Titanium(IV) oxide TiO_2
Thallium(III) nitrate $Tl(NO_3)_3$

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(Q) Which is the correct name for Cu_2S?

A. copper sulfide
B. copper(II) sulfide
C. copper(II) sulfate
D. copper(I) sulfide
E. copper(I) sulfite

(Q) Which is the correct formula for ammonium sulfite?

NH_4^+ SO_3^{2-}
$(NH_4)_2SO_3$

A. NH_4SO_3
B. $(NH_4)_2SO_3$
C. $(NH_4)_2SO_4$
D. NH_4S
E. $(NH_4)_2S$

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(Q) Name the following compounds:

(a) $Fe(NO_3)_2$ Iron(II) nitrate

(b) Na_2HPO_4 Sodium monohydrogen phosphate

(c) $(NH_4)_2(C_2O_4)$ Ammonium oxalate

(Q)Write chemical formulas for the following compounds:

(a) cesium sulfide Cs_2S

(b) calcium phosphate $Ca_3(PO_4)_2$

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➢ Naming Hydrates

1.Name ionic compound
2.Give number of water molecules in formula using Greek prefixes

$Ca(SO_4).2H_2O$ calcium sulfate dihydrate

$CoCl_2.6H_2O$ cobalt(II) chloride hexahydrate

$FeI_3{\cdot}3H_2O$ iron(III) iodide trihydrate

$Fe(NO_2)_3.9H_2O$ iron(III) nitrite nonahydrate

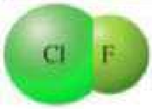
TABLE 2.6
Greek Prefixes for Naming Compounds

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-

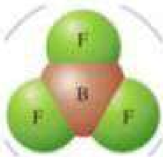
PCl_5	phosphorus pentachloride

disulfur dichloride	S_2Cl_2
tetraphosphorus trisulfide	P_4S_3
carbon disulfide	CS_2
sulfur trioxide	SO_3

nitrogen dioxide



Chlorine monofluoride



Boron trifluoride

Hydrogen selenide
Or dihydrogen selenide

$GaBr_3$	metal + non-metal	Gallium (III) bromide
$GeBr_4$	metalloid + non-metal	Germanium tetrabromide
$CaBr_2$	metal + non-metal	Calcium bromide
$Hg_2(NO_2)_2.H_2O$	hydrate	Mercury(I) nitrite monohydrate

➢ Acids and Corresponding Anions

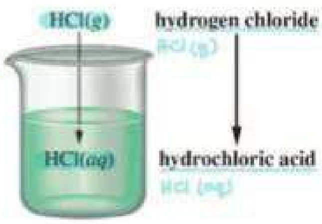
Anion Suffix		*Acid Suffix*
-ate	→	*-ic*
-ite	→	*-ous*

Acid	Contains	Name
HNO_3 →	nitrate anion therefore nitric acid	ate to ic
HNO_2 →	nitrite anion therefore nitrous acid	ite to ous

Table 2.8 Some Oxoanions and Their Corresponding Oxoacids

Oxoanion		Oxoacid	
CO_3^{2-}	*Carbonate ion*	H_2CO_3	*Carbonic acid*
NO_2^-	*Nitrite ion*	HNO_2	*Nitrous acid*
NO_3^-	*Nitrate ion*	HNO_3	*Nitric acid*
PO_4^{3-}	*Phosphate ion*	H_3PO_4	*Phosphoric acid*
SO_3^{2-}	*Sulfite ion*	H_2SO_3	*Sulfurous acid*
SO_4^{2-}	*Sulfate ion*	H_2SO_4	*Sulfuric acid*
ClO^-	*Hypochlorite ion*	$HClO$	*Hypochlorous acid*
ClO_2^-	*Chlorite ion*	$HClO_2$	*Chlorous acid*
ClO_3^-	*Chlorate ion*	$HClO_3$	*Chloric acid*
ClO_4^-	*Perchlorate ion*	$HClO_4$	*Perchloric acid*

Binary Compound	*Acid Solution*
HBr(*g*), hydrogen bromide	*hydrobromic acid,* HBr(*aq*)
HF(*g*), hydrogen fluoride	*hydrofluoric acid,* HF(*aq*)



(Q)Selenium has an oxoacid H_2SeO_4, called selenic acid. What is the formula and name of the corresponding anion?

b. $HC_2H_3O_2(aq) + NaOH(aq) \longrightarrow NaC_2H_3O_2(aq) + H_2O(l)$

weak acid

$HC_2H_3O_2(aq) + \cancel{Na^+(aq)} + OH^-(aq) \longrightarrow \cancel{Na^+(aq)} + C_2H_3O_2^-(aq) + H_2O(l)$

$$\mathbf{HC_2H_3O_2(aq) + OH^-(aq) \longrightarrow C_2H_3O_2^-(aq) + H_2O(l)}$$

c. $NH_3(aq) + HCl(aq) \longrightarrow NH_4Cl(aq)$

weak base

Ionic: $NH_3(aq) + H^+(aq) + Cl^-(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$

Net ionic: $NH_3(aq) + H^+(aq) \longrightarrow NH_4^+(aq)$

Write weak electrolytes in "molecular form"

✓ **Many ways to make PbI_2**

$Pb^{2+} + 2NO_3^- + 2K^+ + 2I^- \rightarrow PbI_2 + 2K^+ + 2NO_3^-$

1. $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$
2. $Pb(C_2H_3O_2)_2(aq) + 2NH_4I(aq) \rightarrow PbI_2(s) + 2NH_4C_2H_3O_2(aq)$

$Pb^{2+} + 2C_2H_3O_2^- + 2NH_4^+ + 2I^- \rightarrow PbI_2 + 2NH_4^+ + 2C_2H_3O_2^-$

Different starting reagents Same net ionic equation

$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$

Exercise 4.2 Write complete ionic and net ionic equations for each of the following molecular equations.

a. $2HNO_3(aq) + Mg(OH)_2(s) \rightarrow 2H_2O(l) + Mg(NO_3)_2(aq)$

Ionic:

$2H^+(aq) + 2NO_3^-(aq) + Mg(OH)_2(s) \rightarrow 2H_2O(l) + Mg^{2+}(aq) + 2NO_3^-(aq)$

Net Ionic:

$2H^+(aq) + Mg(OH)_2(s) \rightarrow 2H_2O(l) + Mg^{2+}(aq)$

b. $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) + 2NaNO_3(aq)$

Ionic:

$Pb^{2+}(aq) + 2NO_3^-(aq) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2Na^+(aq) + 2NO_3^-(aq)$

Net Ionic:

$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$

(Q) Write the correct ionic equation for each:

$Pb(NO_3)_2(aq) + 2NH_4IO_3(aq) \rightarrow Pb(IO_3)_2(s) + 2NH_4NO_3(aq)$

$Pb^{2+}(aq) + 2NO_3^-(aq) + 2NH_4^+(aq) + 2IO_3^-(aq) \rightarrow Pb(IO_3)_2(s) + 2NH_4^+(aq) + 2NO_3^-(aq)$

net ionic ⇒ $Pb^{+2} + 2IO_3^- \rightarrow Pb(IO_3)_2$

$2NaCl(aq) + Hg_2(NO_3)_2(aq) \rightarrow 2NaNO_3(aq) + Hg_2Cl_2(s)$

$2Na^+(aq) + 2Cl^-(aq) + Hg_2^{2+}(aq) + 2NO_3^-(aq) \rightarrow 2Na^+(aq) + 2NO_3^-(aq) + Hg_2Cl_2(s)$

net ionic ⇒ $2Cl^- + Hg_2^{+2} \rightarrow Hg_2Cl_2$

(Q) Consider the following reaction :

$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow 2NaCl(aq)$

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Write the correct **ionic** equation.

A. $2Na^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + Cl_2^{2-}(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + BaSO_4(s)$

B. $2Na^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2Cl^-(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + BaSO_4(s)$

C. $2Na^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + Cl_2^{2-}(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + Ba^{2+}(s) + SO_4^{2-}(s)$

D. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

E. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Ba^{2+}(s) + SO_4^{2-}(s)$

Consider the following molecular equation:

$(NH_4)_2SO_4(aq) + Ba(CH_3CO_2)_2(aq) \rightarrow 2NH_4CH_3CO_2(aq) + BaSO_4(s)$

Write the correct **net** ionic equation.

A. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

B. $2NH_4^+(aq) + 2CH_3CO_2^-(aq) \rightarrow 2NH_4CH_3CO_2(s)$

C. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(aq)$

D. $2NH_4^+(aq) + Ba^{2+}(aq) + SO_4^{2-}(aq) + 2CH_3CO_2^-(aq) \rightarrow 2NH_4^+(aq) + 2CH_3CO_2^-(aq) + BaSO_4(s)$

E. $2NH_4^+(aq) + 2CH_3CO_2^-(aq) \rightarrow 2NH_4CH_3CO_2(aq)$

What is the net ionic equation for the following reaction?

Molecular equation

$Mg(OH)_2(s) + 2HC_2H_3O_2(aq) \longrightarrow Mg(C_2H_3O_2)_2(aq) + 2H_2O$

Ionic equation

$Mg(OH)_2(s) + 2HC_2H_3O_2(aq) \longrightarrow Mg^{2+}(aq) + 2H_2O + 2C_2H_3O_2^-(aq)$

- There are NO spectator ions!

between compounds that, when written as a molecular equation, appears to involve the exchange of parts between the two reactants

Example 4.3 Deciding Whether a Precipitation Reaction Occurs

For each of the following, decide whether a precipitation reaction occurs. If it does, write the balanced molecular equation and then the net ionic equation. If no reaction occurs, write the compounds followed by an arrow and then *NR* (no reaction).

a. Aqueous solutions of sodium chloride and iron(II) nitrate are mixed.

$NaCl + Fe(NO_3)_2 \rightarrow NaNO_3 + FeCl_2$ (not balanced)

$2NaCl + Fe(NO_3)_2 \rightarrow 2NaNO_3 + FeCl_2$ (balanced)

soluble soluble soluble soluble

$2Na^+ + 2Cl^- + Fe^{2+} + 2NO_3^- \rightarrow 2Na^+ + 2NO_3^- + Fe^{2+} + 2Cl^-$

$$\mathbf{NaCl(\mathit{aq}) + Fe(NO_3)_2(\mathit{aq}) \rightarrow NR}$$

No reaction
(no precipitate forms)

b. Aqueous solutions of aluminum sulfate and sodium hydroxide are mixed.

