TRINITY COLLEGE SCHOOL

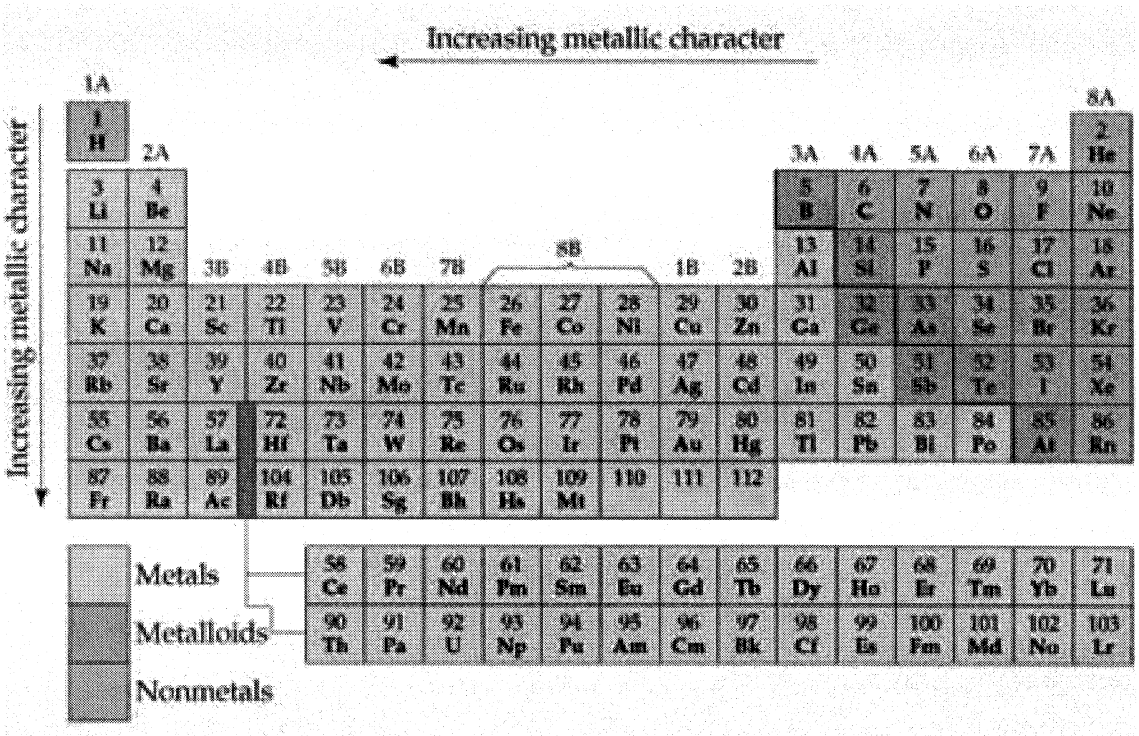
Advanced Placement Chemistry, SCH4UAP

EXAMINATION REVIEW

Equations

Combination, Decomposition & Combustion Reactions

Know these trends:



Know these properties:

TABLE 7.3 Characteristic Properties of Metals and Nonmetals

Metals	Nonmetals
Have a shiny luster; various colors, although most are silvery	Do not have a luster; various colors
Solids are malleable and ductile	Solids are usually brittle; some are hard, and some are soft
Good conductors of heat and electricity	Poor conductors of heat and electricity
Most metal oxides are ionic solids that are basic	Most nonmetallic oxides are molecular substances that form acidic solutions
Tend to form cations in aqueous solution	Tend to form anions or oxyanions in aqueous solution

Certain Nonmetals

- You should know that the following nonmetals are diatomic: **H_2, N_2, O_2, F_2, Cl_2, Br_2 & I_2.**
- Phosphorus exists as **P_4**; phosphorus oxide can exist either as **P_4O_{10}** (most likely) or as **P_4O_6.**

Combination Reactions

In ***combination*** reactions, two or more substances (elements or compounds) _____ _____ to form one product.

Reaction of Metals with Nonmetals

Such reactions are examples of *Combination Reactions*.

For example:

$Zn + I_2 \rightarrow$ _____

Note:

When reactions occur between metals such as Fe, Cu, & Sn that can form multiple ions (Fe^{2+} & Fe^{3+}; Cu^{+} & Cu^{2+}; Sn^{2+} & Sn^{4+}, etc.) and reactive nonmetals, such as O_2, Cl_2 & F_2 , the metal will always be oxidised to the ion with the higher positive charge.

For example:

$Fe + Cl_2 \rightarrow$ _____

Decomposition Reactions

During decomposition, one compound splits apart into two, or more, entities. These entities can be elements or (smaller than the original) compounds. This can be represented as:

AB --> A + B

- **If they decompose, binary compounds simply split into their constituent elements**. For example:
  - H_2O ---> ____ + ____
  - $MgCl_2$ ---> ___ + ____
  - Ag_2O ---> ____ + ___
  - $NaN_3 \rightarrow$ ____ + ___

- **Carbonates decompose – usually to give the corresponding oxide and carbon dioxide**. For example:
  - $CaCO_3$ ---> _____ + CO_2
  - Na_2CO_3 ---> _____ + CO_2
  - $Al_2(CO_3)_3$ → _____ + CO_2

- **Bicarbonates (also called hydrogen carbonates) decompose to give the corresponding carbonate, water and carbon dioxide gas.** For example:
  - $KHCO_3$ → _____ + H_2O + CO_2

- **Chlorates decompose to give the corresponding binary salt and oxygen gas.**

  For example.
  - $KClO_3$ → _____ + O_2
  - $Ba(ClO_3)_2$ → _____ + O_2

- **<u>Peroxides</u> are not particularly stable, and they decompose to form oxides and oxygen gas when heated gently.** For example:
  - Na_2O_2 ----> _____ + O_2
  - H_2O_2 ---> _____ + _____**(this even occurs if H_2O_2 is left in sunlight)**

Combustion Reactions

Combustion reactions are rapid reactions that produce a flame. Most of the combustion reactions that we observe involve O_2 (usually from air) as a reactant.

