Materials **Chromium**

Introduction

Chromium as a metallic element was first discovered two hundred years ago, in 1797, but the history of chromium began several decades before this.

In 1761, Johann Gottlob Lehmann visited the Beresof Mines on the eastern slopes of the Ural Mountains where he obtained samples of an orange-red mineral that he termed Siberian red lead. On his return to St. Petersburg in 1766 he analysed this mineral and discovered that it contained lead "mineralised with a selenitic spar and iron particles". In fact, the mineral was crocoite, a lead chromate ($PbCrO_4$).

In 1770, Peter Simon Pallas also visited the Beresof Mines and observed "a very remarkable red lead mineral which has never been found in any other mine. When pulverised, it gives a handsome yellow guhr which could be used in miniature painting...". In spite of its rarity and the difficulty with which it was obtained from the Beresof Mines, the use of Siberian red lead as a paint pigment was quickly appreciated and it was mined both as a collector's item and for the paint industry. A bright yellow made from crocoite quickly became the fashionable colour for the carriages of the nobility in both France and England.

In 1797, Nicolas-Louis Vauquelin, Professor of chemistry and assaying at the School of Mines in Paris, received some samples of crocoite ore. His subsequent analysis revealed a new metallic element, which he called chromium after the Greek word khrôma, meaning colour. After further research he detected trace elements of chromium in precious gems – giving the characteristic red colour of rubies and the distinctive green of emeralds, serpentine, and chrome mica.

In 1798, Lowitz and Klaproth independently discovered chromium in a sample of a heavy black rock found further north from the Beresof Mines and in 1799 Tassaert identified chromium in the same mineral from a small deposit in the Var region of south-eastern France. This mineral he determined as the chromium-iron spinel now known as chromite ($FeO.Cr_2O_3$).

Processing of Chromium

The most useful source of chromium commercially is the ore chromite, $FeCr_2O_4$. This ore is oxidised by air in molten alkali to produce sodium chromate (VI), Na_2CrO_4 in which the chromium is in the +6 oxidation state. This is converted into chromium (III) oxide, Cr_2O_3, by extraction into water, precipitation and reduction with carbon. The oxide is further reduced with aluminium or silicon to form chromium metal.

$$Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$$

$$2Cr_2O_3 + 3Si \rightarrow 4Cr + 3SiO_2$$

Another type of chromium isolation is by an electroplating process. This involves the dissociation of Cr_2O_3 in sulphuric acid to give an electrolyte used for chromium electroplating.

Properties of Chromium

Chromium is a steel-grey, lustrous, hard metal that can take a brilliant polish. Chromium compounds are toxic and should only be handled with the correct protective equipment and clothing.

Property	Value
Chemical symbol	Cr
Atomic number	24
Relative atomic mass	51.9961
Melting point	2180 K
Boiling point	2944 K
Density	7140 kg m^{-3}

Hard chromium plating, as found on hydraulic actuator rods, offers a rare combination of physical and mechanical properties: low coefficient of friction, high hardness, good corrosion resistance, high heat resistance and anti-galling properties.

Chemical Reactions of Chromium

- Chromium metal does not react with air, oxygen or water at room temperature.

- Chromium reacts directly the halogens.

  Chromium reacts directly with fluorine, F_2, at 400°C and 200-300 atmospheres to form yellow chromium(VI) fluoride, CrF_6. Under milder conditions, the red chromium(V) fluoride, CrF_5, is formed.

  Under milder conditions still, chromium metal reacts with the halogens fluorine, F_2, chlorine, Cl_2, bromine, Br_2, and iodine, I_2, to form the corresponding trihalides chromium(III) fluoride, CrF_3, chromium(III) chloride, $CrCl_3$, chromium(III) bromide, $CrBr_3$, or chromium(III) iodide, CrI_3.

- Chromium reaction with acids:

  Chromium metal dissolves in dilute hydrochloric acid to form solutions containing the aqueous Cr(II) ion, liberating hydrogen gas, H_2.

  $$Cr_{(s)} + 2HCl_{(aq)} \rightarrow Cr^{2+}{}_{(aq)} + 2Cl^{-}{}_{(aq)} + H_{2(g)}$$

  In practice, the Cr(II) is present as the complex ion $[Cr(OH_2)_6]^{2+}$. Similar results are seen for sulphuric acid but pure samples of chromium may be resistant to attack. Chromium metal does not react with nitric acid (HNO_3) and in fact is passivated.

- Chromium does not react with alkalis.

Uses of Chromium

Chromium is used industrially in the following applications:

- Hardening of steel.
- Manufacture of stainless steel.
- Manufacture of other alloys.
- Electroplating, to produce either a decorative finish or a hard wearing surface.
- As a catalyst.

The refractory industry has found chromite useful for forming bricks and shapes, as it has, a high melting point, moderate thermal expansion, and stability of crystalline structure.

Internet Resources

The International Chromium Development Association details the history, properties, industrial uses and health hazards associated with Chromium.
http://www.chromium-asoc.com/

The health hazards associated with chromium and its compounds are addressed by the HSE. http://www.hse.gov.uk/pubns/indg346.pdf

A general description of chromium and its uses and provided by Web elements.
http://www.webelements.com/webelements/elements/text/Cr/key.html

Phoenix Electroplating presents hard chromium plating techniques and applications.
http://www.electroplating.co.uk/chrome.htm

The United States Environmental Protection Agency presents a detailed technical and health fact sheet on chromium together with its uses.
http://www.epa.gov/reg5rcra/wptdiv/wastemin/chrmfina.pdf