

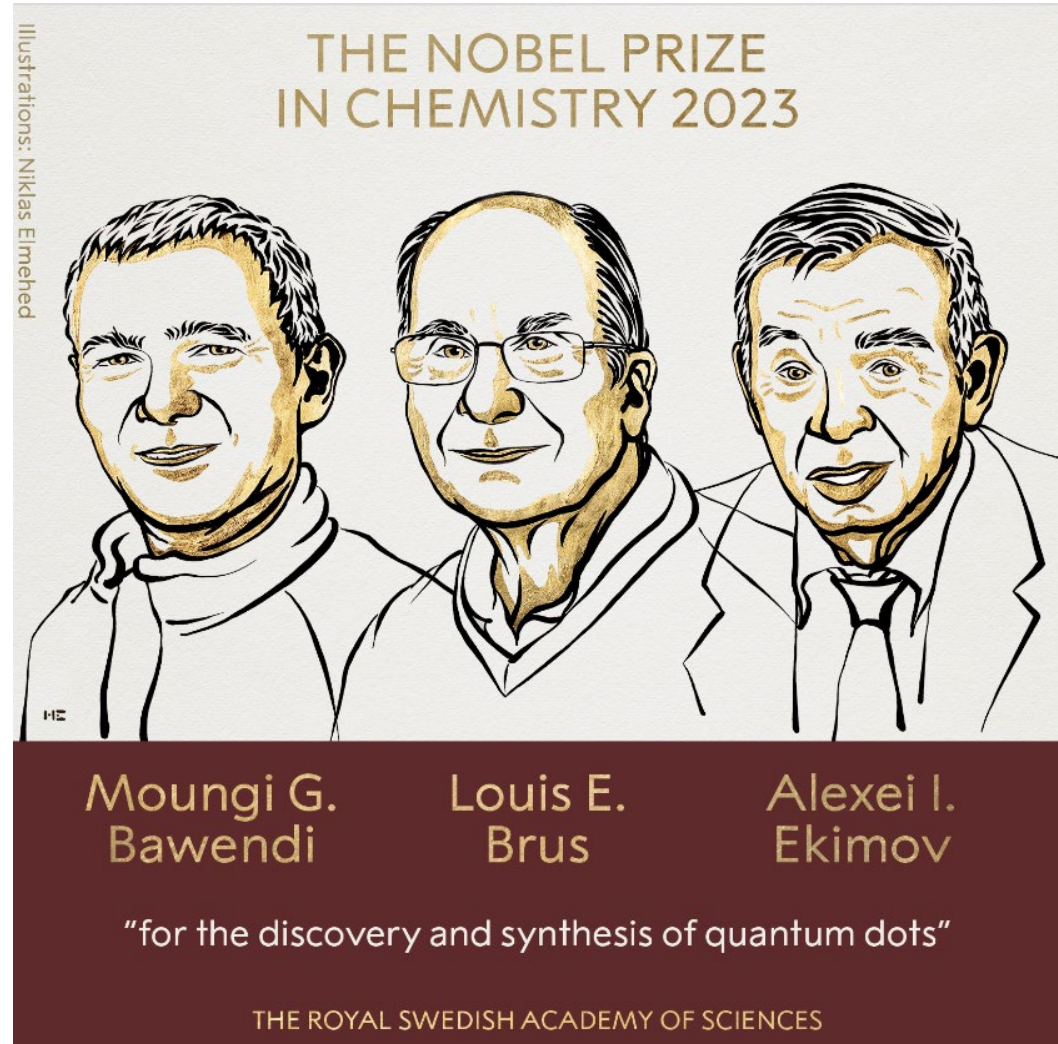
Chemistry 2023 Nobel Prize Awarded to Quantum Dots

