Ch03

Formulas

The molecular blueprint.

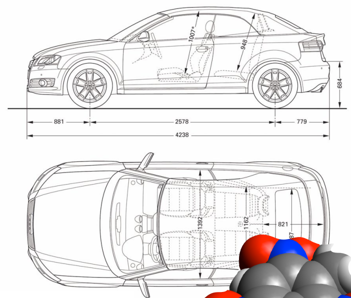
Showing how atoms combine to make compounds.

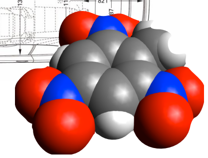
version 1.5

Ch03

Formulas

- Formulas
  - Atom Count
  - Molar Mass
  - Molecular Composition
    - Elemental Analysis
    - Finding Formulas from Composition
- Equations
  - Showing Reactions
  - Classifying Reactions
    - by Kinetics (mutually exclusive labels)
      - Combination
      - Decomposition,
      - Single Displacement
      - Double Displacement
    - by Reactivity (not mutually exclusive labels)
      - Combustion
      - Gas Evolution
      - Precipitation





$C_6H_2(NO_2)_3CH_3$

- Writing Equations
  - Identify reactants, products, conditions, then apply nomenclature
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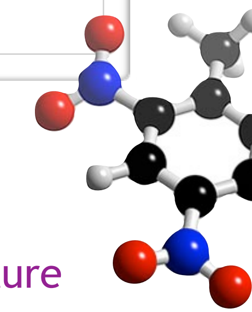
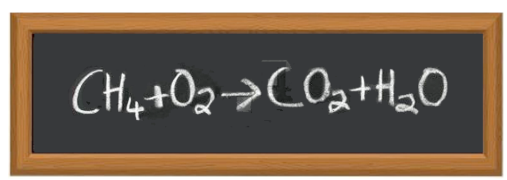




Symbols into Formulas

- We use symbols to represent elements and also to represent atoms of that element.
  - You must memorize the symbols of the first 18 elements! (this is easier than it sounds)
- The order of elements goes from the most metal-like element to the least. Na before C before H before F, etc (we'll talk more about this later)
- We use subscripts to indicate the number of atoms of that element.
  - Subscripts of 1 are omitted.
  - Omitted subscripts mean 1.
- We use superscripts to indicate the net charge (if any) on the entire particle.
  - Superscripts of 0 are omitted.
  - Omitted superscripts are assumed to mean 0.

Au $AlBr_3$ CH_4 Cl^{-} Na^{+} HF Br_2 Al^{3+} NO_2^{-} Sn $C_6H_8NO_4$ PO_4^{2-}

H_2O

Water is a binary compound, it is a polyatomic molecule composed of 2 hydrogen atoms and 1 oxygen atom. It has a charge of zero.

SO_4^{2-}

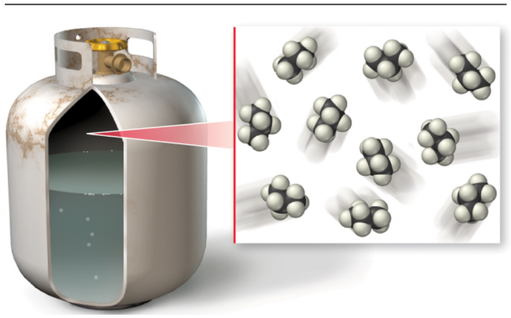
Charge

Atom Count

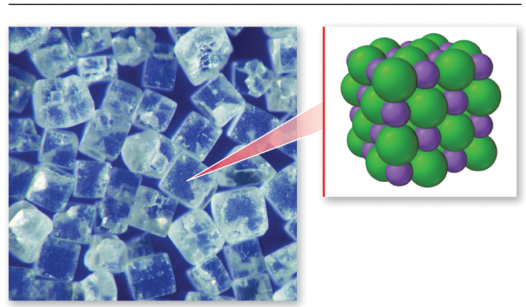
Sulfate is a binary ion, it is a polyatomic ion composed of sulfur atom and 4 oxygen atoms. It has a charge of minus two.

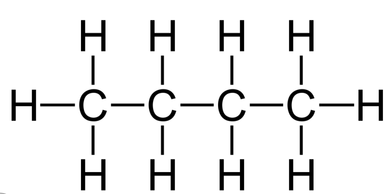
Chemical Formula

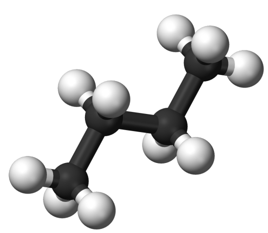
A Molecular Compound

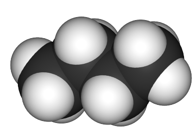


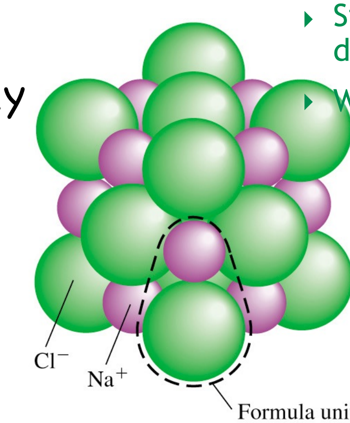
An Ionic Compound



	Butane	Salt
Empirical	C_2H_5	NaCl
Molecular	C_4H_{10}	does not apply
Structural		does not apply

