

## SOME TRANSITION METALS

Properties	Iron	Nickel	Chromium
Earth's crust abundance	6.3	$9 \times 10^{-3}$	$1.4 \times 10^{-2}$
Electron configuration	$[\text{Ar}]3d^6 4s^2$	$[\text{Ar}]3d^8 4s^2$	$[\text{Ar}]3d^5 4s^1$
Melting point ( $^{\circ}\text{C}$ )	1538	1455	1907
Boiling point ( $^{\circ}\text{C}$ )	2861	2913	2671
Density	7.87	8.9	7.19
Common oxidation num.	+2, +3	2	+2, +3, +6
Physical State	solid	solid	solid
Color	greyish-tinge	greyish-tinge	Silvery metallic

Properties	Titanium	Zinc	Cadmium
Earth's crust abundance	0.66	$7.9 \times 10^{-3}$	$1.5 \times 10^{-5}$
Electron configuration	$[\text{Ar}]3d^2 4s^2$	$[\text{Ar}]3d^{10} 4s^2$	$[\text{Kr}]3d^{10} 4s^2$
Melting point ( $^{\circ}\text{C}$ )	1668	419.5	321.1
Boiling point ( $^{\circ}\text{C}$ )	3287	907	767
Density	4.5	7.14	8.65
Common oxidation num.	+2, +3, +4	2	2
Physical State	solid	solid	solid
Color	Silvery metallic	Bluish-pale grey	Silvery metallic

### Introduction

- Electronic configurations end with d orbital.
- Good conductors of heat and electricity.
- Less reactive than 1A and 2A elements.
- Have more than one oxidation state.
- Mostly form colored compounds.
- Hard, dense and shiny.
- Called block elements.
- Malleable and ductile.
- Melting and boiling points are higher than 1A and 2A metals.
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## Iron, Fe

### Introduction

- Used in Egypt as early as 3000 B.C.
- Lustrous, soft metal.
- Has important magnetic property.
- Malleable and ductile.
- Very reactive chemically.
- Rapidly corrodes.

### 1. Occurrence

- Not found in elemental form in nature.
- Found in clays, sandstones and granites.
- Basic component of hemoglobin.
- Second most abundant metal.
- Gives red color to the blood.
- Elemental iron is found only in meteors with cobalt and nickel as alloy.
- Common iron minerals are hematite,  $\text{Fe}_2\text{O}_3$ , Magnetite,  $\text{Fe}_3\text{O}_4$ , Pyrite,  $\text{FeS}_2$ , Siderite,  $\text{FeCO}_3$ .
- Pyrite,  $\text{FeS}_2$ , is a mineral popularly known as 'fool's gold' because of its metallic luster and yellow color.

### Preparation

- In industry, it is obtained in a blast furnace from ores of iron oxides by oxidation of carbon.
- In laboratory,
 
$$\text{Fe}_2\text{O}_3 + 3\text{H}_2 \rightarrow 2\text{Fe(s)} + 3\text{H}_2\text{O}$$

$$3\text{FeO(l)} + 2\text{Al(s)} \rightarrow 3\text{Fe(s)} + \text{Al}_2\text{O}_3$$

$$\text{Fe}_2\text{O}_3 + 2\text{Al(s)} \rightarrow 2\text{Fe(s)} + \text{Al}_2\text{O}_3$$

$$\text{FeCl}_2 \rightarrow \text{Fe(s)} + \text{Cl}_2$$

### 2. Chemical Properties

- Iron reacts with dilute solutions of strong acids.
 
$$\text{Fe(s)} + 2\text{HCl(dil.)} \rightarrow \text{FeCl}_2 + \text{H}_2$$
- Fe produces  $\text{Fe}_3\text{O}_4$  by reacting with water vapor.
 
$$3\text{Fe(s)} + 4\text{H}_2\text{O} \rightarrow \text{Fe}_3\text{O}_4 + 4\text{H}_2$$
- When iron is heated with sulfur, FeS forms
 
$$\text{Fe(s)} + \text{S(s)} \rightarrow \text{FeS(s)}$$
- At high temperature, it reacts with halogens.
 
$$2\text{Fe(s)} + 3\text{Cl}_2 (1200^{\circ}\text{C}) \rightarrow 2\text{FeCl}_3$$
- Moisture and  $\text{O}_2$  form  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ 

$$4\text{Fe(s)} + 3\text{O}_2 + 2n\text{H}_2\text{O} \rightarrow 2\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$$

### 3. Compounds

- $\text{Fe}^{+2}$  ion is called ferrous,  $\text{Fe}^{+3}$  is ferric.
- $\text{Fe}^{+2}$  ion has green color.  $\text{Fe}^{+3}$  is colorless.

