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Metals and Non-Metals

Physical Properties

Metals are generally shiny, hard (except sodium and mercury), malleable, ductile, and good conductors of heat and electricity. Non-metals can be solids, liquids, or gases, usually dull, brittle, and poor conductors.

Chemical Properties of Metals

Metals react with air to form metal oxides, with water to form metal hydroxides and hydrogen gas, and with acids to produce salt and hydrogen gas. More reactive metals can displace less reactive metals from their salts.

Reactions of Metals and Non-Metals

Metals lose electrons to form cations, while non-metals gain electrons to form anions. Ionic compounds formed are usually solid, brittle, have high melting points, dissolve in water, and conduct electricity when molten.

Occurrence and Extraction of Metals

Metals occur in the earth's crust and seawater. Extraction depends on the metal's reactivity, using methods like roasting, reduction, or electrolysis. Refining purifies metals using anodes and cathodes.

Corrosion and Prevention

Corrosion is the deterioration of metals due to reactions with oxygen, water, or chemicals, such as rust on iron. Prevention includes painting, coating, and alloying metals to resist corrosion.

Solved Examples

Example 1: Write the balanced chemical equation for the reaction of magnesium with oxygen.

Solution:

Magnesium reacts with oxygen to form magnesium oxide.

Unbalanced equation: $Mg + O_2 \rightarrow MgO$

Balancing oxygen atoms requires 2 Mg atoms:

$2Mg + O_2 \rightarrow 2MgO$

This is the balanced chemical equation.

Example 2: Describe the reaction of sodium with water.

Solution:

Sodium reacts vigorously with water to form sodium hydroxide and hydrogen gas.

Equation: $2Na + 2H_2O \rightarrow 2NaOH + H_2 (\uparrow)$

This reaction releases heat and hydrogen gas.

Practice Set

- **Level 1:** What are the physical properties of metals?
- **Level 1:** Define amphoteric oxides with an example.
- **Level 2:** Write the balanced chemical equation for the reaction of aluminum oxide with hydrochloric acid.

Answer Key

- **Level 1:** Metals are shiny, hard (except sodium and mercury), malleable, ductile, and good conductors of heat and electricity.
- **Level 1:** Amphoteric oxides are metal oxides that react with both acids and bases to form salt and water. Example: Aluminum oxide (Al_2O_3).
- **Level 2:** $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

Properties

Physical Properties Comparison

Metals have lustre, are mostly hard, solid (except mercury), malleable, ductile, good conductors, dense, sonorous, and have basic oxides. Non-metals are dull, brittle, can be solid/liquid/gas, poor conductors (except graphite), less dense, non-sonorous, and have acidic oxides.

Chemical Properties of Metals

Metals react with oxygen to form metal oxides, with water to form metal hydroxides and hydrogen gas, with acids to produce salt and hydrogen, and can displace less reactive metals from their salts.

Solved Examples

Example 1: Write the reaction of copper with oxygen.

Solution:

Copper reacts with oxygen to form copper(II) oxide.

$2Cu + O_2 \rightarrow 2CuO$

Example 2: Write the reaction of magnesium oxide with water.

Solution:

Magnesium oxide reacts with water to form magnesium hydroxide.

$MgO + H_2O \rightarrow Mg(OH)_2$

Practice Set

- **Level 1:** What is the state of mercury at room temperature?
- **Level 2:** Write the balanced chemical equation for the reaction of potassium with water.
- **Level 3:** Explain why aluminum oxide is amphoteric.

Answer Key

- **Level 1:** Mercury is liquid at room temperature.
- **Level 2:** $2K + 2H_2O \rightarrow 2KOH + H_2 (\uparrow)$
- **Level 3:** Aluminum oxide reacts with both acids and bases to form salt and water, showing amphoteric behavior.

Reactions

Reaction with Air

Metals react with oxygen in air to form metal oxides. For example, copper forms copper(II) oxide, aluminum forms aluminum oxide, and magnesium forms magnesium oxide.

Amphoteric Oxides

Some metal oxides react with both acids and bases to form salt and water. These are called amphoteric oxides. Example: Aluminum oxide.

Reaction with Water

Metals react with water to form metal hydroxides and hydrogen gas. Sodium and potassium react vigorously with cold water, magnesium reacts with hot water, and aluminum reacts with steam.

Reaction with Acids

Metals react with dilute acids to produce salt and hydrogen gas. For example, magnesium reacts with sulfuric acid to form magnesium sulfate and hydrogen gas.

Reaction with Salt Solutions

More reactive metals can displace less reactive metals from their salt solutions. For example, iron displaces copper from copper sulfate solution.

Solved Examples

Example 1: Write the reaction of iron with copper sulfate solution.

Solution:

$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

Example 2: Write the reaction of aluminum oxide with sodium hydroxide.

Solution:

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

Practice Set

- **Level 1:** What is the product when magnesium reacts with oxygen?
- **Level 2:** Write the balanced chemical equation for the reaction of sodium with water.
- **Level 3:** Explain the displacement reaction with an example.

Answer Key

- **Level 1:** Magnesium oxide (MgO) is formed.
- **Level 2:** $2Na + 2H_2O \rightarrow 2NaOH + H_2 (\uparrow)$
- **Level 3:** A more reactive metal displaces a less reactive metal from its salt solution. Example: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

Reactivity Series

Definition and Order

The reactivity series is a list of metals arranged in decreasing order of their reactivity. Potassium is the most reactive, and platinum is the least reactive.

