ACIDS

Molecular Compounds that yield hydrogen ions (H^+) and an anion, when dissolved in water

$$HA \xrightarrow{H_2O} H^+(aq) + A^-(aq)$$

aq = aqueous (dissolved in water)

CLASSIFICATION OF ACIDS

	I. BINARY ACIDS	II. OXOACIDS	
Contain	(H + NONMETAL)	(H + NONMETAL + O)	
		1. **More O atoms**	2. **Fewer O atoms**
Names	Hydro + Nonmetal+ ic + acid	nonmetal + **ic** + acid	nonmetal + **ous** + acid
Examples	HCl(aq) hydrochloric acid	$HClO_3$(aq) chlor**ic** acid	$HClO_2$(aq) chlor**ous** acid
	H_2S(aq) hydrosulfuric acid	H_2SO_4(aq) sulfur**ic** acid	H_2SO_3(aq) sulfur**ous** acid
	----------	HNO_3(aq) nitr**ic** acid	HNO_2(aq) nitr**ous** acid
	----------	H_3PO_4(aq) phosphor**ic** acid	H_3PO_3(aq) phosphor**ous** acid
	----------	H_2CO_3(aq) carbon**ic** acid	----------
	----------	$HC_2H_3O_2$(aq) acet**ic** acid	----------

Other important facts to remember about some common acids.

1. Common Binary Acids (H + Nonmetal) contain Group VIIA and VIA nonmetals:

Nonmetals		Binary Acids	
VIA	VIIA	VIA	VIIA
	F		HF(aq) hydrofluoric acid
S	Cl	H_2S(aq) hydrosulfuric acid	HCl(aq) hydrochloric acid
	Br		HBr(aq) hydrobromic acid
	I		HI(aq) hydrobromic acid

2. Some nonmetals form more than two oxoacids with varying number of O atoms

$HClO$(aq)	$HClO_2$**(aq)**	$HClO_3$**(aq)**	$HClO_4$(aq)
?????	chlor**ous** acid	chlor**ic** acid	?????
less O than chlor**ous** acid			more O than chlor**ic** acid
hypochlorous acid			~~hy~~perchloric acid

Summing up:

$HClO_1$(aq)	$HClO_2$(aq)	$HClO_3$(aq)	$HClO_4$(aq)
hypochlor**ous** acid	chlor**ous** acid	chlor**ic** acid	perchlor**ic** acid
fewer O atoms		more O atoms	

TERNARY IONIC COMPOUNDS

- contain at least 3 elements
- contain at least one Polyatomic Ion
  - an ion consisting of 2 or more atoms bonded together and carrying a common charge. Example: SO_4^{2-} (sulfate ion)
- ending depends on the name of the anion.

TERNARY IONIC COMPOUNDS

CATION(s)		ANION(s)		
Monoatomic	Polyatomic	Monoatomic	Polyatomic	
Na^+, Mg^{2+}, Al^{3+},etc.	NH_4^+ ammonium ion	Cl^-, O^{2-}, N^{3-}, etc	OH^- hydroxide ion	**Oxoanions** (derived from oxoacids)

OXOANIONS

- are derived from oxoacids by partial or complete removal of hydrogen ions (H^+)
- Negative Charge of Oxoanion = Number of H^+ ions removed from oxoacids

OXOANIONS

MORE O atoms		FEWER O atoms	
Oxoacids ("ic")	- H^+(s) → Oxoanions("ate")	Oxoacids("ous")	- H^+(s) → Oxoanions ("ite")
$HClO_3$(aq) chloric acid	ClO_3^- chlorate ion	$HClO_2$(aq) chlorous acid	ClO_2^- chlorite ion
H_2SO_4(aq) sulfuric acid	HSO_4^- hydrogen sulfate ion SO_4^{2-} sulfate ion	H_2SO_3(aq) sulfurous acid	HSO_3^- hydrogen sulfite ion SO_3^{2-} sulfite ion
HNO_3(aq) nitric acid	NO_3^- nitrate ion	HNO_2(aq) nitrous acid	NO_2^- nitrite ion
H_3PO_4(aq) phosphoric acid	$H_2PO_4^-$ dihydrogen phosphate HPO_4^{2-} monohydrogen phosphate ion PO_4^{3-} phosphate ion	H_3PO_3(aq) phosphorous acid	$H_2PO_3^-$ dihydrogen phosphite ion HPO_3^{2-} monohydrogen phosphite ion PO_3^{3-} phosphite ion
H_2CO_3(aq) carbonic acid	HCO_3^- hydrogen carbonate ion CO_3^{2-} carbonate ion	----------	----------

