

# N-34

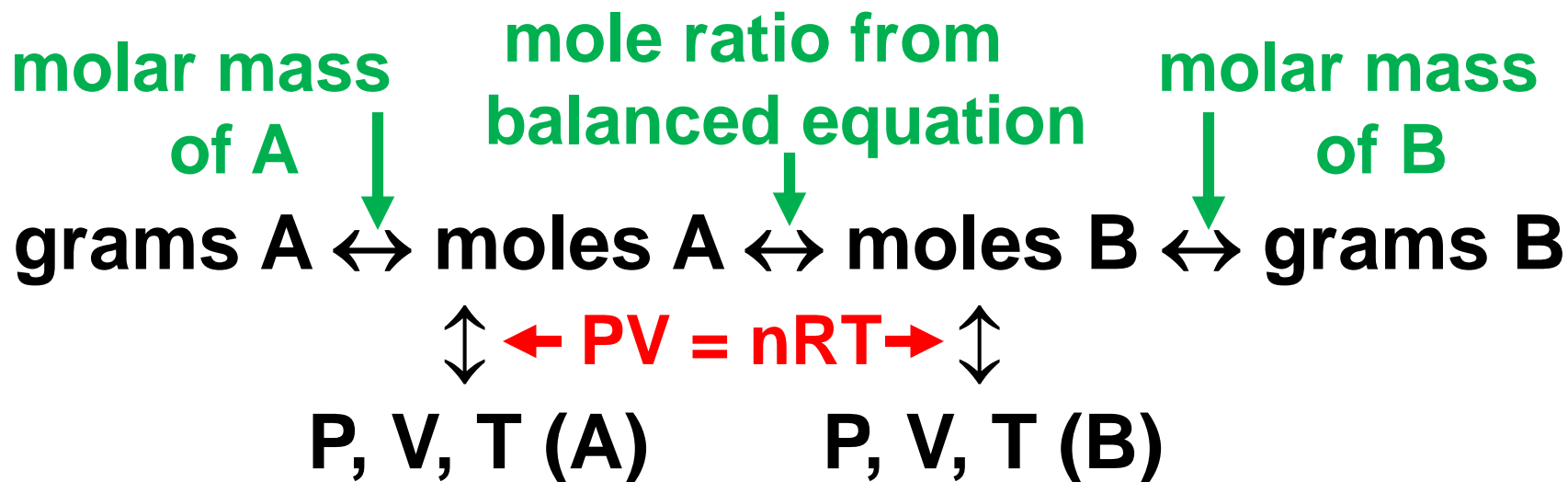
## Gas Stoichiometry

*Its still just regular stoichiometry! Just need a gas law equation instead of a conversion factor sometimes!*

**Target: I can use gas laws to help me solve stoichiometry problems when one or more of the chemicals is a gas.**

# 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!***



*At times you will be able to use 22.4 L/mol at STP  
or 24.8 L/mol at SATP as shortcuts (SATP=298K instead of 273K)*

# Sample problem 1

**CH<sub>4</sub> burns in O<sub>2</sub>, producing CO<sub>2</sub>+ H<sub>2</sub>O(g). A 1.22 L CH<sub>4</sub> cylinder, at 15°C, has a pressure of 328 kPa.**

a) What volume of O<sub>2</sub> at 100kPa and 298K will be required to react completely with all of the CH<sub>4</sub>?



***Pathway:***

**L of A → mol A → mol B → L of B**

**PV = nRT  
of A**

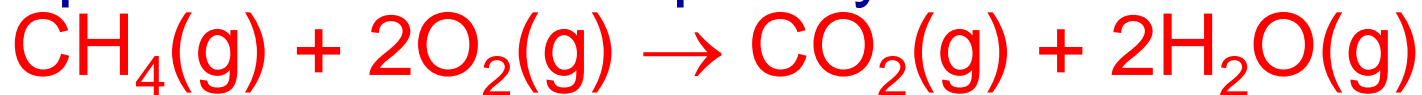
**Mole Ratio**

**PV = nRT  
of B**

# Sample problem 1

CH<sub>4</sub> burns in O<sub>2</sub>, producing CO<sub>2</sub>+ H<sub>2</sub>O(g). A 1.22 L CH<sub>4</sub> cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O<sub>2</sub> at 100kPa and 298K will be required to react completely with all of the CH<sub>4</sub>?



***L of A → mol A***

$$PV = nRT$$

*of A*

$$PV = nRT$$

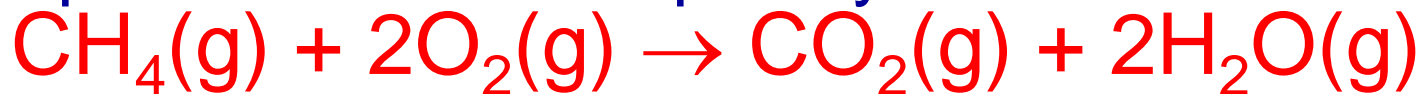
$$P = 328 \text{ kPa}, V = 1.22 \text{ L}, T = 288 \text{ K}$$

$$\frac{(328 \text{ kPa})(1.22 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(288 \text{ K})} = n = \mathbf{0.167 \text{ mol CH}_4}$$

# Sample problem 1

CH<sub>4</sub> burns in O<sub>2</sub>, producing CO<sub>2</sub>+ H<sub>2</sub>O(g). A 1.22 L CH<sub>4</sub> cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O<sub>2</sub> at 100kPa and 298K will be required to react completely with all of the CH<sub>4</sub>?



