Welcome to our CHEM 4 lecture

Clicker question: Review from last class

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1) Which of the following compounds has the smallest mass % of manganese? See if you can find the answer without doing any calculations.
   - A) manganese(III) thiosulfate
   - B) manganese(III) sulfide
   - C) manganese(III) sulfate
   - D) manganese(III) sulfite

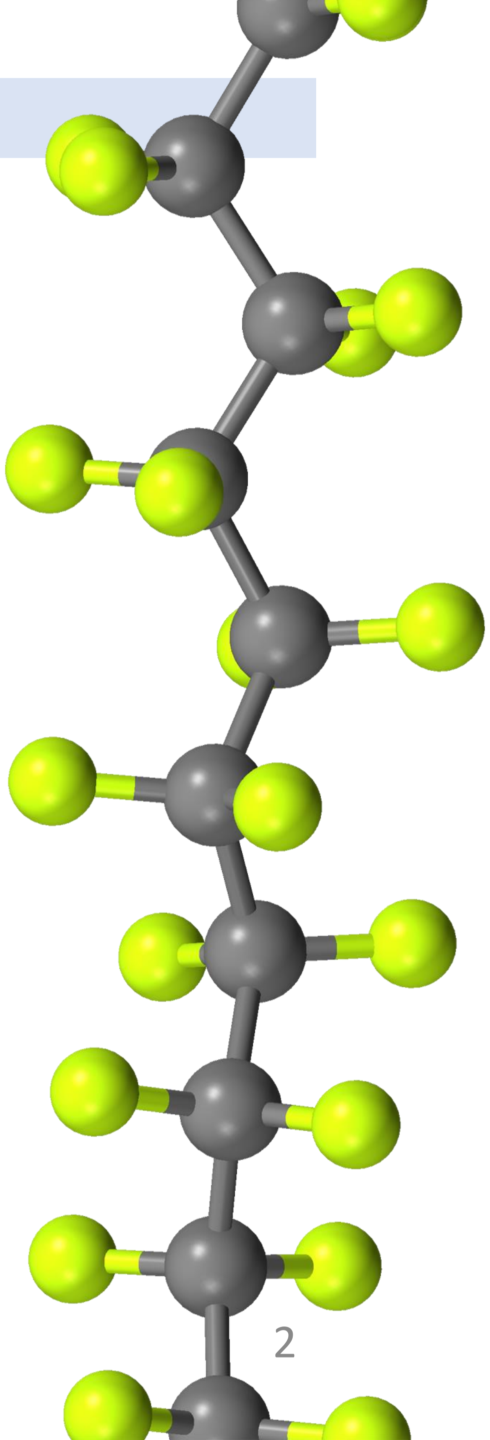
Answer: **formulas:** A) $Mn_2(S_2O_3)_3$ C) $Mn_2(SO_4)_3$ B) Mn_2S_3 D) $Mn_2(SO_3)_3$

- We want the smallest mass % Mn = $\left(\frac{\text{mass of Mn in 1 mole of compound}}{\text{mass of 1 mol of compound}}\right)$ x 100%
- For each calculation, the numerator is the same (2 x mass of Mn)
- So, to get the smallest overall mass %, we want the biggest denominator (i.e. the compound with the greatest mass).
- $Mn_2(S_2O_3)_3$ has the largest total mass and therefore the smallest mass % Mn.

Need to make changes in how you study for CHEM 4?

Here's our checklist of key behaviors that lead to success in CHEM 4:

- ✓ Study efficiently with a focus on the homework:
  - ✓ (1) do the assigned reading, then (2) attend lecture, then (3) review the lecture slides or video. You should then be ready to do the homework.
  - ✓ If you do (1) - (3) and start the required homework and have trouble, then put aside the homework and redo (1) and (3). Then try the optional homework.
  - ✓ If you still have trouble, put the homework aside and come to my office hours.
  - ✓ Remember is it okay if the homework is late, the most important thing is that you are really understanding the homework.
- ✓ Get help when needed:
  - ✓ Put together a weekly study group.
  - ✓ Jeff's office hours: MWF 9 – 9:30 am and 11 – 11:30 am; and by appointment.
  - ✓ PAL office hours: link is on our CHEM 4 website.
- ✓ Complete all of the practice exams.
- ✓ Visit our CHEM 4 website regularly: tinyurl.com/SacStateChem4



CHEM 4 lecture

Monday, November 16, 2020

Sec 6.8 – 6.9

Molecular and empirical formulas

Reading clicker question: Molecular and empirical formulas (Sec 6.8 - 6.9)
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2) Which of the following statements about *empirical* and *molecular formulas* is true?