- **<u>Elements</u> react with oxygen (when heated in air or pure oxygen) to form oxides.**

  For example:
  - Mg + O_2 → _____
  - Bi + O_2 → _____
  - P_4 + O_2 → _____

    [<u>Note</u>: Although phosphorus oxide is best written as P_4O_{10}, P_4O_6 would also be acceptable]

- **<u>Organic compounds</u> undergo (complete) combustion for form CO_2 and H_2O.**
  For example:
  - $CH_4 + O_2 \rightarrow CO_2 + H_2O$
  - $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

  <u>MORE ON ORGANIC COMPOUNDS IN A SUBSEQUENT UNIT!</u>

- **When a <u>metallic (or non-metallic) sulphide</u> is strongly heated in oxygen, both the metal (or non-metal) and the sulphur are oxidised.** <u>For example:</u>
  - $PbS + O_2$ ---> _____ + SO_2
  - $Bi_2S_3 + O_2$ ----> _____ + SO_2
  - $H_2S + O_2$ ----> _____ + SO_2
  - $CS_2 + O_2$ ----> _____ + SO_2

Reactions with Nitrogen

The more reactive metals react with nitrogen gas to form nitrides. For example:

- $Ca + N_2 \rightarrow$ _____
- $Mg + N_2 \rightarrow$ _____

Questions

Give the formulas to show the reactants and the products for the following chemical equations. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. ***You need not balance.***

a) Pure solid phosphorus (white form) is burned in air.

b) Calcium metal is strongly heated in nitrogen gas.

c) A piece of solid bismuth is heated strongly in oxygen

d) White phosphorus is exposed to air

e) Butanol (C_4H_9OH) is burned in air (AP, 2000).

f) Solid sodium hydrogen carbonate (sodium bicarbonate) is strongly heated (AP, 2002)

g) Ethene gas (C_2H_4) is burned in air.

ANSWERS

a) $P_4 + O_2 \rightarrow P_4O_{10}$
b) $Ca + N_2 \text{ ---> } Ca_3N_2$
c) $Bi + O_2 \text{ ---> } Bi_2O_3$
d) $4P(s) + 5O_2(g) \text{ ---> } 2P_2O_5(s)$
e) $C_4H_{10}O + O_2 \rightarrow CO_2 + H_2O$
f) $NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$
g) $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

4.2 - Precipitation Reactions

Question 1

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a) A solution of copper(II) sulfate is added to a solution of barium hydroxide. [1991 exam]

b) Solutions of strontium nitrate and sodium sulphate are mixed. [2001 exam]

c) A solution of copper(II) chloride is added to a solution of sodium sulphide [2000 exam]

d) Solutions of sodium iodide and lead nitrate are mixed [1990 exam]

e) Solutions of tri-potassium phosphate and zinc nitrate are mixed. [1993 exam]

f) Solutions of silver nitrate and lithium bromide are mixed. [1989 exam]

Answers to Question 1

a) $Cu^{2+} + OH^- \rightarrow Cu(OH)_2$

b) $Sr^{2+} + SO_4^{2-} \rightarrow SrSO_4$

c) $Cu^{2+} + S^{2-} \rightarrow CuS$

d) $Pb^{2+} + I^- \rightarrow PbI_2$

e) $Zn^{2+} + PO_4^{3-} \rightarrow Zn_3(PO_4)_2$

f) $Ag^+ + Br^- \rightarrow AgBr$

Question 2 [AP, 1984]

The net ionic equation for the reaction between silver carbonate and hydrochloric acid is:

(A) $Ag_2CO_3(s) + 2\ H^+ + 2\ Cl^- \text{---> } 2\ AgCl(s) + H_2O + CO(g)$
(B) $2\ Ag^+ + CO_3^{2-} + 2\ H^+ + 2\ Cl^- \text{---> } 2\ AgCl(s) + H_2O + CO_2(g)$
(C) $CO_3^{2-} + 2\ H^+ \text{---> } H_2O + CO_2(g)$
(D) $Ag^+ + Cl^- \text{---> } AgCl(s)$
(E) $Ag_2CO_3(s) + 2\ H^+ \text{---> } 2Ag^+ + H_2CO_3$

10.12: AP Equations Involving Gases

Combustion Reactions

Combustion reactions are rapid reactions that produce a flame. Most of the combustion reactions that you will encounter involve O_2 (usually from air) as a reactant.

- **<u>Elements</u> react with oxygen (when heated in air or pure oxygen) to form oxides.**
  For example:
  - $Mg + O_2 \rightarrow MgO$
  - $Bi + O_2 \rightarrow Bi_2O_3$
  - $P_4 + O_2 \rightarrow P_4O_{10}$
    [<u>Note</u>: Although phosphorus oxide is best written as P_4O_{10}, P_4O_6 would also be acceptable]

- **<u>Organic compounds</u> undergo (complete) combustion for form CO_2 and H_2O.**
  For example:
  - $CH_4 + O_2 \rightarrow CO_2 + H_2O$
  - $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

- **When a <u>metallic (or non-metallic) sulphide</u> is strongly heated in oxygen, both the metal (or non-metal) and the sulphur are oxidised.** <u>For example:</u>
  - $PbS + O_2$ ---> $PbO + SO_2$
  - $Bi_2S_3 + O_2$ ----> $Bi_2O_3 + SO_2$
  - $H_2S + O_2$ ----> $H_2O + SO_2$
  - $CS_2 + O_2$ ----> $CO_2 + SO_2$

Reactions with Nitrogen

The more reactive metals react with nitrogen gas to form nitrides. For example:
- $Ca + N_2 \rightarrow Ca_3N_2$
- $Mg + N_2 \rightarrow Mg_3N_2$

Decomposition Reactions

During decomposition, one compound splits apart into two, or more, entities. These entities can be elements or (smaller than the original) compounds. This can be represented as:

$$AB \dashrightarrow A + B$$

- **If they decompose, binary compounds simply split into their constituent elements.** For example:
  - H_2O ---> $H_2 + O_2$
  - $MgCl_2$ ---> $Mg + Cl_2$
  - Ag_2O ---> $Ag + O_2$
- **Carbonates decompose – usually to give the corresponding oxide and carbon dioxide.** For example:
  - $CaCO_3$ ---> $CaO + CO_2$
  - Na_2CO_3 ---> $Na_2O + CO_2$
  - $Al_2(CO_3)_3 \rightarrow Al_2O_3 + CO_2$
  - **Note this slightly different reaction:** $(NH_4)_2CO_3 \rightarrow NH_3 + H_2O + CO_2$
- **Bicarbonates (also called hydrogen carbonates) decompose to give the corresponding carbonate, water and carbon dioxide gas.** For example:
  - $KHCO_3 \rightarrow K_2CO_3 + H_2O + CO_2$
- **Chlorates decompose to give the corresponding binary salt and oxygen gas.** For example.
  - $KClO_3 \rightarrow KCl + O_2$
  - $Ba(ClO_3)_2 \rightarrow BaCl_2 + O_2$
- **Oxyacids decompose to form an oxide (usually a gas) and water.** For example:
  - $H_2CO_3 \rightarrow H_2O + CO_2$
  - $H_2SO_3 \rightarrow H_2O + SO_2$
  - H_3PO_4 ---> $P_4O_{10} + H_2O$

