



Zinc and its chemistry

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OVERVIEW

1. General information
2. Chemistry
3. Compounds
4. Applications

General information

1. General information

- **Discovered by Andreas Marggraf, 1746, German**
- **Zinke = Prong, Tooth**
- **Properties: Brittleish, silver-gray, relatively low m.p.**
- **Uses: Galvanization (50%), batteries, dietary supplements**
- **24th most abundant in earth's crust**
- **Annual production: ~14 million tonnes (recycling ~30%)** [1]

Chemistry of zinc

2. Chemistry of zinc

Periodic Table of the Elements

Atomic Number → 1
Symbol ← H
Name → Hydrogen
Atomic Weight ← 1.008
Electrons per shell → 1

State of matter (color of name)
GAS LIQUID SOLID UNKNOWN

Subcategory in the metal-metalloid-nonmetal trend (color of background)
Alkali metals, Alkaline earth metals, Transition metals, Lanthanides, Actinides, Post-transition metals, Metalloids, Reactive nonmetals, Noble gases, Unknown chemical properties

1 IA 1 H Hydrogen 1.008	2 IIA 4 Be Beryllium 9.0122											13 IIIA 5 B Boron 10.81	14 IVA 6 C Carbon 12.011	15 VA 7 N Nitrogen 14.007	16 VIA 8 O Oxygen 15.999	17 VIIA 9 F Fluorine 18.998	18 VIIIA 2 He Helium 4.0026																		
3 Li Lithium 6.94	4 Be Beryllium 9.0122	11 Na Sodium 22.98976928	12 Mg Magnesium 24.305	21 Sc Scandium 44.955908	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938044	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798																
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90637	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	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 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29	55 Cs Cesium 132.90545196	56 Ba Barium 137.327	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89-103 Actinides	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (267)	111 Rg Roentgenium (268)	112 Cn Copernicium (284)	113 Nh Nihonium (285)	114 Fl Flerovium (289)	115 Mc Moscovium (290)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)																		
57 La Lanthanum 138.905	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.93002	70 Yb Ytterbium 173.05468	71 Lu Lutetium 174.96706	89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)						