Ana Florescu & Mudita Goyal

Chemistry MIT Professor Moungi Bawendi Receives 2023 Nobel Prize

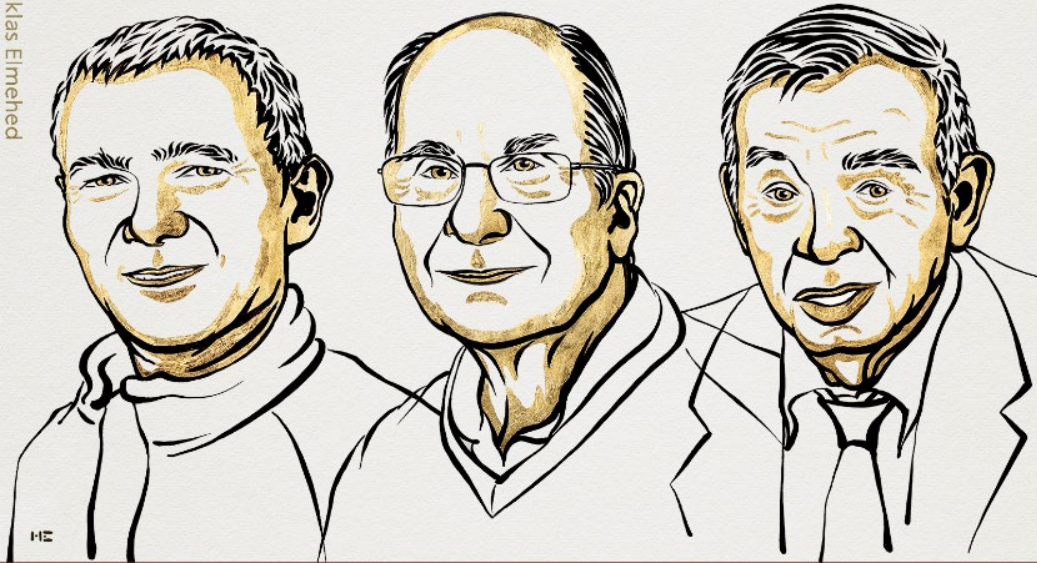


Photo: Len Rubenstein



Illustrations: Niklas Elmehed

THE NOBEL PRIZE
IN CHEMISTRY 2023



Moungi G.
Bawendi

Louis E.
Brus

Alexei I.
Ekimov

"for the discovery and synthesis of quantum dots"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

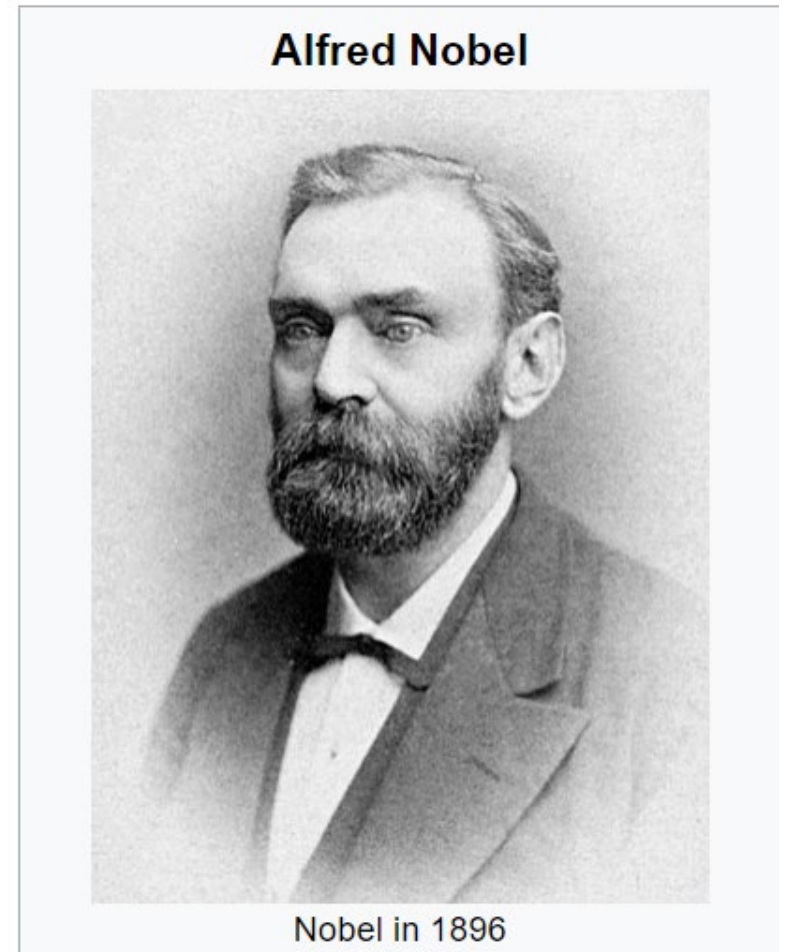
What is the Nobel Prize?

Nobel was a chemist, engineer, philanthropist and inventor of dynamite

The Nobel Prize is awarded to those “who conferred the greatest benefit to humankind”

The synthetic element Nobelium was named in the honor of Alfred Nobel

The Nobel Prize represents the highest scientific distinction



Nobel Prize

- The Nobel Prize is awarded to professionals from six areas
- Physics
- Chemistry
- Physiology & Medicine
- Economy
- Peace
- Literature