  (Note: You should never write H_2CO_3 or H_2SO_3 as a product of reaction. Instead, separate the products as shown above)
- **NH_4OH will decompose to form ammonia gas (NH_3) and water**, as follows:
  - $NH_4OH \rightarrow H_2O + NH_3$

  (Note: You should never write NH_4OH as a product of reaction. Instead, separate the products as shown above)
- **Peroxides are not particularly stable, and they decompose to form oxides and oxygen gas when heated gently.** For example:
  - $Na_2O_2(s)$ ----> $Na_2O(s) + \frac{1}{2}O_2(g)$
  - $H_2O_2(l)$ ---> $H_2O(l) + \frac{1}{2}O_2(g)$ **(this even occurs if H_2O_2 is left in sunlight)**

Dimerization & Polymerization

A *dimerization* reaction is one in which two identical entities (monomers) combine to form one (dimer).

- **You will study the following equilibrium reaction in Unit I.** For example:
  - $2\ NO_2(g) \Leftrightarrow N_2O_4(g)$

A *polymerization* reaction is one in which many identical entities (monomers) combine to form one (polymer).

- **You will study Polymerization Reactions in the Organic Chemistry Unit.** For example:
  - (ethene) $nC_2H_4(g) \rightarrow$ (polyethylene) $(C_2H_4)_n$

Questions

Give the formulas to show the reactants and the products for the following chemical equations. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. ***You need not balance.***

a) A piece of solid bismuth is heated strongly in oxygen
b) Calcium metal is strongly heated in nitrogen gas.
c) White phosphorus is exposed to air
d) Butanol is burned in air (AP, 2000)
e) Solid sodium hydrogen carbonate (sodium bicarbonate) is strongly heated (AP, 2002)
f) Ethene gas is burned in air.

ANSWERS

(a) $Bi + O_2 \text{ ---> } Bi_2O_3$
(b) $Ca + N_2 \text{ ---> } Ca_3N_2$
(c) $4P(s) + 5O_2(g) \text{ ---> } 2P_2O_5(s)$
(d) $C_4H_{10}O + O_2 \rightarrow CO_2 + H_2O$
(e) $NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$
(f) $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

16.2 - Strong and Weak Acids and Bases

Strong and Weak Acids

A small percentage of all acids are considered to be ***strong acids***, acids that are completely ionized in aqueous solution.

All of the remaining common acids are ***weak acids***, meaning that, when they are dissolved in water, only a small percentage of the molecules dissociate into ions.

Strong acids are strong electrolytes; weak acids are weak electrolytes.

LEARN the "Big Six" Strong Acids

$HClO_4$ (perchloric acid)
HNO_3 (nitric acid)
HCl, HBr, HI (hydrochloric, hydrobromic, and hydroiodic acids)
H_2SO_4 (sulphuric acid)

As far as the AP Chemistry course is concerned, these six are the only strong acids that you are required to know. Since they completely ionize, they should always be written in ionic form in an equation (either as reactants or as products).

It is safe to assume that any other acid that you come across in this course will be a weak (or 'moderate') acid and it should, therefore, be written in molecular, rather than ionic, form. Two common examples of moderate acids that you should know are:

H_3PO_4 (phosphoric acid)
$(COOH)_2$ (oxalic acid)

By definition, the **strong acids** are 100% ionized in aqueous solution and should, therefore, always be written in ionic, rather than molecular, form. In other words, strong acids should be written as represented on the **right** hand side of the following equations:

(perchloric acid)	**$HClO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + ClO_4^-(aq)$**
(nitric acid)	**$HNO_3(aq) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$**
(hydrochloric acid)	**$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$**
(hydrobromic acid)	**$HBr(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Br^-(aq)$**
(hydroiodic acid)	**$HI(aq) + H_2O(l) \rightarrow H_3O^+(aq) + I^-(aq)$**
(sulphuric acid)	**$H_2SO_4(aq) + 2\,H_2O(l) \rightarrow 2\,H_3O^+(aq) + SO_4^{2-}(aq)$**

By definition, the **weak acids** are only slightly ionized in aqueous solution and should, therefore, always be written in molecular, rather than ionic, form. In other words, they should be written as represented on the **left** hand side of the following equations (note the double arrows!):

(hydrofluoric acid)	**$HF(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + F^-(aq)$**
(carbonic acid)	**$H_2CO_3(aq) + 2\,H_2O(l) \leftrightarrow 2\,H_3O^+(aq) + CO_3^{2-}(aq)$**
(phosphoric acid)	**$H_3PO_4(aq) + 3\,H_2O(l) \leftrightarrow 3\,H_3O^+(aq) + PO_4^{3-}(aq)$**

The majority of weak acids are organic (carboxylic) acids.

YOU WILL LEARN A LOT MORE ABOUT *WEAK ACIDS* LATER IN THIS UNIT!

It is worth remembering at this time that acidic solutions are also created by certain substances that react with water to form $H^+(aq)$ions.
You have already learned that non-metal oxides react with water to form acidic solutions. For example:

$$SO_2(g) + H_2O(l) \rightarrow SO_3^{2-}(aq) + 2H^+(aq)$$

Strong and Weak Bases

Strong bases are bases that produce a high concentration of $OH^-(aq)$ ions in aqueous solution.

As with strong acids, there are also relatively few common strong bases.

Soluble hydroxides and **soluble carbonates** will produce strong bases.

Since most hydroxides have low solubilities, very few hydroxides form strong bases. **The hydroxides of the Group IA Alkali Metals have high solubilities and, therefore, produce strong bases; $Ba(OH)_2$ and $Sr(OH)_2$ are moderately soluble hydroxides that produce moderately strong bases**.

