CHM 3400 – Fundamentals of Physical Chemistry
First Hour Exam

There are five problems on the exam. Do all of the problems. Show your work

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R = 0.08206 L·atm/mole·K	$N_A = 6.022 \times 10^{23}$
R = 0.08314 L·bar/mole·K	1 L·atm = 101.3 J
R = 8.314 J/mole·K	1 atm = 1.013 bar = 1.013×10^5 N/m^2
	1 atm = 760 torr

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1. (20 points) A gas mixture contains two gases, neon (Ne, M = 20.17 g/mol) and argon (Ar, M = 39.95 g/mol). The density of the gas mixture, at T = 300.0 K, is ρ = 0.562 g/L, and the partial pressure of neon in the gas mixture is p(Ne) = 328. torr. You can assume ideal gas behavior for the gases in the mixture.

a) Find the mass of neon contained in 1.000 L of the above gas mixture.

b) Find p(Ar), the partial pressure of argon in the above gas mixture. Give your final answer in units of torr.

2. (20 points) In an experiment, 4296. J of heat is added to a sample of a substance (<u>not an ideal gas</u>). The addition of heat is carried out reversibly and at a constant external pressure p_{ex} = 24.10 atm. The temperature of the substance increases from an initial value T_i = 22.8 °C to a final value T_f = 37.9 °C. During the process, the volume occupied by the substance increases by 9.8 mL. Based on the above information, find the following:

a) C_p, the average value for the constant pressure heat capacity for the substance over the temperature range of the process carried out above.

b) q, w, ΔU, and ΔH for the process.

3. (20 points) Ammonia (NH_3, M = 17.03 g/mol) is a trace gas in the Earth's atmosphere, and is also found in the atmospheres of other planets and moons.

a) What is the v_{rms}, the rms average speed of an ammonia molecule, at T = 500.0 °C?

b) One formula for modeling the temperature dependence of the constant pressure molar heat capacity of a gas has been developed by researchers at NASA. They fit experimental data to a polynomial expression in terms of temperature. For ammonia (NH_3) the equation they use is as follows:

$$C_{p,m}(NH_3(g)) = a + bT + cT^2 \qquad (3.1)$$

For ammonia, the values for the fitting parameters are a = 24.619 J/mol·K, b = 3.75×10^{-2} J/mol·K^2, and c = $- 0.138 \times 10^{-5}$ J/mol·K^3. Note that T in eq 3.1 is the absolute temperature (in Kelvin).

Find the values for q, w, ΔU, and ΔH when the temperature of 1.000 mole of ammonia gas changes from an initial value T_i = 300.0 K to a final value T_f = 800.0 K by a reversible heating of the gas at a constant pressure p = 5.00 torr. You may assume that for the conditions of pressure and temperature in the problem ammonia obeys the ideal gas law.

4. (20 points) Pyrogallol (1,2,3-trihydroxybenzene, $C_6H_3(OH)_3(s)$) is used in some hair dyes and also in the analysis of the oxygen content of gas samples.

a) Give the correctly balanced formation and combustion reaction for pyrogallol.

b) Based on the data below, find the value for $\Delta H°_f(C_6H_3(OH)_3(s))$, the enthalpy of formation for pyrogallol.

Combustion data	Formation data
$\Delta H°_c(C_6H_3(OH)_3(s)) = -2672.3$ kJ/mol	$\Delta H°_f(CO_2(g)) = -393.51$ kJ/mol
	$\Delta H°_f(H_2O(\ell)) = -285.83$ kJ/mol

5. (20 points) Thermodynamic data for several pure chemical substances are given below (at T =298.0 K), and may be of use in doing the following problem.

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol·K)	$C_{p,m}$ (J/mol·K)
CuO(s)	- 157.3	- 129.7	42.63	42.30
$Cu_2O(s)$	- 168.6	- 146.0	93.14	63.64
$O_2(g)$	0.0	0.0	205.14	29.36

a) What are the values for $\Delta G°_{rxn}$, $\Delta H°_{rxn}$, and $\Delta S°_{rxn}$ (at T = 298.0 K) for the following reaction?

$2\ Cu_2O(s) + O_2(g) \rightarrow 4\ CuO(s)$

b) What is the value of S° for CuO(s) at T = 373. K?