Completion of gas law chapter

Ch 5 of Zumdahl

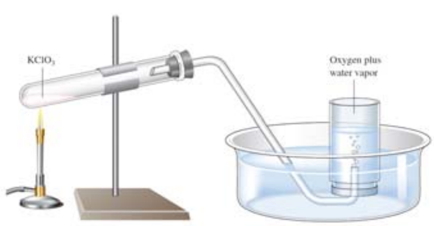
Next Week: Week 7

- GA7

Problem #3, page 222

$2\ KClO_3(s) = 2\ KCl(s) + 3\ O_2(g)$

- Oxygen is collected over water.
- Gas contains the oxygen generated plus the equilibrium vapor pressure of water at this temp.

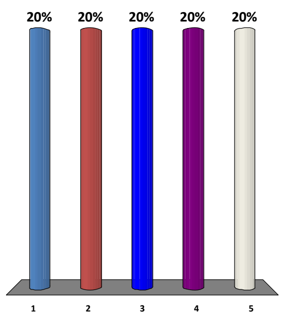


Problem #3, page 222

- Oxygen is collected over water.
- Gas contains the oxygen generated plus the equilibrium vapor pressure of water at this temp.
- 1^{st}: what is the partial pressure of oxygen?
- 2^{nd}: How many moles of oxygen
- 3^{rd}: How many moles of potassium chlorate?

What is the partial pressure of oxygen?

1. 755.3 torr
2. 23.8 torr
3. 779.1 torr
4. 731.5 torr
5. 760 .0 torr



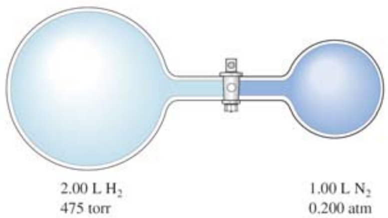
Problem #3, page 222

- 1^{st}: what is the partial pressure of oxygen?
- 2^{nd}: How many moles of oxygen?
- 0.0394 mol O_2
- 3^{rd}: How many moles of potassium chlorate?
- 0.0262 mol $KClO_3$

Problem 5-29

317 torr H_2; 50.7 torr N_2

- What are final partial pressures of H_2 and N_2.
- V_f = 3.00 L.



Problem 5-37

970 K

- Bursts at 2500 torr
- T = 21.0 °C
- P = 758 torr
- Then heated
- At what Temp will it burst?

Problem 5-57

- Sample of CH_4 contains small amount of He
- Density = 0.70902 g/L at 0.0°C and 1.000 atm
- What is the volume % of He?
- 98.84% methane

Problem 4-59

- Fe(s) + H_2SO_4(aq) = $FeSO_4$(aq) + H_2(g)
- Volume of hydrogen = 4800 m^3 x 1.20 =?
- T=0^{o}C, and P = 1.0 atm: moles of H_2?
- What mass of iron was needed?
- 1.5 x 10^7 g Fe

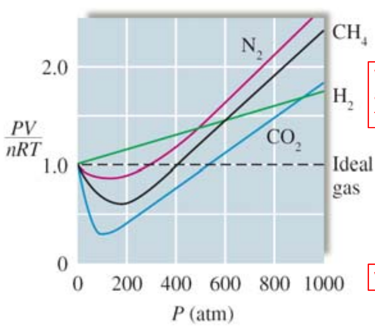
Real Gases vs Ideal Gases

- For an ideal gas:

$$PV = nRT$$

$$\frac{PV}{nRT} = 1$$

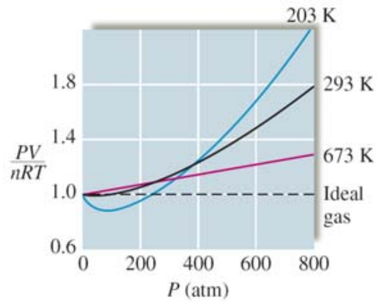
Real Gases



What is interesting about H_2 compared to these others?