$Al_2(SO_4)_3 + NaOH \rightarrow Al(OH)_3 + Na_2SO_4$ (not balanced)

soluble soluble insoluble soluble

$Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$ (balanced)

$$2Al^{3+}(aq) + \cancel{3SO_4^{2-}(aq)} + \cancel{6Na^+(aq)} + 6OH^-(aq) \longrightarrow 2Al(OH)_3(s) + \cancel{6Na^+(aq)} + \cancel{3SO_4^{2-}(aq)}$$

$$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$$

Precipitate

4.4 Acid–Base Reactions

- ✓ Acids have sour taste. Bases have bitter taste & soapy feel.
- ✓ An **acid–base indicator** is *a dye used to distinguish between acidic and basic solutions by means of color change*

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

① $H_2SO_4 + KOH \rightarrow KHSO_4 + H_2O$ (strong)

② $KHSO_4 + KOH \rightarrow K_2SO_4 + H_2O$ (weak)

① $H_2SO_{4(aq)} + KOH_{(aq)} \rightarrow KHSO_{4(aq)} + H_2O_{(l)}$

$H^+ + \cancel{HSO_4^-} + \cancel{K^+} + OH^- \rightarrow \cancel{K^+} + \cancel{HSO_4^-} + H_2O$

net $H^+ + OH^- \rightarrow H_2O$

$H_2SO_4 + 2H_2O$

② $KHSO_{4(aq)} + KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + H_2O_{(l)}$

$\cancel{K^+} + HSO_4^- + \cancel{K^+} + OH^- \rightarrow \cancel{2K^+} + SO_4^{2-} + H_2O$

net $HSO_4^- + OH^- \rightarrow SO_4^{2-} + H_2O$

Acid–Base Reactions with Gas Formation

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + \underbrace{H_2O(l) + CO_2(g)}_{H_2CO_3(aq)}$$

$2Na^+ + CO_3^{-2} + 2H^+ + 2Cl^- \rightarrow 2Na^+ + 2Cl^- + H_2O + CO_2$

Net ionic eqn. $\quad CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

$$\overset{2H^+}{\curvearrowleft}$$

$$CO_3^{2-}(aq) + 2H_3O^+(aq) \longrightarrow H_2CO_3(aq) + 2H_2O(l) \longrightarrow 3H_2O(l) + CO_2(g)$$

Table 4.4 Some Ionic Compounds That Evolve Gases When Treated with Acids

Ionic Compound	Gas	Example
Carbonate (CO_3^{2-})	CO_2	$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$
Sulfite (SO_3^{2-})	SO_2	$Na_2SO_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2$
Sulfide (S^{2-})	H_2S	$Na_2S + H_2SO_4 \longrightarrow Na_2SO_4 + H_2S$

Example 4.6 Writing an Equation for a Reaction with Gas Formation

(Q)Write the molecular equation and the net ionic equation for the reaction of zinc sulfide with hydrochloric acid.

$$\mathbf{ZnS(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2S(g)}$$

$$ZnS(s) + 2H^+(aq) + \cancel{2Cl^-(aq)} \longrightarrow Zn^{2+}(aq) + \cancel{2Cl^-(aq)} + H_2S(g)$$

$$\mathbf{ZnS(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2S(g)}$$

Exercise 4.7 Write the molecular equation and the net ionic equation for the reaction of calcium carbonate with nitric acid.

$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2CO_3(aq)$

$CaCO_3(s) + 2H^+(aq) + 2NO_3^-(aq) \rightarrow$
$Ca^{2+} + 2NO_3^-(aq) + H_2O(l) + CO_2(g)$

$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+} + H_2O(l) + CO_2(g)$

➢ Oxidation-Number Rules:

Table 4.5 Rules for Assigning Oxidation Numbers

Rule	Applies to	Statement
1	Elements	The oxidation number of an atom in an element is zero.
2	Monatomic ions	The oxidation number of an atom in a monatomic ion equals the charge on the ion.
3	Oxygen	The oxidation number of oxygen is −2 in most of its compounds. (An exception is O in H_2O_2 and other peroxides, where the oxidation number is −1.)
4	Hydrogen	The oxidation number of hydrogen is +1 in most of its compounds. (The oxidation number of hydrogen is −1 in binary compounds with a metal, such as CaH_2.)
5	Halogens	The oxidation number of fluorine is −1 in all of its compounds. Each of the other halog (Cl, Br, I) has an oxidation number of −1 in binary compounds, except when the oth element is another halogen above it in the periodic table or the other element is oxyg
6	Compounds and ions	The sum of the oxidation numbers of the atoms in a compound is zero. The sum of the oxidation numbers of the atoms in a polyatomic ion equals the charge on the ion.

Examples:

SO_2: $S-4=0 \Rightarrow \boxed{S=+4}$

$HClO_4$: $1+Cl-8=0 \Rightarrow \boxed{Cl=+7}$

ClO_3^-: $Cl-6=-1 \Rightarrow \boxed{Cl=+5}$

$K_2Cr_2O_7$: $2+2Cr-14=0 \Rightarrow \boxed{Cr=+6}$

MnO_4^-: $Mn-8=-1 \Rightarrow \boxed{Mn=+7}$

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➢ Describing Oxidation–Reduction Reactions

$$\overset{0}{Fe}(s) + \overset{+2}{Cu}{}^{2+}(aq) \longrightarrow \overset{+2}{Fe}{}^{2+}(aq) + \overset{0}{Cu}(s)$$

We can write this reaction in terms of two half-reactions

$$\overset{0}{Fe}(s) \longrightarrow \overset{+2}{Fe}{}^{2+}(aq) + 2e^- \qquad \text{(electrons lost by Fe)}$$

$$\overset{+2}{Cu}{}^{2+}(aq) + 2e^- \longrightarrow \overset{0}{Cu}(s) \qquad \text{(electrons gained by Cu}^{2}$$

oxidation

$$\underbrace{\overset{0}{Fe}(s)}_{\text{reducing agent}} + \underbrace{\overset{+2}{Cu}{}^{2+}(aq)}_{\text{oxidizing agent}} \longrightarrow \overset{+2}{Fe}{}^{2+}(aq) + \overset{0}{Cu}(s)$$

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reduction

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➢ Some Common Oxidation–Reduction Reactions

4.6 Balancing Simple Oxidation-Reduction Equations

(Q) Apply the half-reaction method to balance the following equation: $Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$

$$\overset{0}{Mg}(s) + \overset{0}{N_2}(g) \longrightarrow \overset{+2}{Mg_3}\overset{-3}{N_2}(s)$$

$Mg \longrightarrow Mg^{2+} + 2e^-$ (balanced oxidation half-reaction)

$N_2 + 6e^- \longrightarrow 2N^{3-}$ (balanced reduction half-reaction)

$$3 \times (Mg \longrightarrow Mg^{2+} + 2e^-)$$
$$\underline{1 \times (N_2 + 6e^- \longrightarrow 2N^{3-})}$$
$$3Mg + N_2 + \cancel{6e^-} \longrightarrow 3Mg^{2+} + 2N^{3-} + \cancel{6e^-}$$

$$\mathbf{3Mg + N_2 \longrightarrow 3Mg^{2+} + 2N^{3-}}$$

$$3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$$

4.66 Balance the following oxidation–reduction reactions by the half-reaction method.

a. $FeI_3(aq) + Mg(s) \rightarrow Fe(s) + MgI_2(aq)$

$Mg \rightarrow Mg^{2+} + 2e^-$ (oxidation half-reaction)

$Fe^{3+} + 3e^- \rightarrow Fe$ (reduction half-reaction)

$$3 \times (Mg \rightarrow Mg^{2+} + 2e^-)$$
$$\underline{2 \times (Fe^{3+} + 3e^- \rightarrow Fe)}$$
$$2Fe^{3+} + 3Mg + \cancel{6e^-} \rightarrow 2Fe + 3Mg^{2+} + \cancel{6e^-}$$

$$2Fe^{3+} + 3Mg \rightarrow 2Fe + 3Mg^{2+}$$

$$2FeI_3(aq) + 3Mg(s) \rightarrow 2Fe(s) + 3MgI_2(aq)$$

$Mg \rightarrow Mg^{2+} + 2e^-$ (oxidation half-reaction)
$Fe^{3+} + 3e^- \rightarrow Fe$ (reduction half-reaction)

$$3 \times (Mg \rightarrow Mg^{2+} + 2e^-)$$
$$\underline{2 \times (Fe^{3+} + 3e^- \rightarrow Fe)}$$
$$2Fe^{3+} + 3Mg + \cancel{6e^-} \rightarrow 2Fe + 3Mg^{2+} + \cancel{6e^-}$$

$$2Fe^{3+} + 3Mg \rightarrow 2Fe + 3Mg^{2+}$$

$$2FeI_3(aq) + 3Mg(s) \rightarrow 2Fe(s) + 3MgI_2(aq)$$

4.7 Molar Concentration

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$

(Q) A sample of $NaNO_3$ weighing 0.38 g is placed in a 50.0 mL volumetric flask. The flask is then filled with water to the mark on the neck. What is the molarity of the resulting solution?

$$\text{Molarity} = \frac{4.47 \times 10^{-3} \text{ mol } NaNO_3}{50.0 \times 10^{-3} \text{ L soln}} = \mathbf{0.089\ } \boldsymbol{M} \mathbf{\ NaNO_3}$$

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4.8 Diluting Solutions

$$M_i \times V_i = M_f \times V_f$$

(Q)You are given a solution of 14.8 M NH_3. How many milliliters of this solution do you require to give 100.0 mL of 1.00 M NH_3 ?

$$V_i = \frac{1.00 \cancel{M} \times 100.0 \text{ mL}}{14.8 \cancel{M}} = \mathbf{6.76 \text{ mL}}$$

✓ Number of moles does not change

(Q) What is the molar concentration of Na^+ in a solution made by dissolving 1.59 g of Na_2CO_3 (molar mass = 106g/mol) in 100 mL H_2O?

1mol Na_2CO_3 → 2mol Na^+

$$M_{Na_2CO_3} = \frac{n}{V} = \frac{m}{M \times V} = \frac{1.59}{106 \times .1} = .15 M$$

$$M_{Na^+} = 2 \times M_{Na_2CO_3} = 2 \times .15 = \underline{.3 M}$$

$$M = \frac{n}{V}$$

$106 \times 1 \rightarrow 2 \times 17$

$1.59 \rightarrow x$

$$x = \frac{2 \times 17 \times 1.59}{106}$$

4.9 Gravimetric Analysis

is *a type of quantitative analysis* in which the amount of a species in a materia~~l is determined by conver~~ting the species to

25 mL of 0.5 M
75 mL of 0.3 M
n_{total}= (25 x 10^{-3} x 0.5) + (75 x 10^{-3} x 0.3)
V_{total}= (25 + 75)x 10^{-3}
M_{total} =n_{total} / V_{total}= $\frac{.036}{.1}$ = .36

4.140 Potassium hydrogen phthalate (abbreviated as KHP) has the molecular formula $KHC_8H_4O_4$ and a molar mass of 204.22 g/mol. KHP has one acidic hydrogen. A solid sample of KHP is dissolved in 50 mL of water and titrated to the equivalence point with 22.90 mL of a 0.5010 *M* NaOH solution. How many grams of KHP were used in the titration?

