The Molar Volume of Nitrogen Gas

Last revised: 2024/09/08

Preparation

- Put on your lab coat and safety goggles
- Turn off your mobile phone
- Place your backpack in the drawer or the cabinet
- Put your prelab on the lab bench (hold it down with something heavy) for ATA to sign

Collect the following items

- ❑ Two small test tubes (to be distributed by TA)
- ❑ An iron stand, two three-prong clamps
- ❑ 250 mL Erlenmeyer flask, 500 mL Florence flask, a rubber stopper with rubber tube and glass tube

Objective and Principles

- **Objective:** Using the ideal gas law to deduce the molar volume of nitrogen gas at STP

- **Lab techniques:**
  - Using an electronic balance to weigh chemicals
  - Measuring volume, pressure, and temperature

- **Definitions:**
  - Molar volume: the volume of a mole of substance
  - STP (standard temperature and pressure): 0 °C, 1 atm
  - For ideal gas, molar volume = 22.414 L at STP

Nitrogen-Producing Reaction

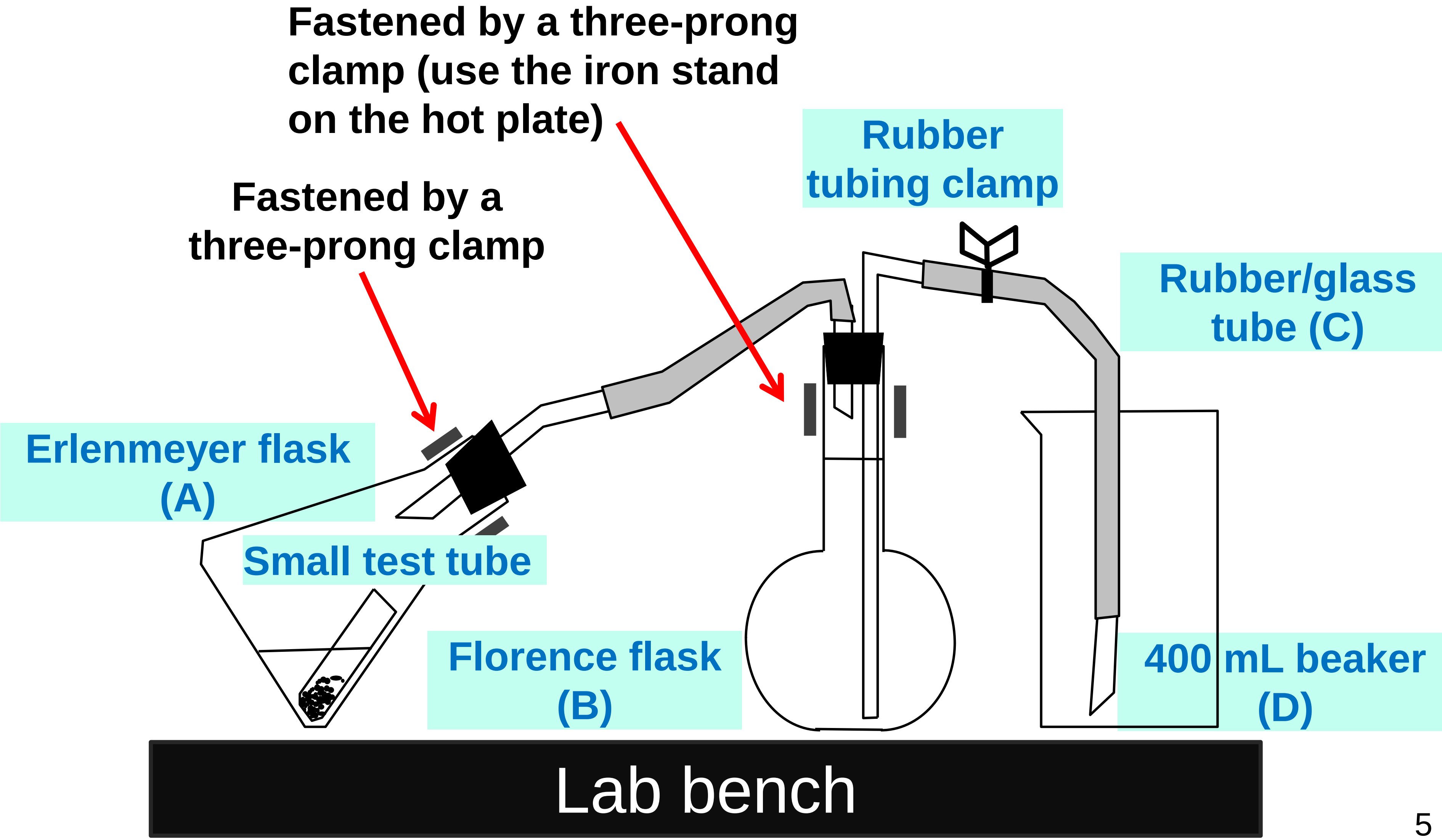
$$H_2NSO_3H(s) + NO_2^-(aq) \rightarrow HSO_4^-(aq) + H_2O(l) + N_2(g)$$

