Instructions: You should have with you several number two pencils, an eraser, your 3" x 5" note card, a calculator, and your University ID Card. If you have notes with you, place them in a sealed backpack and place the backpack OUT OF SIGHT or place the notes directly on the table at the front of the room.

Fill in the front page of the Scantron answer sheet with your test form number (listed above), last name, first name, middle initial, and student identification number. Leave the class section number blank.

This exam consists of 25 multiple-choice questions. Each question has four points associated with it. Select the best multiple-choice answer by filling in the corresponding circle on the rear page of the answer sheet. If you have any questions before the exam, please ask. If you have any questions during the exam, please ask the proctor. Open and start this exam when instructed. When finished, place your Scantron form in the appropriate stack. You may keep the exam packet, so please show your work and mark the answers you selected on it.

\[ K_a[\text{CH}_3\text{COOH} (aq)] = 1.80 \times 10^{-5} \quad \text{K}_a[\text{C}_6\text{H}_5\text{COOH} (aq)] = 6.30 \times 10^{-5} \]
\[ \text{(acetic acid)} \quad \text{(benzoic acid)} \]
\[ K_a[\text{CH}_2\text{CICOOH} (aq)] = 1.40 \times 10^{-3} \quad \text{K}_a[\text{NH}_3 (aq)] = 1.80 \times 10^{-5} \]
\[ \text{(chloroacetic acid)} \quad \text{(ammonia)} \]
\[ K_a[\text{HCOOH} (aq)] = 1.80 \times 10^{-4} \quad \text{K}_{sp} [\text{PbCl}_2, \text{lead chloride}] = 1.6 \times 10^{-5} \]
\[ \text{(formic acid)} \]
\[ \text{K}_{sp} [\text{PbF}_2, \text{lead fluoride}] = 3.6 \times 10^{-8} \quad \text{K}_{sp} [\text{MgF}_2, \text{magnesium fluoride}] = 3.7 \times 10^{-8} \]
1. The pH of 0.515 M HNO₃ (aq) is:

(A) 3.14  
(B) 1.57  
(C) 0.0269  
(D) 0.288  
(E) 0.718

\[ \text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^- \]

\[ \text{H}^+ = -\log(0.515) = 0.288 \]

2. The pH of 0.515 M CH₂CICOOH (aq) is:

(A) 3.14  
(B) 1.57  
(C) 0.0269  
(D) 0.288  
(E) 0.718

\[ \text{CH}_2\text{CICOOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_2\text{CICOO}^- + \text{H}_3\text{O}^+ \]

\[ K_a = 1.4 \times 10^{-3} = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[\text{CH}_2\text{CICOO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_2\text{CICOOH}]} \]

\[ 1.4 \times 10^{-3} = \frac{x^2}{0.515} \]

\[ x = [\text{H}^+] = 0.0269 \]

\[ \text{pH} = -\log([\text{H}^+]) = -\log(0.0269) = 1.57 \]

3. The pOH of 0.400 M HCl (aq) is:

(A) 0.398  
(B) 11.34  
(C) 7.80  
(D) 13.60  
(E) 0.400

\[ \text{HCl} \rightarrow \text{H}^+ + \text{Cl}^- \]

\[ \text{H}^+ = -\log(0.400) = 0.398 \]

\[ \text{pH} + \text{pOH} = 14 \]

\[ \text{pOH} = 14 - 0.398 = 13.60 \]
4. A student measures the **pOH** of an aqueous solution to be 3.40. This solution is:

(A) acidic
(B) neutral
(C) basic

5. The **pH** of an aqueous system is measured to be 3.00. The **pOH** of this system is:

(A) $3.0 \times 10^{-7}$ M
(B) 3.00
(C) 7.00
(D) 10.00
(E) **11.00**

6. The **pH** of a buffer system which is 3.00 M CH$_2$ClCOOH (aq) and 3.00 M CH$_2$ClCOONa (aq) is:

(A) 1.43
(B) 1.50
(C) **2.85**
(D) 3.00
(E) 6.00

\[
\text{CH}_2\text{ClCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_2\text{ClCOO}^- + \text{H}_3\text{O}^+
\]

\[
K_a = \frac{[\text{CH}_2\text{ClCOO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_2\text{ClCOOH}]} = \frac{(3.00 \text{ M})[\text{H}_2\text{O}^+]}{(3.00 \text{ M})}
\]

\[
1.40 \times 10^{-3} = [\text{H}_3\text{O}^+]
\]

\[
\text{pH} = -\log [\text{H}^+] = -\log (1.40 \times 10^{-3}) = 2.85
\]
7. Which of the following three buffer systems has the **lowest** pH?

