Chemistry 3A

Introductory General Chemistry

Experiment 8a

Determination of Gas Constant ***R***

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Introduction

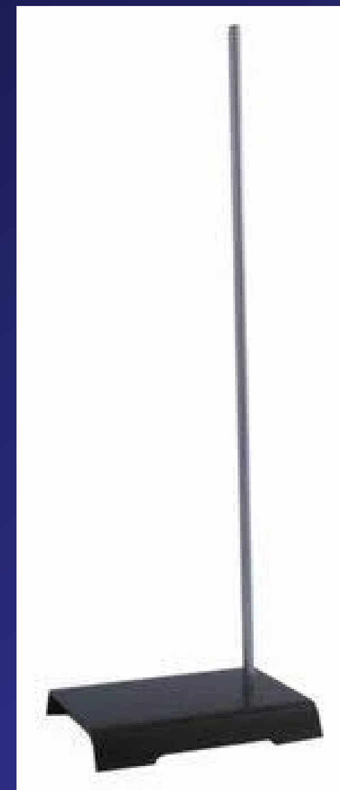
- The metal magnesium (Mg) solid will react with acids (in this experiment, hydrochloric acid HCl) to produce hydrogen (H_2) gas as shown in this reaction

$$\mathbf{Mg}\ (s) + 2\ \mathrm{HCl}\ (aq) \rightarrow \mathbf{H_2}\ (g) + \mathrm{Mg}^{2+}\ (aq) + 2\ \mathrm{Cl}^{-}\ (aq)$$

- The ideal gas law equation ***PV = nRT*** will be used to determine the value of ***R***, the ideal gas law constant
- You will use the mass (in grams) of **Mg** and its molar mass value, along with knowing volume ***V***, pressure ***P***, and temperature ***T***, to compute the ***R*** value

Equipment You Will Use

400, 600 or 800 mL beaker



50 mL gas collection tube (eudiometer)

Consumables

Mg ribbon

Pre-Lab Preparation/Questions

A pre-lab quiz has been made for you

THIS IS AN EXTRA CREDIT quiz that is worth 15% (30 points) of the value of a lab report (200 points). I suggest you do the quiz if you have been wanting extra credit points for the course

It will help you understand and complete this laboratory report as well

The quiz is at this URL

CRC Handbook

- Your lab manual wants you to look up a reference for the water vapor at a particular temperature
- The manual mentions an authoritative reference called the ***CRC Handbook of Chemistry and Physics***
- Fortunately, this reference is available online at [this link]
- This is a PDF which may load directly in your browser
- If you did a search for "water vapor" or "vapor pressure" inside the PDF, you would find the table you are looking for. The "vapor pressure" search worked in this case.

VAPOR PRESSURE OF WATER FROM 0 TO 370° C

This table gives the vapor pressure of water at intervals of 1° C from the melting point to the critical point.

REFERENCE

Haar, L., Gallagher, J.S., and Kell, G.S., *NBS/NRC Steam Tables*, Hemisphere Publishing Corp., New York, 1984.

t/°C	*P*/kPa	*t*/°C	*P*/kPa	*t*/°C	*P*/kPa	*t*/°C	*P*/kPa
0	0.61129	53	14.303	106	125.03	159	602.11
1	0.65716	54	15.012	107	129.39	160	617.66
2	0.70605	55	15.752	108	133.88	161	633.53
3	0.75813	56	16.522	109	138.50	162	649.73
4	0.81359	57	17.324	110	143.24	163	666.25
5	0.87260	58	18.159	111	148.12	164	683.10
6	0.93537	59	19.028	112	153.13	165	700.29
7	1.0021	60	19.932	113	158.29	166	717.83
8	1.0730	61	20.873	114	163.58	167	735.70

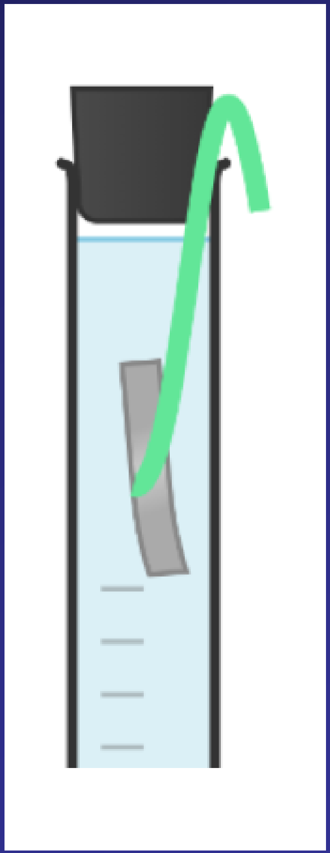
- You can use this table, but you might have to convert to other pressure units (keep this in mind)
- For your citation: write in the URL. You can even add at the end of the URL the string "#page=<page number you find>" and it will go straight to the page

