The Molar Volume of Nitrogen Gas

Last revised: 2023/10/14

Preparation

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

Collect the following items

- ❑ Two small test tubes (oven)
- ❑ An iron stand and two three prong clamps
- ❑ 250 mL Erlenmeyer flask, 500 mL Florence flask, a rubber stopper with rubber tube and glass tube (boxes on the central islands)

Objective and Principles

- **Objective:** Using the ideal gas law to deduce the molar volume of nitrogen gas at STP
- **Lab techniques:**
  - Using an analytical 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^{o}C, '**1 atm**'
  - For ideal gas, molar volume = 22.414 L at STP

✓ STP: Abbreviation for standard temperature (273.15 K or 0°C) and pressure (105 Pa). Ref: *IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book")*

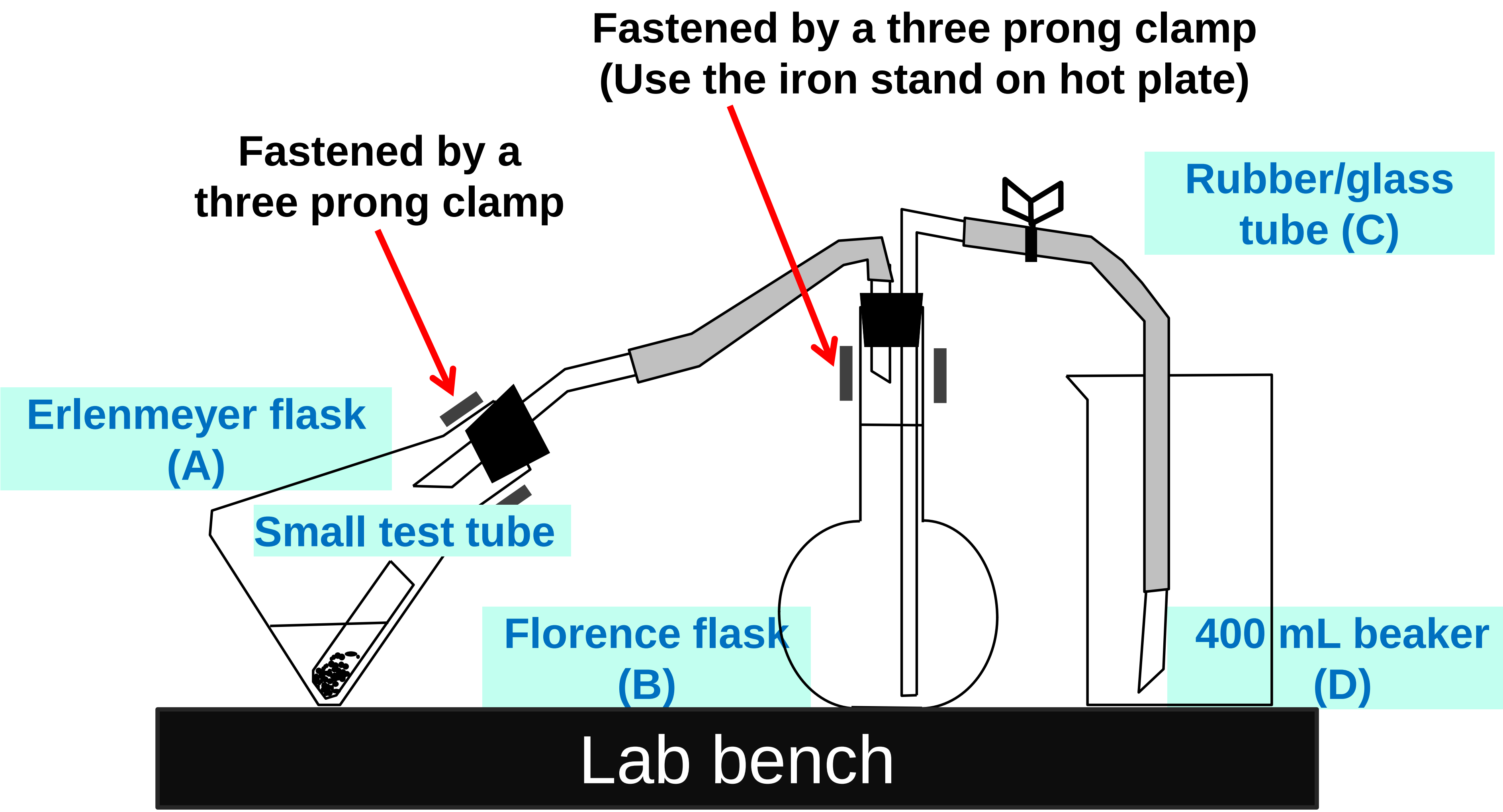
Nitrogen-Producing Reaction

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

	H_2NSO_3H	NO_2^-	HSO_4^-	H_2O	N_2
Initial:	$\mathbf{n_1}$	n_2			
Change:	$-n_1$	$-n_1$	$+n_1$	$+n_1$	$+n_1$
Final:	0	n_2-n_1	n_1		$\mathbf{n_1}$

- Sulfamic acid (H_2NSO_3H, n_1 mole) being the limiting reagent
- Sodium nitrite ($NaNO_2$) being the excess reagent ($n_2 > n_1$)

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 ($n_2 > n_1$)
- As per ideal gas law, the molar volume of N_2 at STP (0^oC, 1 atm) can be related to the volume of N_2 (V_1) at room temperature (T_1) given the number of mole (n_1):

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

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 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: Measuring Chemicals

Place a small beaker
(container)

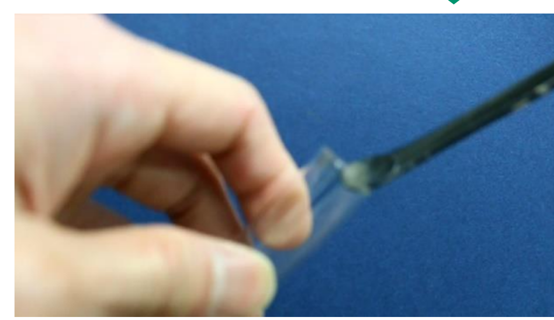
Close windshield & zeroing (**TARE**)

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 small test tube



Use the skinny end of a spatula to put ~1 g of H_2NSO_3H (ca. 5 times) in the small test tube