Very high pressures

Real Gases: N_2



How does nonideality change with temperature?

Very high pressures

Real Gases: van der Waals

$$P = \frac{nRT}{V} \quad \text{(for ideal case)}$$

b represents the volume unavailable due to volume of the actual molecules. It is a *molar* quantity. For example, for N_2 it is 0.0391 L/mol

How do we expect b to vary from gas to gas?

Real Gases: van der Waals

$$PV = nRT \quad \text{(for ideal case)}$$

$$P' = \frac{nRT}{V - nb} \quad \text{(correctio n measured V is too large)}$$

P' would be observed if molecules have volume but are noninteracting.

Real molecules attract each other, giving lower pressure.

$P_{obs} < P'$, *and we introduce a correction factor*

$P_{obs} = P' - P''$

Real Gases: van der Waals

$PV = nRT$ (for ideal case)

$P' = \frac{nRT}{V - nb}$ (correction : measured V is too large)

$P_{obs} = P' - P''$

Correction factor P” is proportional to the square of the molecule density, because the number of collisions is thusly proportional: ~$(n/V)^2$

$$P_{obs} = P' - P'' = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2 \text{ (measured P is too small)}$$

Real Gases: van der Waals

$PV = nRT$ (for ideal case)

$P' = \frac{nRT}{V - nb}$ (correction : measured V is too large)

$$P_{obs} = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2 \text{ (P is reduced by interactions)}$$

Real Gases: van der Waals

$PV = nRT$ (for ideal case)

$P' = \frac{nRT}{V - nb}$ (correction : measured V is too large)

$$\left[P_{obs} + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT \text{ (van der Waals)}$$

a represents the pressure reduction due to attraction between the actual molecules. It is a *molar* quantity. For example, for N_2 it is 1.39 atm L^2/mol^2

What magnitude is $(n/V)^2$

How do we expect a to vary from gas to gas?

TABLE 5.3
Values of van der Waals Constants for Some Common Gases

Gas	$a\left(\frac{\text{atm L}^2}{\text{mol}^2}\right)$	$b\left(\frac{\text{L}}{\text{mol}}\right)$
He	0.034	0.0237
Ne	0.211	0.0171
Ar	1.35	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0511
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
CO_2	3.59	0.0427
CH_4	2.25	0.0428
NH_3	4.17	0.0371
H_2O	5.46	0.0305

- Do the values support the trends we predicted?

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H_2O	5.46	0.0305

Problem 5-87

- 0.5000 mol N_2
- 1.000L flask
- 25.0^{o}C
- What is the pressure?
- Ideal: 12.24 atm
- VDW: 12.13 atm
- Difference: 0.91%

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Problem 5-93

- Of the molecules H_2, N_2, CO_2, and CH_4, predict which has the strongest intermolecular interactions.
- CO_2

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H_2O	5.46	0.0305

- What trend do you see regarding intermolecular interactions for the rare gases: He, Ne, Ar, Kr, and Xe
- The “heaviest” have the strongest interactions

Key Questions – Hanson 11-2

- The clicker quiz on the key questions of Hanson 11-2 will commence in 5 minutes.
- Discuss these questions (1-5, page 214) with your neighbor and make sure you understand them.

$(KE)_{avg} = (3/2)\ RT$

- Derived from Kinetic Theory of Gases
- Kinetic energy is $(1/2)mv^2$
- Molecules move with a distribution of velocities.
- Absolute temperature (T) is a direct measure of the average kinetic energy of the molecules.
- *Relates the macroscopic T to the microscopic kinetic energy.*

Do Exercise #2, p. 215 with partner

- What is the KE of 1 mol of hydrogen molecules at 25^{0}C ?
- Note: use R=8.314 J/mol K for this type of problem!!!
- 3.72 x 10 ^{3} J/mol

The kinetic energy of 1 mol of SF_6 molecules is:

1. Less than that of 1 mol of hydrogen
2. The same as that of 1 mol of hydrogen
3. Greater than that of 1 mol hydrogen

$$\mathbf{KE} = \tfrac{1}{2} M \left\langle \mathrm{v}^2 \right\rangle = \tfrac{3}{2} RT$$

- **Solve for the average speed and the root mean square speed:**

$$\tfrac{1}{2} M \left\langle v^2 \right\rangle = \tfrac{3}{2} RT$$

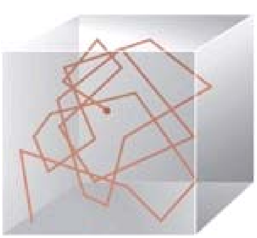
$$\sqrt{\langle v^2 \rangle} = \sqrt{\frac{3RT}{M}} \quad (\text{root mean square speed})$$

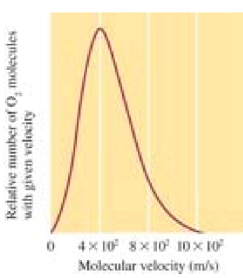
At the projector calculate the rms speed of an H_2molecle at 25^0C.
With your partner calculate the rms speed of an SF_6molecule at 25^0C
226 m/s

Exercise 4, p. 216

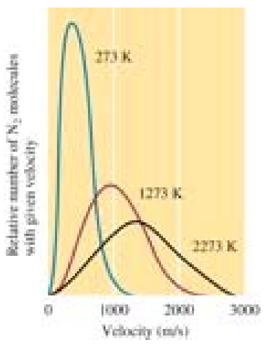
- At the projector, calculate the ratio of the rms speeds of $H_2$and SF_6 at 25^oC.
- With your partner compare this to the ratios of the molecular masses and the square roots of the molecular roots.

Random directions, distribution of velocities





Velocity depends on temperature



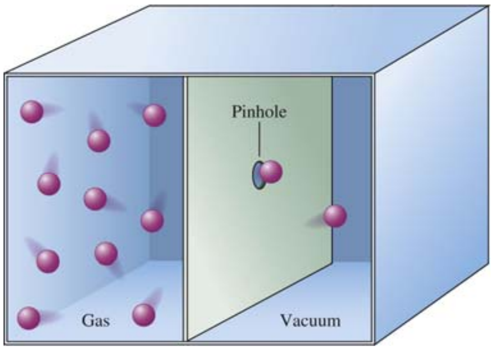
Exercise 5, p.216

Condition	Average Kinetic Energy	Mean Square Velocity	Frequency of Collisions	Force per Collision
temperature increases	*Increases*	*Increases*		
volume increases	*Stays the same*	*Stays the same*		
gas added	*Stays the same*	*Stays the same*		
H_2 replaced with N_2	*Stays the same*	*Decreases*		

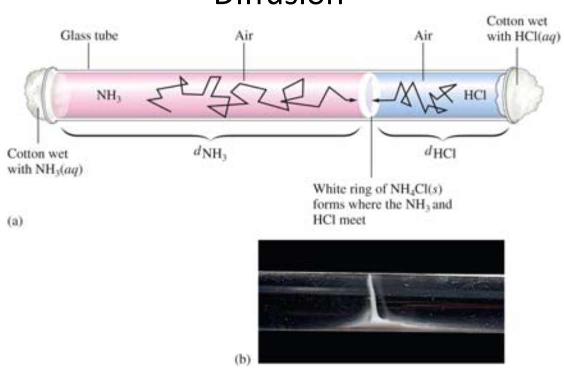
Problem 1, p217 – out of class

- v (Xe) = 238 m/s
- v (airliner) = 500 miles/h = 222 m/s
- Be sure you can convert this last number.
- 1 in = 2.54 cm

Effusion



Diffusion



Prob 2, p 217. According to the kinetic theory, the rate of diffusion:

- 33% 1. Does not depend upon temperature
- 33% 2. Increases with increasing temperature
- 33% 3. Decreases with increasing temperature

Prob 2, p 217. According to the kinetic theory, the rate of diffusion:

1. Does not depend upon molecular mass
2. Increases with increasing molecular mass
3. Decreases with increasing molecular mass

Problem 3, p. 218

- Does the rate of diffusion depend in direct proportion on either the mass of the molecule or its temperature?
- NO; NO

diffusion depends upon velocity

$$v \propto \sqrt{T}$$

$$v \propto 1/\sqrt{M}$$

Problem 4, p. 218

- For SF_6: diffusion rate = 18.7 mm/min, M = 146.1 g/mol
- Unknown gas: diffusion rate = 39.9 mm/min
- What is the molar mass of the unknown gas?

diffusion depends upon velocity

$$v \propto \sqrt{T}$$

$$v \propto 1/\sqrt{M}$$

M = 32.1 g/mol

Chapter 6

- **Thursday, Feb 21, 2013**
- **Hanson 15-1**

Hanson Activity 15-1

- Discuss Key Questions 1-9 of Activity 15-1, pages 269 - 70, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Key Question #5

- What examples of a dynamic equilibrium?

Exercise #1, page 260

- At the Projector

  $H_2O(g) + CO(g) = H_2(g) + CO_2(g)$

- Initially at equilibrium, all of the CO(g) is suddenly converted to $^{14}CO(g)$ (C-14 isotope)

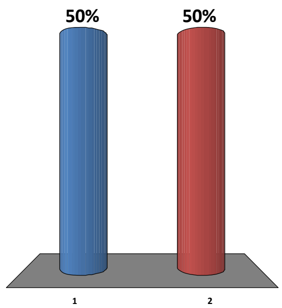
- Where will the C-14 be found after a long time period?

Exercise #2, p. 270

- Answer with your partner

At equilibrium, the second flask will have more hydrogen gas

1. True
2. False



$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$

When carbon monoxide is added, the number of moles of hydrogen will:

1. Increase
2. Decrease
3. Not change

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$

When water vapor is removed, the number of moles of hydrogen will:

1. Increase
2. Decrease
3. Not change

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$
When methane is added, the number of moles of hydrogen will:

1. Increase
2. Decrease
3. Not change

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$
When carbon monoxide is added, the number of moles of hydrogen will:

1. Increase
2. Decrease
3. Not change

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$

- At equilibrium, the total pressure is increased by adding argon gas. (The partial pressures of the reactants and products do not change.)
- What happens to the number of moles of hydrogen when equilibrium is reestablished?

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$

- At equilibrium, the total volume is suddenly increased, reducing the partial pressures of all components.
- Since there are four moles of gas on the product side, the reaction will shift to the right.
- The number of moles of H_2 will increase.

3g: add a catalyst

- Catalysts change the underlying mechanism, but do not affect the equilibrium.
- No change in the moles of hydrogen
- Equilibrium may be established more rapidly, but is the same.

Getting a bit ahead of ourselves

- Endothermic reactions absorb heat from the surroundings
- Exothermic reactions release heat to the surroundings
- Le Chatelier's Principle also applies to temperature stress: the equilibrium will shift to partially counter the temperature change.

$CH_4(g) + H_2O(g) = 3\ H_2(g) + CO(g)$

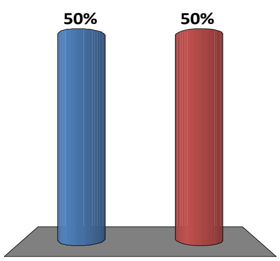
This reaction is endothermic – absorbs heat from the environment

$CH_4(g) + H_2O(g) + \text{energy}$
$= 3\ H_2(g) + CO(g)$

If at equilibrium, the temperature of the vessel is increased, what will happen? Discuss with your partner

When the temperature is raised, the number of moles of hydrogen will decrease

1. True
2. False

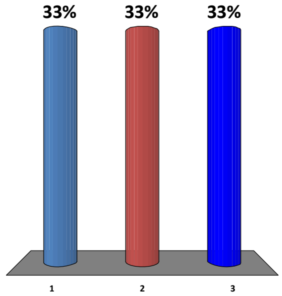


Problem 1, page 272

- $N_2(g) + O_2(g) = 2\ NO(g)$
- Volume is suddenly decreased, as in an engine.
- Discuss with your partner

