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Teacher: Ms. Ella

Unit 2: Chemical reactions

4.1: Introduction of Chemical Reactions

Evidence of Chemical Reactions:

- There is an unexpected change in colour.
- Energy is released or absorbed.
- A gas is produced.
- A precipitate forms.

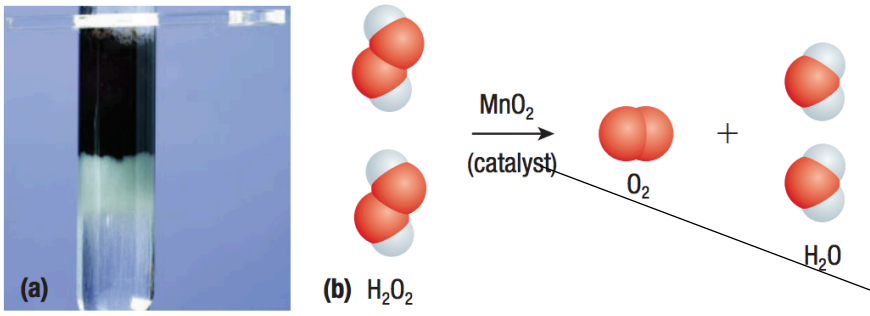


Figure 3 (a) Hydrogen peroxide breaks down in the presence of black manganese dioxide. The products are water and oxygen. (b) All the atoms in the reactants are accounted for in the products. Notice the subscripts, indicating the numbers of atoms in each molecule.

Figure 2 Adding yellow potassium chromate solution to colourless silver nitrate solution produces solid red silver chromate.

A substance that makes a chemical reaction occur faster without itself being consumed in the

Two different ways to describe chemical reactions:

Word equation: hydrogen peroxide $\xrightarrow[\text{(catalyst)}]{MnO_2}$ water + oxygen + energy

Chemical equation: $2\ H_2O_2(aq) \xrightarrow[\text{(catalyst)}]{MnO_2} 2\ H_2O(l) + O_2(g) + \text{energy}$

Table 1 State Symbols

Symbol	Meaning
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous (dissolved in water)

- chemical formulas of the reactants and products
- their state
- specific conditions required for the reaction to occur
- ratio in which the chemicals react (coefficient) – in terms of Law of conservation

Practice

1. Balance the following chemical equations: K/U C

(a) $P + O_2 \rightarrow P_2O_5$

(b) $K_2O + H_2O \rightarrow KOH$

(c) $AlBr_3 + K_2SO_4 \rightarrow KBr + Al_2(SO_4)_3$

(d) $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$

(e) $AgNO_3 + H_2S \rightarrow Ag_2S + HNO_3$

(f) $(NH_4)_2CO_3 \rightarrow NH_3 + H_2O + CO_2$

4.1 Summary

- Evidence of a chemical reaction includes colour change; absorption or release of energy; production of a gas (except evaporating or boiling of a liquid); and formation of a precipitate.
- During a chemical reaction, reactant atoms rearrange to form products.
- Chemical reactions are described using word equations or chemical equations.
- A balanced chemical equation gives the correct proportions of chemicals in a chemical reaction. As a result, it obeys the law of conservation of mass.

Homework: Textbook pg155. #1, 3, 5

There are thousands of potential reactions, each one of them unique but can always be classified into 5 major types of chemical reactions as shown below:

Reaction type	Generalization
combustion	AB + oxygen → commmon oxides of A and B
synthesis	A + B → AB
decomposition	AB → A + B
single displacement	A + BC → AC + B
double displacement	AB + CD → AD + CB

Unit 2: Chemical Reactions

4.2: Combustion, Synthesis and Decomposition reaction

Type 1: Combustion reaction

the reaction of a substance with oxygen, producing oxides and energy (exothermic reaction).

- For combustion to proceed, three things must be present: **fuel, oxygen, and heat**.
- To successfully predict the products of a **complete combustion reaction**, we must know the most common oxides.
  1) For metal: the most common oxide is the one formed with the metal's most common ion.

