**FUNDAMENTALS OF INDUSTRIAL HYGIENE, 6TH ED.**

**HOMEWORK #3**

**INDIVIDUAL SIMPLE AND IDEAL GAS LAWS**

**Name: KEY *40 pts. possible***

**EXERCISES:** Perform the calculations identified below. Show your work neatly and clearly in a manner similar to the examples provided above (i.e., write the formula, define each variable in the formula, show steps of your calculations, identify any conversion factors used).

After calculating each step, round the answer to the nearest tenth before proceeding to the next step’s calculation.

**Part I: Calculation of Volume**

A DOT 3AA-2265 high-pressure cylinder is used to store nitrogen (N2).

The tank measures 7 inches (18 centimeters) in diameter and 43 inches (109 centimeters) high.

Calculate the volume of the cylinder (*in liters*). *(7 points)*

Formula: ***V = πr2h***

where: ***V* = volume (in liters)**

 ***π* = 3.14**

 ***r* = radius of cylinder (in centimeters)**

 ***h* = height of cylinder (in centimeters)**

Calculations:

$$V=3.14  \left(9 cm  9 cm\right)  109 cm$$

$$V=3.14  81 cm^{2}  109 cm$$

$$V=3.14  8829 cm^{3}$$

$$V=27723.1 cm^{3}$$

Conversion: 1000 *cm*3 = 1.0 *L*

$$V=27723.1 cm^{3}  \left(\frac{1.0 L}{1000 cm^{3}}\right) $$

$$V= \frac{27723.1 cm^{3}  L}{1000 cm^{3}} $$

$$V= 27.7 L$$

**Part II: Calculation of Weight**

What is the weight (*in pounds*) of the gas in the cylinder if it were filled with 185 moles of nitrogen?

*(5 points)*

Atomic weight of nitrogen = **14.00**

However, free nitrogen consists of a diatomic molecule (N2).

Therefore, the weight of one mole of N2 is: $N\_{2}=14.00  2=28.00$ ***grams***

The weight of gas in the cylinder is: (show work)

$$185 mol  \frac{28 g}{1 mol} = \frac{185 mol  28 g}{mol} = 5180 g$$

Conversion #1 *(grams to ounces)*: 28.35 *g* = 1 *oz*

$$Weight= 5180 g  \frac{1 oz}{28.35 g} = \frac{5180 g  oz}{28.35 g} = 182.7 oz$$

Conversion #2 *(ounces to pounds)*: 1 *lb* = 16 *oz*

$$Weight= 182.7 oz  \frac{1 lb}{16 oz} = \frac{182.7 oz  lb}{16 oz} = 11.4 lb$$

**Part III: Calculation of Pressure**

Calculate the internal pressure (*in psi*) if the cylinder had been filled at 65 °*F*. *(9 points)*

Formula:***PV = nRT***

where: ***P* = *unknown***

 ***V* = 27.7 *L***

 ***n* = 185 *mol***

 ***R* = 0.08206 *atm****** L/mol*** ** ***°K***

***T* = [5/9**  **(65 - 32) + 273] = [5/9 (33) + 273] = [18.3 + 273] = 291.3 °*K***

Calculations:

$$P  27.7 L=185 mol  \frac{0.08206 atm  L}{mol  °K}  291.3 °K$$

$$P  27.7 L= \frac{185 mol  0.08206 atm  L  291.3 °K}{mol  °K}$$

$$P  27.7 L= 185  0.8206 atm  L  291.3$$

$$P  27.7 L= 4422.3 atm  L$$

$$P= \frac{4423.3 atm  L}{27.7 L}$$

$$P = 159.7 atm$$

Note: The standard weight of the atmosphere (*atm*), or air pressure, at sea level is equivalent to 760 *mmHg* (22.9 *inHg*) or 14.7 *psi*.

Conversion: **1 *atm* = 14.7 *psi***

Pressure = $159.7 atm  \frac{14.7 psi}{atm}= 2347.6 psi$

**Part IV:**

Determine the test pressure (*in psi*) for this tank (Note: The rated service pressure is 2265 *psi*). *(2 points)*

Test pressure equals **1.67** X rated service pressure.

Calculation: **2265  1.67 = 3783 *psi***

Do you have any concerns about having this cylinder in your facility or on your job site? Why or why not?

