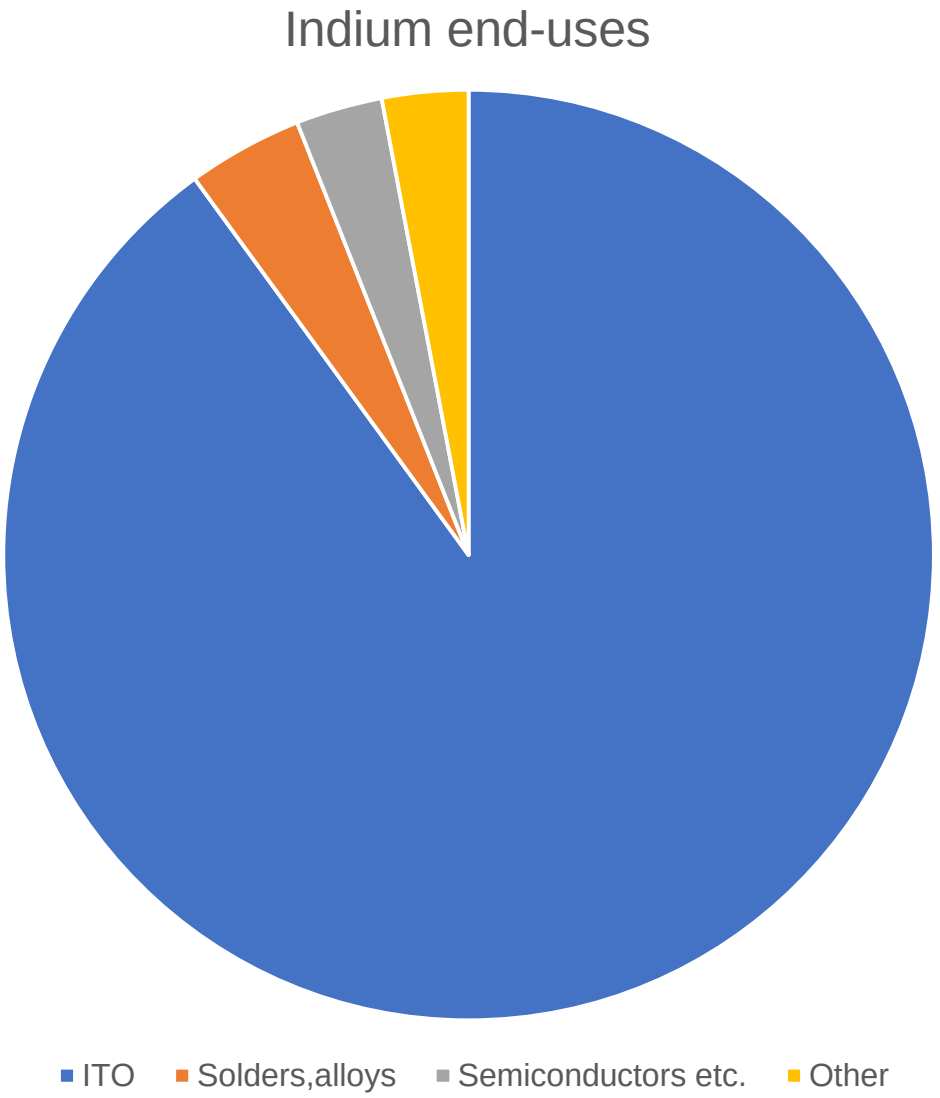
Chemical properties

- $[Kr]4d^{10}5s^25p^1$
- Relativistic effects stabilize 5s orbital, and thus oxidation state +I is possible, though much rarer than +III
- Intermediate properties between other group 13 metals (gallium and thallium)
- 39 different known isotopes, the most common being In-115 (radioisotope)

Oxidation states	+I, +II, **+III**
Electronegativity	1,78
Atomic radius	1,55 Å
Effective ionic radius (+III)	0,80 Å
Main isotopes	In-115, In-113 (95.7% and 4.3 % respectively)
Electron affinity	28.9 kj/mol^{-1}

