Chem. 1B Midterm 1
Practice Test 2 Solutions

Name__________________________________________

Student Number _________________________________

All work must be shown on the exam for partial credit. Points will be taken off for incorrect or no units and for the incorrect number of significant figures. Calculators are allowed. On short answer problems you must show your work in order to receive credit for the problem. If your cell phone goes off during the exam you will have your exam removed from you.

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Fundamental Questions

Each of these fundamental chemistry questions is worth 6 points. You must show work to get credit. Little to no partial credit will be rewarded. Make sure to report answers in the correct number of significant figures and with the proper units.

1) 6 pts  A certain reaction releases 213 kJ of heat. During the reaction the surrounding does 112 kJ of work. What is the change in internal energy for the reaction?

\[ q = -213 \text{ kJ negative because heat was released} \]
\[ w = 112 \text{ kJ positive because the surroundings did work} \]
\[ \Delta E = q + w = -213 \text{ kJ} + 112 \text{ kJ} = -101 \text{ kJ} \]

2) 6 pts  Consider the following exothermic reaction at 25°C and 1 atm.

\[ 2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(g) \]

Circle the correct answer for each of the following quantities: \( w \), \( \Delta H \), \( \Delta E \), \( \Delta S \), and \( \Delta G \).

\[ w < 0 \quad w > 0 \quad w = 0 \]
\[ \Delta H < 0 \quad \Delta H > 0 \quad \Delta H = 0 \]
\[ \Delta E < 0 \quad \Delta E > 0 \quad \Delta E = 0 \]
\[ \Delta S < 0 \quad \Delta S > 0 \quad \Delta S = 0 \]
\[ \Delta G < 0 \quad \Delta G > 0 \quad \Delta G = 0 \]

3) 6 pts  \( \Delta G^\circ_{\text{rxn}} \) for \( 2\text{SO}_2(g) + \text{O}_2(g) \rightarrow 2\text{SO}_3(g) \) is \( -141.74 \dfrac{\text{kJ}}{\text{mol}} \) at 25.00°C. What is \( \Delta G_{\text{rxn}} \) when the partial pressure of each gas is 100. atm? What is the spontaneous direction of the reaction under these conditions?

\[ \Delta G = \Delta G^\circ + RT \ln(Q) \]
\[ \Delta G = \Delta G^\circ + RT \ln \left( \dfrac{P_{\text{SO}_2}^2}{P_{\text{SO}_3} P_{\text{O}_2}} \right) \]
\[ \Delta G = -141.74 \dfrac{\text{kJ}}{\text{mol}} + \left(0.0083145 \dfrac{\text{kJ}}{\text{mol} \text{K}} \right) \left(298.15 \text{K} \right) \ln \left( \dfrac{100^2}{100 \cdot 100} \right) \]
\[ \Delta G = -153.16 \dfrac{\text{kJ}}{\text{mol}} \]

Since \( \Delta G \) is negative the reaction is spontaneous in the forward direction.
4) 6 pts If the heat capacity of a calorimeter is 44.7 \( \frac{kJ}{^\circ C} \) and the temperature of the water in the calorimeter rises 25.3\(^\circ\)C when 20.0 mol of a substance is combusted. What is \( \Delta E_{\text{com}} \) (\( \frac{kJ}{mol} \)) of the substance?

\[
\Delta E_{\text{com}} = q_{\text{com}} + w_{\text{com}}
\]

Volume is constant therefore \( w_{\text{com}} = 0 \)

\[
\Delta E_{\text{com}} = q_{\text{com}} = -q_{\text{cal}} = -C_{\text{cal}} \Delta T
\]

\[
\Delta E_{\text{com}} = -(44.7 \frac{kJ}{^\circ C})(25.3^\circ C) = -1130 \text{kJ}
\]

\[
\Delta E_{\text{com}} = \frac{-1130 \text{kJ}}{20.0 \text{mol}} = -56.5 \frac{kJ}{mol}
\]

5) 6 pts If \( \Delta H \) is -12.4 \( \frac{kJ}{mol} \) and \( \Delta S \) is 0.91 \( \frac{kJ}{mol K} \) what is \( \Delta G \) at 75\(^\circ\)C and is the reaction spontaneous.

\[
\Delta G = \Delta H - T \Delta S = -12.4 \frac{kJ}{mol} - (348 \text{K})(0.00091 \frac{kJ}{mol K}) = -12.7 \frac{kJ}{mol}
\]

Since \( \Delta G \) is negative the reaction is spontaneous.

6) 6 pts The reusable booster rockets of the space shuttle use a mixture of aluminum and ammonium perchlorate as fuel. A possible reaction is given below.

\[
3\text{Al}(s) + 3\text{NH}_4\text{ClO}_4(s) \rightarrow \text{Al}_2\text{O}_3(s) + \text{AlCl}_3(s) + 3 \text{NO}(g) + 6 \text{H}_2\text{O}(g)
\]

Calculate \( \Delta H^\circ \) for this reaction. Is this reaction endothermic or exothermic?

