DO NOT OPEN THIS EXAM UNTIL INSTRUCTED. CALCULATORS ARE NOT TO BE SHARED.

Test Form 1

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.

\[
\begin{align*}
K_a[\text{CH}_3\text{COOH (aq)}] &= 1.80 \times 10^{-5} \\
(\text{acetic acid}) &\quad K_a[\text{C}_6\text{H}_5\text{COOH (aq)}] = 6.30 \times 10^{-5} \\
(\text{benzoic acid}) \\
K_a[\text{CH}_2\text{ClCOOH (aq)}] &= 1.40 \times 10^{-3} \\
(\text{chloroacetic acid}) &\quad K_b[\text{NH}_3 (aq)] = 1.80 \times 10^{-5} \\
(\text{ammonia}) \\
K_a[\text{HCOOH (aq)}] &= 1.80 \times 10^{-4} \\
(\text{formic acid}) &\quad K_{sp} [\text{PbCl}_2, \text{lead chloride}] = 1.6 \times 10^{-5} \\
K_{sp} [\text{PbF}_2, \text{lead fluoride}] = 3.6 \times 10^{-8} &\quad K_{sp} [\text{MgF}_2, \text{magnesium fluoride}] = 3.7 \times 10^{-8}
\end{align*}
\]
1. The pH of 0.315 M HNO₃ (aq) is:

   \[ \text{HNO}_3(\text{aq}) \xrightarrow{100\%} \text{H}^+ (\text{aq}) + \text{NO}_3^- (\text{aq}) \]

   \[
   \text{pH} = -\log [\text{H}^+] = -\log (0.315) = 0.502
   \]

   (A) 3.14  
   (B) 1.57  
   (C) 0.269  
   (D) 0.288  
   (E) 0.502

2. The [H⁺] of 0.407 M CH₂ClCOOH (aq) is:

   \[ \text{CH}_2\text{ClCOOH}(\text{aq}) \rightleftharpoons \text{CH}_2\text{ClCOO}^- (\text{aq}) + \text{H}^+ (\text{aq}) \]

   \[
   K_a = 1.40 \times 10^{-3} = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[\text{CH}_2\text{ClCOO}^-][\text{H}^+]}{[\text{CH}_2\text{ClCOOH}]} = \frac{x^2}{0.407 - x} \]

   \[
   1.40 \times 10^{-3} = \frac{x^2}{0.407} 
   \]

   If you had wanted the pH...

   \[
   \text{pH} = -\log [\text{H}^+] = -\log (0.0239) = 1.62
   \]

   (A) 0.150 M  
   (B) 0.0239 M  
   (C) 2.51 M  
   (D) 2.74 M  
   (E) 3.74 M

3. The pH of 0.330 M NH₃ (aq) is:

   \[ \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_4^+ (\text{aq}) + \text{OH}^- (\text{aq}) \]

   \[
   K_b = 1.80 \times 10^{-5} = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = \frac{x^2}{0.330 - x} \]

   \[
   1.80 \times 10^{-5} = \frac{x^2}{0.330} \]

   \[
   x = [\text{OH}^-] = 0.00244
   \]

   \[
   \text{pOH} = -\log [\text{OH}^-] = -\log (0.00244) = 2.61
   \]

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

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

   \[
   \text{pH} = 14 - 2.61 = 11.4
   \]

   (A) 0.0024  
   (B) 2.61  
   (C) 0.0269  
   (D) 0.288  
   (E) 11.4
4. A student measures the \([H^+]\) in an aqueous solution to be \(7.0 \times 10^{-2}\) M. This solution is:

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

\[ \text{pH} = -\log([H^+]) = -\log (7.0 \times 10^{-2}) = 1.15 \]

5. The pH of an aqueous system is measured to be 3.46. The [OH⁻] of this system is:

(A) 3.30 \times 10^{-7} M
(B) 3.46 \times 10^{-7} M
(C) 2.88 \times 10^{-11} M
(D) 3.46 \times 10^{-10} M
(E) 10.54 M

\[ [\text{OH}^-] = 10^{-\text{pOH}} = 10^{-10.54} = 2.88 \times 10^{-11} \text{ M} \]

6. The pOH of 0.040 M HCl (aq) is:

(A) 10.0
(B) 4.00
(C) 1.40
(D) 12.6
(E) 26.5

\[ \text{HCl(aq)} \rightarrow \text{H}^+(	ext{aq}) + \text{Cl}^- (\text{aq}) \quad \text{pH} = -\log ([\text{H}^+]) = -\log (0.040) = 1.40 \]

\[ \text{pOH} = 14 - \text{pH} = 14 - 1.40 = 12.6 \]

7. The pH of a buffer system which is 0.120 M \(C_6H_5COOH\) (aq) and 0.120 M \(C_6H_5COONa\) (aq) is:

(A) 0.300
(B) 1.00
(C) 3.00
(D) 4.20
(E) 7.00

\[ K_a = 6.30 \times 10^{-5} = \frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]} = \frac{(0.120)[H^+]}{(0.120)} \]

\[ [H^+] = 6.30 \times 10^{-5} \quad \text{pH} = -\log ([H^+]) = -\log (6.30 \times 10^{-5}) = 4.20 \]
8. Which of the following three buffer systems has the **lowest** pH?

