Exam I

CH 353 Summer '09

Vanden Bout

Name: KEY

Carefully read all the problems. The exam should have 4 pages of questions. The first page has potentially useful information. The last page is for extra writing space. Problems may have extraneous information.

Potentially useful information

$R = 8.314\ J\ K^{-1}\ mol^{-1}$ $R = 8.314 \times 10^{-2}\ L\ bar\ K^{-1}\ mol^{-1}$ $R = 8.206 \times 10^{-2}\ L\ atm\ mol^{-1}\ K^{-1}$

1 cal = 4.184 J 1 atm = 1.01325 bar T/K = T/°C + 273.15

1 atm-L = 101.325 J 1 bar-L = 100 J

$$\int \frac{dx}{a+x} = \ln(a+x) \qquad \int \frac{dx}{x^2} = -\frac{1}{x}$$

Van der Waals equation $(P + \frac{a}{V_m^2})(V_m - b) = RT$

$$w = -\int P_{ex} dV$$

$$q = \int C_v dT \qquad q = \int C_P dT$$

$$\Delta U = q + w \qquad H \equiv U + PV$$

Please sign at the bottom to certify that you have worked on your own.

I certify that I have worked the following exam without the help of others, and that the work I am turning in is my own.

Signed: --

Signature Date

1. True/False (10 points each)
Classify the following as either True or False

T	(F)	For a reversible process ΔU is always = 0.	true if cyclic
T	(F)	ΔH is always equal to the heat	only at constant P
(T)	F	Real gases behave ideal in the limit of low pressure	
T	(F)	For any process that increases the temperature of the system, q must be greater than zero.	example: adiabatic compression
(T)	F	If a gas is compressed irreversibly in a single step, the final volume will be larger if the compression is carried out adiabatically compared to isothermally.	

2. Short Answer (25 points each)

A. A van der Waals gas has coefficients $a = 4.225\ L^2\ bar\ mol^{-2}$ and $b = 0.037\ L\ mol^{-1}$.

What is the pressure when 1 mole of gas has a volume of 0.25 L at 400 K?

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2} = \frac{(0.08314\ L\,bar\,K^{-1}mol^{-1})(400K)}{0.25\ L mol^{-1} - 0.037\ L mol^{-1}} - \frac{4.225 L^2 bar\ mol^{-2}}{(0.25\ L mol^{-1})^2}$$

$$P = 88.51\ bar$$

Are the intermolecular forces for this gas dominated by attractions or repulsions? Give a numerical justification for your answer.

$$Z = \frac{PV_m}{RT} \quad \frac{(88.51\ bar)(0.25\ L mol^{-1})}{(0.08314\ L bar K^{-1} mol^{-1})(400K}$$

$Z = 0.66 < 1$ Attractions dominate

B. 2 moles of an ideal gas ($C_{V,m}$= 1.5R) are in a constant temperature bath at 25°C and an initial pressure of 1 bar. If the pressure is suddenly increased in one step to a pressure of 4 bar and the gas compresses until mechanical equilibrium is reached, what are q, w, and ΔU for this process (give your answer in J).

Isothermally, irreversibly $\Delta U = 0$ $q = -w$

$w = -P_{ex}\Delta V = -P(V_f - V_i)$ $V_f = 4V_i$

$PV = nRT$

$w = -P_f V_f - 4P_i V_i = -n3RT = -6RT$

$V_i = \frac{n_i RT}{P_i}$

$w = -6\,mol(8.314\ J K^{-1} mol^{-1})(298\ K) = 14866\ J$

$V_f = \frac{n_f RT}{P_f}$

$q = -w = -14866\ J$

$n_i = n_f = 2$

3. (50 points)

The following reaction is part of the Ostwald process for the production of Nitric Acid

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

Substance	$\Delta_f H°$ (kJ mol^{-1}) 298K	S° (J K mol^{-1})	C_P (J K^{-1} mol^{-1})
O_2 (g)	0	205.4	29.4
H_2O (g)	-241.8	188.8	33.6
NH_3 (g)	-46.1	192.5	35.1
NO (g)	+90.25	210.7	29.8

What is $\Delta_R H°$ at 298 K

$\Delta_r H° = \sum_{prod} \nu_i \Delta_f H_i° - \sum_{reactants} \nu_i \Delta_f H_i° = -905.4$ kJ/mol

What is $\Delta_R H°$ at 1000 K

If 100 g of ammonia are reacted with excess oxygen at 1000 K, what are

ΔH, ΔU, q, and w?

At 1000 K: $\Delta_r H°(1000\,K) = \Delta_r H°(298\,K) + \Delta C_P (1000-298)$

$\Delta_r H(1000\,K) = -905.4$ kJ/mol $+ (6(33.6) + 4(29.8) - 5(29.4) - 4(35.1))\,702$ J/mol

$\Delta H_r(1000\,K) = -905.4$ kJ/mol $+ (33.4)(702)(10^{-3})$ kJ/mol

$\Delta H_r(1000\,K) = -881.9$ kJ/mol

$n = \frac{100\,g\,NH_3}{} \cdot \frac{1\,mol\,NH_3}{17\,g} \cdot \frac{1\,mol\,rxn}{4\,mol\,NH_3} = 1.47$ mol

$\Delta H = n\,\Delta_r H(1000\,K) = (1.47)(-881.9) = 1296$ kJ/mol

$\Delta U = \Delta H - \Delta n RT$ $\Delta n = 10 - 9 = 1$

$\Delta_r U = -881.9$ kJ/mol $- (1)(8.314\,J K^{-1} mol^{-1})(1000\,K)$

$\Delta_r U = -890.2$ kJ/mol

$\Delta U = n \Delta_r U = 1.47(-890.2) = -1308$ kJ

$\Delta H = q_P = -1296$ kJ

$dU = dq + dw$

$U = q + w$

$w = (+1296) + (-1308) = -12$

$\Delta_f H°_{298} =$ -905.4 kJ/mol

$\Delta_f H°_{1000} =$ -881.9 kJ/mol

ΔH = -1296 kJ

ΔU = -1308 kJ

w = -12 kJ

q = -1296 kJ

4. (50 points)

2 moles of an ideal gas with an unknown heat capacity are in a piston at an initial temperature of 300K. The piston is held at constant pressure. The piston is brought into contact with a constant temperature bath of an unknown temperature. Heat flows into the system causing the gas to both expand and change temperature. After the temperature has equilibrated, the work for this process is found to be, w= -3.325 kJ. **What is the temperature of the bath?**

Constant pressure

$w = -P_{ext}\Delta V = -P(V_f - V_i)$

$-3.325 = -P_f V_f + P_i V_i$

$-3.325\,kJ = -nRT_f + nRT_i$

$-3.325\,kJ = -nR(\Delta T)$

$\Delta T = \frac{(-3.325\,kJ)1000}{(-2)(8.314\,J\,K^{-1}\,mol^{-1})}$

$\Delta T = 200\,K$

$T_f = 200K + 300K = 500K$

$T_f = 500K$

Extra Credit (10 points) If the piston raised up 0.1 m, how much does the mass weigh?

$w = mgh$ $\quad m = \frac{w}{gh} = \frac{3325\,J}{(9.8\,ms^{-2})(0.1\,m)}$

$J = kg\,m^2 s^{-2}$

$m = 3392\,kg$