Chapter 7

Electrochemistry

CHAPTER 7 1

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Short Questions (Exercise)

1. What is oxidation state?

The oxidation state (or oxidation number) is the charge an atom would have if all bonds were ionic, indicating the number of electrons lost or gained by an atom in a compound.

2. What is the oxidation number of Cr in chromic acid (H_2CrO_4)?

Let the oxidation number of Cr be x.

$2(+1) + x + 4(-2) = 0$

$x = +6$

The oxidation number of Cr is +6.

3. Identify the reducing agent in the reaction $CuO + H_2 \rightarrow Cu + H_2O$:

Reducing agent: H_2 (it donates electrons, reducing CuO to Cu).

4. Why is tin plated steel used to make food cans?

Tin plating prevents corrosion of steel and protects food from reacting with the metal.

5. Explain one example from daily life involving an oxidation-reduction reaction:

Example: Rusting of iron:

- Oxidation: $Fe \rightarrow Fe^{2+} + 2e^-$
- Reduction: $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$

This leads to the formation of hydrated iron(III) oxide ($Fe_2O_3 \cdot xH_2O$).

6. Compare and contrast oxidation and reduction:

- Oxidation: Loss of electrons, increase in oxidation state.
- Reduction: Gain of electrons, decrease in oxidation state.

7. Define oxidation and reduction in terms of loss or gain of electrons:

- Oxidation: The process where an atom or ion loses electrons.
- Reduction: The process where an atom or ion gains electrons.

8. Explain how food and beverage industries deal with corrosion:

Food and beverage industries use coatings like tin, chromium, or plastic to prevent corrosion of metal containers. They also use inert gases to prevent oxidation.

9. State whether substances are oxidized or reduced in the following reactions:

- (a) $N_2 + 3H_2 \rightarrow 2NH_3$:
  N_2: Reduced, H_2: Oxidized.
- (b) $CO_2 + 2Mg \rightarrow 2MgO + C$:
  CO_2: Reduced (to C), Mg: Oxidized (to MgO).
- (c) $H_2S + Cl_2 \rightarrow 2HCl + S$:
  H_2S: Oxidized (to S), Cl_2: Reduced (to HCl).
- (d) $2NH_3 + 3CuO \rightarrow 3Cu + N_2 + 3H_2O$:
  NH_3: Oxidized (to N_2), CuO: Reduced (to Cu).

10. Find the oxidation state of nitrogen in the following compounds:

- (a) NH_3: -3
- (b) N_2O: +1
- (c) NO: +2
- (d) HNO_3: +5

11. Find the oxidation state of S in the following compounds:

- (a) H_2S: -2
- (b) H_2SO_4: +6
- (c) Na_2SO_3: +4

12. Define oxidizing and reducing agents:

- Oxidizing Agent: Accepts electrons and is reduced in a reaction.
- Reducing Agent: Donates electrons and is oxidized in a reaction.

13. Identify the oxidizing and reducing agents in the following reactions:

- (a) $H_2S + Cl_2 \rightarrow 2HCl + S$:
  Oxidizing Agent: Cl_2, Reducing Agent: H_2S.
- (b) $2FeCl_3 + Cl_2 \rightarrow 2FeCl_4$:
  Oxidizing Agent: Cl_2, Reducing Agent: $FeCl_3$.
- (c) $2NaI + Cl_2 \rightarrow 2NaCl + I_2$:
  Oxidizing Agent: Cl_2, Reducing Agent: NaI.

- (d) $Mg + 2HCl \rightarrow MgCl_2 + H_2$:
Oxidizing Agent: HCl, Reducing Agent: Mg.

Project

What is Corrosion?

Corrosion is a natural chemical process in which metals undergo deterioration due to reactions with the environment. It typically involves oxidation-reduction reactions, where metals react with oxygen, water, or other substances to form compounds like oxides, hydroxides, or sulfides. Corrosion weakens the metal and reduces its utility, often resulting in economic losses and structural damage.

Type of Chemical Reaction

Corrosion is primarily an oxidation-reduction (redox) reaction. In this process:

1. Oxidation occurs at the surface of the metal:
   - The metal loses electrons and forms metal ions.
   - Example: $Fe \rightarrow Fe^{2+} + 2e^-$ (oxidation of iron).
2. Reduction occurs as oxygen and water combine to accept the electrons:
   - $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$.

