Chemistry 342
September 25, 1998
First Exam

$1\ \mathrm{J} = 1\ \mathrm{kg\ m^2\ s^{-2}}$ $k_B = 1.38066\times10^{-23}\ \mathrm{J\ K^{-1}}$ $R = N_{Avogadro}k_B$

$R = 8.31441\ \mathrm{J\ mol^{-1}\ K^{-1}} = 1.98718\ \mathrm{cal\ mol^{-1}\ K^{-1}} = 0.082057\ \mathrm{L\ atm\ mol^{-1}\ K^{-1}}$

$p/p_0 = \exp[-(M/RT)gz]$ *barometric formula*

$C_p - C_V = \{p + (\partial U/\partial V)_T\}(\partial V/\partial T)_p$ $(\partial H/\partial p)_T = [p + (\partial U/\partial V)_T](\partial V/\partial p)_T + V$

$\mu_{JT} = (\partial T/\partial p)_H$ $(\partial H/\partial p)_T = -C_p\,\mu_{JT}$

monatomic gas molar heat capacity: $C_V = (3/2)R$

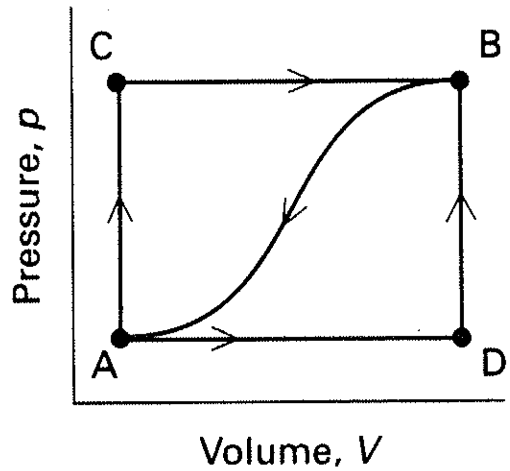
1. Investigate some of the technicalities of ballooning using the perfect gas law. Suppose your balloon has a capacity of $10^3\ \mathrm{m^3}$ is filled with He at 20°C and 1 atm pressure. Assume that the volume of the baloon is constant, the atmosphere isothermal at 20°C and the molecular weight of air is 28.8 and the ground level pressure is 1 atm. The balloon itself is made of material whose mass may be neglected compared to the load.

(a) What is the density of air at ground level?

(b) What is the load that the balloon can lift at ground level? [Hint: Archimedes]

(c) If the balloon is loaded with 80% of the load that it can lift at ground level, at what height will the balloon come to rest?

2. When a system is taken from state A to state B along the path ACB in the figure below, 80 J of heat flows into the system and the system does 30 J of work.



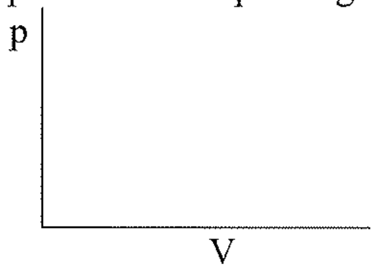
(a) How much heat flows into the system along path ADB if the work done is 10 J?

(b) When the system is returned from state B to A along the curved path, the work done on the system is 20 J. Does the system absorb or liberate heat, and how much?

(c) If U_D-U_A = +40 J, find the heat absorbed in each of the processes AD and DB.

3. Assume that air behaves as an ideal gas with $C_p = (7/2)R$.

(a) In one experiment 1.00 mole of "air molecules" is compressed from 1.00 atm to 10.0 atm at 25°C by the following reversible process: (1) heating at constant volume to the final pressure, followed by (2) cooling at constant pressure to 25°C. Sketch these processes on a pV diagram.



(Initial)$_1$ (Final)$_1$& (Initial)$_2$ (Final)$_2$

Calculate ΔU, ΔH, q, and W, in kJ for each step in the process and for the overall process.

step 1	*step 2*	*overall*
q	*q*	*q*
W	*W*	*W*
ΔU	ΔU	ΔU
ΔH	ΔH	ΔH

4. n moles of a gas obeying the equation of state $p(V-nb) = nRT$ ($b = 10^{-1}$ L mol^{-1}) and has $(\partial U/\partial V)_T = 0$, $(\partial H/\partial p)_T = -b$ is subjected to an isothermal reversible expansion from an initial volume of 1.00 L to 24.8 L at 298 K. Calculate the values of ΔU, ΔH, q, and W, in kJ (in terms of n).

q	W
ΔU	ΔH

5. Calculate the standard enthalpy of formation $\Delta_f H^{\ominus}$ of $KClO_3$ from the enthalpy of formation of KCl (-436.75 kJ mol^{-1}) together with the following information all at 298 K:

$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ $\qquad \Delta H^{\ominus} = -89.4$ kJ mol^{-1}

6. A cylindrical container of fixed total volume is divided into three sections, S_1, S_2, and S_3. The sections S_1 and S_2 are separated by an adiabatic piston, whereas S_2 and S_3 are separated by a diathermic (heat conducting) piston. The pistons can slide along the walls of the cylinder without friction. Each section of the cylinder contains 1.00 mole of a perfect diatomic gas [$C_V = (5/2)R$]. Initially the gas pressure in all three sections is 1.00 atm and the temperature is 298 K. The gas in S_1 is heated slowly until the temperature of the gas in S_3 reaches 348 K.

Find the final temperature, pressure, and volume, as well as the change in internal energy for each section.

S_1	S_2	S_3
p_f	p_f	p_f
V_f	V_f	V_f
T_f	T_f	T_f
ΔU	ΔU	ΔU

Determine the total energy supplied to the gas in S_1.