(A) the aqueous buffer system which is \([\text{CH}_3\text{COOH}] = 2.00 \text{ M and } [\text{CH}_3\text{COONa}] = 1.00 \text{ M.}\)

(B) the aqueous buffer system which is \([\text{CH}_3\text{COOH}] = 1.00 \text{ M and } [\text{CH}_3\text{COONa}] = 1.00 \text{ M.}\)

(C) the aqueous buffer system which is \([\text{CH}_3\text{COOH}] = 1.00 \text{ M and } [\text{CH}_3\text{COONa}] = 2.00 \text{ M.}\)

8. A student titrates 0.413 grams of an unknown acid to the equivalence point with 29.15 mL of 0.0983 M NaOH (aq). The molecular mass of the unknown acid is:

\[
\text{M}_{\text{base}} V_{\text{base}} = \frac{\text{mass}}{\text{M}_{\text{acid}}} = \frac{0.413 \text{ g}}{0.02915 \text{ L}} = \frac{0.144 \text{ g/mol}}{
\text{M}_{\text{acid}}} = \frac{144 \text{ g/mol}}{\text{M}_{\text{acid}}}
\]

9. Consider the reaction of acetic acid and water. The conjugate base is:

(A) \(\text{CH}_3\text{COOH}\).

(B) \(\text{CH}_3\text{COO}^-\).

(C) \(\text{NH}_4^+\).

(D) \(\text{H}_2\text{O}\).

(E) \(\text{H}_3\text{O}^+\).
10. The pH of 1.00 M sodium acetate, CH₃COONa (aq), is:

(A) Greater than 7.00
(B) 7.00
(C) Less than 7.00

\[ \text{CH}_3\text{COO}^- (aq) + \text{H}_2\text{O}(l) \rightarrow \text{CH}_3\text{COOH} (aq) + \text{OH}^- (aq) \]

11. Consider 0.500 M NH₄NO₃ (aq). The spectator ion is:

(A) NH₃ (aq)
(B) NH₄⁺ (aq)
(C) HNO₃ (aq)
(D) NO₃⁻ (aq)
(E) H₂O (aq)

12. A student titrates 25.00 mL of HCl (aq) with 36.50 mL of 0.1502 M NaOH (aq) to reach the equivalence point. The concentration of HCl (aq) is:

(A) 0.1032 M
(B) 5.482 x 10⁻³ M
(C) 0.1322 M
(D) 7.000 M
(E) 0.2193 M

\[ \text{acid} \times \text{Vacid} = \text{base} \times \text{Vbase} \]

\[ (\text{acid})(25.00 \text{ mL}) = (0.1502 \text{ M}) \times 36.50 \text{ mL} \]

\[ \text{acid} = 0.2193 \text{ M} \]
13. The structure shown is:

(A) a strong acid
(B) a strong base
(C) a weak acid
(D) a weak base
(E) a salt which yields a pH near 7

14. The solubility of MgF₂ (K_{sp} on front page) is:

(A) 1.9 \times 10^{11} \text{ M}
(B) 1.9 \times 10^{8} \text{ M}
(C) 1.9 \times 10^{7} \text{ M}
(D) 2.1 \times 10^{-3} \text{ M}
(E) 1.4 \times 10^{-2} \text{ M}

\[ \text{MgF}_2(s) \rightleftharpoons \text{Mg}^{2+}(aq) + 2\text{F}^-(aq) \]

\[ K_{sp} = [\text{Mg}^{2+}][\text{F}^-]^2 = (x)(2x)^2 = 4x^3 \]

\[ x = \text{solubility}\]

\[ 3.7 \times 10^{-8} = 4x^3 \]

\[ x = 0.0021 \text{ or } 2.1 \times 10^{-3} \text{ M} \]
15. A student prepares a solution that is $3.5 \times 10^{-3}$ M in $[\text{Mg}^{2+}]$ and $3.5 \times 10^{-3}$ M in $[\text{CO}_3^{2-}]$. The $K_{sp}$ of $\text{MgCO}_3$ is $3.5 \times 10^{-8}$.