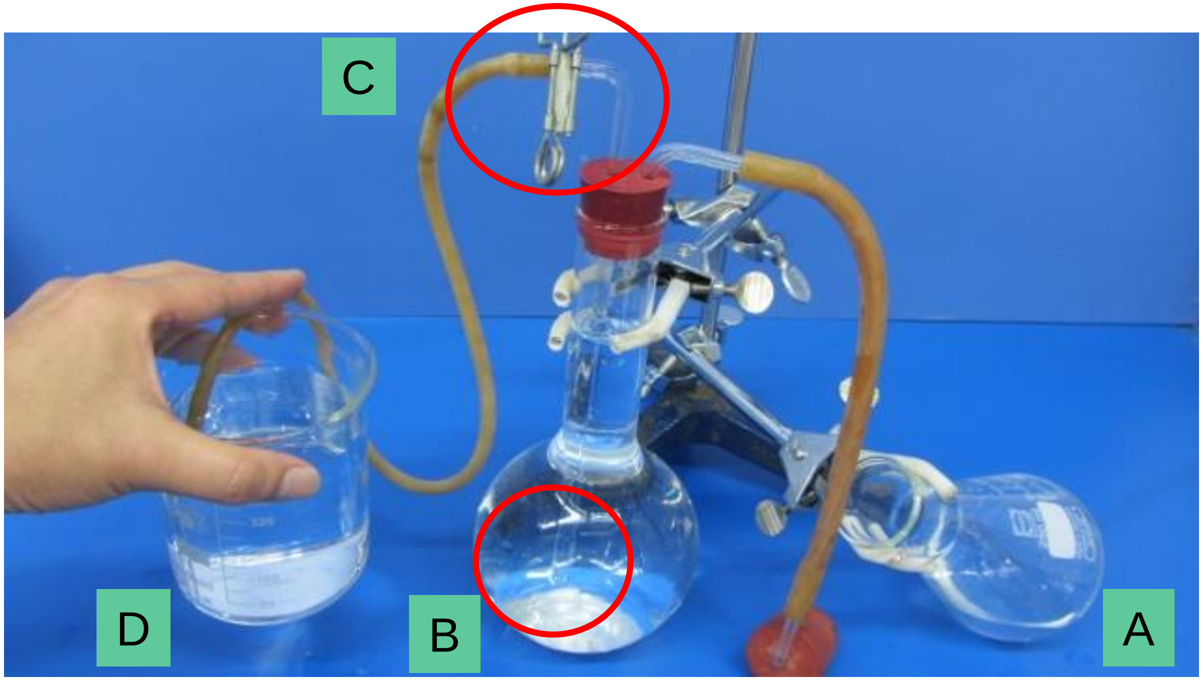
Place test tube in and close windshield

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 pinch clamp
- Fix the Florence flask with a three prong clamp to avoid breaking
- Use the rubber/glass tube C to connect B and D
- Loosen the pinch clamp and check if the water can flow freely between the two container; re-apply the clamp



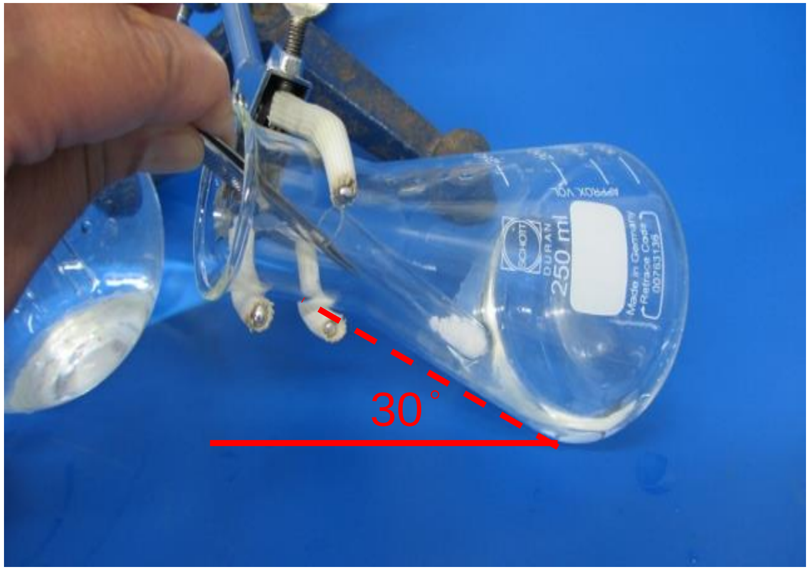
- ✓ The end of glass tube shaft should nearly touch the bottom of the Florence flask
- ✓ Check whether there is air bubbles in the rubber/glass tube

