N-34
Gas Stoichiometry

Target: I can use gas laws to help me perform stoichiometry problems involving gases.

Link to YouTube Presentation: https://youtu.be/HgeCwZgoqcI

N-34

Gas Stoichiometry

Its still just regular stoichiometry!

Just need a gas law equation instead of a conversion factor sometimes!

Gas Stoichiometry

- **"Normal" stoichiometry**
  = using molecules, masses & molar masses.
- **We can use stoichiometry for gas reactions!**
- ***STILL need mole ratios…might need gas laws to help you find # of moles though!***

molar mass of A ↓ **mole ratio from balanced equation** ↓ **molar mass of B** ↓

grams A ↔ moles A ↔ moles B ↔ grams B

↕ ← PV = nRT → ↕

P, V, T (A) * P, V, T (B)

Sometimes you can use **MOLAR VOLUME as shortcuts*
***22.4 L/mol at STP** or*
***24.8 L/mol at SATP** (S-Ambiant-TP=298K instead of 273K)*

Sample problem 1

CH_4 burns in O_2, producing CO_2+ $H_2O(g)$. A 1.22 L CH_4 cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O_2 at 100kPa and 298K will be required to react completely with all of the CH_4?

First: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Pathway:

L of A → mol A → mol B → L of B

PV = nRT *of A*

Mole Ratio

PV = nRT *of B*

Sample problem 1

CH_4 burns in O_2, producing CO_2+ H_2O(g). A 1.22 L CH_4 cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O_2 at 100kPa and 298K will be required to react completely with all of the CH_4?

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

L of A → ***mol A***

PV = nRT

of A

P = 328 kPa, V = 1.22 L, T = 288 K

PV = nRT

$$\frac{(328\ \text{kPa})(1.22\ \text{L})}{(8.31\ \text{kPa}\bullet\text{L/K}\bullet\text{mol})(288\ \text{K})} = n = \mathbf{0.167\ mol\ CH_4}$$

Sample problem 1

CH_4 burns in O_2, producing CO_2+ H_2O(g). A 1.22 L CH_4 cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O_2 at 100kPa and 298K will be required to react completely with all of the CH_4?

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

moles of A → moles of B ***mol CH_4 → mol O_2 :***

Mole Ratio

$$\frac{0.167 \text{ mol } \cancel{CH_4}}{} \left| \frac{2 \text{ mol } O_2}{1 \text{ mol } \cancel{CH_4}} \right. = \mathbf{0.334 \text{ mol } O_2}$$

Sample problem 1

CH_4 burns in O_2, producing CO_2+ $H_2O(g)$. A 1.22 L CH_4 cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O_2 at 100kPa and 298K will be required to react completely with all of the CH_4?

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

mol B → L of B

P= 100 kPa, n= 0.334 mol, T= 298 K

PV = nRT

of B

$$\frac{(0.334\ \text{mol})(8.31\ \text{kPa}\bullet\text{L/K}\bullet\text{mol})(298\ \text{K})}{(100\ \text{kPa})}$$

= V of O_2= 8.28 L

Sample problem 1 continued

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

b) How many grams of $H_2O(g)$ are produced?

mol A → mol B → g B

Mole Ratio

Molar Mass of B

$$\frac{0.167 \text{ mol } CH_4}{} \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } CH_4} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 6.02 \text{ g } H_2O$$

Sample problem 1 continued

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

b) How many grams of $H_2O(g)$ are produced?

mol A → mol B → g B

Mole Ratio (mol A → mol B); **Molar Mass of B** (mol B → g B)

OR use moles of O_2 and a different mole ratio!

$$\frac{0.334 \text{ mol } O_2}{} \times \frac{2 \text{ mol } H_2O}{2 \text{ mol } O_2} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 6.02 \text{ g } H_2O$$

Sample problem 1 continued

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

c) What volume of CO_2 (at STP) is produced if only 2.15 g of the CH_4 was burned?

g of A → mol A → mol B → L of B

Molar Mass of A | Mole Ratio | PV = nRT *of B*

$$\frac{2.15\ \text{g}\ CH_4}{} \left| \frac{1\ \text{mol}\ CH_4}{16.05\ \text{g}\ CH_4} \right| \frac{1\ \text{mol}\ CO_2}{1\ \text{mol}\ CH_4} = 0.134\ \text{mol}\ CO_2$$