Learn these five important Strong Bases:

LiOH, NaOH, KOH, $Ba(OH)_2$, $Sr(OH)_2$

Soluble carbonates (which, for all practical purposes, means the carbonates of the Group IA Alkali metals also produce moderately strong bases when dissolved in water since the carbonate ion reacts with water molecules according to the equation:

$$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \text{ ----> } HCO_3^-{}_{(aq)} + OH^-{}_{(aq)}$$

Strongly basic solutions are also created by certain substances that react with water to form OH^- *(aq)*ions. The most common of these contain the oxide ion. You have already learned that metal oxides react with water to form basic solutions. For example:

$$K_2O(s) + H_2O(l) \rightarrow 2\ K^+(aq) + 2\ OH^-(aq)$$

Ionic hydrides also react with H_2O to form OH^-. For example:

$$LiH + H_2O \text{ ---> } Li^+ + OH^- + H_2$$

AP Question

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1. Solid cesium oxide is added to water. [2002, Form A]
2. Sulphur dioxide gas is bubbled into a beaker of water. [2002, Form B]
3. Solid calcium hydride is added to distilled water. [1995]
4. Phosphorous(V) oxide powder is sprinkled over distilled water. [1994]
5. Sulfur trioxide gas is added to excess water. [1988]
6. Powdered strontium oxide is added to distilled water. [2000]
7. Calcium oxide powder is added to distilled water. [1999]
8. Solid sodium oxide is added to distilled water. [1998]
9. Drops of liquid dinitrogen trioxide are added to distilled water. [1996]
10. Solid lithium hydride is added to water. [1992]
11. Samples of boron trichloride gas and ammonia gas are mixed. [1989]

Answers

1. $Cs_2O + H_2O \rightarrow Cs^+ + OH^-$ (Note: Alkali metal hydroxides are soluble)
2. $SO_2 + H_2O \rightarrow H_2SO_3$ (Note: H_2SO_3 is a weak acid and is written in molecular, not ionic, form)
3. $CaH_2 + H_2O \text{ --> } Ca(OH)_2 + H_2$ (Note: $Ca(OH)_2$ is only slightly soluble!)
4. $P_4O_{10} + H_2O \text{ ---> } H_3PO_4$ (Note: H_3PO_4 is a moderateacid and is written in molecular, not ionic, form)
5. $SrO + H_2O \rightarrow Sr^{2+} + OH^-$ (or $Sr(OH)_2$ since it is not very soluble!)
6. $CaO + H_2O \rightarrow Ca(OH)_2$ (Note: $Ca(OH)_2$ is only slightly soluble!)
7. $Na_2O + H_2O \rightarrow Na^+ + OH^-$ (Note: Alkali metal hydroxides are soluble)
8. $N_2O_3 + H_2O \text{ ---> } HNO_2$ (Note: HNO_2 is a weak acid and is written in molecular, not ionic, form)
9. $LiH + H_2O \text{ ---> } Li^+ + OH^- + H_2$
10. $BCl_3 + NH_3 \text{ ---> } Cl_3BNH_3$
11. $SO_3 + H_2O \rightarrow H^+ + SO_4^{2-}$ (Note: H_2SO_4 is a strong acid and is written in ionic, not molecular, form)

16.11: Writing (Net Ionic) Equations for Reactions involving Acids and Bases

You have already encountered numerous AP equations in this course. This handout contains AP equations that involve acids, either as reactants or as products.

Reactions of Acids

Reaction of Acids with Hydroxides

Neutralization occurs, in which: $H^+ + OH^- \rightarrow H_2O$

Notes:
1. Most hydroxides are insoluble.
2. LiOH, NaOH, KOH, $Ba(OH)_2$ and $Sr(OH)_2$ are all soluble and, consequently, form **strong bases** in aqueous solution.
3. The anion from the acid and the cation from the hydroxide are usually spectator ions. However, they sometimes precipitate out of solution.

Examples:
1. Sulphuric acid + sodium hydroxide solution:
   $H^+ + OH^- \text{ ----> } H_2O$ (both the SO_4^{2-} and Na^+ are spectator ions)
2. Sulphuric acid + barium hydroxide solution
   $H^+ + SO_4^{2-} + Ba^{2+} + OH^- \rightarrow H_2O + BaSO_4$ (since $BaSO_4$ is insoluble)

Reaction of Acids with Carbonates and with Hydrogen Carbonates

(Carbonates): Neutralization occurs, in which: $H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$
(Hydrogen Carbonates): Neutralization occurs, in which: $H^+ + HCO_3^- \rightarrow H_2O + CO_2$

Notes:
1. Most carbonates are **insoluble**. The carbonates of the alkali metals being the notable exceptions.
2. The anion from the acid and the cation from the carbonate are usually spectator ions. However, they sometimes precipitate out of solution.

Examples:
1. Sulphuric acid + sodium carbonate solution:
   $H^+ + CO_3^{2-} \text{ ----> } H_2O + CO_2$ (the SO_4^{2-} and Na^+ are spectator ions)
2. Hydrochloric acid + solid calcium carbonate
   $CaCO_3 + H^+ \text{ ----> } Ca^{2+} + H_2O + CO_2$ (the Cl^- from the acid are spectator ions)
3. Hydrochloric acid + potassium hydrogen carbonate solution
   $H^+ + HCO_3^- \rightarrow H_2O + CO_2$ (HCl is a strong acid and ∴ ionized; Cl^- are spectator ions)

Reaction of Acids with Metallic Sulphides

Hydrogen sulphide gas (H_2S) is formed.

Note:

1. Most sulphides are insoluble. The sulphides of the alkali metals being the notable exceptions.

Example:

1. Hydrochloric acid + solid zinc sulphide:
   $H^+ + ZnS^- \rightarrow H_2S + Zn^{2+}$ (the Cl^- ions from the acid are spectators)

Reaction of Acids with Metals

METALS WITH DILUTE SOLUTIONS OF STRONG ACIDS (excluding HNO_3)

Redox reactions occur when metals react with a dilute solution of strong acids

Examples:

1. Dilute sulphuric acid + magnesium:
   $H^+ + Mg \rightarrow H_2 + Mg^{2+}$ (the SO_4^{2-} ions are spectator ions)
2. Dilute hydrochloric acid + aluminum
   $H^+ + Al \rightarrow H_2 + Al^{3+}$ (the Cl^- from the acid are spectator ions)

METALS WITH DILUTE NITRIC ACID

HNO_3 is a powerful oxidising agent, and this is why it is usually employed in reactions.