The overall process results in the formation of rust, a hydrated form of iron(III) oxide ($Fe_2O_3 \cdot xH_2O$).

Examples of Corrosion

1. Rusting of Iron (Fe):
   - Reaction: $4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$
   - The product, $Fe(OH)_3$, dehydrates to form rust ($Fe_2O_3 \cdot xH_2O$).

2. Tarnishing of Silver (Ag):
   - Reaction: $4Ag + 2H_2S + O_2 \rightarrow 2Ag_2S + 2H_2O$
   - Silver reacts with hydrogen sulfide and oxygen to form a black layer of silver sulfide (Ag_2S).

3. Corrosion of Copper (Cu):
   - Reaction: $2Cu + H_2O + CO_2 + O_2 \rightarrow Cu(OH)_2 \cdot CuCO_3$
   - Copper reacts with moisture, carbon dioxide, and oxygen to form a green patina of copper hydroxide carbonate ($Cu(OH)_2 \cdot CuCO_3$).

4. Galvanic Corrosion:
   - Occurs when two different metals come into electrical contact in the presence of an electrolyte. The more reactive metal (anode) corrodes, while the less reactive metal (cathode) is protected.

Prevention of Corrosion

1. Coating and Painting:
   - Applying a protective layer such as paint or plastic prevents contact with oxygen and water.

2. Galvanization:
   - Coating steel or iron with zinc to prevent rusting.

3. Cathodic Protection:
   - Using a more reactive metal (sacrificial anode) to protect the less reactive metal.

4. Alloying:
   - Adding chromium to steel forms stainless steel, which resists corrosion.

Conclusion

Corrosion is a redox reaction that has significant practical implications, particularly in construction, transportation, and industry. Understanding the mechanisms of corrosion and its prevention is crucial for maintaining the integrity of materials and reducing economic losses.

Extera Short Questions (Topic Wise)

7.1: Oxidation and Reduction

What is oxidation?

Oxidation is the loss of electrons by an atom or ion. Example: In $Na \rightarrow Na^+ + e^-$, sodium is oxidized.

What is reduction?

Reduction is the gain of electrons by an atom or ion. Example: In $Cl_2 + 2e^- \rightarrow 2Cl^-$, chlorine is reduced.

What happens to the oxidation number during oxidation?

It increases. Example: $Fe^{2+} \rightarrow Fe^{3+}$.

What happens to the oxidation number during reduction?

It decreases. Example: $Cu^{2+} \rightarrow Cu$.

7.2: Oxidation States and Rules for Assigning Oxidation States

What is an oxidation state?

It is the apparent charge of an atom in a compound.

What is the oxidation state of oxygen in most compounds?

−2, except in peroxides (−1) and with fluorine (+2).

What is the oxidation state of hydrogen?

+1 in most compounds, but −1 in metal hydrides. Example: NaH.

What is the sum of oxidation states in a neutral compound?

The sum is zero. Example: H_2O: $2(+1) + (-2) = 0$.

7.3: Formula of Ionic Compounds

How are ionic compounds formed?

By the transfer of electrons from metals to non-metals, forming cations and anions. Example: $Na^+ + Cl^- \rightarrow NaCl$.

What is the formula of magnesium chloride?

$MgCl_2$, as Mg^{2+} and $2Cl^-$ balance the charges.

What must the total charge of an ionic compound equal?

It must equal zero.

What is the formula for aluminum oxide?

Al_2O_3, with 2 Al^{3+} and 3 O^{2-} ions balancing charges.

7.4: Oxidizing and Reducing Agents

What is an oxidizing agent?

A substance that causes oxidation by gaining electrons itself. Example: O_2 in $2Mg + O_2 \rightarrow 2MgO$.

What is a reducing agent?
A substance that causes reduction by losing electrons itself. Example: Mg in $2Mg + O_2 \rightarrow 2MgO$.

What happens to the oxidizing agent in a reaction?
It gets reduced.

What happens to the reducing agent in a reaction?
It gets oxidized.

7.5: Corrosion and its Prevention

What is corrosion?
Corrosion is the gradual deterioration of metals due to oxidation. Example: Rusting of iron $Fe + O_2 + H_2O \rightarrow Fe_2O_3$.

