Dalton's Law with Stoichiometry

Name:
Period: Key

Another way to power a rocket is using a chemical that will decompose to release heat and gases. One very common way to power rockets is the use of hydrazine, N_2H_4, hydrazine will decompose to nitrogen and hydrogen gas when exposed to a catalyst according the the reaction given below:

$$N_2H_{4(l)} \longrightarrow N_{2(g)} + 2H_{2(g)}$$

The reaction releases large quantities of heat and the reaction chamber will frequently reach 800.°C very quickly. Liquid hydrazine has a density of 1.02 g/mL.

1-A) A rockets combustion chamber has a volume of 10.5L, during a test of the chamber 15.00mL of liquid hydrazine is pumped into the initially empty chamber and decomposes.

i) What would be the pressure of the nitrogen gas in the chamber after the reaction?

$$15.00\text{mL} \cdot \frac{1.02\text{g}}{1\text{mL}} \cdot \frac{1\text{mol}}{32.05\text{g}} \cdot \frac{1\text{mol } N_2}{1\text{mol}} = 0.477\text{mol } N_2$$

$$P = \frac{0.477\text{mol} \cdot 0.0821 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} \cdot 1073\text{K}}{10.5\text{L}} = 4.00\text{atm } N_2$$

ii) What would be the pressure of the hydrogen gas in the chamber after the reaction?

$$4.00\text{atm } N_2 \cdot \frac{2H_2}{1N_2} = 8.00\text{atm } H_2$$

iii) What would be the total pressure in the chamber after the reaction?

$$P_T = P_{H_2} + P_{N_2} = 8 + 4 = 12.00\text{atm}$$

1-B) The chamber where the hydrazine reacts is connected to another second pressure vessel with a volume of 5.5L. The second vessel contains oxygen gas at a pressure of 16.0 atm at 800°C. After the reaction in part A has finished happening the valve connecting the two tanks is opened.

i) What would be the pressure of oxygen gas after the valve has been opened?

$$P_1V_1 = P_2V_2 \qquad 16.0\text{atm} \cdot 5.5\text{L} = P_2 \cdot 16.0\text{L} \qquad P_{O_2} = 5.5\text{atm}$$

ii) What would be the pressure of hydrogen gas after the valve has been opened?

$$8.00\text{atm} \cdot 10.5\text{L} = P_{H_2} \cdot 16.0\text{L} \qquad P_{H_2} = 5.25\text{atm}$$

iii) What would be the pressure of nitrogen gas after the valve has been opened?

$$4.00\text{atm} \cdot 10.5\text{L} = P_{N_2} \cdot 16.0\text{L} \qquad P_{N_2} = 2.63\text{atm}$$

1-C) At the temperates in the container the hydrogen and oxygen gas will react to produce water vapor. This reaction releases heat and raises the temperature to 950.°C

i) Write a balanced chemical equation for the reaction.

$2H_2 + O_2 \rightarrow 2H_2O$

ii) What is the limiting reactant for the reaction between the hydrogen gas and oxygen gas?

5.25 atm H_2 5.5 atm O_2

$5.25\text{ atm } H_2 \cdot \frac{1 O_2}{2 H_2} = 2.625\text{ atm } O_2$ needed to use all the H_2 so H_2 is limiting

iii) What will be the pressure of water vapor after the hydrogen and oxygen have reacted?

$5.25\text{ atm } H_2 = 0.954\text{ mol } H_2$

$0.954\text{ mol } H_2 \cdot \frac{1 H_2O}{1 H_2} = 0.954\text{ mol } H_2O$ but temp has changed

$\frac{5.25\text{ atm}}{1073} = \frac{P_{H_2O}}{1223}$ $\quad P_{H_2O} = 5.98\text{ atm}$

iv) What will be the new total pressure in the containers after the hydrogen gas and oxygen gas have reacted?

$P_{Total} = P_{H_2O} + P_{O_2} + P_{N_2} = 5.98\text{ atm} + 3.28\text{ atm} + 3.00\text{ atm}$

$P_T = 12.26\text{ atm}$

$P_{O_2} = 5.5\text{ atm} - 2.625\text{ atm}$

$= 2.875\text{ atm}$ @ 800°C

$\frac{2.875\text{ atm}}{1073} = \frac{P_{O_2}}{1223}$

$P_{O_2} = 3.28\text{ atm}$

$\frac{2.63\text{ atm } N_2}{1073} = \frac{P_{N_2}}{1223}$

$P_{N_2} = 3.00\text{ atm}$