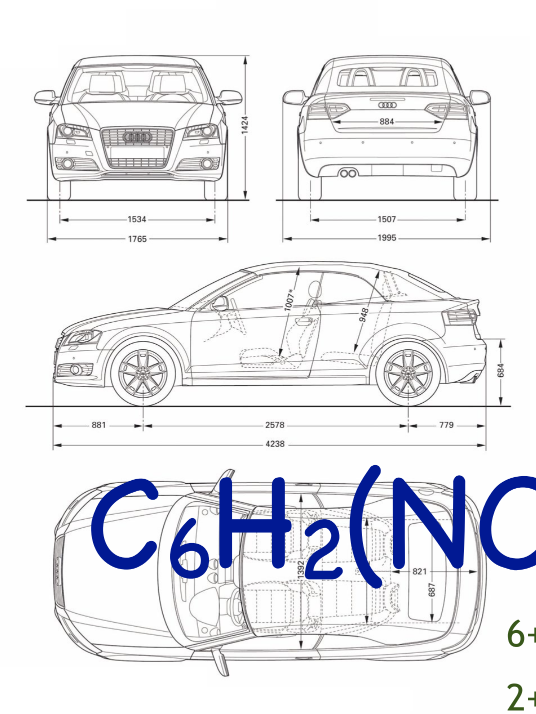






- We use chemical formulas to describe both types of compound.
- There are three kinds of chemical formulas.
- Empirical formula describe the ratio of elements in the compound.
  - Empirical formulas can be applied to molecular or ionic compounds.
  - The smallest whole number ratio of elements is a formula unit.
- Molecular formulas describe the number of atoms in each molecule.
  - Molecular formulas can only be used to describe molecular compounds.
- Structural formulas graphically describe the connectivity between atoms.
  - Structural formals can only be used to describe molecular compounds.
  - We'll talk about these in a later chapter.

The Molecular Blueprint



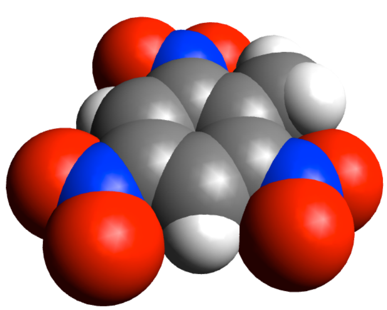
$$C_6H_2(NO_2)_3CH_3$$

6+1 Carbon Atoms

2+3 Hydrogen Atoms

3 NO_2 Groups

- 3 (3x1) Nitrogen Atoms
- 6 (3x2) Oxygen Atoms



- Chemical Formulas Identify Compounds
  - We use them as shorthand to name of a substance ("Pass me the H_2O")
- Chemical Formulas indicate the composition of a substance.
  - Each element is indicated with it's symbol.
  - The a subscript indicates the total number of atoms of that element.
    - Subscripts of 1 are omitted.
    - Omitted subscripts mean 1.
  - Parenthesis are used to indicate groups of atoms.
- Chemical Formulas may contain hints of the connectivity of the atoms.
- Chemical Formulas may show a CH_3 group of atoms and three NO_2 groups of atoms are bonded to a C_6H_2 group by writing:

$$C_6H_2(NO_2)_3CH_3$$

instead of: $C_7H_5N_3O_6$

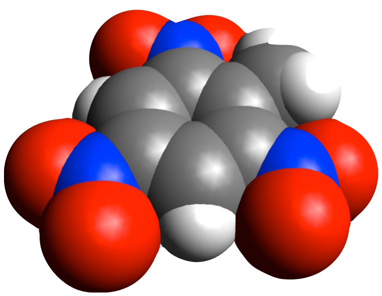
Problem:

You have 2.85 mols of $C_6H_2(NO_2)_3CH_3$ (trinitrotoluene). How many atoms of oxygen do you have?

Solution

mol TNT → molecules TNT → atoms O

6.022×10^{23} singles = 1 mol



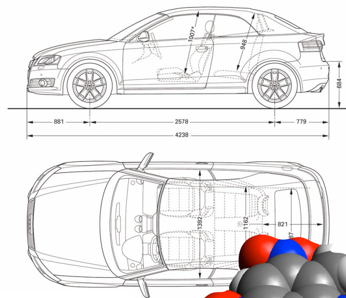
1 $C_6H_2(NO_2)_3CH_3$ = 6 O

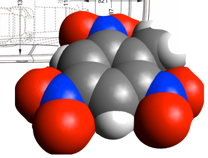
$$2.85 \text{ mol TNT} \cdot \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \cdot \frac{6 \text{ oxygen atoms}}{1 \text{ molecule TNT}}$$

$$= 1.029762 \times 10^{25} \text{ atoms}$$

$$= \boxed{1.03 \times 10^{25} \text{ atoms O}}$$

Formulas





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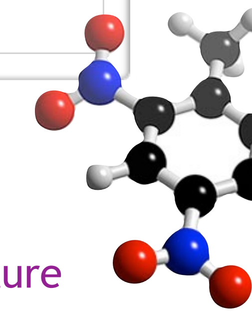

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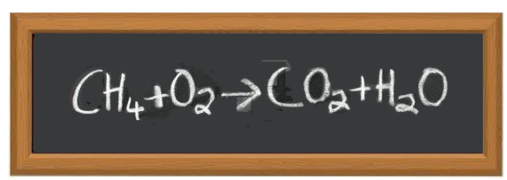
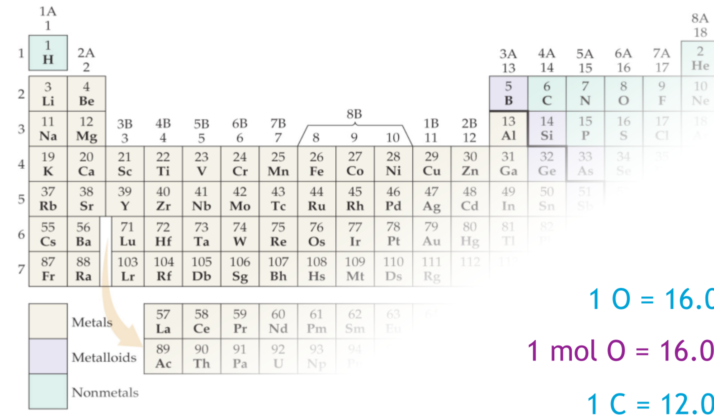


Molecular Weight/Molar Mass

- Molar Mass also applies to molecules and compounds.
- We know the atomic weight of elements,
  what one atoms weighs in amu and
  what one mole of atoms weigh in grams.
- We can use that information to figure out for compounds what one molecule weighs or one mole of molecules weigh.