NOTE:

1. $HC_2H_3O_2(aq) \xrightarrow{-H^+} C_2H_3O_2^-(aq)$
   acetic acid → acetate ion

2. $HClO_4(aq) \xrightarrow{-H^+} ClO_4^-$
   perchloric acid → perchlorate ion

   $HClO_3(aq) \xrightarrow{-H^+} ClO_3^-$
   chloric acid → chlorate ion

   $HClO_2(aq) \xrightarrow{-H^+} ClO_2^-$
   chlorous acid → chlorite ion

   $HClO(aq) \xrightarrow{-H^+} ClO^-$
   hypochlorous acid → hypochlorite ion

FORMULAS AND NAMES OF TERNARY IONIC COMPOUNDS

In writing the correct formulas, keep in mind that:
1. the formulas and the charges of the ions must be known,
2. the ionic charges must cancel (the compound as a whole is neutral)

Examples:

1. Write the formula of sodium sulfate: Na^+ SO_4^{2-}
   $Na^+ SO_4^{2-} \longrightarrow Na_2SO_4$
   ??????
2. Write the formula of calcium nitrate: Ca^{2+} NO_3^-
   $Ca^{2+} NO_3^- \longrightarrow Ca(NO_3)_2$
   ??????
3. Write the formula of ammonium (NH_4^+) hydroxide (OH^-)
   NH_4OH

4. What is the name of $CuCO_3$?

Copper carbonate

??? Which copper carbonate ?

- copper (I) carbonate (cuprous carbonate)

OR

- copper (II) carbonate (cupric carbonate)

The ionic charge of the Copper ion in the compound must be known!

$\overset{?}{Cu}CO_3^{2-} \longrightarrow \overset{2+}{Cu}CO_3^{2-}$

copper (II) carbonate

cupric carbonate

5. Write the formula of ammonium (NH_4^+) phosphate (PO_4^{3-})

$(NH_4)_3PO_4$

6. Write the formula of ammonium (NH_4^+) hydroxide (OH^-)

NH_4OH

7. Write the formula of calcium (Ca^{2+}) hydrogen carbonate (HCO_3^-)

$Ca(HCO_3)_2$

8. Write formulas of the following compounds:

sodium (**Na^+**) carbonate (**CO_3^{2-}**)	:	Na_2CO_3
sodium (Na^+) hydrogen carbonate (HCO_3^-)	:	$NaHCO_3$
ammonium (NH_4^+) acetate ($C_2H_3O_2^-$)	:	$NH_4C_2H_3O_2$
barium (Ba^{2+}) hydroxide (OH^-)	:	$Ba(OH)_2$
barium (Ba^{2+}) sulfate (SO_4^{2-})	:	$BaSO_4$

9. Give the correct name for the following compounds:

	? 2-	3+ 2-	
$Fe_2(SO_4)_3$	$Fe_2(SO_4)_3$	$Fe_2(SO_4)_3$	iron(III) sulfate, or ferric sulfate
	? **2-**	**2+** 2-	
$CuSO_4$	$CuSO_4$	$CuSO_4$	copper(II)sulfate,or cupric sulfate
$CaCO_3$	calcium carbonate (Ca ion can have one charge only: Ca^{2+})		
Na_2HPO_4	sodium hydrogen phosphate		
NH_4Cl	ammonium chloride		
NH_4NO_2	ammonium nitrite		
	? 1-	2+ 1-	
$Ni(NO_3)_2$	$Ni(NO_3)_2$	$Ni(NO_3)_2$	nickel (II) nitrate