(common ionic charges in compounds)

1 H 1+																	2 He n/a
3 Li 1+	4 Be 2+											5 B n/a	6 C n/a	7 N 3-	8 O 2-	9 F 1-	10 Ne n/a
11 Na 1+	12 Mg 2+											13 Al 3+	14 Si n/a	15 P 3-	16 S 2-	17 Cl 1-	18 Ar n/a
19 K 1+	20 Ca 2+	21 Sc 3+	22 Ti 4+,3+,2+	23 V 5+,4+,3+,2+	24 Cr 6+,3+,2+	25 Mn 7+,4+,3+,2+	26 Fe 3+,2+	27 Co 3+,2+	28 Ni 3+,2+	29 Cu 2+,1+	30 Zn 2+	31 Ga 3+	32 Ge 4+,2+	33 As 5+,3+,3-	34 Se 2-	35 Br 1-	36 Kr n/a
37 Rb 1+	38 Sr 2+	39 Y 3+	40 Zr 4+	41 Nb 5+,3+	42 Mo 6+	43 Tc 7+,6+,4+	44 Ru 3+	45 Rh 3+	46 Pd 4+,2+	47 Ag 1+	48 Cd 2+	49 In 3+	50 Sn 4+,2+	51 Sb 5+,3+,3-	52 Te 6+,4+,2-	53 I 1-	54 Xe n/a
55 Cs 1+	56 Ba 2+	57 La 3+	72 Hf 4+	73 Ta 5+	74 W 6+	75 Re 7+,6+,4+	76 Os 4+,3+	77 Ir 4+,3+	78 Pt 4+,2+	79 Au 3+,1+	80 Hg 2+,1+	81 Tl 3+,1+	82 Pb 4+,2+	83 Bi 5+,3+	84 Po 4+,2+,2-	85 At 1+,1-	86 Rn n/a
87 Fr 1+	88 Ra 2+	89 Ac 3+	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112	113	114	115	116	117	118

Nonmetals ↕ Metals

Transition Metals

Not Yet Named

2) For non-metal: see the table

Combustion situation	Element in reactant	Common oxide
coal in a coal-fired electricity generator	carbon	$CO_{2(g)}$
burning of rocket fuel	hydrogen	$H_2O_{(g)}$
commercial production of sulfuric acid	sulfur	$SO_{2(g)}$
lightning strikes and volcanoes	nitrogen	$NO_{2(g)}$

Carbon dioxide: wood burning; living organism cellular respiration;

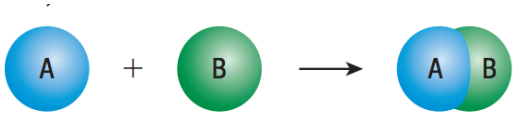
Sulphur dioxide: volcanic eruptions; contribute to natural acidity of rain forming sulfuric acid (i.e., SO_2 is being oxidized to SO_3, then react with water to become H_2SO_4);

Nitrogen dioxide: oxide from lightning strikes; plant decay; burning of gasoline at high temperature;

***Homework**: List ONE environmental issue related to combustion reactions. Write a short paragraph, approximately 300 words, to describe the phenomenon of issue and propose some practical tips and suggestions to prevent it from happening. (Hint: greenhouse effect)*

Type 2: Synthesis reaction

a chemical reaction in which two or more substances combine to form a more complex substance.



In cases where the reactants are elements:

- **Metals with non-metal**: Sodium with chlorine

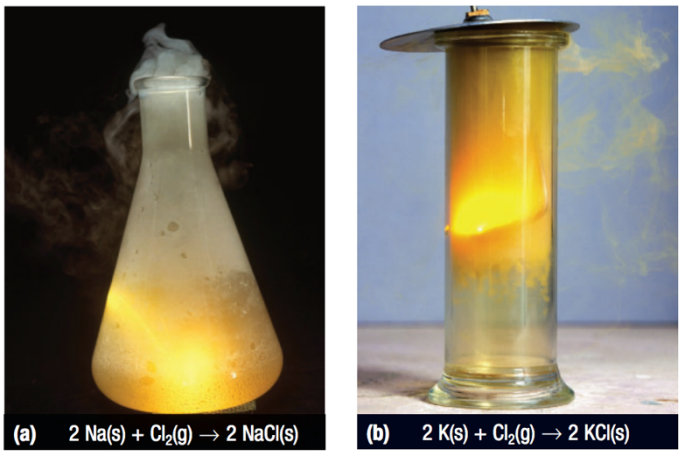


Figure 1 Alkali metals are highly reactive elements. They react with chlorine to form very stable compounds.