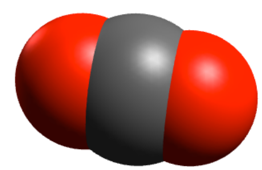


1 O = 16.00 amu

1 mol O = 16.00 g

1 C = 12.01 amu

1 mol C = 12.01 g



What is the molecular weight of CO_2? (in amu)

1 C atom	12.01 amu	
2 O atom	32.00 amu	(2 × 16.00 amu)
1 CO_2 =	44.01 amu	

What is the molar mass of CO_2? (in grams)

1 mol C	12.01 grams	
2 mol O	32.00 grams	(2 × 16.00 g)
1 mol CO_2 =	44.01 grams	

What does 2.57 mol of CO_2 weigh?

$$2.57 \text{ mol } CO_2 \cdot \frac{44.01 \text{ g}}{1 \text{ mol } CO_2} = 113.1057 \text{ g}$$

3 sf. 4 sf. 113 g CO_2 (3 sf.)

How many moles of CO_2 are in 53.256 grams?

$$53.256 \text{ g } CO_2 \cdot \frac{1 \text{ mol } CO_2}{44.01 \text{ g}} = 1.2100886 \text{ mol}$$

5 sf. 4 sf. 1.210 mol CO_2 (4 sf)

Problem:

Your experiment requires 4.26 mols of magnesium chloride ($MgCl_2$). What mass of magnesium chloride do you weigh out for this experiment?

Solution

① Find molar mass of $MgCl_2$

② mol → g

Mg 24.31 g/mol

Cl 35.45 g/mol

① 1 (Mg) = 1 (24.31) = 24.31 g

2 (Cl) = 2 (35.45) = 70.90 g

95.21 g

$MgCl_2$ 95.21 g/mol

② $4.26 \text{ mol } MgCl_2 \cdot \frac{95.21 \text{ g}}{1 \text{ mol}} = 405.5946 \text{ g}$

406 g $MgCl_2$

Problem:

You do an experiment that produces 15.35 grams of nitrogen trioxide (NO_3).

How many moles of NO_3 were produced?

Solution

① Find molar mass of NO_3

② g → mol

N = 14.01 g/mol

O = 16.00 g/mol

① 1 (N) = 1 (14.01) = 14.01 g

3 (O) = 3 (16.00) = 48.00 g

62.01 g

NO_3 62.01 g/mol

② $15.35 \text{ g } NO_2 \cdot \frac{1 \text{ mol}}{62.01 \text{ g}} = 0.2475407 \text{ g}$

= 0.2475 g

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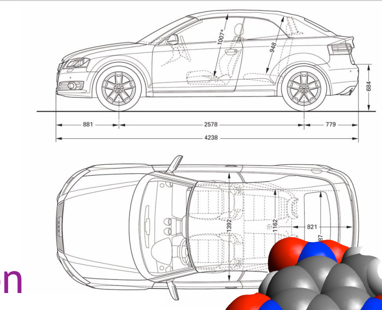

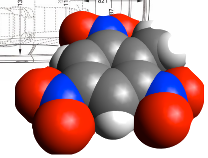

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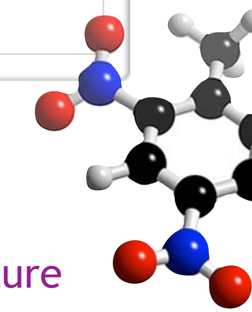
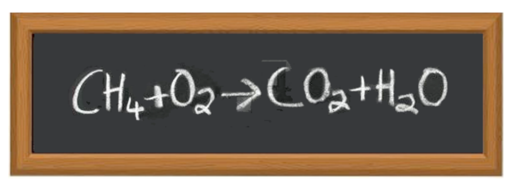
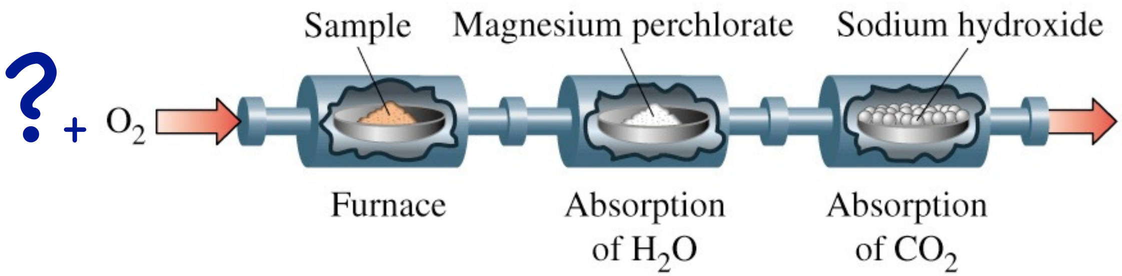