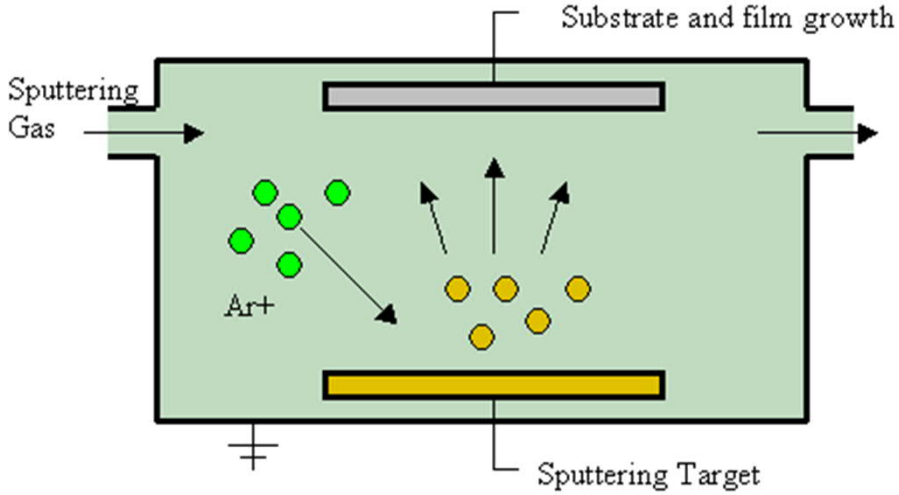
Main compounds

- Pure indium
  - *Solders, sealings, gaskets, thermal conductors*
- Indium tin oxide
  - *Degenerate semiconductor, optoelectronics*
- Indium phosphite
  - *Semiconductors, optics*
- Indium antimonide
  - *Narrow-gap semiconductor*



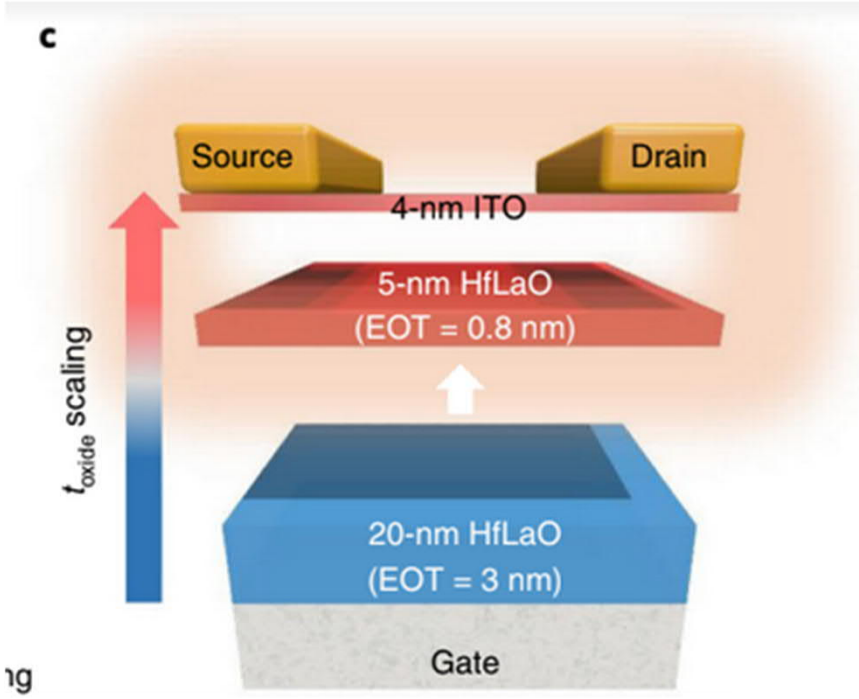
Indium tin oxide

- In_2O_3 doped with SnO_2
- Rare combination of transparency and conductivity: very commonly used in displays
- N-type semiconductor, band gap of 4 eV: tin oxide doping gives near metallic-like conductance
- Thin films easily made with physical vapor deposition methods