Step 3/6: Set up the Reaction Vessel

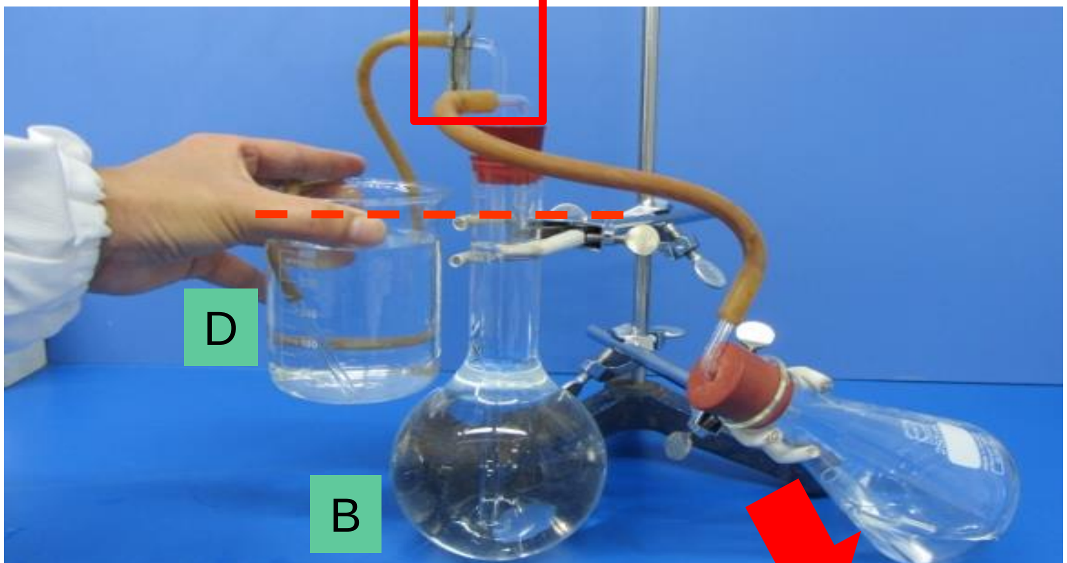
- Use a three prong clamp to fix the Erlenmeyer flask A at a tilted angle
- Place the small test tube containing H_2NSO_3H at the bottom of Erlenmeyer flask A using a tweezer
- Install the rubber stopper onto the Erlenmeyer flask

✓ Practice with the empty test tube first

✓ If $NaNO_2$ is accidentally mixed with H_2NSO_3H, clean the glassware and re-weight both chemicals

