

Name: _____

CHEM 452
FINAL EXAM, December 11, 2008

Name: _____ (please print)
Student ID number: _____

Do not open this test booklet until instructed to do so. This is a closed-book, no notes exam.

- Please sit according to the seating chart.
- Express all answers in SI units unless otherwise indicated. Be mindful of the signs.
- Box your answers.
- You may use a calculator.
- Partial credit will be given on most problems. In order to receive partial credit, please show your work and keep track of units.
- Answers without documentation of how the problem was solved may not be given full credit.

“I attest that I have not given or received any aid on this exam.”

(your signature)

CONSTANTS:

$$R=8.314 \text{ J K}^{-1}\text{mole}^{-1}$$

$$c \approx 3 \times 10^8 \text{ m/s}$$

$$N_A \approx 6.02 \times 10^{23} \text{ mole}^{-1}$$

$$h \approx 6.63 \times 10^{-34} \text{ J s}$$

$$g \approx 9.8 \text{ m s}^{-2}$$

$$k_B \approx 1.38 \times 10^{-23} \text{ J K}^{-1}$$

$$e \approx -1.602 \times 10^{-19} \text{ C}$$

$$F=96490 \text{ C mole}^{-1}$$

USEFUL CONVERSIONS:

$$\text{Newton, N} = \text{kg m s}^{-2}$$

$$\text{Joule, J} = \text{N m}$$

$$\text{Watt, W} = \text{J/s}$$

$$\text{Pascal, Pa} = \text{N/m}^2$$

$$\text{Liter, L} = 10^{-3} \text{ m}^3 (1\text{mL} = 1\text{cm}^3)$$

$$\text{Calorie, 1 cal} = 4.184 \text{ J}$$

$$1 \text{ atm} \approx 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ torr}$$

$$\text{K} = \text{°C} + 273.15$$

$$\text{°C} = (\text{°F} - 32) (5/9)$$

$$1 \text{ kg} \approx 2.2 \text{ lb}$$

$$1 \text{ inch} = 2.54 \text{ cm}$$

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Problem 1 _____

Problem 2 _____

Problem 3 _____

Problem 4 _____

Problem 5 _____

Problem 6 _____

TOTAL _____

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Problem 1 (a-d) (30 points)

Write if the listed thermodynamic quantities are zero, greater than zero or less than zero **for the system** in each of the following scenarios. Show or state your reasoning in a brief sentence for each case. Assume only PV (pressure-volume) work.

a) 1 mole of superheated steam condenses to water spontaneously at 110 °C and 1 atm

	Insert <, > or =		Reason
q		0	
w		0	
ΔH		0	
ΔS		0	
ΔG		0	
ΔA		0	
ΔT		0	
ΔV		0	
μ_{steam}		μ_{water}	

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b) Hot water is mixed with cold water in a thermally insulated, closed container of fixed volume.

	Insert <, > or =		Reason
q		0	
w		0	
ΔH		0	
ΔS		0	
ΔU		0	
ΔG		0	

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c) A rubber band undergoes the following reaction at room temperature and pressure.

Rubber Band (contracted) \rightarrow Rubber Band (stretched)

	Insert <, > or =		Reason
q		0	
w		0	
ΔH		0	
ΔS		0	
ΔG		0	
$\mu_{\text{stretched}}$		$\mu_{\text{contracted}}$	

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d) One mole of an ideal gas undergoes a reversible adiabatic compression.

	Insert <, > or =		Reason
q		0	
w		0	
ΔU		0	
ΔH		0	
ΔT		0	
ΔA		0	
ΔG		0	
ΔS		0	
ΔV		0	

Problem 2 (a-g) (65 points)

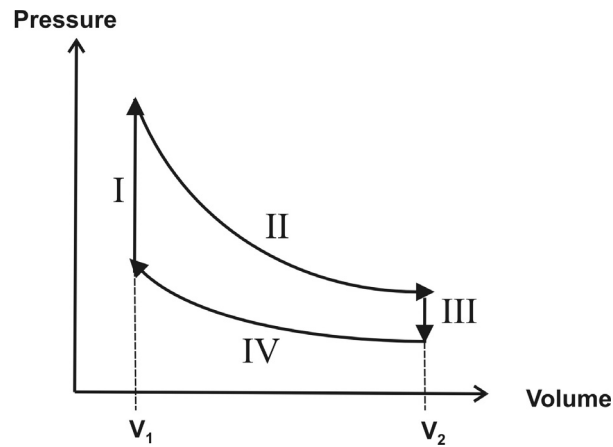
The figure below shows a modified Otto Cycle, a model for a gasoline engine. Assume that one mole of an ideal gas with a specific heat capacity of \bar{C}_V completes this cycle. It consists of the following steps:

Step 1: Constant volume heating from T_1 to T_2 at volume V_1 .

