#457697
Topic: Extraction of crude metals from concentrated ores

Copper can be extracted by hydrometallurgy but not zinc. Explain.

Solution

More electropositve zinc ($E^o = -0.76$ V) is highly reactive and cannot be easily displaced from zinc sulphate solution. Less electropositive copper ($E^o = +0.34$ V) is less reactive and can be displaced from copper sulphate solution by using more active metal such as zinc. $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

#457698
Topic: Concentration or benefaction of ore (Ore-dressing)

What is the role of depressant in froth floatation process?

Solution

Depressants prevent certain types of particles from forming froth with bubbles. Due to this, we can separate two sulphide ores. For example, sodium cyanide is a depressant used for an ore containing ZnS and PbS. $NaCN$ forms a layer of the complex $Na_2[Zn(CN)_4]$ on the surface of ZnS and prevents it from forming a froth. Thus, it acts as a depressant. However, $NaCN$ does not prevent PbS from forming froth and allows it to come with froth.

#457700
Topic: Refining

Explain: (i) Zone refining (ii) Column chromatography.

Solution

(i) Zone refining

It is used for refining Si, B, Ga, In etc. Impurities are more soluble in the molten state of metal than in solid state. There is a circular mobile heater at one end of a rod of impu metal. Heater and the molten zone moves from one end to another end. Pure metal crystallizes out of the melt and the impurities pass onto the adjacent molten zone. Repetitic of this process several times segregates impurities at one end of a rod. The end with impurities can then be cut off.

(ii) Column chromatography.

It is used for the separation and purification. It is based on the difference in the tendency for adsorption of a metal and its impurities on a suitable adsorbent. Different components of a mixture are differently adsorbed on an adsorbent.

#457701
Topic: Thermodynamic principles of metallurgy

Out of C and CO, which is a better reducing agent at $673K$?

Solution

At $673\ K$, the ΔG^o vs T line for CO, CO_2 is lower than that of $C,\ CO$ line. Hence, CO can be used as better reducing agent than C at $673\ K$.

#457702
Topic: Extraction of copper

Name the common elements present in the anode mud in electrolytic refining of copper. Why are they present?

Solution

In the electrolytic refining of copper, the anode mud contains antimony, selenium, tellurium, silver gold and platinum. These are impurities in blister copper. They are less reacti and unaffected by $CuSO_4 - H_2SO_4$ solution and hence, settle down under anode as anode mud.

#457703
Topic: Extraction of crude metals from concentrated ores

Write down the reactions taking place in different zones in the blast furnace during the extraction of iron.

Solution

In blast furnace, iron oxides are reduced at different temperature ranges. In the lower part of the blast furnace, the temperature is as high as $2200\ K$. It is called combustion zone. At the top, the temperature is as low as $500-800\ K$. It is called reduction zone. In the lower temperature range, carbon is the reducing agent and in the higher temperature range, CO is the reducing agent. In the reduction zone ($500-800\ K$), following reactions occur.

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$

$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$

$Fe_2O_3 + CO \rightarrow 2FeO + CO_2$

In the temperature range 900-1500 K, following reactions occur.

$C + CO_2 \rightarrow 2CO$

$FeO + CO \rightarrow Fe + CO_2$

Around 1270 K (middle portion), decomposition of limestone gives lime (CaO) and CO_2. Lime is a flux and combines with silicate impurity to form slag of calcium silicate.

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + SiO_2 \rightarrow CaSIO_3$

#457704

Topic: Extraction of crude metals from concentrated ores

Write chemical reactions taking place in the extraction of zinc from zinc blende.

Solution

During extraction of Zn from zinc blende (ZnS), following reactions occur:

(i) ZnS is roasted in excess air at 1200 K to form ZnO.

$2ZnS + 2O_2 \xrightarrow{\Delta} 2ZnO + 2SO_2$

(ii) ZnO is heated with crushed coke at 1673 K, where it is reduced to Zn.

