Redox

Definitions

Reduction: When a substance gains electrons and decreases their oxidation number

Oxidation: When a substance loses electrons and increases their oxidation number

Reducing agent: The substance in a redox reaction which is oxidized

Oxidizing agent: The substance in a redox reaction which is reduced

Oxidation number: The charge of an atom if the compound was composed of ions

Determine whether an element undergoes oxidation or reduction

1. Identify the reactants and products and balance the equation
2. Utilize the oxidation number rules to identify the oxidation numbers of the reactants and products
3. The element that increases its oxidation number undergoes oxidation and the element that decreases its oxidation number undergoes reduction

Example

Reaction: $2Na+Cl_2 \rightarrow 2NaCl$

1. Identify Reactants and Products:

   Reactants: Na (sodium) and Cl_2 (chlorine gas)

   Products: NaCl (sodium chloride)

2. Assign Oxidation States:

   Na (in Na) = 0 (elemental form)

   Cl (in Cl_2) = 0 (elemental form)

   Na (in NaCl) = +1

   Cl (in NaCl) = -1

3. Compare Oxidation States:

   Sodium: 0 (in Na) → +1 (in NaCl) → oxidation (increase in oxidation state)

   Chlorine: 0 (in Cl_2) → -1 (in NaCl) → reduction (decrease in oxidation state)

4. Determine Oxidation and Reduction:

Oxidation: Sodium (Na) is oxidized (0 to +1).

Reduction: Chlorine (Cl_2) is reduced (0 to -1).

Identify Oxidizing and Reducing agent in redox reactions

1. Determine Oxidation and Reduction:

   Identify which elements undergo oxidation (increase in oxidation state) and which undergo reduction (decrease in oxidation state).

2. Identify the Oxidizing and Reducing Agents:

   Reducing Agent: The substance that donates electrons and is oxidized. It causes another substance to be reduced.

   Oxidizing Agent: The substance that accepts electrons and is reduced. It causes another substance to be oxidized.

Example

Reaction: $2Na+Cl_2 \rightarrow 2NaCl$

1. Determine Oxidation and Reduction:

   Sodium (Na) undergoes oxidation: 0 (in Na) → +1 (in NaCl).

   Chlorine (Cl_2) undergoes reduction: 0 (in Cl_2) → -1 (in NaCl).

2. Identify the Oxidizing and Reducing Agents:

   Reducing Agent: Sodium (Na) is the reducing agent because it donates electrons and is oxidized (0 to +1).

   Oxidizing Agent: Chlorine (Cl_2) is the oxidizing agent because it accepts electrons and is reduced (0 to -1).

Writing simple half equations to represent simple half equations

1. Identify the Oxidation and Reduction Processes:

   Determine which element is being oxidized and which is being reduced.

2. Write the Oxidation Half Equation:

Show the element losing electrons and becoming more positive. Balance the atoms of the element being oxidized. Add electrons (e^-) to the product side to balance the charge.

3. Write the Reduction Half Equation:

   Show the element gaining electrons and becoming more negative. Balance the atoms of the element being reduced. Add electrons (e^-) to the reactant side to balance the charge.

Example

Reaction: $2Na+Cl_2 \rightarrow 2NaCl$

1. Identify Oxidation and Reduction:
   Sodium (Na) is oxidized: 0 (in Na) → +1 (in NaCl). Chlorine (Cl_2) is reduced: 0 (in Cl_2) → -1 (in NaCl).
2. Write the Oxidation Half Equation:

   Sodium atoms are oxidized: $2Na \rightarrow 2Na^+ + 2e^-$

3. Write the Reduction Half Equation:
   Chlorine molecules are reduced $Cl_2+2e^- \rightarrow Cl_2^-$

Electrolysis

Definitions

Electrolysis: separating molten ionic compounds using electricity

Electrolyte: The ionic compounds that are either dissolved in water or in molten state, thus carrying mobile charged particles

Anode: The positive electrode where oxidation occurs during electrolysis due to the attraction of anions

