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Your name: ______________________________

Chemistry 342

First Exam

September 24, 1999

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

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

$p/p_0 = \exp[-(M/RT)gz]$ *barometric formula where* g = 9.80665 m s^{-2}

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

General relations for any equation of state:

$(\partial U/\partial V)_T = T(\partial p/\partial T)_V - p$ $(\partial H/\partial p)_T = -T(\partial V/\partial T)_p + V$

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

1. A monatomic gas obeys the equation of state $pV = nRT + nap$ where a = 0.02 L mol^{-1}, such that $(\partial U/\partial V)_T = 0$ for the gas. This gas is taken from state $\mathcal{A}$ (10. L, 1 atm, T= 304.7 K) to state $\mathcal{B}$ (? L, 20 atm, T= 304.7 K) by several possible paths.

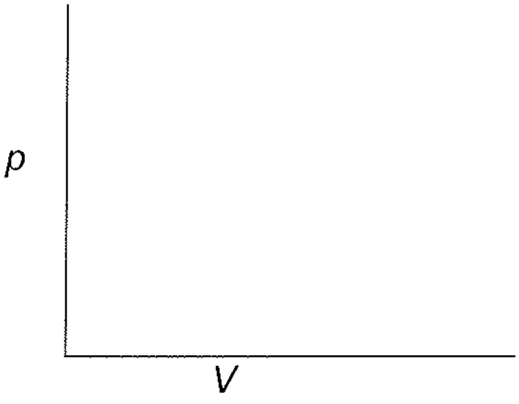
Path I : A compression along the isotherm connecting initial and final states.

Path II: A constant volume process which takes the gas from the initial pressure to the final pressure, followed by a constant pressure (20 atm) process which takes the gas to the final state.

Path III: A constant pressure (1 atm) process which takes the gas from the initial volume to the final volume, followed by a constant volume process which takes the gas to the final state.

Consider each $\mathcal{A}\rightarrow\mathcal{B}$ path and **calculate** ΔU and ΔH in joules **for each path.** **For each path**, **calculate** q and W where possible (if not, say why not).

First, **draw** these three paths on the pV diagram of the gas:



Path I	Path II	Path III
W	*W*	*W*
q	*q*	*q*
Δ***U***	Δ***U***	Δ***U***
Δ***H***	Δ***H***	Δ***H***

2. The biochemical reactions necessary to sustain life in a person produce about 6000 kJ day^{-1} of heat at constant pressure. This is the basal metabolic rate. Consider one of the large number of reactions that may occur:

$$3O_2(g, 1\ \text{atm}) + 2\ \text{glycine(aq.)} \rightarrow \text{urea(aq.)} + 3CO_2(g, 1\ \text{atm}) + 3H_2O(l)$$

Suppose that you have obtained from the data section of your textbook, the following *standard enthalpies of transformation at 298 K in kJ mol*$^{-1}$:

$\Delta H^{\ominus}$ of oxidation of 1 mol solid glycine to CO_2 , ammonia, and liquid water $= a$

$\Delta H^{\ominus}$ of hydrolysis of 1 mol solid urea to CO_2 and ammonia $= b$

$\Delta H^{\ominus}$ of dissolution of solid glycine $= c$

$\Delta H^{\ominus}$ of dissolution of solid urea $= d$

In case you have forgotten: glycine NH_2CH_2COOH urea H_2NCONH_2
(aq.) means very dilute aqueous solutions

Suppose n moles of urea are produced via this reaction per day,
how many kJ day^{-1} is the contribution of this reaction to the metabolic rate?

3. If two gases A and B of molecular weight x and y (g mol^{-1}) respectively are found at equal abundance in the atmosphere at sea level, at what height should we expect to find gas A to be three times as abundant as gas B? You may assume that the atmosphere is isothermal at 298 K.

4. If a compound is burned under adiabatic conditions so that all the heat evolved is used in heating the product gases, the maximum temperature reached is called the adiabatic flame temperature. **Calculate this temperature** for the burning of acetylene (ethyne) in oxygen sufficient for complete combustion to CO_2 and $H_2O(g)$. **Predict**: Do you expect the flame temperature of an oxyacetylene torch to be higher or lower when excess oxygen is used?

For ease of calculations, assume independent of temperature the following data:

	C_p J mol^{-1} K^{-1}	C_V J mol^{-1} K^{-1}
$H_2(g)$	28.824	20.5
$O_2(g)$	29.355	21.0
$H_2O(g)$	33.58	25.3
$H_2O(l)$	75.291	75.2
$CO_2(g)$	37.11	28.8
HCCH(g)	43.93	35.0

Also, you may use the following values at 298 K

$\Delta_f H^\ominus$ for the formation of	$\Delta_f H^\ominus$ kJ mol^{-1}
$H_2O(g)$	-241.82
$H_2O(l)$	-285.83
$CO_2(g)$	-393.51
HCCH(g)	+226.73

and at 373 K

$\Delta_{vap} H^\ominus$ for H_2O kJ mol^{-1}
40.656

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~~6~~. Ten moles of nitrogen at 300 K are held by a piston under 40 atm pressure. The pressure is suddenly released to 10 atm and then the gas expands adiabatically. If C_V for N_2 is assumed to be constant and equal to 20.8 J mol^{-1} K^{-1}, calculate the final temperature of the gas. Assume the gas is ideal. Calculate ΔU and ΔH for the change in the gas.

ΔU	ΔH