HYDRATES

are Ionic Compounds that contain water molecules chemically bound with the crystals of the Ionic Compound

Examples:	Common Name	IUPAC Name
$CuSO_4 \cdot \mathbf{5H_2O}$	Root killer	copper(II) sulfate **pentahydrate**
$MgSO_4 \cdot \mathbf{7H_2O}$	Epsom Salt	magnesium sulfate **heptahydrate**
$CaSO_4 \cdot \mathbf{2H_2O}$	Gypsum	calcium sulfate **dihydrate**
$Na_2CO_3 \cdot \mathbf{10H_2O}$	Washing Soda	sodium carbonate **decahydrate**

$CuSO_4 \cdot \mathbf{5H_2O}$ $MgSO_4 \cdot \mathbf{7H_2O}$ $CaSO_4 \cdot \mathbf{2H_2O}$ $Na_2CO_3 \cdot \mathbf{10H_2O}$

WATER OF HYDRATION

The water of hydration can be easily removed by heating:

$$CuSO_4 \cdot 5H_2O(s) \xrightarrow{\text{Heat}} CuSO_4(s) + 5\ H_2O(g)$$

copper (II) sulfate pentahydrate (hydrated salt) → copper (II) sulfate (anhydrous salt) + water of hydration

blue crystals

white powder

NOTE:

The hydrated salts are crystalline, whereas the corresponding anhydrous salts are powders.

$$MgSO_4 \cdot 7H_2O(s) \xrightarrow{\text{Heat}} MgSO_4(s) + 7\ H_2O(g)$$

hydrated salt (White Crystals) → anhydrous salt (White Powder) + water of hydration

Balancing Chemical Equations

A Chemical Equation:

- is a representation of a chemical reaction in terms of chemical formulas

Example:

1. Word Description of a Chemical Reaction

   When methane gas (CH_4) burns in the presence of oxygen gas, it produces carbon dioxide gas and water vapor.

2. Word Equation

   - distinguishes between the starting substances (**REACTANTS**) and the substances that result from the chemical reaction (**PRODUCTS**)
   - indicates the chemical change with an arrow, referred to a the "**YIELD**" sign (⟶)

YIELD

REACTANTS ⟶ **PRODUCTS**

Yield

Methane gas + Oxygen Gas ⟶ Carbon Dioxide gas + Water Vapor

3. Unbalanced Chemical Equation

- represents Reactants and Products with correct chemical formulas
- indicates the physical state (phase designation) of all substances involved:
  - "s" for solid
  - 'l" for liquid
  - "g" for gas
  - "aq" for "dissolved in water (aqueous solution)
- does not attempt to account for the number of atoms involved in the reaction.

$$CH_4(g) + O_2(g) \xrightarrow{\text{yields}} CO_2(g) + H_2O(l)$$

(recall that oxygen gas is made of diatomic molecules)

NOTE:

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$$

4 H atoms ≠ 2 H atoms

2 O atoms ≠ 3 O atoms

This equation is not in agreement with one of the postulates of Dalton's Atomic Theory:

A Chemical Reaction consists of the **REARRANGEMENT OF ATOMS** present in the reacting substances.

ATOMS ARE NEITHER CREATED, NOR DESTROYED IN A CHEMICAL REACTION.

4. Balanced Chemical Equation

- the number of atoms of each element are equal on both sides of the arrow
- uses "**coefficients**" to ensure that the "equation is balanced"
  - coefficients – are the **smallest set of whole numbers** placed in front of the formulas in order to balance the equation.

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$$

To balance:

First:

- check number of atoms of each element on both sides of the arrow

1 C	→	1 C	balanced
4 H	→	**2 H**	**not balanced**
2 O	→	**3 O**	**not balanced**

Second:

- balance first the atoms for elements that occur in only one substance on each side of equation.

