Chemistry 20 – Chemical Equations – Balancing and Classifying

Balance the following equations:

1) 2 $NaNO_3$ + ___ PbO → ___ $Pb(NO_3)_2$ + ___ Na_2O

2) 6 AgI + ___ $Fe_2(CO_3)_3$ → 2 FeI_3 + 3 Ag_2CO_3

3) ___ $C_2H_4O_2$ + 3 O_2 → 2 CO_2 + 2 H_2O

4) ___ $ZnSO_4$ + ___ Li_2CO_3 → ___ $ZnCO_3$ + ___ Li_2SO_4

5) ___ V_2O_5 + 5 CaS → 5 CaO + ___ V_2S_5

6) ___ $Mn(NO_2)_2$ + ___ $BeCl_2$ → ___ $Be(NO_2)_2$ + ___ $MnCl_2$

7) 3 AgBr + ___ $GaPO_4$ → ___ Ag_3PO_4 + ___ $GaBr_3$

8) 3 H_2SO_4 + 2 $B(OH)_3$ → __ $B_2(SO_4)_3$ + 3 H_2O

9) ___ S_8 + ___ O_2 → ___ SO_2

10) ___ Fe + ___ $AgNO_3$ → ___ $Fe(NO_3)_2$ + ___ Ag

Classifying Chemical Reactions

Reaction type	Generalization
formation	elements → compound
simple decomposition	compound → elements
complete combustion	substance + oxygen → most common oxides
single replacement	element + compound → element + compound (metal + compound → metal + compound or nonmetal + compound → nonmetal + compound)
double replacement	compound + compound → compound + compound

Example: Classify each of the following reactions.

1) $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ Combustion

2) $2\ Fe + 6\ NaBr \rightarrow 2\ FeBr_3 + 6\ Na$ S. R.

3) $CaSO_4 + Mg(OH)_2 \rightarrow Ca(OH)_2 + MgSO_4$ D.R.

4) $NH_4OH + HBr \rightarrow H_2O + NH_4Br$ D.R

5) $Pb + O_2 \rightarrow PbO_2$ F.

6) $Na_2CO_3 \rightarrow Na_2O + CO_2$ Decomp.

Types of Reactions Practice

Balance the following equations and indicate the type of reaction taking place:

1) ___3___ NaBr + ____ H_3PO_4 → ____ Na_3PO_4 + ___3___ HBr

Type of reaction: D.R.

2) ___3___ $Ca(OH)_2$ + ____ $Al_2(SO_4)_3$ → ___3___ $CaSO_4$ + ___2___ $Al(OH)_3$

Type of reaction: D.R

3) ___3___ Mg + ____ Fe_2O_3 → ___2___ Fe + ___3___ MgO

Type of reaction: S.R

4) ___2___ C_2H_4 + ___3___ O_2 → ___2___ CO_2 + ___2___ H_2O

Type of reaction: C.

5) ___2___ $PbSO_4$ → ___2___ $PbSO_3$ + ____ O_2

Type of reaction: D.

6) ___2___ NH_3 + ___3___ I_2 → ____ N_2I_6 + ___3___ H_2

Type of reaction: S.R.

7) ____ H_2O + ____ SO_3 → ____ H_2SO_4

Type of reaction: F.

8) ____ H_2SO_4 + ___2___ NH_4OH → ___2___ H_2O + ____ $(NH_4)_2SO_4$

Type of reaction: D.R

Practice

2. For each of the following reactions,

- classify the reaction type as formation or simple decomposition,
- predict the product(s) of the reaction,
- complete and balance the chemical equation
- ~~complete the word equation~~.

Assume the most common ion charges and that the products are at SATP.

(a) Since the Bronze Age (about 3000 B.C.E.), copper has been produced by heating the ore that contains CuO(s).

$2CuO$

copper(II) oxide $\rightarrow 2Cu(s) + O_2(g)$ decomposition

(b) When aluminium reacts with air, a tough protective coating forms. This coating helps prevent acidic substances, such as soft drinks (**Figure 4**), from reacting with the acids and thereby corroding the aluminium.

$4\,Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ formation

(c) Sodium hydroxide can be decomposed into its elements by melting it and passing electricity through it.