- Non-metals with non-metals:

  Hydrogen with chlorine produce HCl ⟶

  Nitrogen with oxygen, products can be more than one. $N_{2(g)} + O_{2(g)} \rightarrow NO_{(g)}$, then further oxidation reaction makes $NO_{(g)}$ turns into $NO_{2(g)}$, such as $NO_{(g)} + O_{2(g)} \rightarrow NO_{2(g)}$

Figure 4 Colourless hydrogen gas from the tube reacts with yellow chlorine gas in the cylinder to produce toxic hydrogen chloride gas.

- Compound with compound:

  Formation of carbonic acid when carbon dioxide is bubbled into water.

  The formation of excess carbonic acid due to increase of greenhouse gases not only increase acidity of rain, also increase ocean acidification.

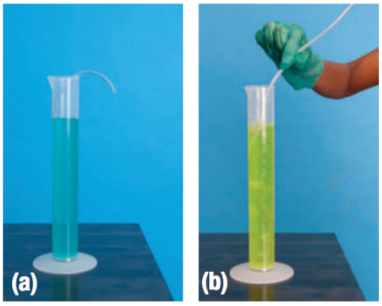


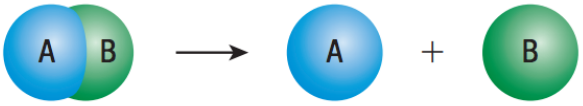
Figure 6 A colour change of bromothymol blue indicator from (a) blue to (b) yellow indicates that an acid is forming in the solution.

Example: Sulfur trioxide is a byproduct of the combustion of gasoline in car engines. In the atmosphere it reacts with condensed water on dust particles, producing sulfuric acid. Write a word equation and a balanced chemical equation for the reaction.

Figure 7 Acidification of the oceans threatens coral reefs.

Type 3: Decomposition reactions

a chemical reaction in which a compound is broken down into two or more simpler substances.



- Decomposition reactions of simple binary compounds generally yield, as products, the two elements that make up the compound.

  For instance: sodium chloride decomposes into sodium and chlorine.

  $$2NaCl_{(l)} \rightarrow 2Na_{(l)} + Cl_{2(g)}$$

- Decomposition of compounds consisting of more than two elements often decompose to form simpler compounds.

  For instance: dehydration of copper (II) sulfate pentahydrate.

  $$CuSO_4 \cdot 5H_2O_{(s)} \rightarrow CuSO_{4(s)} + 5H_2O_{(l)}$$

- **Thermal decomposition**: particularly taken place when heat applied. Even though it becomes more difficult to predict products, but the production of an oxide and water is a common result of decomposition.

$2\ KClO_3(s) \xrightarrow{heat} 2\ KCl(s) + 3\ O_2(g)$

Figure 10 The head of a match contains potassium chlorate, among other chemicals. Oxygen, a product of the decomposition reaction, makes the match burn faster.

$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$

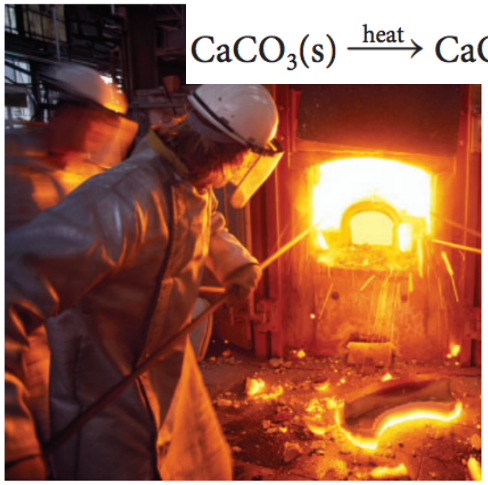


Figure 11 Cement kilns must operate at high temperatures to decompose limestone (calcium carbonate).

