

# Cobalt (Co)

—  
Element, chemistry,  
compounds, and  
applications

Yutong Song, Umaid Lone  
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Aalto-yliopisto  
Aalto-universitetet  
Aalto University

# Element

# Introduction

## ORIGIN OF NAME:

- German term *kobold*, meaning ‘goblin’, or ‘evil spirit’.
- Used by miners that was really difficult to mine and harmful to the miners’ health.<sup>[2]</sup>

## HISTORY OF DISCOVERY:

- Over four thousand years ago, Cobalt has been used for blue dyes in pottery, glass, and glazes.
- First isolated (1735) by Swedish chemist Georg Brandt.
- Brandt finally determined (1742) that the blue colour of those ores was due to the presence of cobalt<sup>[3]</sup>.

Ancient Egyptian  
cobalt blue  
glass beads<sup>[4]</sup>



Ancient Roman  
cobalt blue  
glass bottle<sup>[5]</sup>

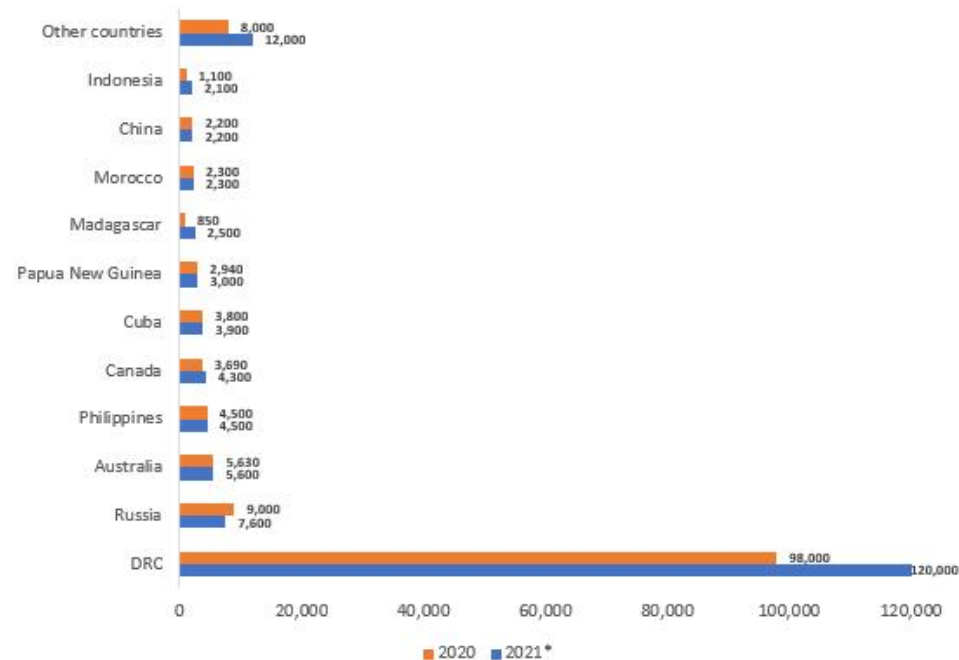


Early Chinese  
blue and white  
porcelain<sup>[1]</sup>

# Occurrence & Production

- The abundance of cobalt in earth's crust is around 25 ppm (only 0.001%) by weight<sup>[6]</sup>.
- The main ores of cobalt are cobaltite (CoAsS), erythrite (hydrated arsenate of cobalt), glaucodot (Co,Fe)AsS, and skutterudite (Co,Ni)As<sub>3</sub>.
- Generally produced as a by-product of nickel and copper mining<sup>[7]</sup>.
- Congo (Kinshasa) has been a dominant world producer since 1920<sup>[8]</sup>.

Mine cobalt production, tonnes<sup>[9]</sup>.  
Source: USGS. Preliminary data for 2021.