$n_{KHP} = n_{NaOH}$

$\frac{m}{204.22} = \frac{22.9}{100} \times .5010$

$\frac{m}{204.22} = .5010 \times .0229$

$m = .5010 \times .0229 \times 204.22$
$= 2.342$ g KHP

4.74 What is the volume (in milliliters) of 0.100 *M* H_2SO_4 containing 0.949 g H_2SO_4 (98.07 g/mol)?

$V = \frac{n}{M} = \frac{\frac{m}{mr}}{M} = \frac{.949}{.1 \times 98.07}$

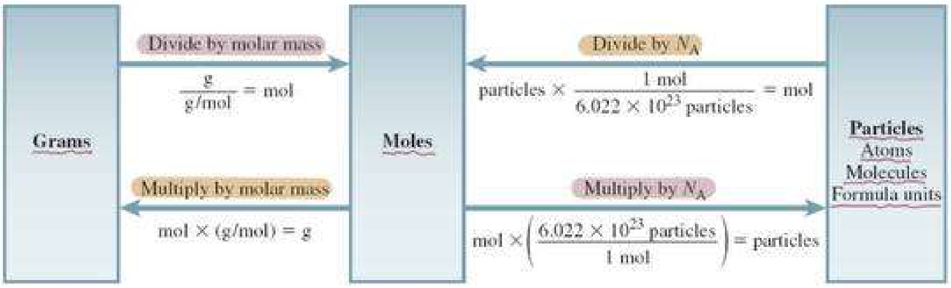
$= .09677$ L $\times 1000$

$= 96.77$ ml

$$\text{No of Moles} = \frac{\text{Mass (g)}}{\text{Molar Mass (g/mole)}}$$

avogadro's number

$$\text{No of Atoms} = \text{No of Moles} \times \frac{6.022 \times 10^{23}\ \text{atom}}{1\ \text{mole}}$$



من mol لـ molecule, atom ← بنضرب بـ 6.022×10^{23}

من molecule لـ mol ← بنقسم على 6.022×10^{23}

(Q) How many molecules are there in a 3.46-g sample of hydrogen chloride, HCl? Note → when you see "How many" remember avogadro's number

$Mr_{HCl} = 1 + 35.5 = 36.5$

molecules of HCl $= n_{HCl} \times N_A$

$= \frac{3.46}{36.5} \times 6.022 \times 10^{23}$ molecules

$= .571 \times 10^{23}$

$= 5.71 \times 10^{22}$ molecules

(Q) How many S atoms are there in 16.3 g of S?

$Mr_S = 32.1$

atoms of S $= n_S \times N_A$

$= \frac{16.3}{32.1} \times 6.022 \times 10^{23}$

$= 3.06 \times 10^{23}$ atoms

(Q) How many molecules are there in a 3.46-g sample of hydrogen chloride, HCl?

$$3.46\ \text{g HCl} \times \frac{1\ \text{mol HCl}}{36.5\ \text{g HCl}} \times \frac{6.022 \times 10^{23}\ \text{HCl molecules}}{1\ \text{mol HCl molecules}} =$$

(Q) How many S atoms are there in 16.3 g of S?

$$16.3\ \text{g S} \times \frac{1\ \text{mol S}}{32.1\ \text{g S}} \times \frac{6.022 \times 10^{23}\ \text{S atoms}}{1\ \text{mol S atoms}} =$$

$$16.3 \text{ g S} \times \frac{1 \text{ mol S}}{32.1 \text{ g S}} \times \frac{6.022 \times 10^{23} \text{ S atoms}}{1 \text{ mol S atoms}} =$$

Example 3.3 Calculating the Mass of an Atom or Molecule

a. What is the mass in grams of one chlorine atom, Cl?

b. What is the mass in grams of one HCl molecule?

Note: when you see no. of atoms and molecules ⇒ remember avogadro's number

(a) $Mr_{Cl} = 35.5$ $\quad 1 \text{ atom Cl} = \frac{1}{6.022 \times 10^{23}} \text{ mol}$

$$m = n \times Mr$$

$$= \frac{1}{6.022 \times 10^{23}} \times 35.5 = 5.89 \times 10^{-23} \text{ g Cl}$$

or $\quad 1 \cancel{\text{atom}} \times \frac{1 \cancel{\text{mol}}}{6.022 \times 10^{23} \cancel{\text{atom}}} \times \frac{35.5 \text{ g}}{\cancel{\text{mol}}} = \frac{35.5}{6.022 \times 10^{23}}$

(b) $n = \frac{1}{6.022 \times 10^{23}} \text{ mol}$ $\quad Mr_{HCl} = 36.5$

$$m = n \times Mr$$

$$= \frac{36.5}{6.022 \times 10^{23}} \text{ g HCl.}$$

(Q) How much, in grams, do 8.85×10^{24} atoms of zinc weigh? $Mr_{Zn} = 65.4$

A. 3.49×10^{49} g

B. 961 g

C. 4.45 g

D. 5.33×10^{47} g

E. 1.47 g

$$m = \frac{8.85 \times 10^{24}}{6.022 \times 10^{23}} \times 65.4 = 961 \text{ g Zn}$$

$$8.85 \times 10^{24} \cancel{\text{atoms}} \times \left(\frac{1 \cancel{\text{mol}}}{6.022 \times 10^{23} \cancel{\text{atoms}}} \right) \times \left(\frac{65.41 \text{ g Zn}}{1 \cancel{\text{mol}}} \right)$$

= 961 g Zn

(Q) How many hydrogen atoms are present in 25.6 g of urea $[(NH_2)_2CO]$? molar mass of urea = 60.06 g/mol.

grams of urea ⟶ moles of urea ⟶ moles of H ⟶ atoms of H

$$25.6 \cancel{\text{ g } (NH_2)_2CO} \times \frac{1 \text{ mol } \cancel{(NH_2)_2CO}}{60.06 \cancel{\text{ g } (NH_2)_2CO}} \times \frac{4 \cancel{\text{ mol H}}}{1 \text{ mol } \cancel{(NH_2)_2CO}} \times \frac{6.022 \times 10^{23} \text{ H atoms}}{1 \cancel{\text{ mol H}}}$$

$$\left(\frac{\ }{\text{g total}}\right)\times 100\% \quad \left(\frac{\ }{0.5462\text{ g}}\right)$$

% Composition of O

$$\left(\frac{\text{g O}}{\text{g total}}\right)\times 100\% = \left(\frac{0.4045\text{ g O}}{0.5462\text{ g}}\right)\times 1 \quad \%$$

(Q) a.Calculate the mass percentages of the elements in formaldehyde (CH_2O) molar mass = 30g/mol

total mass

$$\% \text{ C} = \frac{12.0 \text{ g}}{30.0 \text{ g}} \times 100\% = \mathbf{40.0\%}$$

$$\% \text{ H} = \frac{2 \times 1.01 \text{ g}}{30.0 \text{ g}} \times 100\% = \mathbf{6.73\%}$$

% **O** = 16/30 x100% = 53.3 %

$$\% \text{ O} = 100\% - (40.0\% + 6.73\%) = \mathbf{53.3\%}$$

b. How many grams of carbon are there in 83.5 g of CH_2O?

CH_2O is 40.0% C, so the mass of carbon in 83.5 g CH_2O i
83.5 g X 0.400 = **33.4 g**

(Q) Calculate the mass percentages of the elements in H_3PO_4
molar mass = 97.99 g/mol

total mass

$$\%H = \frac{3(1.008\text{ g})\ H}{97.99\text{ g } H_3PO_4} \times 100\% = 3.086\%$$

$$\%P = \frac{30.97\text{ g P}}{97.99\text{ g } H_3PO_4} \times 100\% = 31.61\%$$

$$\%O = \frac{4(16.00\text{ g})\ O}{97.99\text{ g } H_3PO_4} \times 100\% = 65.31\%$$

➢**Determining Empirical and Molecular Formulas**

Empirical Formula الصيغة الإبتدائية

– Simplest ratio of atoms of each element in compound
– Obtained from experimental analysis of compound

Molecular Formula الصيغة الجزيئية

e.g., 43.64% P and 56.36% O

3. **From Combustion Data**
   - Given masses of combustion products

   e.g., The combustion of a 5.217 g sample of a compound of C, H, and O in pure oxygen gave 7.406 g CO_2 and 4.512 g of H_2O

٢٤ من ٤٨

1. Empirical Formula from Mass Data

When a 0.1156 g sample of a compound was analyzed, it was found to contain 0.04470 g of C, 0.01875 g of H, and 0.05215 g of N. Calculate the empirical formula of this compound.

Step 1: Calculate moles of each substance

$$0.04470\,\cancel{g\,C} \times \frac{1\text{ mol C}}{12.011\,\cancel{g\,C}} = 3.722 \times 10^{-3}\text{ mol C}$$

$$0.01875\,\cancel{g\,H} \times \frac{1\text{ mol H}}{1.008\,\cancel{g\,H}} = 1.860 \times 10^{-2}\text{ mol H}$$

$$0.05215\,\cancel{g\,N} \times \frac{1\text{ mol N}}{14.0067\,\cancel{g\,N}} = 3.723 \times 10^{-3}\text{ mol N}$$

Step 2: Select the smallest number of moles

4.95 → 5 ✓
4.997 → 5 ✓
4.94 → 5 ✗
1.33 → 1 ✗
1.7 → 2 ✗
2.8 → 3 ✗

- Smallest is 3.722×10^{-3} mole

	Mole ratio	Integer ratio
$C = \dfrac{3.722\times10^{-3}\text{ mol C}}{3.722\times10^{-3}\text{ mol C}}$ =	1.000	= 1
$H = \dfrac{1.860\times10^{-2}\text{ mol H}}{3.722\times10^{-3}\text{ mol C}}$ =	4.997	= 5
$N = \dfrac{3.723\times10^{-3}\text{ mol N}}{3.722\times10^{-3}\text{ mol C}}$ =	1.000	= 1

Step 3: Divide all number of moles by the smallest one

Empirical formula = CH_5N

molecular formula

$$n = \frac{\text{molar mass molecular}}{\text{molar mass empirical}}$$

then multiply the empirical formula by n to find the molecular formula

2. Empirical Formula from Percentage Composition

Calculate the empirical formula of a compound whose

- $H = \frac{\quad}{3.722 \times 10^{-3} \text{ mol C}} = 4.997 \quad = 5$

- $N = \frac{3.723 \times 10^{-3} \text{ mol N}}{3.722 \times 10^{-3} \text{ mol C}} = 1.000 \quad = 1$

Step 3: Divide all number of moles by
one

Empirical formula = CH_5N

molecular formula

$n = \frac{\text{molar mass molecular}}{\text{molar mass empirical}}$

then multiply the empirical formula by n to find the molecular formula

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2. Empirical Formula from Percentage Composition

Calculate the empirical formula of a compound whose percentage composition data is 43.64% P and 56.36% O. If the molar mass is determined to be 283.9 g/mol, what is the molecular formula?

molecular mass

Step 1: Assume 100 g of compound

- 43.64 g P 1 mol P = 30.97 g
- 56.36 g O 1 mol O = 16.00 g

$$43.64 \cancel{\text{g P}} \times \frac{1 \text{ mol P}}{30.97 \cancel{\text{g P}}} = 1.409 \text{ mol P}$$

$$56.36 \cancel{\text{g O}} \times \frac{1 \text{ mol O}}{16.00 \cancel{\text{g O}}} = 3.523 \text{ mol O}$$

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Step 2: Divide by smallest number of moles

$$\frac{1.409 \text{ mol P}}{1.409 \text{ mol P}} = 1.000$$

$$\frac{3.523 \text{ mol O}}{1.409 \text{ mol P}} = 2.500$$

1.33×3

Step 3: Multiple to get integers

$1.000 \times 2 = 2$
$2.500 \times 2 = 5$

$n = \frac{\text{Mr of molecular}}{\text{Mr of empirical}} = \frac{283.9}{2 \times 31 + 5 \times 16} = \frac{283.9}{142} = 2$

Empirical formula = P_2O_5

molecular formula = P_4O_{10}

molecular = n × empirical
= 2(P_2O_5)
= P_4O_{10}

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(Q) Ascorbic acid (vitamin C) is composed of 40.92 percent carbon (C), 4.58 percent hydrogen (H), and 54.50 percent oxygen (O) by mass. Determine its empirical formula.

