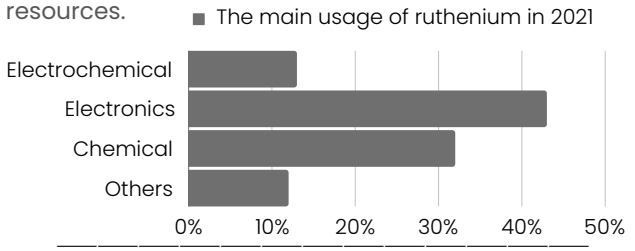
RUTHENIUM AND SUSTAINABILITY

The basics of ruthenium

Ru in solid state

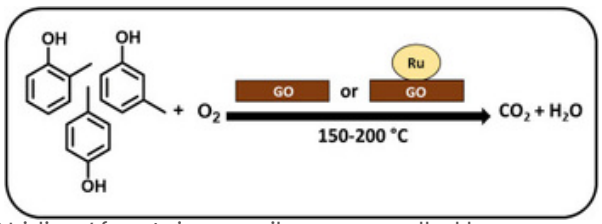
- **Name:** ruthenium (Ru)
- **Atomic number:** 44
- **Atomic weight:** 101.07
- **Atomic radius:** Van der Waals Atomic Radius
- **Element classification:** metal
- **Crystal structure:** hexagon
- **Physical state at 20°C:** Solid
- **Melting point:** 2250°C, 2603 K
- **Boiling point:** 4150°C, 4423°C
- **Oxidation states:** +3
- **Density:** 12.1 (grams per cubic centimetre)
- **Colour:** silver-white
- **Hardness:** 6½ on Mohs scale
- **Discovered by:** Karl Klaus in 1844
- **Ruthenium is…**
  1) one of the rarest metals on Earth - it comprises roughly 10% of the crust of the Earth
  2) a hard, shiny metal
  3) not attacked by hot or cold acids, it reacts with molten alkali and halogens and can oxidize explosively
  4) extremely difficult to work because it remains hardand brittle even at temperatures as high as 1500°C
- **Where is ruthenium naturally found?** Ruthenium is found as the free metal, sometimes associated with platinum, osmium and iridiu, in North and South America, and in South Africa.

In 1844, while analyzing the residue of a sample of platinum ore obtained from the Ural Mountains, **ruthenium** was discovered by Karl Karlovich Klaus, a Russian chemist. Nowadays, ruthenium has become everywhere. Therefore, the discovery of ruthenium soon led to the **improvement of sustainability**, as ruthenium has been used indifferent ways to conserve natural resources.



Economic sustainability

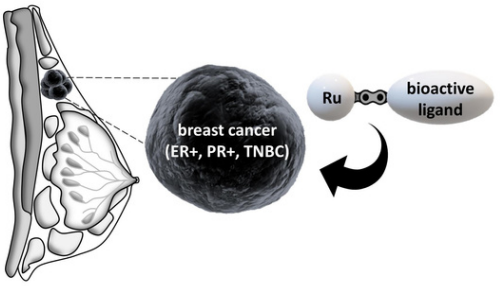
1. Ruthenium is used in catalytic wet air oxidation (CWAO) for the treatment of industrial wastewater. CWAO is a development of the wet air oxidation (WAO), it can remove oxidizable inorganic components such as cyanides. CWAO process plants can be highly automated for unattended operation, have relatively small plant footprints. Therefore it is very economical (and environmental) friendly in electrochemical industry.



2. Iridium' fountain pen nibs are so called because they used to be fashioned from iridium, but these days that's no longer the case .Present day fountain pen nibs are more likely to be topped with ruthenium. (Cost of using iridium is higher)
3. Electrolytic chlorination is the preferred method for ballast water treatment, accounting for more than one third of the world's installed systems. It uses ruthenium coated electrodes to produce diluted sodium hypochlorite in situ. Over time, electrodes degrade, creating a regular replenishment demand for metals. Also, the process disinfects the water and makes it safe for human use, such as for drinking water or swimming pools.

Social sustainability

1. In the chemical industry, ruthenium catalyst is used in acetic acid production (acetic acid is human-made. No effects on human health have been identified for acetic acid. According to information considered under the ERC Approach, acetic acid was identified as having a low ecological hazard potential.)



2. Ruthenium complex compounds are widely used in cancer therapy. These compounds are used to treat different types of cancers like melanoma, ovarian, or breast cancer (WangF. et al., 2002; AngW. and Dyson, 2006; Iida et al., 2016). The interest in these compounds was connected with synthesis and application of cisplatin in anticancer therapies. Generally, the use of ruthenium compounds in comparison with cisplatin is characterized by lower toxicity, higher efficiency, and lower number of side

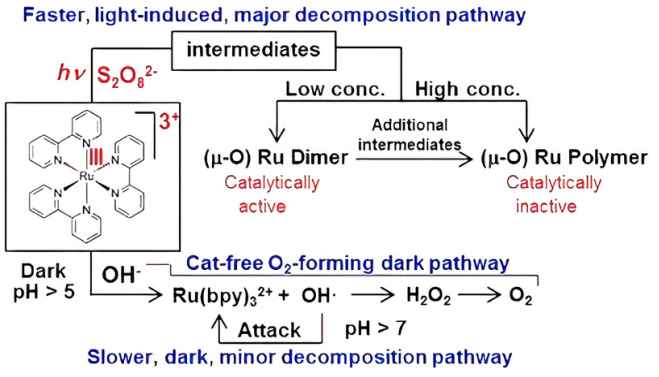
3. Ruthenium tetroxide is a potential staining agent. It is used to expose latent fingerprints by turning to the brown/black ruthenium dioxide when in contact with fatty oils or fats contained in sebaceous contaminants of the print.

Ruthenium can improve human health development in both direct and indirect way.

Environmental sustainability

1. Ruthenium Oxide Coating Titanium Blades for Pool System Chlorine Generator (The salt cell in a pool chlorinator generally consists of a series of titanium electrodes with clear housing; it generates chlorine through electrolysis).
2. Stable and oxidative charged Ru enhance the acidic oxygen evolution reaction activity in two-dimensional ruthenium-iridium oxide.

- Ru-based oxides and their derivatives have sufficient corrosion resistance to withstand the harsh acid corrosion and oxidation environments of OER.
- RuO_2 and IrO_2, Ru/Ir atoms have the same valence state, the same crystal structure type and similar chemical properties, which are conducive to synthesis substitutional solid solution.



3. A crystalline compound called ruthenium dioxide is widely used in industrial processes, where it is particularly important for catalyzing a chemical reaction that splits molecules of water and releases oxygen. The catalytic process, known as the oxygen evolution reaction, is crucial for producing hydrogen and ammonia for energy use, making synthetic carbon-neutral fuels, and making metals from metal oxides. Ruthenium dioxide surfaces are "the gold standard of catalysts for water splitting".

Conclusion: Ruthenium is a free, hard metal, so they react with other types of substances and is not attacked by hot or cold acids. Ruthenium is used to produce many chemical compounds and the demand of it is rising nowadays, therefore it helps develop sustainability in various ways.