One example you should know for AP Chemistry:

Copper + dilute HNO_3

$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO + H_2O$

METALS WITH CONCENTRATED ACIDS

There are, obviously, numerous different reactions involving concentrated solutions of strong acids. Unfortunately, they do not follow any general patterns, and are difficult to summarise.
You should, however, be aware of the following:

Copper + concentrated HNO_3

$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO_2 + H_2O$

Copper +concentrated sulphuric acid

$Cu + H^+ + SO_4^{2-} \rightarrow Cu^{2+} + SO_2 + H_2O$

Miscellaneous Reactions Involving Acids

Preparation of chlorine gas

1. $MnO_2 + H^+ + Cl^- \rightarrow Mn^{2+} + Cl_2 + H_2O$
2. $KMnO_4 + H^+ + Cl^- \rightarrow K^+ + Mn^{2+} + Cl_2 + H_2O$

Reactions of Hydroxides

Miscellaneous Reactions Involving Aqueous Solutions of NaOH and KOH

Reaction with Hydrogen Sulphide (H_2S) gas

Hydrogen Sulphide is a *weak acid*, ∴ **neutralization** occurs

$H_2S + OH^- \rightarrow S^{2-} + H_2O$ (K^+ ions are *spectator*)

Reaction with Chlorine gas

$Cl_2 + OH^- \rightarrow OCl^- + Cl^- + H_2O$

Reaction with Solid Ammonium Chloride

$NH_4Cl + OH^- \rightarrow NH_3 + Cl^- + H_2O$

Precipitation Reactions Involving Acids and Bases

You covered precipitation reactions earlier in this course. Acids and bases can participate in such reactions.

Reactions of Oxides

You have already learned that **metals tend to form ionic *oxides* that are *basic*; whereas non-metals tend to form covalent oxides that are *acidic*. Aluminum, chromium and zinc form *amphoteric* oxides.**

REACTIONS OF IONIC (BASIC) OXIDES

Reaction With Water

Most ionic oxides are insoluble in water, but those that do dissolve (oxides of Group IA & IIA metals) form OH^- ions:

Examples: **$Na_2O + H_2O \rightarrow Na^+ + OH^-$** (since NaOH is very soluble)

$CaO(s) + H_2O \rightarrow Ca(OH)_2$ (since $Ca(OH)_2$ is only slightly soluble)

Reaction With Acids

Since ionic oxides are **basic**, a **neutralization** reaction will occur when an ionic oxide reacts with a base (**salt** and **water** being formed).

Example: magnesium oxide with (dilute) sulphuric acid

$MgO + H^+ \rightarrow Mg^{2+} + H_2O$ (since H_2SO_4 is completely ionized)

REACTIONS OF COVALENT (ACIDIC) OXIDES

Reaction With Water

Covalent oxides usually dissolve in water and, when they do so, an **acid** is formed.

Examples: **$SO_3 + H_2O \rightarrow SO_4^{2-} + H^+$** (since H_2SO_4 is a strong acid)

$CO_2 + H_2O \rightarrow H_2CO_3$ (since H_2CO_3 is a weak acid)

$P_4O_{10} + H_2O \rightarrow H_3PO_4$ (since H_3PO_4 is a weak acid)

Reaction With Bases

Since covalent oxides are **acidic**, a **neutralization** reaction will occur when a covalent oxide reacts with a base (**salt** and **water** being formed).

Example: the reaction of sulphur trioxide gas with sodium hydroxide solution

$SO_3 + OH^- \rightarrow SO_4^{2-} + H_2O$

REACTIONS OF AMPHOTERIC OXIDES

Amphoteric oxides (such as Al_2O_3, Cr_2O_3 and ZnO) do not dissolve in water but, since they are amphoteric, they react with **acids** and with **bases**.

For example: $\mathbf{Al_2O_3 + H^+ \text{ ----> } Al^{3+} + H_2O}$

$\mathbf{Al_2O_3 + OH^- \text{ ----> } Al(OH)_4^- + H_2O}$

Reactions of Hydrides

Reaction with Water

Metallic (ionic) hydrides react with H_2O to form OH^-.

For example:

$$LiH + H_2O \text{ ---> } Li^+ + OH^- + H_2$$

A Final Note Regarding H_2CO_3, H_2SO_3 & NH_4OH

Aqueous solutions of H_2CO_3, H_2SO_3 and NH_4OH readily decompose with gases being produced in each case. If they are present as products then break them up as follows:

$\mathbf{H_2CO_3 \rightarrow H_2O + CO_2}$

$\mathbf{H_2SO_3 \rightarrow H_2O + SO_2}$

$\mathbf{NH_4OH \rightarrow H_2O + NH_3}$

AP Question

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1. Solid cesium oxide is added to water. [2002, Form A]
2. Sulphur dioxide gas is bubbled into a beaker of water. [2002, Form B]
3. Solutions of potassium hydroxide and propanoic acid are mixed. [2001]
4. Excess hydrobromic acid solution is added to a solution of potassium hydrogen carbonate. [2000]
5. Solid lead carbonate is added to 0.5 M sulphuric acid solution. [1999]
6. Solutions of cobalt(II) nitrate and sodium hydroxide are mixed. [1998]
7. Excess potassium hydroxide solution is added to a solution of aluminum nitrate. [1997]
8. Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide. [1995]
9. Excess concentrated sulfuric acid is added to solid calcium phosphate. [1995]
10. Solid calcium hydride is added to distilled water. [1995]
11. Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide. [1994]
12. A concentrated solution of hydrochloric acid is added to solid potassium permanganate. [1994]
13. A strip of copper is immersed in dilute nitric acid. [1993]
14. Concentrated hydrochloric acid is added to solid manganese(II) sulfide. [1993]
15. Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide. [1993]
16. An excess of sodium hydroxide solution is added to a solution of magnesium nitrate. [1992]
17. Solid lithium hydride is added to water. [1992]
18. Solid aluminum oxide is added to a solution of sodium hydroxide. [1991]
19. A concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated. [1991]
20. Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide. [1990]