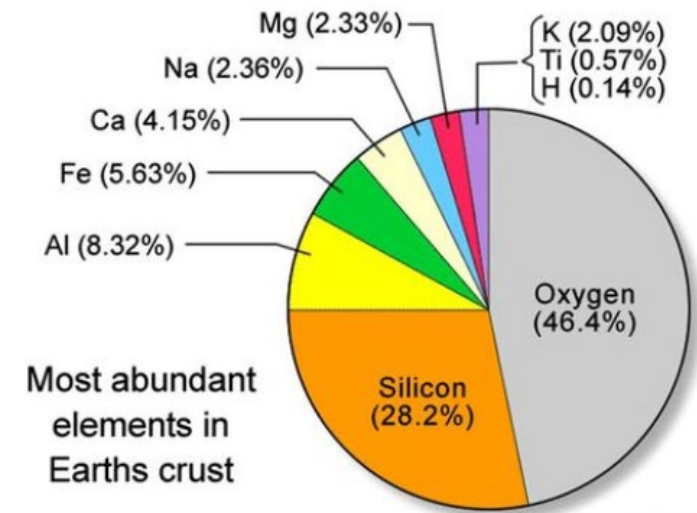
Chemistry Around Us

Periodic Table of the Elements

1 H Hydrogen 1.01																	2 He Helium 4.00																														
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18																														
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95																														
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 83.80																														
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29																														
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium [208.98]	85 At Astatine 209.98	86 Rn Radon 222.02																														
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]																														
<table border="1"> <tr> <td>57 La Lanthanum 138.91</td> <td>58 Ce Cerium 140.12</td> <td>59 Pr Praseodymium 140.91</td> <td>60 Nd Neodymium 144.24</td> <td>61 Pm Promethium 144.91</td> <td>62 Sm Samarium 150.36</td> <td>63 Eu Europium 151.96</td> <td>64 Gd Gadolinium 157.25</td> <td>65 Tb Terbium 158.93</td> <td>66 Dy Dysprosium 162.50</td> <td>67 Ho Holmium 164.93</td> <td>68 Er Erbium 167.26</td> <td>69 Tm Thulium 168.93</td> <td>70 Yb Ytterbium 173.06</td> <td>71 Lu Lutetium 174.97</td> </tr> <tr> <td>89 Ac Actinium 227.03</td> <td>90 Th Thorium 232.04</td> <td>91 Pa Protactinium 231.04</td> <td>92 U Uranium 238.03</td> <td>93 Np Neptunium 237.05</td> <td>94 Pu Plutonium 244.06</td> <td>95 Am Americium 243.06</td> <td>96 Cm Curium 247.07</td> <td>97 Bk Berkelium 247.07</td> <td>98 Cf Californium 251.08</td> <td>99 Es Einsteinium [254]</td> <td>100 Fm Fermium 257.10</td> <td>101 Md Mendelevium 258.10</td> <td>102 No Nobelium 259.10</td> <td>103 Lr Lawrencium [262]</td> </tr> </table>																		57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.06	71 Lu Lutetium 174.97	89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [254]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]
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Alkali Metal		Alkaline Earth		Transition Metal								Basic Metal		Metalloid		Nonmetal		Halogen		Noble Gas		Lanthanide		Actinide																							