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

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

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

---

9. A student titrates 25.00 mL of NaOH (aq) with 28.50 mL of 0.09331 M HCl (aq) to reach the equivalence point. The concentration of NaOH (aq) is:

(A) 9.401 M

(B) 6.706 M

(C) 0.1064 M

(D) 1.072 x 10^{-3} M

(E) 0.1064 M

---

10. A student titrates 0.5222 grams of KHP (potassium hydrogen phthalate; MW=204.2 g/mol) to the equivalence point with 24.08 mL of NaOH (aq). The concentration of the NaOH solution is:

(A) 0.09722 M

(B) 0.1722 M

(C) 0.1062 M

(D) 1.722 x 10^{-4} M

(E) 9.416 M
11. Consider the reaction of ammonia, NH₃, and water. The conjugate acid is:

(A) HCOOH
(B) \( \text{NH}_3 \)
(C) \( \text{NH}_4^+ \)
(D) \( \text{H}^+ \)
(E) HCOO⁻

\[
\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)
\]

base acid conjugate acid conjugate base

12. The pH of 0.300 M CH₃COONa (aq), is:

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

\[
\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}
\]
spectator ion

13. The compound:

(A) is a strong acid
(B) is a weak acid
(C) is a strong base
(D) is a weak base

can accept a proton
14. Consider CH₃COOH, CH₂ClCOOH, and C₆H₅COOH. The strongest acid is:

(A) CH₃COOH
(B) CH₂ClCOOH
(C) C₆H₅COOH

15. 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

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

\[ (\text{exothermic}) \rightarrow (\text{greater disorder}) \]

16. Which of the following does not reflect an increase in entropy?

(A) Dissolving salt in a pot of water
(B) Opening up a bottle of perfume
(C) Rubbing alcohol evaporating off a table
(D) Steam from an iron condensing on your arm
(E) Dry ice subliming during a concert for a thrilling effect
17. Which of the following processes exhibits an increase in entropy of the system?

(A) \( \text{H}_2\text{O} \text{ (g)} \rightarrow \text{H}_2\text{O} \text{ (l)} \)
(B) \( \text{CO}_2 \text{ (g)} \rightarrow \text{CO}_2 \text{ (s)} \)
(C) \( \text{CH}_3\text{OH} \text{ (l)} \rightarrow \text{CH}_3\text{OH} \text{ (s)} \)
(D) \( \text{N}_2 \text{ (l)} \rightarrow \text{N}_2 \text{ (g)} \)
(E) \( 2 \text{ C}_2\text{H}_2\text{(g)} + 5 \text{ O}_2\text{(g)} \rightarrow 4 \text{ CO}_2\text{(g)} + 2 \text{ H}_2\text{O}(g) \)

18. Consider the "cold pack" reaction. Which of the following statements is correct?

\[ \text{NH}_4\text{NO}_3 \text{ (s)} \rightarrow \text{NH}_4\text{NO}_3 \text{ (aq)} \quad \Delta H = +50.6 \text{ kJ} \]

(A) The process is endothermic; entropy decreases.
(B) The process is endothermic; entropy increases.
(C) The process is exothermic; entropy decreases.
(D) The process is exothermic; entropy increases.

19. \( \Delta H = +88 \text{ kJ} \) and \( \Delta S = +288 \text{ J/K} \) for a process. Determine the temperature in which the system is at equilibrium?

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

\[ \Delta G = 88 \text{ kJ} - (T) \times \frac{288 \text{ kJ}}{T} \]

(A) 19.0 K
(B) 327 K
(C) 253 K
(D) 3273 K
(E) 306 K

\[ T = 306 \text{ K} \]
20. Consider the combustion of pentane: \[ \text{C}_5\text{H}_{12} (g) + 8 \text{ O}_2 (g) \rightarrow 5 \text{ CO}_2 (g) + 6 \text{ H}_2\text{O} (g). \]

(A) \[ \Delta H = (+) \quad \Delta S = (+) \quad \Delta G = (-) \]

(B) \[ \Delta H = (+) \quad \Delta S = (-) \quad \Delta G = (-) \]

(C) \[ \Delta H = (-) \quad \Delta S = (+) \quad \Delta G = (-) \]

