Experiment 2

MOLAR VOLUME OF NITROGEN GAS

Objective

The purpose of this experiment is to determine the molar volume of nitrogen gas under standard temperature and pressure (STP), by utilizing the reaction between sulfamic acid and sodium nitrite and the ideal gas law.

Lab techniques

- Weighing chemicals.
- Measuring volume, pressure, and temperature.

Introduction

A mole of substance refers to an amount containing 6.02×10^{23} of the smallest particles of that substance, including atoms, ions or molecules. One mole of hydrogen gas and one mole of nitrogen gas each contain 6.02×10^{23} molecules, but different molar mass, i.e. 2.016 g and 28.02 g, respectively.

The term molar volume refers to the volume occupied by one mole of a given substance. For an ideal gas at STP (0^oC and 1 atm), the molar volume is 22.414 L. Although hydrogen and nitrogen are non-ideal gases, their molar volumes at STP are very close to this value.

In this experiment, we are going to produce nitrogen gas by reacting a known amount of sulfamic acid (H_2NSO_3H), here as a limiting reagent, with an excess amount of sodium nitrite ($NaNO_2$) as shown in equation 2-1.

$$NO_2^-(aq) + H_2NSO_3H(s) \rightarrow HSO_4^-(aq) + H_2O(l) + N_2(g) \qquad (2\text{-}1)$$

Using the number of moles of the nitrogen produced (n_1), temperature (T_1), pressure (P_1), and volume (V_1), and the ideal gas equation (PV = nRT), we can determine the molar volume of nitrogen gas at STP (V_{STP}).

$$\frac{1\,(\text{atm}) \times V_{STP}\,(\text{L})}{1\,(\text{mol}) \times 273.15\,(\text{K})} = \frac{P_{N_2} \times (V + \Delta V)}{n_1 \times T_1} = \frac{(P_{atm} - P_{H_2O}) \times \Delta V}{n_1 \times T_1} \qquad (2\text{-}2)$$

Apparatus

Erlenmeyer flask (250 mL), beaker (400 mL), small glass test tube (7.5 cm × 1.2 cm), graduated cylinder (50 mL), Florence flask (500 mL), tweezers, electronic balance, analytical balance, and thermometer.

Chemicals

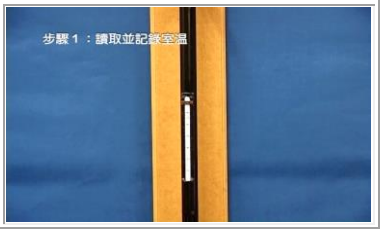
Sulfamic acid, H_2NSO_3H
Sodium nitrite, $NaNO_2$

Procedure

★ Demo video: http://www.youtube.com/user/ntuchemistrylab

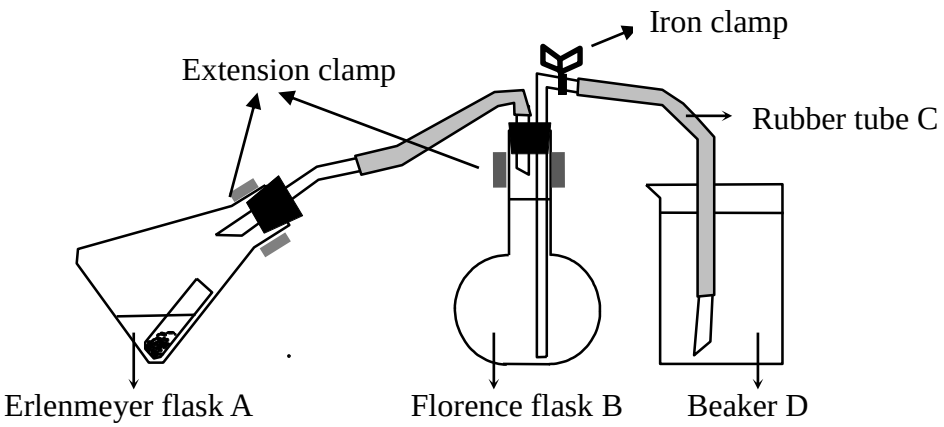
	Procedure	Illustration
1.	Wash and oven dry two small test tubes and allow them to cool to room temperature. Measure and record the accurate weight of one of the tubes. Note: Refer to the experimental skills videos to learn how to weigh chemicals.	
2.	Carefully measure 1~1.1 g of H_2NSO_3H and carefully transfer into the small test tube. Measure and record its accurate weight.	
3.	Weigh about 1~1.1 g of $NaNO_2$ accurately and record its accurate weight. Pour the weighed $NaNO_2$ to the 250 mL flask and add 50 mL of DI water to dissolve it. Note: Refer to the experimental skills videos to learn how to use a graduated cylinder.	
4.	(1) Fill flask B and 400 mL beaker D with water, up to the level as shown in Fig. 2-1(a). (2) Fill rubber tube C with water, clamp it with a iron clamp, and then connect all apparatus according to the diagram. Carefully adjust the glass tube in flask B such that the end of the longer pipe nearly touches the bottom of the flask.	