PV = nRT

P = 101.3 kPa, n = 0.134 mol, T = 273 K

$$\frac{(0.134\ \text{mol})(8.31\ \text{kPa•L/K•mol})(273\ \text{K})}{(101.3\ \text{KPa})} = V = 3.00\ \text{L}\ CO_2$$

Sample problem 1 continued

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

c) What volume of CO_2 (at STP) is produced if only 2.15 g of the CH_4 was burned?

g of A → mol A → mol B → L of B

Molar Mass of A | **Mole Ratio** | **PV = nRT *of B*** | ***OR use molar volume!***

2.15 g CH_4	1 mol CH_4	1 mol CO_2	22.4 L CO_2
	16.05 g CH_4	1 mol CH_4	1 mol CO_2

= 3.00 L CO_2

Sample problem 2

Ammonia (NH_3) gas can be synthesized from nitrogen gas + hydrogen gas. What volume of ammonia at 450 kPa and 80°C can be obtained from the complete reaction of 7500 g hydrogen?

First: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

g A → mol A → mol B → L of B

$$\frac{7500\ \text{g}\ H_2}{} \times \frac{1\ \text{mol}\ H_2}{2.02\ \text{g}\ H_2} \times \frac{2\ \text{mol}\ NH_3}{3\ \text{mol}\ H_2} = 2475\ \text{mol}\ NH_3$$

PV = nRT

P = 450 kPa, n = 2475 mol, T = 353 K

$$\frac{(2475\ \text{mol})(8.31)(353\ \text{K})}{(450\ \text{KPa})} = V = 16135\ \text{L of}\ NH_3$$

Sample problem 3

Hydrogen gas (and NaOH) is produced when sodium metal is added to water. What mass of Na is needed to produce 20.0 L of H_2 at STP?

First: $2Na(s) + 2H_2O(l) \rightarrow H_2(g) + 2NaOH(aq)$

PV = nRT

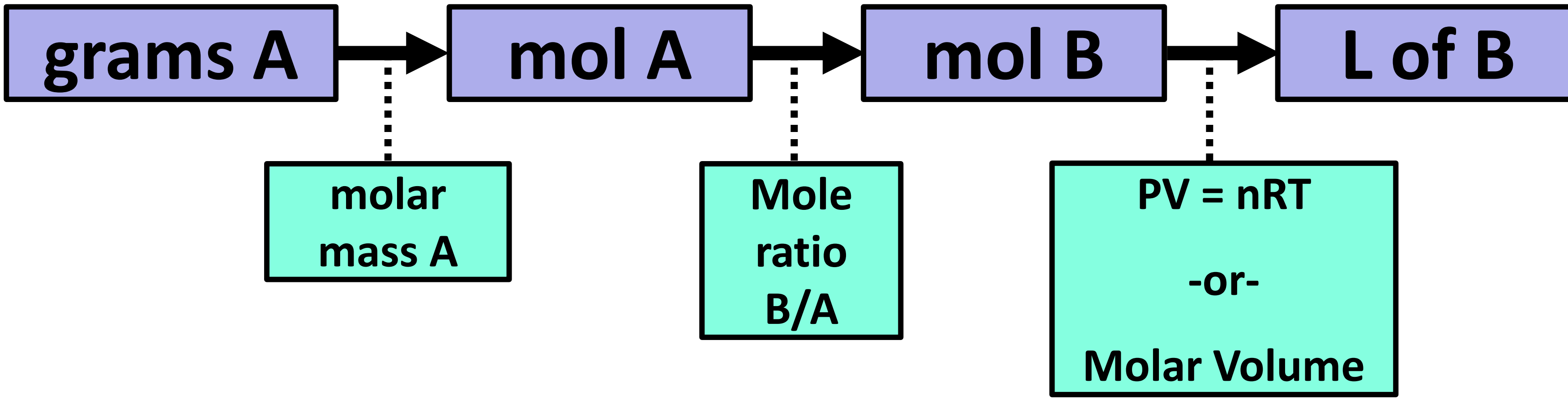
P= 101.3 kPa, V= 20.0 L, T= 273 K

$$\frac{(101.3\ \text{kPa})(20.0\ \text{L})}{(8.31\ \text{kPa•L/K•mol})(273\ \text{K})} = n = 0.893\ \text{mol}\ H_2$$

$$\frac{0.893\ \text{mol}\ H_2}{} \left|\frac{2\ \text{mol Na}}{1\ \text{mol}\ H_2}\right| \frac{22.99\ \text{g Na}}{1\ \text{mol Na}} = 41.1\ \text{g Na}$$