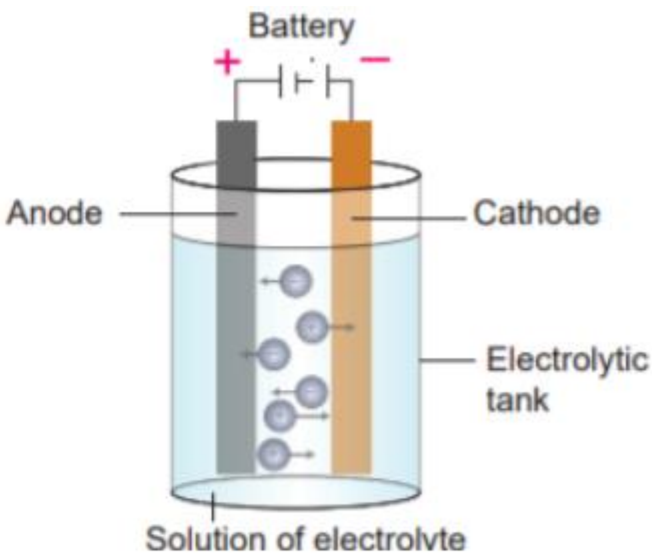
Cathode: The negative electrode where reduction occurs during electrolysis due to the attraction of cations

Corrosion: When the surface of a metal wears way due to chemical reactions between the surface of the metal and the surrounding environment

Reactivity Series: A list of metals ordered and categories by their reactivity with different substances

Ore: Rock containing valuable minerals and that has a higher concentration of a certain substance, typically metals.

Diagram of components of electrolytic cell



How current is conducted in an electrolytic cell (example of Molten NaCl)

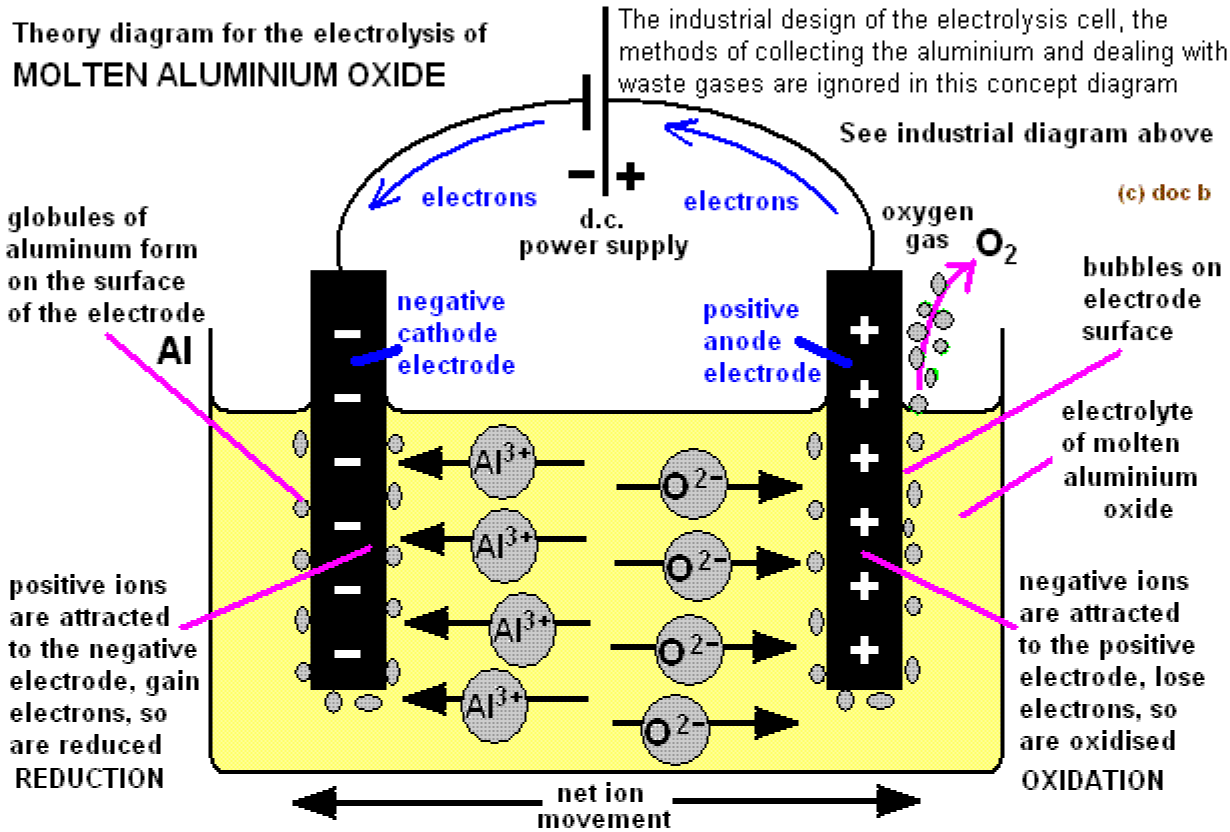
1. Setup:
   In an electrolytic cell, you have two electrodes (usually made of inert materials like graphite or platinum) immersed in an electrolyte solution (in this case, NaCl dissolved in water).
2. Electrolyte:
   The electrolyte solution contains ions, which are electrically charged particles. In the case of NaCl, when dissolved in water, it dissociates into Na^+ ions (sodium ions) and Cl^- ions (chloride ions).
3. Electric Current:
   When an electric voltage is applied across the two electrodes, it creates an electric field in the solution. This electric field causes the ions in the solution to move towards oppositely charged electrodes.
4. Ion Movement:
   Positively charged ions (like Na^+) move towards the negatively charged electrode (called the cathode), while negatively charged ions (like Cl^-) move towards the positively charged electrode (called the anode).
5. Electrode Reactions:
   At the electrodes, the ions undergo reactions. At the cathode, where reduction occurs, Na^+ ions gain electrons and form sodium atoms or compounds, depending on the