#### Iron (II) Chloride, $\text{FeCl}_2$

- Obtained by passing HCl over heated iron.
 
$$\text{Fe(s)} + 2\text{HCl(g)} \rightarrow \text{FeCl}_2 + \text{H}_2$$

#### Iron (II) Sulfate, $\text{FeSO}_4 \cdot \text{H}_2\text{O}$

- Obtained by the reaction of dilute  $\text{H}_2\text{SO}_4$  with iron.
 
$$\text{Fe(s)} + \text{H}_2\text{SO}_4 \rightarrow \text{FeSO}_4 + \text{H}_2$$

#### Iron (II) Oxide, $\text{FeO}$

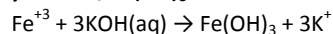
- Produced by decomposition of iron (II) oxalate  

$$\text{FeC}_2\text{O}_4(\text{s}) \rightarrow \text{FeO} + \text{CO}(\text{g}) + \text{CO}_2(\text{g})$$

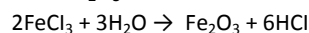
#### Iron (III) Chloride, $\text{FeCl}_3$

- $2\text{Fe}(\text{s}) + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3$

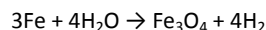
#### Iron (III) Hydroxide, $\text{Fe}(\text{OH})_3$



#### Iron (III) Oxide, $\text{Fe}_2\text{O}_3$



#### Iron (II, III) Oxide, $\text{Fe}_3\text{O}_4$



#### Uses

- Raw material for production of steel.
- In the medical treatment of anemia.
- In bridges, buildings, automobiles, airplanes.
- As pigment in paints.

#### Nickel, Ni

##### Introduction

- Nickel takes its name from kopper nickel, meaning copper gin in Swedish.
- Shows the properties of all metals.
- It is a magnetic element.

##### 1. Occurrence

- Nickel makes up 10% of molten magma.
- Nickel minerals are nikelite, NiAs, millerite, NiS, nickel glance, NiAsS.
- In the preparation of Ni Mond Method is used.

##### 2. Chemical Properties

- It is inactive in chemical reactions.
- It is very stable in humidity and water.
- Reacts with nonmetals at high temperatures.  

$$2\text{Ni} + \text{O}_2 \rightarrow 2\text{NiO}$$
- Reacts with different acids.  

$$\text{Ni} + \text{H}_2\text{SO}_4 \rightarrow \text{NiSO}_4 + \text{H}_2$$
- Form complexes with water,  $\text{NH}_3$ ,  $\text{CN}^-$ , CO.  

$$\text{Ni}^{+2} + 6\text{H}_2\text{O} \rightarrow \text{Ni}(\text{H}_2\text{O})_6^{+2}$$
- Aqueous  $\text{Ni}^{+2}$  ions have green color, and unhydrated  $\text{Ni}^{+2}$  salts have yellow color.

##### 3. Compounds

- Aqueous  $\text{Ni}^{+2}$  ions have green color, and unhydrated  $\text{Ni}^{+2}$  salts have yellow color.

#### Nickel (II) Hydroxide, $\text{Ni}(\text{OH})_2$

- Obtained by addition of bases into  $\text{Ni}^{+2}$  solutions.  

$$\text{Ni}^{+2} + 2\text{OH}^-(\text{aq}) \rightarrow \text{Ni}(\text{OH})_2$$

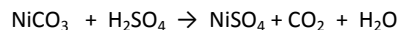
#### Nickel (II) Oxide, NiO

- Obtained by decomposition of nickel  $\text{NiCO}_3$  or  $\text{Ni}(\text{OH})_2$ .  

$$\text{Ni}(\text{OH})_2 \rightarrow \text{NiO} + \text{H}_2\text{O}$$

#### Nickel (II) sulfate, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$

- Obtained by reacting  $\text{NiCO}_3$  with dilute  $\text{H}_2\text{SO}_4$ .



#### Uses

##### Ni-Cu Alloy

- Used to prevent corrosion in propellers
- In space technology.

##### Al-Ni-Co Alloy

- In telephone wires, wireless and radio receivers.

##### Ni-Cu-Zn Alloy

- In brilliants, jewelry and coins.

##### Nicrome, Ni-Cr-Fe Alloy, Chromel, Ni-Cr Alloy

- In electrical wires with high resistance, high resistance to extreme coldness and hotness, steels, batteries, kitchen tools, laboratory instruments.
- In organic reactions as catalyst.