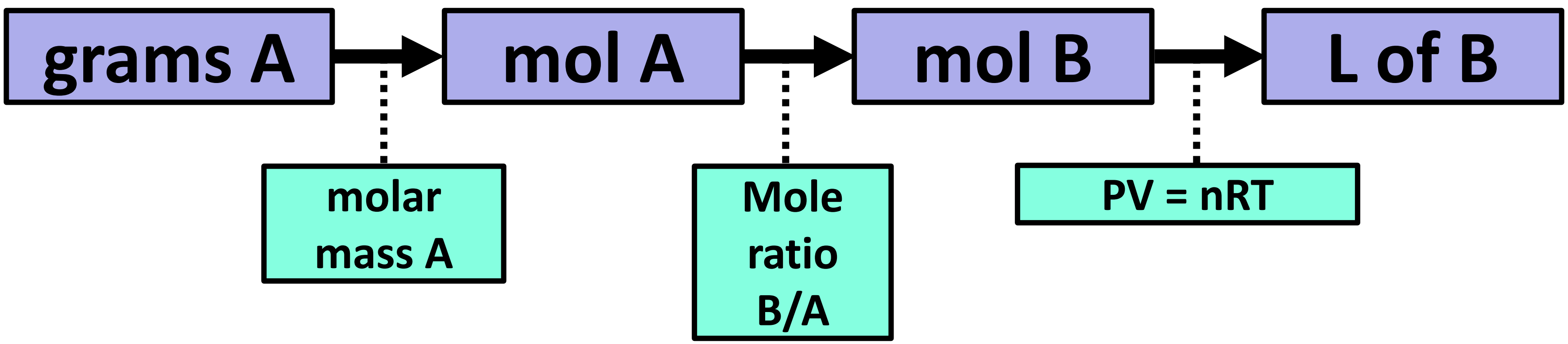
Extra Practice

1) What volume of oxygen at STP is needed to completely burn 15 g of methanol (CH_3OH) in a fondue burner? (CO_2 + H_2O are products)