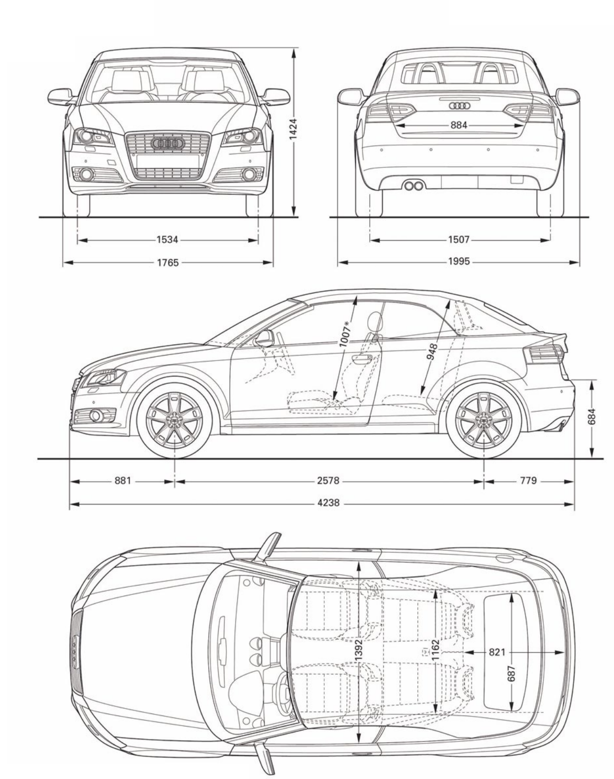


Combustion Analysis / Percent Composition



52.17% C
13.04% H → C_2H_5OH
34.78% O

- A useful technique for analyzing unknown compounds Combustion Analysis, burning an unknown compound and measuring the amounts of products made.
  - This is generally used for organic compounds containing C, H, O.
- By knowing the mass of the unknown and composition of elements in each product, the original amount of each element can be determined.
  - All the original C forms CO_2, the original H forms H_2O, and the original mass of O is found by subtraction.
- This is one way to get the percent composition (also called elemental analysis or elemental composition), of an unknown material.
- Percent Composition is the % by weight of each element in the compound.
- We won't go into the details of combustion analysis calculations, but we will talk using percent composition in different ways.
  - You can calculate percent composition from a chemical formula of a compound you know and compare it to the result of combustion analysis to identify it as the unknown.
  - You can also calculate the chemical formula of an unknown from percent composition, to begin to understand an entirely new compound. (This requires you also know the molecular weight).



Problem:

A detectives observes a substance at a crime scene and hypothesizes that the substance may be phenol. You have a combustion analysis experiment done, here's the report:

You lookup the formula of phenol and find it is C_6H_6O, could the detectives hypothesis be correct?

Report:
C 57.14 %
H 4.796 %
O 38.06 %

Solution

① Find total mass of 1 molecule C_6H_6O

② Divide amount of each element in the molecule by the total mass, to get % of each element.

C_6H_6O

$6(C) = 72.066$ amu
$6(H) = 6.048$ amu
$+ \quad O = 16.00$ amu

94.1018

mm = 94.11 amu

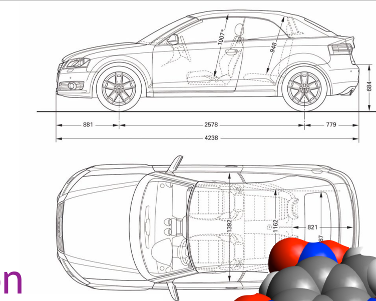
$$\%C = \frac{6 \cdot C}{C_6H_6O} = \frac{72.06 \text{ amu}}{94.11 \text{ amu}} \times 100 = 76.57\%$$

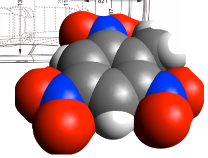
$$\%H = \frac{6 \cdot H}{C_6H_6O} = \frac{6.048 \text{ amu}}{94.11 \text{ amu}} \times 100 = 6.427\%$$

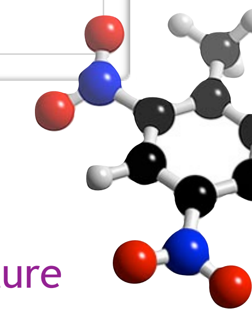
$$\%O = \frac{1 \cdot O}{C_6H_6O} = \frac{16.00 \text{ amu}}{94.11 \text{ amu}} \times 100 = 17.00\%$$

The percent compositions do not match.
It's not phenol.

Formulas







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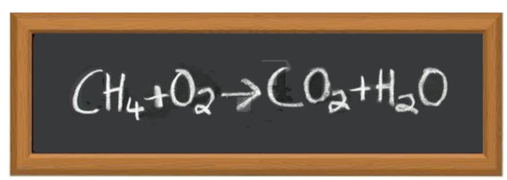


Finding the Empirical Formula

- If you have the elemental analysis, you can figure out the ratio of elements to each other.
- This ratio is the Empirical Formula.
- To find the empirical formula, assume you have 100.00 grams of the substance.
  1. Calculate the grams of each element.
  2. Calculate the moles of each element.
  3. Divide the moles of each element, but the smallest number of moles you find.
  4. You'll get a ratio of each element.
- You may need to multiply it by a small whole number if you get a simple fraction (if you get ½ multiply everything by 2, if you get ⅓ or ⅔ multiply by 3, etc).

Report:
C 57.14 %
H 4.796 %
O 38.06 %

Assume 100.00g of sample:

57.14% of 100.00g is 57.14g C

4.796% of 100.00g is 4.796g H

38.06% of 100.00g is 38.06g O

$$57.14\,g\,C \cdot \frac{1\,mol}{12.01\,g} = 4.758\text{ mol C atoms}$$

$$4.796\,g\,H \cdot \frac{1\,mol}{1.008\,g} = 4.758\text{ mol H atoms}$$

$$38.06\,g\,O \cdot \frac{1\,mol}{16.00\,g} = 2.379\text{ mol O atoms}$$

$$\underset{C}{\frac{4.758}{2.379}} : \underset{H}{\frac{4.758}{2.379}} : \underset{O}{\frac{2.379}{2.379}}$$