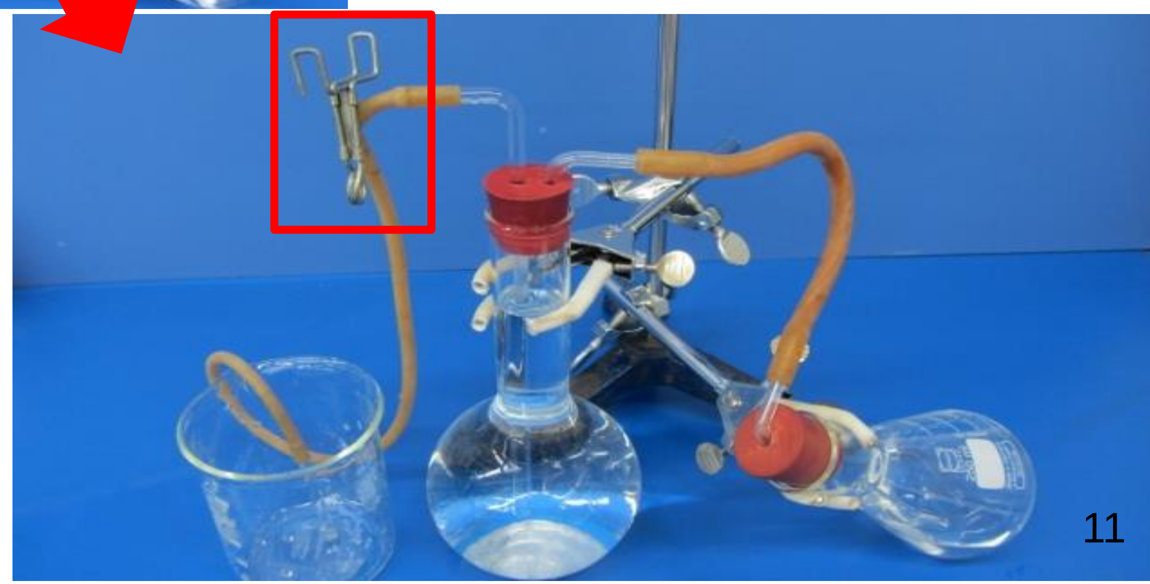


Step 4/6: Balance the Pressure

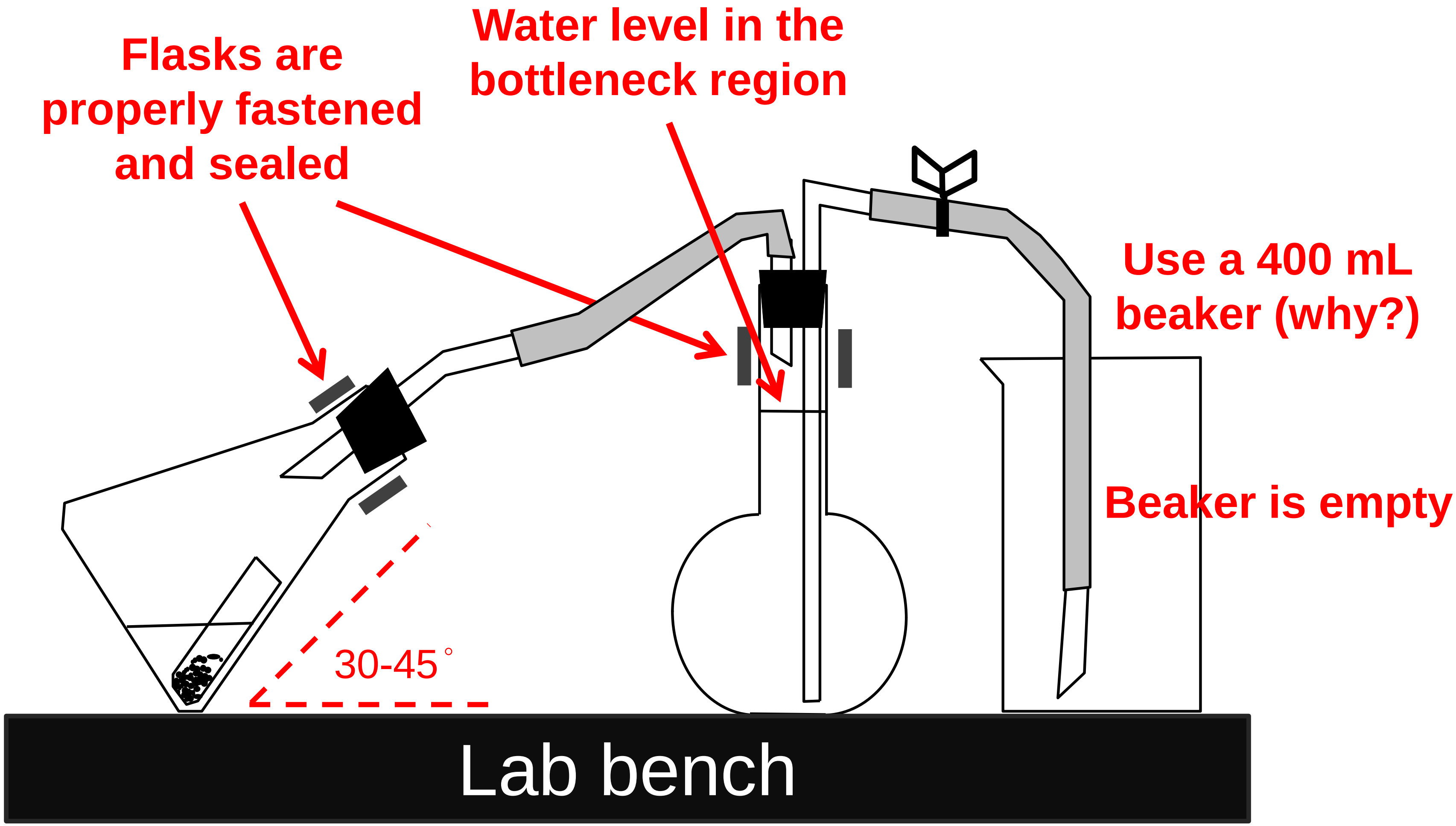


- Ensure all rubber stoppers are tightly fitted
- Loosen the pinch clamp, adjust the height of beaker so that the water levels in B & D become equal

