P J3 (pg 1 of 4) Stoichiometry with Gases

Name______________________Per___

Write out your dimensional analysis work. If you need more room, work on another piece of paper. Circle your final answer. Put units, identifiers and descriptors on your answers. Concern yourself at least a little bit with significant figures.

1. Your little Honda Fit holds 10 gallons of gas, which is 37.85 L. On a cold day in December, 5ºC and 0.985 atm pressure, you decide to go on trip and you use up an entire tank of gas. Write a balanced equation for the combustion of octane, C_8H_{18} which is the major component of gasoline in the space below. The density of liquid octane is 0.703 g/ml.

Molar Mass g/mol	
C_8H_{18}	114.26
O_2	32.00
CO_2	44.01
H_2O	18.02

Helpful Info	
R	0.0821 Latm/molK
R	62.4 LmmHg/molK
1atm = 760 mmHg	
K = ºC + 273	

(a) Calculate the volume of oxygen gas that would be required to react with the full tank of gas.

(b) What volume of air is this?

2. Excess nitrogen was reacted with 2.54 L of hydrogen gas. What volume of ammonia gas could be produced if the reaction is held at −75ºC at 22.5 atm of pressure throughout the reaction.

 Stoichiometry with Gases

3. Sodium carbonate will react with hydrochloric acid solution to produce sodium chloride, water, and carbon dioxide gas. Calculate the volume of carbon dioxide that would be collected when 45.0 ml of 2.5 M hydrochloric acid solution is poured over an excess of solid sodium carbonate. The carbon dioxide is collected at a pressure of 755 mm Hg at 15ºC.

Helpful Info	
R	0.0821 Latm/molK
R	62.4 LmmHg/molK
1atm = 760 mmHg	
K = ºC + 273	

4. The reaction below represents the preparation of carbon disulfide by reacting coke (carbon) with sulfur dioxide.
   (a) Balance the equation below, and then calculate the volume of sulfur dioxide required to process 650. kg of carbon into carbon disulfide. The sulfur dioxide is stored in 40.0 L tanks at 250. atm of pressure at 20.0ºC
   (b) How many tanks of sulfur dioxide should the foundry have on hand for every 650. kg of carbon?
   (c) The carbon monoxide is collected and stored in the same size 40.0 L tanks also at 250. atm of pressure. How many tanks of carbon monoxide can the foundry expect to produce for the 650. kg of carbon reacted?

$$C \quad + \quad SO_2 \quad \rightarrow \quad CS_2 \quad + \quad CO$$

Molar Mass g/mol	
C	12.01
SO_2	64.07
CS_2	76.15
CO	28.01

 Stoichiometry ***ANSWERS***

Write out your dimensional analysis work. If you need more room, work on another piece of paper. Circle your final answer. Put units, identifiers and descriptors on your answers. Concern yourself at least a little bit with significant figures.

1. Your little Honda Fit holds 10 gallons of gas, which is 37.85 L. On a cold day in December, 5ºC and 0.985 atm pressure, you decide to go on trip and you use up an entire tank of gas. Write a balanced equation for the combustion of octane, C_8H_{18} which is the major component of gasoline in the space below. The density of liquid octane is 0.703 g/ml.

Molar Mass g/mol	
C_8H_{18}	114.26
O_2	32.00
CO_2	44.01
H_2O	18.02

Helpful Info	
R	0.0821 Latm/molK
R	62.4 LmmHg/molK
1atm = 760 mmHg	
K = ºC + 273	

$$2\,C_8H_{18} + 25\,O_2 \rightarrow 16\,CO_2 + 18\,H_2O$$

(a) Calculate the volume of oxygen gas that would be required to react with the full tank of gas.

Convert the liquid octane to mass of octane using density

$$37.85\,L\,C_8H_{18} \times \frac{1000\,mL}{1\,L} \times \frac{0.703\,g}{1\,mL} = 26{,}609\,g\,C_8H_{18}$$

now you can start like any other typical stoichiometry prob.

$$26{,}609\,g\,C_8H_{18} \times \frac{1\,mol\,C_8H_{18}}{114.26\,g\,C_8H_{18}} \times \frac{25\,mol\,O_2}{2\,mol\,C_8H_{18}} = 2{,}911\,mol\,O_2$$

no we can use $PV = nRT$ to calculate the volume of oxygen

$$V_{O_2} = \frac{nRT}{P} \quad \frac{2{,}911\,mol \cdot 0.0821\,\frac{L\,atm}{mol \cdot K} \cdot 278\,K}{0.985\,atm} = 67{,}451\,L\,O_2 \quad (67{,}500\,L\ 3SF)$$

(b) What volume of air is this? Perhaps you remember air is ~20% O_2 ~80% N_2 → $\frac{1}{5}$th or $\frac{1\,part\,O_2}{5\,parts\,air}$

$$67{,}451\,L\,O_2 \times \frac{5\,parts\,Air}{1\,part\,O_2} = 337{,}255\,L\ of\ air \quad (337{,}000\,L\ 3SF)$$

2. Excess nitrogen was reacted with 2.54 L of hydrogen gas. What volume of ammonia gas could be produced if the reaction is held at −75ºC at 22.5 atm of pressure throughout the reaction.

