UNIT A: CHEMISTRY

Topic 5
Chemical Reactions

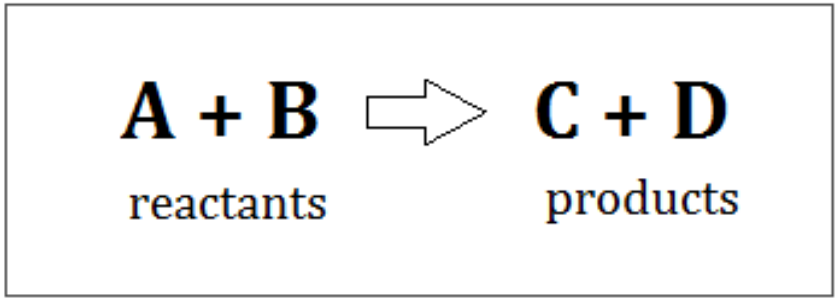
Candle burning

Metal rusting

Chemical Reactions

- A chemical reaction occurs when one or more substances react to form new **products** with different chemical **properties**.

- A chemical reaction is also known as ***chemical change***.



Word & Chemical Equations

aq = aqueous (dissolved in water)

- Scientists represent chemical reactions in two ways:
  Word equations - uses chemical **names**, **plus** signs, and an **arrow** to show the reaction. Example:

Reactants

Sodium bicarbonate + acetic acid → Carbon dioxide + water + Sodium Carbonate

Products

Chemical equations - uses chemical **formulas**, **plus** signs, and an **arrow** to show the reaction. **States of matter** are also shown in **subscripts** after each chemical substance. Example:

$$NaHCO_{3(s)} + CH_3COOH_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + NaC_2H_3O_{2(aq)}$$

Examples

s = solid
l = liquid
g = gas

aq = aqueous (dissolved in H_2O)

Write the word and chemical equations for each of the following reactions:

1. When solid magnesium metal is burned in the presence of oxygen gas (O_2), solid magnesium oxide is produced.

Word: magnesium + oxygen → magnesium oxide

Chemical eqn:

$$Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$$

Examples

Write the word and chemical equations for each of the following reactions:

2. Solid aluminum chloride can be separated into its elements: solid aluminum metal and chlorine gas (Cl_2).

Word eqn

aluminum chloride → aluminum + chlorine

chemical eqn

$$AlCl_{3(s)} \rightarrow Al_{(s)} + Cl_{2(g)}$$

3+ 1

Examples

rxn

Write the word and chemical equations for each of the following reactions:

vapor

3. When propane gas (C_3H_8) is burned in the presence of oxygen (O_2), carbon dioxide gas and water are produced.

IUPAC

tricarbon octahydride

Word eq'n

propane + oxygen $\xrightarrow{\text{fire}}$ carbon dioxide + water

chemical eq'n

$C_3H_{8(g)} + O_{2(g)} \xrightarrow{\text{burns}} CO_{2(g)} + H_2O_{(g)}$

PRACTICE

Write the word and chemical equations for each of the following reactions:

Charge on iron

1. When iron metal is heated in the presence of chlorine gas (Cl_2) the elements combine to form iron (III) chloride.

word eq'n

iron + chlorine $\xrightarrow{\text{heated}}$ iron (II) chloride

1-
Cl

chemical eq'n

$Fe_{(s)} + Cl_{2(g)} \xrightarrow{\text{heated}} FeCl_{3(s)}$

PRACTICE

Write the word and chemical equations for each of the following reactions:

2. When hydrogen peroxide is improperly stored, it decomposes into its elements: hydrogen gas (H_2) and oxygen gas (O_2).

word eq'n

hydrogen peroxide $\xrightarrow{\text{decomposes}}$ hydrogen + oxygen

chemical eq'n $H_2O_{2(l)} \rightarrow H_{2(g)} + O_{2(g)}$

PRACTICE

Write the word and chemical equations for each of the following reactions:

3. Methane (CH_4) (also called natural gas) is burned in the presence of oxygen gas (O_2) to produce water vapour and carbon dioxide gas.