Assume you have 100 g

التفسير المولي

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

N_2	+	$3H_2$	$\longrightarrow$	$2NH_3$	
1 molecule N_2	+	3 molecules H_2	$\longrightarrow$	2 molecules NH_3	
1 mol N_2	+	3 mol H_2	$\longrightarrow$	2 mol NH_3	(molar interpretation)
28.0 g N_2	+	3×2.02 g H_2	$\longrightarrow$	2×17.0 g NH_3	(mass interpretation)

3.7 Amounts of Substances in a Chemical Reaction

Example 3.13

Relating the Quantity of Reactant to Quantity of Product

In the following reaction:

1000 g — mass??

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

How many grams of Fe(s) can be produced from 1.00 kg Fe_2O_3?

Molar masses are: Fe = 55.8 g/mol and Fe_2O_3 = 160 g/mol

Solution The calculation is as follows:

$$1.00 \times 10^3\ \text{g}\ \cancel{Fe_2O_3} \times \frac{1\ \cancel{\text{mol}\ Fe_2O_3}}{160\ \cancel{\text{g}\ Fe_2O_3}} \times \frac{2\ \cancel{\text{mol Fe}}}{1\ \cancel{\text{mol}\ Fe_2O_3}} \times \frac{55.8\ \text{g Fe}}{1\ \cancel{\text{mol Fe}}} = \mathbf{698\ g\ Fe}$$

theoritical yeild

way 2:

1 mol Fe_2O_3 → 2 mol Fe

1×160 g Fe_2O_3 → 2×55.8 g Fe

1000 g Fe_2O_3 → X g Fe

$X = \frac{2 \times 55.8 \times 1000}{160} = 697.5 = 698$ g Fe

Example 3.14

Relating the Quantities of Two Reactants (or Two Products)

In the following reaction:

? g — 5 g

$4HCl(aq) + MnO_2(s) \rightarrow 2H_2O(l) + MnCl_2(aq) + Cl_2(g)$, How many grams of HCl react with 5.00 g of MnO_2, according to this equation? Molar masses are: MnO_2=86.9g/mol &HCl=36.5 g/mol

$$5.00\ \text{g}\ \cancel{MnO_2} \times \frac{1\ \cancel{\text{mol}\ MnO_2}}{86.9\ \cancel{\text{g}\ MnO_2}} \times \frac{4\ \cancel{\text{mol HCl}}}{1\ \cancel{\text{mol}\ MnO_2}} \times \frac{36.5\ \text{g HCl}}{1\ \cancel{\text{mol HCl}}} = \mathbf{8.40\ g\ HCl}$$

way 2:

4 mol HCl → 1 mol MnO_2

4×36.5 g HCl → 86.9 g MnO_2

x g HCl → 5 g MnO_2

$X = \frac{4 \times 5 \times 36.5}{86.9} = 8.40$ g HCl

Exercise 3.16 oxygen can be prepared by heating mercury(II) oxide, HgO. Mercury metal is the other product. If 6.47 g of oxygen is collected, how many grams of mercury

&HCl=36.5 g/mol

$$5.00\ \cancel{g\ MnO_2} \times \frac{1\ \cancel{mol\ MnO_2}}{86.9\ \cancel{g\ MnO_2}} \times \frac{4\ \cancel{mol\ HCl}}{1\ \cancel{mol\ MnO_2}} \times \frac{36.5\ g\ HCl}{1\ \cancel{mol\ HCl}} = \mathbf{8.40\ g\ HCl}$$

way 2 :
4 mol HCl → 1 mol MnO_2
4×36.5 g HCl → 86.9 g MnO_2
x g HCl → 5 g MnO_2

$x = \frac{4 \times 5 \times 36.5}{86.9} = 8.40\text{g HCl}$

Exercise 3.16 oxygen can be prepared by heating mercury(II) oxide, HgO. Mercury metal is the other product. If 6.47 g of oxygen is collected, how many grams of mercury metal are also produced?
Molar masses are: O_2=32.00g/mol &Hg=200.59 g/mol

$$2HgO \rightarrow 2Hg + O_2$$

way 2 :
1 mol O_2 → 2 mol Hg
32 g O_2 → 200.59×2 g Hg
6.47 g O_2 → x g Hg

$x = \frac{200.59 \times 6.47 \times 2}{32} = 81.1\text{g Hg}$

$$6.47\ g\ O_2 \times \frac{1\ mol\ O_2}{32.00\ g\ O_2} \times \frac{2\ mol\ Hg}{1\ mol\ O_2} \times \frac{200.59\ g\ Hg}{1\ mol\ Hg} = 81.\underline{1}1 = 81.1\ g\ Hg$$

How many grams of Al_2O_3 are produced when 41.5 g Al react? Molar masses are: Al=26.98g/mol Al_2O_3=101.96g/mol

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(l)$$

A. 78.4 g
B. 157 g
C. 314 g
D. 22.0 g
E. 11.0 g

2 mol Al → 1 mol Al_2O_3
2×26.98 g → 101.96 g
41.5 g → x g

$x = \frac{101.96 \times 41.5}{2 \times 26.98} = 78.4\text{g } Al_2O_3$

$$41.5\ \cancel{g\ Al}\left(\frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g\ Al}}\right)\left(\frac{1\ \cancel{mol\ Al_2O_3}}{2\ \cancel{mol\ Al}}\right)\left(\frac{101.96\ g\ Al_2O_3}{1\ \cancel{mol\ Al_2O_3}}\right)$$

$$= 78.4\ g\ Al_2O_3$$

How many grams of sodium dichromate are required to produce 24.7 g iron(III) chloride from the following reaction? Molar masses are: $FeCl_3$=162.2 g/mol $Na_2Cr_2O_7$ =262.0 g/mol

$$\mathbf{14HCl + Na_2Cr_2O_7 + 6FeCl_2 \rightarrow 2CrCl_3 + 7H_2O + 6FeCl_3 + 2NaCl}$$

A. 6.64 g $Na_2Cr_2O_7$
B. 0.152 g $Na_2Cr_2O_7$

$\left(\frac{1\ \cancel{mol\ FeCl_3}}{\ }\right)$

1 mol $Na_2Cr_2O_7 \rightarrow$ 6 mol $FeCl_3$
1×262 g → 6×162.2 g
x g → 24.7 g

$X = \frac{262 \times 24.7}{6 \times 162.2} = 6.64$ g $Na_2Cr_2O_7$

3.8 Limiting Reactant; Theoretical and Percentage Yields

Example 3.15 Calculating with a Limiting Reactant (Involving Moles)

* اذا كان معطيني معلومات عن مادتين متفاعلتين والسؤال عن اشي ثاني بكون limiting reactant ... عن LR مع المطلوب

Zinc metal reacts with hydrochloric acid by the following reaction: If 0.30 mol Zn is added to a solution containing 0.52 mol HCl, how many moles of H_2 are produced? → n??

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$\frac{.3\,mol}{1} = .3$ $\frac{.52\,mol}{2} = .26$ (أقل)

HCl → is the limiting reactant المادة المحددة
Zn → is the excess الفائضة

2 mol HCl → 1 mol H_2
.52 mol HCl → X mol H_2
$X = \frac{.52}{2} = .26$ mol H_2 are produced

3.91 Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen. If a reaction vessel contains 0.25 mol KO_2 and 0.15 mol H_2O, what is the limiting reactant? How many moles of oxygen can be produced?

$$4KO_2(s) + 2H_2O(l) \rightarrow 4KOH(s) + 3O_2(g)$$

$\frac{.25\,mol}{4} = .0625$ (أقل) $\frac{.15\,mol}{2} = .075$

KO_2 → L.R
H_2O → excess

4 mol KO_2 → 3 mol O_2
.25 mol KO_2 → X mol O_2
$X = \frac{3 \times .25}{4} = .1875$ mol O_2 are produced

Calculating with a Limiting Reactant (Involving Masses)

3.96 Hydrogen cyanide, HCN, is prepared from ammonia, air, and natural gas (CH_4) by the following process:

$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$

If a reaction vessel contains 11.5 g NH_3, 12.0 g O_2, and 10.5 g CH_4, what is the maximum mass in grams of hydrogen cyanide that could be made, assuming the reaction goes to completion as written? Molar masses are: NH_3=17 g/mol, O_2 O_2=32 g/mol, CH_4 =16 g/mol , HCN = 27 g/mol

$$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$$

$\frac{11.5\,g / 17}{2} = .3382$ mol excess $\frac{12\,g / 32}{3} = .125$ mol L.R $\frac{10.5\,g / 16}{2} = .3281$ mol excess

3 mol O_2 → 2 mol HCN
3×32 g O_2 → 2×27 g HCN
12 g O_2 → x g HCN

$X = \frac{2 \times 12 \times 27}{3 \times 32} = 6.75$ g HCN is made

➢ **Theoretical yield and percentage yield**

$$\text{Percentage yield} = \frac{\boxed{\text{actual yield}}}{\text{theoretical yield}} \times 100\%$$

mass, experimental
mass

Example 3.14

Relating the Quantities of Two Reactants (or Two Products)

In the following reaction:
$4HCl(aq) + MnO_2(s) \rightarrow 2H_2O(l) + MnCl_2(aq) + Cl_2(g)$. How many grams of HCl react with 5.00 g of MnO_2, according to this equation? Molar masses are: MnO_2=86.9g/mol &HCl=36.5 g/mol

4 mol HCl → 1 mol MnO_2
4×36.5 g HCl → 86.9 g MnO_2
X g HCl → 5 g MnO_2

$5.00\ g\ MnO_2 \times \frac{1\ mol\ MnO_2}{...} \times \frac{4\ mol\ HCl}{...} \times \frac{36.5\ g\ HCl}{...} = 8.40\ g\ HCl$