EARTH'S CRUST

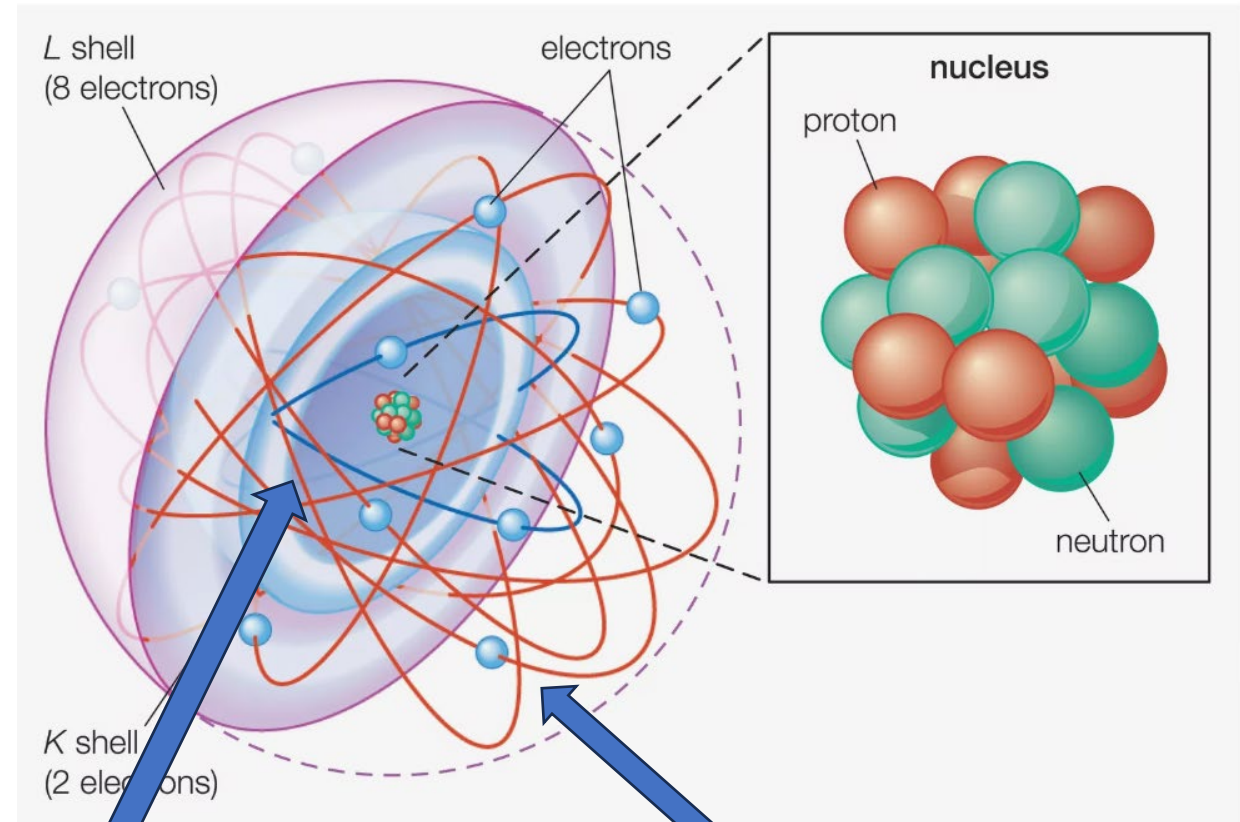
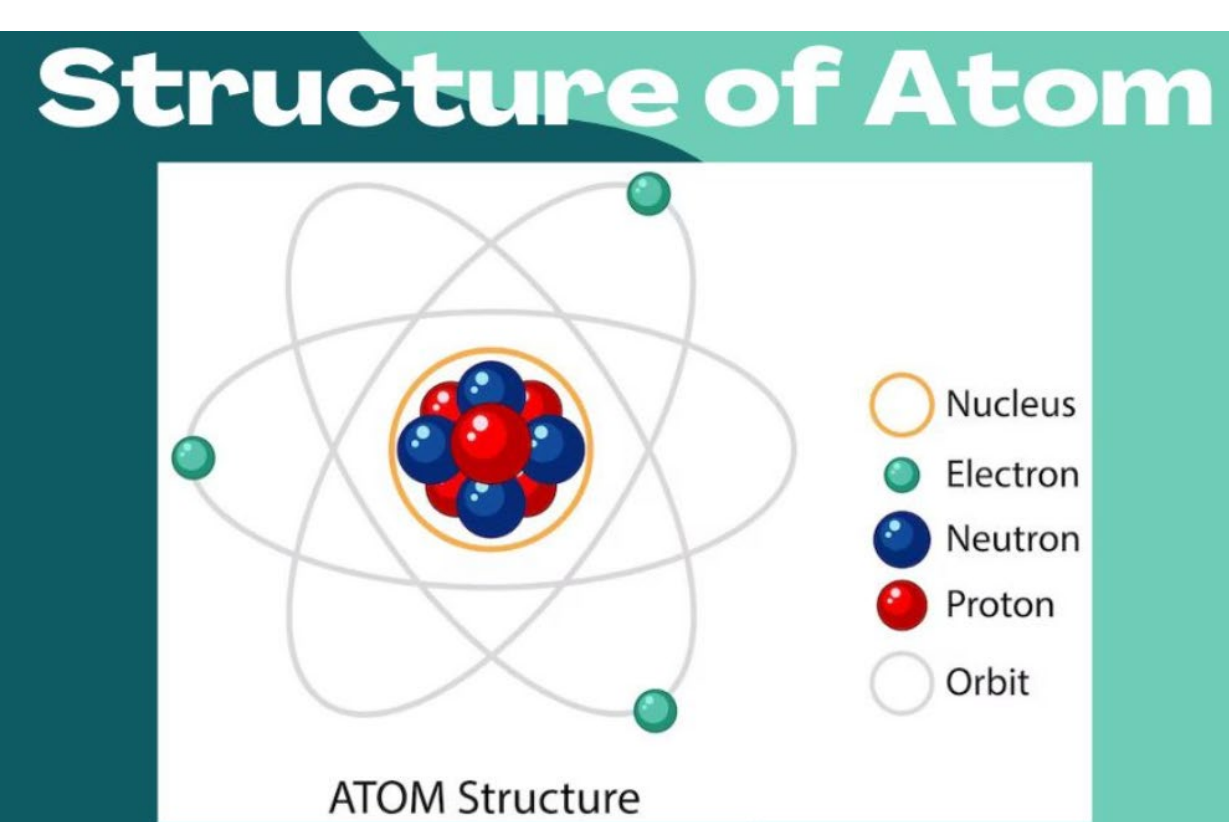
- Percentage of Elements in Earth's crust: **Oxygen (46%), Silicon (28%), Al, Fe, Mg, Ca, etc.**
- Aluminum is extracted from bauxite



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Each Chemical Element Has Its Own Electronic Structure Conferring Unique Chemical Properties