Hint: Use your constants sheet to find \( \Delta H^\circ_{\text{rxn}} \).

\[
\Delta H^\circ_{\text{rxn}} = \sum \Delta H^\circ_{\text{prod}} - \sum \Delta H^\circ_{\text{react}}
\]

\[
\Delta H^\circ_{\text{rxn}} = \Delta H^\circ_{\text{Al}_2\text{O}_3} + \Delta H^\circ_{\text{AlCl}_3} + 3\Delta H^\circ_{\text{NO}} + 6\Delta H^\circ_{\text{H}_2\text{O}} - \Delta H^\circ_{\text{Al}} - \Delta H^\circ_{\text{NH}_4\text{ClO}_4}
\]

\[
\Delta H^\circ_{\text{rxn}} = -1676 \frac{kJ}{mol} + (-704 \frac{kJ}{mol}) + 3(90 \frac{kJ}{mol}) + 6(-242 \frac{kJ}{mol}) - 3(0 \frac{kJ}{mol}) - 3(-295 \frac{kJ}{mol}) = -2677 \frac{kJ}{mol}
\]

Since \( \Delta H^\circ_{\text{rxn}} \) is negative the reaction is exothermic.
1) Consider the process

\[ A(\text{l}, 75^\circ \text{C}) \rightarrow A(\text{g}, 155^\circ \text{C}) \]

which is carried out at constant pressure. The total \( \Delta S \) for this process is known to be 75.0 \( \frac{\text{J}}{\text{Kmol}} \). For A(l) and A(g), \( C_P \) values are 75.0 \( \frac{\text{J}}{\text{Kmol} \cdot \text{K}} \), and 29.0 \( \frac{\text{J}}{\text{Kmol} \cdot \text{K}} \), respectively, and are not dependent on temperature. Calculate \( \Delta H_{\text{vap}} \) for A(l) at 125°C (its boiling point).

Break this process into 3 steps

A(l) (75°C to 125°C) \( \rightarrow \) A(l) to Al(g) 125°C \( \rightarrow \) A(g) (125°C to 155°C)

Step 1:

\[
\Delta S = C_P \ln \left( \frac{T_2}{T_1} \right) = (75.0 \frac{\text{J}}{\text{molK}}) \ln \left( \frac{398K}{348K} \right) = 10.1 \frac{\text{J}}{\text{molK}}
\]

Step 2:

Phase change, therefore, T is constant. The problem indicates that P is also constant.

\[
\Delta S = \frac{q_{\text{rev}}}{T} = \frac{\Delta H_{\text{vap}}}{T} = \frac{\Delta H_{\text{vap}}}{398K}
\]

Step 3:

\[
\Delta S = C_P \ln \left( \frac{T_2}{T_1} \right) = (29.0 \frac{\text{J}}{\text{molK}}) \ln \left( \frac{428K}{398K} \right) = 2.11 \frac{\text{J}}{\text{molK}}
\]

\[
\Delta S_{\text{tot}} = 10.1 \frac{\text{J}}{\text{molK}} + \frac{\Delta H_{\text{vap}}}{398K} + 2.11 \frac{\text{J}}{\text{molK}} = 75.0 \frac{\text{J}}{\text{molK}}
\]

\[
\frac{\Delta H_{\text{vap}}}{398K} = 62.8 \frac{\text{J}}{\text{molK}}
\]

\[
\Delta H_{\text{vap}} = 2.50 \times 10^4 \frac{\text{J}}{\text{mol}} = 25.0 \frac{\text{kJ}}{\text{mol}}
\]
2) **17 pts** 200. mL of 0.862 M HCl is mixed with 200. mL of 0.431 M Ba(OH)\(_2\) in a constant pressure calorimeter of negligible heat capacity. The initial temperature of the HCl and Ba(OH)\(_2\) solutions are the same at 20.48°C. For the process

\[ \text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O(l)} \]

the \(\Delta H_{\text{rxn}}\) is -56.2 \(\frac{\text{kJ}}{\text{mol}}\). What is the final temperature of the mixed solution?

Helpful Information: \(C_{\text{H}_2\text{O}} = 4.18 \frac{\text{J}}{\text{g} \cdot \text{°C}}\) and \(d_{\text{H}_2\text{O}} = 1.00 \frac{\text{g}}{\text{mL}}\)

\[
\begin{align*}
\text{Ba(OH)}_2(\text{aq}) + 2 \text{HCl(}aq \rightarrow & \text{BaCl}_2(\text{aq}) + 2 \text{H}_2\text{O(}aq) \\
q_{\text{cal}} &= -q_{\text{sol}} \\
\Delta H_{\text{rxn}} &= -q_{\text{sol}} \\
\Delta H_{\text{cal}} &= -mC_\Delta T \\
\text{Calculate } \Delta H_{\text{rxn}} \text{ in J} \\
\text{Net Ionic Equation:} \\
\text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow & \text{H}_2\text{O(l)} \quad \Delta H_{\text{rxn}} = -56.2 \frac{\text{kJ}}{\text{mol}}
\end{align*}
\]

