Worksheet for Quiz 7 (and Exam 3)

→ *Italicized parts* **are optional; I recommend skipping them.**

- Here is a way to understand the calculation of molar mass: If you imagine "ripping apart" 1 mole of C_5H_{12} into atoms, you'll have 5 moles of C + 12 moles of H, so "molar mass" is (5 mol C)(12 g/mol) + (12 mol H)(1 g/mol) = 72 g/mol, with 60 g of C + 12 g of H = 72 g C_5H_{12}

- An **amount** can be described as number, mass, or volume. Dr Lwants you to be able to think logically about amounts by mentally visualizing relative amounts and using analogies with everyday objects that are lightweight and heavyweight. If you have 1000 tennis balls and 1000 bowling balls (same number of each) which has larger mass? And if you have 9000 g of tennis balls and 9000 g of bowling balls (same mass) do you see why there is a larger number of tennis balls? You can use similar logic for atoms & molecules, IF you develop a clear idea of which atoms are relatively light and heavy, and think clearly about the implications.

1a. For example, consider H_2 (2 g/mol) and O_2 (32 g/mol). If you have the same number of each (like 3.27 mol of H_2 and 3.27 mol of O_2) which will have a larger mass, and by what ratio-factor? (By what number do you multiply "mass of H_2" to get "mass of O_2"? Or vice versa, by what factor do you need to multiply "mass of O_2" to get "mass of H_2"?)

1b. If you have equal mass of each (such as 4.87 g H_2, 4.87 g O_2), which sample has a larger number of atoms, and by what multiplicative ratio-factor? {1a-1b answers are below}

note: You can do 1a & 1b with intuitive visualizing-logic, or with mathematical-logic by actually doing the math and developing intuitive math-logic by asking, "does dividing by a larger number make the result smaller (compared with dividing by a small number) or larger?" And does dividing by a small number make the result relatively larger (yes, it does) or smaller (no, it doesn't). Compare 64/32 (=2) and 64/4 (=16) and 64/.4 (=160); the result is literally larger when you divide by a number < 1, as when dividing 64 by .4 (which is < 1) gives 160, which is larger than 64.

- You can use similar "intuitive logic" for amounts of molecules in chemical reactions. For example, let's look at this reaction: <u>1</u> C_5H_{12} + <u>8</u> O_2 --> <u>5</u> CO_2 + <u>6</u> H_2O. We can think of this rxn at the level of molecules, or scaled-up by a factor of a million, or a mole, or by any other number; "million" is a word that means a large number (1,000,000 = 1×10^6) and "mole" is a word that means a much larger number (6.02×10^{23}). If we "scale up" a reaction by any number-factor, the AMOUNTS change but RATIOS remain the same. The reaction ratios (**1**-to-**8**-to-**5**-to-**6**) are the same whether 1 molecule of C_5H_{12} produces 5 molecules of CO_2 or if 1 mole of C_5H_{12} produces 5 moles of CO_2. This idea of "RATIOS remaining the same when AMOUNTS are scaled-up" is a key to thinking about chemical reactions, and mastering chemistry calculations.

- *Or mass can be scaled-up from grams to kilograms, pounds, or tons, with conversion factors: metric (1000 g = 1 kg), non-metric (454 g = 1 lb, 2000 lbs = 1 ton). If 2.35 g is scaled-up by x454 (making its mass 454 times larger) the math is (235 g)(<u>x454</u>)(1 lb / 454 g) so it's now 235 lb. "1 lb / 454 g" is a conversion factor (describing the same thing in two ways, so it = 1 because top & bottom are equal) but the scaling-factor (<u>x454</u>) actually makes the amount larger.*

<u>1a</u>. O_2 has more mass, by factor of 32/2 = 16, H_2 has less (1/16).
<u>1b</u>. There is more H_2 by a factor of 32/2 = 16, as in Problem 4.

- These equations describe the same amounts in two ways,

<u>1 mole</u> C_5H_{12} + <u>8 moles</u> O_2 --> <u>5 moles</u> CO_2 + <u>6 moles</u> H_2O
<u>72 g</u> C_5H_{12} + <u>256 g</u> O_2 --> <u>220 g</u> CO_2 + <u>108 g</u> H_2O

because "8 moles O_2" is the same as "256 g O_2" (they're just different ways to describe the same amount of O_2) and so on.