specific conditions. At the anode, where oxidation occurs, Cl^- ions lose electrons and form chlorine gas or other chlorine-containing compounds.

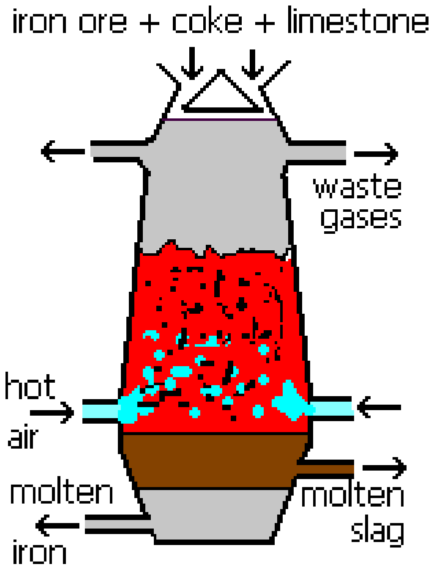
6. Conduction:
   This process continues if there is an external source of electric potential driving the reaction. This process continues if there is an external source of electric potential driving the reaction.

Extraction of metals using smelting and electrolysis

Electrolysis:



Smelting:



Ore Preparation:

Iron ore is mined and crushed into a fine powder or concentrate.

Smelting Furnace:

The crushed ore, along with coke (carbon) and limestone (flux), is continuously fed into the top of a blast furnace.

<u>Role of Coke (Carbon):</u>

As a Fuel: Coke is ignited at the base of the furnace, and hot air is blown in, burning the coke to form carbon dioxide (CO2), releasing a lot of heat energy.

As a Reducing Agent: At high temperatures, carbon dioxide reacts with more coke to form carbon monoxide (CO). Carbon monoxide acts as the reducing agent, removing oxygen from the iron oxide ore.

Reduction Reaction: The carbon monoxide reacts with the iron oxide ore, reducing it to iron and forming carbon dioxide.

Example Reaction: $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO$

Formation of Slag:

The impurities in the ore react with limestone to form a molten slag, mainly calcium silicate, which floats on top of the molten iron.