	$H_2NSO_3H(s)$	$NO_2^-(aq)$	$HSO_4^-(aq)$	$H_2O(l)$	$N_2(g)$
Initial:	**n_1**	n_2			
Change:	$-n_1$	$-n_1$	$+n_1$	$+n_1$	$+n_1$
Final:	0	n_2-n_1	n_1		**n_1**

$(n_2 > n_1)$

- Sulfamic acid (H_2NSO_3H, n_1 mole) being the limiting reagent
- Sodium nitrite ($NaNO_2$) being the excess reagent

Experimental Setup



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- Sulfamic acid (H_2NSO_3H, n_1 mole) being the limiting reagent
- Sodium nitrite ($NaNO_2$) being the excess reagent
- The molar volume of N_2 at 0°C and 1 atm, V_{STP}, can be related to the volume of N_2 (V_1) at room temperature (T_1) given the number of mole (n_1):

$$\frac{1(atm) \times V_{STP}(L)}{1(mol) \times 273.15(K)} = \frac{P_{N_2} \times V_1}{n_1 \times T_1} = \frac{(P_{atm} - P_{H_2O}) \times \Delta V}{n_1 \times T_1}$$

Mercury barometer (P_{atm})

Vapor pressure of water (P_{H_2O})

Volume of collected water (ΔV)

\# mole H_2NSO_3H (n_1)

Thermometer (T_1)

Step 1/6: Measuring Chemicals

- Measure roughly 1 g $NaNO_2$ and dissolve them with 50 mL DI water in the Erlenmeyer flask A
- Measure the weight of an empty small test tube **(W_1)** using an analytical balance
- Place roughly 1.0-1.1 g H_2NSO_3H into the small test tube, record the accurate weight **(W_2)**

✓ Use a small beaker to hold the test tube

✓ Only the weight difference ($W_2 – W_1$) matters

Step 1/6: Analytical Balance

Place a small beaker (container) on the weighing pan

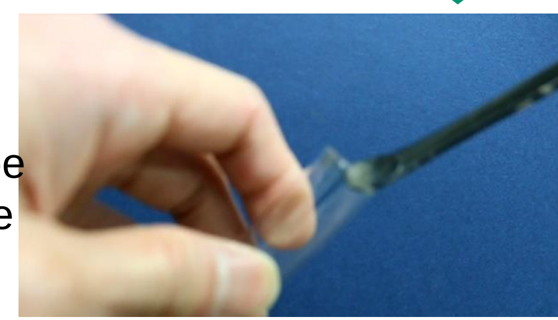
Close windshield & zeroing (**TARE**)

Display shows 0.0000 g
(Deduction of container's mass)

Place test tube in & close windshield

W_1: 7.5757 g
(Mass of small test tube)

Take out the small test tube



Use the skinny end of a spatula to put ~1 g of H_2NSO_3H (ca. 4 times) into the small test tube