	Note 1: To fill rubber tube C with water, bring one end of the tube under the faucet until water flows freely from the other end; then clamp it tightly with the iron clamp. Note 2: While adjusting the height of the glass tube, wrap a piece of dishcloth around it, and adjust its height by rotating it. Do this gently to avoid breaking the glass and causing injury.	
5.	Loosen the clamp to make sure that the rubber tube is completely filled with water and the water can flow freely from flask B to beaker D while adjusting the height of beaker D. Then tighten the clamp again.	
6.	With a pair of tweezers, carefully position the small test tube at the bottom of the tilted flask A (Fig. 2-1(a)). After the small test tube is positioned securely, stopper flask A tightly. Caution: The tube must not topple; if it does, $NaNO_2$ will immediately react with H_2NSO_3H. Should this happen, wash the flask and tube with plenty of water and repeat the procedure. You may practice how to position the test tube into the flask safely with empty tube.	 
7.	(1) Loosen the iron clamp and adjust the height of beaker D such that the water levels in beaker D and flask B are equal to balance the pressure of the reaction system in flasks A and B to the atmospheric pressure. (2) When this balance is achieved, tighten the clamp and discard the water in the beaker. (3) Measure and record the weight of empty beaker. Note: Gently rotate rubber stoppers for ca. 15° to make sure it is tightly sealed.	 

8.	(1) Loosen and position flask A on the table such that the small test tube topples, thus allowing the $NaNO_2$ solution in flask A to enter the tube and react with the H_2NSO_3H in it. Do not shake the flask to avoid reacting too fast. (2) Effervescence will be observed. Loosen the clamp on rubber tube C, at the same time allowing water to flow out freely. (3) Swirl flask A gently until the reaction is complete and no more gas is produced. Keep the rubber tube underneath the water in the beaker all the time. (4) The reaction in this experiment is exothermic. Cool flask A in a water bath. Note: This reaction has a side reaction producing toxic reddish-brown NO_2 gas.	  
9.	After flask A cools to room temperature, adjust the height of beaker D or flask B until the water levels are equal. At this time, the internal pressure of the reaction system is equal to the atmospheric pressure. Tighten the iron clamp. Note: The calculation of experimental data is premised on keeping temperature and pressure constant before and after the reaction. Hence, the temperature must return to room temperature before the pressure is adjusted.	
10.	Measure the volume of water collected in beaker D by weighing method.	
11.	Measure and record the corresponding room temperature and atmospheric pressure.	

12.	After the experiment, pour off the reacted solution and rinse the glassware immediately to avoid the NO_2 evolved.	

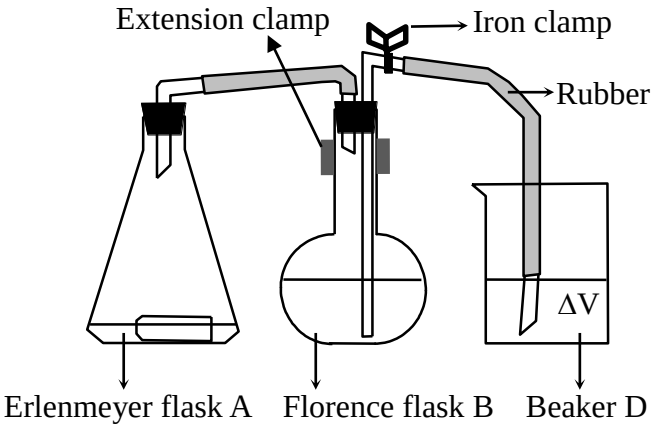
(a) Initial setup



Internal system before reaction:
- Volume of gas: V
- Temperature of gas: T_1
- Pressure of gas: P_{atm}

$P_{atm} = P_{air} + P_{H_2O}$

(b) Final state



Internal system after reaction:
- Volume of gas: V + ΔV
- Temperature of gas: T_1
- Pressure of gas: P_{atm}

$P_{atm} = P_{N_2} + P'_{air} + P_{H_2O}$

Figure 2-1 The apparatus for determining molar volume of nitrogen