<u>72 g</u> C_5H_{12} + <u>256 g</u> O_2 --> <u>220 g</u> CO_2 + <u>108 g</u> H_2O
<u>72 lbs</u> C_5H_{12} + <u>256 lbs</u> O_2 --> <u>220 lbs</u> CO_2 + <u>108 lbs</u> H_2O
<u>72 tons</u> C_5H_{12} + <u>256 tons</u> O_2 --> <u>220 tons</u> CO_2 + <u>108 tons</u> H_2O

Compared with the first two equations (1 mole... and 72 g...) the final two equations (72 lbs... and 72 tons...) are scaled-up by 454 and 454x2000) so they have different AMOUNTS, and "8 mole O_2 = 256 lbs O_2" is false; but all 4 equations have the same RATIOS: "mass CO_2 produced / mass C_5H_{12} reacting" = (220 g / 72 g) = (220 lbs / 72 lbs) = (220 tons / 72 tons) = 3.06, and their "constant ratio" is useful for doing problems like this:

2a. In a complete combustion of 43.8 grams C_5H_{12}, what mass of CO_2 (in g) is produced? **2b**. In the complete combustion of 43.8 tons C_5H_{12}, what weight of CO_2 (in tons) is produced? **2a.**

(43.8 g C_5H_{12})(1 mol C_5H_{12} / 72 g C_5H_{12})(5 mol CO_2 / 1 mol C_5H_{12})(44 g CO_2 / 1 mol CO_2) = 134 g CO_2. <u>2b</u>. An easy solution is to "scale up" the reaction from grams to tons, so if 43.8 g C_5H_{12} produces 134 g CO_2, then 43.8 tons C_5H_{12} will produce 134 tons CO_2. *Or, if you convert from tons into grams, work the problem (as in 2a) with g, and then convert from grams back to tons, you'll see 2000 & 454 each used twice, once on fraction-top and once on fraction-bottom, so the 2000's and 454's "cancel" and the only remaining numbers are those in the 2a solution: 43.8 (1/72) (5/1) (44/1).* **For more practice, do problems 6a-6b.**

3a. What weight of CO_2 (in grams + pounds) is produced by complete combustion of 1 gallon of gasoline? (1 gallon = 3785 mL; assume gasoline is pure octane; C_8H_{18} density = .70 g/mL) [answer is 18.0 lbs; a solution-setup is at end of worksheet] = 8180 g

3b. Solve 3a using info from Sceptical Chymist 3.18 (pg 130), "a clean-burning automobile engine will emit about 5 lb of C in the form of CO_2 for every gallon of gasoline it consumes."

<u>3b</u>: If an engine emits "5 lb of <u>C</u> in the form of CO_2" it will emit more than 5 lbs of CO_2 by a factor of (44 g CO_2/12 g C) which — because a mass-ratio ***between*** *molecules (as in 2a) or* ***within*** *a molecule (here) is the same whether masses are in g or lbs — is also (44 lb CO_2 / 12 lb C), so (5 lbs C) (44 lb CO_2 / 12 lb C) = 18 lbs CO_2 emitted, same as in 3a.*

Problem-Solving Tips

Almost always, **if grams are "given"** you will convert this to moles by using moles/gram; and **if moles are "given"** you will convert this to grams by using grams/mole. For example, in #2a "g/mol" is used twice (flipped & as-is) and in-between you use the mole/mole reaction-ratio to convert from moles of what you are GIVEN into moles of what you are asked to FIND.

If you are asked to find an AMOUNT, you **must** begin with an AMOUNT, and then use conversion factors (= 1) to convert it into a different description of the same AMOUNT.

If you are asked to find a RATIO, either you can begin with a RATIO or (more commonly) use the "miles/hour strategy" as in this example: if you know that a sample of n-octane has mass = 265 g, and volume = 379 mL, to find its density in g/mL you divide the g by mL, (265 g / 379 mL) = .699 g/mL.

4. 64 g of <u>oxygen gas</u> is __ mol, 64 g hydrogen gas is __ mol. The key idea here is that "oxygen gas" means "the naturally occurring form of oxygen" which is <u>diatomic</u> O_2 not just O. Which 7 gases are diatomic? (He Ne,... are monotomic gas); memory - HAH (Hydrogen Air Halogens, 124), BrINClHOF.

5a. What is the mass of 234 mL n-C_8H_{18}? (density = .70 g/mL)
5b. What is the volume of 164 g of n-C_8H_{18}? **[mL ↔ g]**
5c. If 234 mL of n-C_8H_{18} is 164 g of it, what is its density?