Stoichiometry and Gas Laws

Calculate the number of liters of nitrogen gas that will be produced from the complete decomposition of 1.03 liters of nitroglycerin. The products for this reaction are carbon dioxide gas, nitrogen gas, oxygen gas and water vapor.

Given:

T = 4°C
P = 97.5 kPa
Density of nitroglycerin = 1.43 g/mL

METHOD 1: Use $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ to calculate the answer.

Step 1) Write a balanced chemical equation

$$\underset{1.03\ L}{4\ C_3H_5O_9N_3\ (l)} \rightarrow 12\ CO_2\ (g) + \underset{x\ L}{6\ N_2\ (g)} + O_2\ (g) + 10\ H_2O\ (g)$$

Step 2) Calculate the mass of nitroglycerin

$$x\ g\ C_3H_5O_9N_3 = 1.03\ L\ C_3H_5O_9N_3\left(\frac{1000\ mL}{1L}\right)\left(\frac{1.43\ g\ C_3H_5O_9N_3}{1mL\ C_3H_5O_9N_3}\right) = 1473\ g\ C_3H_5O_9N_3$$

Step 3) Calculate the volume of nitrogen gas (@ STP) using ideal stoichiometry.

$$x\ L\ N_2 = 1473\ g\ C_3H_5O_9N_3\left(\frac{1mol\ C_3H_5O_9N_3}{227\ g\ C_3H_5O_9N_3}\right)\left(\frac{6\ mol\ N_2}{4\ mol\ C_3H_5O_9N_3}\right)\left(\frac{22.4\ L\ N_2}{1mol\ N_2}\right) = 218\ L\ N_2\ @\ STP$$

Step 4) Calculate the volume the nitrogen gas would occupy under the specified conditions.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 101.3\ kPa$ $\quad V_1 = 218\ L$ $\quad T_1 = 273\ K$

$P_2 = 97.5\ kPa$ $\quad V_1 = ?\ L$ $\quad T_1 = 4^oC + 273 = 277\ K$

$$\frac{(101.3\ kPa)(218\ L)}{(273\ K)} = \frac{(97.5\ kPa)(V_2)}{(277\ K)}$$

$V_2 = 229.8\ L$

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METHOD 2: Use **PV = nRT** to calculate the answer.

Step 1) Write a balanced chemical equation

$$\underset{1.03\ L}{4\ C_3H_5O_9N_3\ (l)} \rightarrow 12\ CO_2\ (g) + \underset{x\ L}{6\ N_2\ (g)} + O_2\ (g) + 10\ H_2O\ (g)$$

Step 2) Calculate the moles of nitrogen gas produced.

$$x\ mol\ N_2 = 1473\ g\ C_3H_5O_9N_3\left(\frac{1\ mol\ C_3H_5O_9N_3}{227\ g\ C_3H_5O_9N_3}\right)\left(\frac{6\ mol\ N_2}{4\ mol\ C_3H_5O_9N_3}\right) = 9.73\ mol\ N_2$$

Step 3) Calculate the volume of the gas produced.

$$PV = nRT$$
$$\therefore V = \frac{nRT}{P}$$

$$P = 97.5\ kPa$$
$$T = 4^o\ C + 273 = 277\ K$$
$$R = 8.314\ kPa \cdot L/mol \cdot K$$
$$n = 9.73\ mol\ N_2$$
$$V = ?\ L$$

$$V = \frac{nRT}{P} \Rightarrow \frac{9.73\ mol\ N_2 \cdot 8.314\ kPa \cdot L/mol \cdot K \cdot 277\ K}{97.5\ kPa}$$

$$V = 229.8\ L\ N_2$$