2 : 2 : 1

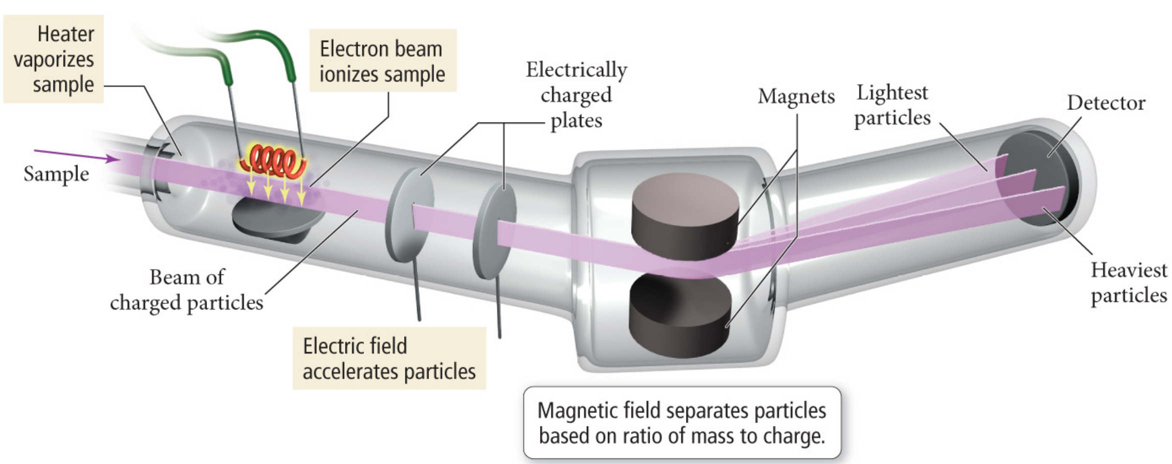
C_2H_2O

Finding the Molar Mass

- The molar mass can only be determined (without already knowing the molecular formula) by experiment.
  - The device we use for this experiment is a mass spectrometer.
  - The material is atomized and shot through a magnet.
  - An electron is knocked of one molecule.
  - By varying the magnetic field you see how much energy is bend the path of the molecule.
  - Once you know how much force it takes to move it, you can get the momentum.
  - If you know the speed and momentum, you can get the mass.

Report:
C 57.14 %
H 4.796 %
O 38.06 %

A mass spectrometer experiment gives us the mass of a molecule like caffeine, the same way it gave us the mass of an atom like copper.



Problem:

A detectives observes a substance at a crime scene. You have a combustion analysis experiment done. You also use a mass spec to find it's molar mass is 126.11 g/mol. What is the molecular formula of this compound?

Report:

C	57.14 %
H	4.796 %
O	38.06 %

Solution

Assume 100.00g of sample:

57.14% of 100.00g is 57.14g C

4.796% of 100.00g is 4.796g H

38.06% of 100.00g is 38.06g O

$$57.14\text{g C} \cdot \frac{1\text{ mol}}{12.01\text{g}} = 4.758\text{ mol C atoms}$$

$$4.796\text{g H} \cdot \frac{1\text{ mol}}{1.008\text{g}} = 4.758\text{ mol H atoms}$$

$$38.06\text{g O} \cdot \frac{1\text{ mol}}{16.00\text{g}} = 2.379\text{ mol O atoms}$$

$$\text{C: } \frac{4.758}{2.379} : \text{H: } \frac{4.758}{2.379} : \text{O: } \frac{2.379}{2.379}$$

2 : 2 : 1

2(C) 24.021
2(H) 2.016
1(O) + 16.00
42.0316

42.04 g/mol

C_2H_2O ← (empirical formula)

$$\frac{126.11\text{ g}}{42.04\text{ g}} = 2.99976213$$

∴ there are 3 C_2H_2O's in the molecular formula.

$$(C_2H_2O)_3 = \boxed{C_6H_6O_3}$$

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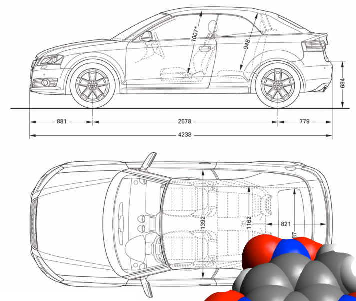

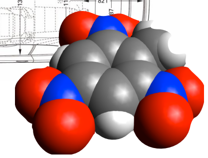

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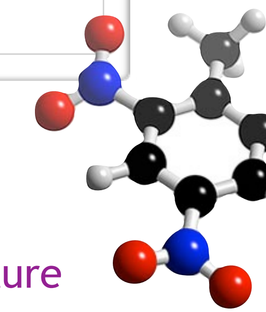
$$C_6H_2(NO_2)_3CH_3$$



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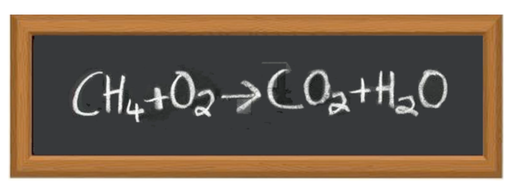


Parts of a Chemical Equation

- Reactants are what you start with.
  - They are always on the left.
- Then an arrow pointing to the right.
  - $\rightarrow$ by default, read it "yields"
  - $\rightleftarrows$ means reversible (equilibrium)
  - Do not use $\leftrightarrow$ or $\Rightarrow$ or $\leftarrow$ (they mean other things)
- Products are what you end up with.
  - They are always on the right.
- Put a "+" between substances
- Order doesn't matter.
- Over the arrow is optional:
  - Δ means add heat
  - hv means add light
  - chemical formula is solvent
  - temperature means temperature
  - $\upharpoonleft\downharpoonright$ means reflux (boil)

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

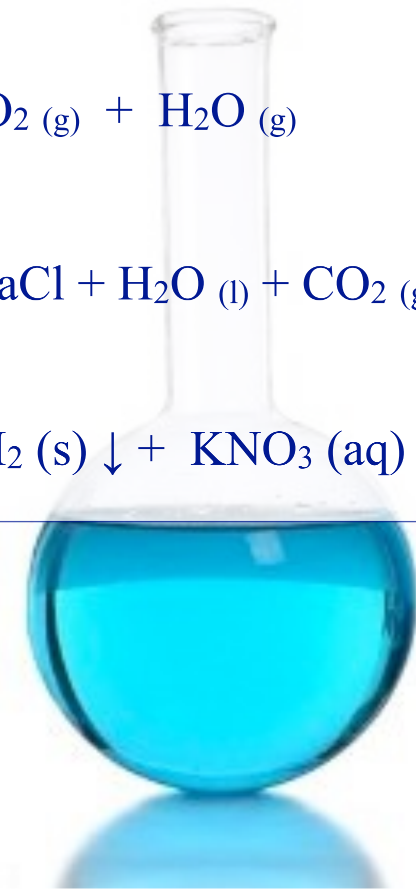
$$C_2H_4 + Br_2 \overset{hv}{\rightleftarrows} C_2H_4Br_2$$

