Ideal Gases

Chapter 5,
Sections 5.4, 5.5, and 5.7

Ideal Gases Suggested Problems from chapter 5

- 41, 43, 45, 55, 63, 75, and 79
- Also available at http://www.western.edu/faculty/dorth

Ideal Gases

- 5.4 Ideal gas law
- 5.5 Calculations with the ideal gas law
- 5.7 Stoichiometry revisited

Properties of Gases

- Mixtures are homogeneous
  - Easily diffuse into one another
- Compressible (99% empty space)
- Little or no intermolecular forces
- Exert pressure on whatever surrounds them
- Expand into whatever volume is available

Variables for gases

- Volume, V
  - common unit is liter (SI is m^3)
- Amount (number of moles), n
- Temperature, T
  - K = ^{o}C + 273
- Pressure, P
- Standard Temperature and Pressure (STP)
  - T = 273.15 K and P = 1 atm

Pressure

- Force/area
- Common units
  - psi
  - atmospheres (atm)
  - torr (mm Hg)
- 760 torr = 1 atm
- SI unit is N/m^2 -- pascal
  - too tiny for everyday use
  - 1 atm = 101 kPa

Ideal Gas Law: PV=nRT

- R = 0.08206 (L·atm)/(mol ·K)

What volume would 2.00 moles of nitrogen occupy at a temperature of 22 °C and a pressure of 589 torr?

- Convert Temperature to Kelvin
  - T = 22 + 273 = 295 K
- Convert Pressure to atm

$$P = 589\ \text{torr} \left(\frac{1\text{atm}}{760\ \text{torr}}\right) = 0.775\ \text{atm}$$

- Rearrange Ideal gas law for variable desired
  - PV = nRT, rearranged for V:
  - V = nRT/P
- Plug in numbers

$$V = \frac{(2\ \text{mol})\ (0.0821\ \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(295\ \text{K})}{0.775\ \text{atm}}$$

V = 62.5 L

An unknown gas is place in a 1.500 L bulb at a pressure of 356 mm Hg and a T of 22.5 °C.

- The bulb is weighed and found to have a mass of 0.9847 g.
- What is the Molecular Weight of the gas?
- PV = nRT

$$\frac{PV}{RT} = n = \frac{\left(\frac{356}{760}atm\right)1.5L}{\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)295.65K} = 0.0289mol$$

$$MW = \frac{0.9847g}{0.0289mol} = 34.02\ g/mol$$

A bottle is capped at a temperature of 25 °C and a pressure of 1 atm. The bottle is thrown into a fire where the temperature is 1000 °C. What is the new pressure in the bottle?

- Identify what is constant and rearrange ideal gas law for the constant quantity
- V and n are not changing

PV = nRT rearranges to

$$\frac{P}{T} = \frac{nR}{V} = \text{constant}$$

$$\frac{P_1}{T_1} = \text{constant} = \frac{P_2}{T_2}$$

Convert Temperatures to Kelvin

T_1 = 25 + 273 = 298

T_2 = 1000 + 273 = 1273

Plug numbers into relationship above

$$\frac{1\ \text{atm}}{298\ \text{K}} = \frac{P_2}{1273\ \text{K}} \qquad P_2 = 4.27\ \text{atm}$$

If a balloon is blown up inside where the temperature is 25 °C, it has a volume of 4.5 L. What is the volume of the balloon outside, where the temperature is -20 °C?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- V_2 = 3.8 Liters

What volume of gases are released when 3.95 g of ethanol (C_2H_5OH) are burned? Assume the gases are at 100 °C and 1 atm.

- Write balanced reaction for combustion:
  - $C_2H_5OH_{(l)} + 3\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 3\ H_2O_{(g)}$
- Determine moles of ethanol

$$3.95\text{ g EtOH}\left(\frac{1\text{ mol EtOH}}{46.1\text{ g EtOH}}\right) = 0.0857\text{ mol EtOH}$$

What volume of gases are released when 0.0857 mol of ethanol (C_2H_5OH) are burned? Assume the gases are at 100 °C.

- $C_2H_5OH_{(l)} + 3\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 3\ H_2O_{(g)}$
- 5 moles of gas (CO_2 and H_2O) are produced from each mole of ethanol

$$0.0857\text{ mol EtOH}\left(\frac{5\text{ mol gas}}{1\text{ mol EtOH}}\right) = 0.429\text{ mol gases}$$

0.429 moles of gases are produced at 100 °C and 1 atm. What is the volume?

- PV = nRT

$$V = \frac{nRT}{P} = \frac{(0.429\text{ mol})(0.0821\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(373\text{ K})}{1\text{ atm}} = 13.1\text{ L}$$