   A) *Molecular formulas* are for covalent compounds and *empirical formulas* are for ionic compounds.

   B) Different compounds can have the same *empirical formula*.

   C) The *empirical formula* gives the specific number of each type of atom in a compound.

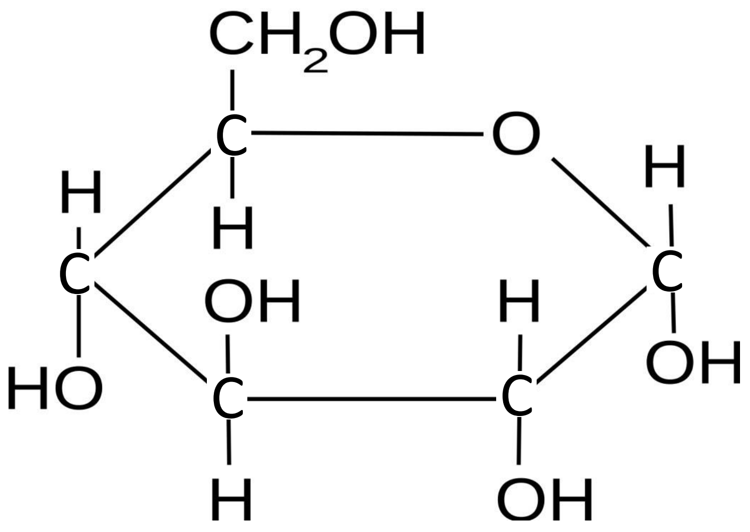
   D) The *molecular formula* gives the smallest whole-number ratio of each atom in the compound.

   E) The *molecular formula* is never identical to the *empirical formula*.

The definitions in C and D are switched

Sample problem: Determining molecular and empirical formulas

Ex: Determine molecular and empirical formula for glucose:



Molecular formula = $C_6H_{12}O_6$ (matches the actual molecule)

Empirical formula = CH_2O (doesn't necessarily match the actual molecule)

Clicker question: Determining molecular and empirical formulas

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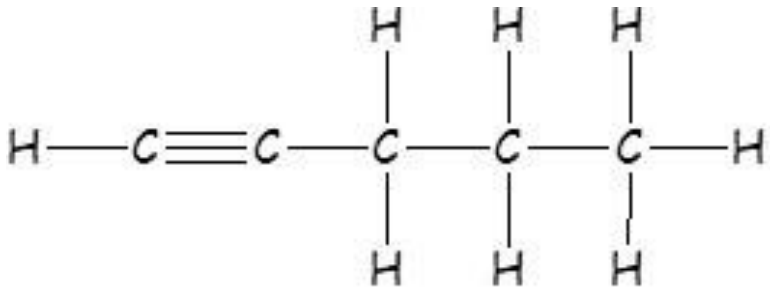
3) What are the molecular and empirical formulas for 1-pentyne?



A) C_5H_8, C_5H_8

B) C_4H_8, C_2H_4

C) C_4H_{10}, C_2H_5

D) C_4H_7, C_4H_7

Here we see a molecular and empirical formula that are the same.