? $CH_4(g) + O_2(g) \longrightarrow CO_2(g) +$ **?** $H_2O(l)$

1 $CH_4(g) + O_2(g) \longrightarrow CO_2(g) +$ **2** $H_2O(l)$

usually ommited

H is now balanced (4 H atoms on both side of the equation)

Third:

Balance all other atoms:

$CH_4(g)$ + ? $\mathbf{O_2}(g)$ ⟶ ? $C\mathbf{O_2}(g)$ + **2** $H_2\mathbf{O}(l)$

2 O atoms 2 O atoms

2 O atoms 4 O atoms

$CH_4(g)$ + 2 $\mathbf{O_2}(g)$ ⟶ $C\mathbf{O_2}(g)$ + **2** $H_2\mathbf{O}(l)$

4 O atoms 4 O atoms

The equation is now balanced:

$CH_4(g)$ + 2 $O_2(g)$ ⟶ $CO_2(g)$ + 2 $H_2O(l)$

Examples:

1. Propane gas (C_3H_8) burns in the presence of oxygen and produces carbon dioxide gas and water vapor.

(A) Word Equation

propane gas + oxygen gas ⟶ carbon dioxide gas + water vapor

(B) Unbalanced Chemical Equation (include State Designations)

$C_3H_8(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(C) Balanced Chemical Equation

$C_3H_8(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

3 C — 1 C

8 H — 2 H

2 O — 2 O — 1 O

First: Balance C (occurs in only one substance):

$\mathbf{C_3}H_8(g) + O_2(g) \longrightarrow \mathbf{?}\ CO_2(g) + H_2O(g)$

$\mathbf{C_3}H_8(g) + O_2(g) \longrightarrow \mathbf{3}\ CO_2(g) + H_2O(g)$

Second: Balance H (occurs in only one substance):

$C_3\mathbf{H_8}(g) + O_2(g) \longrightarrow 3\ CO_2(g) + \mathbf{?}\ H_2O(g)$

$C_3\mathbf{H_8}(g) + O_2(g) \longrightarrow 3\ CO_2(g) + \mathbf{4}\ H_2O(g)$

Third: Balance O (occurs in more than one substance on right hand side):

$C_3H_8(g) + ? O_2(g) \longrightarrow 3 CO_2(g) + + 4 H_2O(g)$

6 O 4 O

2O 10 O

$C_3H_8(g) + 5 O_2(g) \longrightarrow 3 CO_2(g) + + 4 H_2O(g)$

The Equation is now balanced:

$C_3H_8(g) + 5 O_2(g) \longrightarrow 3 CO_2(g) + + 4 H_2O(g)$

2. Ethane gas (C_2H_6) burns in the presence of oxygen and produces carbon dioxide gas and water vapor.

(A) Word Equation

ethane gas + oxygen gas ⟶ carbon dioxide gas + water vapor

(B) Unbalanced Chemical Equation (include State Designations)

$C_2H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(C) Balanced Chemical Equation

$C_2H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

2 C 1 C

6 H 2 H

2 O 2 O 1 O

First: Balance C (occurs in only one substance):

$\mathbf{C_2}H_6(g) + O_2(g) \longrightarrow \mathbf{?}\ CO_2(g) + H_2O(g)$

$\mathbf{C_2}H_6(g) + O_2(g) \longrightarrow \mathbf{2}\ CO_2(g) + H_2O(g)$

Second: Balance H (occurs in only one substance):

$C_2\mathbf{H_6}(g) + O_2(g) \longrightarrow 2\ CO_2(g) + \mathbf{?}\ \mathbf{H_2}O(g)$

$C_2\mathbf{H_6}(g) + O_2(g) \longrightarrow 2\ CO_2(g) + \mathbf{3}\ \mathbf{H_2}O(g)$

Third: Balance O (occurs in more than one substance on right hand side):

$C_2H_6(g) + ?\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$

4 O + 3 O = 7 O

2O

$C_2H_6(g) + 7/2\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$

7 O = 7 O

NOTE: The equation is balanced, but it uses a fractional coefficient (3/2)
- while this is mathematically correct, the fractional coefficient is not consistent with the chemical reality (half molecules do not exist)