Answers

1. $Cs_2O + H_2O \rightarrow Cs^+ + OH^-$ (Note: Alkali metal hydroxides are soluble)
2. $SO_2 + H_2O \rightarrow H_2SO_3$ (Note: H_2SO_3 is a weak acid and is written in molecular, not ionic, form)
3. $OH^- + C_2H_5COOH \rightarrow C_2H_5COO^- + H_2O$ (Neutralization; C_2H_5COOH is a weak acid, ∴molecular)
4. $H^+ + HCO_3^- \rightarrow H_2O + CO_2$ (HBr is a strong acid and ∴ ionized; Br^- are spectator ions)
5. $PbCO_3 + H^+ \rightarrow PbSO_4 + CO_2 + H_2O$ ($PbSO_4$ is only slightly soluble)
6. $Co^{2+} + OH^- \rightarrow Co(OH)_2$
7. $Al^{3+} + OH^- \text{---> } Al(OH)_3$
8. $Cl_2 + OH^- \text{ --> } OCl^- + Cl^- + H_2O$
9. $H^+ + SO_4^{2-} + Ca_3(PO_4)_2 \rightarrow H_3PO_4 + CaSO_4$ (H_2SO_4 is a strong acid, H_3PO_4 is weak; $CaSO_4$ has a low solubility)
10. $CaH_2 + H_2O \text{ --> } Ca^{2+} + OH^- \text{ (or } Ca(OH)_2) + H_2$ ($Ca(OH)_2$ has a moderate solubility)
11. $CO_2 + OH\text{- ---> } CO_3^{2-} + H_2O$ (K^+ ions are spectators)
12. $KMnO_4 + H^+ + Cl^- \text{ --> } K^+ + Mn^{2+} + Cl_2 + H_2O$
13. $Cu + H^+ + NO_3^- \text{ --> } Cu^{2+} + NO + H_2O$
14. $H^+ + MnS \text{ --> } H_2S + Mn^{2+}$
15. $SO_2 + OH^- \text{ --> } HSO_3^-$
16. $Mg^{2+} + OH^- \text{ --> } Mg(OH)_2$
17. $LiH + H_2O \text{ ---> } Li^+ + OH^- + H_2$
18. $Al_2O_3 + OH^- \text{ ---> } Al(OH)_4^-$
19. $H^+ + Cl^- + MnO_2 \text{ ---> } Mn^{2+} + Cl_2 + H_2O$
20. $H_2S + OH^- \text{ -----> } S^{2-} + H_2O$

17.12: Neutralization Revisited

Neutralization Reactions Involving Monoprotic Acids

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1) Solutions of potassium hydroxide and propanoic acid are mixed. [2001]

2) Excess hydrobromic acid solution is added to a solution of potassium hydrogen carbonate. [2000]

3) Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide. [1994]

Answers

1. $OH^- + C_2H_5COOH \rightarrow C_2H_5COO^- + H_2O$ (Neutralization; C_2H_5COOH is a weak acid, ∴molecular)
2. $H^+ + HCO_3^- \rightarrow H_2O + CO_2$ (HBr is a strong acid and ∴ ionized; Br^- are spectator ions)
3. $CO_2 + OH^- \text{---> } CO_3^{2-} + H_2O$ (K^+ ions are spectators)

Stepwise Dissociation of Triprotic Acids

Phosphoric acid (a *weak* acid) dissociates in three steps - one proton being lost in each step...

H_3PO_4 <----> $H_2PO_4^-(aq) + H^+(aq)$

$H_2PO_4^-(aq)$ <----> $HPO_4^{2-}(aq) + H^+(aq)$

$HPO_4^{2-}(aq)$ <----> $PO_4^{3-}(aq) + H^+(aq)$

The product, or products, formed in the neutralization of a polyprotic acid depends upon the amount of base used. When one mole of hydroxide ions per mole of phosphoric acid reacts, the equation is...

$3H^+(aq) + PO_4^{3-}(aq) + OH^-(aq)$ ----> $H_2PO_4^-(aq) + H_2O$

However, when two moles of hydroxide ions per one mole of phosphoric acid reacts, the equation is...

$3H^+(aq) + PO_4^{3-}(aq) + 2OH^-(aq)$ ----> $HPO_4^{2-}(aq) + 2H_2O$

And, when three moles of hydroxide ions per mole one mole of phosphoric acid reacts, the equation is... $3H^+(aq) + 3OH^-(aq)$ ----> $3H_2O$ (the PO_4^{3-} ions are spectator)

AP Questions

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1) Equal volumes of 0.1 M sodium phosphate and 0.1 M hydrochloric acid are mixed. [2002, Form B]

2) Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed. [1998]

3) Equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed. [1996]

4) Equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed. [1991]

Answers

1. $PO_4^{3-} + H^+ \rightarrow HPO_4^{2-}$
2. $H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$ (H_3PO_4 is a weak acid, ∴ molecular)
3. $HPO_4^{2-} + H^+$ ---> $H_2P0_4^-$ (Na^+ ions are spectators)

20.11 - Common Oxidising & Reducing Agents

Two of the most common **oxidising agents** employed in the laboratory are permanganate (MnO_4^-) and dichromate ($Cr_2O_7^{2-}$). These two oxidising agents are usually employed in **acid solution**, where the **reduction half-equations** are as follows:

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$
(PURPLE) **(LIGHT PINK)**

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$
(ORANGE) **(GREEN)**

If you come across reactions involving either permanganate or dichromate, it is safe to assume that they will be redox reactions, and that the MnO_4^- or $Cr_2O_7^{2-}$ ions will be reduced.

Permanganate is also employed as an oxidising agent in both **neutral** and **basic** solutions. The corresponding half-equations are as follows:

NEUTRAL (OR SLIGHTLY ACIDIC)

$MnO_4^-(aq) + 4H^+(aq) + 3e^- \longrightarrow MnO_2(s) + 4H_2O$
(PURPLE) **(BLACK PPT.)**

BASIC

$MnO_4^-(aq) + e^- \longrightarrow MnO_4^{2-}(aq)$
(PURPLE) **(GREEN)**

Something else, obviously, will be oxidised, and here are some possibilities for the **oxidation half equations:**

$Fe^{2+} \longrightarrow Fe^{3+} + e^-$
$Sn^{2+} \longrightarrow Sn^{4+} + 2e^-$
$2\,I^- \longrightarrow I_2 + 2e^-$ **(Note: I_2 is purple in colour)**
$2\,Br^- \longrightarrow Br_2 + 2e^-$ **(Note: Br_2 is orange/brown in colour)**
$C_2O_4^{2-} \longrightarrow 2\,CO_2 + 2e^-$
$SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2\,H^+ + 2e^-$
$H_2O_2 \longrightarrow O_2 + 2\,H^+ + 2e^-$

Other possibilities are listed on the Table of Standard Reduction Potentials.