Step 2: Adiabatic expansion from V_1 to V_2 with the temperature changing from T_2 to T_3 .

Step 3: Constant volume cooling from T_3 to T_4 at volume V_2 .

Step 4: Adiabatic compression from V_2 to V_1 with the temperature changing from T_4 to T_1 .



- (a) Calculate ΔU , ΔH , ΔS , q and w for step I. Express your answers in terms of T_1 , T_2 , T_3 , T_4 , C_V , C_P , V_1 and V_2 .

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(b) Calculate ΔU , ΔH , ΔS , q and w for step II. Express your answers in terms of T_1 , T_2 , T_3 , T_4 , C_V , C_P , V_1 and V_2 .

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(c) Calculate ΔU , ΔH , ΔS , q and w for step III. Express your answers in terms of T_1 , T_2 , T_3 , T_4 , C_V , C_P , V_1 and V_2 .

(d) Calculate ΔU , ΔH , ΔS , q and w for step IV. Express your answers in terms of T_1 , T_2 , T_3 , T_4 , C_V , C_P , V_1 and V_2 .

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- (e) Calculate ΔU , ΔH , ΔS , q and w for the entire cycle. Express your answers in terms of T_1 , T_2 , T_3 , T_4 , C_V , C_P , V_1 and V_2 .

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(f) The efficiency of the cycle is defined as: $\varepsilon = \frac{-(w_{II} + w_{IV})}{q_{II}}$. Show that $\varepsilon = 1 - \left(\frac{V_1}{V_2}\right)^{\frac{R}{C_V}}$.

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(g) Suppose $\left(\frac{V_2}{V_1}\right) = 8$ and for a diatomic gas $\bar{C}_V = \frac{5}{2}R$. What is the efficiency of the engine if we burn a diatomic gas.

Problem 3 (15 points)

The measured osmotic pressure of sea water at 273 K is 25 atm. The partial molar volume of water in sea water is 0.018 liter/mole. Recall that:

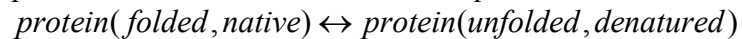
$$X_{solute} = \frac{\Pi \bar{V}_{solvent}}{RT}$$

- a) What is the mole fraction of water in sea water at 273 K?
- b) The vapor pressure of pure water at 273 K is 6.1×10^{-3} atm. What is the vapor pressure of water in seawater at 273 K?
- c) What temperature would you expect seawater to freeze? You may assume that the density of sea water is 1 kg/liter and $K_f=1.86$ for water.

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Problem 4 (15 points)

The folded protein RNase A is found to be in equilibrium with unfolded forms:



The following concentration data are measured:

Temperature	Native concentration	Denatured concentration
50	$9.97 \times 10^{-4} \text{ M}$	$3.00 \times 10^{-6} \text{ M}$
100	$8.6 \times 10^{-4} \text{ M}$	$1.4 \times 10^{-4} \text{ M}$

Determine ΔH° for the denaturation reaction assuming it to be independent of temperature.

Problem 5

In photosystem I, light energy is converted into chemical energy. Energy in the form of photons is absorbed by a chlorophyll complex P700 which donates an electron to A. The electron is passed down an electron-transport chain, at the end of which NADP^+ is reduced. The *reduction potentials* of P700^+ , A and NADP^+ at pH7 and 25 °C are 0.490 V, -0.900 V, and -0.350 V respectively.

(a) Calculate E^0 of the reaction at 25 °C: $\text{P700} + \text{A} \rightarrow \text{P700}^+ + \text{A}^-$.

(b) Calculate ΔG^0 for the same reaction.

(c) How many photons of 800 nm ($1 \text{ nm} = 1 \times 10^{-9} \text{ m}$) light are required?

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Problem 6 (30 points)

(a) The boiling point of water at the top of a mountain is found to be 95 °C. Calculate the atmospheric pressure at the top of the mountain. The boiling point of water at 1 atm pressure is 100 °C and $\overline{\Delta H}_{vap} = 40.66$ kJ/mole. State any assumptions you make in the calculation.

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(b) How much oxygen in grams is dissolved in 1 L of the climber's blood at the mountain top? Assume that the density of blood is 1 kg/L, the Henry's Law constant for oxygen in blood is 4.95×10^4 bar and that there is 21% of O_2 in air by volume.