Empirical & Molecular Formulas, % Comp & Hydrates How – to Guide for the difficult problems

Plus – mole conversion review

Empirical & Molecular Formulas w/ Combustion Analysis

Aniline, a starting material for urethane plastic foams, consists of C, H, and N. Combustion of such compounds yields CO_2, H_2O, and N_2 as products. If the combustion of 9.71 g of aniline yields 6.63 g H_2O and 1.46 g N_2, what is its empirical formula? The molar mass of aniline is 93 g/mol. What is its molecular formula?

- Aniline + O_2 → CO_2 + H_2O + N_2

  9.71 g 6.63 g 1.46 g

To determine empirical formula, 1st determine # of grams of C, N, H; then convert grams →moles; use lowest # of moles to determine ratio; multiply to get whole # if needed.

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  9.71 g 6.63 g 1.46 g

Nitrogen (N) is given. N = 1.46g

Hydrogen (H) we can calculate from % comp of water to determine grams of H in aniline

2.02 g/mol H / 18.01 g/mol H_2O = 0.1121

0.1121 = X g H / 6.63 g H_2O

x = 0.7432 g H

Now that we know 2 parts of aniline, we can subtract to know the amount of carbon.

9.71 g aniline – (1.46 g N + 0.7432 g H) = 7.5068 g C

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- Now that we have the grams of each component, we can convert to moles.

We do not use diatomic molar mass because nitrogen is a part of a molecule in aniline

Nitrogen

$$1.46\text{g N} * (1\text{ mol N} / 14.01\text{ g N}) = 0.1042\text{ mol N}$$

Hydrogen

$$0.7432\text{ g H} * (1\text{ mol H} / 1.01\text{ g H}) = 0.73358\text{ mol H}$$

Carbon

$$7.5068\text{ g C} * (1\text{ mol C} / 12.01\text{ g C}) = 0.6250\text{ mol C}$$

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- From the moles, we determine ratio by dividing all moles by lowest mole #. For this one, that's nitrogen.

Nitrogen

0.1042 mol N / 0.1042 mol N = 1

Hydrogen

0.73358 mol H / 0.1042 mol N = 7

Carbon

0.6250 mol C / 0.1042 mol N = 6

Empirical Formula is C_6H_7N

11. Aniline, a starting material for urethane plastic foams, consists of C, H, and N. Combustion of such compounds yields CO_2, H_2O, and N_2 as products. If the combustion of 9.71 g of aniline yields 6.63 g H_2O and 1.46 g N_2, what is its empirical formula?

12. The molar mass of aniline is 93 g/mol. What is its molecular formula?

- From the empirical formula, we can determine molecular formula by calculating the empirical formula's molar mass

Empirical Formula is C_6H_7N

C = 12.01 x 6 = 72.06 g/mol

H = 1.01 x 7 = 7.07 g/mol

N = 14.01 x 1 = 14.01 g/mol

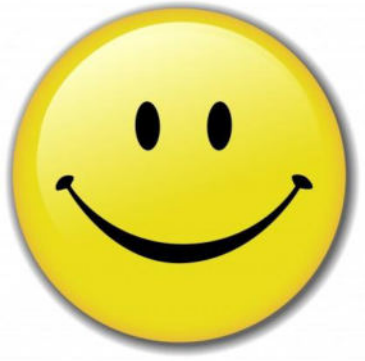
Total = 93.14 g/mol

Divide molecular mass by empirical mass to find the multiplier.

93 g/mol / 93.14 g/mol = 1

Molecular Formula: C_6H_7N

YOU TRY THIS ONE



A certain hydrocarbon, CxHy, is burned (reacts with O_2 gas) and produces 1.955 grams of CO_2 for every 1.000 gram of H_2O. What is the empirical formula of this hydrocarbon?

$$CxHy + O_2 \rightarrow CO_2 + H_2O$$

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Where do we start?

$CxHy$	+	O_2	$\rightarrow$	CO_2	+	H_2O
??				1.955 g		1.000 g

(1) Find the % of hydrogen in water and the % carbon in carbon dioxide.

H: 2.02 g/mol H / 18.01 g/mol H_2O = 0.1121

0.1121 = X g H / 1.000 g H_2O

x = 0.1121 g H

C: 12.01 g/mol C / 44.01 g/mol CO_2 = 0.2729

0.2729 = X g C / 1.955 g CO2

x = 0.5335 g C

A certain hydrocarbon, CxHy, is burned (reacts with O_2 gas) and produces 1.955 grams of CO_2 for every 1.000 gram of H_2O. What is the empirical formula of this hydrocarbon? What is the molecular formula of the hydrocarbon if it's molar mass is 87 grams/mole?

Where do we start?

$$\underset{??}{CxHy} + O_2 \rightarrow \underset{1.955\ g}{CO_2} + \underset{1.000\ g}{H_2O}$$

(2) Convert grams of C & H to moles using molar mass.

H: 0.1121 g H * (1 mol H/ 1.01g H) = 0.1110 mol H

C: 0.5353 g C * 1 mol C /12.01 g C) = 0.0444 mol C

(3) Divide by smallest # of moles to determine mole ratio. If not whole number, multiply

H: 0.1110 mol H / 0.0444 mol C = 2.5 (2) = 5

C: 0.0228 mol C / 0.0444 mol C = 1 (2) = 2

$EF = C_2H_5$

(4) Molecular Formula: 87 g/mol / 29.07 g/mol = 3

$MF = C_6H_{15}$

% Composition

Which of the following has the highest percentage of nitrogen: calcium nitrate or ammonium sulfate?

- First write the correct formulas for each substance.
  - $Ca(NO_3)_2$
  - $(NH_4)_2SO_4$
- Determine the molar masses of each
  - $Ca(NO_3)_2$: 40.08 + 14.01(2) + 16.00(6) = 164.10 g/mol
  - $(NH_4)_2SO_4$:14.01(2) + 1.01(8) + 32.07 + 16.00(4) = 132.15 g/mol
- Divide nitrogen molar mass by compound's molar mass & multiply by 100.
  - $Ca(NO_3)_2$: 28.02 g/mol / 164.10 g/mol x 100 = 17.07%
  - $(NH_4)_2SO_4$: 28.02 g/mol / 132.15 g/mole x 100 = 21.12%

$(NH_4)_2SO_4$ has the largest % nitrogen

Hydrates

A hydrate of Na_2CO_3 has a mass of 4.31 g before heating. After heating, the mass of the anhydrous compound is found to be 3.22 g. Determine the formula of the hydrate and then write out the name of the hydrate.

1) Determine mass of water driven off:

4.31g - 3.22g = 1.09 g of water

2) Determine moles of Na_2CO_3 and water:

$Na_2CO_3 \Rightarrow$ 3.22 g / 105.988 g/mol = 0.0304 mol
$H_2O \Rightarrow$ 1.09 g / 18.015 g/mol = 0.0605 mol3)

3) Find a whole number molar ratio:

$Na_2CO_3 \Rightarrow$ 0.0304 mol / 0.0304 mol = 1
$H_2O \Rightarrow$ 0.0605 mol / 0.0304 mol = 2

Answer: $Na_2CO_3 \cdot 2H_2O$
Name: sodium carbonate dihydrate

Mole Conversions

Y diagram refresher

Representative Particles

ionic compound = formula unit → ions

covalent = molecules → atoms

Elements = atoms