Question 1

A 0.1-molar solution of which of the following ions is orange?
(A) $Fe(H_2O)_4^{2+}$
(B) $Cu(NH_3)_4^{2+}$
(C) $Zn(OH)_4^{2-}$
(D) $Zn(NH_3)_4^{2+}$
(E) $Cr_2O_7^{2-}$ {E}

Question 2 [AP, 1984]

When a solution of potassium dichromate is added to an acidified solution of iron(II) sulfate, the products of the reaction are
(A) $FeCr_2O_7(s)$ and H_2O
(B) $FeCrO_4(s)$ and H_2O
(C) Fe^{3+}, CrO_4^{2-}, and H_2O
(D) Fe^{3+}, Cr^{3+}, and H_2O
(E) $Fe_2(SO_4)_3(s)$, Cr^{3+} and H_2O {D}

AP Equations Involving REDOX Reactions

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1. Acidified solutions of potassium permanganate and iron(II) nitrate are mixed together. [2002, Form A]

2. A bar of iron metal is added to a solution of iron(III) chloride. [2002, Form B]

3. Solutions of tin(II) chloride and iron(III) chloride are mixed. [1998]

4. A piece of nickel metal is immersed in a solution of copper(II) sulfate. [1996]

5. Solutions of potassium permanganate and sodium oxalate are mixed. [1996]

6. A bar of zinc metal is immersed in a solution of copper(II) sulfate. [1995]

7. A solution of potassium dichromate is added to an acidified solution of iron(II) chloride. [1994]

8. Potassium permanganate solution is added to an acidic solution of hydrogen peroxide. [1993]

Equations for Reactions Involving Metals

Reaction of Metals with Nonmetals

Such reactions are examples of *Combination Reactions*. They are also *Redox Reactions* (later in the course!).

For example:

$Zn + I_2 \rightarrow$ _____

Note:

When reactions occur between metals such as Fe, Cu, & Sn that can form multiple ions (Fe^{2+} & Fe^{3+}; Cu^{+} & Cu^{2+}; Sn^{2+} & Sn^{4+}, etc.) and reactive nonmetals, such as O_2, Cl_2 & F_2 , the metal will always be oxidised to the ion with the higher positive charge.

For example:

$Fe + Cl_2 \rightarrow$ _____

Reaction of Metals with Water (or Steam)

- The metal atoms are oxidized to metal ions.
- The water molecules are reduced ($2H_2O + 2e^- \text{---> } 2OH^- + H_2$)

For example....

$Na + H_2O \text{ ---> } \_\_\_\_ + OH^- + H_2$

$Ca + H_2O \text{ ---> } \_\_\_\_ + OH^- + H_2$

Reaction of Metals with Dilute Acids

- The metal atoms are oxidized to metal ions.
- The hydrogen ions in the acid are reduced ($2H^+ + 2e^- \text{---> } H_2$)
- The anions in the acid are *spectator ions*.

For example....

$Na + H^+ \text{ ---> } Na^+ + H_2$

$Ca + H^+ \text{ ---> } Ca^{2+} + H_2$

Reaction of Metals with Metal Salt Solutions (Single Displacement Reactions)

- The metal atoms are oxidized to metal ions.
- The metal ions are reduced to metal atoms.
- The anions combined originally with the metallic cations are spectator ions.

For example....

$$Cu + Ag^{+} \text{ ---> } Cu^{2+} + Ag$$
$$Al + Cu^{2+} \text{ ---> } Al^{3+} + Cu$$

(Special) Reactions involving Fe^{2+} and Fe^{3+} ions

$$Fe(s) + 2\ Fe^{3+}(aq) \text{ ----> } 3\ Fe^{2+}(aq)$$

$$Fe^{2+}(aq) + Cl_2(aq) \text{ ----> } Fe^{3+}(aq) + 2\ Cl^{-}(aq)$$

Questions

Give the formulas to show the reactants and the products for the following chemical equations. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. ***You need not balance.***

a) Pure solid phosphorus (white form) is burned in air.

b) Calcium metal is strongly heated in nitrogen gas.

c) A piece of aluminum metal is added to a solution of silver nitrate.

d) A small piece of calcium metal is added to hot distilled water (2000).

e) Zinc metal is added to a solution of copper(II) nitrate.

f) A mixture of powdered iron (III) oxide and powdered aluminum is heated strongly (1999)

ANSWERS

a. $P_4 + O_2 \rightarrow P_4O_{10}$
b. $Ca + N_2 \text{ ---> } Ca_3N_2$
c. $Al + Ag^+ \text{ ----> } Al^{3+} + Ag$
d. $Ca + H_2O \rightarrow Ca^{2+} + H_2 + OH^-$
e. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$
f. $Fe_2O_3 + A^o \rightarrow Fe + Al_2O_3$

22.2: Additional Equations for Reactions involving Non-metals

You have already encountered numerous AP equations in this course, and many of these equations involve non-metallic elements. This handout contains some additional reactions that involve non-metals.

Reactions involving Hydrogen

Reaction of Hydrogen with Active Metals

Ionic hydrides are formed when the *alkali metals* and the heavier *alkaline earths* (Ca, Sr, and Ba) react with hydrogen. These active metals are less electronegative than hydrogen. Consequently, hydrogen acquires electrons from them to form hydride, H^-, ions as illustrated below:

$$Na + H_2 \rightarrow NaH$$

$$Ca + H_2 \rightarrow \_\_\_\_\_$$

Metallic hydrides, like metallic oxides, are basic. Solid calcium hydride, CaH_2, would, therefore, react with water as follows:

$$CaH_2 + H_2O \rightarrow \_\_\_\_\_ + \_\_\_\_\_ + H_2$$

Reaction of Hydrogen with Non-metals

Molecular hydrides are formed by non-metals reacting with hydrogen. For example:

$$N_2 + H_2 \rightarrow NH_3$$

$$H_2 + Cl_2 \rightarrow \_\_\_\_\_$$

$$H_2 + O_2 \rightarrow \_\_\_\_\_$$

Reaction of Hydrogen with Metal Oxides

Hydrogen is an effective reducing agent for many metal oxides. For example, when H_2 is passed over heated CuO, copper is produced.

$$CuO + H_2 \rightarrow Cu + H_2O$$

Reactions of Halogens

Halogens tend to gain electrons from other substances and thereby serve as oxidizing agents. The oxidizing ability of the halogens is, of course, indicated by their E^o values.

Question

Write the balanced equation for the reaction, if any, that occurs between **(a)** $I^-(aq)$ and $Br_2(l)$; **(b)** $Cl^-(aq)$ and $I_2(s)$. {***Ans***: (a) reaction; (b) no reaction}

Reactions involving Nitrogen

The N_2 molecule is very unreactive because of the strong triple bond between nitrogen atoms. When substances burn in air, they normally react with O_2 but not with N_2. However, when magnesium burns in air, reaction with N_2 also occurs to form magnesium nitride, Mg_3N_2. A similar reaction occurs with lithium.

$$Mg + N_2 \rightarrow Mg_3N_2 \quad \text{(unbalanced)}$$

$$Li + N_2 \rightarrow \_\_\_\_\_$$

Oxides of Nitrogen

Nitrogen forms three common oxides: N_2O (nitrous oxide), NO (nitric oxide), and NO_2 (nitrogen dioxide).