30

65.38

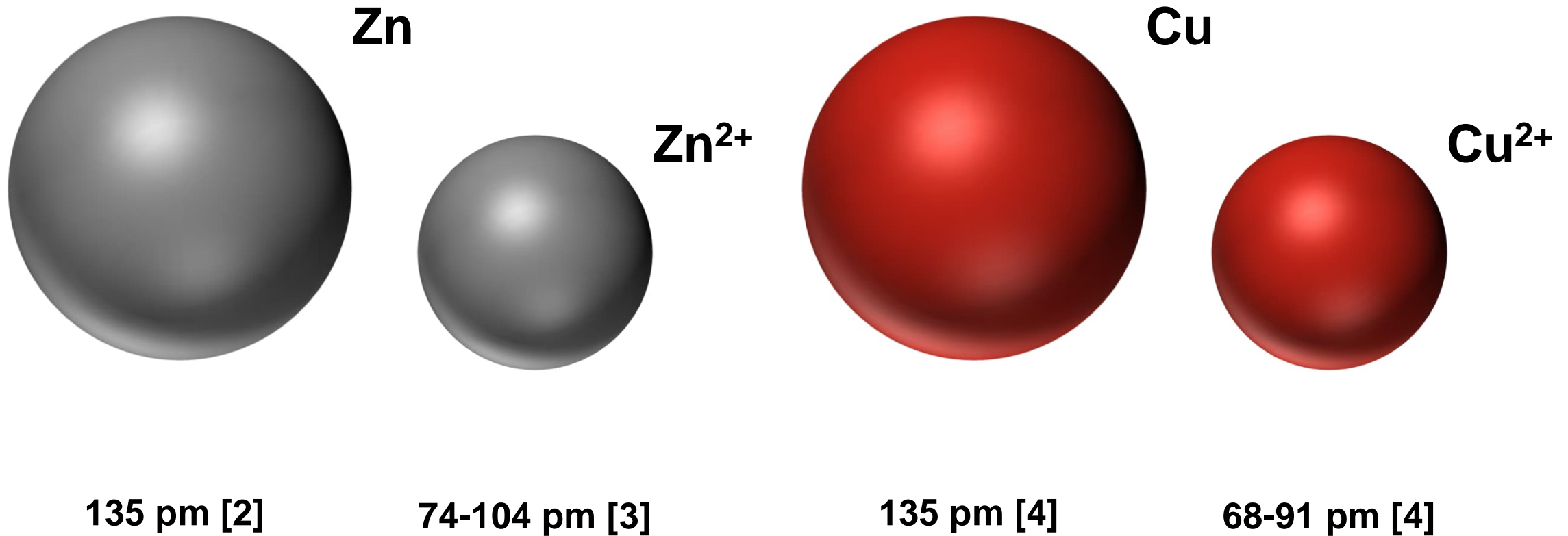
Zn

Zinc

[Ar] 3d¹⁰ 4s²

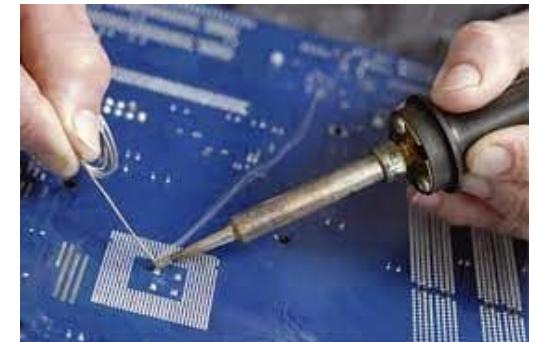
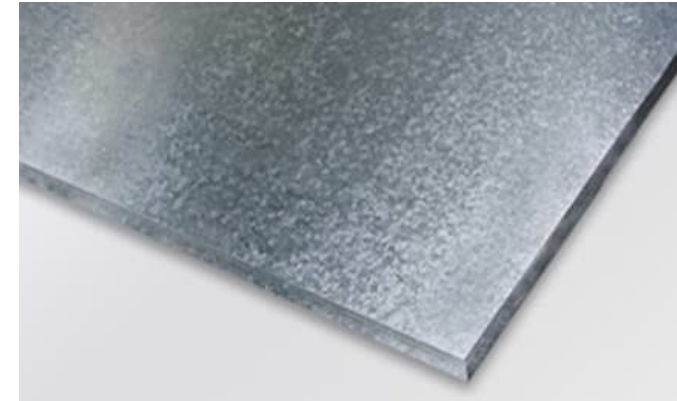
Transition Metals

2. Chemistry of zinc



2. Chemistry of zinc

- Reaction with air \rightarrow ZnO
- Reaction even with weak acids \rightarrow H₂
- Reaction with alkalies \rightarrow zincates
[Zn(OH)₄]²⁻
- Alloying with similarly sized metal atoms



Compounds

3. Compounds and their properties and common applications

Zinc Oxide, ZnO

- High melting point of 1975 C
- One of the most common zinc compounds used in industry. Common uses are use in rubber, photocopy paper and paints.

Zinc carbonate, ZnCO₃

- Colourless crystal or white crystalline powder. Evolves carbon dioxide at 300 C
- Used as fireproofing filler for rubber and plastic compositions exposed to high temperatures

Zinc chloride, ZnCl₂

- Melting point of 275 C and boiling point of 756 C
- High variety of applications ranging from fluxes to use in medicine.

[5]

3. Compounds and their properties and common applications

Zinc acetate, $(\text{CH}_3\text{COO})_2\text{Zn}$

- Decomposes at 200 C
- Common uses are in wood preserving,

Zinc fluoride, ZnF_2

- Exists as colourless crystals or white crystalline mass. Melting point 872 C and boiling point 1502 C
- Used in fluorination of organic compounds and manufacturing of phosphors for fluorescent lights. Also used in medicine. **[5]**

3. Compounds and their properties and common applications

Other common zinc compounds:

- Zinc chromate, ZnCrO_4
- Zinc cyanide, $\text{Zn}(\text{CN})_2$
- Zinc phosphide, Zn_3P_2
- Zinc sulfate, ZnSO_4
- Zinc sulfide, ZnS

[5]