(A) a solid will form from $\text{Mg}_3\text{CO}_3(s) \rightleftharpoons \text{Mg}^{2+}(aq) + \text{CO}_3^{2-}(aq)$
(B) a solid will not form

$$K_{sp} = [\text{Mg}^{2+}]^3[\text{CO}_3^{2-}]$$

$$K_{\text{experimental}}(Q) = [\text{Mg}^{2+}]^3[\text{CO}_3^{2-}]$$

$$Q = (3.5 \times 10^{-3})(3.5 \times 10^{-3}) = 1.225 \times 10^{-5}$$

$$Q > K_{sp}$$

a solid will form (too much ion present)

16. Consider the combustion of octane: $2 \text{C}_8\text{H}_{18}(l) + 25 \text{O}_2(g) \rightarrow 16 \text{CO}_2(g) + 18 \text{H}_2\text{O}(g)$

(A) $\Delta H = (+), \Delta S = (+)$, and $\Delta G = (-)$
(B) $\Delta H = (+), \Delta S = (-)$, and $\Delta G = (-)$
(C) $\Delta H = (-), \Delta S = (+)$, and $\Delta G = (-)$
(D) $\Delta H = (-), \Delta S = (-)$, and $\Delta G = (-)$

Combustion is exothermic: $\Delta H = (-)$

25 mol gas $\rightarrow$ 34 mol gas

More disorder $\rightarrow$ $\Delta S = (+)$

$\Delta G = (-) - (+)(+)(-) = (-)$ spontaneous

Example

17. Which of the following statements is true?

(A) All endothermic processes which result in a system of greater disorder are spontaneous.
(B) All endothermic processes which result in a system of greater order are spontaneous.
(C) All exothermic processes which result in a system of greater disorder are spontaneous.
(D) All exothermic processes which result in a system of greater order are spontaneous.
18. Consider the "cold pack" reaction: \( \text{NH}_4\text{NO}_3 (s) \rightarrow \text{NH}_4\text{NO}_3 (aq) \).

(A) \( \Delta H = (-), \Delta S = (+), \text{ and } \Delta G = (-) \)
(B) \( \Delta H = (-), \Delta S = (-), \text{ and } \Delta G = (-) \)
(C) \( \Delta H = (+), \Delta S = (+), \text{ and } \Delta G = (-) \)
(D) \( \Delta H = (+), \Delta S = (-), \text{ and } \Delta G = (-) \)

19. Consider the process: \( \text{H}_2\text{O} (s) \rightarrow \text{H}_2\text{O} (l) \).

(A) \( \Delta S \) is negative
(B) \( \Delta S \) is positive

20. Which of the following processes exhibits an increase in entropy of the system?

(A) \( \text{NaCl (aq) } \rightarrow \text{NaCl (s) } \times \)
(B) \( \text{CH}_3\text{OH (g) } \rightarrow \text{CH}_3\text{OH (l) } \times \)
(C) \( \text{H}_2\text{O (g) } \rightarrow \text{H}_2\text{O (s) } \times \)
(D) \( 2 \text{ NO}_2 (g) \rightarrow \text{N}_2\text{O}_4 (g) \times \)
(E) \( \text{CH}_3\text{CH}_2\text{OH (s) } \rightarrow \text{CH}_3\text{CH}_2\text{OH (l) } \)
21. \( \Delta H^\circ = -123 \text{ kJ} \) and \( \Delta S^\circ = -203 \text{ J/K} \) for a process. Determine \( \Delta G^\circ \) at 298 K.