$2\,NaOH(l) \rightarrow 2Na(s) + O_2(g) + H_2(g)$ decomposition

(d) Very reactive sodium metal reacts with the poisonous gas chlorine to produce an inert, edible chemical.

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$ formation

(e) A frequent technological problem associated with the operation of swimming pools is that copper pipes react with aqueous chlorine.

$Cu(s) + Cl_2(aq) \rightarrow CuCl_2(s)$ formation

(f) A major scientific breakthrough occurred in 1807 when Sir Humphry Davy isolated potassium by passing electricity through molten (melted) potassium oxide.

$2K_2O(l) \rightarrow 4K(s) + O_2(g)$ decomposition

(g) When zinc is exposed to oxygen, a protective coating forms on the surface of the metal. This reaction makes zinc coating of metals (galvanizing) a desirable process for resisting corrosion.

zinc + oxygen $\rightarrow$

$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$ formation

5. Rewrite each of the following reactions as a word equation or a balanced chemical equation, and classify each reaction as formation, simple decomposition, or complete combustion. (Some reactions may have two classifications.)

(a) Electricity is used to produce elements from molten potassium bromide at a high temperature.

$2\,KBr(l) \rightarrow 2\,K(l) + Br_2(g)$

Formation

Potassium bromide decomposes into potassium and bromine gas.

(b) Coal burns in a power plant to produce heat for generating electrical energy.

carbon + oxygen → carbon dioxide

Formation

Carbon dioxide gas is formed from it's building blocks.

(d) Poisonous hydrogen sulfide from natural gas is eventually converted to elemental sulfur using this reaction as a first step in about 50 gas plants in Alberta.

$2\,H_2S(g) + 3\,O_2(g) \rightarrow 2\,SO_2(g) + 2\,H_2O(g)$

combustion

(e) Hydrogen gas may be the automobile fuel of the future.

hydrogen + oxygen → water

formation

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

(f) Toxic hydrogen cyanide gas can be destroyed in a waste treatment plant, such as the one at Swan Hills, Alberta.

Combustion

$4HCN(g) + 9O_2(g) \rightarrow$

$4CO_2(g) +$

$2H_2O(g)$

$+ 4NO_2(g)$

Four moles of hydrogen cyanide gas react with nine moles of oxygen gas to produce four moles of carbon dioxide gas, two moles of water vapour, and four moles of nitrogen dioxide gas.

Chemical Reactions in Solutions

When dealing with single and double replacement reactions we are usually dealing with reactions that are in solution. When a solute (solid chemical compound) is dissolved in a (solvent) the solution is said to be aqueous (aq).

When a reaction occurs either a new aqueous solution is formed or a precipitate is formed. But how do we know which one is form?

To distinguish between the two we use a solubility table for the products formed. The solubility table will indicate if the product is a precipitate or an aqueous solution.

To use the table you look for the anion part along the top of the table. You then determine if the cation part fits into the top row or the bottom row.

Top row → Soluble (aq) Bottom row → insoluble (s)

Ion	Cl^- Br^- I^-	S^{2-}	OH^-	SO_4^{2-}	CO_3^{2-} PO_4^{3-} SO_3^{2-}	CH_3COO^-	NO_3^- ClO_3^- ClO_4^-	Group 1 NH_4^+ H_3O^+ (H^+)
very soluble (aq) ≥ 0.1 mol/L	most	Group 1, NH_4^+, Group 2	Group 1, NH_4^+, Sr^{2+}, Ba^{2+}, Tl^+	most	Group 1, NH_4^+	most	all	all
slightly soluble (s) < 0.1 mol/L (at SATP)	Ag^+, Pb^{2+}, Tl^+, Hg_2^{2+}, Cu^+	most	most	Ag^+, Pb^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Ra^{2+}	most	Ag^+, Hg_2^{2+}	none	none

We can now use this and our previous knowledge to write balanced equations that include the states.

Example: For each of the following write a balanced equation using the states.