$$C_3H_{8\ (g)} + O_{2\ (g)} \overset{\Delta}{\rightarrow} CO_{2\ (g)} + H_2O_{\ (g)}$$

$$Na_2CO_3 + HCl_{\ (aq)} \overset{H_2O}{\rightarrow} NaCl + H_2O_{\ (l)} + CO_{2\ (g)} \uparrow$$

$$KI\ (aq) + Pb(NO_3)_2\ (aq) \overset{\upharpoonleft\downharpoonright}{\rightarrow} PbI_2\ (s) \downarrow + KNO_3\ (aq)$$

- After the substance (can be written subscript):
  - (aq) means in water
  - (s), (l), (g) means solid, liquid, gas state
  - $\uparrow$ means gas evolved (escaped)
  - $\downarrow$ means precipitate (solid fell out)



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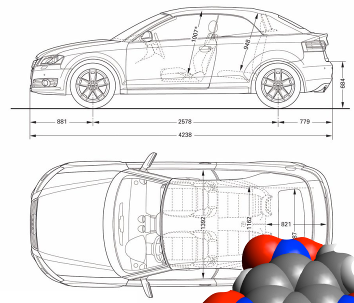

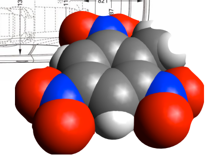

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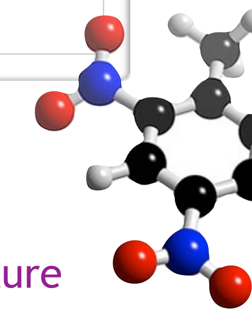

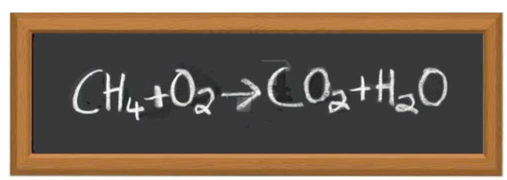

Labeled by Kinetics

Combination Reaction:

$$A + B \rightarrow C$$

eg. $C(s) + O_2\ (g) \rightarrow CO_2\ (g)$

Decomposition Reaction:

$$A \rightarrow B + C$$

eg. $Cu(OH)_2\ (s) \rightarrow CuO\ (s) + H_2O\ (l)$

Single Displacement Reaction:

$$A + BC \rightarrow B + AC$$

eg. $Zn\ (s) + SnCl_2\ (aq) \rightarrow Sn\ (s) + ZnCl_2\ (aq)$

Double Displacement Reaction:

"trade partners"

$$AB + CD \rightarrow AD + CB$$

eg. $2\ KI_{(aq)} + Pb(NO_3)_{2\ (aq)} \rightarrow PbI_{2\ (s)} \downarrow + 2\ KNO_{3\ (aq)}$

- Labels based on what "boxes" the atoms fall into and the general pattern of what moves where.
- A very generic label.
- Each label is mutually exclusive, reaction is one or another — never two.

Labeled by Reactivity

- Patterns we see frequently in reactions.
- These labels are not mutually exclusive, with each other or with kinetics.

  - Combustion Reaction (in oxygen is generally assumed)
    - Pattern: "something" + $O_2 \xrightarrow{\Delta} CO_2 + H_2O + NO_2$ ...
    - Burning something. (Yes, you can use something other than oxygen but it's uncommon.)
    - Ex: $C_3H_{8\,(g)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{(l)}$
  - Gas Evolution
    - Pattern: Reactants → Products + $X_{(g)} \uparrow$
    - One product is gas and it floats away.
    - Ex: $2\ KClO_3\ (s) \rightarrow 2\ KCl\ (s) + 3\ O_{2\,(g)} \uparrow$
  - Precipitation
    - Pattern: Reactants $_{(aq)}$ → Products $_{(aq)}$ + $X_{(s)} \downarrow$
    - Reaction in solution, a solid forms and it falls out.
    - Ex: $NaCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow NaNO_{3\,(aq)} + AgCl_{(s)} \downarrow$

  - more coming next chapter: Red-Ox, Acid-Base, and Neutralization Rxns

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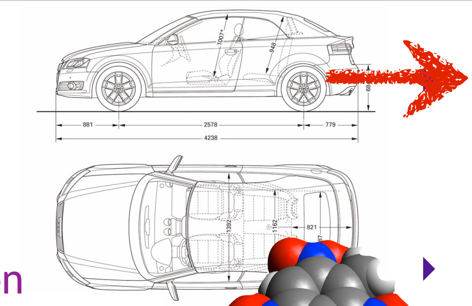

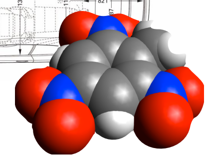

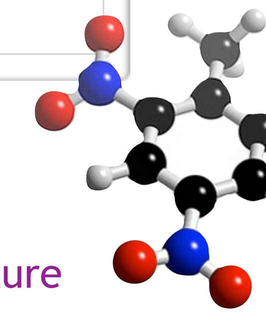

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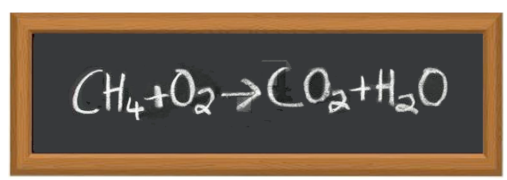