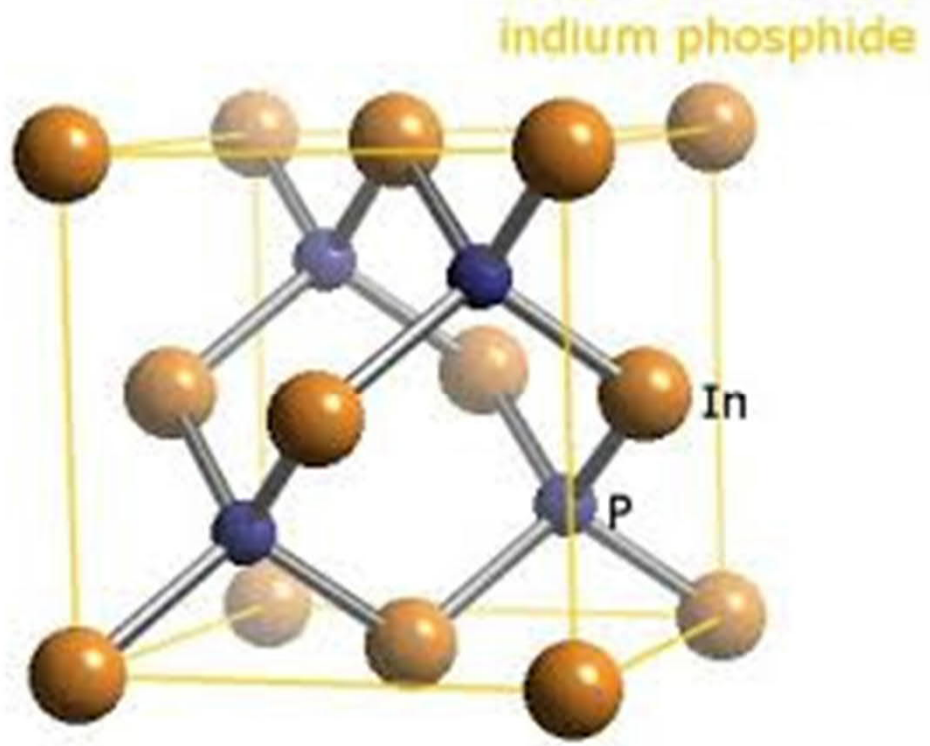
Indium tin oxide

- Jung et al (2019): Wearable electronics and sensors
- Li et al (2019): ultrathin ITO with HfLaO used to manufacture fast transistors
- High resistance to heat -> strain gauges, sensors etc for high temperature applications
- Coatings to reflect infrared radiation, defrosting