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

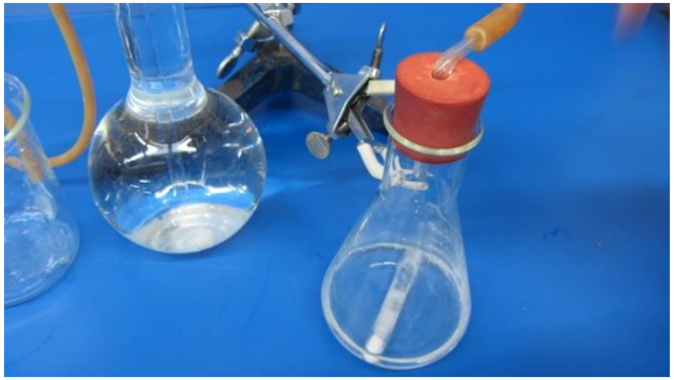


Ask a TA/ATA to Check Your Setup



Step 5/6: Start Generating Nitrogen

- Straighten the Erlenmeyer flask and let the chemicals mix
- Loosen the pinch clamp quickly
- Swirl the flask gently and observe water flow
- Maintain the rubber tube beneath the water level in the beaker



✓ Rubber tubes shouldn’t be twisted

✓ Brown NO_2 gas may be produced via a side reaction

Step 6/6: Adjust Pressure and Temp.

- Place the Erlenmeyer flask A in a room-temperature water bath
- Adjust the height of the Florence flask so that the water levels in B & D become equal
- Re-apply the pinch clamp onto the rubber tube C
- Measure the weight of repelled water in beaker → ΔV
- Record room temperature T_1 and pressure P_{atm}
- Use Appendix 7 to find P_{H_2O} (vapor pressures of water)

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

$V_{STP} = ?$

Clean-Up and Check-Out

- Clean and return the small test tubes
- Pour the solution waste into the drain directly
- 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)
- **Use the correct significant figures and units** (e.g. 1.0445 g, 25.13 °C, and 359.12 mL)
- This is a **Brief Report** experiment:
  – Complete calculation using correct significant figures
  – **Hand in prelab/lab note/report together to the TA**

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

Notes and Reminders

- Wear personal protective equipment (PPE, i.e. lab coat, safety goggle, closed-toe shoes, long pants) at all time in the laboratory
- Bring a scientific calculator (smartphone is not allowed)
- Communicate with your lab buddy
- Communicate with TA/ATA should you have any question

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)

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

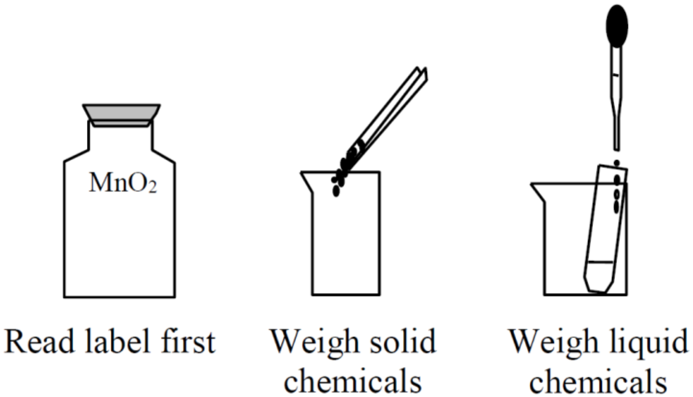


Figure T10-1 Weighing chemicals

- 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)