Writing Chemical Equations

- "When sulfur trioxide reacts with water, a solution of sulfuric acid forms"

sulfur trioxide + water → sulfuric acid (aq)

$$SO_3 + H_2O \rightarrow H_2SO_4\,(aq)$$

- "An aqueous solution of lead (II) nitrate is mixed with an aqueous solution of sodium iodide an aqueous solution of sodium nitrate is formed and a yellow solid lead (II) iodide appears."

lead (II) nitrate (aq) + sodium iodide → sodium nitrate (aq) + lead (II) iodide (s) ↓

$$Pb(NO_3)_2\,(aq) + NaI \rightarrow NaNO_3\,(aq) + PbI_2\,(s)\downarrow$$

- "When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphoric acid and hydrochloric acid."

phosphorus trichloride (l) + water → phosphoric acid + hydrochloric acid

$$PCl_3\,(l) + H_2O\,(l) \rightarrow H_3PO_4 + HCl\,(aq)$$

- "Hydrogen sulfide gas is passed over hot iron (III) hydroxide, the resulting reaction produces solid iron (III) sulfide and gaseous water."

hydrogen sulfide (g) + iron (III) hydroxide $\xrightarrow{\Delta}$ iron (III) sulfide (s) + water (g)

$$H_2S\,(g) + Fe(OH)_3 \xrightarrow{\Delta} Fe_2S_3\,(s) + H_2O\,(g)$$

Problem:

Magnesium metal was put in a solution containing aluminum nitrate. The solution bubbled, a new metal appears as the magnesium dissolved. What happened? (write the chemical equation describing the reaction)

copper silver nitrate $\rightarrow$

$Mg + Al(NO_3)_3$

$Mg^0 + Al^{3+} NO_3^{1-} \rightarrow Al^0 + Mg^{2+} NO_3^{1-}$

Single Displacement

$Al + Mg(NO_3)_2$

$Mg + Al(NO_3)_3 \rightarrow Al + Mg(NO_3)_2$

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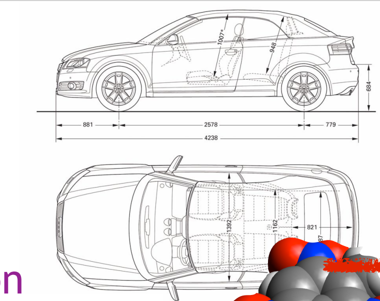

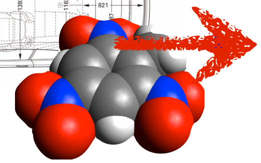

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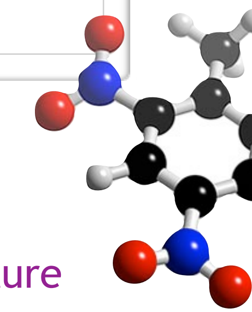

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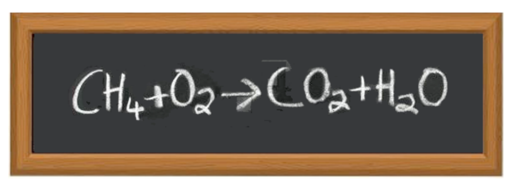
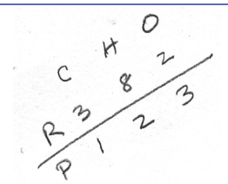


Balanced Equations

- Both equations are valid chemical equations.
- The difference is the addition of coefficients.
- Coefficients indicate relative quantities.
- The second equation has the same number and flavor of atoms in reactants as it does in products.
- All the mass is accounted for.
- We say the second equations is balanced.
- We can do a **<u>lot</u>** with a balanced equation.

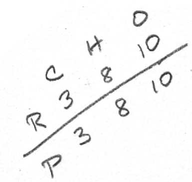
Eq 1:

$$C_3H_8\,(g) + O_2\,(g) \rightarrow CO_2\,(g)\uparrow + H_2O\,(l)$$



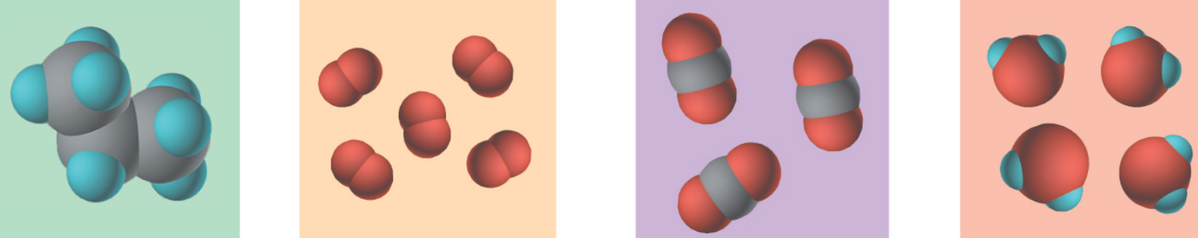
Eq 2:

$$C_3H_8\,(g) + 5\ O_2\,(g) \rightarrow 3\ CO_2\,(g) + 4\ H_2O\,(l)$$

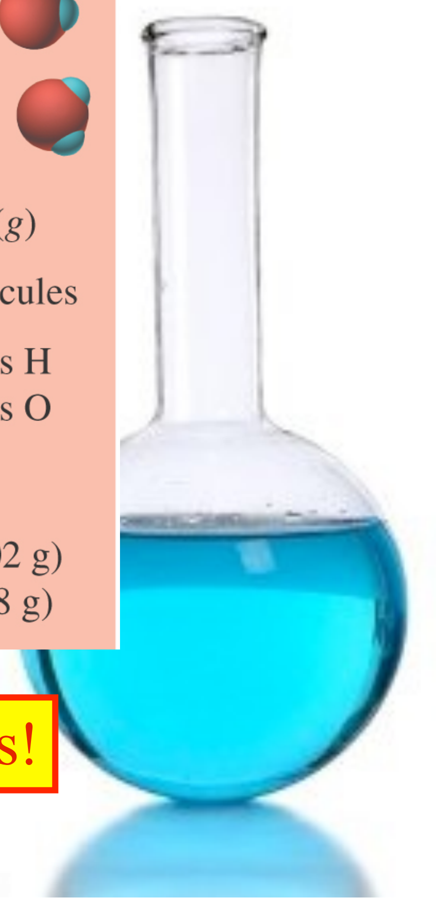


Reading a Balanced Equation

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



Propane		Oxygen		Carbon dioxide		Water
$C_3H_8(g)$	+	$5\ O_2(g)$	$\rightarrow$	$3\ CO_2(g)$	+	$4\ H_2O(g)$
1 molecule		5 molecules		3 molecules		4 molecules
3 atoms C 8 atoms H		10 atoms O		3 atoms C 6 atoms O		8 atoms H 4 atoms O
1 mol		5 mol		3 mol		4 mol
44.09 g		5 (32.00 g) (160.0 g)		3 (44.01 g) (132.0 g)		4 (18.02 g) (72.08 g)