Word eq'n

methane + oxygen → water + carbon dioxide

Chemical eq'n

$$CH_{4(g)} + O_{2(g)} \xrightarrow{\text{burns}} H_2O_{(g)} + CO_{2(g)}$$

Not all changes to matter are chemical…

… a chemical change only happens if a new substance is produced.

Evidence of Chemical Change

- Energy absorbed or produced (e.g. change in temp)
- Change in colour
- Change in odour
- Change in pH
- Formation of gas bubbles
- Formation of a precipitate

A **precipitate** is a solid that forms as the result of a **chemical reaction** in aqueous solution (water).

Are these changes chemical or physical?

Note that a **change in state (e.g. solid to liquid) and the process of dissolving one substance in another are **NOT indicative of chemical change.***

Solubility of Ionic Compounds

- Solubility is the **physical** property of a substance referring to the degree to which it can **dissolve** in another substance (usually water)
- A **precipitate** will form during an aqueous chemical reaction if one of the products is **insoluble** in water.

Kool-Aid is soluble in water

Sand is insoluble in water

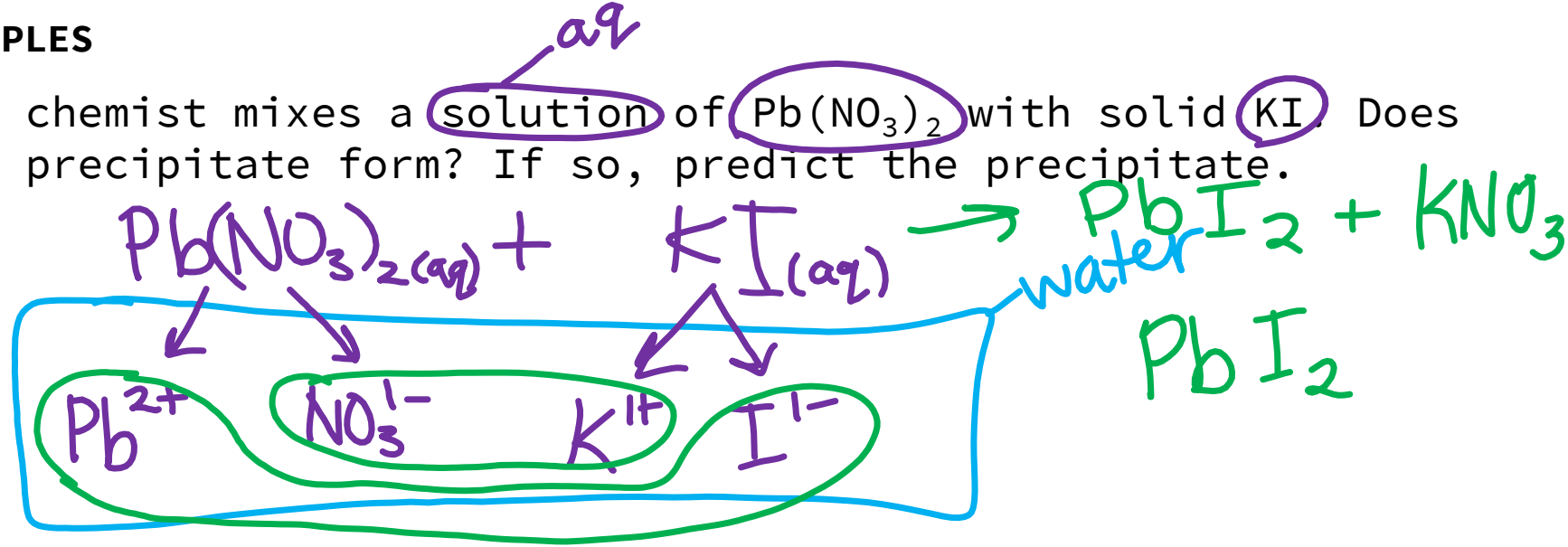
Predicting Solubility

Affix your brand new SOLUBILITY TABLE to the back of your periodc table!!