Teacher: Ms. Ella

Practice:

1) Decomposition of sodium hydrogen carbonate:

2) Decomposition of carbonic acid:

3) Decomposition of calcium hydroxide

4) Decomposition of aluminum nitrate:

5) Decomposition of magnesium chlorate:

6) Zinc carbonate undergoes thermal decomposition to product zinc oxide and carbon dioxide. Represent this reaction in a word equation and a balanced chemical equation.

Homework: Textbook pg161. # 1 – 8

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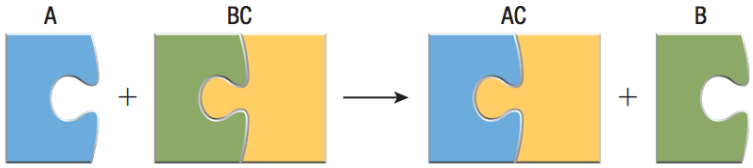
Unit 2: Chemical Reactions

4.4: Single displacement reactions

Type 4: Single displacement reactions:

the reaction of an element with a compound to produce a new element and a new compound.



- Like displaces like – a metallic element takes the place of a metal in a compound; a non-metallic element takes the place of a non-metal in a compound.
- In order to predict whether a single displacement reaction will take place, we need to refer to an Activity Series.

1) The **Activity Series** was created in terms of the concept of electronegativity. **For the metals**, the lower the electronegativity, the more reactive the metal should be.

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$$

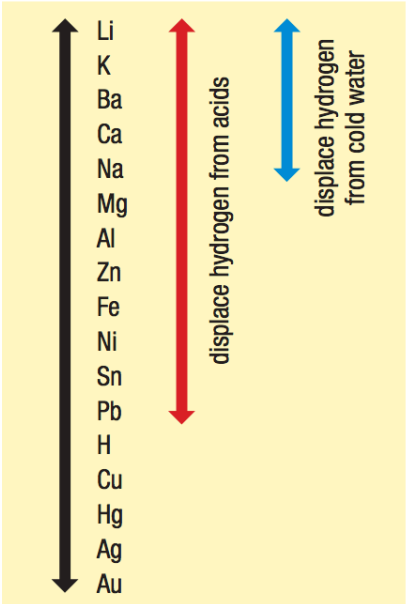
$$Li(s) + H_2SO_4(aq) \rightarrow Li_2SO_4(aq) + H_2(g)$$

$$2\,Na(s) + 2\,H_2O(l) \rightarrow 2\,NaOH(aq) + H_2(g)$$

Figure 6 The reaction of sodium metal (small ball in the centre) with water containing phenolphthalein indicator. The magenta colour of the indicator shows that hydroxide ions are being produced.

Element	Electronegativity
lithium	1.0
potassium	0.8
barium	0.9
calcium	1.0
sodium	0.9
magnesium	1.2
aluminum	1.5
zinc	1.6
iron	1.8
nickel	1.8
tin	1.8
lead	1.8
hydrogen	2.1
copper	1.9
silver	1.9
gold	2.4

most reactive



least reactive

2) For the non-metals (Halogen), the higher the electronegativity, the more reactive. Such that chorine will be displaced from a compound by fluorine.

3) The farther apart two elements are, the more likely it is that the displacement reaction will occur quickly.

Example: in welding operations, aluminum is reacted with iron (III) oxide in what is called the Thermite process. Use the activity series to predict the products of this reaction and represent the reaction in a balanced chemical equation.

Example: Use the activity series to predict whether zinc reacts with magnesium nitrate and, if so, the products of this reaction.

Example: Predict the products of the reaction (if any) between chlorine gas and a solution of sodium bromide obtained from seawater (brine). Represent the reaction in a balanced equation.

