CH301H – Principles of Chemistry I: Honors
Fall 2012, Unique 51390

Exam 4
29 November 2012

Name: Key

You may use your textbook and a calculator for arithmetic.

Assume ideal gas unless otherwise stated.

Honor Code:

"The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community."

I certify that the work on this exam is entirely my own.

Signature Date

1. (20 points) True / False: Determine whether each of the following statements are true or false.

a. True False A gas that demonstrates attractive intermolecular forces will have a real pressure that is lower than the pressure estimated by the ideal gas law.

b. True False If a molecule of $N_2(g)$ and a molecule of $H_2(g)$ collide, the reduced mass of the system is approximately equal to the mass of $H_2(g)$.

c. True False If the temperature of an ideal gas is doubled, the root mean square speed of molecules in that gas is doubled as well. $c \propto T^{1/2}$

d. True False van der Waals forces are only generated between two molecules containing a permanent dipole moment.

e. True False All gases are ideal in the limit of low pressure.

f. True False 10 g of hydrogen gas contains more hydrogen atoms than 100 g of water.

2. (20 points) While boarding an airplane in Austin, where the external air pressure is 1.0 atm and the temperature of the airport is 25°C, you are given a balloon filled with helium. Using the string to which it is tied, you measure the circumference of the balloon to be 40 cm. When your plane reaches an altitude of 36,000 ft, the temperature of the cabin has decreased to 21°C and circumference of the balloon has increased to 45.5 cm. What is the air pressure of the cabin? Assume a spherical balloon, and that the helium is behaving as an ideal gas.

@ P_1: $P_1 = 1\text{atm}$

$T_1 = 298\text{K}$

$V_1 = \frac{4}{3}\pi r^3 \quad r = \frac{C}{2\pi} = \frac{40\text{cm}}{2\pi} = 6.4\text{cm}$

$V_1 = \frac{4}{3}\pi (6.4\text{cm})^3 = 1083\text{cm}^3 \left(\frac{1\text{dm}}{10\text{cm}}\right)^3 \left(\frac{1\text{L}}{1\text{dm}^3}\right) = 1.083\text{L}$

@ P_2: $T_2 = 294\text{K}$

$V_2 = \frac{4}{3}\pi r^3 \;;\; r = \frac{45.5\text{cm}}{2\pi} = 7.24\text{cm}$

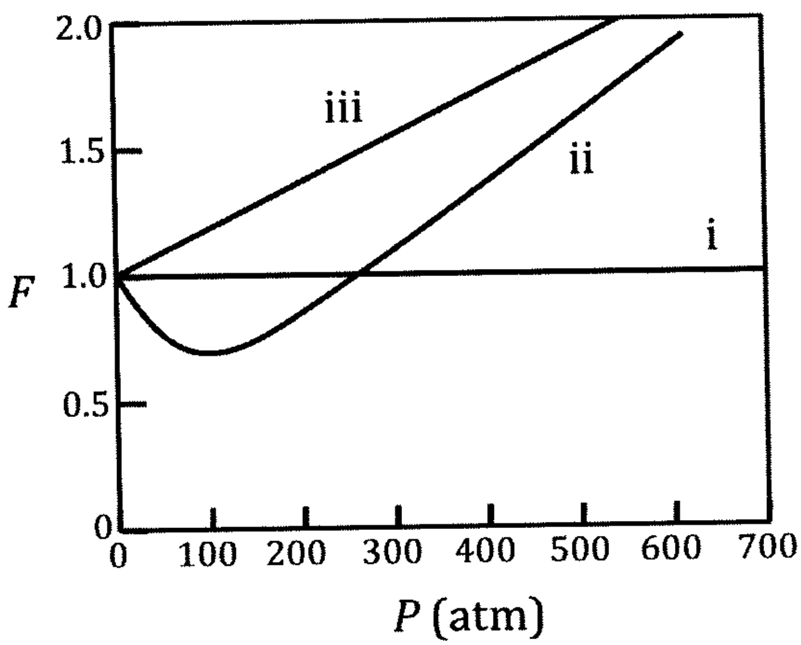
$V_2 = \frac{4}{3}\pi (7.24\text{cm}^3) = 1589.7\text{cm}^3 = 1.59\text{L}$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow P_2 = \frac{P_1 V_1 T_2}{T_1 V_2} = \frac{(1\text{atm})(1.083\text{L})(298\text{K})}{(294\text{K})(1.59\text{L})} = \boxed{0.69\text{atm}}$

3. (25 points) The easiest way to determine if gas molecules are expressing intermolecular forces is to compare the real pressure of the gas, $P(real)$, to the pressure calculated from the ideal gas law, $P(ideal)$. Let's define a constant, called a "nonideality factor," F, that is the ratio of these two pressures:

$$F = \frac{P(real)}{P(ideal)}$$

A plot of F *vs.* $P(real)$ for three gasses (labeled i, ii, and iii) is shown below:



a) What are the units of F? unitless

b) Describe the intermolecular forces (i.e. attractive or repulsive) for each of these gasses.

i) Ideal : Preal = Pideal under all pressures

ii) at low P, attractive forces dominate, at high P, repulsive forces dominate

iii) repulsive forces dominate at all P

c) Based on these descriptions, what happens to gas ii at P = 300 atm and why? Justify your answer.

Initially the sample is dominated by attractive forces, but as P↑, V↓, eventually molecules are too close together and repulsive forces take over. This will happen to all materials at high enough P.

4. (15 points) A mixture of 12.0 moles of an unknown gas and 15.5 moles of O_2 is held in a rigid container at 3 atm. A thermostat is used to maintain the temperature of the system at 300 K. The unknown gas begins to decompose to form 2 moles of gaseous product. When 4.8 moles of the unknown gas remain, what is the partial pressure of O_2?

$P_{TOT} = \sum_i P_i$

The partial pressure of O_2 does not change, even if the composition of the system is changing, because it is in a ridgid vessel (container won't expand). P_{TOT} is increasing, but $P(O_2)$ is constant.

P_1 = low
T_1 = 323k
n_1 = 2.0 mols

5. (20 points) 2.0 moles of an ideal gas is held in a container at a low pressure and heated to 50°C. Describe quantitatively the effects that each of the following changes will have on the i) system pressure, ii) average speed of an individual molecule of gas, iii) frequency of collisions between two molecules of gas, and iv) mean free path of an individual molecule of gas.

i) $P = \frac{nRT}{V}$

ii) $c = \left(\frac{3RT}{FW}\right)^{1/2}$

iii) $Z = \frac{PN_A}{RT}\sigma c_{rel}$

$c_{rel} = \sqrt{2}\,c$

iv) $\lambda = \frac{RT}{PN_A\sigma}$

a) The temperature is decreased to -50°C. $T_2 = 223k$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $P_2 = \frac{P_1 T_2}{T_1} = P_1\left(\frac{223k}{323k}\right) = \boxed{0.7 P_1 = P_2}$

$c\downarrow$ by $\sqrt{100}$ | $Z\downarrow$ by $\sqrt{100}$, $Z\uparrow$ by 0.001 $\Rightarrow Z\downarrow$ | $\lambda\downarrow$ cancel acceptable answer

b) The volume is doubled.

$P\downarrow$ by 1/2 c = no change, $Z\downarrow$ by $P\downarrow$

$\lambda\uparrow$ by $P\downarrow$

c) The amount of ideal gas is increased to 3.0 moles.

$P\uparrow$ by $\frac{3}{2}$ c = no change, $Z\uparrow$ by $P\uparrow$, $\lambda\downarrow$ by $P\uparrow$