Nitrous oxide, N_2O, is also known as laughing gas and can be prepared by heating ammonium nitrate:

$$NH_4NO_3 \rightarrow N_2O + H_2O \quad \text{(unbalanced)}$$

Nitric oxide, NO, can be prepared by the reduction of **dilute** nitric acid, using copper or iron as a reducing agent:

$$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO + H_2O \quad \text{(unbalanced)}$$

Nitrogen dioxide is a yellow-brown gas and, like NO, it is a major constituent of smog. It is poisonous and has a choking odor. Nitrogen dioxide can be prepared by reacting copper with **concentrated** nitric acid.

$$Cu + H^+ + NO_3^- \text{ --> } Cu^{2+} + NO_2 + H_2O \quad \text{(unbalanced)}$$

Nitrogen dioxide dimerizes, and NO_2 and N_2O_4 exist in equilibrium:

$$2\,NO_2 \Leftrightarrow N_2O_4$$

Inorganic Reactions involving Carbon

Carbon exists in three crystalline forms: *graphite*, *diamond*, and *buckminsterfullerene*.

Graphite is a soft, black, slippery solid that has a metallic luster and conducts electricity. It consists of parallel sheets of carbon atoms; the sheets are held together by _____ forces.

Diamond is a clear, hard solid in which the carbon atoms form a covalent network.

Buckminsterfullerene is a molecular form of carbon that was discovered in the mid-1980s. This form of carbon consists of C_{60} molecules that resemble soccer balls

Charcoal, *coke* and *carbon black* are the three **amorphous** forms of carbon that exist.

Oxides of Carbon

Carbon forms two principal oxides: carbon monoxide, CO, and carbon dioxide, CO_2.

Carbon monoxide is a good reducing agent and is widely used in metallurgical operations to reduce metal oxides. For example:

$$Fe_3O_4 + CO \rightarrow Fe + CO_2 \quad \text{(unbalanced)}$$

Carbon dioxide is produced, for example, when many carbonates are heated:

$$CaCO_3 \rightarrow \_\_\_\_\_ + \_\_\_\_\_$$

It is worth noting that heating solid ammonium carbonate produces ammonia gas in addition to CO_2:

$$(NH_4)_2CO_3 \text{ ---> } NH_3 + H_2O + CO_2$$

Carbonic Acid and Carbonates

Carbon dioxide is moderately soluble in H_2O at atmospheric pressure. The resultant solutions are moderately acidic as a result of the formation of carbonic acid, H_2CO_3:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3$$

Carbonic acid is, of course, a weak diprotic acid.

Carbides

Ionic *carbides* are formed by the more active metals. The most important ionic carbide is calcium carbide, CaC_2, which is produced by the reduction of CaO with carbon at high temperature:

$$CaO + C \rightarrow CaC_2 + CO_2 \quad \text{(unbalanced)}$$

The carbide ion is a very strong base that reacts with water to form acetylene, H —C ≡C —H:

$$CaC_2 + H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad \text{(unbalanced)}$$

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1. Liquid bromine is carefully added to a solution of potassium iodide. [2002, Form B]
2. Powdered magnesium carbonate is heated strongly. [2001]
3. Carbon monoxide gas is passed over hot iron(III) oxide. [2000]
4. Pure solid phosphorus (white form) is burned in air. [2002, Form A]
5. Solid ammonium nitrate is heated to temperatures above 300°C. [1999]
6. Hydrogen gas is passed over hot iron(II) oxide powder. [1997]
7. Solid calcium carbonate is strongly heated. [1996]
8. Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide. [1995]
9. Solid barium oxide is added to distilled water. [1995]
10. Solid calcium hydride is added to distilled water. [1995]
11. Solid ammonium carbonate is heated. [1994]
12. Excess chlorine has is passed over hot iron filings. [1993]
13. Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate. [1992]
14. Solid copper(II) sulfide is heated strongly in oxygen gas. [1991]
15. Solid calcium oxide is heated in the presence of sulfur trioxide gas. [1991]
16. Calcium metal is heated strongly in nitrogen gas. [1991]
17. A solution of hydrogen peroxide is heated. [1990]
18. A piece of solid bismuth is heated. [1990]
19. Carbon disulfide vapor is burned in excess oxygen. [1989]
20. Solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst. [1988]

Answers

1. $Br_2 + I^- \rightarrow Br^- + I_2$
2. $MgCO_3 \rightarrow MgO + CO_2$
3. $CO + Fe_2O_3 \rightarrow CO_2 + Fe$
4. $P_4 + O_2 \rightarrow P_4O_{10}$
5. $NH_4NO_3 \rightarrow N_2O + H_2O$
6. $H_2 + FeO \text{ ---> } H_2O + Fe$
7. $CaCO_3 \rightarrow CaO + CO_2$
8. $Cl_2 + OH^- \text{ --> } OCl^- + Cl^- + H_2O$
9. $BaO + H_2O \text{ --> } Ba^{2+} + OH^-$
10. $CaH_2 + H_2O \text{ --> } Ca^{2+} + OH^- \text{ (or } Ca(OH)_2) + H_2$
11. $(NH_4)_2CO_3 \text{ ---> } NH_3 + H_2O + CO_2$
12. $Fe + Cl_2 \text{ --> } FeCl_3$
13. $CaCO_3 + CO_2 + H_2O \text{ ---> } Ca^{2+} + HCO_3^-$
14. $CuS + O_2 \text{ ---> } Cu + SO_2$
15. $CaO + SO_3 \text{ ---> } CaSO_4$
16. $Ca + N_2 \text{ ---> } Ca_3N_2$
17. $H_2O_2 \text{ -----> } H_2O + O_2$
18. $Bi + O_2 \text{ -----> } Bi_2O_3$
19. $CS_2 + O_2 \text{ ---> } CO_2 + SO_2$
20. $KClO_3 \text{ ---> } KCl + O_2$

25.13: Organic Chemistry Equations

AP Questions

Give the formulas to show the reactants and the products for each of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

1. A sample of 1-propanol is burned in air. [2002, Form B]
2. Solutions of potassium hydroxide and propanoic acid are mixed. [2001]
3. Butanol is burned in air. [2000]
4. Ethanol is burned in oxygen. [1995]

Answers

1. $C_3H_7OH + O_2 \rightarrow CO_2 + H_2O$
2. $C_2H_5COOH + OH^- \rightarrow C_2H_5COO^- + H_2O$
3. $C_4H_9OH + O_2 \rightarrow CO_2 + H_2O$
4. $C_2H_5OH + O_2 \text{ --> } CO_2 + H_2O$