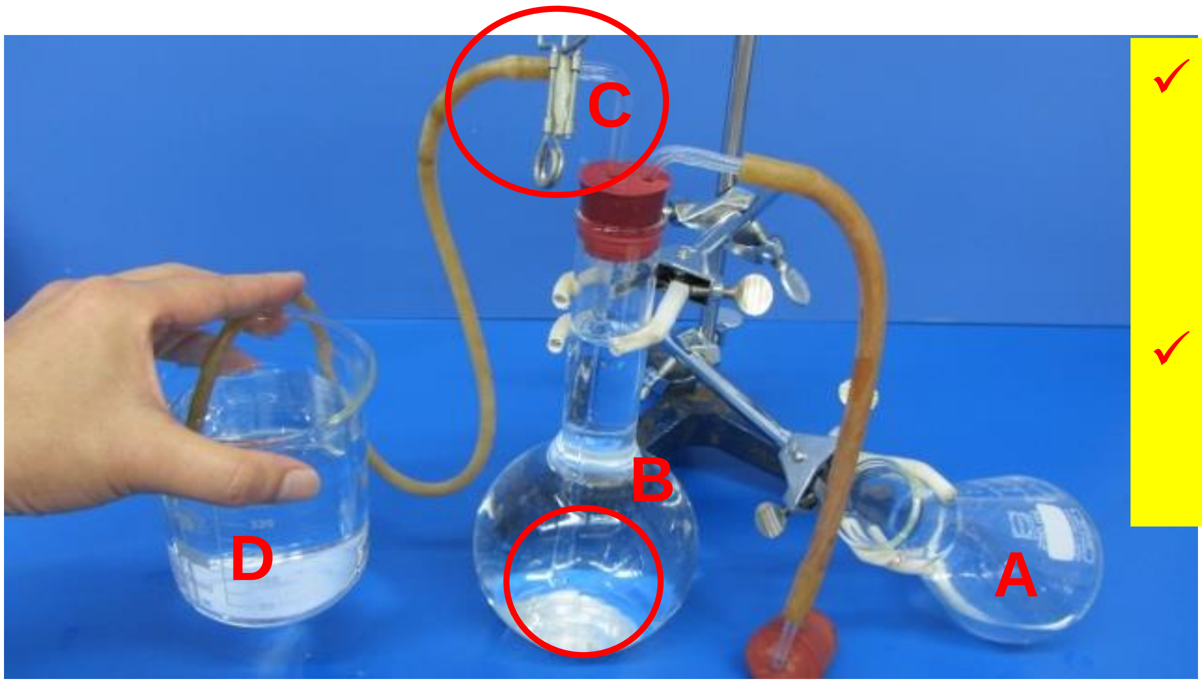
Place the test tube back in and close the windshield

W_2: 8.6202 g
(Mass of test tube and H_2NSO_3H)

Mass of H_2NSO_3H
$W_2 - W_1 = 1.0445$ g
(Five s.f.)

Step 2/6: Check the Water Flow

- Fill both the Florence flask B and the beaker D with water
- Fill the rubber/glass tube C with water, apply the tubing clamp
- Use the rubber/glass tube C to connect B and D
- Loosen the tubing clamp and check if the water can flow freely between the two containers; re-apply the tubing clamp

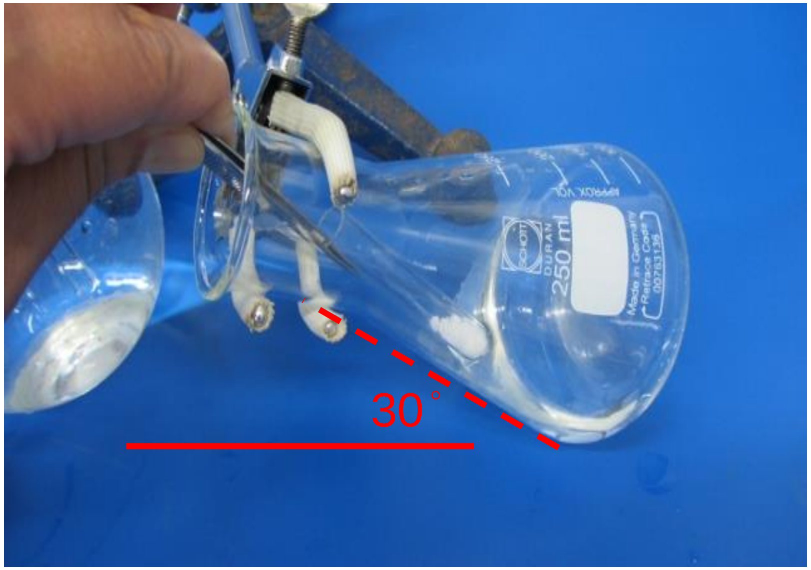


- ✓ The end of glass tube shaft should nearly touch the bottom of the Florence flask
- ✓ Check whether there are air bubbles in the rubber/glass tube