Separation and Casting:

The molten iron, now freed from oxygen, trickles down to the base of the blast furnace and is collected. It is then cast into ingots or transferred directly to a steel-producing furnace.

Treatment of Waste Gases:

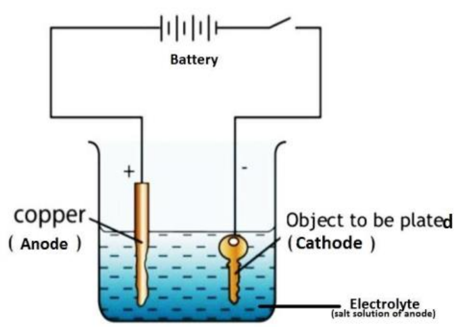
The waste gases and dust from the blast furnace, including harmful carbon monoxide, are appropriately treated to avoid environmental pollution. Carbon monoxide can be burnt to produce carbon dioxide, and acidic gases like sulfur dioxide can be neutralized using alkali solutions.

Disposal of Waste:

Waste slag, used for road construction or filling, is appropriately disposed of, and contaminated water is treated before release.

<u>**Electroplating**</u>

Electroplating Process



Electroplating is the process of plating one metal onto another using electrolysis. Here is how it works (example of coating brass with copper):

1. An anode, cathode and an electrolyte is present, where the cathode is the object, you want to be plated with, the anode is the metal you want to plate with, and the electrolyte is a solution containing the metal you want to coat with. (e.g.) If you want to coat a brass key with copper, the cathode would be the brass spoon, the anode would be copper based, and the electrolyte would contain the ion to be plated. In the case of copper, it's usually copper sulfate CuSo4

2. When a current begins flowing through the circuit, the copper ions are attracted to the negatively charged brass, creating a thin layer of copper. The metal ions reduced at the cathode leads to them being deposited on the object's surface. $Cu^{2+} + 2e^- \rightarrow Cu$
3. Meanwhile, the sulfate ions are attracted to the copper anode. The supplied current causes the Copper atoms on the cathode to oxidize and dissolve into the electrolyte solution, leading to the deterioration of the anode. $Cu \rightarrow Cu^{2+} + 2e^-$
4. Due to these reactions happening simultaneously, the solution concentration remains the same because the copper is building up on the cathode and being reduced, while the anode is deteriorating, dissolving more copper into the electrolyte. The idea is that these reactions happen at the same rate; whatever copper is lost from the electrolyte is replaced by the anode.
5. Over time, the anode deteriorates, and the brass cathode has a layer of copper on it

Purification of copper using electroplating

1. Impure copper is used as the anode, and a pure copper sheet serves as the cathode. They are both immersed in an electrolyte solution containing copper ions, typically copper sulfate ($CuSO_4$) dissolved in water.
2. When electric current is passed through the electrolyte solution, copper ions from the electrolyte migrate towards the cathode, while impurities from the anode are released into the electrolyte solution.
3. At the cathode (pure copper sheet), copper ions gain electrons and are reduced to form solid copper atoms, which plate onto the surface of the cathode, gradually increasing its thickness.
4. Meanwhile, impurities present in the impure copper anode either remain in the electrolyte solution or settle at the bottom as sludge, leaving behind a purer copper.
5. After the electroplating process is complete, the pure copper-coated cathode is removed from the electrolyte solution. The deposited copper layer can then be peeled off from the cathode, resulting in purified copper sheets or wires.