Core electrons

Valence shell electrons

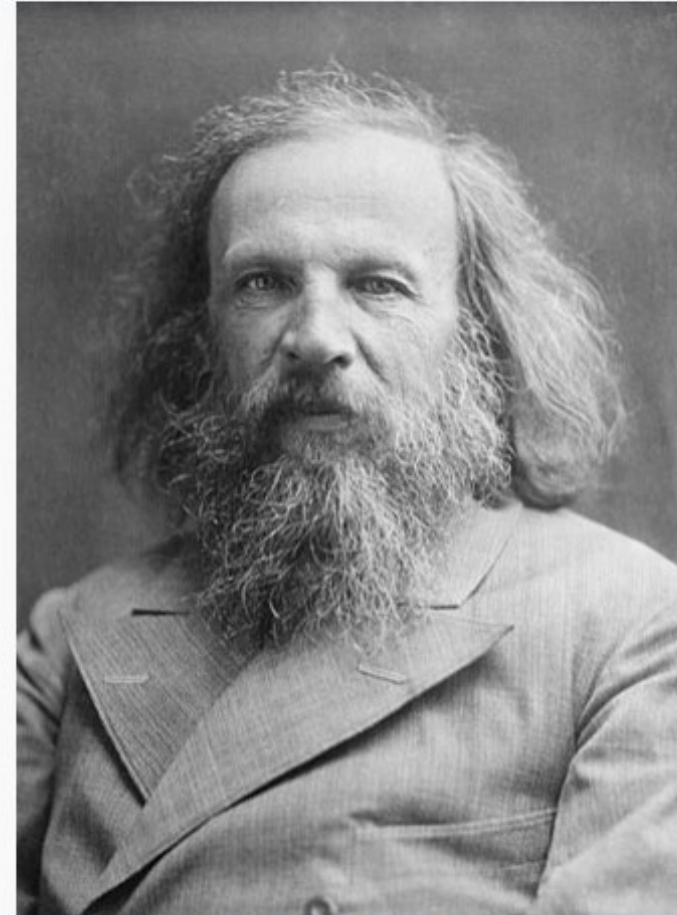
Mendeleev's Periodic Law

I saw in a dream a table where all elements fell into place as required. Awakening, I immediately wrote it down on a piece of paper, only in one place did a correction later seem necessary.
—*Mendeleev, as quoted by Inostrantzev*

Law of the Periodic Table of Elements in summary:

The elements, if arranged according to their atomic weight, exhibit an apparent periodicity of properties.

Dmitri Mendeleev



Dmitri Mendeleev before 1907

Chemistry Nowadays and Its Applications to the Real World

Impact on U.S. Economy

The U.S. chemical industry is responsible for more than a quarter of the U.S. GDP, supports the production of almost all commercial and household goods, and is essential to economic growth.

The U.S. chemical industry is a **\$768 billion** enterprise that supports more than

25% of total U.S. GDP



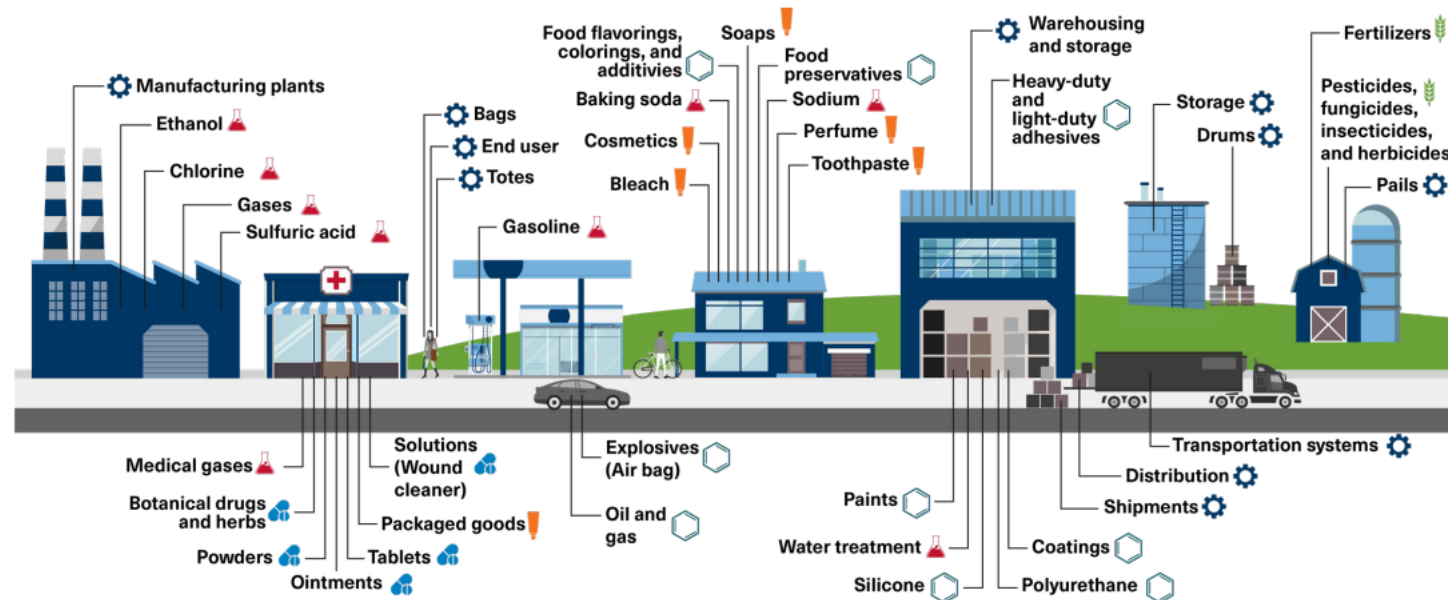
of U.S. goods in 2016 were manufactured using Chemical Sector products



The U.S. chemical industry is one of the world's **largest chemical producers**

15%

of the world's chemicals come from the U.S.



11,114

U.S. chemical manufacturing facilities (2016)

States with the greatest concentration of facilities: California, Texas, Ohio, Illinois, and Pennsylvania

★ Louisiana and Texas account for about 70% of all primary petrochemicals produced in the U.S.

Progress Happens in a Gradual Manner

Discovery → Understanding → Optimization → Output



What is a Semiconductor?

- Semiconductors are materials whose electrical and thermal properties lie in between those of an insulator and a metal.
- Resistance of semiconductors decreases with increasing temperature, thus accounting for them acquiring relevant properties.