*(1 point)*

***Yes. It is already over its rated service pressure.***

**Part V: Recalculation of Pressure**

Recalculate the internal pressure (*in psi*) if the cylinder becomes heated to 110 °*F*. *(7 points)*

Formula: $\frac{P\_{1}V\_{1}}{T\_{1}}= \frac{P\_{2}V\_{2}}{T\_{2}}$

where: ***P*1 = 2347.6 *psi***

***V*1 = 27.7 *L***

***T*1 = 291.3 °*K***

***P*2 = *unknown***

***V*2 = 27.7 *L***

***T*2 = [5/9**  **(110 - 32) + 273] = [5/9  (78) + 273] = [43.3 + 273] = 316.3 °*K***

$$\frac{2347.6 psi  27.7 L}{291.3 °K}= \frac{ P\_{2} 27.7 L}{316.3 °K}$$

$$\frac{2347.6 psi  27.7 L  316.3 °K}{291.3 °K}= P\_{2}  27.7 L$$

$$\frac{2347.6 psi  27.7 L  316.3}{291.3 27.7 L}= P\_{2} $$

$$\frac{742546.9 psi}{291.3}= P\_{2} $$

$$2549.1 psi = P\_{2} $$

***‘or’***

*Formula:*  ***PV = nRT***

where: ***P* = *unknown***

***V* = 27.7 *L***

***n* = 185 *mol***

***R* = 0.08206 *atm  L/mol  °K***

***T* = [5/9**  **(110 - 32) + 273] = [5/9**  **(78) + 273] = [43.3 + 273] = 316.3 °*K***

$$P  27.7 L=185 mol  \frac{0.08206 atm  L}{mol  °K}  316.3 °K$$

$$P  27.7 L= \frac{185 mol  0.08206 atm  L  316.3 °K}{mol  °K}$$

$$P  27.7 L= 185  0.08206 atm  L  316$$

$$P  27.7 L= 4797.2 atm  L$$

$$P= \frac{4797.2 atm  L}{27.7 L}$$

$P = 173.2 atm$

$$P= 173.2 atm  \frac{14.7 psi}{1 atm} = \frac{173.2 atm  14.7 psi}{atm} = 2546.0 psi$$

**Part VI: Calculation of Moles**

DOT regulations prohibit filling a tank more than its rated service pressure at 70 °*F*.

a) What is the maximum number of moles of nitrogen that can be placed in the cylinder at this temperature and not exceed DOT regulations? *(7 points)*

Formula:***PV = nRT***

where: ***P* = 2265 *psi* =** $[2265 psi  \frac{1 atm}{14.7 psi}=154 atm]$

***V* = 27.7 *L***

***n* = *unknown***

***R* = 0.08206 *atm  L/mol*** ** ***°K***

***T* = [5/9  (70 - 32) + 273] = [5/9  (38) + 273] = [21.1 + 273] = 294.1 °*K***

$$154 atm  27.7 L= n  \frac{0.08206 atm  L}{mol  °K}  294.1 °K$$

$$4265.8 atm  L = n  \frac{0.08206 atm  L  294.1 °K}{mol  °K} $$

$$4265.8 atm  L = n  \frac{24.1 atm  L }{mol} $$

$$4265.8 atm  L  \frac{mol }{24.1 atm  L} = n $$

$$\frac{4265.8 atm  L  mol }{24.1 atm  L} = n$$

$$\frac{4265.8 mol }{24.1} = n$$

$$177 mol= n$$

b) What is the maximum weight (*in pounds*) of nitrogen that can be placed in the cylinder at this temperature and not exceed DOT regulations? *(2 points)*

$$Weight= 177 mol  \frac{28 g}{1 mol} = \frac{177 mol  28 g}{mol} = 4956 g$$

Conversion #1*(grams to ounces)*: 28.35 *g* = 1 *oz*

$$Weight= 4956 g  \frac{1 oz}{28.35 g} =\frac{ 4956 g  oz}{28.35 g} = 174.8 oz$$

Conversion #2 *(ounces to pounds)*: 1 *lb* = 16 *oz*

$$Weight= 174.8 oz  \frac{1 lb}{16 oz} = \frac{174.8 oz  lb}{16 oz} = 10.9 lb$$