Clicker question: Determining molecular and empirical formulas
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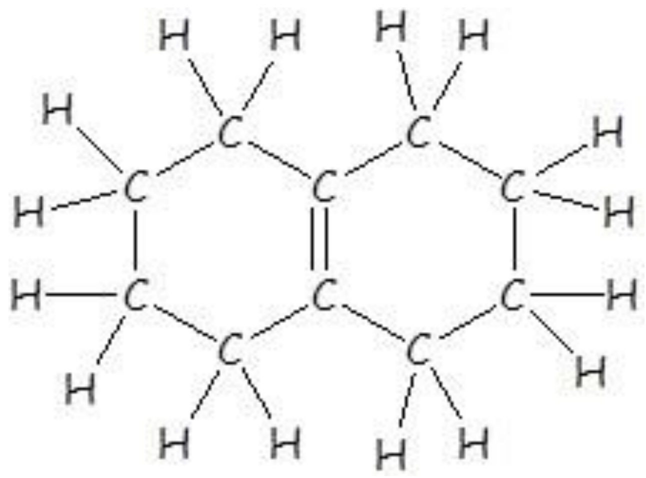
4) What are the molecular and empirical formulas for the following compound?



A) $C_{10}H_{14}$, C_5H_7

B) C_9H_{16}, C_9H_{16}

C) $C_{10}H_{16}$, C_5H_8

D) $C_{12}H_{14}$, C_6H_7

Notice that this empirical formula is the same as the one from the last clicker question even though the molecules are very different.

Sample calculation: Determining a compound's molecular formula

Ex: You make a new blood pressure drug in lab and send if off for analysis. The test results show the following:

(1) percentage composition = 40.00% C, 6.71% H, and 53.29% O

(2) molar mass = 240.2 g/mol

What is the molecular formula of the drug?

Answer: Assume 100.00 g sample, gives: 40.00 g C, 6.71 g H, and 53.29 g O. Convert all of these masses to moles:

Divide each by the smallest value (in this case, 3.331)

- $(40.00\ \text{g C})\left(\frac{1\ \text{mol C}}{12.01\ \text{g C}}\right) = 3.331\ \text{mol C}$ /3.331 = 1 C
- $(6.71\ \text{g H})\left(\frac{1\ \text{mol H}}{1.008\ \text{g H}}\right) = 6.657\ \text{mol H}$ /3.331 = 1.998 ≈ 2 H **(can round to 10ths place)**
- $(53.29\ \text{g O})\left(\frac{1\ \text{mol O}}{16.00\ \text{g O}}\right) = 3.331\ \text{mol O}$ /3.331 = 1 O
- This gives the **empirical formula = CH_2O**.
- Sometimes this is the end of the question, but in this case we need to keep going…

Sample calculation continued… Determining a compound's molecular formula

Answer continued… We can now compare the empirical formula that we just found CH_2O to the molar mass that the lab determined.

- Notice that the molar mass for the empirical formula CH_2O = 30.026 g/mol.
- Since this does not match the molar mass provided by the lab (240.2 g/mol), we know that this empirical formula is not the molecular formula.
- So we have to figure out what to multiply the empirical formula by. This can be found by:

$$\frac{\text{Molar mass from molecular formula}}{\text{Molar mass from empirical formula}} = \frac{240.2}{30.026} = 7.9997 \approx 8$$ **(can round to 10^{ths} place)**

- So the molecular formula must be 8 x empirical formula = 8 x CH_2O
- **Final answer:** the **molecular formula = $C_8H_{16}O_8$**
- Note that this compound has the mass % and the molar mass that the lab reported.

Clicker question: Determining a compound's molecular formula
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5) A fuel contains 92.24% C by mass (the remainder is H). If the molar mass of the fuel is 78.29 g/mol, what is the molecular formula of the fuel?

A) C_5H_{18}
B) CH
C) C_3H_2
D) C_2H_3
E) $\boxed{C_6H_6}$
F) CH_2

Answer: Assume 100.00 g sample: 92.24 g C and 7.76 g H. Convert these masses to moles:

- $(92.24\ \text{g C})\left(\frac{1\ \text{mol C}}{12.01\ \text{g C}}\right) =$ 7.680 mol C /7.680 = 1 = 1C
- $(7.76\ \text{g H})\left(\frac{1\ \text{mol H}}{1.008\ \text{g H}}\right) =$ 7.698 mol H /7.680 = 1.002 ≈ 1 H **(can round to 10ths place)**
- This gives the **empirical formula = CH** which has a molar mass = 13.018 g/mol.
- Comparing this to the reported molar mass gives: $\frac{78.29}{13.018} = 6.01 \approx$ **6**
- So the **molecular formula** = **6** x empirical formula = **6** x CH **= C_6H_6**

Sample calculation: Harder example of determining a molecular formula

Sometimes when you divide by the smallest number of moles, you don't get all whole numbers in the 10^{ths} place. In that case you need to determine what to multiply everything by to get a whole number.