1. A silver nitrate solution is reacted with copper to produce silver metal and copper nitrate.

$2AgNO_3(aq) + Cu(s) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$

2. Calcium chloride solution is reacted with a sodium producing .....

$CaCl_2(aq) + 2Na(s) \rightarrow 2NaCl(aq) + Ca(s)$

Section 2.6 Questions

1. The following chemical reactions occur in a water environment (e.g., in water in a beaker). Write the balanced chemical equation, including the states of matter, (s) or (aq), for each reaction:
   (a) lead(II) nitrate + lithium chloride → lead(II) chloride + lithium nitrate
   (b) ammonium iodide + silver nitrate → silver iodide + ammonium nitrate
   (c) The net reaction during the discharge cycle of a car battery is one mole of lead and one mole of solid lead(IV) oxide reacting with two moles of sulfuric acid to produce two moles of water and two moles of lead(II) sulfate.

(a) $Pb(NO_3)_2(aq) + 2LiCl(aq) \rightarrow PbCl_2(aq) + 2LiNO_3(aq)$

(b) $NH_4I(aq) + AgNO_3(aq) \rightarrow AgI(s) + NH_4NO_3(aq)$

(c) $Pb(s) + PbO_2(s) \rightarrow 2H_2SO_4(aq) + 2H_2O(l) + 2PbSO_4(s)$

2. The following reactions occur in a water environment. Write the balanced chemical equation, including SATP states of matter, for each chemical.
   (a) Copper can be extracted from solution by reusing cans that contain iron.
   iron + copper(II) sulfate → copper + iron(III) sulfate
   (b) Water can be clarified by producing a gelatinous precipitate.
   aluminium sulfate + calcium hydroxide → aluminium hydroxide + calcium sulfate
   (c) Chlorine is used to extract bromine from sea water.
   $Cl_2(g) + 2NaBr(aq) \rightarrow Br_2(l) + 2NaCl(aq)$
   (d) During photosynthesis in a plant, carbon dioxide reacts with water to produce glucose and oxygen.
   carbon dioxide + water → glucose + oxygen

(a) $2Fe(s) + 3CuSO_4(aq) \rightarrow 3Cu(s) + Fe_2(SO_4)_3(aq)$

(b) $Al_2(SO_4)_3(aq) + 3Ca(OH)_2(aq) \rightarrow 2Al(OH)_3(s) + 3CaSO_4(s)$

(d) $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

3. Use the solubility table (**Table 1**, page 61), the generalization that all elements (except chlorine) are slightly soluble in water, and the molecular solubility in **Table 2** to predict the solubility of the following chemicals in water. Classify the chemical and then write the chemical formula with (aq) to indicate that the chemical is very soluble and with the pure state of matter, (s), (l), or (g), to indicate that the chemical is slightly soluble.
   (a) Zn (dry cell container and reactant)
   (b) P_4 (white phosphorus)
   (c) $C_{12}H_{22}O_{11}$ (sugar)
   (d) methanol (windshield and gasoline antifreeze)
   (e) octane (gasoline component)
   (f) barium sulfate (gastric X-rays)
   (g) sodium hydroxide (drain cleaner)
   (h) ammonia (window and general cleaner)
   (i) hydrogen fluoride (used to etch glass)

Answers: **(Page 64)**

1. (a) $Pb(NO_3)_2(aq) + 2\ LiCl(aq) \rightarrow PbCl_2(s) + 2\ LiNO_3(aq)$
   (b) $NH_4I(aq) + AgNO_3(aq) \rightarrow AgI(s) + NH_4NO_3(aq)$
   (c) $Pb(s) + PbO_2(s) + 2\ H_2SO_4(aq) \rightarrow 2\ H_2O(l) + 2\ PbSO_4(aq)$
2. (a) $2\ Fe(s) + 3\ CuSO_4(aq) \rightarrow 3\ Cu(s) + Fe_2(SO_4)_3(aq)$
   (b) $Al_2(SO_4)_3(aq) + 3\ Ca(OH)_2(s) \rightarrow 2\ Al(OH)_3(s) + 3\ CaSO_4(s)$
   (c) $Cl_2(g) + 2\ NaBr(aq) \rightarrow Br_2(l) + 2\ NaCl(aq)$
   (d) $6\ CO_2(g) + 6\ H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6\ O_2(g)$
3. (a) $Zn(s)$
   (b) $P_4(s)$
   (c) $C_{12}H_{22}O_{11}(aq)$
   (d) $CH_3OH(aq)$
   (e) $C_8H_{18}(l)$
   (f) $BaSO_4(s)$
   (g) $NaOH(aq)$
   (h) $NH_3(aq)$
   (i) $HF(aq)$