&HCl=36.5 g/mol

$$5.00\text{ g }MnO_2 \times \frac{1\text{ mol }MnO_2}{86.9\text{ g }MnO_2} \times \frac{4\text{ mol HCl}}{1\text{ mol }MnO_2} \times \frac{36.5\text{ g HCl}}{1\text{ mol HCl}} = \mathbf{8.40\text{ g HCl}}$$

4×36.5 g HCl → 86.9 g MnO_2
X g HCl → 5 g MnO_2
$X = \frac{5 \times 4 \times 36.5}{86.9}$
= 8.4 g HCl

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3.97 Aspirin (acetylsalicylic acid) is prepared by heating salicylic acid, $C_7H_6O_3$, with acetic anhydride, $C_4H_6O_3$. The other product is acetic acid, $C_2H_4O_2$. What is the theoretical yield (in grams) of aspirin, $C_9H_8O_4$, when 2.00 g of salicylic acid is heated with 4.00 g of acetic anhydride? If the actual yield of aspirin is 1.86 g, what is the percentage yield?

salicylic acid, $C_7H_6O_3$	138.12 g/mol
acetic anhydride, $C_4H_6O_3$	102.09 g/mol
Aspirin, $C_9H_8O_4$	180.16 g/mol

$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + C_2H_4O_2$

$\frac{2g / 138.12}{1}$ = .0145 L.R

$\frac{4g / 102.09}{1}$ = .0391 excess

1mol $C_7H_6O_3$ → 1mol $C_9H_8O_4$
138.12 g → 180.16 g
2g → X g
$X = \frac{180.16 \times 2}{138.12} = 2.61$ g $C_9H_8O_4$ theoritical yeild

percentage yeild of $C_9H_8O_4$ = $\frac{\text{actual yeild}}{\text{theoritical yeild}} \times 100\%$
$= \frac{1.86}{2.61} \times 100\%$
$= .713 \times 100\%$
= 71.3%

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(Q) When 6.40 g of CH_3OH was mixed with 10.2 g of O_2 and ignited, 6.12 g of CO_2 was obtained. What was the percentage yield of CO_2?

actual yeild

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$$

CH_3OH	32.04 g/mol
O_2	32.00 g/mol
CO_2	44.01 g/mol
H_2O	18.02 g/mol

$\frac{6.40g / 32.04}{2}$ = .0999 L.R

$\frac{10.2g / 32}{3}$ = .1063 excess

2mol CH_3OH → 2mol CO_2
2×32.04 g → 2×44.01 g
6.40g → X g CO_2
$X = \frac{2 \times 44.01 \times 6.40g}{2 \times 32.04}$
= 8.79 g CO_2 theoritical yeild

percentage yeild CO_2 = $\frac{6.12}{8.79} \times 100\%$
= 69.6%

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(Q) When 6.40 g of CH_3OH was mixed with 10.2 g of O_2 and ignited, 6.12 g of CO_2 was obtained. What was the percentage yield of CO_2?

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$$

MM(g/mol) (32.04) (32.00) (44.01) (18.02)

A. 6.12%
B. 8.79%
C. 100%
D. 142%
E. 69.6%

$$6.40\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32.04\text{ g }CH_3OH} \times \frac{3\text{ mol }CO_2}{2\text{ mol }CH_3OH} \times \frac{32.00\text{ g }O_2}{1\text{ mol }O_2}$$

= 9.59 g O_2 needed; CH_3OH limiting

$$6.40\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32.04\text{ g }CH_3OH} \times \frac{2\text{ mol }CO_2}{2\text{ mol }CH_3OH} \times \frac{44.01\text{ g }CO_2}{1\text{ mol }CO_2}$$

= 8.79 g CO_2 in theory

$$\frac{6.12\text{ g }CO_2\text{ actual}}{8.79\text{ g }CO_2\text{ theory}} \cdot 100\ \% = 69.6\%$$

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Q) For each calculation, give the answer to the **correct number of significant figures**.

1. 10.0 g + 1.03 g + 0.243 g = **11.3 g** or **1.13×10^1 g**
2. 19.556 °C – 19.552 °C = **0.004 °C** or **4×10^{-3} °C**
3. 327.5 m × 4.52 m = **1480.3 = 1.48×10^3 m^2**
4. 15.985 g ÷ 24.12 mL = **0.6627 g/mL** or **6.627×10^{-1} g/mL**

Q) When the expression,

412.272 + 0.00031 – 1.00797 + 0.000024 + 12.8

is evaluated, the result should be expressed as:

A. 424.06

B. 424.064364

C. 424.1

D. 424.064

E. 424

Q) For the following calculations, give the answer to the correct number of **significant figures**.

1. $$\frac{(71.359\text{ m} - 71.357\text{ m})}{(3.2\text{ s} \times 3.67\text{ s})} = \frac{(0.002\text{ m})}{(11.744\text{ s}^2)}$$

= (0.002/12)=(1.666 × 10^{-4}) =2 × 10^{-4} m/s^2

2. $$\frac{(13.674\text{ cm} \times 4.35\text{ cm} \times 0.35\text{ cm})}{(856\text{ s} + 1531.1\text{ s})}$$

Significant Figures in Calculations

Multiplication and Division

- Number of significant figures in answer = number of significant figures in **least precise** measurement

e.g., $10.54 \times 31.4 \times 16.987$ **= 5621.9 = 5.62×10^3**
4 sig. figs. × 3 sig. figs. × 5 sig. figs. = 3 sig. figs.

e.g., $5.896 \div 0.008$ **= 737 = 7×10^2**
4 sig. figs. ÷ 1 sig. fig. = 1 sig. fig.

Give the value of the following calculation to the correct number of significant figures.

$$\left(\frac{635.4 \times 0.0045}{2.3589}\right) = 2 \text{ sig fig}$$

A. 1.21213
B. 1.212
C. 1.212132774
D. 1.2
E. 1

Significant Figures in Calculations

Addition and Subtraction

- Answer has same number of decimal places as quantity with **fewest number** of decimal places.

e.g.,	12.9753	4 decimal places
	+319.5	1 decimal place
	+ 4.398	3 decimal places
	336.9	1 decimal place

e.g.,	397	0 decimal places
	− 273.15	2 decimal places
	124	0 decimal place

$N \times 10^n$

N is non zero
Single digit number
(1-10) 10 is not included

n is a positive or
negative integer

Rules for Significant Figu...

1. All non-zero numbers are significant.
   e.g., 3.456 has (**4** sig. figs)

2. Zeros between non-zero numbers are significant.
   e.g., 20089 has (**5** sig. figs)
   Can be written as or 2.0089×10^4 (**5** sig. figs)
3. Trailing zeros always count as significant **if number has decimal point**
   e.g., 500. or 5.00×10^2 has **3** sig. figs

Rules for Significant Figures

4. Final zeros on number without decimal point are
   → **Not significant**

Or **We don't know how many significant numbers**

e.g., 104956000
(more than one answer)

Q) 10056 ??
521369 ??

Final zeros to right of decimal point are significant
e.g., 3.00 has **3** sig. figs.

6. Leading zeros, to left of first nonzero digit, are never counted as significant
   e.g., 0.00012 or 1.2×10^{-4} has **2** sig. figs.

How many significant figures does each of the following numbers have?

		Scientific Notation	# of Sig. Figs.
1.	413.97	4.1397×10^2	**5**
2.	0.0006	6×10^{-4}	**1**
3.	5.120063	5.120063	**7**
4.	161000		**More than one answer**
5.	3600.	3.600×10^3	**4**

$N \times 10^n$

N is a single
Non-zero digit

n is a positive or
negative integer

$$36.00\text{ in} \times \left(\frac{\text{ft.}}{12\text{ in.}}\right) =$$

A. 3 ft.
B. 3.0 ft
C. 3.00 ft.
D. 3.000 ft.
E. 3.00000 ft.

Q) For the following calculation, give the answer to the correct number of significant figures.

$$\frac{(14.5\text{ cm} \times 12.334\text{ cm})}{(2.223\text{ cm} - 1.04\text{ cm})}$$

A. 179 cm^2
B. 1.18 cm
C. 151.2 cm
D. 151 cm
E. 178.843 cm^2

$$\frac{(178.843\text{ cm}^2)}{(1.183\text{ cm})}$$

=151.177

3 sig.fig.

=151

Rounding intermediate steps →
= 179 / 1.18
= 151.694
=152

Note: Do not round intermediate answers !

Perform the following calculations and round the answers to the correct number of significant figures (units of measurement have been omitted).

a. $\frac{2.568 \times 5.8}{4.186}$ b. $5.41 - 0.398$

c. $3.38 - 3.01$ d. $4.18 - 58.16 \times (3.38 - 3.01)$

a = 3.6
b = 5.01
c = 0.37
d = - 17

(1 km = 1000 m) ➔ (1 km^3 = $(1000)^3$ m^3)

(1 m = 100 cm) ➔ 1 m^3 = $(100)^3$ cm^3

1 L = 1000 mL=1000 cm^3

$$1.35 \times 10^9\ km^3 \times \frac{(1000)^3\ m^3}{1\ km^3} \times \frac{(100)^3\ cm^3}{1\ m^3} \times \frac{1L}{1000\ cm^3}$$

$1\ m^3 = 1000\ L$

1 km^3 = 10^{12} L

or $1.35 \times 10^9 \times 10^9\ m^3 \times \frac{10^3\ L}{1\ m^3}$

$= 1.35 \times 10^{21}\ L$

or $1L = 1\ dm^3$

$1\ km^3 = (10^4)^3\ dm^3$

$1.35 \times 10^9 \times 10^{12}\ dm^3$

$= 1.35 \times 10^{21}\ L$

Density

- Ratio of object's mass to its volume

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad \boxed{d = \frac{m}{V}}$$

- Units (depends on what units we use for mass and volume.
  - **g/mL** or **g/cm³**
  - **Or g/L** or **kg/L**

- A student weighs a piece of gold that has a volume of 11.02 cm^3 of gold. She finds the mass to be 212 g. What is the density of gold?