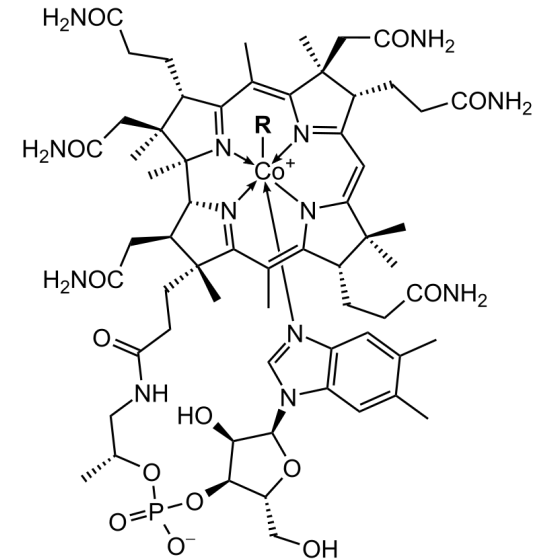
# Biological role & Health issues

## BIOLOGICAL ROLE:

- Cobalt is a component of cobalamin, also known as vitamin B12, which supports the production of red blood cells<sup>[10]</sup>.
- An essential trace element for humans and animals.
- Cobalt deficiency symptoms resemble anemic disorders<sup>[11]</sup>.

## HEALTH ISSUES:

- Cobalt poisoning can occur when you are exposed to large amounts of it.
- Toxic to the heart muscle<sup>[12]</sup>.
- It causes respiratory problems when inhaled and skin problems when touched<sup>[1]</sup>.



R = 5'-deoxyadenosyl, CH<sub>3</sub>, OH, CN

**Molecular structure of  
vitamin B12<sup>[11]</sup>**

# Chemistry

# Cobalt in Periodic Table<sup>[13]</sup>

The Periodic Table of Elements



- Group: 9
- Period: 4
- Block: d

	1											18						
1	1H Hydrogen											2He Helium						
2	3Li Lithium	4Be Beryllium											5B Boron	6C Carbon	7N Nitrogen	8O Oxygen	9F Fluorine	10Ne Neon
3	11Na Sodium	12Mg Magnesium	3	4	5	6	7	8	9	10	11	12	13Al Aluminum	14Si Silicon	15P Phosphorus	16S Sulfur	17Cl Chlorine	18Ar Argon
4	19K Potassium	20Ca Calcium	21Sc Scandium	22Ti Titanium	23V Vanadium	24Cr Chromium	25Mn Manganese	26Fe Iron	27Co Cobalt	28Ni Nickel	29Cu Copper	30Zn Zinc	31Ga Gallium	32Ge Germanium	33As Arsenic	34Se Selenium	35Br Bromine	36Kr Krypton
5	37Rb Rubidium	38Sr Strontium	39Y Yttrium	40Zr Zirconium	41Nb Niobium	42Mo Molybdenum	43Tc Technetium	44Ru Ruthenium	45Rh Rhodium	46Pd Palladium	47Ag Silver	48Cd Cadmium	49In Indium	50Sn Tin	51Sb Antimony	52Te Tellurium	53I Iodine	54Xe Xenon
6	55Cs Cesium	56Ba Barium	*	72Hf Hafnium	73Ta Tantalum	74W Tungsten	75Re Rhenium	76Os Osmium	77Ir Iridium	78Pt Platinum	79Au Gold	80Hg Mercury	81Tl Thallium	82Pb Lead	83Bi Bismuth	84Po Polonium	85At Astatine	86Rn Radon
7	87Fr Francium	88Ra Radium	**	104Rf Rutherfordium	105Db Dubnium	106Sg Seaborgium	107Bh Bohrium	108Hs Hassium	109Mt Meitnerium	110Ds Darmstadtium	111Rg Roentgenium	112Cn Copernicium	113Nh Nihonium	114Fl Flerovium	115Mc Moscovium	116Lv Livermorium	117Ts Tennessine	118Og Oganesson

Lanthanide Series*	57La Lanthanum	58Ce Cerium	59Pr Praseodymium	60Nd Neodymium	61Pm Promethium	62Sm Samarium	63Eu Europium	64Gd Gadolinium	65Tb Terbium	66Dy Dysprosium	67Ho Holmium	68Er Erbium	69Tm Thulium	70Yb Ytterbium	71Lu Lutetium
Actinide Series**	89Ac Actinium	90Th Thorium	91Pa Protactinium	92U Uranium	93Np Neptunium	94Pu Plutonium	95Am Americium	96Cm Curium	97Bk Berkelium	98Cf Californium	99Es Einsteinium	100Fm Fermium	101Md Mendelevium	102No Nobelium	103Lr Lawrencium



# Properties<sup>[6, 7]</sup>

[15]



**Cobalt element**

Atomic number: 27  
Symbol: Co  
Name: Cobalt  
Electron configuration: [Ar] 3d<sup>7</sup> 4s<sup>2</sup>