We can use the **solubility table** to predict the solubility of the **products** of a chemical reaction

EXAMPLES

1. A chemist mixes a solution of $Pb(NO_3)_2$ with solid KI. Does a precipitate form? If so, predict the precipitate.



Predicting Solubility

EXAMPLE *(cont'd)*

$PbI_2(s) \rightleftharpoons Pb^{2+} + I^{1-}$

$KNO_3(aq) \rightleftharpoons K^{+} + NO_3^{1-}$

Solubility of Some Common Ionic Compounds in Water

Ion	Group 1 NH_4^+ H_3O^+ (H^+)	ClO_3^- NO_3^- ClO_4^-	CH_3COO^-	Cl^- Br^- I^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-} SO_3^{2-} CO_3^{2-}
Very Soluble (aq)	all	all	most	most	most	only with: Group 1 Group 2 NH_4^+	only with: Group 1 NH_4^+ Sr^{2+} Ba^{2+} Tl^+	only with: Group 1 NH_4^+
Slightly Soluble (s)	none	none	only with: Ag^+ Hg^+	only with: Ag^+ Pb^{2+} Hg^+ Cu^+ Tl^+	only with: Ca^{2+} Sr^{2+} Ba^{2+} Ra^{2+} Pb^{2+} Ag^+	most	most	most

Predicting Solubility

barium hydroxide

Soluble = aq

Slightly soluble = s

EXAMPLE

2. Will the compound $Ba(OH)_2$ be soluble in water?

Ba^{2+} OH^{1-}

Yes, $Ba(OH)_2$ is soluble in water (aqueous)

PRACTICE

PRACTICE

1. Determine whether each of the following ionic compounds is soluble or insoluble in water

a) Barium Nitrate Ba^{2+} NO_3^{1-} soluble (aq)

b) Potassium Carbonate K^{+} CO_3^{2-} soluble (aq)

c) Sodium Sulfate Na^{+} SO_4^{2-} soluble (aq)

d) Copper (II) Hydroxide Cu^{2+} OH^{-} insoluble (s)

e) Mercury (I) Chloride Hg^{1+} Cl^{1-} insoluble (s)

f) Ammonium Phosphate NH_4^{1+} PO_4^{3-} soluble (aq)

g) Chromium (III) Sulfide Cr^{3+} S^{2-} insoluble (s)

h) Lead (II) Sulfate Pb^{2+} SO_4^{2-} insoluble (s)

PRACTICE

NO_3^{4-}

Mg^{2+} NO_3^{1-}

2. Write the chemical equation. Use your solubility chart to determine the states of matter for the products that are ionic compounds.

Ag^{1+} NO_3^{1-}

a) When magnesium metal is mixed into a silver nitrate solution, the products are silver metal and magnesium nitrate.

water

$$Mg_{(s)} + AgNO_{3(aq)} \rightarrow Ag_{(s)} + Mg(NO_3)_{2(aq)}$$

PRACTICE

b) When lead (II) nitrate solution is added to sodium iodide solution the products are solid lead (II) iodide and aqueous sodium nitrate.

$Pb(NO_3)_{2(aq)} + NaI_{(aq)} \rightarrow PbI_{2(s)} + NaNO_{3(aq)}$

PRACTICE

c) A silver nitrate solution is added to potassium chloride solution. The products are silver chloride and potassium nitrate

$$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$$

Energy Change

All chemical reactions either **release** or **absorb** energy...

- Reactions that **release energy** are referred to as ***exothermic*** (exiting)
  - **Temperature of surroundings increases** as chemical bonds form
  - EXAMPLES: cellular respiration, combustion
    - cellular respiration → pushups
    - combustion → burning

Energy Change

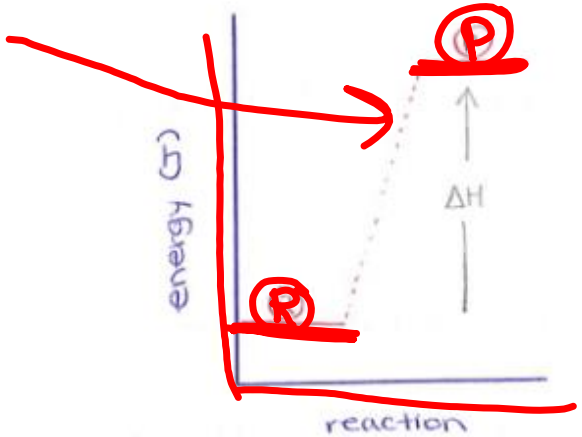
All chemical reactions either **release** or **absorb** energy...