* الكثافة ثابتة للمادة نفسها

$$d = \frac{m}{V}$$

$$d = \frac{212\ g}{11.02\ cm^3} = \mathbf{19.3\ g/cm^3}$$

Another student has a piece of gold with a volume of 1.00 cm^3. What does it weigh? **19.3 g**

$m = 19.3 \times 1.00 = 19.3\ g$

What if it were 2.00 cm^3 in volume? **38.6 g**

$m = dV = 19.3 \times 2.00 = 38.6\ g$

(Q) If the density of an object is 2.87 x 10^{-4} lbs/cubic inch, what is its density in g/ml ? (1 lb = 454 g, 1 inch = 2.54 cm)

Temperature Conversions

- Common laboratory thermometers are marked in Celsius scale
- How to convert to Kelvin scale

$\boxed{K = {}^0C + 273.15}$

273.1 ١٤ من ٣٤

373.15 K = 100 ^{0}C

- Amounts to adding 273.15 to Celsius temperature

Example: What is the Kelvin temperature of a solution at 25 °C?

$$T_K = (25\ ^\circ C + 273.15\ ^\circ C)\frac{1\ K}{1\ ^\circ C} \quad \mathbf{= 298\ K}$$

1. Convert 121 °F to the Celsius scale.

$${}^0F = \frac{9}{5} \times {}^0C + 32 \qquad t_C = (t_F - 32\ ^\circ F)\left(\frac{5\ ^\circ C}{9\ ^\circ F}\right)$$

$$t_C = (121\ ^\circ F - 32\ ^\circ F)\left(\frac{5\ ^\circ C}{9\ ^\circ F}\right) \quad \mathbf{= 49\ ^\circ C}$$

2. Convert 121 °F to the Kelvin scale.

– We already have in °C so…

$$T_K = (t_C + 273.15\ ^\circ C)\frac{1\ K}{1\ ^\circ C} = (49 + 273.15\ ^\circ C)\frac{1\ K}{1\ ^\circ C}$$

$$\boldsymbol{T_K = 322\ K}$$

3. Convert 77 K to the Celsius scale.

$$T_K = (t_C + 273.15\ ^\circ C)\frac{1\ K}{1\ ^\circ C} \qquad t_C = (T_K - 273.15\ K)\frac{1\ ^\circ C}{1\ K}$$

$$t_C = (77\ K - 273.15\ K)\frac{1\ ^\circ C}{1\ K} \quad \mathbf{= -196\ ^\circ C}$$

4. Convert 77 K to the Fahrenheit scale.

– We already have in °C so

$$t_F = \left(\frac{9\ ^\circ F}{5\ ^\circ C}\right)(-196\ ^\circ C) + 32\ ^\circ F \quad \mathbf{= -321\ ^\circ F}$$

$$16.3 \text{ g S} \times \frac{1 \text{ mol S}}{32.1 \text{ g S}} \times \frac{6.022 \times 10^{23} \text{ S atoms}}{1 \text{ mol S atoms}} =$$

Example 3.3 Calculating the Mass of an Atom or Molecule

a. What is the mass in grams of one chlorine atom, Cl?

b. What is the mass in grams of one HCl molecule?

Note: when you see no of atoms and molecules ⇒ remember avogadro's number

(a) $M_{r_{Cl}} = 35.5$ 1 atom Cl $= \frac{1}{6.022 \times 10^{23}}$ mol

$m = n \times Mr$

$= \frac{1}{6.022 \times 10^{23}} \times 35.5 = 5.89 \times 10^{-23}$ g Cl

or $1 \text{ atom} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atom}} \times \frac{35.5 \text{ g}}{\text{mol}} = \frac{35.5}{6.022 \times 10^{23}}$

(b) $n = \frac{1}{6.022 \times 10^{23}}$ mol $M_{r_{HCl}} = 36.5$

$m = n \times Mr$

$= \frac{36.5}{6.022 \times 10^{23}}$ g HCl.

(Q) How much, in grams, do 8.85×10^{24} atoms of zinc weigh? $M_{r_{Zn}} = 65.4$

$m = \frac{8.85 \times 10^{24}}{6.022 \times 10^{23}} \times 65.4 = 961$ g Zn

A. 3.49×10^{49} g

B. 961 g

C. 4.45 g

D. 5.33×10^{47} g

E. 1.47 g

$$8.85 \times 10^{24} \cancel{\text{atoms}} \times \left(\frac{1 \cancel{\text{mol}}}{6.022 \times 10^{23} \cancel{\text{atoms}}}\right) \times \left(\frac{65.41 \text{ g Zn}}{1 \cancel{\text{mol}}}\right)$$

= 961 g Zn

(Q) How many hydrogen atoms are present in 25.6 g of urea [$(NH_2)_2CO$]? molar mass of urea = 60.06 g/mol.

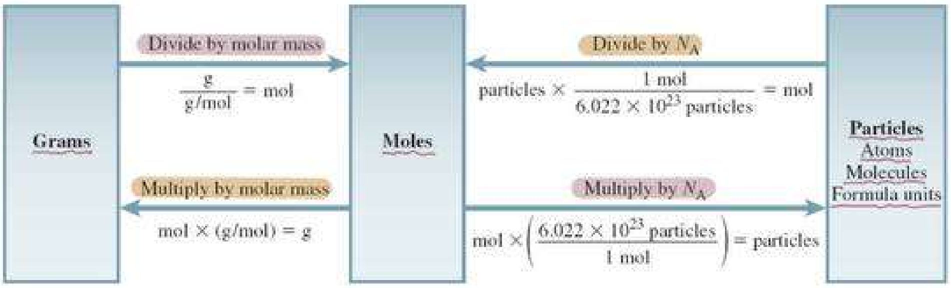
grams of urea ⟶ moles of urea ⟶ moles of H ⟶ atoms of H

$$25.6 \cancel{\text{ g } (NH_2)_2CO} \times \frac{1 \text{ mol } \cancel{(NH_2)_2CO}}{60.06 \cancel{\text{ g } (NH_2)_2CO}} \times \frac{4 \cancel{\text{ mol H}}}{1 \cancel{\text{ mol } (NH_2)_2CO}} \times \frac{6.022 \times 10^{23} \text{ H atoms}}{1 \cancel{\text{ mol H}}}$$

$$\text{No of Moles} = \frac{\text{Mass (g)}}{\text{Molar Mass (g/mole)}}$$

avogadro's number

$$\text{No of Atoms} = \text{No of Moles} \times \frac{6.022 \times 10^{23}\ \text{atom}}{1\ \text{mole}}$$



من mol لـ molecule, atom ← بنضرب بـ 6.022×10^{23}

من molecule لـ mol ← بنقسم على 6.022×10^{23}

(Q) How many molecules are there in a 3.46-g sample of hydrogen chloride, HCl? Note → when you see "How many" remember avogadro's number

$Mr_{HCl} = 1 + 35.5 = 36.5$

molecules of HCl $= n_{HCl} \times N_A$

$= \frac{3.46}{36.5} \times 6.022 \times 10^{23}$ molecules

$= .571 \times 10^{23}$

$= 5.71 \times 10^{22}$ molecules

(Q) How many S atoms are there in 16.3 g of S?

$Mr_S = 32.1$

atoms of S $= n_S \times N_A$

$= \frac{16.3}{32.1} \times 6.022 \times 10^{23}$

$= 3.06 \times 10^{23}$ atoms

(Q) How many molecules are there in a 3.46-g sample of hydrogen chloride, HCl?

$$3.46\ \text{g HCl} \times \frac{1\ \text{mol HCl}}{36.5\ \text{g HCl}} \times \frac{6.022 \times 10^{23}\ \text{HCl molecules}}{1\ \text{mol HCl molecules}} =$$

(Q) How many S atoms are there in 16.3 g of S?

$$16.3\ \text{g S} \times \frac{1\ \text{mol S}}{32.1\ \text{g S}} \times \frac{6.022 \times 10^{23}\ \text{S atoms}}{1\ \text{mol S atoms}} =$$

- $H = \frac{}{3.722\times10^{-3}\text{ mol C}} = 4.997 \quad = 5$

- $N = \frac{3.723\times10^{-3}\text{ mol N}}{3.722\times10^{-3}\text{ mol C}} = 1.000 \quad = 1$

Step 3: Divide all number of moles by one

٣٦ من ٤٨

Empirical formula = CH_5N

molecular formula

$n = \frac{\text{molar mass molecular}}{\text{molar mass empirical}}$

then multiply the empirical formula by n to find the molecular formula

2. Empirical Formula from Percentage Composition

Calculate the empirical formula of a compound whose percentage composition data is 43.64% P and 56.36% O. If the molar mass is determined to be 283.9 g/mol, what is the molecular formula?

molecular mass

Step 1: Assume 100 g of compound

- 43.64 g P 1 mol P = 30.97 g
- 56.36 g O 1 mol O = 16.00 g

$$43.64\ \cancel{gP} \times \frac{1\text{ mol P}}{30.97\ \cancel{gP}} = 1.409\text{ mol P}$$

$$56.36\ \cancel{gO} \times \frac{1\text{ mol O}}{16.00\ \cancel{gO}} = 3.523\text{ mol O}$$

Step 2: Divide by smallest number of moles

$$\frac{1.409\text{ mol P}}{1.409\text{ mol P}} = 1.000$$

$$\frac{3.523\text{ mol O}}{1.409\text{ mol P}} = 2.500$$

1.33×3

Step 3: Multiple to get integers

$1.000 \times 2 = 2$
$2.500 \times 2 = 5$

Empirical formula = P_2O_5

molecular formula = P_4O_{10}

$n = \frac{\text{Mr of molecular}}{\text{Mr of empirical}} = \frac{283.9}{2\times31 + 5\times16} = \frac{283.9}{142} = 2$

molecular = n * empirical
$= 2(P_2O_5)$
$= P_4O_{10}$

(Q) Ascorbic acid (vitamin C) is composed of 40.92 percent carbon (C), 4.58 percent hydrogen (H), and 54.50 percent oxygen (O) by mass. Determine its empirical formula.

Assume you have 100 g

$\left(\frac{}{\text{g total}}\right) \times 100\% \quad \left(\frac{}{0.5462\text{ g}}\right)$

% Composition of O

$$\left(\frac{\text{g O}}{\text{g total}}\right)\times 100\% = \left(\frac{0.4045\text{ g O}}{0.5462\text{ g}}\right)\times 1$$

٢٠ من ٤٨

(Q) a.Calculate the mass percentages of the elements in formaldehyde (CH_2O) molar mass = 30g/mol

total mass

$$\% \, \mathbf{C} = \frac{12.0\text{ g}}{30.0\text{ g}} \times 100\% = \mathbf{40.0\%}$$

$$\% \, \mathbf{H} = \frac{2 \times 1.01\text{ g}}{30.0\text{ g}} \times 100\% = \mathbf{6.73\%}$$

% **O** = 16/30 x100% = 53.3 %

$$\% \, \mathbf{O} = 100\% - (40.0\% + 6.73\%) = \mathbf{53.3\%}$$

b. How many grams of carbon are there in 83.5 g of CH_2O?

CH_2O is 40.0% C, so the mass of carbon in 83.5 g CH_2O i
83.5 g X 0.400 = **33.4 g**

(Q) Calculate the mass percentages of the elements in H_3PO_4
molar mass = 97.99 g/mol

total mass

$$\%H = \frac{3(1.008\text{ g})\text{ H}}{97.99\text{ g }H_3PO_4} \times 100\% = 3.086\%$$

$$\%P = \frac{30.97\text{ g P}}{97.99\text{ g }H_3PO_4} \times 100\% = 31.61\%$$

$$\%O = \frac{4(16.00\text{ g})\text{ O}}{97.99\text{ g }H_3PO_4} \times 100\% = 65.31\%$$

➢ **Determining Empirical and Molecular Formulas**

Empirical Formula الصيغة الإبتدائية

– Simplest ratio of atoms of each element in compound
– Obtained from experimental analysis of compound

Molecular Formula الصيغة الجزيئية

e.g., 43.64% P and 56.36% O

3. **From Combustion Data**
   - Given masses of combustion products

e.g., The combustion of a 5.217 g sample of a compound of C, H, and O in pure oxygen gave 7.406 g CO_2 and 4.512 g of H_2O

1. Empirical Formula from Mass Data

When a 0.1156 g sample of a compound was analyzed, it was found to contain 0.04470 g of C, 0.01875 g of H, and 0.05215 g of N. Calculate the empirical formula of this compound.