The first point-contact transistor was developed in 1947 and based on semiconductors.



Karl Ferdinand Braun developed the [crystal detector](#), the first [semiconductor device](#), in 1874.

Examples of Semiconductors

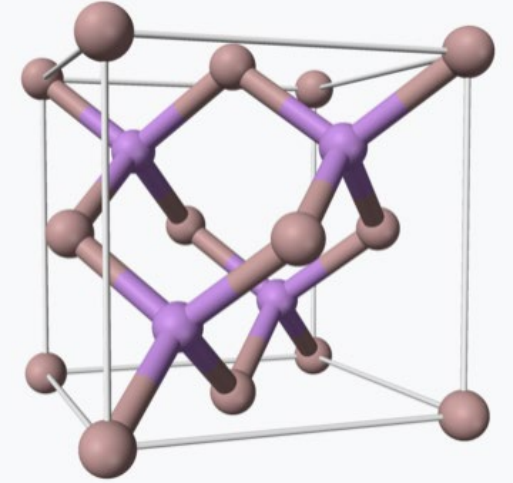


silicon crystals



Germanium

Gallium arsenide

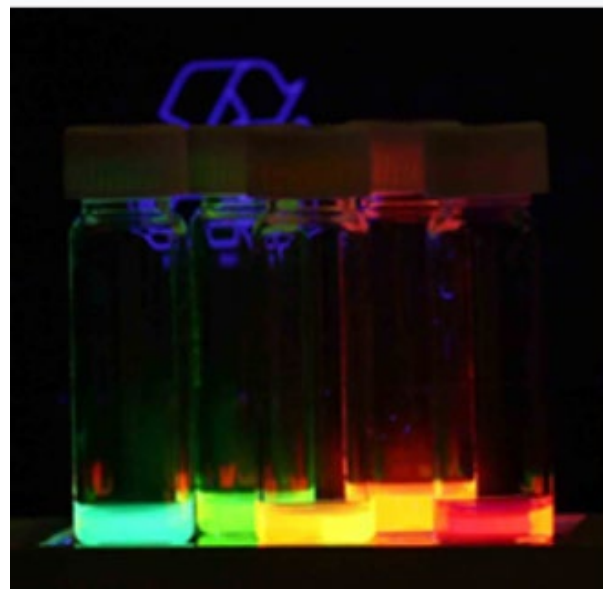
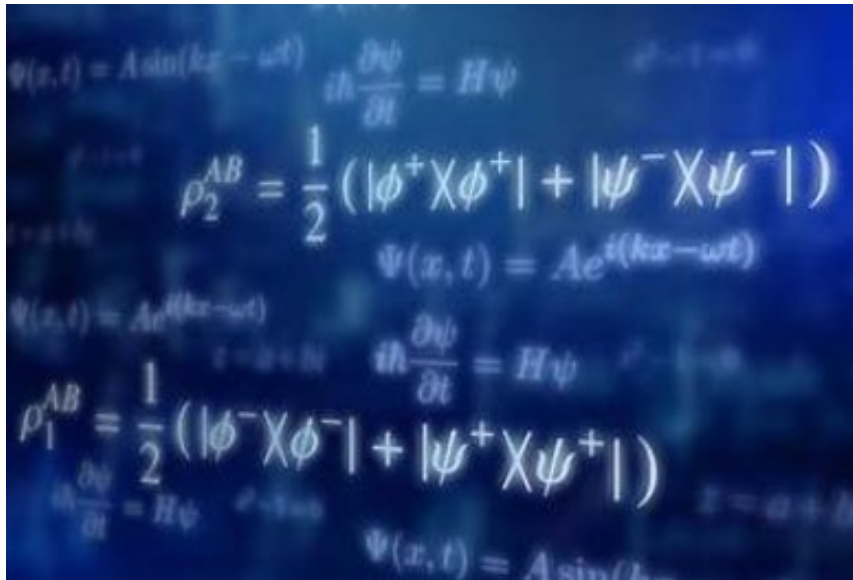