$ZnO + C \xrightarrow{1676\ K} Zn + CO$

(iii) Electrorefining is carried out for refining of impure zinc. Anode is impure zinc and cathode is pure zinc. Electrolyte is a mixture of zinc sulphate and dilute sulphuric acid (sm
amount). When current is passed, zinc is deposited on cathode and is collected.

At anode : $Zn \rightarrow Zn^{2+} + 2e^-$

At cathode: $Zn^{2+} + 2e^- \rightarrow Zn$

#457706

Topic: Extraction of crude metals from concentrated ores

State the role of silica in the metallurgy of copper.

Solution

During roasting, copper pyrites give FeO and Cu_2O.

$2CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + 2FeS + SO_2$

$2Cu_2S + 3O_2 \xrightarrow{\Delta} 2Cu_2O + 2SO_2$

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

Roasted ore is then mixed with silica (acidic flux) and heated to remove FeO (basic) as a slag of iron silicate.

$FeO + SiO_2 \rightarrow FeSiO_3$

Lighter slag forms upper layer and is removed through slag hole.

#457707

Topic: Refining

What is meant by the term chromatography?

Solution

Chromatography is used for the separation and purification. It is based on the difference in the tendency for adsorption of a metal and its impurities on a suitable adsorbent.

Different components of a mixture are differently adsorbed on an adsorbent.

#457708

Topic: Refining

What criterion is followed for the selection of the stationary phase in chromatography?

Solution

The stationary phase is an adsorbent and has following characteristics:

(1) Its adsorption power should be high and selective.

(2) To offer greater surface area for adsorption, it should be finely divided.

(3) It should have high mechanical stability. This will prevent dust formation.

(4) It should be chemically inert to sample and eluting solvents.

(5) It should have high purity.

#457709

Topic: Refining

Describe a method for refining nickel.

Solution

The method for refining nickel involves the following:

Ni is heated with CO to form volatile nickel tetracarbonyl.

$Ni + 4CO \xrightarrow{330-350K} Ni(CO)_4$

At high temperature, nickel tetracarbonyl decomposes to pure Ni.

$Ni(CO)_4 \xrightarrow{450-470K} Ni + 4CO$

This is Mond's process for refining Ni.

#457710

Topic: Extraction of Aluminium

How can you separate alumina from silica in a bauxite ore associated with silica? Give equations, if any.

Solution

Bauxite ore containing silica is heated with conc. $NaOH$ solution at $473-523$ K and $35-36$ bar pressure. Alumina forms sodium aluminate and silica forms sodium silicate.

Impurities are left behind.

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na[Al(OH)_4]$

Carbon dioxide neutralizes the aluminate to precipitate hydrated alumina.

$2Na[Al(OH)_4] + 2CO_2 \rightarrow Al_2O_3.xH_2O + 2NaHCO_3$

Sodium silicate remains in the solution and hydrated alumina is filtered and dried. On heating, hydrated alumina gives pure alumina.

$Al_2O_3.xH_2O \xrightarrow{1473\ K} Al_2O_3(s) + xH_2O$

#457711

Topic: Extraction of crude metals from concentrated ores

Giving examples, differentiate between roasting and calcination.

Solution

Calcination	Roasting
Ore is heated in absence of air. $Fe_2O_3 \cdot xH_2O \xrightarrow{\Delta} Fe_2O_3 + xH_2O$ $ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2$ $CaCO_3 \cdot MgCO_3 \xrightarrow{\Delta} CaO + MgO + 2CO_2$	Ore is heated in regular air supply below the melting temperature for metal. $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ $2Cu - 2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$ $2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$
It is used for carbonates and oxide ores.	It is used for sulphide ores.
Moisture and organic impurities are removed.	Volatile impurites are removed as oxides such as SO_2, P_2O_5, As_2O_4.

#457712

Topic: Extraction of iron

How is cast iron different from pig iron?

Solution

Pig iron is obtained from blast surface. It contains 4% C and trace of impurities such as S, P, Si, Mn etc.

