Lecture 14
Still Chapter 5  Gases

- Announcements
- Density
- Demo
- Partial Pressures
What is the answer to #3 from the worksheet?

1. 0 torr
2. 340 torr
3. 670 torr
4. 1340 torr
Speed Depends on $m$ and $T$

Maxwell-Boltzmann Distribution

There was some confusion on the CAPA set, so I wanted to put this up again to make sure things were absolutely clear!
Ideal Gas Law Gives Density

- Density is mass/volume
- We can rearrange ideal gas law to include mass

\[ PV = nRT \quad \text{and} \quad n = \frac{m}{MM} \]

\[ PV = \frac{m}{MM} RT \quad \leftarrow \text{This form of the IGL is handy sometimes} \]

\[ P(MM) = \frac{m}{V} RT \quad \text{but} \quad \frac{m}{V} = \rho_{\text{gas}} \]

\[ \rho_{\text{gas}} = \frac{P(MM)}{RT} \]
Summary of mole relationships:

- **Solids, liquids**  \[ \text{Moles} = \frac{\text{Mass}}{\text{Molar mass}} \]

- **Solutions**  \[ \text{Moles} = \text{Molarity} \times \text{Volume} \]

- **Gases**  \[ \text{Moles} = \frac{\text{PV}}{\text{RT}} \]

Practice!
Crush the Can Demo

• Small amount of water in can
• Heat can to turn water into steam
• Cool can in water and it implodes

• Why?

• Hot can contains mixture of gases including lots of water vapor
• Gases in can are at about 100 C or 373 K
• Gases in can cool very slightly, turning water vapor into liquid
• Very rapid decrease in the number of moles of gas in the can
• P inside can is now low, atmospheric pressure wins!
Crush the can calculations

- Can volume about 350 ml
  \[ n = \frac{PV}{RT} = \frac{1 \cdot 0.35}{0.08206 \cdot 373} = 0.011 \text{ mol total} \]

- Let’s say about half is water vapor
  - 0.005 moles of steam
- When can cools the steam turns to liquid
  - Volume of 0.005 moles of water is essentially zero!
    - Actually about 0.1 ml
- Now only 0.06 moles of gas in can

\[ P_{\text{inside}} = \frac{nRT}{V} = \frac{0.006 \cdot 0.08206 \cdot 372}{0.35} = 0.52 \text{ atm} \]

\[ V_{\text{inside}} = \frac{nRT}{P_{\text{final}}} = \frac{0.006 \cdot 0.08206 \cdot 372}{1} = 0.18 \text{ L} \]
Mixtures of gases

- For each gas, ideal gas law holds
  \[ P_i V = n_i RT \]

- For total gases, ideal gas law holds
  \[ P_{tot} V = n_{tot} RT \]

- This means pressures are additive
  \[ P_{tot} = P_i + P_j + P_k + \ldots \]

- Mole fraction is the composition, but now with moles rather than mass
  \[ \chi_i \equiv \frac{n_i}{n_{tot}} \text{ for an ideal gas } \quad \frac{n_i}{n_{tot}} = \frac{p_i}{p_{tot}} = \chi_i \]
More units…

- Gas concentrations are often given in mole fraction
  \[ \chi_i = \frac{n_i}{n_{\text{tot}}} = \frac{p_i}{p_{\text{tot}}} \]

- Or sometimes percent (which is also pph)
  \[ \chi \text{ in pph} = \frac{n_i}{n_{\text{tot}}} \times 100 = \frac{n_i}{n_{\text{tot}}} \times 10^2 \]

- For things that are dilute ppm or ppb
  \[ \chi \text{ in ppm} = \frac{n_i}{n_{\text{tot}}} \times 1,000,000 = \frac{n_i}{n_{\text{tot}}} \times 10^6 \]
  \[ \chi \text{ in ppb} = \frac{n_i}{n_{\text{tot}}} \times 1,000,000,000 = \frac{n_i}{n_{\text{tot}}} \times 10^9 \]
Today

• Finish CAPA #8

By Friday

• Read up on atmospheric chemistry
  – Ozone
  – $\text{NO}_x$
  – Hurricanes
• Read first couple sections of Chapt 6