Step 1: Calculate moles of each substance

$$0.04470\, \cancel{g\,C} \times \frac{1\text{ mol C}}{12.011\, \cancel{g\,C}} = 3.722 \times 10^{-3}\text{ mol C}$$

$$0.01875\, \cancel{g\,H} \times \frac{1\text{ mol H}}{1.008\, \cancel{g\,H}} = 1.860 \times 10^{-2}\text{ mol H}$$

$$0.05215\, \cancel{g\,N} \times \frac{1\text{ mol N}}{14.0067\, \cancel{g\,N}} = 3.723 \times 10^{-3}\text{ mol N}$$

Step 2: Select the smallest number of moles

4.95 → 5 ✓
4.997 → 5 ✓
4.94 → 5 ✗
1.33 → 1 ✗
1.7 → 2 ✗
2.8 → 3 ✗

- Smallest is 3.722×10^{-3} mole

	Mole ratio	Integer ratio
$C = \dfrac{3.722\times10^{-3}\text{ mol C}}{3.722\times10^{-3}\text{ mol C}} =$	1.000	= 1
$H = \dfrac{1.860\times10^{-2}\text{ mol H}}{3.722\times10^{-3}\text{ mol C}} =$	4.997	= 5
$N = \dfrac{3.723\times10^{-3}\text{ mol N}}{3.722\times10^{-3}\text{ mol C}} =$	1.000	= 1

Step 3: Divide all number of moles by the smallest one

Empirical formula = CH_5N

molecular formula

$$n = \frac{\text{molar mass molecular}}{\text{molar mass empirical}}$$

then multiply the empirical formula by n to find the molecular formula

2. Empirical Formula from Percentage Composition

Calculate the empirical formula of a compound whose

&HCl=36.5 g/mol

$$5.00\ \cancel{\text{g MnO}_2} \times \frac{1\ \cancel{\text{mol MnO}_2}}{86.9\ \cancel{\text{g MnO}_2}} \times \frac{4\ \cancel{\text{mol HCl}}}{1\ \cancel{\text{mol MnO}_2}} \times \frac{36.5\ \text{g HCl}}{1\ \cancel{\text{mol HCl}}} = \mathbf{8.40\ g\ HCl}$$

way 2 : 4 mol HCl → 1 mol MnO_2

4×36.5 g HCl → 86.9 g MnO_2

x g HCl → 5 g MnO_2

$x = \frac{4 \times 5 \times 36.5}{86.9} = 8.40\text{g HCl}$

Exercise 3.16 oxygen can be prepared by heating mercury(II) oxide, HgO. Mercury metal is the other product. If 6.47 g of oxygen is collected, how many grams of mercury metal are also produced?

Molar masses are: O_2=32.00g/mol &Hg=200.59 g/mol

$$2HgO \rightarrow 2Hg + O_2$$

way 2 : 1 mol O_2 → 2 mol Hg

32 g O_2 → 200.59×2 g Hg

6.47 g O_2 → x g Hg

$x = \frac{200.59 \times 6.47 \times 2}{32} = 81.1\text{g Hg}$

$$6.47\ \text{g O}_2 \times \frac{1\ \text{mol O}_2}{32.00\ \text{g O}_2} \times \frac{2\ \text{mol Hg}}{1\ \text{mol O}_2} \times \frac{200.59\ \text{g Hg}}{1\ \text{mol Hg}} = 81.11 = 81.1\ \text{g Hg}$$

How many grams of Al_2O_3 are produced when 41.5 g Al react? Molar masses are: Al=26.98g/mol Al_2O_3=101.96g/mol

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(l)$$

A. 78.4 g
B. 157 g
C. 314 g
D. 22.0 g
E. 11.0 g

2 mol Al → 1 mol Al_2O_3

2×26.98 g → 101.96 g

41.5 g → x g

$x = \frac{101.96 \times 41.5}{2 \times 26.98} = 78.4\text{g Al}_2\text{O}_3$

$$41.5\ \cancel{\text{g Al}}\left(\frac{1\ \cancel{\text{mol Al}}}{26.98\ \cancel{\text{g Al}}}\right)\left(\frac{1\ \cancel{\text{mol Al}_2\text{O}_3}}{2\ \cancel{\text{mol Al}}}\right)\left(\frac{101.96\ \text{g Al}_2\text{O}_3}{1\ \cancel{\text{mol Al}_2\text{O}_3}}\right)$$

$$= 78.4\ \text{g Al}_2\text{O}_3$$

How many grams of sodium dichromate are required to produce 24.7 g iron(III) chloride from the following reaction? Molar masses are: $FeCl_3$=162.2 g/mol $Na_2Cr_2O_7$ =262.0 g/mol

$14HCl + Na_2Cr_2O_7 + 6FeCl_2 \rightarrow 2CrCl_3 + 7H_2O + 6FeCl_3 + 2NaCl$

A. 6.64 g $Na_2Cr_2O_7$

B. 0.152 g $Na_2Cr_2O_7$ ... $\left(\frac{1\ \cancel{\text{mol FeCl}_3}}{}\right)$

1 mol $Na_2Cr_2O_7 \rightarrow$ 6 mol $FeCl_3$
1×262 g → 6×162.2 g
x g → 24.7 g

$X = \frac{262 \times 24.7}{6 \times 162.2} = 6.64$ g $Na_2Cr_2O_7$

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3.8 Limiting Reactant; Theoretical and Percentage Yields

Example 3.15 Calculating with a Limiting Reactant (Involving Moles)

* اذا كان معطيني معلومات من مادتين متفاعلتين والسؤال عن اشي ثاني لازم ... limiting reactant ... L.R ... مع الكلاويط

Zinc metal reacts with hydrochloric acid by the following reaction: If 0.30 mol Zn is added to a solution containing 0.52 mol HCl, how many moles of H_2 are produced? → n??

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$\frac{.3 \text{mol}}{1}$ = .3 $\frac{.52 \text{mol}}{2}$ = .26 أقل

HCl → is the limiting reactant المادة المحددة
Zn → is the excess الفائضة

2 mol HCl → 1 mol H_2
.52 mol HCl → X mol H_2
* X = $\frac{.52}{2}$ = .26 mol H_2 are produced

3.91 Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen. If a reaction vessel contains 0.25 mol KO_2 and 0.15 mol H_2O, what is the limiting reactant? How many moles of oxygen can be produced?

$$4KO_2(s) + 2H_2O(l) \rightarrow 4KOH(s) + 3O_2(g)$$

$\frac{.25 \text{mol}}{4}$ = .0625 أقل $\frac{.15 \text{mol}}{2}$ = .075

KO_2 → L.R
H_2O → excess

4 mol KO_2 → 3 mol O_2
.25 mol KO_2 → X mol O_2
X = $\frac{3 \times .25}{4}$ = .1875 mol O_2 are produced

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Calculating with a Limiting Reactant (Involving Masses)

3.96 Hydrogen cyanide, HCN, is prepared from ammonia, air, and natural gas (CH_4) by the following process:

$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$

If a reaction vessel contains 11.5 g NH_3, 12.0 g O_2, and 10.5 g CH_4, what is the maximum mass in grams of hydrogen cyanide that could be made, assuming the reaction goes to completion as written? Molar masses are: NH_3=17 g/mol, O_2 O_2=32 g/mol, CH_4 =16 g/mol , HCN = 27 g/mol

$$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$$

$\frac{11.5g / 17}{2}$ = .3382 mol excess
$\frac{12g / 32}{3}$ = .125 mol L.R
$\frac{10.5g / 16}{2}$ = .3281 mol excess

3 mol O_2 → 2 mol HCN
3×32 g O_2 → 2×27 g HCN
12 g O_2 → x g HCN

$X = \frac{2 \times 12 \times 27}{3 \times 32} = 6.75$ g HCN is made

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➢ **Theoretical yield and percentage yield**

$$\text{Percentage yield} = \frac{\overset{\text{experimental}}{\boxed{\text{actual yield}}}_{\text{mass}}}{\text{theoretical yield}_{\text{mass}}} \times 100\%$$

Example 3.14
Relating the Quantities of Two Reactants (or Two Products)
In the following reaction:
$4HCl(aq) + MnO_2(s) \rightarrow 2H_2O(l) + MnCl_2(aq) + Cl_2(g)$. How many grams of HCl react with 5.00 g of MnO_2, according to this equation? Molar masses are: MnO_2=86.9g/mol &HCl=36.5 g/mol

4 mol HCl → 1 mol MnO_2
4×36.5 g HCl → 86.9 g MnO_2
X g HCl → 5 g MnO_2

$$5.00 \text{ g } MnO_2 \times \frac{1 \text{ mol } MnO_2}{\ldots} \times \frac{4 \text{ mol HCl}}{\ldots} \times \frac{36.5 \text{ g HCl}}{\ldots} = 8.40 \text{ g HCl}$$

التفسير الجزئي

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

N_2	+	$3H_2$	$\longrightarrow$	$2NH_3$	
1 molecule N_2	+	3 molecules H_2	$\longrightarrow$	2 molecules NH_3	(…
1 mol N_2	+	3 mol H_2	$\longrightarrow$	2 mol NH_3	(molar interpretation)
28.0 g N_2	+	3×2.02 g H_2	$\longrightarrow$	2×17.0 g NH_3	(mass interpretation)

3.7 Amounts of Substances in a Chemical Reaction

Example 3.13

Relating the Quantity of Reactant to Quantity of Product

In the following reaction: mass??

1000 g

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

How many grams of Fe(s) can be produced from 1.00 kg Fe_2O_3?