Pig iron is melted (using hot air blast) with scrap iron and coke to form cast iron. Carbon content is around 3% and cast iron is extremely hard and brittle.

#457713

Topic: General Introduction

Differentiate between minerals and ores.

Solution

Minerals are naturally occurring chemical substances. They are present in earth's crust and obtained by mining. Ores are the minerals from which a metal can be economically and conveniently extracted.

Thus, bauxite $(Al_2O_3 \cdot 2H_2O)$ and clay $(Al_2O_2 \cdot 2SiO_2 \cdot 2H_2O)$ are minerals of Al. However, bauxite is an ore of Al as Al can be economically and conveniently extracted from bauxite.

#457714

Topic: Extraction of copper

Why copper matte is put in silica lined converter?

Solution

Copper matte contains Cu_2S and FeS. Hot air blast converts FeS to FeO. FeO is removed as slag when it reacts with silica. Hence, copper matte is placed in silica lined converter.

$2FeS + O_2 \rightarrow 2FeO + 2SO_2$

$FeO + SiO_2 \rightarrow FeSiO_3$

Cu_2S or CuO is converted to copper.

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$

#457715

Topic: Extraction of Aluminium

What is the role of cryolite in the metallurgy of aluminium?

Solution

Before electrolysis, cryolite is added to bauxite ore because of the following reasons.

(1) It acts as a solvent.

(2) It decreases the melting temperature of alumina to 1173 K.

(3) It increases the electrical conductivity.

#457716

Topic: Extraction of copper

How is leaching carried out in case of low grade copper ores?

Solution

Acid in presence of air is used to leach out copper from low grade copper.

$Cu + 2H^+ + 0.5O_2 \rightarrow Cu^{2+} + H_2O$

Solution is then treated with scrap iron or hydrogen.

$Cu^{2+} + H_2 \rightarrow Cu + 2H^+$

#457717

Topic: Thermodynamic principles of metallurgy

Why is zinc not extracted from zinc oxide through reduction using CO?

Solution

Zinc is not extracted from zinc oxide through reduction using CO.

Reducing agent should have more negative ΔG value. However in present case, Zn has more negative ΔG value then CO, so it can not be reduced by CO.

#457718

Topic: Extraction of Aluminium

The value of $\Delta_f G^0$ for formation of Cr_2O_3 is $-540\ kJmol^{-1}$ and that of Al_2O_3 is $-827kJmol^{-1}$. Is the reduction of Cr_2O_3 possible with Al?

Solution

$\frac{4}{2}Al + O_2 \rightarrow \frac{2}{3}Al_2O_3\ \Delta_f G^o(Al, Al_2O_3 = -827\ kJ/mol)$.....(i)

$\frac{4}{3}Cr + O_2 \rightarrow \frac{2}{3}Cr_2O_3\ \Delta_f G^o(Cr, Cr_2O_3) = -540\ kJ/mol$.....(ii)

Substract equation (ii) from equation (i), we get

$\frac{4}{3}Al + \frac{2}{3}Cr_2O_3 \rightarrow \frac{2}{3}Al_2O_3 + \frac{4}{3}Cr\ \Delta_r G^o = -287\ kJ/mol$

Because, for the combined reaction, $\Delta_r G^o < 0$ (negative), the reaction is spontaneous and the reduction of Cr_2O_3 by Al is possible.

#457719

Topic: Thermodynamic principles of metallurgy

Out of C and CO, which is a better reducing agent for ZnO?

Solution

Out of C and CO, the better reducing agent for ZnO is C.

$ZnO + C \xrightarrow{1673\ K} Zn + CO$

#457720

Topic: Thermodynamic principles of metallurgy

The choice of a reducing agent in a particular case depends on thermodynamic factor. How far do you agree with this statement? Support your opinion with two examples.