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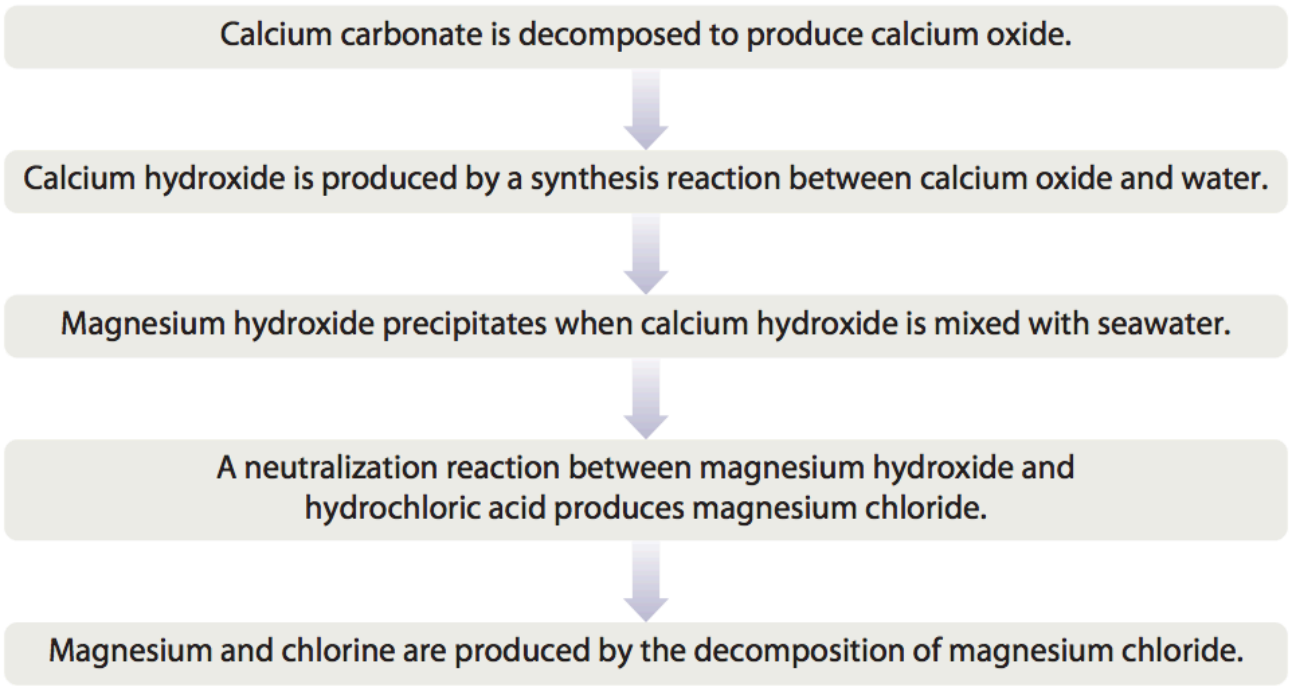
Homework: Read the text provided and answer the following questions.

Part 1: Extracting metals: Magnesium mining from seawater

1) From seawater, sodium is the most abundant cations and magnesium is the second most abundant.
2) Steps in the process of Magnesium mining



3) What happen next? Manufacturing of aluminum-magnesium alloys.

   What is alloy?

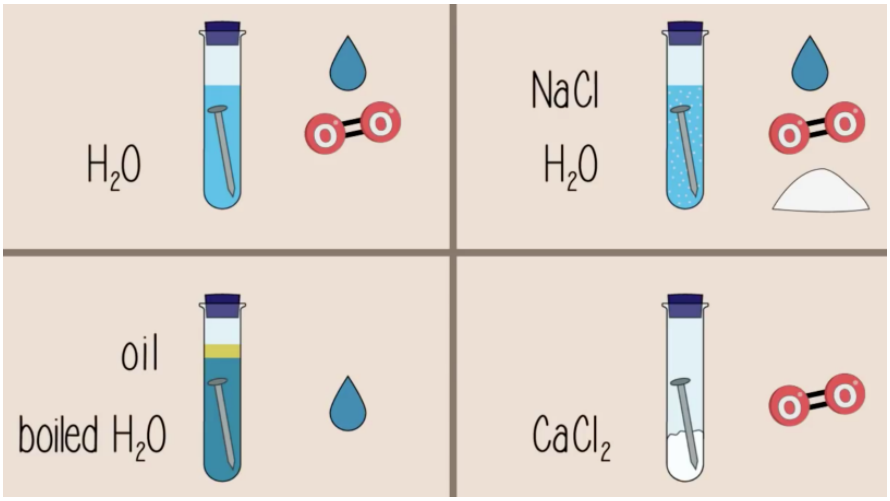
   Why alloy?

