

### Sample problem 1

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

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



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

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

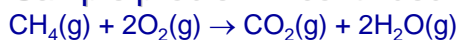
$$\# \text{ mol O}_2 = 0.167 \text{ mol CH}_4 \times \frac{2 \text{ mol O}_2}{1 \text{ mol CH}_4} = 0.334 \text{ mol}$$

$$PV = nRT \quad P = 100 \text{ kPa}, n = 0.334 \text{ mol}, T = 298 \text{ K}$$

$$\frac{(0.334 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(298 \text{ K})}{(100 \text{ kPa})} = V = 8.28 \text{ L}$$

$$\text{or } \# \text{ L} = 0.334 \text{ mol} \times 24.8 \text{ L/mol} = 8.28 \text{ L}$$

### Sample problem 1 continued



b) How many grams of H<sub>2</sub>O(g) are produced?

$$\# \text{ g H}_2\text{O} = 0.334 \text{ mol O}_2 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 6.02 \text{ g H}_2\text{O}$$

c) What volume of CO<sub>2</sub> (at STP) is produced if only 2.15 g of the CH<sub>4</sub> was burned?

$$\# \text{ mol CO}_2 = 2.15 \text{ g CH}_4 \times \frac{1 \text{ mol CH}_4}{16.05 \text{ g CH}_4} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol CH}_4} = 0.134 \text{ mol CO}_2$$

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

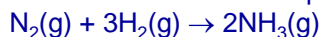
$$\frac{(0.134 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})}{(101.3 \text{ kPa})} = V = 3.00 \text{ L CO}_2$$

$$\text{or } \# \text{ L} = 0.134 \text{ mol} \times 22.4 \text{ L/mol} = 3.00 \text{ L}$$

### 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 7.5 kg hydrogen?

First we need a balanced equation:



$$\# \text{ mol NH}_3 = 7500 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.02 \text{ g H}_2} \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} = 2475 \text{ mol}$$

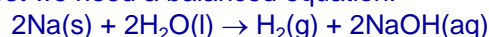
$$PV = nRT \quad P = 450 \text{ kPa}, n = 2475 \text{ mol}, T = 353 \text{ K}$$

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

### 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?

First we need a balanced equation:



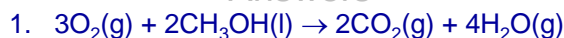
$$PV = nRT \quad P = 101.3 \text{ kPa}, V = 20.0 \text{ L}, T = 273 \text{ K}$$

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

$$\text{or } \# \text{ mol} = 20.0 \text{ L} \times 1 \text{ mol} / 22.4 \text{ L} = 0.893 \text{ mol}$$

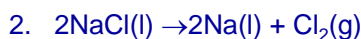
$$\# \text{ g Na} = 0.893 \text{ mol H}_2 \times \frac{2 \text{ mol Na}}{1 \text{ mol H}_2} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 41.1 \text{ g Na}$$

### Answers



$$\# \text{ L O}_2 =$$

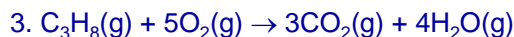
$$15 \text{ g CH}_3\text{OH} \times \frac{1 \text{ mol CH}_3\text{OH}}{32.05 \text{ g CH}_3\text{OH}} \times \frac{3 \text{ mol O}_2}{2 \text{ mol CH}_3\text{OH}} \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2} = 15.7 \text{ L O}_2$$



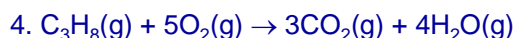
$$\# \text{ mol Cl}_2 = 105 \text{ g Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g Na}} \times \frac{1 \text{ mol Cl}_2}{2 \text{ mol Na}} = 2.284 \text{ mol Cl}_2$$

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

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



$$\# \text{ g C}_3\text{H}_8 = 20 \text{ L O}_2 \times \frac{1 \text{ mol O}_2}{24.8 \text{ L O}_2} \times \frac{1 \text{ mol C}_3\text{H}_8}{5 \text{ mol O}_2} \times \frac{44.11 \text{ g C}_3\text{H}_8}{1 \text{ mol C}_3\text{H}_8} = 7.1 \text{ g C}_3\text{H}_8$$



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

$$\# \text{ mol O}_2 = 2.8 \text{ mol C}_3\text{H}_8 \times \frac{5 \text{ mol O}_2}{1 \text{ mol C}_3\text{H}_8} = 14 \text{ mol O}_2$$

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

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

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

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

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

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

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

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

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

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

$$\# \text{ mol all gases} =$$

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

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

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