Exam I

CH 353 Summer '08

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 = 8.314x10^{-2} L bar K^{-1} mol^{-1} R = 8.206x10^{-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 cyclic process ΔT is always = 0.
T	F	An ideal gas has no kinetic energy
T	F	The van der Waals a constant is larger for H_2O than for O_2.
T	F	If $\Delta T = 0$, then q is always = 0
T	F	At constant volume, ΔH is always = ΔU.

2. Short Answer (25 points each)

A gas obeys the following equation of state

$$PV_m + \frac{\beta}{V_m} = RT \text{ where } \beta \text{ is a positive constant}$$

Are the intermolecular forces for this gas dominated by attractions or repulsions or does it depend on the temperature?

$$P = \frac{RT}{V_m} - \frac{\beta}{V_m^2} \qquad Z = \frac{PV_m}{RT} = \left(\frac{RT}{V_m} - \frac{\beta}{V_m^2}\right)\left(\frac{V_m}{RT}\right)$$

$$Z = 1 - \frac{\beta}{V_m RT} < 1 \text{ at all } T$$

$\therefore$ always in attractive limit.

B. Imagine you had a substance for which

$$\left(\frac{\partial V}{\partial T}\right)_P = 0$$

Do you think this substance would have a constant volume heat capacity that was larger, smaller, or the same as it constant pressure heat capacity?

The same. Since $\left(\frac{\partial V}{\partial T}\right)_P = 0$ there is no volume change when the temperature changes at const P. $\Delta V = 0$ $w = 0$ & $C_p = C_v$.

3. (50 points)

You synthesize a new solid compound with the molecular formula $C_{12}H_{22}O_{11}$

Substance	$\Delta_f H°$ (kJ mol^{-1})	C_P (J K^{-1} mol^{-1})
O_2 (g)	0	29.4
H_2O (l)	-286	75.3
CO_2 (g)	-393.5	37.11

You completely react 2 g of the compound with excess oxygen to form gaseous CO_2 and liquid H_2O. You perform this reaction at a constant pressure of 1 atm.

The heat released from the reaction is measured to be 33 kJ.

300K

What are ΔH, ΔU, and w for the reaction?

What is std. enthalpy of formation ($\Delta_f H°$) for the compound you synthesize?

$$C_{12}H_{22}O_{11}(s) + 12 O_2(g) \longrightarrow 12 CO_2(g) + 11 H_2O(l)$$

$$M.W. = 342.3 \text{ g mol}^{-1}$$

$$n = \frac{2}{342.3} = 5.843 \cdot 10^{-3} \text{ mol}$$

$$\Delta H = n \times \Delta_r H° \qquad \Delta_r H° = \frac{\Delta H}{n} = \frac{q}{n} = \frac{-33}{5.843 \cdot 10^{-3}} = -5648 \text{ kJ mol}^{-1}$$

$$\Delta_r H° = 12 \times \Delta_f H°_{CO_2(g)} + 11 \Delta_f H°_{H_2O} - \Delta_f H°_{C_{12}H_{22}O_{11}}$$

$$-5648 = 12(-393) + 11(-286) - \Delta_f H°_{C_{12}H_{22}O_{11}}$$

$$\Delta_f H°_{C_{12}H_{22}O_{11}} = -2214 \text{ kJ mol}^{-1}$$

ΔH = -33 kJ

ΔU = -33 kJ

w = 0

$\Delta_f H°$ = -2214 kJ mol^{-1}

$$\Delta H = q$$

$$\Delta U = \Delta H - \Delta(PV)$$

$$\Delta U = \Delta H - \cancel{\Delta n RT}^{\,0} = \cancel{0}$$

4. (50 points)

2 moles of an ideal gas with a molar constant volume heat capacity of 1.5R is initially at a pressure of 1 bar, and a temperature of 300 K.

1st. The gas is compressed isothermally by a constant external pressure of 5 bar until mechanical equilibrium is reached.

2nd. The gas is cooled at constant volume until the pressure is 3 bar

What are ΔU, ΔH, q, and w for the combined two processes?

$\Delta H_1 = 0$

step 1 $\quad \Delta T_1 = 0 \quad \Delta U_1 = 0 \quad w_1 = -q_1$

$W_1 = -P_{ex}\Delta V = -P_f(V_f - V_i) = -P_f V_f + \frac{P_f}{P_i} P_i V_i$

$w_1 = -nRT + 5nRT = 4nRT$

$w_1 = 4(2)(8.314)(300) = 19.95\ kJ$

$q_1 = -19.95\ kJ$

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step 2 at const V to make P=3 atm

$T_f = \frac{3}{5} T_i = \frac{3}{5} 300 = 180K$

$q_2 = \Delta U_2 = C_v \Delta T = 3R(180-300) = -2.99\ J$

$W_2 = 0$

$\Delta H_2 = C_p \Delta T = 5R(-120) = -4.99\ kJ$

ΔH = -5 kJ

ΔU = -3 kJ

w = +20 kJ

q = -25 kJ

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