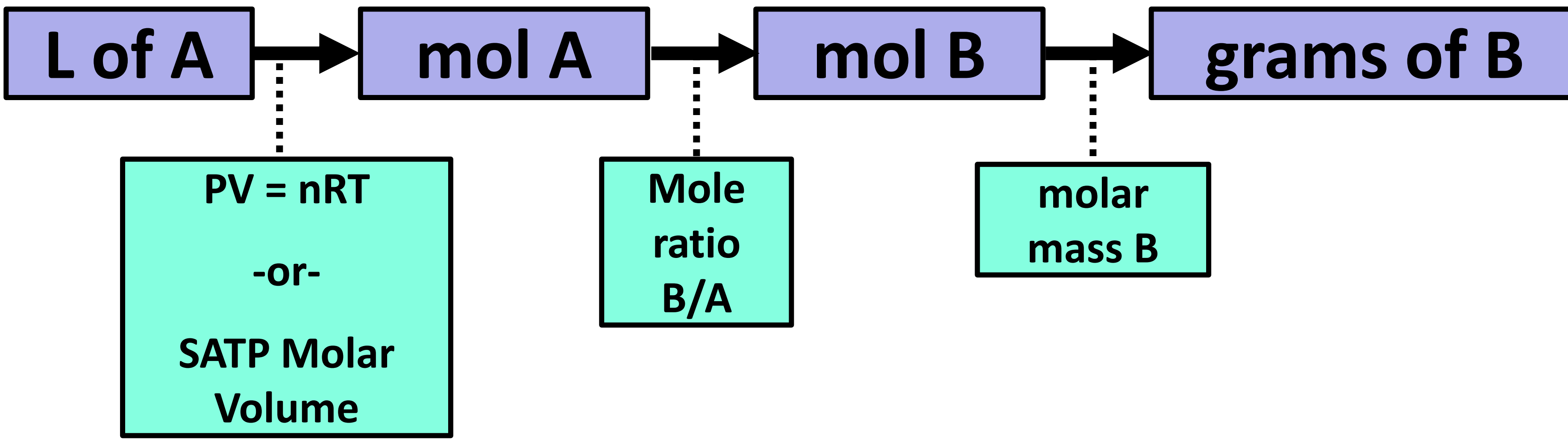
Extra Practice

2) When sodium chloride is heated to 800°C it can be electrolytically decomposed into Na metal & chlorine (Cl_2) gas. What volume of chlorine gas is produced (at 800°C and 100 kPa) if 105 g of Na is also produced?



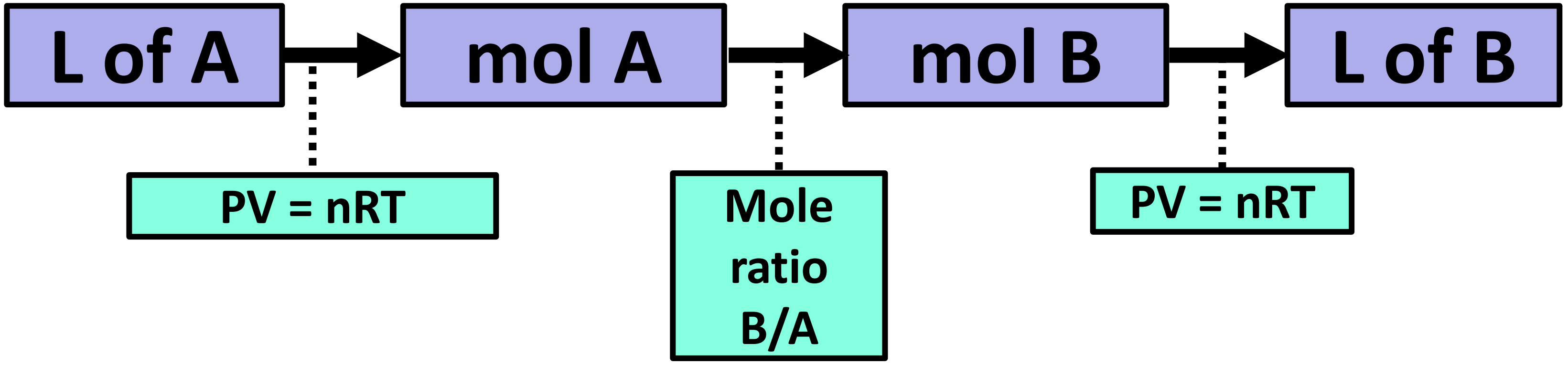
Extra Practice

3) What mass of propane (C_3H_8) can be burned using 100 L of air at SATP? Note: 1) air is 20% O_2, so 100 L of air holds 20 L O_2, 2) CO_2 and H_2O are the products of this reaction.



Extra Practice

4) A 5.0 L tank holds 13 atm of propane (C_3H_8) at 10°C. What volume of O_2 at 10°C & 103 kPa will be required to react with all of the propane?