Atomic mass (u): 58.933  
Atomic radius (van der Waals): 192 pm  
Electrons arrangement: [2, 8, 15, 2]

Ionization energy: 7.881 eV  
Electronegativity (Pauling): 1.88  
Valency: 3, 2  
Crystal structure: HCP

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- Density(293 K): 8.90g/cm<sup>3</sup>
- Main isotope: <sup>59</sup>Co
- atomic radius: 125 pm
- ionic radius (2+ ion): 83.8 pm
- ionic radius (3+ ion): 71.8 pm<sup>[14]</sup>

- Bluish-white, lustrous, hard, brittle solid.
- Ferromagnetic: Cobalt stays magnetic to the highest temperature of all the magnetic elements (it has a Curie point of 1121°C).



# Reactivity

## REACTIONS OF COBALT WITH AIR<sup>[16]</sup>:

- Cobalt does not react readily with air at room temperature.
- $3 \text{Co(s)} + 4 \text{O}_2(\text{g}) \xrightarrow{\Delta} 2 \text{Co}_3\text{O}_4(\text{s})$
- $2 \text{Co(s)} + \text{O}_2(\text{g}) \xrightarrow{900^\circ\text{C}} 2 \text{CoO(s)}$
- It does not react with H<sub>2</sub> or N<sub>2</sub> even when heated<sup>[1]</sup>.

## REACTIONS OF COBALT WITH ACIDS:

- $\text{Co(s)} + \text{H}^+(\text{aq})$  (dilute H<sub>2</sub>SO<sub>4</sub>, HCl)  $\longrightarrow$  Co<sup>2+</sup>(aq) + H<sub>2</sub>(g)
- $3\text{Co(s)} + 8\text{HNO}_3(\text{aq}) \longrightarrow 3\text{Co}(\text{NO}_3)_2 + 2\text{NO}(\text{g}) + 4\text{H}_2\text{O}(\text{l})$ <sup>[17]</sup>
- Concentrated nitric acid reacts quickly with cobalt at room temperature, but passivates the cobalt surface at -10°C<sup>[18]</sup>.
- **Cobalt does not react with water that is at room temperature**<sup>[19]</sup>.

# Reactivity

## REACTIONS OF COBALT WITH HALOGENS<sup>[16, 20]</sup>:

- $\text{Co(s)} + \text{F}_2(\text{g}) \xrightarrow{520\text{K}} \text{CoF}_3(\text{s})$  (brown)
- $\text{Co(s)} + \text{Cl}_2(\text{g}) \xrightarrow{\Delta} \text{CoCl}_2(\text{s})$  (blue)
- $\text{Co(s)} + \text{Br}_2(\text{g}) \xrightarrow{\Delta} \text{CoBr}_2(\text{s})$  (green)
- $\text{Co(s)} + \text{I}_2(\text{g}) \xrightarrow{\Delta} \text{CoI}_2(\text{s})$  (blue-black)

## REACTIONS OF COBALT WITH NON-METALS<sup>[21]</sup>:

- It reacts with boron, carbon, phosphorus, arsenic and sulfur when heated<sup>[1]</sup>.
- $\text{Co(s)} + \text{S(s)} \longrightarrow \text{CoS(s)}$ <sup>[18]</sup>
- $\text{Co(s)} + \text{P(s)} \longrightarrow \text{Co}_2\text{P(s)}$ <sup>[22]</sup>

# Compounds

## Cobalt Compounds

**In its compounds cobalt nearly always exhibits a +2 or +3 oxidation state, although states of +4, +1, 0, and -1 are known [3].**

- ❖ The compounds in which cobalt exhibits the +2 oxidation state ( $\text{Co}^{2+}$ , the ion being stable in water) are called cobaltous [23].
- ❖ Compounds in which cobalt exhibits the +3 oxidation state ( $\text{Co}^{3+}$ ) are called cobaltic [23].
- ❖ Both  $\text{Co}^{2+}$  and  $\text{Co}^{3+}$  form numerous coordination compounds, or complexes [23].