Procedure

1. **Magnesium ribbon: DO NOT HANDLE THE RIBBON WITH BARE HANDS!!! ONLY HANDLE Mg ribbon with gloves!** Otherwise it might irritate your hands
2. Clean the **Mg** ribbon by lightly rubbing with steel wool. It may become “shiny” as an oxide outer layer is removed
3. Put weighing paper on the balance, zero it, and put the ribbon on the balance: you are looking for a target mass of about **0.05 g (50 mg)**. If the **mass > 0.05 g**, estimate carefully how much ribbon to break off, break it, then re-weigh it to get the final mass you will use. Record the mass (all the digits from the balance) in your lab manual

Procedure

4. You need to break off the ribbon so as not to lose too much mass: you will need to tie your Mg ribbon to fishing line (~15 cm long)
5. Set up the clamp on a ring stand and beaker as shown in figure below. Fill the beaker halfway with water



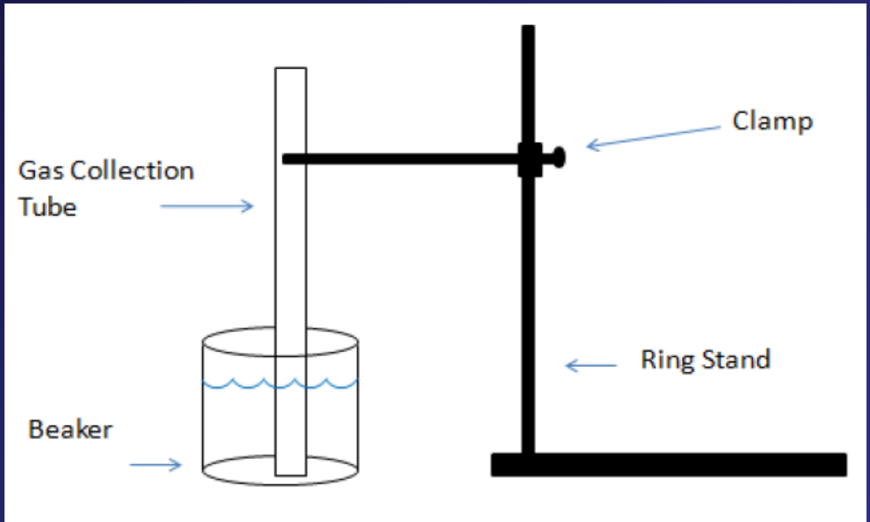


Figure 1: Gas Collection Set-up

Procedure

6. Using a small (10 mL) graduated cylinder, pour **8-10 mL** of 6 M (molar) hydrochloric acid (**HCl**) into the gas collection tube (eudiometer)
7. For this step of adding DI water, I suggest you first tip the eudiometer tube at an angle so that the water comes in down the side of the wall of the eudiometer tube. VERY SLOWLY AT FIRST add water to the eudiometer to avoid MIXING the water with the acid. As you add more water, the mixing effect will lessen but still add it slowly. Bring the level of the water to the brim of the eudiometer tube, this time holding the tube quite vertically.
8. Put the Mg ribbon in the water JUST INSIDE THE TUBE. Some of the fishing line should be OUTSIDE the tube.
9. Place a rubber stopper in the tube, making sure it holds the fishing line

Procedure

10. Put your GLOVED finger over the hole in the rubber stopper: INVERT the tube with your finger still over the hole and immerse your gloved hand—finger still over the hole—into the beaker of water. Quickly but carefully put the tube in the clamp and hold it. You can remove your finger but only with tube with stopper immersed in beaker water.
11. Use a thermometer to record beaker water temperature to nearest 0.1°C. Also get the classroom barometric pressure
12. The reaction is done WHEN
    - There are no bubbles forming
    - The Mg ribbon is not visible
    - The headspace gas is not increasing

    You might want to ask your instructor if he thinks the reaction is complete
13. Record volume of gas produced.

The Fishing Line: Why?

🎯 Why the magnesium ribbon is tied with fishing line

1. **Controlled reaction start**
   - If you just dropped the Mg ribbon directly into the HCl at the bottom of the eudiometer, the reaction would begin *immediately* while you're still trying to invert and set up the tube.
   - By suspending the Mg ribbon higher up in the water column, the acid doesn't touch it until the apparatus is inverted and the acid diffuses downward. This gives you time to get the setup stable before gas starts evolving.
2. **Preventing premature mixing**
   - Remember, the HCl is carefully layered at the bottom, with water above it. If the Mg ribbon fell straight into the acid layer, the reaction would be violent and uncontrolled.
   - The fishing line holds the ribbon in place above the acid, so the reaction begins gradually as the acid diffuses upward into the water and reaches the Mg.
3. **Keeping the Mg in place**
   - Without the line, the ribbon might float, stick to the glass, or move unpredictably as bubbles form.
   - The line ensures the Mg stays suspended in the same spot, making the reaction more reproducible and the gas collection more reliable.
4. **Safety and measurement accuracy**
   - A sudden burst of H_2 could blow liquid out of the stopper hole or cause splashing.
   - By slowing the initial contact, the fishing line helps the reaction proceed at a manageable rate, so the gas volume can be measured accurately.