   Reason 1: Reason 2: Reason 3:

Part 2: Rusting and protection:

Rusting (or corrosion) may happen when Iron gets exposed to moisture, oxygen, and salt from surrounding atmosphere leads chemical reaction to take place. The rusting of iron will be forming hydrated iron (III) oxide that undergone an oxidation reaction.

Watch the video and take notes down: https://www.youtube.com/watch?v=jQoE_9x37mQ



How to prevent it?

Way 1:

Way 2:

Way 3:

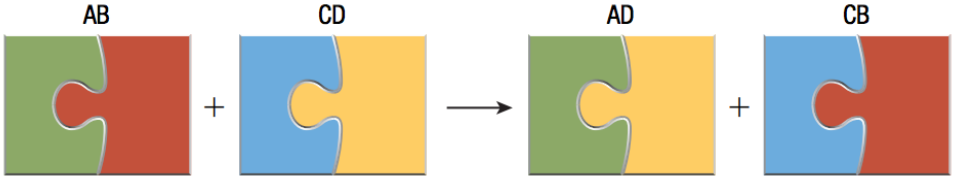
Homework: Textbook pg169. #1 – 4, 6, 8, 9

Unit 2: Chemical Reactions

4.6: Double displacement reactions

Type 5: Double displacement reactions

a reaction in which aqueous ionic compounds rearrange cations and anions, resulting in the formation of new compounds.



There are **three main types** of double displacement reaction:

1) **Precipitation reactions**

- In order to predict whether a precipitation reaction will take place, we need to refer to a Solubility Table.

Table 1 Solubility of Ionic Compounds at Room Temperature

Solubility	Ion	Exceptions
very soluble (aq) ≥ 0.1 mol/L	NO_3^-	none
	Cl^- and other halides	except with Cu^+, Ag^+, Hg_2^{2+}, Pb^{2+}
	SO_4^{2-}	except with Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
	$C_2H_3O_2^-$	Ag^+
	Na^+ and K^+	none
	NH_4^+	none
slightly soluble (s) < 0.1 mol/L	CO_3^{2-}	except with Group 1 ions and NH_4^+
	PO_4^{3-}	except with Group 1 ions and NH_4^+
	OH^-	except with Group 1 ions, Ca^{2+}, Ba^{2+}, Sr^{2+}
	S^{2-}	except with Groups 1 and 2 ions and NH_4^+

