DAWSON COLLEGE
DEPARTMENT OF CHEMISTRY & CHEMICAL TECHNOLOGY

FINAL EXAMINATION  CHEMISTRY 202-NYB-05
May 22, 2009
9:30 – 12:30

Print your Name: __________________________________________   MARK DISTRIBUTION
Student Number: ____________________________

INSTRUCTORS: Please circle the name of your instructor:
J. Ali                          I. Dionne                          M. Haniff
D. Baril                        M. Di Stefano                      S. Makinen
O. Behar                        N. Duxin                           S. Mutic

INSTRUCTIONS:
This exam set consists of 15 questions. Please ensure that your copy of this examination is complete.

Answer all questions in the space provided.

1. Calculators may not be shared. Programmable calculators are not permitted.
2. No books or extra paper are permitted.
3. In order to obtain full credit, you must show the method used to solve all problems involving calculations and express your answers to the correct number of significant figures.
4. Your attention is drawn to the College policy on cheating.
5. A Periodic Table is provided. You may detach the Periodic Table.
6. If a mathematical equation is used to solve a problem, the equation should be clearly written.
7. Write your answer in the appropriate box when required

USEFUL DATA:
Avogadro’s Number \( N_A = 6.022 \times 10^{23} \text{ mol}^{-1} \)
Gas Constant \( R = 0.08206 \text{ L \cdot atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1} \)
\( = 8.314 \text{ L \cdot kPa} \cdot \text{K}^{-1} \cdot \text{mol}^{-1} \)
\( = 8.314 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1} \)
1 atm = 101.3 kPa = 760 mmHg = 760 torr
1 J = 1 kg m\(^2\) s\(^{-2}\)
101.3 J = 1 L\cdot atm

TOTAL /100
Question 1

The electrolyte of an automobile lead storage battery is a 3.75 M sulfuric acid (H₂SO₄) solution in water. It has a density of 1.23 g/mL. Calculate for the sulfuric acid:

a. the mass percent

b. the molality

c. the mole fraction

d. What volume of 3.75 M sulfuric acid must be used to prepare 1.5 L of a 0.10 M H₂SO₄(aq) solution?

Answers

| a. mass percent: | b. molality: | c. mole fraction: | d. volume: |
Question 2

Knowing that a human eye has an osmotic pressure of 7.97 atm at 37.0°C, an eye-drop solution with the same osmotic pressure and temperature is prepared by adding 0.242 g of NaCl in 25.0 mL water. Calculate the van’t Hoff factor for NaCl in this solution. Assume the density of the solution to be 1.00 g/mL.

Answer

van’t Hoff factor:

Question 3

At a high altitude camp in the Rockies, water boils at 95.4°C instead of 100.0°C. A visitor has requested a soft-boiled egg (usually boiled for 3.00 minutes at 100.0°C). The activation energy for the reaction in question is 453 kJ/mol.

\[ \text{egg protein (l)} \xrightarrow{\text{activation energy}} \text{egg protein (s)} \]

How long will it take to cook his egg at 95.4°C?

Answer

time:
The following data were obtained for the reaction:

\[
2\text{ClO}_2(aq) + 2\text{OH}^-(aq) \rightarrow \text{ClO}_3^-(aq) + \text{ClO}_2(aq) + \text{H}_2\text{O}(l)
\]

Where \( \text{Rate} = -\frac{\Delta [\text{ClO}_2]}{2\Delta t} \)

<table>
<thead>
<tr>
<th>Experiment no.</th>
<th>[ClO(_2)](_o) (mol\cdot L(^{-1}))</th>
<th>[OH(^-)](_o) (mol\cdot L(^{-1}))</th>
<th>Initial rate (mol\cdot L(^{-1})\cdot s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0500</td>
<td>0.100</td>
<td>5.75\times10(^{-2})</td>
</tr>
<tr>
<td>2</td>
<td>0.100</td>
<td>0.100</td>
<td>2.30\times10(^{-1})</td>
</tr>
<tr>
<td>3</td>
<td>0.200</td>
<td>0.0250</td>
<td>2.30\times10(^{-1})</td>
</tr>
</tbody>
</table>

a. Determine the rate law \( \text{3 marks} \)

b. Calculate the value of the rate constant (with units). \( \text{2 marks} \)

c. What is the overall order of this reaction? \( \text{1 mark} \)

**Answers**

<table>
<thead>
<tr>
<th>a. rate law :</th>
<th>b. rate constant :</th>
<th>c. overall order :</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Question 5