Details of Reaction

🧪 Step-by-step sequence after inversion

1. **Before inversion**
   - Tube is filled: ~8–10 mL of 6 M HCl at the bottom, carefully layered water above.
   - Mg ribbon is suspended on fishing line, held near the top of the column, away from the acid.
   - No reaction yet, because the Mg hasn't touched the acid.
2. **Inversion into the beaker of water**
   - Tube is inverted and placed in the water bath.
   - The stopper hole allows displaced liquid to escape as gas is later produced.
   - The Mg ribbon is now hanging "below" the acid layer (since the tube is upside down), but still separated by water.
3. **Diffusion begins**
   - HCl slowly diffuses upward into the water column.
   - As the acid front reaches the Mg ribbon, the reaction starts gradually:

$$\mathrm{Mg}\ (s) + 2\ \mathrm{HCl}\ (\mathrm{aq}) \ \rightarrow\ \mathrm{MgCl_2}(aq) + \mathrm{H_2}(g)$$

Details of Reaction

🎯 Why the fishing line matters in this timeline

- It **delays the start** of the reaction until the setup is stable.
- It **controls the position** of the Mg so the acid reaches it gradually.
- It **prevents chaos** (Mg floating, sticking, or reacting too violently).

Details of Reaction

4. **Gas evolution**
    - Hydrogen gas bubbles form on the Mg surface.
    - The bubbles rise and collect at the top of the inverted tube, displacing water out through the stopper hole.
    - The fishing line keeps the Mg in place so it doesn't float away or stick to the glass.
5. **Reaction continues**
    - Acid keeps diffusing, sustaining the reaction until the Mg is consumed.
    - The gas volume increases steadily, pushing more water out.
    - Students can then read the gas volume against the scale on the eudiometer.
6. **Completion**
    - Once all Mg is reacted, gas collection stops.
    - The measured gas volume (corrected for water vapor pressure and temperature) is used to calculate moles of H_2, and from that, the experimental gas constant R.

Clean Up

- Lift the tube and remove the stopper to allow the contents of the tube to drain in the beaker water
- Take the beaker—which contains the strong HCl acid—to the sink. Use the $NaHCO_3$ solid at your bench and add very small amounts of it to the beaker to neutralize the acid. When it stops producing gas, it is neutralized. Pour the contents in the sink while running the tap water (not DI) for a minute or so
- Rinse the beaker out with small amounts of DI water with some swirling. Do this 2-3 times. Place the beaker where it belongs. It is not essential to dry it out with a paper towel
- The eudiometer tube should be filled up a couple of times with DI water and the rinse discarded in sink.

Example Data Analysis

- Use the mass of Mg ribbon to calculate the theoretical yield of H_2 gas
- Calculate the pressure of H_2 gas using the atmospheric pressure and the vapor pressure of H_2O. Conver the pressure to atm units
- Use the $PV=nRT$ equation to calculate R.
- Calculate a percent error
- Do not determine significant digits until the final calculation: record all the digits from your calculator for intermediate calculations

Example Data Analysis

- These are all EXAMPLE DATA, but probably close to what your data will look like

DATA

Mass of the magnesium ribbon 0.04684 g

Temperature of water 21.2°C

Pressure in the room 753.1 mmHg

Vapor pressure of water at your temperature* 18.88 mmHg

Volume of gas in collection tube 42.50 mL

Example Data Analysis

CALCULATIONS

Show your work, complete with units.

1. Moles of hydrogen gas based on mass of Mg used $0.001928\ mol\ H_2$

$$0.04686\ g\ Mg \times \frac{1\ mol\ Mg}{24.31\ g\ Mg} \times \frac{1\ mol\ H_2\ produced}{1\ mol\ Mg\ consumed}$$

$$= 1.928 \times 10^{-3}\ mol\ H_2 = 0.001928\ mol\ H_2$$

2. Pressure of hydrogen gas (mmHg) $734.6\ mmHg$

$$P_{air} = P_{water\_vapor} + P_{hydrogen\ (H2)}$$

$$P_{H2} = P_{air} - P_{water\_vapor} = 753.1 - 18.88 = 734.6\ mmHg$$

3. Pressure of hydrogen gas (atm) $0.9666\ atm\ H_2$

$$734.6\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.9666\ atm\ H_2$$

Example Data Analysis

4. Experimentally determined R value 0.07243 L atm/mol K

R=PV/nT

$$= 0.9666 \text{ atm} \times 42.50 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1}{0.001928 \text{ mol}} \times \frac{1}{(273 + 21.2)\text{K}} = \frac{0.07243 \text{ L atm}}{\text{mol K}}$$

5. % Error -11.73%

$$\frac{(0.07243 - 0.08205)}{0.08205} \times 100\% = -11.73\%$$