(D) \[ \Delta H = (-) \quad \Delta S = (-) \quad \Delta G = (-) \]

21. Consider a process in which \( K = 2.8 \times 10^{-9} \).

(A) \( \Delta G \) will be negative and the process is spontaneous

(B) \( \Delta G \) will be positive and the process is spontaneous

(C) \( \Delta G \) will be negative and the process is not spontaneous

(D) \( \Delta G \) will be positive and the process is not spontaneous

\[ \Delta G = -RT \ln K = -(+)(+)(-) = (+) \]

22. The system \( \text{MgO} (s) + \text{C} \) (graphite) \( \leftrightarrow \text{Mg} (s) + \text{CO} (g) \) is allowed to reach equilibrium where \( q_{\text{rev}} \) is measured to be 468 kJ at 298 K. \( \Delta S \) is:

(A) \( \frac{1570 \text{ J/K}}{1} \)

(B) \( 1.39 \times 10^5 \text{ J/K} \)

(C) \( -170 \text{ J/K} \)

(D) \( 766 \text{ J/K} \)

(E) \( -1.39 \times 10^5 \text{ J/K} \)

\[ \Delta S = \frac{q_{\text{rev}}}{T} = \frac{468 \text{ kJ}}{298 \text{ K}} = 1.57 \frac{\text{ kJ}}{\text{ K}} \text{ or } \frac{1570}{T} \]
23. Determine $\Delta S$ for the reaction $2 \text{C}_2\text{H}_4\text{O} (l) + 2 \text{H}_2\text{O} (l) \rightarrow 2 \text{C}_2\text{H}_6\text{O} (l) + \text{O}_2 (g)$ using the following two reactions:

(1) $2 \text{CO}_2 (g) + 3 \text{H}_2\text{O} (l) \rightarrow \text{C}_2\text{H}_6\text{O} (l) + 3 \text{O}_2 (g)$ \hspace{1cm} $\Delta S_1 = +371 \text{ kJ}$

(2) $2 \text{CO}_2 (g) + 2 \text{H}_2\text{O} (g) \rightarrow \text{C}_2\text{H}_4\text{O} (l) + 5/2\text{O}_2 (g)$ \hspace{1cm} $\Delta S_2 = -1167 \text{ kJ}$

\[ 4\text{O}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{C}_2\text{H}_6\text{O} + 6\text{O}_2 \quad \Delta S_1' = +371 \text{ kJ} \times 2 \]

\[ 2\text{C}_2\text{H}_4\text{O} + 5\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O} \quad \Delta S_2' = +1167 \text{ kJ} \times 2 \]

\[ 2\text{C}_2\text{H}_4\text{O} + 2\text{H}_2\text{O} \rightarrow 2\text{C}_2\text{H}_6\text{O} + \text{O}_2 \quad \Delta S = +3076 \text{ kJ} \]

(A) - 796 kJ
(B) + 1538 kJ
(C) - 1592 kJ
(D) $\leq 3076$ kJ
(E) - 1963 kJ
24.

<table>
<thead>
<tr>
<th>Formula</th>
<th>$\Delta H_f^o (kJ/mol)$</th>
<th>$\Delta G_f^o (kJ/mol)$</th>
<th>$S^o (J/mol\cdot K)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C$_3$H$_8$ (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$_2$O (l)</td>
<td>-285.8</td>
<td>-237.2</td>
<td>69.91</td>
</tr>
</tbody>
</table>

\[ C_3H_8 (g) + 5 O_2 (g) \rightarrow 3 CO_2 (g) + 4 H_2O (l) \]
\[ \Delta S_{reaction}^o = \text{products} - \text{reactants} \]
\[ \Delta S_{reaction}^o = \left( 3 \text{mol CO}_2 (g) \times 213.6 \frac{J}{\text{mol} \cdot K} \right) + \left( 4 \text{mol H}_2O (l) \times 69.91 \frac{J}{\text{mol} \cdot K} \right) - \left( \text{5mol} \times 205.0 \frac{J}{\text{mol} \cdot K} \right) = -374.8 \frac{J}{K} \]

(A) \(-374.8 \frac{J}{K}\)
(B) +393.5 J/K
(C) 0 J/K
(D) -393.5 J/K
(E) +374.8 J/K

25. So, Exam 1 is over. And now...

(A) I’m goin’ Party like it’s 1999.
(B) Vegas.
(C) Sax. I’m going to a nightclub and play the saxophone with a band.
(D) I will be titrating some snacks.
(E) I will be laying out on the grass. Looking up at the sky. Trying to envision each cloud as a piece of chemistry glassware.

[Understand this... since this notion is in your psyche, every time you look at a cloud you will smile and see an Erlenmeyer Flask.]

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