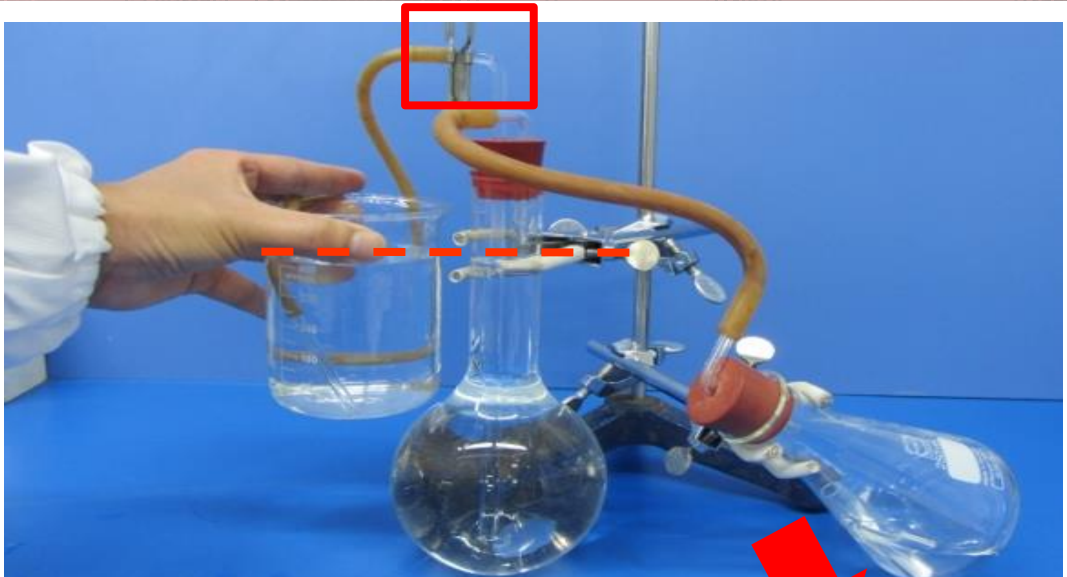
Step 3/6: Set up the Reaction Vessel

- Use a three-prong clamp to fix the Erlenmeyer flask A at a tilted angle
- Use a tweezer to place the test tube containing H_2NSO_3H at the bottom of Erlenmeyer flask A
- Install the rubber stopper onto the Erlenmeyer flask

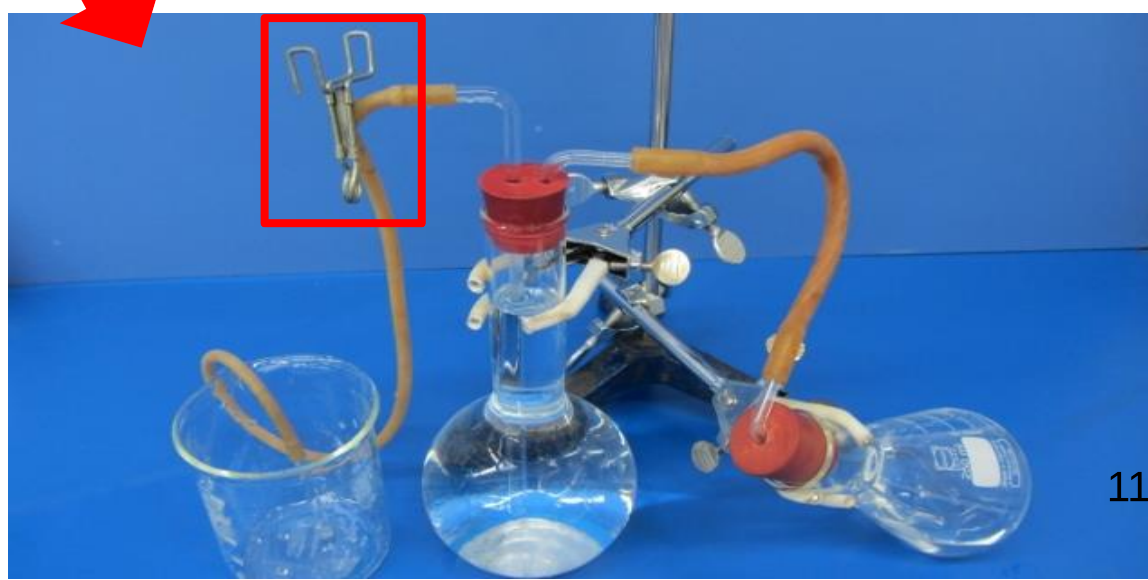
- ✓ The small test tube must not topple
- ✓ Once it does, $NaNO_2$ will immediately react with H_2NSO_3H
- ✓ Should this happen, wash the flask and tube with plenty of water and redo the procedure.