Mercury Barometer

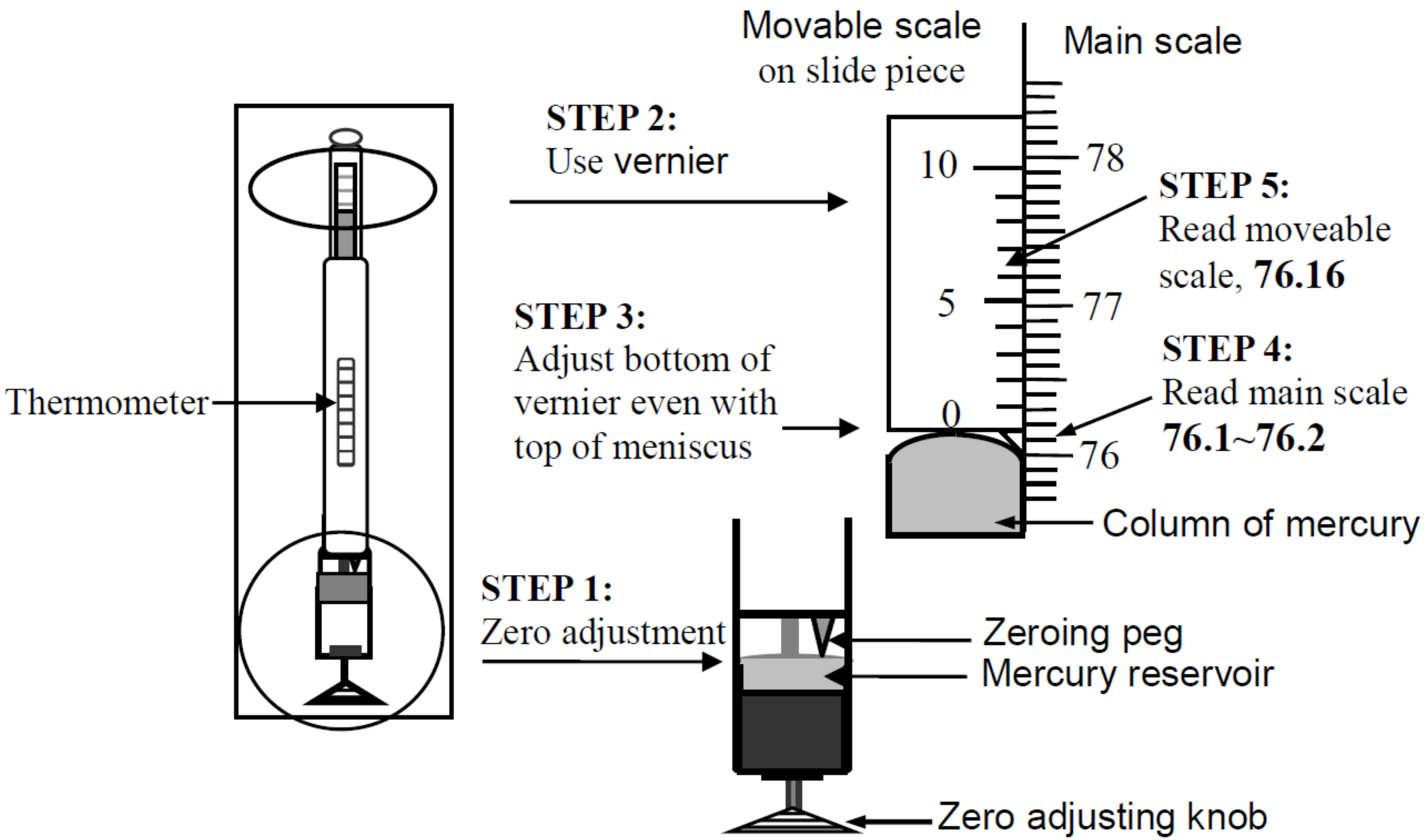


Figure T3-1 Illustration of mercury barometer