Quiz I

CH 353 Summer '10

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

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

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 Conservation of energy tells that $\Delta U = 0$ for all processes. $\Delta U = q + w$

T F For an adiabatic process, ΔH is always zero only for const P $\Delta H = q$

T F Real gases behave ideally in the limit of low pressure

T F If adding 25 J of heat to a 5.6 g block of iron increases it temperature by 10° C, then adding 25 J of heat to a 2.8 g block of iron will increase its temperature by 20°C.

T F When the heat for a process is positive, there is always an increase in temperature. for example isothermal expansion IG

2. Short Answer (25 points each)

A. Explain **briefly** why the constant pressure heat capacity is always bigger than the constant volume heat capacity. Unnecessarily long answers will lose points

At constant volume all the energy entering the system must go to temperature change as there is no expansion. At constant pressure some of the heat goes to temperature change and some leaves the system as work. ∴ for the same ΔT you require more heat at const P

B. You have two containers that each are holding 1 mole of a gas. Both containers have a temperature of 400 K and are at a pressure of 1 bar.

Container A has a volume of 33.268 L
Container B has a volume of 32.894 L

State whether the forces for each gas are dominated by attractions or repulsions.

One of the gases is Helium and the other is Butane. Which do you think is which and why? (credit is for the explanation not just guessing correctly)

What is the volume of IG under these conditions.

$$V = \frac{nRT}{P} = \frac{(1\ \text{mol})(.08314\ \text{L-bar}\,K^{-1}\text{mol}^{-1})(400\ K)}{(1\ \text{bar})} = 33.256\ L$$

Container A

$$\frac{V_A}{V_{IG}} > 1$$

dominated by repulsions

V_A almost equal to V_{IG}

NEARLY IDEAL

He (few interparticle forces)

container B

$$\frac{V_B}{V_{IG}} < 1$$

dominated by attractions

V_B significantly different from V_{IG}

Butane (more interparticle interactions)

3. (50 points)

A certain material has a heat capacity of 10 J K g^{-1}. Over a certain range this material expands linearly with temperature such that it increases in size by 0.1% every 10 K. The density of the material is 10 g cm^{-3}.

You initially have a 100 g block of this material at 300 K. You hold it in contact with a constant temperature source at 325 K and a constant pressure of 1 bar, until it reaches thermal equilibrium. What are ΔU, ΔH, q, and w for this process?

$$C = (10\ J K^{-1} g^{-1})(100\ g) = 10^3\ J K^{-1}$$

$$q = C\Delta T = (10^3\ J K^{-1})(325 K - 300 K) = 25{,}000\ J \boxed{= 25\ kJ}$$

$$\boxed{\Delta H = q = 25\ kJ}$$

$$\Delta U = q + w$$

$$w = -P_{ex}\Delta V \quad \text{what are } V_i \text{ \& } V_f$$

$$V_i = \frac{100\ g}{10\ g\ cm^{-3}} = 10\ cm^{-3} = 0.01\ L$$

$$V_f = 0.01 L + (\overset{.1\%}{.001})(2.5)(.01) = .010025\ L$$

$$\Delta V = 2.5 \cdot 10^{-5} L$$

$$w = -P_{ex}\Delta V = -(1\ bar)(2.5 \cdot 10^{-5} L) = -2.5 \cdot 10^{-5}\ L\text{-bar}$$

$$\boxed{w = -2.5 \cdot 10^{-3}\ J}$$

ΔH = 25 kJ

ΔU = 24.9999975 kJ

w = $-2.5 \cdot 10^{-3}$ J

q = 25 kJ

$$\Delta U = 25\ kJ - 2.5 \cdot 10^{-3} J$$

$$\boxed{= 24{,}999.9975\ J \approx 25\ kJ}$$

4. (50 points)

2 moles of an ideal gas ($\overline{C}_V = 1.5$ R) are initially at a pressure of 1 bar, and a temperature of 400 K.

First the gas is heated at constant pressure until the volume is doubled.

Second the gas is cooled at constant volume until the pressure is 0.75 bar.

Last, the gas is returned to a pressure of 1 atm and 400 K by an unknown process that requires 7000 J of work.

Find, q, w, ΔU, and ΔH for the total of all three steps.

initial

$P_i = 1$ bar $T_i = 400$ K

final

$P_f = 1$ bar $T_f = 400$ K

CYCLIC Process $(1 \to 2 \to 3)$ after all three steps

$\boxed{\Delta U = 0 \quad \Delta H = 0}$

step 1 $T_f = 2 \times T_i = 800$ K

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

$w_1 = -\cancel{P_f}\left(\frac{nRT_f}{\cancel{P_f}} - \frac{nRT_i}{\cancel{P_f}}\right)$

$= -nR\Delta T$

$= -(2)(8.314\ \mathrm{J\,K^{-1}mol^{-1}})(400\ \mathrm{K})$

$\boxed{w_1 = -6651.2\ \mathrm{J}}$

step 2

$\Delta V = 0$

$\boxed{w_2 = 0}$

step 3

$\boxed{w_3 = 7000\ \mathrm{J}}$

given

ΔH = 0

ΔU = 0

w = 348.8 J

q = -348.8 J

$w = w_1 + w_2 + w_3$

$$\boxed{\begin{aligned} w &= -6651.2 + 0 + 7000 = 348.8\ \mathrm{J} \\ q &= \Delta U - w = 0 - 348.8 = -348.8\ \mathrm{J} \end{aligned}}$$