*moles of A → moles of B*      *mol CH<sub>4</sub> → mol O<sub>2</sub> :*

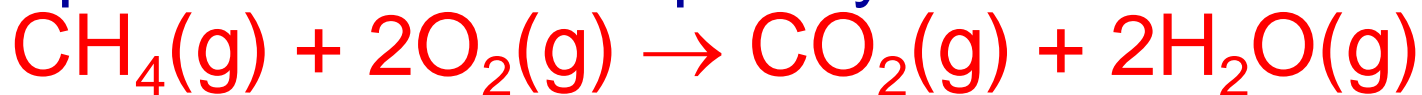
**Mole Ratio**

$$\frac{0.167 \text{ mol } \cancel{\text{CH}_4}}{1 \text{ mol } \cancel{\text{CH}_4}} \times \frac{2 \text{ mol O}_2}{1} = \mathbf{0.334 \text{ mol O}_2}$$

# Sample problem 1

CH<sub>4</sub> burns in O<sub>2</sub>, producing CO<sub>2</sub>+ H<sub>2</sub>O(g). A 1.22 L CH<sub>4</sub> cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O<sub>2</sub> at 100kPa and 298K will be required to react completely with all of the CH<sub>4</sub>?



**mol B → L of B**

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

$$PV = nRT$$

*of B*

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

$$(100 \text{ kPa})$$

$$= V \text{ of O}_2 =$$

$$8.28 \text{ L}$$



# Sample problem 1 continued



What volume of  $\text{CO}_2$  (at STP) is produced if only 2.15 g of the  $\text{CH}_4$  was burned?

**g of A  $\rightarrow$  mol A  $\rightarrow$  mol B  $\rightarrow$  L of B**

Molar Mass of A	Mole Ratio	PV = nRT of B	<i>Or use molar volume!</i>
<del>2.15 g <math>\text{CH}_4</math></del>	<del>1 mol <math>\text{CH}_4</math></del>	1 mol $\text{CO}_2$	= 0.134
	<del>16.05 g <math>\text{CH}_4</math></del>	<del>1 mol <math>\text{CH}_4</math></del>	mol $\text{CO}_2$

$$\text{PV} = n\text{RT}$$

$$P = 101.3 \text{ kPa}, n = 0.134 \text{ mol}, T = 273 \text{ K}$$

$$\frac{(0.134 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})}{(101.3 \text{ kPa})} = V = 3.00 \text{ L CO}_2$$



# Sample problem 2

Ammonia (NH<sub>3</sub>) 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:**  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$

g A → mol A → mol B → L of B

<del>7500 g H<sub>2</sub></del>	<del>1 mol H<sub>2</sub></del>	2 mol NH <sub>3</sub>	= 2475 mol NH <sub>3</sub>
	<del>2.02 g H<sub>2</sub></del>	<del>3 mol H<sub>2</sub></del>	

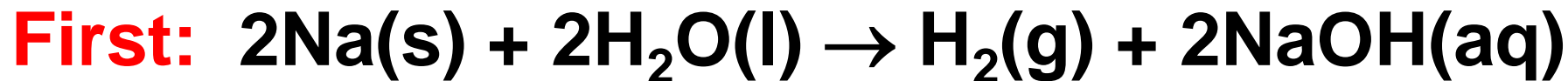
$$PV = nRT$$

$$P = 450 \text{ kPa}, n = 2475 \text{ mol}, T = 353 \text{ K}$$

$$\frac{(2475 \text{ mol})(8.31)(353 \text{ K})}{(450 \text{ kPa})} = V = 16135 \text{ L of NH}_3$$

# 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<sub>2</sub> at STP?



$$PV = nRT$$

$$P = 101.3 \text{ kPa}, V = 20.0 \text{ L}, T = 273 \text{ K}$$

$$\frac{(101.3 \text{ kPa})(20.0 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L/K}\cdot\text{mol})(273 \text{ K})} = n = 0.893 \text{ mol H}_2$$

$0.893 \text{ mol H}_2$	$\frac{2 \text{ mol Na}}{1 \text{ mol H}_2}$	$\frac{22.99 \text{ g Na}}{1 \text{ mol Na}}$	$= 41.1 \text{ g Na}$
<hr/>	<hr/>	<hr/>	

# Extra Practice

- 1) What volume of oxygen at STP is needed to completely burn 15 g of methanol ( $\text{CH}_3\text{OH}$ ) in a fondue burner? ( $\text{CO}_2 + \text{H}_2\text{O}$  are products)
- 2) When sodium chloride is heated to  $800^\circ\text{C}$  it can be electrolytically decomposed into Na metal & chlorine ( $\text{Cl}_2$ ) gas. What volume of chlorine gas is produced (at  $800^\circ\text{C}$  and 100 kPa) if 105 g of Na is also produced?
- 3) What mass of propane ( $\text{C}_3\text{H}_8$ ) can be burned using 100 L of air at SATP? Note: 1) air is 20%  $\text{O}_2$ , so 100 L of air holds 20 L  $\text{O}_2$ , 2)  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are the products of this reaction.