Fourth: To remove the fractional coefficient, the whole equation (all the coefficients) are multiplied by 2:

$1\ C_2H_6(g) + 7/2\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$ | X 2

$2\ C_2H_6(g) + 7\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O(g)$

4 C		=	4C		
12 H		=			12 H
	14 O	=	8 O	+	6 O

Balanced Chemical Equation:

$2\ C_2H_6(g) + 7\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O(g)$

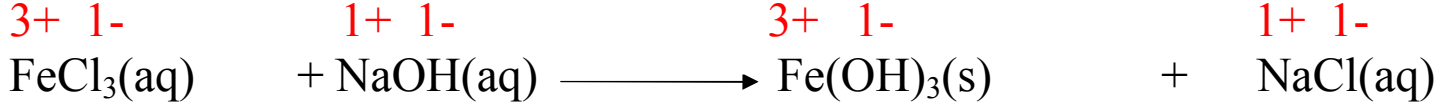
3. An aqueous solution of iron (III) chloride reacts with an aqueous solution of sodium hydroxide and forms solid iron (III) hydroxide and an aqueous solution of sodium chloride.

Write a balanced chemical equation that illustrates this chemical reaction.

(A) Word Equation

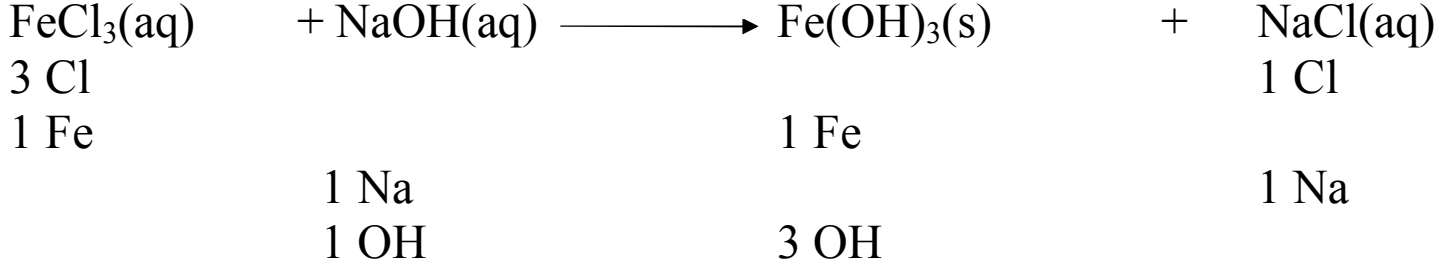
iron(III)chloride (aq) + sodium hydroxide (aq) ⟶ iron(III)hydroxide + sodium chloride(aq)

(B) Unbalanced Chemical Equation



NOTE: Make absolutely sure that all formulas are correctly written before you go to the next step (consider the names given and the charges of ions)

(C) Balanced Chemical Equation



(since the OH^- ion does not change, it may be balanced as a group)

First: Balance Cl:

$FeCl_3(aq) + NaOH(aq) \longrightarrow Fe(OH)_3(s) + \mathbf{?}\ NaCl(aq)$

$FeCl_3(aq) + NaOH(aq) \longrightarrow Fe(OH)_3(s) + \mathbf{3}\ NaCl(aq)$

Second: Balance Na:

$FeCl_3(aq) + \mathbf{?}\ NaOH(aq) \longrightarrow Fe(OH)_3(s) + \mathbf{3}\ NaCl(aq)$

$FeCl_3(aq) + \mathbf{3}\ NaOH(aq) \longrightarrow Fe(OH)_3(s) + \mathbf{3}\ NaCl(aq)$

Third: Check all other atoms and groups:

$FeCl_3(aq) + 3\ NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\ NaCl(aq)$

1 Fe = 1 Fe

3 Cl = 3 Cl

3 Na = 3 Na

3 OH = 3 OH

The equation is correctly balanced:

$$\mathbf{FeCl_3(aq) + 3\ NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\ NaCl(aq)}$$