

CHEM 2011 INTRODUCTION TO THERMODYNAMICS

TEST 2

March 27, 2022
1:30 PM-3:00 PM (90 minutes)

FIRST NAME:

LAST NAME:

STUDENT NUMBER:

TEST INSTRUCTIONS

- The test is out of 50.
- The test is 11 pages long and contains 4 questions.
- You may write in pen or pencil.
- Only allowable aid is a non-programmable calculator.
- If you need extra space, you can write at the back of a page, but you must clearly indicate it, otherwise it won't be marked.
- Constants, equation sheet and periodic table are provided.

GOOD LUCK!

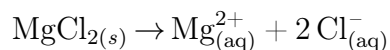
Question:	1	2	3	4	Total
Points:	12	13	12	13	50
Score:					

1. (12 points) Answer the following questions.

- (a) (3 points) What is the bond dissociation enthalpy for Xe–F, knowing that the enthalpy of formation of $\text{XeF}_{4(g)}$ is -252.0 kJ/mol and that the bond dissociation energy of $\text{F}_{2(g)}$ is 158.0 kJ/mol .
- (b) (4 points) Using the enthalpy of combustion values provided in the table below. Calculate the enthalpy of formation of 32 g of $\text{C}_3\text{H}_{8(g)}$ (M.W. of $\text{C}_3\text{H}_8 = 44.096 \text{ g/mol}$). Note that the combustion product for the substances listed in the table are $\text{H}_2\text{O}_{(l)}$ and $\text{CO}_{2(g)}$ when applicable. *Hint:* Ensure to balance the reactions before proceeding.

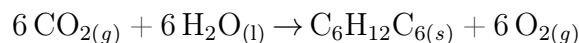
Unbalanced Reactions	Enthalpy of Combustion
$\text{C}_3\text{H}_{8(g)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + \text{H}_2\text{O}_{(l)}$	-2219.9 kJ/mol
$\text{C}_{(\text{graphite})} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)}$	-393.5 kJ/mol
$\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow \text{H}_2\text{O}_{(l)}$	-285.8 kJ/mol

- (c) (5 points) Magnesium chloride is soluble in water according to the reaction



and the heat of the solution is -160.0 kJ/mol . Assuming that no heat is transferred to the surroundings, calculate the final temperature when 17.2 g of MgCl_2 are dissolved in 300.0 g of water (at 298 K). Molar mass of MgCl_2 is 95.21 g/mol and the specific heat capacity of water is 4.184 J/K g .

2. (13 points) During photosynthesis, glucose is formed from carbon dioxide and water.



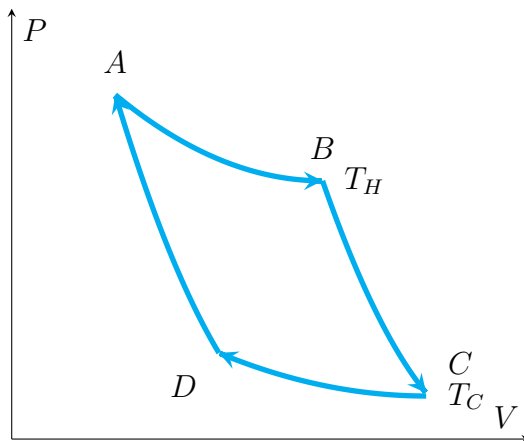
At 298 K, for one mole of the reaction,

$$\Delta_r S^\circ = -262.4 \text{ J/mol K} \quad \Delta_r H^\circ = 2803 \text{ kJ/mol}$$

- (a) (3 points) Calculate the entropy change in the surroundings, ΔS_{surr}° and the universe, ΔS_{tot}° at 298 K.
- (b) (5 points) Calculate $\Delta_r S^\circ$ and $\Delta_r H^\circ$ at 400 K for the reaction shown above. *Hint:* To account for the temperature dependence of entropy, you need to use the values of $C_{P,m}$ provided in the table below.
- (c) (2 points) Calculate the entropy change in the surroundings, ΔS_{surr}° , and the universe, ΔS_{tot}° at 400 K for the reaction shown above.
- (d) (3 points) Based on your results in (a) and (c), comment on the following points. Explain your answer.
- (i) Is the reaction spontaneous at 298 K?
 - (ii) Is the reaction spontaneous at 400 K?
 - (iii) Has the increase in temperature from 298 K to 400 K lead to the reaction being more spontaneous (less non-spontaneous) or less spontaneous (more non-spontaneous)