Step 4/6: Balance the Pressure

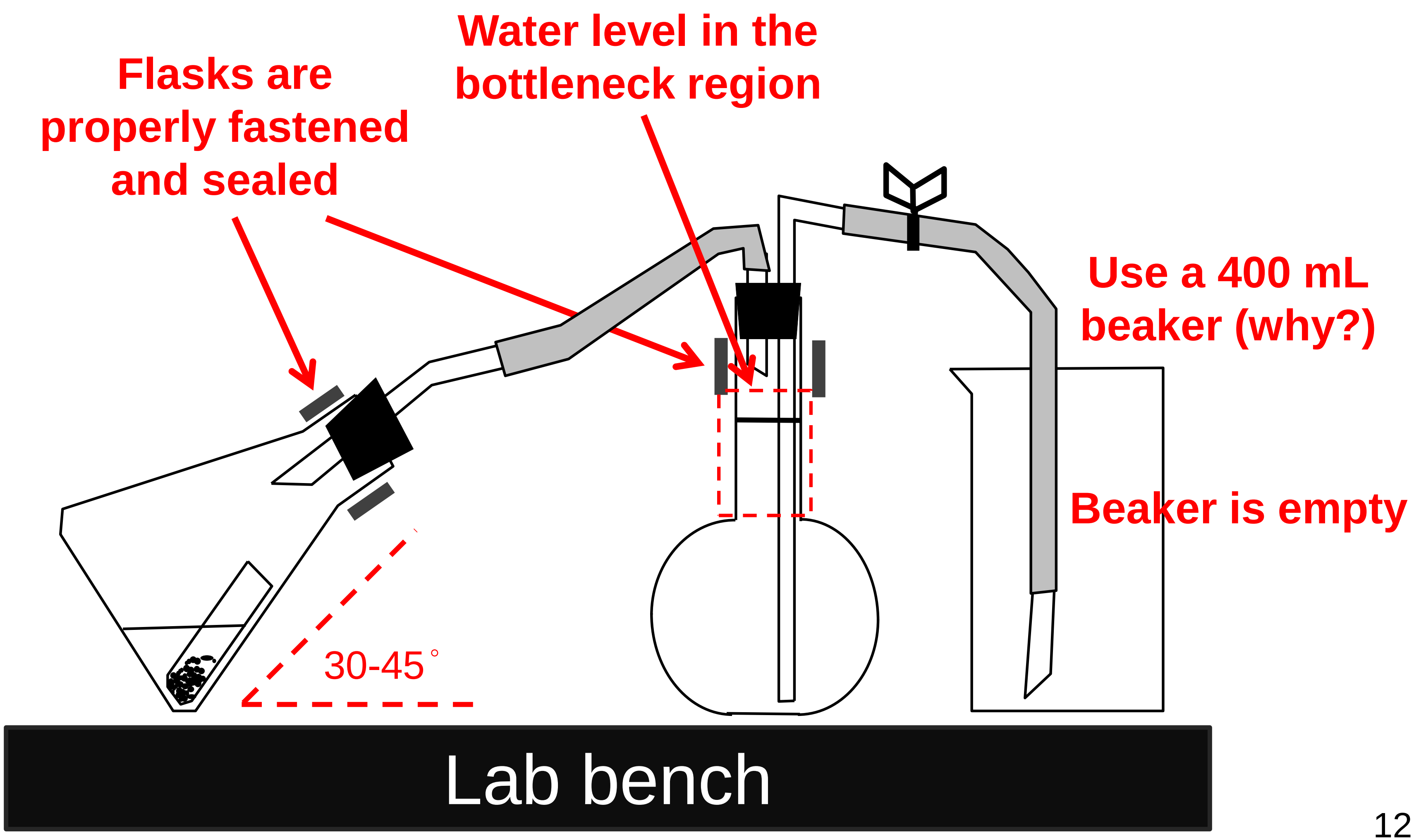


- Ensure all rubber stoppers are tightly fitted
- Loosen the tubing clamp and adjust the height of beaker D so that the water levels in flask & beaker are of the same height



- Tighten the tubing clamp and dispose all the remaining water in the beaker
- Measure the weight of the empty beaker