4. A 5.0 L tank holds 13 atm of propane ( $C_3H_8$ ) at  $10^\circ C$ . What volume of  $O_2$  at  $10^\circ C$  & 103 kPa will be required to react with all of the propane?
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  $C_3H_5(NO_3)_3$ .
- 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  $220^\circ C$ ?

# Answers



# L O<sub>2</sub> =

15 g CH <sub>3</sub> OH	1 mol CH <sub>3</sub> OH	3 mol O <sub>2</sub>	22.4 L O <sub>2</sub>
	32.05 g CH <sub>3</sub> OH	2 mol CH <sub>3</sub> OH	1 mol O <sub>2</sub>

= 15.7 L O<sub>2</sub>



$$\# \text{ mol Cl}_2 = \frac{105 \text{ g Na}}{22.99 \text{ g Na}} \times \frac{1 \text{ mol Na}}{2 \text{ mol Na}} \times \frac{1 \text{ mol Cl}_2}{1 \text{ mol Cl}_2} = 2.284 \text{ mol Cl}_2$$

$$PV = nRT \quad P = 100 \text{ kPa}, \quad n = 2.284 \text{ mol}, \quad T = 1073 \text{ K}$$

$$\frac{(2.284 \text{ mol})(8.31)(1073 \text{ K})}{(100 \text{ kPa})} = V = 204 \text{ L Cl}_2$$



# g	20 L O <sub>2</sub>	1 mol O <sub>2</sub>	1 mol C <sub>3</sub> H <sub>8</sub>	44.11 g C <sub>3</sub> H <sub>8</sub>
C <sub>3</sub> H <sub>8</sub> =		24.8 L O <sub>2</sub>	5 mol O <sub>2</sub>	1 mol C <sub>3</sub> H <sub>8</sub> = 7.1 g C <sub>3</sub> H <sub>8</sub>



$$PV = nRT \quad n = \frac{(1317 \text{ kPa})(5.0 \text{ L})}{(8.31)(283 \text{ K})} = 2.8 \text{ mol C}_3\text{H}_8$$

# mol O <sub>2</sub> =	2.8 mol C <sub>3</sub> H <sub>8</sub>	5 mol O <sub>2</sub>	= 14 mol O <sub>2</sub>
		1 mol C <sub>3</sub> H <sub>8</sub>	

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

$$\frac{(14 \text{ mol})(8.31)(283 \text{ K})}{(103 \text{ kPa})} = V = 320 \text{ L O}_2$$

$$5) \text{ \# mol C}_3\text{H}_5(\text{NO}_3)_3 = 100 \text{ g C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{1 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3}{227.11 \text{ g C}_3\text{H}_5(\text{NO}_3)_3} = 0.4403 \text{ mol}$$

$$\text{\# L CO}_2 = 0.4403 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{12 \text{ mol CO}_2}{4 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 29.6 \text{ L CO}_2$$

$$\text{\# L N}_2 = 0.4403 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{6 \text{ mol N}_2}{4 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 14.8 \text{ L N}_2$$

$$\text{\# L H}_2\text{O} = 0.4403 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{10 \text{ mol H}_2\text{O}}{4 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 24.7 \text{ L H}_2\text{O}$$

$$\text{\# L O}_2 = 0.4403 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{1 \text{ mol O}_2}{4 \text{ mol C}_3\text{H}_5(\text{NO}_3)_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 2.47 \text{ L O}_2$$

5. # mol  $\text{C}_3\text{H}_5(\text{NO}_3)_3 =$

$$200 \text{ g } \text{C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{1 \text{ mol } \text{C}_3\text{H}_5(\text{NO}_3)_3}{227.11 \text{ g } \text{C}_3\text{H}_5(\text{NO}_3)_3} = 0.8806 \text{ mol}$$

# mol all gases =

$$0.8806 \text{ mol } \text{C}_3\text{H}_5(\text{NO}_3)_3 \times \frac{29 \text{ mol gases}}{4 \text{ mol } \text{C}_3\text{H}_5(\text{NO}_3)_3} = 6.385 \text{ mol all gases}$$

$$PV = nRT \quad V = 50 \text{ L}, \quad n = 6.385 \text{ mol}, \quad T = 493 \text{ K}$$

$$\frac{(6.385 \text{ mol})(8.31)(493 \text{ K})}{(50 \text{ L})} = P = 523 \text{ kPa}$$