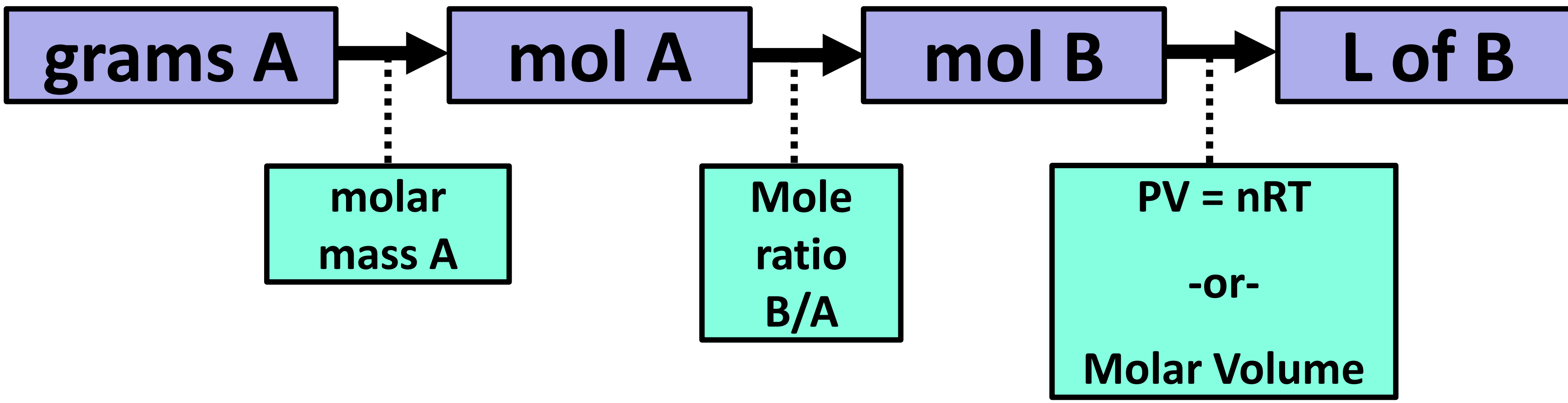


Extra Practice

5) Nitroglycerin explodes according to:

$$4\ C_3H_5(NO_3)_3(l) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$$

a) Calculate the volume, at STP, of each product formed by the reaction of 100 g of $C_3H_5(NO_3)_3$.



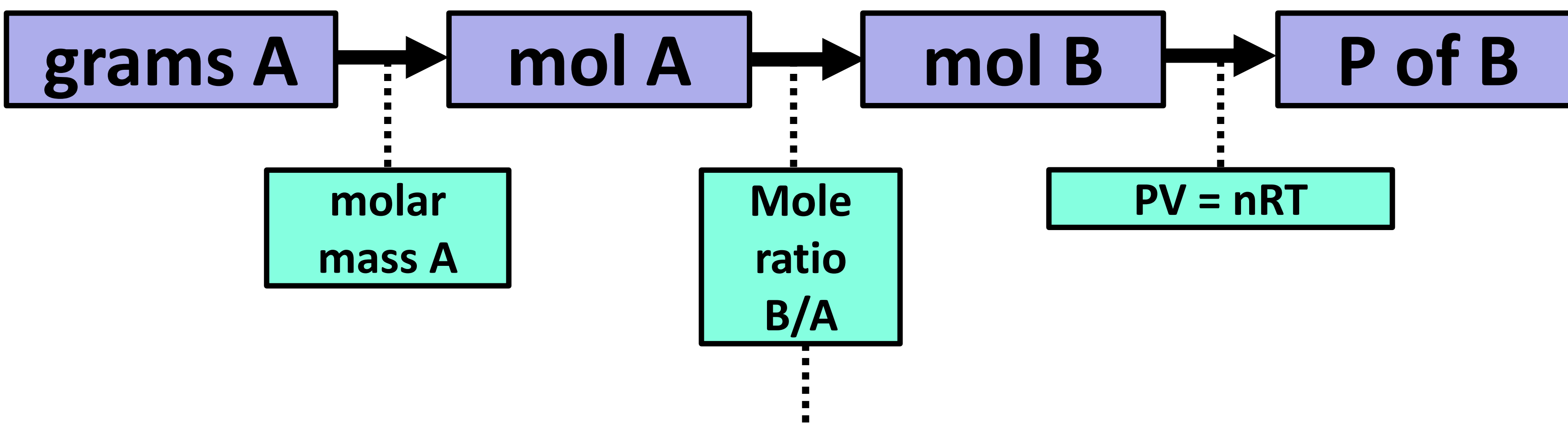
Have to do this for EACH of the products!
Do it four times!

Extra Practice

5) Nitroglycerin explodes according to:

$$4\ C_3H_5(NO_3)_3(l) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$$

b) 200 g of $C_3H_5(NO_3)_3$ is ignited (and completely decomposes) in an otherwise empty 50 L gas cylinder. What will the pressure in the cylinder be if the temperature stabilizes at 220°C?



