CHEM 331
Physical Chemistry
Fall 2010

Problem Set 1

Reading

Chapter on "Empirical Properties of Gases" from the Castellan text (Handout)

Problems

1. A pressure is measured with a McLeod gauge. The gauge has a bulb volume of 150 cm^3, and the diameter of the capillary tube is 1 mm. When the Mercury comes to equilibrium, it reaches a level 6.7 cm below the sealed end of the bulb capillary and rises to 13.6 cm above the sealed end in the side capillary. Calculate the pressure.
[Ans. 9.49 kPa]

2. An oil-diffusion pup aided by a mechanical forepump can readily produce a "vacuum" with pressure 10^{-6} Torr. At 25°C, calculate the number of molecules per cm^3 in the "vacuum".

3. Charles' Law is sometimes written in the form:

$$V = V_o (1 + \alpha\theta)$$

where θ is the Celsius temperature, α is a constant, and V_o is the folume of the sampel at 0°C. The following values of α have been reported for Nitrogen at 0°C:

P [Torr]	$10^3\alpha$ [$^oC^{-1}$]
749.7	3.6717
599.6	3.6697
333.1	3.6665
98.6	3.6643

Using this data calculate the best value for the Absolute Zero of Temperature on the Celsius scale.

4. Calculate the Standard Molar Volume. That is, calculate the volume of 1 mole gas at a the Standard Pressure 101,325 Pa and a temperature of 0°C.
[Ans. 0.022414 m^3]

5. Nitrogen Tetroxide, N_2O_4, partially dissociates into NO_2 according to:

$$N_2O_{4(g)} \rightleftharpoons 2\ NO_{2(g)}$$

When 4.367g N_2O_4 is placed in a flask at 25°C and kept at 101.3 kPa pressure, the volume is 1.356 L when the system reaches equilibrium. To what extent does the gas dissociate? [Ans. 0.166]

6. Water boils at 100°C. The density of Water is 1g/cm^3. Calculate the percentage increasein volume as Water passes from a liquid to a gas at 100°C.

7. In the 1950s, before the Liter was redefined to be exactly 1 dm^3, the Liter was defined as the volume occupied by 1 kg of Water at its maximum density, and it was equal to 1.000028 dm^3. How did this definition affect the difference in the Universal Gas Constant as measured in Liter-Atmospheres?

8. A gas sample is known to be a mixture of Ethane and Butane. A bulb of 200.0 cm^3 capacity is filled with the gas to a pressure of 100.0 kPa at 20.0°C. If the weight of gas in the bulb is 0.3846g, what is the mole percent of Butane in the mixture?

9. The Coefficient of Thermal Expansion (α) is defined as:

$$\alpha = \left(\frac{1}{V}\right)\left(\frac{\partial V}{\partial T}\right)_p$$

The Coefficient of Compressibilty (κ) is defined as:

$$\kappa = -\left(\frac{1}{V}\right)\left(\frac{\partial V}{\partial P}\right)_T$$

Compute the values of α and κ for an Ideal Gas. Express the derivative:

$$\left(\frac{\partial P}{\partial T}\right)_V$$

in terms of α and κ.
[Ans. $\alpha = 1/T$ and $\kappa = 1/P$]

10. For an Ideal Gas, show that:

$$dP = P(n^{-1}dn + T^{-1}dT - V^{-1}dV)$$

Suppose 1.0000 mole of Ideal Gas at 300.00K in a 30.000 L vessel has its temperature increased by 1.00K and its volume increased by 0.050 L. Use the above result to estimate the change in pressure, ΔP. Calculate ΔP exactly and compare it with your estimate.

11. The density of Water vapor at 100°C and 101.3 kPa pressure is 0.0005970 g/cm^3. Calculate the Molar Volume. How does this compare with the Ideal Gas Molar Volume?

12. At 273.15K the density of Nitric Oxide at various pressures was found to be:

P [atm]	ρ [g/dm^3]
1.0000	1.3402
0.8000	1.0719
0.5000	0.66973
0.3000	0.40174

Calculate ρ/P at each pressure and determine and exact value for the Atomic Weight of Nitrogen. Take the Atomic Weight of Oxygen as 15.9994 g/mole.