TA/ATA Check Your Setup

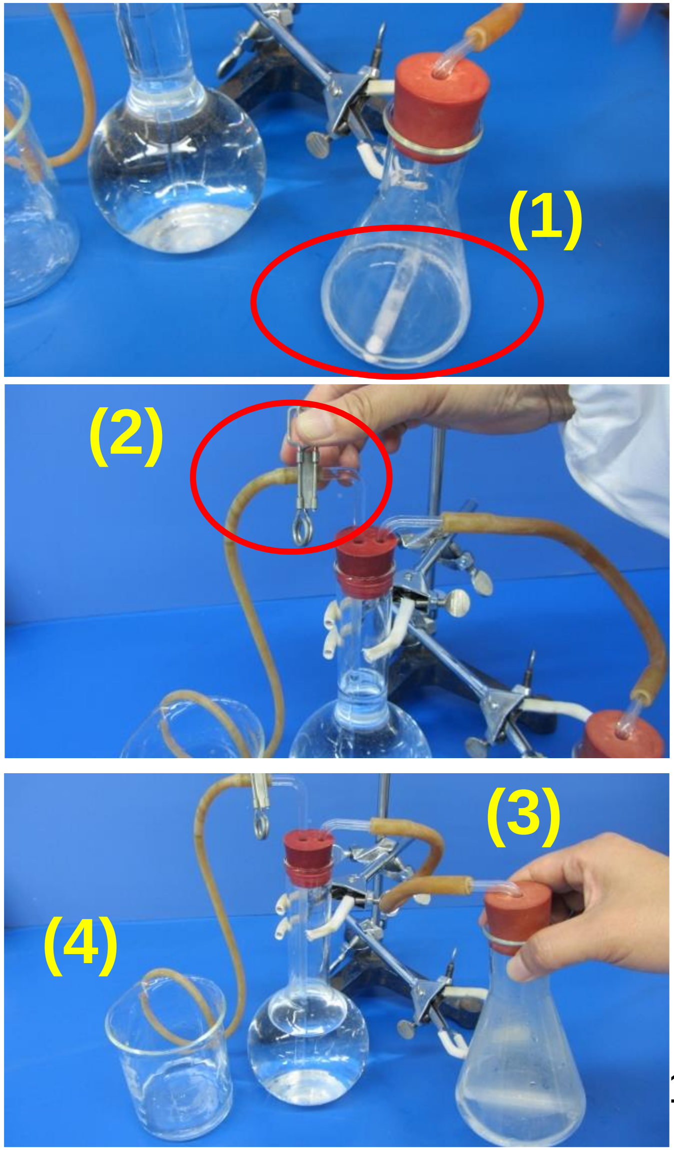


Step 5/6: Start Generating Nitrogen

1) Loosen the three-prong clamp on Erlenmeyer flask, straighten the flask, and let the chemicals mix
2) Once bubbles appear, loosen the tubing clamp quickly
3) Swirl the flask gently and observe the water flow until the reaction is complete and no more gas is produced

✓ Do not twist the rubber tube, and keep outlet of the rubber tube underneath the water in beaker all the time

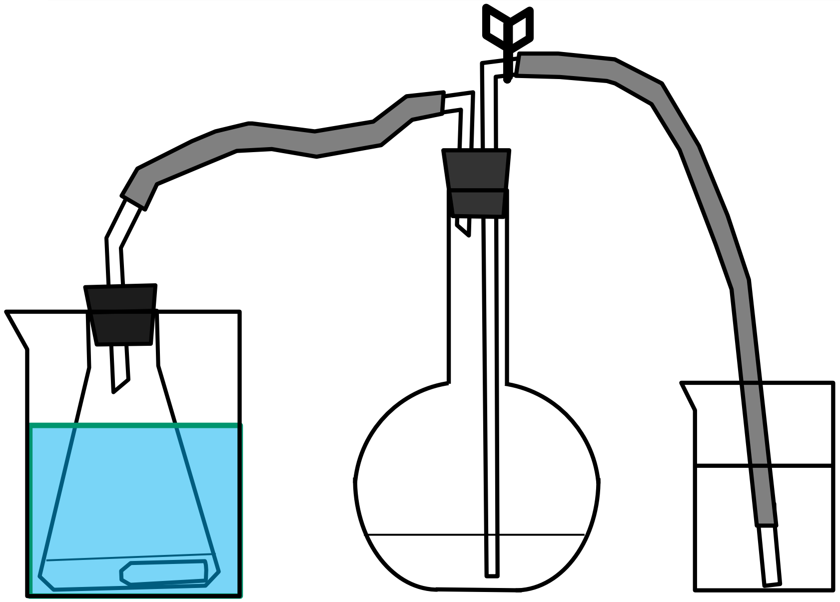
✓ Brown NO_2 gas may be produced via a side reaction



Step 6/6: Adjust Pressure and Temp

- Place the Erlenmeyer flask in a tap water bath to cool to room temp
- Adjust the height of the Florence flask so that the water levels in flask & beaker are at same height
- Tighten the tubing clamp
- Measure the weight of the beaker and water collected
- Record the room temp and pressure, P_{atm}
- Find vapor pressures of water, P_{H2O} from appendix

Keep the pressure and temperature of reacting system same as room temp and ambient pressure before and after reaction



1 L Beaker as water bath

$\Delta V > 250$ mL

Lab Note and Data Analysis

- Use ball pens and avoid correction tapes
- Record operations and raw data (value + units)
- Changes that can be observed:
  – The appearances of reactants and products
  – What happens as reactants mixed together?
  – The reaction rate, exo- or endothermic reaction, color change…..
- Data analysis

$$\frac{1(atm)\ \times\ V_{STP}(L)}{1(mol)\ \times\ 273.15(K)} = \frac{\left(P_{atm} - P_{H_2O}\right)\ \times\ \Delta V}{n_1\ \times\ T_1}$$

V_{STP} = ?