Tricky! Moles of "B" is actually the TOTAL number of moles of gas in the reaction – so it should be 29 mol gas/4 mol $C_3H_5(NO_3)_3$

Answers

1) $3O_2(g) + 2CH_3OH(l) \rightarrow 2CO_2(g) + 4H_2O(g)$

 # L O_2 =

$$\frac{15\text{ g }CH_3OH}{} \left| \frac{1\text{ mol }CH_3OH}{32.05\text{ g }CH_3OH} \right| \frac{3\text{ mol }O_2}{2\text{ mol }CH_3OH} \left| \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} \right.$$

= 15.7 L O_2

2) $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

$$\#\text{ mol }Cl_2 = \frac{105\text{ g Na}}{} \left| \frac{1\text{ mol Na}}{22.99\text{ g Na}} \right| \frac{1\text{ mol }Cl_2}{2\text{ mol Na}} = 2.284\text{ mol }Cl_2$$

PV = nRT P = 100 kPa, n = 2.284 mol, T = 1073 K

$$\frac{(2.284\text{ mol})(8.31)(1073\text{ K})}{(100\text{ KPa})} = V = 204\text{ L }Cl_2$$

3) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

$$\# \text{ g } C_3H_8 = \frac{20 \text{ L } O_2}{} \left| \frac{1 \text{ mol } O_2}{24.8 \text{ L } O_2} \right| \frac{1 \text{ mol } C_3H_8}{5 \text{ mol } O_2} \left| \frac{44.11 \text{ g } C_3H_8}{1 \text{ mol } C_3H_8} \right. = 7.1 \text{ g } C_3H_8$$

4) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

$$PV = nRT \quad n = \frac{(1317 \text{ kPa})(5.0 \text{ L})}{(8.31)(283 \text{ K})} = 2.8 \text{ mol } C_3H_8$$

$$\# \text{ mol } O_2 = \frac{2.8 \text{ mol } C_3H_8}{} \left| \frac{5 \text{ mol } O_2}{1 \text{ mol } C_3H_8} \right. = 14 \text{ mol } O_2$$

$PV = nRT \quad P = 103 \text{ kPa}, \; n = 14 \text{ mol}, \; T = 283 \text{ K}$

$$\frac{(14 \text{ mol})(8.31)(283 \text{ K})}{(103 \text{ KPa})} = V = 320 \text{ L } O_2$$

5) # mol $C_3H_5(NO_3)_3$ =

$$100\text{ g } C_3H_5(NO_3)_3 \times \frac{1\text{ mol } C_3H_5(NO_3)_3}{227.11\text{ g } C_3H_5(NO_3)_3} = 0.4403\text{ mol}$$

$$\#\text{ L } CO_2 = 0.44\underline{0}3\text{ mol } C_3H_5(NO_3)_3 \times \frac{12\text{ mol } CO_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 29.6\text{ L } CO_2$$

$$\#\text{ L } N_2 = 0.44\underline{0}3\text{ mol } C_3H_5(NO_3)_3 \times \frac{6\text{ mol } N_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 14.8\text{ L } N_2$$

$$\#\text{ L } H_2O = 0.44\underline{0}3\text{ mol } C_3H_5(NO_3)_3 \times \frac{10\text{ mol } H_2O}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 24.7\text{ L } H_2O$$

$$\#\text{ L } O_2 = 0.44\underline{0}3\text{ mol } C_3H_5(NO_3)_3 \times \frac{1\text{ mol } O_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 2.47\text{ L } O_2$$

5. **# mol $C_3H_5(NO_3)_3$=**

$$200\ g\ C_3H_5(NO_3)_3 \times \frac{1\ mol\ C_3H_5(NO_3)_3}{227.11\ g\ \ C_3H_5(NO_3)_3} = 0.8806\ mol$$

 # mol all gases=

$$0.8806\ mol\ C_3H_5(NO_3)_3 \times \frac{29\ mol\ gases}{4\ mol\ C_3H_5(NO_3)_3} = 6.385\ mol\ \text{all gases}$$

PV = nRT V = 50 L, n = 6.3<u>8</u>5 mol, T = 493 K

$$\frac{(6.3\underline{8}5\ mol)(8.31)(493\ K)}{(50\ L)} = P = 523\ kPa$$

YouTube Link to Presentation

- https://youtu.be/HgeCwZgoqcI