GaAs wafer of (100) orientation

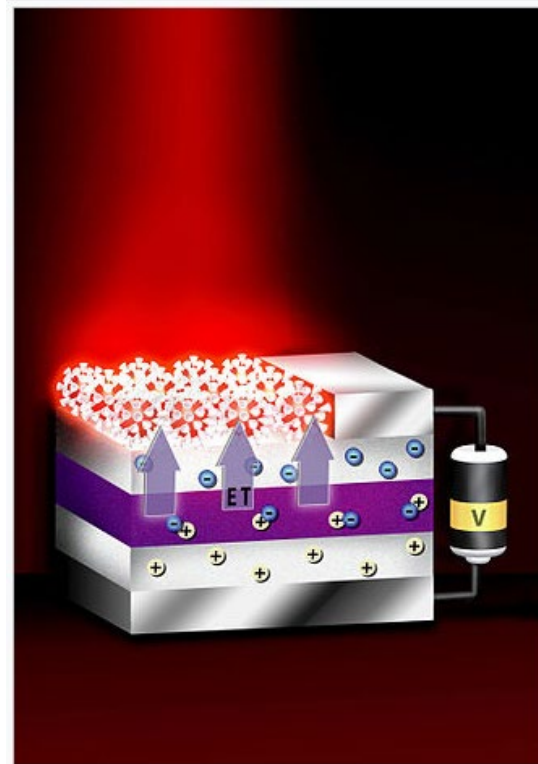
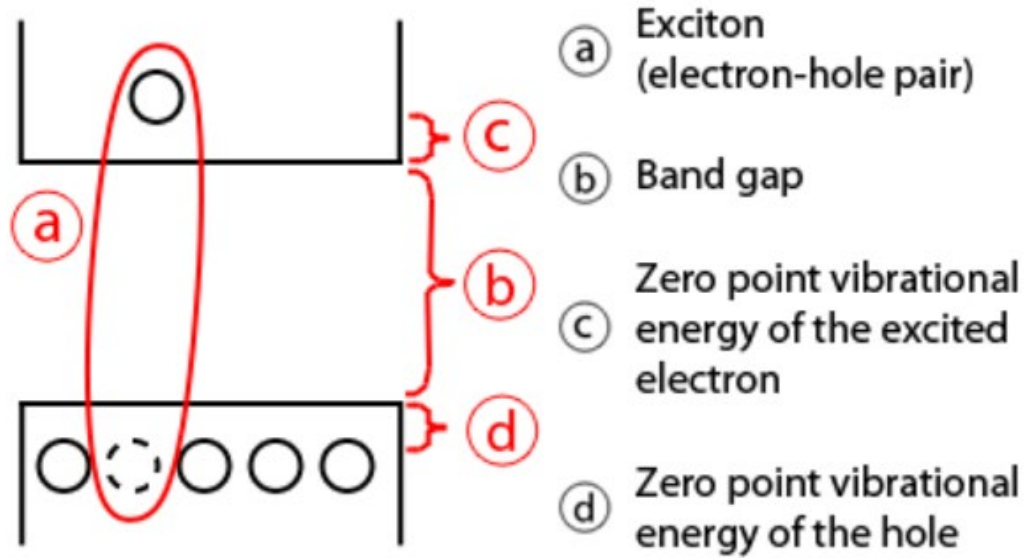
Can anyone spot some periodic trends?

What Are Quantum Dots?

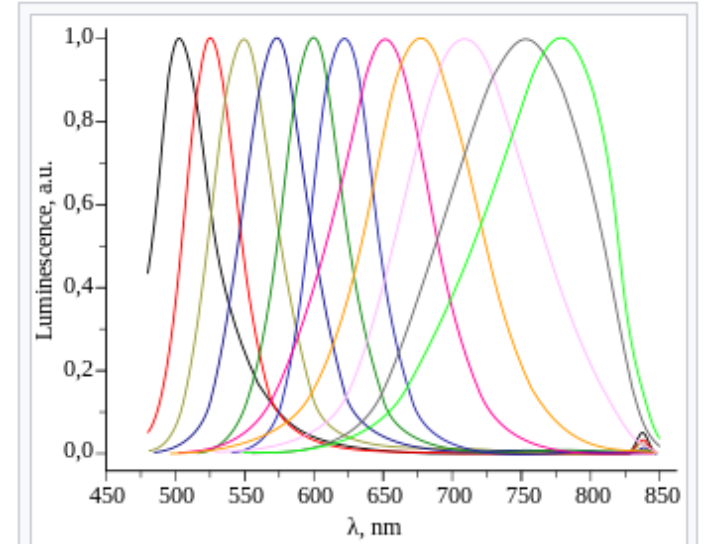
- Quantum dots are semiconductor particles exhibiting a difference in electronic and optical properties compared to the bulk materials.
- The origin of the unusual properties of quantum dots is quantum mechanical.