Calculate the moles of H\(^+\) and OH\(^-\):

\[
\begin{align*}
n_{\text{OH}^-} &= 0.200 \text{L} \text{Ba(OH)}_2 \left( \frac{0.432 \text{mol Ba(OH)}_2}{1 \text{L Ba(OH)}_2} \right) \left( \frac{2 \text{mol OH}^-}{1 \text{mol Ba(OH)}_2} \right) = 0.173 \text{mol OH}^- \\
n_{\text{H}^+} &= 0.200 \text{L} \text{HCl} \left( \frac{0.862 \text{mol HCl}}{1 \text{L HCl}} \right) \left( \frac{1 \text{mol H}^+}{1 \text{mol HCl}} \right) = 0.173 \text{mol H}^+
\end{align*}
\]

Therefore, since H\(^+\) and OH\(^-\) react in a 1 to 1 ratio, both will be completely used up.

\[0.173 \text{mol H}^+ \left( -\frac{56.2 \text{kJ}}{1 \text{mol H}^+} \right) = -9.72 \text{kJ} = -9720 \text{J}\]

Because the solution is mainly water we can use the heat capacity of water \(C_{\text{H}_2\text{O}} = 4.18 \frac{\text{J}}{\text{g} \cdot \text{°C}}\).

Calculate the mass of the solution.

Because the solution is mainly made of water we can use the density of water to calculate the volume.

\[m = Vd = (200.\text{mL} + 200.\text{mL}) \left( \frac{1.00 \text{g}}{1 \text{mL}} \right) = 400.\text{g}\]

\[
\begin{align*}
\Delta H_{\text{rxn}} &= -mC_\Delta T \\
-9720 \text{J} &= -(400.\text{g}) \left( 4.18 \frac{\text{J}}{\text{g} \cdot \text{°C}} \right) (T_f - 20.48\text{°C}) \\
T_f &= 26.26\text{°C}
\end{align*}
\]
Multiple Choice Questions
Each of the following multiple choice questions are worth 5 points. 
**Your answers need to be filled in on the Scantron provided.**
Note: Your Scantrons will not be returned to you, therefore, for your records, you may want to mark your answers on this sheet.
On the Scantron you need to fill in your perm number, test version, and name. Failure to do any of these things will result in the loss of 1 point. Your perm number is placed and bubbled in under the “ID number”. Do not skip boxes or put in a hyphen. In addition, leave bubbles blank under any unused boxes. The version number (A) is bubbled in under the “test form.”

1. Predict which of the following reactions has a negative entropy change.
   I. CH$_4$(g) + 2O$_2$(g) $\rightarrow$ CO$_2$(g) + 2H$_2$O(l)
   II. NH$_3$(g) + HCl(g) $\rightarrow$ NH$_4$Cl(s)
   III. 2KClO$_4$(s) $\rightarrow$ 2KClO$_3$(s) + O$_2$(g)
   
   A) II  
   B) I and II  
   C) I  
   D) III  
   E) II and III

2. Using the information below, calculate $\Delta H^o$ for CH$_3$OH(l).
   
   $$2\text{CH}_3\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(l), \quad \Delta H^o = -1453 \text{ kJ}$$
   
   $\Delta H^o$ for CO$_2$(g) = $-393.5$ kJ/mol
   $\Delta H^o$ for H$_2$O(l) = $-286$ kJ/mol
   
   A) $-3.38 \times 10^3$ kJ/mol  
   B) $-774$ kJ/mol  
   C) $774$ kJ/mol  
   D) $239$ kJ/mol  
   E) None of these

3. For the vaporization of a liquid at a given pressure,
   A) $\Delta G$ is negative at all temperatures.  
   B) $\Delta G$ is negative at low temperatures but positive at high temperatures (and zero at some temperature).  
   C) $\Delta G$ is positive at all temperatures.  
   D) $\Delta G$ is positive at low temperatures but negative at high temperatures (and zero at some temperature).
4. Lowering the activation energy of a reaction makes the reaction more spontaneous.
   A) True
   B) False

5. Two blocks have been sitting in a room for an extended period of time. You walk up to the block and feel them; one block feels cold and the other block feels warm. You then put an ice cube on each block. Which block will melt the ice first?
   A) The block that feels warm will melt the ice first.
   B) Both blocks will melt the ice at the same time because the blocks are at the same temperature.
   C) The block that feels cold will melt the ice first.

6. Which of the following statements is(are) true?
   A) The heat of reaction and change in enthalpy can always be used interchangeably.
   B) A chemist takes the point of view of the surroundings when determining the sign for work or heat.
   C) At least two of these statements are true.
   D) In exothermic reactions, the reactants are lower in potential energy than the products.
   E) Enthalpy is a state function.