University of British Columbia

Midterm Examination – March 6, 2012

Chemistry 201

Time: 70 min

Candidate's Name (in ink): ______________________________
(**family name**) (**first name**)

Student Number (in ink): ______________________________

Candidate's Signature (in ink): ______________________________

This examination consists of FIVE pages in total, including this cover page stapled to FOUR question pages. Please check to ensure that you have a complete examination.

Answer all questions on this examination paper in the space provided.

Read and observe the following rules:

1. Each candidate should be prepared to produce, upon request, his/her library/AMS card.
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions. CAUTION - Candidates guilty of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:
   a) making use of any book, paper, memorandum, recorder, cellular phone or any other electronic device, other than the authorized non-programmable Sharp EL-510R scientific calculator;
   b) speaking or communicating with other candidates;
   c) purposely exposing written papers to the view of other candidates.
   d) copying the exam by any means.

   The plea of accident or forgetfulness shall not be accepted.
3. No candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during that first half-hour.
4. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator in charge.
5. All electronic devices, other than your **Sharp EL-510R calculator**, must be fully turned **off**.

In general, consider all given data good to four significant figures and give your answers to three figures. For example, use: $R = 8.314\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}$
1 L atm = 101.3 J   1 atm = 101.3 kPa   0 K = -273.2 °C

Q1	______ / 10	SHOW ALL WORK AND
Q2	______ / 15	PRESENT YOUR ANSWERS
Q3	______ / 15	WITHIN THE SPACE PROVIDED.
Q4	______ / 10	

Total Marks ______ / 50

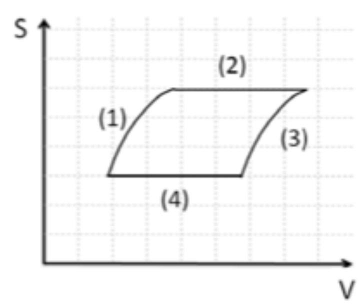
Q1) A sample containing two moles of He gas behaves ideally. In state A, it is at (P_A, V_A, T_A). In the first step of a four step process, it expands isothermally and reversibly to state B, in which $V_B = 2\ V_A$. In the second step, it expands adiabatically and reversibly to state C, in which $T = T_C$. In the third step, it is compressed isothermally and reversibly to state D, in which $V_D = (1/2)\ V_C$. In the fourth and final step, the system returns adiabatically and reversibly to state A.

a) Determine the entropy change for the system for each of the four steps, expressed to three significant figures, in units of J/K. In the space below, provide a justification in words and/or with calculations, as appropriate, for each answer.

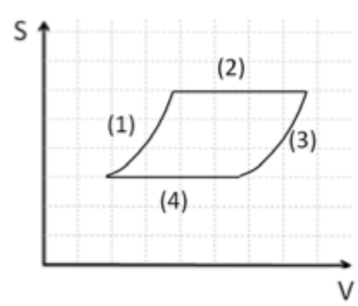
b) The sketches below are not to scale. Which of the shapes in sketches A through E best represents the cycle described in part a)? Note that the vertical axis is entropy, S, and the horizontal axis is volume, V. Each of the four steps is numbered in parentheses. No justification beyond what you presented in part a) is required.

ANSWER: ___________

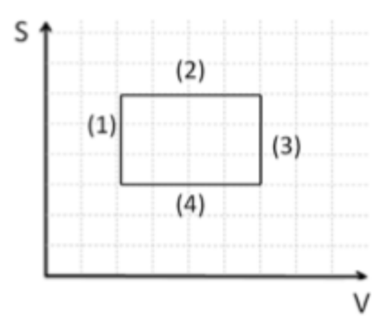
(A)



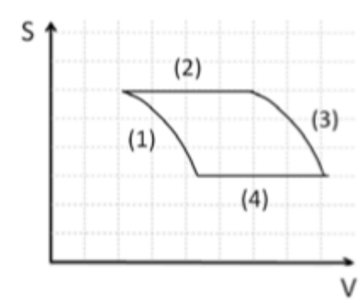
(B)



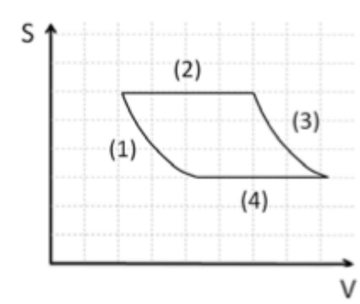
(C)



(D)



(E)



Q2) The four Maxwell relations are:

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V \qquad \left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V \qquad \left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P \qquad \left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$$

a) Starting from the definition of enthalpy, derive the following general expression for a system at constant composition in which only expansion/compression work is performed: $dH = T\,dS + V\,dP$

b) Using the above information, show that:

$$dS = \frac{C_P}{T}dT - \left(\frac{\partial V}{\partial T}\right)_P dP$$

c) For a Clausius gas: $P(V - nb) = nRT$
Integrate the expression for dS from part b) to get one for ΔS for a closed system that consists of 1 mole of a Clausius gas that goes from an initial state at (P_1, V_1, T_1) to a final state at (P_2, V_2, T_2). Assume C_P for the gas to be independent of temperature.

Q3) For benzene in a container open to the atmosphere, T_m = 5.42 ºC = 278.5 K

and T_b = 87.1 ºC = 360.3 K.

Also: $C_{p,\,m,\,solid}$ = 118.4 J mol^{-1} K^{-1} (assume to be independent of T)

$C_{p,\,m,\,liquid}$ = 134.8 J mol^{-1} K^{-1} (assume to be independent of T)

ΔH_{fusion} at T_m = 9.90 kJ/mol and $\Delta H_{vaporization}$ at T_b = 30.77 kJ/mol

a) Determine the enthalpy **and** entropy changes for melting of one mole of solid benzene to the liquid phase at -100 ºC in an open container.

b) Determine the enthalpy **and** entropy changes for the surroundings in the process described in part a).

Q4) Silver carbonate decomposes when heated: $Ag_2CO_3(s) \rightleftharpoons Ag_2O(s) + CO_2(g)$

At 400K, the equilibrium constant for this reaction is 1.41×10^{-2}.
At 500K, the equilibrium constant for this reaction is 1.48.

Use the above information, plus the definition of Gibbs free energy, plus the reaction equilibrium result that at a specified temperature and pressure $\Delta G_{rx} = \Delta G^{o}_{rx} + RT \ln Q$ to determine ΔH^{o}_{rx} **and** ΔS^{o}_{rx} for the decomposition, assuming both to be temperature-independent.