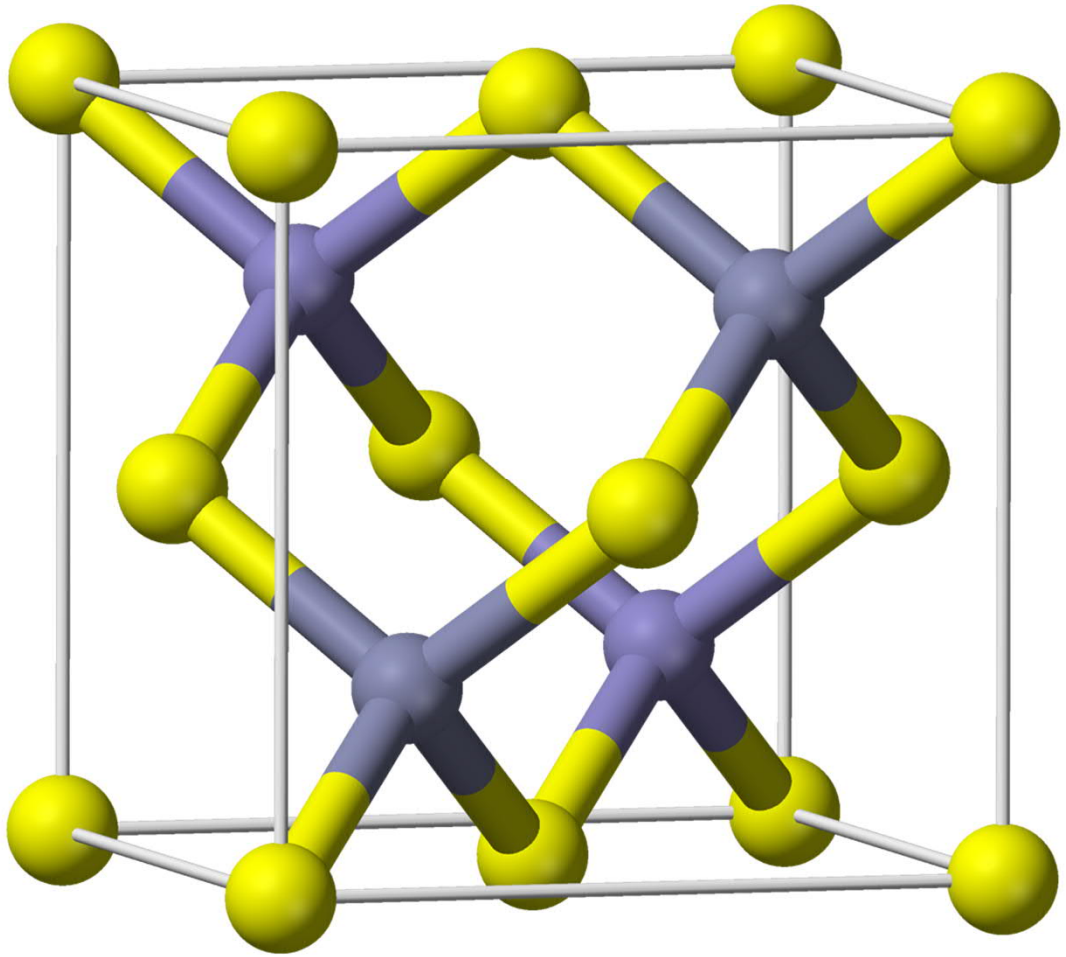
Indium phosphide

- Binary semiconductor, band gap of 1.344eV
- Direct bandgap
- Active and passive optical devices, communication devices due to emission range etc.
- Suitable for high-frequency electronics due to high electron velocity



Indium antimonide

- InSb, narrow gap semiconductor
- 0.17 eV (300 K), 0.23 eV (80K)
- Very high electron velocity, low thermal coefficient
- Low-power, high frequency transistors
- Thermal vision due to IR-range photovoltaics



Future prospects

- Bonaccorso et al (2010): Graphene replaces as a optoelectric material
- Increased use as high-performance semiconductor
- Very limited supply due to rarity and being a side product: price evolution
- Recycling increases from current >1% (USGS)

References

- *"USGS Mineral Commodity Summaries 2011" (PDF). USGS and USDI. Retrieved August 2, 2011.*
- https://www.rsc.org/periodic-table/element/49/indium
- https://www.statista.com/statistics/1060354/price-of-indium-united-states/
- https://en.wikipedia.org/
- R. D. Shannon (1976). Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides"
- Li, S. M,Tian. Gao,Q. Wang,M. Li,T. Hu,Q. Liand,X. Wu,Y (2019).Nanometre-thin indium tin oxide for advanced high-performance electronics.
- Jung et al (2019). Transparent and Flexible Mayan-Pyramid-based Pressure Sensor using Facile-Transferred Indiumtin Oxide for Bimodal Sensor Applications
- Bonaccorso, F., Sun, Z., Hasan, T. *et al.* Graphene photonics and optoelectronics. *Nature Photon* 4, 611–622 (2010).
- https://eom.umicore.com/en/thin-film-products/library/indium-tin-oxide-ito/
- https://davidsscience.weebly.com/physical-properties.html
- http://www.chemistryexplained.com/Hy-Kr/Indium.html
- https://www.americanelements.com/indium-antimonide-1312-41-0