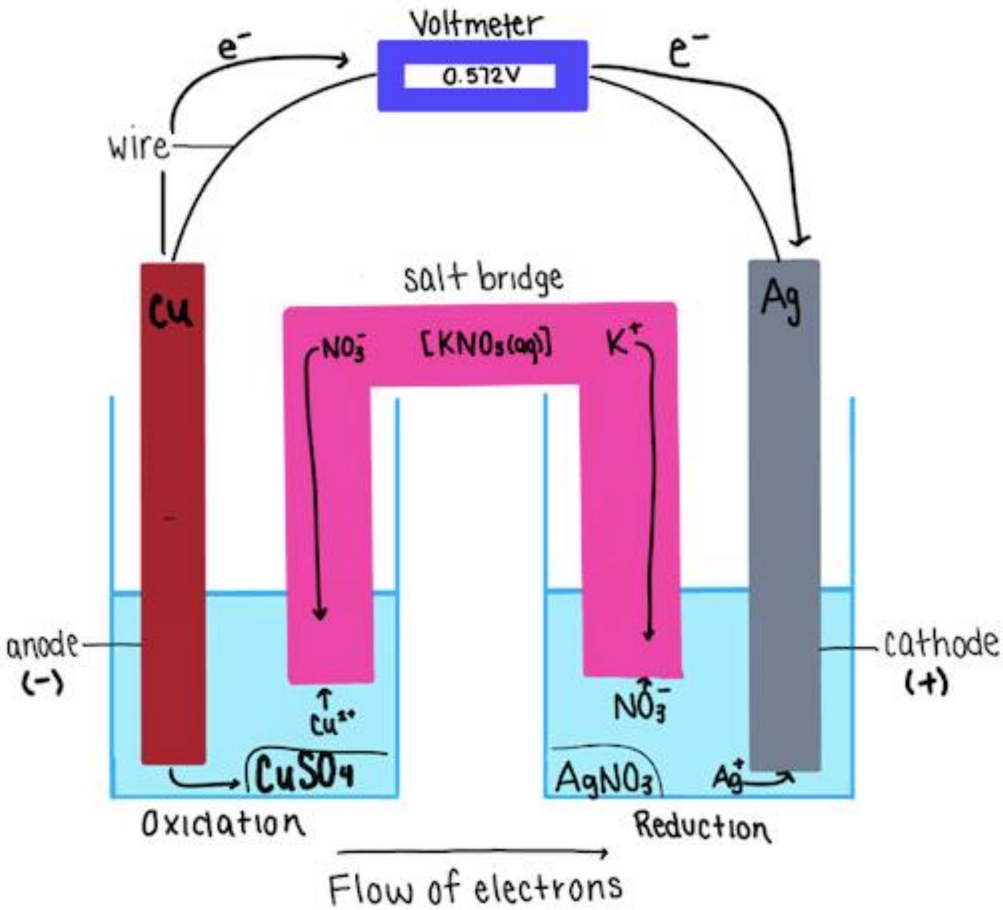
<u>Voltaic Cell</u>

Definitions

Salt bridge: A salt bridge is a device used in an electrochemical cell (such as a galvanic or voltaic cell) to maintain electrical neutrality by allowing the transfer of ions between the two half-cells.

Half cell: A half cell is one part of an electrochemical cell, consisting of a conductive electrode submerged in an electrolyte solution. Each half cell contains a metal electrode and a solution of its ions. In a complete electrochemical cell, two half cells are connected by a salt bridge and external circuit.

Components of voltaic cell



How redox reactions are used to produce electricity in voltaic cells

1. Anode Reaction:
   At the anode, zinc metal undergoes oxidation. Zinc atoms lose electrons to form zinc ions (Zn^{2+}). The reaction can be represented as Zn (s) → Zn^{2+} (aq) + $2e^-$. This process releases electrons into the external circuit.
2. Electron Flow:
   The 2 electrons released by zinc at the anode travel through the external circuit towards the cathode. This flow of electrons through the wire constitutes an electric current, which is harnessed as electricity.

3. Cathode Reaction:
   At the cathode, copper ions (Cu^{2+}) in the electrolyte gain the electrons arriving from the external circuit and are reduced to copper metal. The reaction is Cu^{2+} (aq) + $2e^-$ → Cu (s). Copper metal deposits onto the cathode as a result of this reduction reaction.
4. Ion Movement:
   To maintain electrical neutrality, ions flow through the salt bridge. Anions (negative ions) move towards the anode compartment, and cations (positive ions) move towards the cathode compartment. This movement of ions ensures that the charges in the electrolyte solutions remain balanced, allowing the redox reactions to continue smoothly.