✓ Use the correct significant figures and units to show the answer
✓ T_1 in K
✓ P in atm

Clean-Up and Check-Out

- Brush clean and return the small test tubes
- Pour the solution waste directly into the drain
- Tuck the lab stools underneath the lab bench
- Clean up the lab bench and check personal equipment inventory (have an associate TA signed the check list)

- This is a **Brief Report** experiment:
  - Complete calculation using correct significant figures
  - Give a conclusion of your experiment
  - **Hand in prelab/lab note/report together to the TA**

- Groups on duty shall stay and help clean up the lab

Final Report (Brief Version)

- List the detailed calculations in the blank space (pay attention to unit conversion!)
- Conclusion: Use 1-2 sentences to summarize your experiment formally
- Need not answer the discussion questions in the report sheet (Q1 is the bonus question for the prelab)

Experiment 1

MOLAR VOLUME OF NITROGEN GAS

I. Experimental Data and Results (show all calculations)

1. Weight of small test tube (W_1) ______________
2. Weight of small test tube with H_2NSO_3H (W_2) ______________
3. Weight of H_2NSO_3H ($W_2 - W_1$) ______________
4. Weight of $NaNO_2$ ______________
5. Weight of empty beaker (W_3) ______________
6. Weight of beaker and water collected (W_4) ______________
7. Volume of water expelled (ΔV) ______________
8. Atmospheric pressure (P_{atm}) ______________
9. Room temperature (T) ______________
10. Vapor pressure of water at this temperature (P_{H_2O}) ______________
11. Number of moles of $NaNO_2$ ______________
12. Number of moles of H_2NSO_3H (n) ______________
13. Molar volume of nitrogen gas at STP (show your calculations):

(Refer to question 1)

$$\frac{1\ (\text{atm}) \times V_{STP}\ (\text{L})}{1\ (\text{mol}) \times 273.15\ (\text{K})} = \frac{P_{N_2} \times (V + \Delta V)}{n \times T} = \frac{(P_{atm} - P_{H_2O}) \times \Delta V}{n \times T}$$