Applications

ZnO in thin film technology

4. ZnO in thin film technology

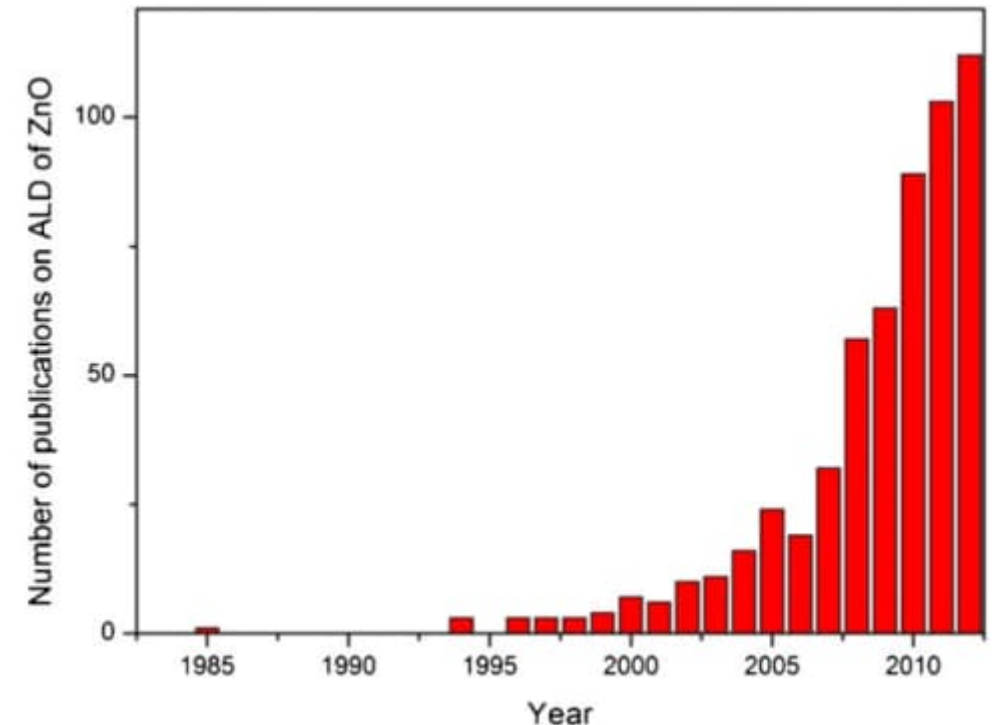
Usefull properties of ZnO for use in thin films

- Band gap of 3.37 eV
- High transparency to visible light
- ZnO is easely synthesized in thin film form using different techniques
- Low cost

Applications for ALD ZnO thin films

- Solar cells
- Thin-film transistors
- Gas sensors

[6]



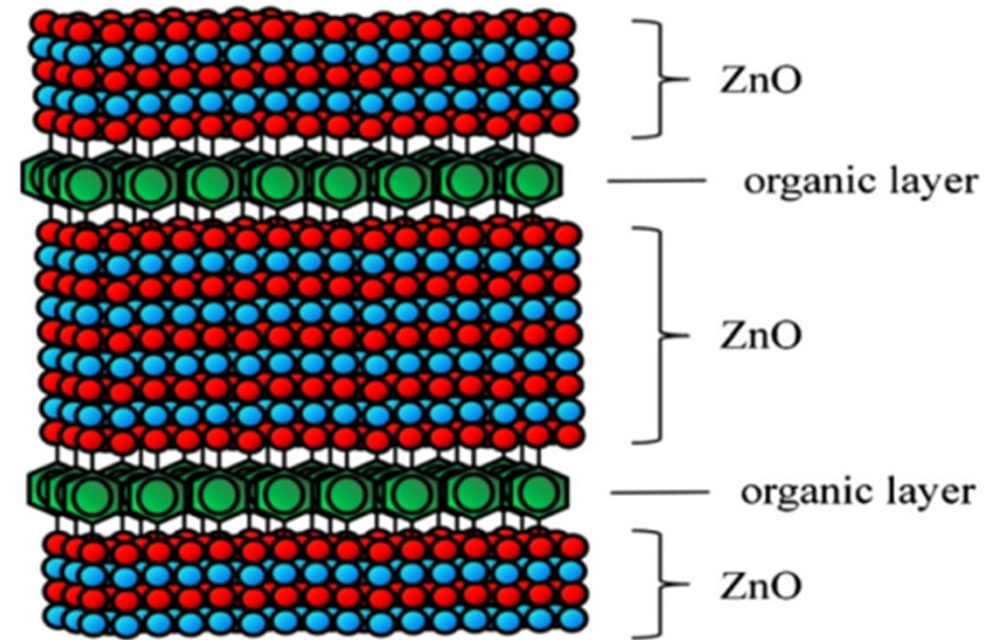
4. ZnO in thin film technology

Inorganic–organic hybrid thin films

- Using organic compounds in inorganic-organic superlattice thin films can be used to modify the properties of thin films
- Properties that can be modified include:
 - *Heat conductivity*
 - *Mechanical properties*

Potential applications

- Wearable electronics
- Implantable medical devices



[7]

