Gas Laws & Stoichiometry Practice

1. Through complex metabolic processes, our bodies oxidize glucose ($C_6H_{12}O_6$) to form carbon dioxide gas and liquid water. ("Oxidize," in this context, means that one of the reactants is oxygen gas.)
   a) Write a balanced equation for this process:

   $$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

   b) A can of Dr. Pepper contains 40.0g of sugar. Assuming that all of this sugar is glucose (it

   $$40.0\text{g } C_6H_{12}O_6 \times \frac{1\text{mole } C_6H_{12}O_6}{180.16\text{g } C_6H_{12}O_6} = 0.222 \text{ mole } C_6H_{12}O_6$$

   isn't, but it's close enough!), how many moles of glucose are in the soda?
   c) How many moles of carbon dioxide are produced when all of the glucose in the soda is completely metabolized?

   $$V = \frac{nRT}{P} = \frac{1.33\text{mole} \times 8.314 \times 310\text{K}}{102\text{kPa}} = 33.7\text{dm}^3$$

   d) What volume is occupied by that carbon dioxide at body temperature (37 °C) and at 102 kPa?

   $$0.222 \text{ mole } C_6H_{12}O_6 \times \frac{6 \text{ mole } CO_2}{1\text{mole } C_6H_{12}O_6} = 1.33 \text{ mole } CO_2$$

2. The average volume of air exhaled in a normal breath for an average-size male is 5.0×10^2

   $$0.500\text{dm}^3 \times 0.05 = 0.025 \text{ dm}^3 CO_2$$

   $$n_{CO_2} = \frac{PV}{RT} = \frac{102\text{kPa} \times 0.025\text{dm}^3}{310\text{K} \times 8.314} = 9.89 \times 10^{-4}\text{mol } CO_2$$

   $$9.89 \times 10^{-4}\text{mol } CO_2 \times \frac{1\text{mole } C_6H_{12}O_6}{6 \text{ mole } CO_2} \times \frac{180.16\text{g } C_6H_{12}O_6}{1\text{mole } C_6H_{12}O_6} = 0.03\text{g } C_6H_{12}O_6$$

   mL. Roughly 5% of that volume is carbon dioxide. What mass of glucose would have been metabolized to produce that amount of carbon dioxide at body temperature (37°C) and 102 kPa pressure?

3. My pet squirrel Randy ate a paintball cartridge that contained 12 g of carbon dioxide. Given that the normal body temperature of a squirrel is 37 degrees Celsius and his internal pressure is typically 110 kPa, what will the final volume of the squirrel be if the paintball cartridge opens up in his belly?

   $$12\text{g } CO_2 \times \frac{1\text{mol } CO_2}{44.01\text{g}CO_2} = 0.27\text{mol } CO_2$$

   $$V = \frac{nRT}{P} = \frac{0.27\text{mol} \times 8.314 \times 310\text{K}}{110\text{kPa}} = 6.4 \text{ dm}^3$$

4. I don't like my next door neighbor, but he doesn't know that. He's a stuntman, and recently hired me to fill the airbag into which he will fall during a "falling out of a building" stunt. I have filled the 144,000 liter airbag with 1500 kg of nitrogen gas at a temperature of 32 degrees Celsius. Given that my neighbor will only survive the fall if the pressure inside the airbag is between 120 and 140 kPa, should I expect to get a new neighbor in the very near future?

$$1500\text{kg}\times\frac{10^3\,\text{g}}{1\text{kg}}\times\frac{1\text{mol N}_2}{28.02\text{g N}_2} = 5.35\times10^4\,\text{mol N}_2$$

$$P = \frac{nRT}{V} = \frac{5.35\times10^4\,\text{mol}\times8.314\times305\text{K}}{144{,}000\text{dm}^3} = 940\text{kPa; new neighbor}$$

5. I am considering remodeling my house, and have a 55 L tank of nitrogen in my shed. This tank contains 15 kilograms of nitrogen gas and can withstand a pressure of 150 atm before exploding. If I were to "accidentally" heat this tank to a temperature of 815 degrees Celsius,

$$n=15\text{kg N}_2\times\frac{10^3\text{gN}_2}{1\text{kgN}_2}\times\frac{1\text{mole N}_2}{28.02\text{g N}_2}=535.3\text{ mole N}_2$$

$$P=\frac{nRT}{V}=\frac{535\text{ mol }\times0.0821\dfrac{L\bullet atm}{mol\bullet K}\times1088\text{K}}{55\text{L}}=869\text{atm; BOOM!}$$

would this tank explode and save me the demolition cost for my coming addition?