T3.1 – Mercury Barometer

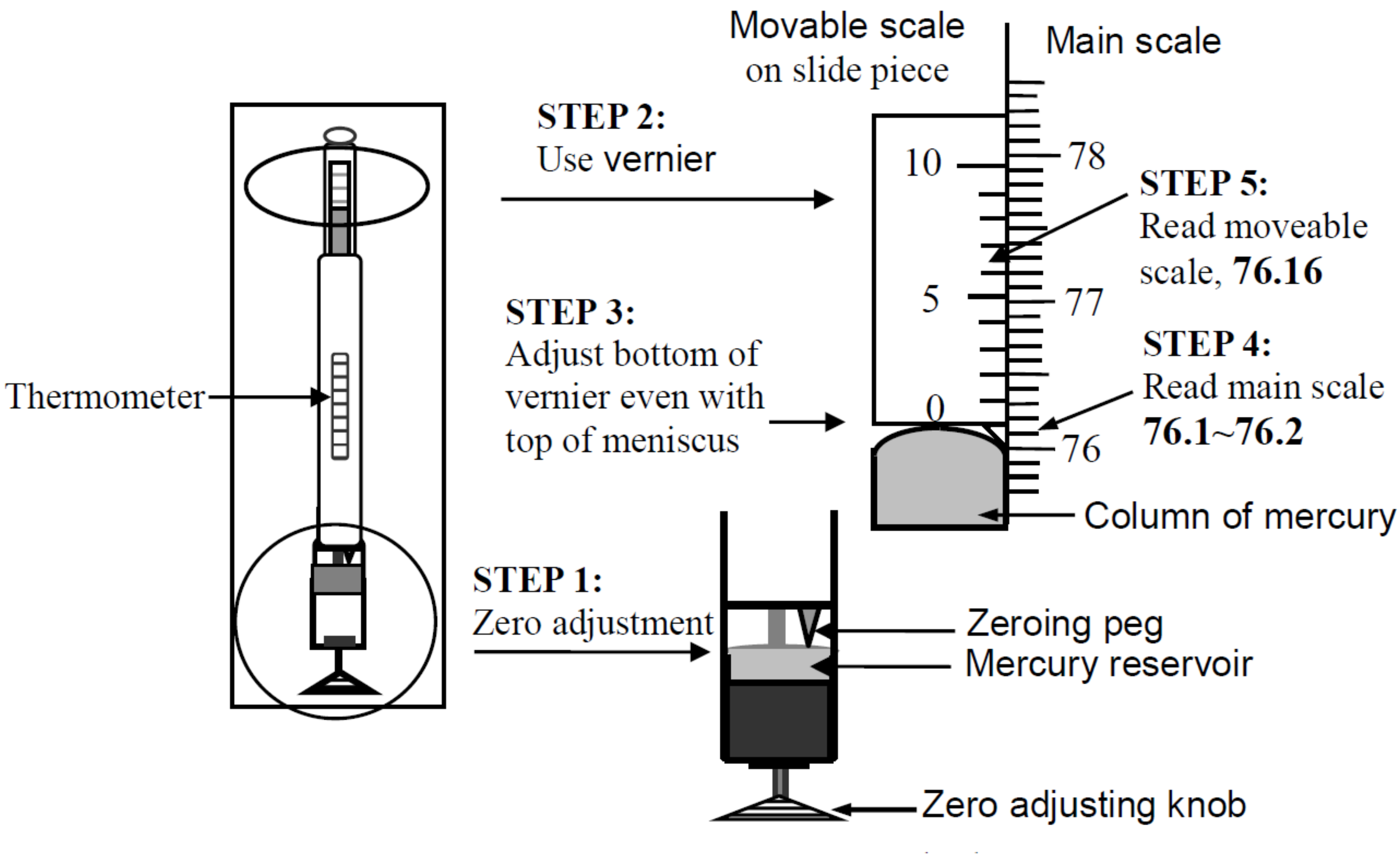


Figure T3-1 Illustration of mercury barometer

[T3 Video (YouTube link)]

T3.2 – Mercury Barometer

- Zero adjustment: Rotate the **Zero Adjustment Knob** at the bottom of barometer to align the tip of **Zeroing Peg** with the top of mercury reservoir
- Read the mercury column height with a **Vernier Scale**:
  1. Adjust the **Slide Piece** so that its bottom is even with the top of mercury meniscus
  2. Read the main scale on the right: In Figure T3-1, the bottom of the slide piece indicates the height of mercury column is between 76.1 and 76.2 cm
  3. Read the movable scale on the left: The percentile of measurement is given by the line that aligns with the mark on the main scale. This value is 6 in Figure T3-1, therefore the measured atmospheric pressure is 76.16 cm-Hg
- For more precise measurement, one should make temperature correction (refer to the manual of barometer)

T3 Video (YouTube link)

T9 – Electronic Balance

- Unless instructed, do not move the balance so that proper calibration is maintained
- Do not overload the balance (the maximum load is 610 grams for *electronic balance*, and 210 grams for *analytical balance*)
- Before use, warm up the balance for at least 30 min and ensure that it is level and clean

Electronic Balance
(resolution 0.01 g)

Analytical Balance
(resolution 0.0001 g)

- Do not put chemicals directly on the weighing pan – use a folded weighing paper, a weighing boat, or a beaker (mind the weight limit) as container
- Close all windshields on the *analytical balance* before zeroing and recording values
- Maintain the tidiness inside and outside the balance; use the provided soft brush to clean spillages
- Do not weigh hot objects as the convective airflow will affect the measured mass

T9 Video (YouTube link)

T10 – Weighing Chemicals

- Read the label on the chemical bottle carefully before proceeding to weigh
- For solid chemicals, place a folded weighing paper or a beaker on the electronic balance to hold chemicals. Use a clean and dry spatula to move chemicals
- For liquid chemicals, use a clean and rinsed dropper pipet

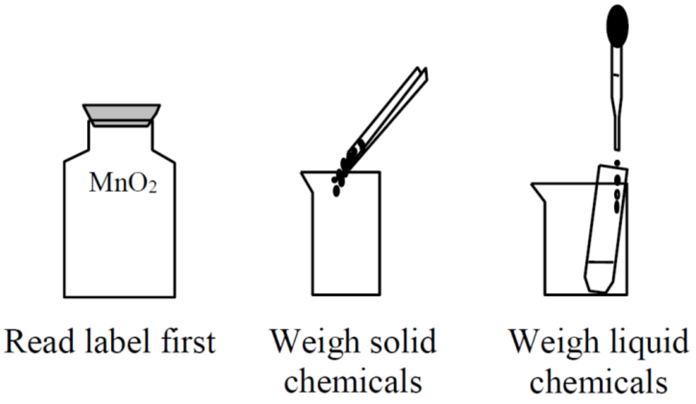


Figure T10-1 Weighing chemicals

- Unless specifically instructed, never return any excess chemical to the original bottle to avoid contamination – use the designated waste bin
- Maintain the tidiness inside and outside the balance – move appropriate amount with spatula to avoid any spillage, and use the provided soft brush to clean scattered chemicals
- Close the cap of chemical bottle immediately after use

T10 Video (YouTube link)