More about Quantum Dots

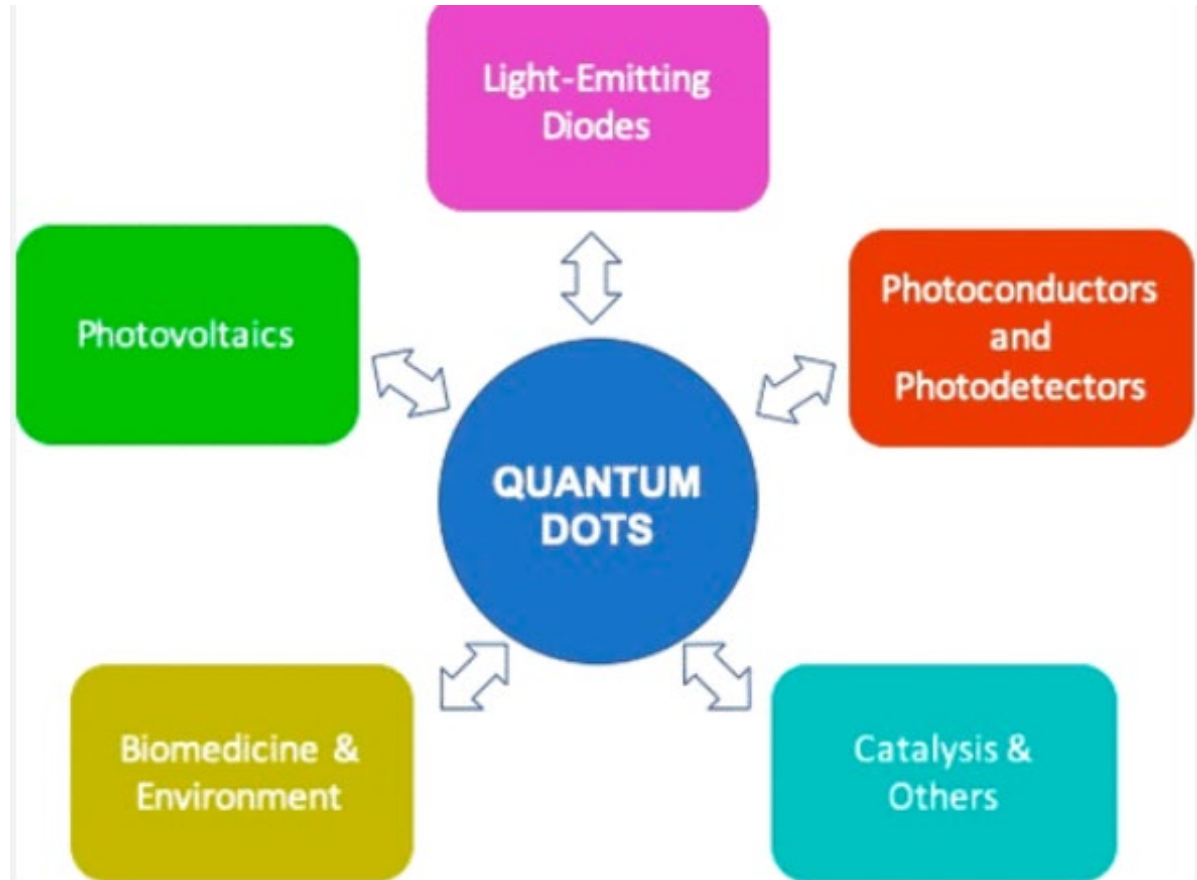


A device that produces [visible light](#), through energy transfer from thin layers of quantum wells to crystals above the layers.^[67]



Fluorescence spectra of CdTe quantum dots of various sizes. Different sized quantum dots emit different color light due to quantum confinement.

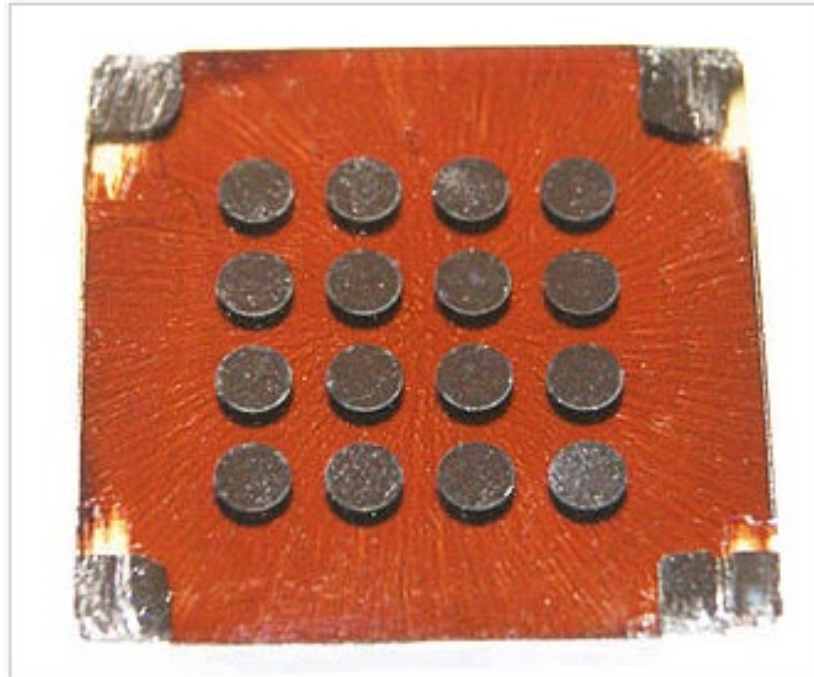
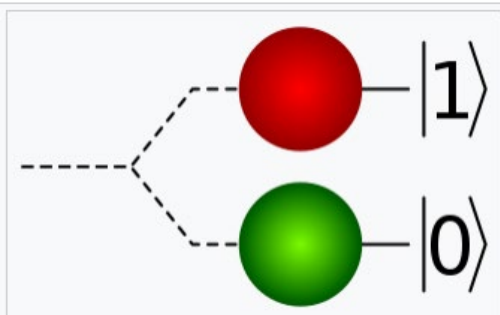
Applications



PbS, PbSe,
CdSe, CdS,
CdTe, InAs,
InP

Applications of Quantum Dots

- Single-electron transistors
- Qubits in quantum information processing
- Diode lasers
- Amplifiers
- Biosensors
- Transdermal patches
- Photovoltaic devices
- Cellular imaging



A 21mg dose [Nicoderm CQ patch](#) applied to the left arm



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