## Oxides [24]

- Cobalt oxide:  $\text{CoO}$
  - Dicobalt trioxide:  $\text{Co}_2\text{O}_3$
  - Tricobalt tetraoxide:  $\text{Co}_3\text{O}_4$
- 
- Tricobalt tetraoxide  $\text{Co}_3\text{O}_4$  contains cobalt in both +2 and +3 oxidation states.
  - Constitutes up to 40 percent of the commercial cobalt oxide
  - Used in the manufacture of **ceramics, glass, and enamel** and in the preparation of **catalysts and cobalt metal powder**<sup>[1]</sup>

## Complexes [24]

- Tricobalt diphosphate octahydrate:  $\text{Co}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$
  - Cobalt nitrate hexahydrate:  $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$
  - Hexaaquacobalt dichloride:  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$
  - Tetraaquacobalt difluoride:  $\text{CoF}_2 \cdot 4\text{H}_2\text{O}$
  - Cobalt dibromide hexahydrate:  $\text{CoBr}_2 \cdot 6\text{H}_2\text{O}$
  - Cobalt sulphate heptahydrate:  $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$
- 
- One of the **more important salts** of cobalt is the **sulfate  $\text{CoSO}_4$** , which is employed in electroplating, in preparing drying agents, and for pasture top-dressing in agriculture<sup>[3]</sup>.
  - Cobaltous chloride ( $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$  in commercial form), a **pink** solid that changes to **blue** as it dehydrates, is utilized in catalyst preparation and as an indicator of humidity <sup>[3]</sup>.
  - Cobaltous phosphate,  $\text{Co}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ , is used in painting porcelain and colouring glass <sup>[3]</sup>.



- Fluorides

- Cobalt difluoride:  $\text{CoF}_2$
- Cobalt trifluoride:  $\text{CoF}_3$
- Cobalt tetrafluoride:  $\text{CoF}_4$

- Chlorides

- Cobalt dichloride:  $\text{CoCl}_2$
- Cobalt trichloride:  $\text{CoCl}_3$
- Cobalt dichloride dihydrate:  $\text{CoCl}_2 \cdot 2\text{H}_2\text{O}$

- Bromides

- Cobalt dibromide:  $\text{CoBr}_2$

- Iodides

- Cobalt diiodide:  $\text{CoI}_2$

- Carbonyls

- Dicobalt octacarbonyl:  $\text{Co}_2(\text{CO})_8$
- Tetracobalt dodecacarbonyl:  $\text{Co}_4(\text{CO})_{12}$
- Hexacobalt hexadecacarbonyl:  $\text{Co}_6(\text{CO})_{16}$

- Sulfides

- Cobalt sulphide:  $\text{CoS}$
- Cobalt persulphide:  $\text{CoS}_2$
- Dicobalt trisulphide:  $\text{Co}_2\text{S}_3$

- Selenides

- Cobalt selenide:  $\text{CoSe}$

- Tellurides

- Cobalt telluride:  $\text{CoTe}$

# Applications

# Cobalt applications

Cobalt has been used in many industrial, commercial, and military applications. Below are some of its common applications

## Superalloys<sup>[25]</sup>

- Cobalt-based superalloys form high-temperature resistant parts for gas turbine aircraft engines, space vehicles, rocket motors, and other aerospace applications.
- Cobalt is used widely as one of the metals needed to create **hard permanent magnets** such as the **aluminium-nickel-cobalt (Al-Ni-Co)** alloy series
- **Alnico magnets** are used in motors, hard disk drives, and sensors. Magnetic resonance imaging is an example of an application for these magnetic alloys.

## Electronics<sup>[26]</sup>

Cobalt oxide, hydroxide, and metals are used in many electrochemical devices that convert chemical energy to electrical energy

### Rechargeable batteries

- Portable devices such as mobile phones, laptops, and other consumer electronic devices right up to electric vehicles, all utilise rechargeable batteries.
- Cobalt acts as a raw material in the cathode technology which is essential for recharging batteries
- Lithium cobalt oxide was the first commercially successful cathode for the lithium-ion battery
- Layered  $\text{LiCoO}_2$  exhibits several features necessary for a good cathode. The  $\text{Li}^+$  and  $\text{Co}^{3+}$  ions order well in alternate layers in  $\text{LiCoO}_2$  ensuring a **good structural stability**, the **direct Co–Co interaction** in the structure **facilitates high electronic conductivity**, and **the interconnected lithium-ion** sites support **fast lithium-ion conductivity**. These built-in favourable characteristics along with an easy synthesis of  $\text{LiCoO}_2$  in ambient air made it an appealing cathode<sup>[27]</sup>

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# Thank you



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