- Reactions that **absorb energy** are referred to as ***endothermic***
  - **Temperature of surroundings decreases** as chemical bonds are broken
  - EXAMPLES: photosynthesis, cold packs

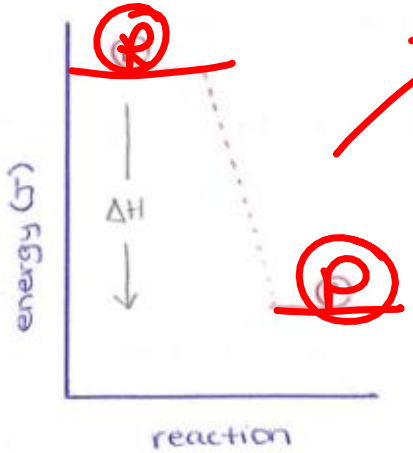
Energy Change

Endothermic

energy absorbed



Exothermic



energy released

EXAMPLES

Br_2 I_2 N_2 Cl_2 H_2 O_2 F_2 twins S_8

EXAMPLES

Write the word and chemical equations for each of the following chemical reactions. Include "energy" on the appropriate side of the arrow to show whether energy is absorbed or produced.

1. Photosynthesis is the chemical reaction performed by plants that turns carbon dioxide and water into glucose ($C_6H_{12}O_6$) and oxygen (O_2). It is endothermic.

Word

carbon dioxide + water + energy (sun) → glucose + oxygen

Chemical

$CO_{2(g)} + H_2O_{(l)} + \text{energy} \rightarrow C_6H_{12}O_{6(s)} + O_{2(g)}$

EXAMPLES

2. During the combustion of fossil fuels to produce electricity, coal is burned in the presence of oxygen gas. The products of combustion are water vapour, carbon dioxide gas, and heat energy.

EXOTHERMIC

word

coal + oxygen → water + carbon dioxide + energy

chemical

$C_{(s)} + O_{2(g)} \rightarrow H_2O_{(g)} + CO_{2(g)} + \text{energy}$

PRACTICE

PRACTICE

1. Cellular respiration is the process your body uses to turn the glucose in your food and the oxygen you breathe in into carbon dioxide, water, and energy for your body to carry out its functions. It is exothermic.

glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_{6(s)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)} + \text{energy}$

(g) or (l)

PRACTICE

2. When bread is baked the rising of the dough is caused by a chemical reaction. When baking soda ($NaHCO_3$) is heated the heat energy is absorbed and the baking soda decomposes into solid sodium carbonate, carbon dioxide gas (these are the bubbles in the bread) and water vapour.

baking soda + energy → sodium carbonate + carbon dioxide + water

$$NaHCO_{3(s)} + \text{energy} \rightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$$

3. Heat is released when sulfur trioxide is formed from sulfur dioxide and oxygen gas.

sulfur dioxide + oxygen → sulfur trioxide + energy

$$SO_{2(g)} + O_{2(g)} \rightarrow SO_{3(g)} + \text{energy}$$

PRACTICE

4. When sulfuric acid ($H_2SO_{4(aq)}$) and aqueous sodium hydroxide are mixed, the reaction is exothermic and produces sodium sulfate and water.

sulfuric acid + sodium hydroxide → sodium sulfate + water + energy

$$H_2SO_{4(aq)} + NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + \text{energy}$$

5. Energy is required to separate aluminum oxide into its elements.

aluminum oxide + energy → aluminum + oxygen

$$Al_2O_{3(s)} + \text{energy} \rightarrow Al_{(s)} + O_{2(g)}$$