Consider the following chemical reaction at 10°C with \([\text{NOBr}]_o = 0.080 \text{ M}]:

\[
2\text{NOBr}(g) \rightarrow 2\text{NO}(g) + \text{Br}_2(g) \quad \text{Rate} = 0.80 \text{ M}^{-1}\text{s}^{-1}[\text{NOBr}]^2
\]

a. Calculate the time required for 85% of the initial NOBr to react. 3 marks

b. What is the half-life of this reaction? 2 marks

c. Indicate whether the following statements are true or false for the chemical reaction described above. 3 marks

i. The rate of the reaction doubles if the concentration of NOBr is doubled
   True ☐  False ☐

ii. The rate of the reaction decreases as time goes on
   True ☐  False ☐

iii. If \([\text{NOBr}]_o = 0.080 \text{ mol/L}\), then after 100 s all the reactant is consumed
   True ☐  False ☐

iv. The half-life of the reaction is 5.0 s when \([\text{NOBr}]_o = 0.040 \text{ mol/L}\)
   True ☐  False ☐

v. The plot of [NOBr] vs. time is a straight line
   True ☐  False ☐

vi. Changing the temperature will affect the order of the reaction
   True ☐  False ☐
Question 6

Consider the following reaction

\[ \text{H}_2\text{S}(g) + \text{I}_2(s) \rightleftharpoons 2\text{HI}(g) + \text{S}(s) \quad K_p = 1.34 \times 10^{-5} \text{ at } 60^\circ\text{C} \]

A 5.00 L reactor contains the following initial mixture at 60°C

- 2.00 g solid iodine (I₂)
- 1.07 g sulfur powder
- 10.1 kPa of hydrogen sulfide (H₂S)

a. What will be the pressure of HI at equilibrium? 3 marks

b. What is the K value for this equilibrium at 60°C? 2 marks

c. What will be the value of \( K_p \) for the following reaction at the same temperature? 2 marks

\[ 4\text{HI}(g) + 2\text{S}(s) \rightleftharpoons 2\text{H}_2\text{S}(g) + 2\text{I}_2(s) \]

Answers

<table>
<thead>
<tr>
<th>a. HI pressure</th>
<th>b. K</th>
<th>c. ( K_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
a. Indicate whether the following statements are true or false  

<table>
<thead>
<tr>
<th>Statement</th>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. The solubility of a gas in water decreases with increasing temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. The presence of a non-volatile solute in a solvent lowers the vapor pressure of the solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Henry’s law states that the amount of a gas dissolved in a solution is directly proportional to the pressure of the gas above the solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv. A liquid-liquid solution that obeys Raoult’s law is called an “ideal solution”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. Colligative properties are based on the number of particles in solution, whatever the “size” of the particle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vi. The addition of an ionic compound to any solvent will cause a boiling point depression.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. The gas Arsine, AsH₃ decomposes as follows:

\[
2\text{AsH}_3(g) \rightleftharpoons 2\text{As}(s) + 3\text{H}_2(g) \quad \Delta H = +122.8 \text{ kJ}
\]

For each of the following cases, in which direction will the position of the equilibrium be shifted if:  

(To the reactant = left, To the products = right, No effect = no change)  

<table>
<thead>
<tr>
<th>Case</th>
<th>left</th>
<th>no change</th>
<th>right</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. As(s) is added</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. the pressure is increased by adding argon gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. the volume of the reaction container is decreased</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv. the temperature is decreased</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. hydrogen is removed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vi. a catalyst is added</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The percent dissociation of chlorous acid $\text{HClO}_2$ in water is 8.0% when its concentration is 1.58 M.

a. What is the pH of this solution?  

b. What is the $K_a$ of this acid?  

c. What will be the percent dissociation if the concentration increases to 4.5 M?

Answers

a. $pH:$  
b. $K_a:$  
c. percent dissociation:
Question 9

a. Order the following from the strongest to the weakest base

i. H₂O
ii. CH₃NH₂
iii. ClO₄⁻

**strongest base**

**weakest base**

b. Arrange the following aqueous solutions in order from most acidic to most basic.

i. 0.1M KF
ii. 0.1M KNO₃
iii. 0.1M NH₄Cl

**most acidic**

**most basic**

c. What will be the pH of an aqueous solution made up of 0.514 g potassium cyanide KCN in 125 mL water.  

\[ K_a \text{ HCN} = 6.2 \times 10^{-10} \]

Answer

pH :
Calculate the mass of KNO₂ that must be added to 500. mL of 0.20 M nitrous acid (HNO₂, $K_a = 4.6\times10^{-4}$) to get a solution of pH = 4.00. Assume no change of the volume of the solution with the addition of KNO₂.