Solution

For the reduction of given metal oxide to metal, consideration of thermodynamic factors helps in selecting a suitable reducing agent. Ellingham diagrams (plots of $\Delta_f G^o$ vs T) can predict the feasibility of thermal reduction. Metals with a more negative standard free energy of formation of oxides can reduce the metal oxides with a less negative standard free energy of formation of respective oxides. Metal will reduce the oxides of other metals which lie above it in Ellingham diagram as the standard free energy change for combined redox reaction will be negative by an amount equal to the difference in $\Delta_f G^o$ of two metal oxides. Thus, both Al and Zn can reduce FeO to Fe but Fe cannot reduce Al_2O_3 to Al or ZnO to Zn. Also, C can reduce ZnO to Zn but not CO.

#457721

Topic: Thermodynamic principles of metallurgy

Name the processes from which chlorine is obtained as a by-product. What will happen if an aqueous solution of $NaCl$ is subjected to electrolysis?

Solution

(1) In Down's process for the manufacture of sodium, the electrolysis of NaCl gives chlorine as a byproduct.

$NaCl(l) \xrightarrow{Electrolysis} Na^+(melt) + Cl^-(melt)$

At anode : $Cl^-(melt) \rightarrow Cl(g) + e^-$

$Cl(g) + Cl(g) \rightarrow Cl_2(g)$

At cathode : $Na^+(melt) + e^- \rightarrow Na(s)$

(2) In Castner Kellner cell, electrolysis of brine solution is carried out to manufacture NaOH (caustic soda). Chlorine is obtained as a byproduct.

#457722

Topic: Thermodynamic principles of metallurgy

What is the role of graphite rod in the electrometallurgy of aluminium?

Solution

During electrometallurgy of aluminium, graphite rod reduces alumina to aluminium.

$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

#457723

Topic: Refining

Outline the principles of refining of metals by the following methods:

(i) Zone refining

(ii) Electrolytic refining

(iii) Vapour phase refining

Solution

(i) Zone refining

It is used for refining Si, B, Ga, In etc. Impurities are more soluble in the molten state of metal than in solid state. There is a circular mobile heater at one end of a rod of impu metal. Heater and the molten zone moves from one end to another end. Pure metal crystallizes out of the melt and the impurities pass onto the adjacent molten zone. Repetitic of this process several times segregates impurities at one end of a rod. The end with impurities can then be cut off.

(ii) Electrolytic refining

It is carried out for refining of impure zinc. The anode is impure zinc and cathode is pure zinc. The electrolyte is a mixture of zinc sulphate and dilute sulphuric acid (small amount). When current is passed, zinc is deposited on the cathode and is collected.

At anode : $Zn \rightarrow Zn^{2+} + 2e^-$

At cathode: $Zn^{2+} + 2e^- \rightarrow Zn$

(iii) Vapour phase refining

Metal is converted into volatile compound and then decomposed to obtain pure metal. This method is used for refining Ni, Zr and Ti.

Ni is heated with CO to form volatile nickel tetracarbonyl.

$Ni + 4CO \xrightarrow{330-350K} Ni(CO)_4$

At high temperature, nickel tetracarbonyl decomposes to pure Ni.

$Ni(CO)_4 \xrightarrow{450-470K} Ni + 4CO$

This is Mond's process for refining Ni.

#457725

Topic: Thermodynamic principles of metallurgy

Predict conditions under which Al might be expected to reduce MgO.

Solution

Below $1350^\circ C$, Mg can reduce Al_2O_3 and above $1350^\circ C$, Al can reduce MgO. This can be inferred from $\Delta G^\ominus Vs\ T$ plots.

$\Delta G^\ominus Vs\ T$ plot for Mg, MgO is below $\Delta G^\ominus Vs\ T$ plot for Al. At the point of intersection (corresponding to $1350^\circ C$), $\Delta G^\ominus$ for combined reaction is zero. After $1350^\circ C$, Mg MgO curve is higher than Al Al_2O_3 curve. There are practical difficulties to attain higher temperature.