Fractional subscript	Equivalent fraction	Multiply by this to get a whole number
__.10	$^1/_{10}$	10
__.20	$^1/_5$	5
__.25	$^1/_4$	4
__.33	$^1/_3$	3
__.40	$^2/_5$	5
__.50	$^1/_2$	2
__.60	$^3/_5$	5
__.66	$^2/_3$	3
__.75	$^3/_4$	4
__.80	$^4/_5$	5

Sample calculation: Harder example of determining a molecular formula

Ex: A laboratory analysis of vanillin, the flavoring agent in vanilla, determined the following:

(1) Mass % composition = 63.15% C, 5.30% H, and 31.55% O

(2) molar mass = approximately 152 g/mol

What is the molecular formula of vanillin?

Answer:

$$(63.15\text{ g C})\left(\frac{1\text{ mol C}}{12.01\text{ g C}}\right) = 5.258\text{ mol C} / 1.972 = \underline{2.6}66 \times 3 = \underline{7.9}99 \approx 8\text{ C}$$

$$(5.30\text{ g H})\left(\frac{1\text{ mol H}}{1.008\text{ g H}}\right) = 5.258\text{ mol H} / 1.972 = \underline{2.6}66 \times 3 = \underline{7.9}99 \approx 8\text{ H}$$

$$(31.55\text{ g O})\left(\frac{1\text{ mol O}}{16.00\text{ g O}}\right) = 1.972\text{ mol O} / 1.972 = 1.0 \times 3 = 3\text{ O}$$

Because we don't have all whole numbers when we round to the 10ths place, we multiply everything by 3.

Here we are dividing by the smallest (1.972)

- Empirical formula = $C_8H_8O_3$, which has a molar mass = 152 g/mol.
- Because this matches the reported molar mass, $C_8H_8O_3$ is also the molecular formula.

Clicker question: Harder example of determining a molecular formula
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6) Elemental analysis of a new compound shows that the crystals are 77.38% C, 4.56% H and 18.06% N by mass. The molar mass of the compound is about 310 g/mol. What is the molecular formula of the compound?

A) $C_{10}H_7N_2$ C) $C_{22}H_{18}N_2$ E) $C_{23}H_6N_2$

B) $C_{19}H_{12}N_5$ D) $C_{21}H_{16}N_3$ F) $\boxed{C_{20}H_{14}N_4}$

Answer: $(77.38 \text{ g C})\left(\frac{1 \text{ mol C}}{12.01 \text{ g C}}\right) = 6.443 \text{ mol C} / 1.289 = \underline{4.998} \times 2 = \underline{9.996} \approx 10 \text{ C}$

$(4.56 \text{ g H})\left(\frac{1 \text{ mol H}}{1.008 \text{ g H}}\right) = 4.524 \text{ mol H} / 1.289 = \underline{3.510} \times 2 = \underline{7.02} \approx 7 \text{ H}$

$(18.06 \text{ g N})\left(\frac{1 \text{ mol N}}{14.01 \text{ g N}}\right) = 1.289 \text{ mol N} / 1.289 = 1.0 \times 2 = 2 \text{ N}$

Because we don't have all whole numbers when we round to the 10ths place, we multiply everything by 2.

- Empirical formula = $C_{10}H_7N_2$, which has a molar mass = 155.18 g/mol.
- Compare this to the reported molar mass: $\frac{310}{155.18} = 1.997 \approx \mathbf{2}$
- So molecular formula = **2** x $C_{10}H_7N_2$ = $C_{20}H_{14}N_4$

Here we are dividing by the smallest (1.289)