First write a balanced equation $N_2 + 3\,H_2 \rightarrow 2\,NH_3$

this problem is actually very simple because of Avogadro's Law

At constant temperature and pressure volume of gas is proportional to # of particles and in this problem, the temp and pressure are held constant

this allows us to do stoichiometry with volumes.

$$2.54\,L\,H_2 \times \frac{2\,mol\,NH_3}{3\,mol\,H_2} = 1.69\,L\ of\ NH_3$$

-- Below this line is more explanation as to why you don't need to use the Ideal Gas Law

$$n = \frac{PV}{RT} \quad \frac{22.5\,atm \cdot 2.54\,L}{0.0821\,\frac{L\,atm}{mol\,K} \cdot 198\,K} = 3.52\,mol\,H_2 \times \frac{2\,mol\,NH_3}{3\,mol\,H_2} = 2.34\,mol\,NH_3$$

$$V_{NH_3} = \frac{nRT}{P} \quad \frac{2.34\,mol\,NH_3 \cdot 0.0821\,\frac{L \cdot atm}{mol \cdot K} \cdot 198\,K}{22.5\,atm} = 1.69\,L\ of\ NH_3$$

Same as above

if you feel the need, you can check the calculation by using the ideal gas law to convert 2.54 L H_2 into 3.52 mol H_2, the use the LINK to get 2.34 mol NH_3, then use the Ideal gas Law to convert back into 1.69 L NH_3

you can see this is not necessary

3. Sodium carbonate will react with hydrochloric acid solution to produce sodium chloride, water, and carbon dioxide gas. Calculate the volume of carbon dioxide that would be collected when 45.0 ml of 2.5 M hydrochloric acid solution is poured over an excess of solid sodium carbonate. The carbon dioxide is collected at a pressure of 755 mm Hg at 15ºC.

Helpful Info	
R	0.0821 Latm/molK
R	62.4 LmmHg/molK
1atm = 760 mmHg	
K = ºC + 273	

Again, a balanced equation: $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

Don't forget molarity = $\frac{\text{moles}}{\text{Liter of solution}}$ and $M \times V = \text{moles}$

$2.5\,M \times 0.045\,L = 0.1125\,\text{mol HCl}$

$0.1125\,\text{mol HCl} \times \frac{1\,\text{mol } CO_2}{2\,\text{mol HCl}} = 0.05625\,\text{mol } CO_2$

$PV = nRT$

$V_{CO_2} = \frac{nRT}{P}$ $\quad \frac{0.05625\,\text{mol} \cdot 62.4 \frac{L \cdot mmHg}{mol \cdot K} \cdot 288\,K}{755\,mmHg} = 1.33\,L\,CO_2$

4. The reaction below represents the preparation of carbon disulfide by reacting coke (carbon) with sulfur dioxide.

(a) Balance the equation below, and then calculate the volume of sulfur dioxide required to process 650. kg of carbon into carbon disulfide. The sulfur dioxide is stored in 40.0 L tanks at 250. atm of pressure at 20.0ºC

(b) How many tanks of sulfur dioxide should the foundry have on hand for every 650. kg of carbon?

(c) The carbon monoxide is collected and stored in the same size 40.0 L tanks also at 250. atm of pressure. How many tanks of carbon monoxide can the foundry expect to produce for the 650. kg of carbon reacted?

Molar Mass g/mol	
C	12.01
SO_2	64.07
CS_2	76.15
CO	28.01

$5\,C + 2\,SO_2 \rightarrow CS_2 + 4\,CO$

$650\,kg\,C \times \frac{1000\,g}{1\,kg} \times \frac{1\,mol\,C}{12.01\,g\,C} \times \frac{2\,mol\,SO_2}{5\,mol\,C} = 21{,}649\,mol\,SO_2$

$PV = nRT$

$V_{SO_2} = \frac{nRT}{P}$ $\quad \frac{21{,}649\,mol \cdot 0.0821 \frac{L \cdot atm}{mol \cdot K} \cdot 293\,K}{250\,atm} = 2083\,L\,\text{of}\,SO_2$ (2080 L 3SF)

$2083\,L \times \frac{1\,\text{tank}}{40\,L} = \sim 52\,\text{tanks}\,SO_2$

Again like in problem #2, since the tanks are at the same temp and pressure, equal volumes (tanks) will have equal numbers (moles) of molecules – Thus you can "do stoichiometry" with the tanks.

$52\,\text{tanks}\,SO_2 \times \frac{4\,mol\,CO}{2\,mol\,SO_2} = 104\,\text{tanks}\,CO$