(A) \(-62.5 \text{ kJ}\)
(B) \(+62.5 \text{ kJ}\)
(C) \(-60,371 \text{ kJ}\)
(D) \(+183 \text{ kJ}\)
(E) \(-183 \text{ kJ}\)

\[ \Delta G = \Delta H - T \Delta S = \left( -123 \text{ kJ} \right) - \left( 298 \text{ K} \right) \left( -0.203 \frac{\text{ kJ}}{\text{ K}} \right) \]

22. Given the following reactions:

- \( 2\text{SO}_2 (g) + \text{O}_2 (g) \rightarrow 2\text{SO}_3 (g) \quad \Delta S_1 = -196 \text{ J/K} \times \frac{1}{2} \text{ and flip} \)
- \( 2\text{S} (s) + 3\text{O}_2 (g) \rightarrow 2\text{SO}_3 (g) \quad \Delta S_2 = -790 \text{ J/K} \times \frac{1}{2} \text{ and flip} \)

Calculate the change in entropy for:

- \( \text{S} (s) + \text{O}_2 (g) \rightarrow \text{SO}_2 (g) \quad \Delta S_3 = ? \)

(A) \( \Delta S_3 = -790 \text{ J/K} \)
(B) \( \Delta S_3 = -199 \text{ J/K} \)
(C) \( \Delta S_3 = -986 \text{ J/K} \)
(D) \( \Delta S_3 = +986 \text{ J/K} \)
(E) \( \Delta S_3 = -297 \text{ J/K} \)

23. \( \Delta H^\circ = -102 \text{ kJ} \) and \( \Delta S^\circ = -224 \text{ J/K} \) for a process. Determine the temperature in which the system is at equilibrium?

(A) \( 298 \text{ K} \)
(B) \( 455 \text{ K} \)
(C) \( 300 \text{ K} \)
(D) \( 0 \text{ K} \)
(E) \( 4 \text{ K} \)

\[ \Delta G = 0 \]

\[ \Delta G = \Delta H - T \Delta S \]

\[ 0 = (-102 \text{ kJ}) - (T)(-0.224 \frac{\text{ kJ}}{\text{ K}}) \]

\[ T = 455 \text{ K} \]
24. 

<table>
<thead>
<tr>
<th>Formula</th>
<th>$\Delta H^\circ_f$ (kJ/mol)</th>
<th>$\Delta G^\circ_f$ (kJ/mol)</th>
<th>$S^\circ$ (J/mol K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_3H_8$ (g)</td>
<td>-103.8</td>
<td>23.56</td>
<td>270.2</td>
</tr>
<tr>
<td>$O_2$ (g)</td>
<td>0</td>
<td>0</td>
<td>205.0</td>
</tr>
<tr>
<td>$CO_2$ (g)</td>
<td>-393.5</td>
<td>-394.4</td>
<td>213.6</td>
</tr>
<tr>
<td>$H_2O$ (l)</td>
<td>-285.8</td>
<td>-237.2</td>
<td>69.91</td>
</tr>
</tbody>
</table>

$C_3H_8$ (g) + 5 $O_2$ (g) → 3 $CO_2$ (g) + 4 $H_2O$ (l)

$\Delta S^\circ_{reaction}$ (298 K) for the combustion of propane is:

(A) $-374.8$ kJ/mol.
(B) +393.5 kJ/mol.
(C) 0 J/mol.
(D) -393.5 J/mol.
(E) +374.8 J/mol.

$\Delta S^\circ_{reaction} = \text{products} - \text{reactants}

= \left[ \left(3 \text{ mol } CO_2 \times 213.6 \text{ J/mol K} \right) + \left(4 \text{ mol } H_2O \times 69.91 \text{ J/mol K} \right) \right] - \left[ \left(1 \text{ mol } C_3H_8 \times 270.2 \text{ J/mol K} \right) + \left(5 \text{ mol } O_2 \times 205 \text{ J/mol K} \right) \right] = -374.76 \text{ J/K}

25. The CH 123 Final Exam is scheduled for Thursday, June 14, 2007, 7:30-9:20am-Good Morning

After the final exam I am going to...

(A) Head home.
(B) Howl like a werewolf; possibly for hours.
(C) Consume mass quantities.
(D) Redecorate my room to resemble Gilbert 124. I plan on reliving general chemistry every day of my life; for it has been a breathtaking experience I cannot live without.
(E) Forget every bit of chemistry knowledge in my brain. The world would be a better place without equilibrium.

[Any response will receive full credit; even no response.]