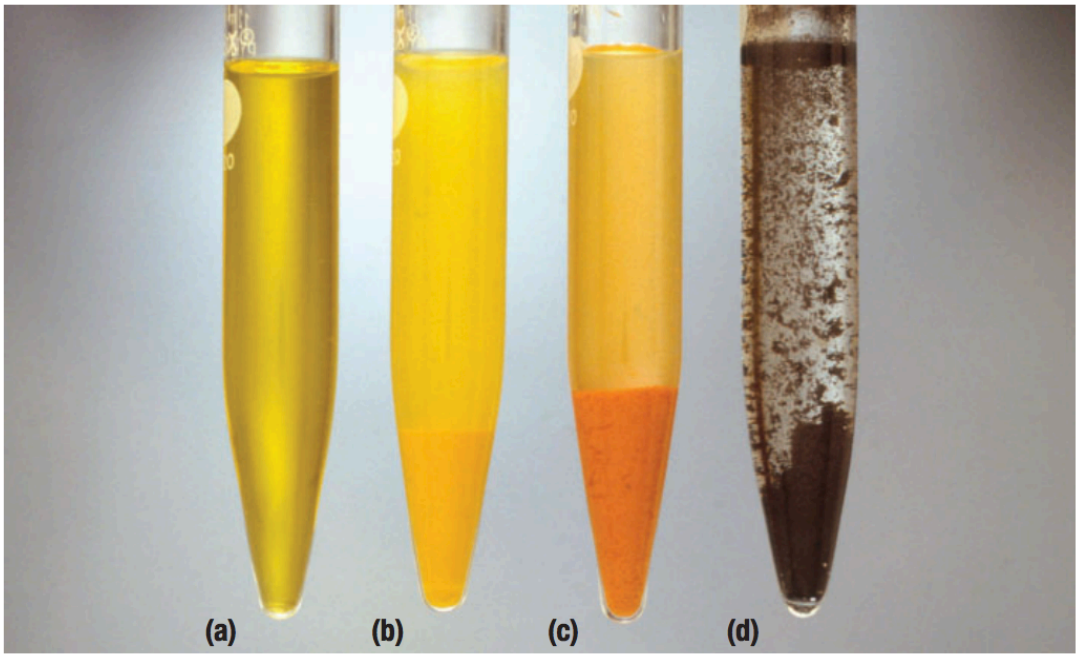


Figure 5 (a) The ammonium ion is one of the few cations whose sulfide, $(NH_4)_2S$, is very soluble. Sulfide compounds of most other cations are only slightly soluble. Examples include (b) cadmium sulfide, CdS, (c) antimony sulfide, Sb_2S_3, and (d) lead(II) sulfide, PbS.

Example: Write a balanced equation to represent the reaction of an aqueous solution of barium chloride with an aqueous solution of potassium sulfate. Indicate the physical state of the reactants and products involved.

Example: Write a balanced equation to represent the reaction of an aqueous sodium hydroxide and aqueous copper (II) sulfate.

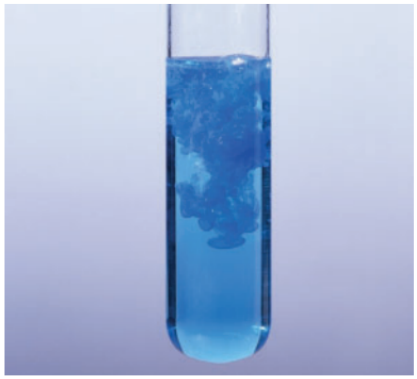


Figure 4 Combining solutions of sodium hydroxide and copper(II) sulfate produces a jellylike precipitate of copper(II) hydroxide.

		Anions						
		Cl^-, Br^-, I^-	S^{2-}	OH^-	SO_4^{2-}	CO_3^{2-}, PO_4^{3-}, SO_3^{2-}	$C_2H_3O_2^-$	NO_3^-
Cations	High solubility (aq) ≥0.1 mol/L (at SATP)	most	Group 1, NH_4^+ Group 2	Group 1, NH_4^+ Sr^{2+}, Ba^{2+}, Tl^+	most	Group 1, NH_4^+	most	all
		All Group 1 compounds, including acids, and all ammonium compounds are assumed to have high solubility in water.						
	Low Solubility (s) <0.1 mol/L (at SATP)	Ag^+, Pb^{2+}, Tl^+, Hg_2^{2+}, (Hg^+), Cu^+	most	most	Ag^+, Pb^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Ra^{2+}	most	Ag^+	none

2) Gas-producing reactions

- A double displacement reaction will take place if the reaction produces a gas

Example: Write a chemical equation when sodium sulfide solution and hydrochloric acid react to produce hydrogen sulfide gas.

3) Neutralization reactions

- When an acid and a base are mixed, water will be produced as well as a salt.

Example: How does Magnesium hydroxide react with hydrochloric acid?

4.6 Summary

- In a double displacement reaction, two elements trade places to form two new compounds. The net result is that two compounds react to form two new compounds.
  The pattern for these reactions is $AB + CD \rightarrow AD + CB$.
- Double displacement reactions can produce a precipitate, a neutralized solution, or a gas.
- Most double displacement reactions produce precipitates that can be predicted using a solubility table.
- The reaction of an acid with a base produces a neutralized solution.

Homework: Textbook pg177. #1 – 7