#### Chromium, Cr

##### Introduction

- "Chroma" means color in Latin word.
- Gives the bright and attractive colors to precious stones such as ruby and sapphire.
- Grey in color, hard and bright like silver.

##### 1. Occurrence

- Exists in volcanic stones and meteors.
- Obtained by reducing chromite mineral.  

$$\text{FeO} \cdot \text{CrCO}_3 + 4\text{C} \rightarrow 2\text{Cr} + \text{Fe} + 4\text{CO}$$
- Important chromium ores are chromite,  $\text{FeO} \cdot \text{Cr}_2\text{O}_3$ , Chrocoite,  $\text{PbCrO}_4$ .

##### 2. Chemical Properties

- Powdered chromium is more active.
- Reacts easily with  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$  compounds, and with  $\text{O}_2$  gas.
- Chromium is not affected by air and water.
- Chromium compounds are generally toxic.
- Reacts with halo-acids, slowly.  

$$\text{Cr} + 2\text{HCl}(\text{dil.}) \rightarrow \text{CrCl}_2 + \text{H}_2$$
- Hot and conc.  $\text{H}_2\text{SO}_4$  reacts with Cr to form  $\text{SO}_2$  gas.
- No reaction with dilute and conc.  $\text{HNO}_3$  at room temperature.
- Reacts with some nonmetals to produce the Cr (III) compounds,  

$$2\text{Cr} + 3\text{Cl}_2 \rightarrow 2\text{CrCl}_3$$

##### 3. Compounds

#### Chromium (III) Oxide, $\text{Cr}_2\text{O}_3$

- Used as pigment, and it is carcinogen.  

$$2\text{Cr}(\text{OH})_3 \rightarrow \text{Cr}_2\text{O}_3 + 3\text{H}_2\text{O}$$

#### Chromium (VI) Oxide, $\text{CrO}_3$

- Powerful oxidizing agent.

#### Chromates, $\text{CrO}_4^{2-}$ , and Dichromates, $\text{Cr}_2\text{O}_7^{2-}$

- Chromates of alkali metals, magnesium and calcium are soluble in water.

- Soluble chromates are usually yellow colored.

#### Uses

- Chromium metal is not used alone.
- Used in the manufacture of stainless steel.
- Used coating metals against corrosion.
- Cr powder for tanning, in dyes and in textiles.
- Cr compounds in the dye as a pigment.
- CrO<sub>3</sub> for cleaning the glassware in laboratories.
- In lasers.
- Chromium dioxide is used in audio tapes.

#### Ferro-Chromium, Fe-Cr Alloy and Nichrome, Ni-Cr

- High resistance to heat
- For building electrical furnaces.

#### Titanium, Ti

##### Introduction

- Titanium means 'son of the earth' in Greek.
- Titanium is very hard and has high resistance to corrosion.
- Ductile and a good conductor of heat and electricity.

##### 1. Occurrence

- Because of its tendency to react with C, O<sub>2</sub> and N<sub>2</sub>, it is very difficult to obtain pure titanium.
- Main titanium minerals are ilmenite, FeTiO<sub>3</sub>, rutile, TiO<sub>2</sub>.
- It is prepared within two steps;  
 $2\text{TiO}_2 + 3\text{C} + 4\text{Cl}_2 \rightarrow 2\text{TiCl}_4 + 2\text{CO} + \text{CO}_2$   
 $\text{TiCl}_4 + 2\text{Mg} \rightarrow \text{Ti} + 2\text{MgCl}_2 + 481 \text{ kJ}$

##### 2. Chemical Properties

- Titanium reacts with halo-acids.  
 $2\text{Ti} + 6\text{HF} \rightarrow 2\text{TiF}_3 + 3\text{H}_2$
- At high temperature, reacts with H<sub>2</sub>SO<sub>4</sub>.  
 $2\text{Ti} + 6\text{H}_2\text{SO}_4 \rightarrow \text{Ti}_2(\text{SO}_4)_3 + 3\text{SO}_2 + 6\text{H}_2\text{O}$
- Reacts with hot water.  
 $\text{Ti} + 2\text{H}_2\text{O} \rightarrow \text{TiO}_2 + 2\text{H}_2$
- Ti reacts with all nonmetals under proper conditions.

##### Uses

- Ti is alloyed with Al, Mo, Mn, Fe and some other metals.
- Ti paints are as reflector in solar observatories.
- TiO<sub>2</sub> is white pigment.
- It is used in the manufacture of airplane frames, engines, ships, tennis rackets, pens, cameras, medical equipments, food and water tanks, golf clubs, bicycles, prosthesis, space technology, eyeglass frames...etc.