$N_2(g) + O_2(g) = 2\,NO(g)$: When volume is decreased, the amount of NO will:

1. Increase
2. Decrease
3. Stay the same



Problem #2, page 272

$N_2(g) + 3H_2(g) = 2NH_3(g)$ + energy

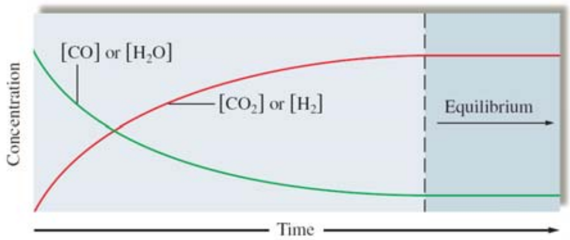
- This reaction is exothermic: gives off heat
- Number of moles of gas decreases during forward reaction
- Discuss with partner: How will changes in pressure and temperature affect the amount of ammonia produced

Problem 2, p. 272
To obtain the highest yield of ammonia:

25% 1. Use high T and P
25% 2. Use low T and P
25% 3. Use high T and low P
25% 4. Use low T and high P

Rates of change:

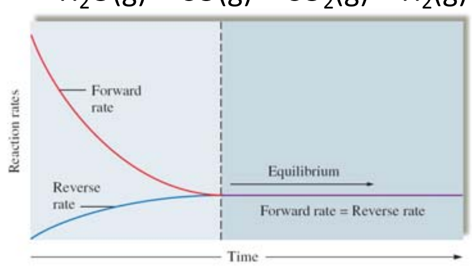
$H_2O(g) + CO(g) = CO_2(g) + H_2(g)$



How do the rates change with time?
How are the rates for change in products and reactants related?

Forward vs Reverse rate:

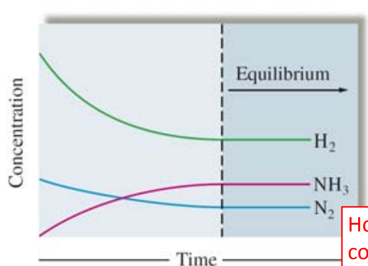
$H_2O(g) + CO(g) = CO_2(g) + H_2(g)$



How do the relative forward and reverse rates change with time?

Another example:

$N_2(g) + 3H_2(g) = 2NH_3(g)$



How are the rates consistent with the reaction coefficients?

The Equilibrium Constant

$N_2(g) + 3\,H_2(g) \;=\; 2NH_3(g)$

Concentrations of gases can be measured either in mol/L or in atm. In mol/L:

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Products in numerator

Reactants in denominator

The Equilibrium Constant

$N_2(g) + 3\,H_2(g) \;=\; 2NH_3(g)$

Exponents come from reaction coefficients

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Multiply by a constant

$2N_2(g) + 6\,H_2(g) \;=\; 4NH_3(g)$

$$K = \frac{[NH_3]^4}{[N_2]^2[H_2]^6}$$

If we multiply the reaction by a constant α

$$K \Rightarrow K^{\alpha}$$

If we reverse the reaction

$$K \Rightarrow \frac{1}{K}$$

Are K and K_p numerically equal?

$N_2(g) + 3\,H_2(g) = 2NH_3(g)$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} \qquad K_p = \frac{P_{NH_3}^2}{P_{N_2} P_{H_2}^3}$$

Related to the change in gas moles in the reaction.

In general $P_i = \frac{n_i RT}{V} = \left(\frac{n_i}{V}\right)RT = C_i RT = [i]RT$

$$K_p = \frac{P_{NH_3}^2}{P_{N_2} P_{H_2}^3} =$$

For the reaction

$N_2(g) + O_2(g) = 2\,NO(g)$

Does $K_p = K$?

1. Yes
2. No