Substance	$C_{P,m}$ (J/mol K)
$\text{CO}_{2(g)}$	37.1
$\text{H}_2\text{O}_{(l)}$	75.3
$\text{C}_6\text{H}_{12}\text{O}_{6(s)}$	219.2
$\text{O}_{2(g)}$	29.4

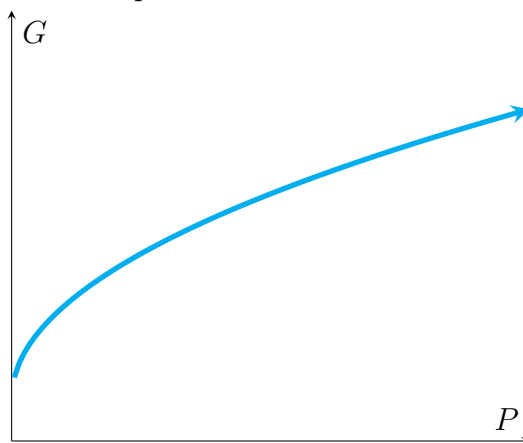
3. (12 points) The diagram below illustrates a reversible Carnot cycle (NOTE: it's only a schematic), where the engine operates between 200°C and 700°C . The initial value at point A , V_A is 3.0 L, and the volume at point B , V_B is 10.0 L. The working substance of 1.5 mol of an ideal diatomic gas.



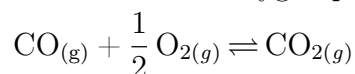
- (1 point) Calculate the thermodynamic efficiency of the cycle.
- (2 points) Calculate q_{AB} , the heat associated with the process $A \rightarrow B$.
- (1.5 points) What is the total work for the whole cycle?
- (1.5 points) Determine ΔS_{sys} , ΔS_{surr} and ΔS_{uni} for the process $D \rightarrow A$.
- (2 points) For the process D to A , two factors contribute to the change in entropy—the volume change as well as temperature change. Explain, on a molecular scale, the sign of the entropy change in the process $D \rightarrow A$ that is only attributed to the volume change (V_D to V_A).
- (2 points) Determine V_D . *Hint:* Use the adiabatic step.
- (2 points) Calculate the change in entropy ΔS , in this step $D \rightarrow A$ that is only attributed due to the volume change V_D to V_A – is the result in agreement with your explanation in part (e)?

4. (13 points) Answer the following questions.

- (a) (2 points) CO is behaving like an ideal gas. Calculate ΔG for the isothermal compression of 2.0 mol of CO at 300 K as the gas is compressed from an initial pressure of 1.0 bar to the final pressure of 5.0 bar.
- (b) (3 points) On a GP graph below, illustrate how the Gibbs Free Energy would change for CO during the process described in (a) of the question. Explain your answer with a key partial derivative expression.



- (c) (4 points) In an experiment CO reacts with oxygen producing carbon dioxide:



Calculate $\Delta_r G^\circ$ and K at 298 K and 1 bar. At equilibrium, would the reaction mixture contain mostly reactants, products, or both? Explain your answer.

Substance	$\Delta_f G^\circ$ (kJ/mol)
CO _(g)	−137.2
CO _{2(g)}	−394.4

- (d) (4 points) If the $\Delta_r H^\circ$ for the reaction in (c) is -283 kJ/mol, calculate $\Delta_r G^\circ$ at 550 K assuming that $\Delta_r H^\circ$ is constant in the temperature interval of interest. Is your calculated result consistent with prediction using Le Châtelier's Principle – would you have expected the equilibrium to shift more towards reactants or products upon the increase of temperature to 550 K compared to 298 K in part (c). Explain your answer.