What causes corrosion?
Exposure to oxygen and moisture.

How can corrosion be prevented?
Applying protective coatings like paint or grease. Using sacrificial anodes (e.g., zinc for galvanization).

What is galvanization?
A method of applying a protective zinc layer to iron to prevent rusting.

Extera Long Questions (Topic Wise)

Explain oxidation and reduction with examples and their role in chemical reactions.

Oxidation is the process where an atom, molecule, or ion loses electrons, resulting in an increase in its oxidation number.
Example: Sodium is oxidized when it reacts with chlorine: $Na \rightarrow Na^+ + e^-$.

Reduction is the process where an atom, molecule, or ion gains electrons, resulting in a decrease in its oxidation number.
Example: Chlorine is reduced when it reacts with sodium: $Cl_2 + 2e^- \rightarrow 2Cl^-$.

Oxidation and reduction always occur together in a redox reaction. While one species loses electrons (oxidation), another gains electrons (reduction).

Role in Reactions:
1. Energy Release: Redox reactions, such as combustion, release energy. Example: Methane combustion: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + Energy.
2. Electrochemical Processes: Batteries operate based on redox reactions. Example: In a zinc-carbon battery, zinc is oxidized, and carbon is reduced.
3. Biological Reactions: Redox reactions are critical in cellular respiration and photosynthesis.

What are oxidation states, and what are the rules for assigning oxidation states? Provide examples.

Oxidation states indicate the degree of oxidation or reduction of an element in a compound.

Rules for Assigning Oxidation States:
1. Free Elements: Oxidation state = 0. Example: O_2, H_2.
2. Ions: Oxidation state = charge. Example: $Na^+ = +1$, $Cl^- = -1$.
3. Oxygen: Usually -2; exceptions include peroxides (-1) and compounds with fluorine (+2).
4. Hydrogen: +1 in most compounds, but -1 in metal hydrides. Example: NaH.
5. Neutral Compounds: Sum of oxidation states = 0. Example: H_2O: 2(+1) + (-2) = 0.
6. Polyatomic Ions: Sum equals the ion's charge. Example: SO_4^{2-}: S = +6, O = -2 (total = -2).

Applications: Used to identify redox reactions, determine electron transfer, and balance equations.
Example: $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$.

How are ionic compounds formed, and what rules govern their chemical formulas? Provide examples.

Ionic compounds form when a metal atom transfers electrons to a non-metal atom, resulting in the formation of oppositely charged ions held together by electrostatic forces.

Formation:

1. Electron Transfer: Metals lose electrons to form cations, and non-metals gain electrons to form anions. Example: $Na^+ + Cl^- \rightarrow NaCl$.
2. Attraction: Oppositely charged ions attract to form ionic bonds.

Rules for Writing Formulas:
1. Determine Charges: Use group numbers to predict charges. Example: Group 1 metals = +1, Group 17 non-metals = -1.
2. Balance Charges: Combine ions to make the compound neutral. Example: Mg^{2+} and $Cl^- \rightarrow MgCl_2$.
3. Use Subscripts: Indicate the ratio of ions. Example: Al^{3+} and $O^{2-} \rightarrow Al_2O_3$.

Examples: Sodium chloride (NaCl), Magnesium oxide (MgO), Potassium sulfate (K_2SO_4).

What is corrosion, and how can it be prevented? Discuss with examples.

Corrosion is the gradual destruction of metals due to chemical reactions with their environment, typically involving oxygen and moisture.

Example: Rusting of iron: $4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$ (hydrated iron oxide).

Causes:
1. Exposure to oxygen and water.
2. Presence of salts or acids.

Prevention Methods:
1. Protective Coatings: Applying paint, grease, or oil. Example: Painted steel bridges resist rust.
2. Galvanization: Coating iron with zinc. Example: Galvanized pipes.
3. Cathodic Protection: Using sacrificial anodes like zinc or magnesium. Example: Ships use zinc plates for protection.
4. Alloying: Mixing metals to resist corrosion. Example: Stainless steel (iron + chromium + nickel) resists rust.

Importance: Preventing corrosion ensures safety, durability, and cost savings in infrastructure, machinery, and transportation.