Don't confuse coefficients and subscripts!

Balancing Equations

- The process:
  - Step 1: Write the skeleton.
  - Step 2: Translate everything into formulas.
  - Step 3: Take Stock. See if it's balanced. If it is goto step 5.
  - Step 4: Rewrite the equation, add a coefficient to balance a component.
    - Repeat Steps 3-4.
  - Step 5: Make sure all coefficients are whole numbers.
  - You're done.

- Tips to Win:
  - Always start with the most complicated molecule.
  - Always finish with the simplest, preferably H_2 or O_2
  - It's iterative, you gotta experiment.
  - You can use polyatomic ions instead of elements, **<u>if</u>** they're kept whole in the reaction.
  - Use fractions (e.g. ½ or 2⅓) to get to the end, but *don't leave it that way*. (see step 5)

Problem:

Diphosphorus trioxide is formed by direct combination of its elements. Find the balanced eqn.

Tip: Save O_2 or H_2 for last.

oxygen + phosphorus → diphosphorus trioxide

$$O_2 + P_4 \rightarrow P_2O_3$$

	O	P
R	2	4
P	3	2

$$O_2 + P_4 \rightarrow 2\,P_2O_3$$

R	2	4
P	6	4

$$3\,O_2 + P_4 \rightarrow 2\,P_2O_3$$

R	6	4
P	6	4

Problem:

Phosphoric acid and calcium hydroxide react to form water and calcium phophate.
Find the balanced eqn.

Tip: use polyatomic ions instead of elements, if they're kept whole in the reaction.

Phosphoric Acid + Calcium Hydroxide → water + Calcium Phosphate

$H_3PO_4 + Ca(OH)_2 \rightarrow H_2O + Ca_3(PO_4)_2$

	PO_4	Ca	H	O
R	1	1	5	2
P	2	3	2	1

$\underline{2}H_3PO_4 + Ca(OH)_2 \rightarrow H_2O + Ca_3(PO_4)_2$

R	2	1	8	2
P	2	3	2	1

$2H_3PO_4 + \underline{3}Ca(OH)_2 \rightarrow H_2O + Ca_3(PO_4)_2$

R	2	3	12	6
P	2	3	2	1

$2H_3 + 3Ca(OH)_2 \rightarrow \underline{6}H_2O + Ca_3(PO_4)_2$

R	2	3	12	6
P	2	3	12	6

Problem:

Ethane is burnt in air. Find the balanced eqn.

Tip: Use fractions to get to the end, but don't leave it that way.

Ethane + oxygen → carbon dioxide + water

	C	H	O
R	2	6	2
P	1	2	3

$$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$$

	C	H	O
R	2	6	2
P	2	2	5

$$C_2H_6 + O_2 \rightarrow 2CO_2 + H_2O$$

	C	H	O
R	2	6	2
P	2	6	7

$$C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$$

	C	H	O
R	2	6	7
P	2	6	7

$$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$$

	C	H	O
R	4	12	14
P	4	12	14

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

Some More Equations to Balance

- $H_2SO_4 + Fe \rightarrow Fe_2(SO_4)_3 + H_2$
- $Al + O_2 \rightarrow Al_2O_3$
- $MnO_2 + CO \rightarrow Mn_2O_3 + CO_2$
- $SO_2 + O_2 \rightarrow SO_3$
- $KI + Br_2 \rightarrow KBr + I_2$
- $K_3PO_4 + BaCl_2 \rightarrow KCl + Ba_3(PO_4)_2$

Some More Equations to Balance

- $Al + MnO_2 \rightarrow Mn + Al_2O_3$
- Copper(II) chloride and water result from the reaction of copper(II) oxide and hydrochloric acid.
- Sugar, $C_{12}H_{22}O_{11}$, is burned in air.
- Hydrogen sulfide gas is passed over hot iron (III) hydroxide, the resulting reaction produces solid iron (III) sulfide and gaseous water.
- When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphoric acid and hydrochloric acid.

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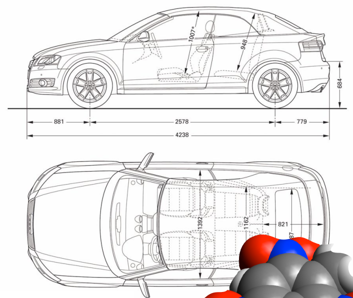

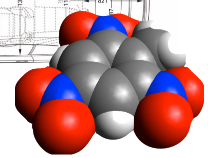

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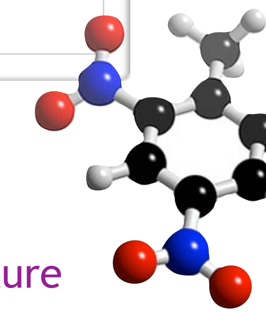

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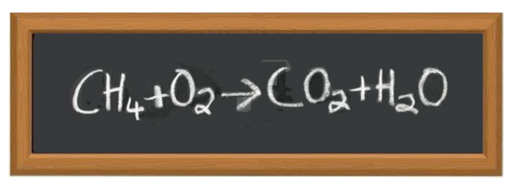

Questions?