Applications

The reactivity series helps predict the reactions of metals with water, acids, and salt solutions, and guides the extraction methods of metals from ores.

Mnemonics

Popular Scientists Can Make A Zoo In The Low Humid Country More Satisfactorily

This helps remember the order: Potassium, Sodium, Calcium, Magnesium, Aluminum, Zinc, Iron, Lead, Hydrogen, Copper, Silver, Gold, Platinum.

Solved Examples

Example 1: Which metal is more reactive: zinc or copper?

Solution:

Zinc is above copper in the reactivity series, so zinc is more reactive.

Example 2: Predict the reaction between iron and copper sulfate solution.

Solution:

Iron is more reactive than copper, so it will displace copper from copper sulfate solution.

$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

Practice Set

- **Level 1:** What is the most reactive metal in the reactivity series?
- **Level 2:** Write the reaction of potassium with water.
- **Level 3:** Explain the use of reactivity series in metal extraction.

Answer Key

- **Level 1:** Potassium is the most reactive metal.
- **Level 2:** $2K + 2H_2O \rightarrow 2KOH + H_2 (\uparrow)$
- **Level 3:** The reactivity series helps determine the method of extraction; highly reactive metals are extracted by electrolysis, moderately reactive by reduction, and least reactive by heating alone.

Ionic Compounds

Formation

Ionic compounds form by the transfer of electrons from metals to non-metals, resulting in positively charged metal ions and negatively charged non-metal ions.

Properties

Ionic compounds are solid, hard, brittle, have high melting and boiling points, are soluble in water, and conduct electricity in molten or aqueous state.

Examples

Common ionic compounds include sodium chloride (NaCl) and magnesium oxide (MgO).

Solved Examples

Example 1: Explain the formation of sodium chloride.

Solution:

Sodium (Na) loses one electron to form Na^+, chlorine (Cl) gains one electron to form Cl^-. These ions attract to form NaCl.

Example 2: Write the formula of magnesium oxide formed from Mg and O.

Solution:

Magnesium forms Mg^{2+} and oxygen forms O^{2-} ions. They combine in 1:1 ratio to form MgO.

Practice Set

- **Level 1:** What type of bond is formed between metals and non-metals?
- **Level 2:** Write the formula of the ionic compound formed between calcium and chlorine.
- **Level 3:** Describe the properties of ionic compounds.

Answer Key

- **Level 1:** Ionic bond.
- **Level 2:** Calcium forms Ca^{2+} and chlorine forms Cl^-. The formula is $CaCl_2$.
- **Level 3:** Ionic compounds are solid, hard, brittle, have high melting and boiling points, soluble in water, and conduct electricity when molten or dissolved.

Extraction

Steps

Extraction of metals involves enrichment of ores, extraction of metal from concentrated ores, and refining of metal.

Methods Based on Reactivity

Highly reactive metals are extracted by electrolysis, moderately reactive metals by reduction of oxides, and least reactive metals by heating alone.

Examples

Mercury is extracted by heating cinnabar (HgS) to form mercury oxide and then mercury.

Solved Examples

Example 1: Describe the extraction of mercury from cinnabar.

Solution:

$HgS + O_2 \rightarrow HgO + SO_2$ (on heating)

$HgO \rightarrow Hg + O_2$ (on further heating)

Example 2: What method is used to extract aluminum?

Solution:

Aluminum is extracted by electrolysis of its molten ore.

Practice Set

- **Level 1:** What is an ore?
- **Level 2:** Name the method used to extract highly reactive metals.
- **Level 3:** Explain the thermite reaction.

Answer Key

- **Level 1:** An ore is a mineral from which a metal can be profitably extracted.
- **Level 2:** Electrolysis is used to extract highly reactive metals.
- **Level 3:** Thermite reaction involves aluminum reducing iron oxide to produce molten iron and aluminum oxide with heat.

Corrosion

Definition

Corrosion is the deterioration of metals due to chemical reactions with the environment, such as rusting of iron.

Examples

Silver reacts with sulfur to form silver sulfide; copper forms green copper carbonate; iron forms rust (hydrated iron oxide).

Prevention

Corrosion can be prevented by painting, oiling, greasing, galvanizing (coating with zinc), and making alloys.

Alloys

Alloys are homogeneous mixtures of metals with metals or non-metals, such as stainless steel, brass, bronze, and solder. Amalgams contain mercury.

Solved Examples

Example 1: What is galvanization?

Solution:

Galvanization is coating iron with zinc to prevent corrosion.

Example 2: Name an alloy of copper and zinc.

Solution:

Brass is an alloy of copper and zinc.

Practice Set

- **Level 1:** What causes rusting of iron?
- **Level 2:** How does galvanization prevent corrosion?
- **Level 3:** Name two alloys and their components.

Answer Key

- **Level 1:** Rusting is caused by reaction of iron with oxygen and moisture.
- **Level 2:** Zinc coating prevents air and moisture from reaching iron, stopping corrosion.
- **Level 3:** Stainless steel (iron, carbon, nickel, chromium), brass (copper and zinc).

Quick Reference Table

Common Mistakes and Misconceptions

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