MCQS

What happens during oxidation?

a) Electrons are gained

b) Electrons are shared

c) Electrons are lost ☑

d) Oxidation number decreases

What happens during reduction?

a) Electrons are lost

b) Oxidation number increases

c) Electrons are gained ☑

d) No change in electrons

What is the oxidation state of hydrogen in most compounds?

a) 0

b) +1 ☑

c) -1

d) +2

What is the oxidation state of oxygen in peroxides?

a) +2

b) -2

c) -1 ☑

d) 0

What is the sum of oxidation states in a neutral compound?

a) Equal to the charge of the compound

b) Negative

c) Positive

d) Zero ☑

What must the total charge of an ionic compound equal?

a) Positive

b) Zero ☑

c) Negative

d) It varies

What is an oxidizing agent?

a) A substance that gains electrons ☑

b) A substance that loses electrons

c) A substance that remains unchanged

d) A substance that absorbs energy

What is a reducing agent?

a) A substance that gains electrons

b) A substance that loses electrons ☑

c) A substance that neutralizes oxidation
d) A compound that releases oxygen

What happens to an oxidizing agent in a reaction?
a) It is oxidized
b) It is reduced ☑
c) It remains unchanged
d) It breaks apart

What happens to the reducing agent in a reaction?
a) It is oxidized ☑
b) It is reduced
c) It gains electrons
d) It remains unchanged

What is the oxidation number of a free element?
a) +1
b) -1
c) 0 ☑
d) +2

What is the oxidation state of fluorine in a compound?
a) +1
b) 0
c) +2
d) -1 ☑

Which ion is formed when magnesium loses two electrons?
a) Mg^-
b) Mg^{2-}
c) Mg^+
d) Mg^{2+} ☑

What is the formula for aluminum oxide?
a) AlO
b) Al_2O_2
c) Al_2O_3 ☑
d) Al_3O_2

Which compound is formed when sodium reacts with chlorine?
a) $NaCl_2$
b) NaCl ☑
c) Na_2Cl
d) ClNa

What is corrosion?
a) The gradual deterioration of metals due to oxidation ☑
b) A rapid chemical reaction releasing heat
c) The process of metal gaining electrons
d) The formation of ions in a solution

What is galvanization?

a) Coating metal with grease

b) Coating iron with zinc to prevent rust ☑

c) Heating metal to remove rust

d) Polishing a metal surface

What type of bonding occurs in NaCl?

a) Ionic bonding ☑

b) Covalent bonding

c) Metallic bonding

d) Hydrogen bonding

What is the sum of oxidation states in a polyatomic ion?

a) Equal to the ion's charge ☑

b) Always zero

c) Always positive

d) Equal to the atomic mass

What is the main cause of corrosion?

a) Heat

b) Salts

c) Exposure to oxygen and moisture ☑

d) Lack of oxygen

Which metal is commonly used as a sacrificial anode?

a) Iron

b) Zinc ☑

c) Copper

d) Silver

What is the oxidation state of sulfur in SO_4^{2-}?

a) +4

b) +6 ☑

c) -2

d) 0

What happens to the oxidation number of an element during oxidation?

a) It decreases

b) It increases ☑

c) It becomes zero

d) It remains the same

What happens to the oxidation number of an element during reduction?

a) It increases

b) It becomes zero

c) It decreases ☑

d) It remains the same

What is the oxidation state of oxygen in most compounds?

a) -2 ☑

b) -1
c) 0
d) +2

What type of agent is oxygen in the reaction $2Mg + O_2 \rightarrow 2MgO$?
a) Reducing agent
b) Oxidizing agent ☑
c) Neutral agent
d) None of the above

How can corrosion be prevented?
a) Using sacrificial anodes like zinc ☑
b) Exposing the metal to moisture
c) Removing oxygen from the environment
d) Heating the metal

What is the oxidation state of chlorine in NaCl?
a) +1
b) 0
c) -1 ☑
d) +2

Which is an example of a redox reaction?
a) Mixing two salts
b) Dissolving sugar in water
c) Rusting of iron ☑
d) Melting of ice

What is the oxidation state of hydrogen in H_2O?
a) 0
b) +1 ☑
c) -1
d) -2