6. Calcium carbonate decomposes at high temperatures to form carbon dioxide and calcium oxide:

$$CaCO_3(s)\rightarrow CO_2(g) + CaO(s)$$

How many grams of calcium carbonate will I need to form 3.45 liters of carbon dioxide at STP?

$$3.45\text{LCO}_2\times\frac{1\text{mole CO}_2}{22.7\text{L}}\times\frac{1\text{mole CaCO}_3}{1\text{mole CO}_2}\times\frac{100.09\text{g CaCO}_3}{1\text{mol CaCO}_3}=15.2\text{g CaCO}_3$$

7. Ethylene burns in oxygen to form carbon dioxide and water vapor:

$$C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$$

How many liters of water can be formed if 1.25 liters of C_2H_4 are consumed in this reaction?

$$1.25\text{L } C_2H_4 \times \frac{2\text{L } H_2O}{1\text{L } C_2H_4} = 2.50\text{L } H_2O$$

8. I have added 15 L of air to a balloon at sea level (100 kPa). If I take the balloon with me to Denver, where the air pressure is 85 kPa, what will the new volume of the balloon be?

$$P_1V_1 = P_2V_2$$
$$15\text{L} \times 100\text{kPa} = 85\text{kPa} \times V_2$$
$$V_2 = 18\text{L}$$

9. If divers rise too quickly from a deep dive, they get a condition called "the bends" which is caused by the expansion of very small nitrogen bubbles in the blood due to decreased pressure. If the initial volume of the bubbles in a diver's blood is 15 mL and the initial pressure is 5.5 atm, what is the volume of the bubbles when the diver has surfaced to 1.00 atm pressure?

$$15\text{mL} \times 5.5\text{atm} = 1.0\text{atm} \times V_2$$
$$V_2 = 83\text{mL}$$

10. As part of some research for the product Alka-Seltzer, a researcher combines 0.840g sodium bicarbonate with 100.0 mL of 0.0500 mol dm^{-3} citric acid ($H_3C_6H_5O_7$). Here is the unbalanced equation:

$$3NaHCO_3(s) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l) + 3CO_2(g)$$

If the dry gas that the student actually collects occupies a volume of 0.196 dm^3 at 25°C and 101 kPa pressure, what is the percentage yield of this reaction?

$$0.100\text{dm}^3 \times \frac{0.0500\text{mol } H_3C_6H_5O_7}{1\text{dm}^3} \frac{3\text{mol } CO_2}{1\text{mol } H_3C_6H_5O_7} = 0.0150 \text{ mol } CO_2$$

$$0.840\text{g } NaHCO_3 \times \frac{1\text{mol } NaHCO_3}{84.01\text{g } NaHCO_3} \times \frac{3\text{mol } CO_2}{3\text{mol } NaHCO_3} = 0.0100 \text{ mol } CO_2$$

So $NaHCO_3$ is the limiting reactant.

$$V = \frac{nRT}{P} = \frac{0.0100 \text{ mol} \times 8.314 \times 298 \text{ K}}{101 \text{ kPa}} = 0.245\text{dm}^3 \text{is the theoretical yield}$$

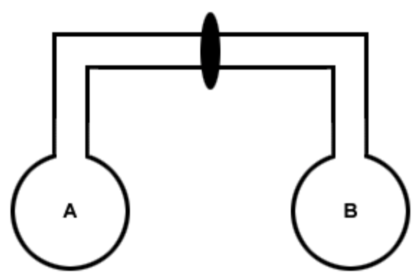
$$\%\text{yield} = \frac{0.196}{0.245} \times 100\% = 79.9\%$$

11. If 500 mL of HCl gas at 300 K and 100 kPa dissolve in 100 mL of pure water, what is the concentration? Assume no volume change of the liquid upon dissolving.

$$n = \frac{PV}{RT} = \frac{100\text{kPa} \times 0.500\text{dm}^3}{8.314 \times 300\text{K}} = 0.02\text{mole}$$

$$[\text{HCl}] = \frac{0.02\text{ mol}}{0.1\text{dm}^3} = 0.2\text{moldm}^{-3}$$

12. Side A of the flask below has a volume of 0.500 dm^3 and contains O_2 at 98.0 kPa. Side B of the flask below has a volume of 1.500 dm^3 and contains N_2 at 49 kPa. What is the partial pressure of each gas when the valve is open and what is the total pressure when the valve is open? Assume no temperature changes.



$$P_1V_1 = P_2V_2$$

$$O_2 : 98.0\text{ kPa} \times 0.500\text{ dm}^3 = P_2 \times 2.000\text{ dm}^3$$

$$P_{O_2} = 24.5\text{ kPa}$$

$$N_2 : 49\text{ kPa} \times 1.500\text{ dm}^3 = P_2 \times 2.000\text{ dm}^3$$

$$P_{N_2} = 37\text{kPa}$$

$$P_{\text{total}} = P_{O_2} + P_{N_2} = 61\text{ kPa}$$

Some of the problems on this worksheet are from:
http://www.science.uwaterloo.ca/~cchieh/cact/c120/gastoichiometry.html
http://www.marin.edu/homepages/ErikDunmire/CHEM131/D5_GasStoich.pdf
https://chemfiesta.wordpress.com/2015/03/26/gases-and-their-laws/