Molar masses are: Fe = 55.8 g/mol and Fe_2O_3 = 160 g/mol

Solution The calculation is as follows:

$$1.00 \times 10^3\ \text{g}\ \cancel{Fe_2O_3} \times \frac{1\ \cancel{\text{mol}\ Fe_2O_3}}{160\ \cancel{\text{g}\ Fe_2O_3}} \times \frac{2\ \cancel{\text{mol}\ Fe}}{1\ \cancel{\text{mol}\ Fe_2O_3}} \times \frac{55.8\ \text{g Fe}}{1\ \cancel{\text{mol Fe}}} = \mathbf{698\ g\ Fe}$$

theoritical yeild

way 2:

1 mol $Fe_2O_3 \rightarrow$ 2 mol Fe

1×160 g $Fe_2O_3 \rightarrow 2 \times 55.8$ g Fe

1000 g $Fe_2O_3 \rightarrow$ X g Fe

$X = \frac{2 \times 55.8 \times 1000}{160} = 697.5 = 698$ g Fe

Example 3.14

Relating the Quantities of Two Reactants (or Two Products)

In the following reaction:

gm?? 5 g

$4HCl(aq) + MnO_2(s) \rightarrow 2H_2O(l) + MnCl_2(aq) + Cl_2(g)$, How many grams of HCl react with 5.00 g of MnO_2, according to this equation? Molar masses are: MnO_2=86.9g/mol &HCl=36.5 g/mol

$$5.00\ \text{g}\ \cancel{MnO_2} \times \frac{1\ \cancel{\text{mol}\ MnO_2}}{86.9\ \cancel{\text{g}\ MnO_2}} \times \frac{4\ \cancel{\text{mol HCl}}}{1\ \cancel{\text{mol}\ MnO_2}} \times \frac{36.5\ \text{g HCl}}{1\ \cancel{\text{mol HCl}}} = \mathbf{8.40\ g\ HCl}$$

way 2:

4 mol HCl $\rightarrow$ 1 mol MnO_2

4×36.5 g HCl $\rightarrow$ 86.9 g MnO_2

x g HCl $\rightarrow$ 5 g MnO_2

$X = \frac{4 \times 5 \times 36.5}{86.9} = 8.40$ g HCl

Exercise 3.16 oxygen can be prepared by heating mercury(II) oxide, HgO. Mercury metal is the other product. If 6.47 g of oxygen is collected, how many grams of mercury

&HCl=36.5 g/mol

$$5.00\text{ g }MnO_2 \times \frac{1\text{ mol }MnO_2}{86.9\text{ g }MnO_2} \times \frac{4\text{ mol HCl}}{1\text{ mol }MnO_2} \times \frac{36.5\text{ g HCl}}{1\text{ mol HCl}} = \mathbf{8.40\text{ g HCl}}$$

4×36.5 g HCl → 86.9 g MnO_2

X g HCl → 5 g MnO_2

$X = \frac{5 \times 4 \times 36.5}{86.9}$

= 8.4 g HCl

3.97 Aspirin (acetylsalicylic acid) is prepared by heating salicylic acid, $C_7H_6O_3$, with acetic anhydride, $C_4H_6O_3$. The other product is acetic acid, $C_2H_4O_2$. What is the theoretical yield (in grams) of aspirin, $C_9H_8O_4$, when 2.00 g of salicylic acid is heated with 4.00 g of acetic anhydride? If the actual yield of aspirin is 1.86 g, what is the percentage yield?

salicylic acid, $C_7H_6O_3$	138.12 g/mol
acetic anhydride, $C_4H_6O_3$	102.09 g/mol
Aspirin, $C_9H_8O_4$	180.16 g/mol

$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + C_2H_4O_2$

$\frac{2g / 138.12}{1}$ $\frac{4g / 102.09}{1}$

= .0145 L.R = .0391 excess

1mol $C_7H_6O_3$ → 1mol $C_9H_8O_4$

138.12 g → 180.16 g

2 g → X g

$X = \frac{180.16 \times 2}{138.12} = 2.61$ g $C_9H_8O_4$ theoritical yeild

percentage yeild of $C_9H_8O_4$ = $\frac{\text{actual yeild}}{\text{theoritical yeild}} \times 100\%$

$= \frac{1.86}{2.61} \times 100\%$

$= .713 \times 100\%$

$= 71.3\%$

(Q) When 6.40 g of CH_3OH was mixed with 10.2 g of O_2 and ignited, 6.12 g of CO_2 was obtained. What was the percentage yield of CO_2?

actual yeild

CH_3OH	32.04 g/mol
O_2	32.00 g/mol
CO_2	44.01 g/mol
H_2O	18.02 g/mol

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$$

$\frac{6.40g / 32.04}{2}$ $\frac{10.2g / 32}{3}$

= .0999 L.R = .1063 excess

2mol CH_3OH → 2mol CO_2

2×32.04 g → 2×44.01 g

6.40 g → x g CO_2

$X = \frac{2 \times 44.01 \times 6.40g}{2 \times 32.04}$

= 8.79 g CO_2 theoritical yeild

percentage yeild CO_2 = $\frac{6.12}{8.79} \times 100\%$

= 69.6%

(Q) When 6.40 g of CH_3OH was mixed with 10.2 g of O_2 and ignited, 6.12 g of CO_2 was obtained. What was the percentage yield of CO_2?

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$$

MM(g/mol) (32.04) (32.00) (44.01) (18.02)

A. 6.12%

B. 8.79%

C. 100%

D. 142%

E. 69.6%

$$6.40\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32.04\text{ g }CH_3OH} \times \frac{3\text{ mol }CO_2}{2\text{ mol }CH_3OH} \times \frac{32.00\text{ g }O_2}{1\text{ mol }O_2}$$

= 9.59 g O_2 needed; CH_3OH limiting

$$6.40\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32.04\text{ g }CH_3OH} \times \frac{2\text{ mol }CO_2}{2\text{ mol }CH_3OH} \times \frac{44.01\text{ g }CO_2}{1\text{ mol }CO_2}$$

= 8.79 g CO_2 in theory

$$\frac{6.12\text{ g }CO_2\text{ actual}}{8.79\text{ g }CO_2\text{ theory}} \cdot 100\ \% = 69.6\%$$

Group 3A 4A 5A 6A 7A

NF_3 not F_3N
H_2S not SH_2
SbH_3 not H_3Sb

➢ Rules for Naming Binary Molecular Compounds

1. The name of the compound has the elements in the order given in the previous formula.
2. Name the first element using the exact element name.
3. Name the second element by writing the stem name of the element with the suffix *-ide*
4. You add a prefix, derived from the Greek, to each element name to denote the subscript of the element in the formula.

Note: the **prefix *mono-*** is not used, unless it is needed to distinguish two compounds of the same two elements.

Examples:

Element	B	Si	C	Sb	As	P	N	H	Te	Se	S	I	Br	Cl	O	F
Group	3A	4A			5A					6A			7A			

N_2O_3 dinitrogentrioxide
HCl hydrogen chloride NOT monohydrogen monochloride
CO carbon monoxide
CO_2 carbon dioxide
SF_4 sulfur tetrafluoride
SF_6 sulfur hexafluoride
ClO_2 chlorine dioxide
Cl_2O_7 dichlorine heptoxide

H_2S dihydrogen sulfide — common name: hydrogen sulfide
NO nitrogen monoxide — common name: nitric oxide
H_2O water
NH_3 ammonia

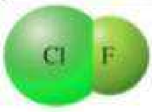
NO_2 nitrogen dioxide
N_2O dinitrogen monoxide
N_2O_4 dinitrogen **tetroxide**
P_4O_6 tetraphosphorus **hexoxide**
Cl_2O_6 dichlorine hexoxide
PCl_3 phosphorus trichloride
PCl_5 phosphorus pentachloride

disulfur dichloride S_2Cl_2
tetraphosphorus trisulfide P_4S_3
carbon disulfide CS_2
sulfur trioxide SO_3

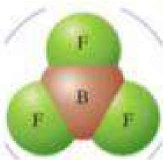
PCl_5	phosphorus pentachloride

disulfur dichloride	S_2Cl_2
tetraphosphorus trisulfide	P_4S_3
carbon disulfide	CS_2
sulfur trioxide	SO_3

nitrogen dioxide



Chlorine monofluoride



Boron trifluoride

Hydrogen selenide
Or dihydrogen selenide

$GaBr_3$	metal + non-metal	Gallium (III) bromide
$GeBr_4$	metalloid + non-metal	Germanium tetrabromide
$CaBr_2$	metal + non-metal	Calcium bromide
$Hg_2(NO_2)_2.H_2O$	hydrate	Mercury(I) nitrite monohydrate

Ga always +3

➢ Acids and Corresponding Anions

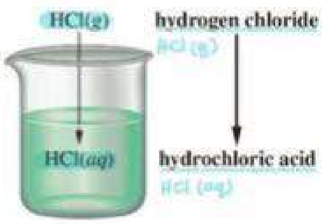
Anion Suffix		*Acid Suffix*
-ate	→	*-ic*
-ite	→	*-ous*

Acid	Contains	Name
HNO_3 →	nitrate anion therefore nitric acid	ate to ic
HNO_2 →	nitrite anion therefore nitrous acid	ite to ous

Table 2.8 Some Oxoanions and Their Corresponding Oxoacids

Oxoanion		Oxoacid	
CO_3^{2-}	*Carbonate ion*	H_2CO_3	*Carbonic acid*
NO_2^-	*Nitrite ion*	HNO_2	*Nitrous acid*
NO_3^-	*Nitrate ion*	HNO_3	*Nitric acid*
PO_4^{3-}	*Phosphate ion*	H_3PO_4	*Phosphoric acid*
SO_3^{2-}	*Sulfite ion*	H_2SO_3	*Sulfurous acid*
SO_4^{2-}	*Sulfate ion*	H_2SO_4	*Sulfuric acid*
ClO^-	*Hypochlorite ion*	$HClO$	*Hypochlorous acid*
ClO_2^-	*Chlorite ion*	$HClO_2$	*Chlorous acid*
ClO_3^-	*Chlorate ion*	$HClO_3$	*Chloric acid*
ClO_4^-	*Perchlorate ion*	$HClO_4$	*Perchloric acid*

Binary Compound	***Acid Solution***
$HBr(g)$, hydrogen bromide	*hydrobromic acid*, $HBr(aq)$
$HF(g)$, hydrogen fluoride	*hydrofluoric acid*, $HF(aq)$



(Q)Selenium has an oxoacid H_2SeO_4, called selenic acid. What is the formula and name of the corresponding anion?

Titanium(IV) oxide TiO_2

Thallium(III) nitrate $Tl(NO_3)_3$

(Q) Which is the correct name for Cu_2S?

A. copper sulfide
B. copper(II) sulfide
C. copper(II) sulfate
D. copper(I) sulfide
E. copper(I) sulfite

(Q) Which is the correct formula for ammonium sulfite?

NH_4^+ SO_3^{2-}

$(NH_4)_2SO_3$

A. NH_4SO_3
B. $(NH_4)_2SO_3$
C. $(NH_4)_2SO_4$
D. NH_4S
E. $(NH_4)_2S$

(Q) Name the following compounds:

(a) $Fe(NO_3)_2$ Iron(II) nitrate

(b) Na_2HPO_4 Sodium monohydrogen phosphate

(c) $(NH_4)_2(C_2O_4)$ Ammonium oxalate

(Q)Write chemical formulas for the following compounds:

(a) cesium sulfide CsS

(b) calcium phosphate $Ca_3(PO_4)_2$

➢ Naming Hydrates

1. Name ionic compound
2. Give number of water molecules in formula using Greek prefixes

$Ca(SO_4).2H_2O$ calcium sulfate dihydrate

$CoCl_2.6H_2O$ cobalt(II) chloride hexahydrate

$FeI_3 \cdot 3H_2O$ iron(III) iodide trihydrate

$Fe(NO_2)_3.9H_2O$ iron(III) nitrite nonahydrate

TABLE 2.6

Greek Prefixes for Naming Compounds

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-