**Answer**

Mass of KNO₂:
A 20.0 mL sample of 0.10 M formic acid (HCOOH) was titrated with 5.0x10^{-2} M Ba(OH)_2. 

*K_a* for HCOOH is 1.8x10^{-4}.

a. Calculate the pH of the solution upon the addition of 15.0 mL of Ba(OH)_2 to the sample.  

**Answer**

a. pH:
b. What volume of $\text{Ba(OH)}_2$ is needed to reach the equivalence point? \hspace{1cm} 2 \text{ marks}

c. Calculate the pH of the solution at the equivalence point. \hspace{1cm} 3 \text{ marks}

\begin{tabular}{|l|}
\hline
\textit{Answers} \\
\hline
\textit{b. volume at equivalence point :} & \textit{c. pH at equivalence point :} \\
\hline
\end{tabular}
Solid NaI is slowly added to a solution that contains both Pb(NO₃)₂ (0.100 M) and AgNO₃ (2.0×10⁻⁴ M).

a. Which begins to precipitate first: the lead iodide or the silver iodide? **Show your work**

b. The concentration of the first cation species to precipitate, either the lead or the silver, decreases as the precipitate forms. What is the concentration in solution of the first species when the second begins to precipitate? Assume no change of volume of the solution with the addition of NaI.

Note: \( K_{sp} \) PbI₂ = 1.4×10⁻⁸, \( K_{sp} \) AgI = 1.5×10⁻¹⁶

**Answers**

a. 

b. 

a. Predict the sign of $\Delta S$ of the system for each of the following processes  

<table>
<thead>
<tr>
<th>Process</th>
<th>$\Delta S &lt; 0$</th>
<th>$\Delta S &gt; 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. A liquid that boils</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>ii. Sugar that crystallized out from a supersaturated sugar solution</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>iii. Iron rusts (formation of Fe₂O₃ from pure Fe and O₂)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>iv. A-B(g) + C-D(s) → A-B-C(g) + D(s)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>v. N₂O₄(g) → 2NO₂(g)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>vi. NaCl(s) $\xrightarrow{H_2O}$ Na⁺(aq) + Cl⁻(aq) $\Delta H_{\text{sol}} = +4.0$ kJ/mol</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

b. For mercury (Hg), the enthalpy of vaporization is 58.51 kJ/mol and the entropy of vaporization is 92.92 J/K.mol. What is the normal boiling point of mercury?

Answer

b. $T_b =$
Question 14

Consider the following reaction

\[ \text{N}_2\text{O}_4(g) \rightarrow 2\text{NO}_2(g) \]

Will the reaction be spontaneous at each of the following temperatures? Show your work.
(assume that \( \Delta H^\circ \) and \( \Delta S^\circ \) do not change very much within the given temperature range)

6 marks

a. 25.0°C
b. 60.0°C

---

**Answers**

a. spontaneous at 25°C:

b. spontaneous at 60°C:

---

**Useful data**

<table>
<thead>
<tr>
<th></th>
<th>( \text{N}_2\text{O}_4(g) )</th>
<th>( \text{NO}_2(g) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta H^\circ ) in kJ/mol</td>
<td>+9.67</td>
<td>+33.8</td>
</tr>
<tr>
<td>( S^\circ ) in J/(mol·K)</td>
<td>+304</td>
<td>+240.5</td>
</tr>
</tbody>
</table>
Question 15

Complete the “experiment 2” laboratory data sheet and find the molar mass of the unknown no 3. The solid unknown added is a non-ionic compound, completely soluble in cyclohexane.

**Experiment 2**

**COLLIGATIVE PROPERTIES**

**DATA SHEET**

$k_f$ cyclohexane = 20.2°C.kg.mol$^{-1}$ \hspace{1cm} $T_f$ cyclohexane = 6.55°C

**Data for the Unknown Solute/Cyclohexane Solution**

<table>
<thead>
<tr>
<th>Unknown Number: 3</th>
<th>Mass of empty test tube, stopper, beaker (g)</th>
<th>185.2235</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass of test tube, stopper, beaker, &amp; cyclohexane (g)</td>
<td>204.5736</td>
</tr>
<tr>
<td></td>
<td>Mass of test tube, stopper, beaker, &amp; unknown solute/cyclohexane solution (g)</td>
<td>204.9847</td>
</tr>
<tr>
<td></td>
<td>Mass of cyclohexane (g)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass of unknown solute (g)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freezing Temperature of unknown solute/cyclohexane solution (°C)</td>
<td>4.27</td>
</tr>
<tr>
<td></td>
<td>Molar mass of unknown solute (g·mol$^{-1}$)</td>
<td></td>
</tr>
</tbody>
</table>

Sample calculation.