#### Zinc, Zn

##### Introduction

- It is bluish-white lustrous, diamagnetic metal.
- Chemically with some respects it is similar to magnesium.
- The metal is hard and brittle at most temperatures above 200°C it becomes brittle again.
- Zinc is a fair conductor of electricity.

- Many alloys contain zinc, including brass, an alloy of zinc and copper.

##### 1. Occurrence

- Exists in nature together with copper and lead.
- Main zinc minerals are Zincblende, ZnS, Willemite, Zn<sub>2</sub>SiO<sub>4</sub>·H<sub>2</sub>O, Smithsonite or Calamine, ZnCO<sub>3</sub>, Franklinite, ZnO·Fe<sub>2</sub>O<sub>3</sub>.
- Zincblende is used in the first method,  
 $2\text{ZnS}(s) + 3\text{O}_2 \rightarrow 2\text{ZnO}(s) + 2\text{SO}_2$   
 $\text{ZnO} + \text{C} \rightarrow \text{Zn} + \text{CO} \quad \Delta H = -232 \text{ kJ}$
- Second method is electrolytic method,  
 $\text{ZnO} + \text{H}_2\text{SO}_4 \rightarrow \text{ZnSO}_4 + \text{H}_2\text{O}$   
 $2\text{ZnSO}_4 + 2\text{H}_2\text{O} \rightarrow 2\text{Zn} + \text{O}_2 + 2\text{H}_2\text{SO}_4$

##### 2. Reactions

- Burns in air with a greenish-blue flame .  
 $2\text{Zn}(s) + \text{O}_2 \rightarrow 2\text{ZnO}(s)$
- Zinc reacts with sulfur when heated.  
 $\text{Zn}(s) + \text{S}(s) \rightarrow \text{ZnS}(s)$
- Zinc reacts with halogens.  
 $\text{Zn}(s) + \text{Cl}_2 \rightarrow \text{ZnCl}_2(s)$
- Zinc reacts with dilute acids, except HNO<sub>3</sub>.  
 $\text{Zn}(s) + 2\text{HCl}(aq) \rightarrow \text{ZnCl}_2 + \text{H}_2$
- Reacts with strong bases.  
 $\text{Zn} + 2\text{NaOH}(\text{conc}) + 2\text{H}_2\text{O} \rightarrow \text{Na}_2[\text{Zn}(\text{OH})_4] + \text{H}_2$

##### Uses

- Zn makes many alloys like brass and bronze, used as protective coating against corrosion in roofs, fences, and gutters.

##### Zinc Oxide, ZnO

- As pigment, Chinese white, as an antiseptic.
- Used in skin treatment of skin irritations, manufacture of floor covering, printing inks, textile, electrical equipments, batteries, and soap.
- Some zinc compounds are used in X-ray screens, TV tubes, phosphorescent.
- ZnCl<sub>2</sub> is used as dehydrating agent.
- ZnSO<sub>4</sub> is used to check bleeding.

#### Cadmium, Cd

##### Introduction

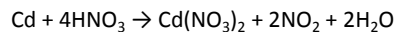
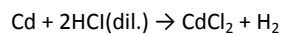
- Softer than zinc
- Malleable and ductile.
- Less active than zinc.
- Forms alloys with Sn and Bi which have low melting points.

##### 1. Occurrence

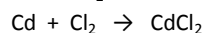
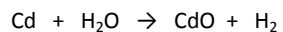
- Found as its carbonates, CdCO<sub>3</sub>, and sulfides, CdS.
- Produced as a by-product in the production of zinc.
- Zinc and cadmium are separated by fractional distillation of their oxides.

## 2. Chemical Properties

- Dissolves in nonoxidizing acids to form +2 charged ions.
- Free cadmium metal is moderately active.
- It acts as a reducing agent
- At room temperature it reacts with acids.



- At higher temperatures it reacts with steam and some non-metals.



## 3. Compounds

- All cadmium compounds are toxic.
- The most important Cd compounds are CdO, Cd(OH)<sub>2</sub>, CdS, CdSO<sub>4</sub>, CdCl<sub>2</sub>.

### Uses

#### Cadmium Sulfide, CdS

- It is used in solar cells, photography, photocopiers, and dyes.

#### Cadmium Sulfate, CdSO<sub>4</sub>

- It is used in electroplating, and standard voltaic cells.

#### Cadmium Oxide, CdO

- It is used in plating by electrolysis.
- Protective coating on other metals.
- Making Ni-Cd batteries.
- Amalgams of cadmium in dental fillings.
- As a catalyst in some Ni-Cd cell reactions.
- Protection of iron against corrosion.
- In aluminum solders.
- In nuclear reactors(captures electrons).