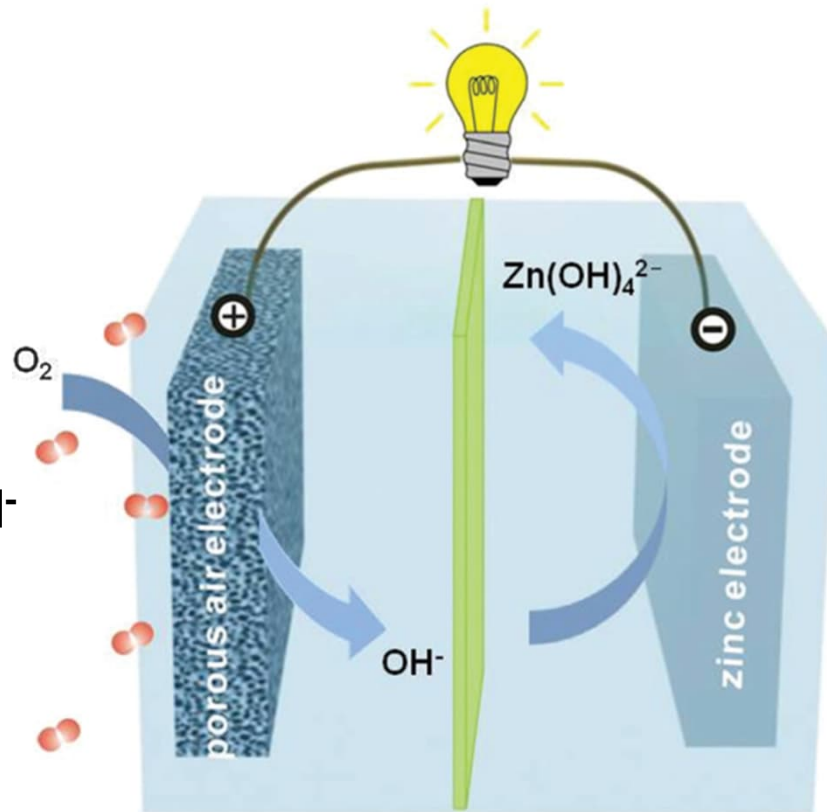
Rechargeable zinc-air batteries

4. Rechargeable zinc-air batteries - Motivation

- **High theoretical energy density**
 - Zinc-air 1086 Wh/kg [8], Li-ion 100-265 Wh/kg now [9]
- **Low price**
 - Zinc-air <10 \$/kWh [8], Li-ion 100-150 \$/kWh
- **Material availability**

4. Rechargeable zinc-air batteries – Principal of operation

Porous positive air electrode with metal catalyst



Negative zinc electrode

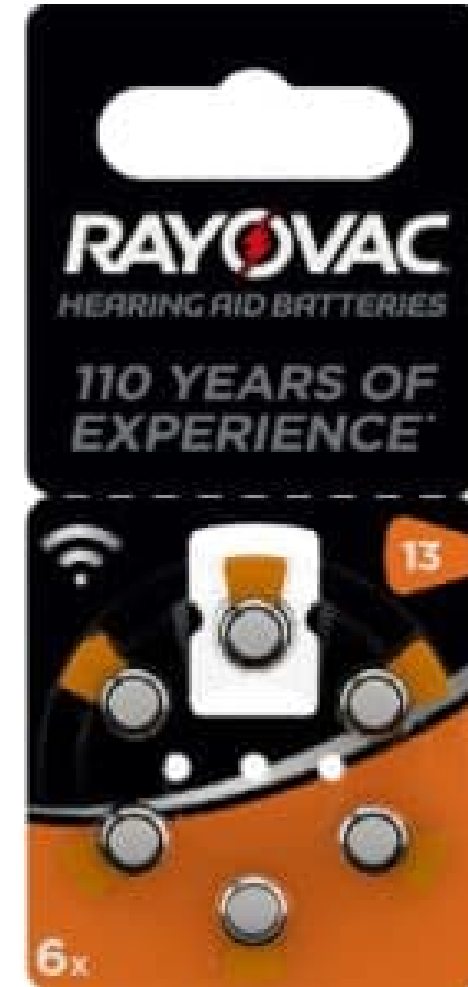


Selective separator for passing OH^-

[8]

4. Rechargeable zinc-air batteries – Areas of improvement

- **Slow kinetics at air electrode**
- **Bifunctional air electrode**
 - OER and ORR
- **Dendrite growth during cycling**
- **Water loss**



[8]

Galvanization

4. Galvanization - Overview

- **Protection**
- **Easy**
- **Doesn't require much equipment**
- **Cost efficient**

4. Galvanization – How is it applied?

- Hot-dip for thicker coating
- Electroplating for thinner

[9]



4. Galvanization – Hot-dip

- **3-step process**
 - Surface treatment – Alkaline/acid, rinse, HCl
 - Galvanization – Metallurgical reaction
 - Post-treatment – Quenching/cooling
(Optional)

[10,11]



4. Galvanization – Electroplating

- **4-step process**
 - Pre-treatment – Alkaline bath & heat
 - Activation/Pickling - removal of oxides with acids
 - Electroplating – controlled electrolysis
 - Post-treatment – Rinse & Dry [12]

4. Galvanization – How does it work?

- **Physical - barrier prevents contact**
- **Chemical – Sacrificial role (Iron/Steel)**
- **Weather improves it – creates a passive layer**

[9,11]

4. Galvanization – Why Zinc over others?

- **Relatively abundant raw material**
- **Low melting point low, energy costs relatively low**
- **"Appropriately" reactive**
- **Easy to apply**

CONCLUSION



Questions?