Instructions: Show all work whenever a calculation is required! You will receive credit for how you worked each problem as well as for the correct answer. If you need more space, you may use the back of your periodic table — Write “See PT” in box and then attach the periodic table. BOX YOUR ANSWERS! Write legibly.

CHAPTER 12. KINETICS
1. Consider the following mechanism:
   Step 1 \( \text{H}_2(\text{g}) + \text{FCl}(\text{g}) \rightarrow \text{HF}(\text{g}) + \text{HCl}(\text{g}) \) slow
   Step 2 \( \text{HF}(\text{g}) + \text{FCl}(\text{g}) \rightarrow \text{HCl}(\text{g}) + \text{F}_2(\text{g}) \) fast
   (a) (3 pts) What is the overall reaction?
   (b) (3 pts) What is the rate law for this mechanism?
   (c) (5 pts) Sketch a reaction profile for this reaction given that the overall reaction is exothermic.
   (d) (6 pts) Circle the catalyst(s) and intermediate(s):
     Catalyst(s) H\(_2\) F\(_2\) HF HCl FCl None
     Intermediate(s) H\(_2\) F\(_2\) HF HCl FCl None
   (e) (4 pts) True-False questions about the role of temperature, \( T \):
     T F Increasing \( T \) increases the rate determining step, as well as the rate of the fast step.
     T F All rate constants increase when \( T \) increases.
     T F Increasing \( T \) does not change \( E_{\text{act}} \).
     T F Increasing \( T \) causes \( \Delta H_{\text{rxn}} \) to decrease.

CHAPTER 13. EQUILIBRIUM
2. (6 pts) Write the \( K_c \) and \( K_p \) expressions for:
   \( \text{Fe}_3\text{O}_4(\text{s}) + 4 \text{H}_2(\text{g}) \rightleftharpoons 3 \text{Fe}(\text{s}) + 4 \text{H}_2\text{O}(\text{g}) \)

3. The vessel at left shows an equilibrium mixture \( \text{A}_2(\text{g}) + \text{B}_2(\text{g}) \rightleftharpoons 2 \text{AB}(\text{g}) \), where A is represented by the open circles.
   (a) (4 pts) Determine the numerical value of the equilibrium constant, \( K_c \). Because the balanced equation has an equal number of moles of gas on each side, knowing the volume is not necessary.
3(b) (4 pts) Determine if the mixture at right is at equilibrium. If it is not, which direction must it shift in order to attain equilibrium?

4. (6 pts) Suppose 4.0 mol H\(_2\)(g) were placed in a 9.0 L vessel containing excess S(s) and allowed to come to equilibrium. What are [H\(_2\)] and [H\(_2\)S] at equilibrium?
   \( \text{H}_2(\text{g}) + \text{S}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g}) \) \( K_c = 4.2 \)

5. (5 pts) Check each equilibrium where \( K_p = K_c \).
   - \( 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g}) \)
   - \( 2 \text{NO}_2\text{Cl}(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g}) + \text{Cl}_2(\text{g}) \)
   - \( \text{Fe}_3\text{O}_4(\text{s}) + 4 \text{H}_2(\text{g}) \rightleftharpoons 3 \text{Fe}(\text{s}) + 4 \text{H}_2\text{O}(\text{g}) \)
   - \( \text{H}_2(\text{g}) + \text{S}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g}) \)
   - \( \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) \)
6. (6 pts) The equilibrium given below is used in the process to make sulfuric acid. Suppose some \( \text{SO}_3(g) \) were placed in an empty vessel. If \( [\text{SO}_3]_i = 0.445 \text{ M} \) and \( [\text{SO}_3]_e = 0.208 \text{ M} \), what is the numerical value of \( K_c \)?

\[
2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \quad K_c = \ldots
\]

10. (5 pts) What is the pH of a 0.0042 \text{ M} solution of hydrochloric acid?

11. (6 pts) What is the pH of a 0.70 \text{ M} solution of benzoic acid, given its \( K_a = 6.5 \times 10^{-5} \)?

12. (4 pts) What is the \([\text{OH}^-]\) of the benzoic acid solution from the previous problem?

13. (6 pts) In order to determine a \( K_a \) value for boric acid, a 0.12 \text{ M} solution was prepared that gave pH of 5.11. What is the \( K_a \) of boric acid?

14. (5 pts) Hydrazine, \( \text{N}_2\text{H}_4 \) is a weak base with a \( K_b = 8.9 \times 10^{-7} \). What is the pH of a 0.50 \text{ M} solution of hydrazine?

15. (1 pts) What is the conjugate acid of hydrazine?

(2 pts) Print your name here and sign Academic Integrity Statement on other side.

Your exam score (100 possible): 

Determine your grade:

\( A+ \geq 95; A \geq 90; B+ \geq 85; B \geq 80; C+ \geq 75; C \geq 70; D \geq 60 \)
ANSWERS

1. (a) \( \text{H}_2(g) + 2 \text{FCl}(g) \rightarrow 2 \text{HCl}(g) + \text{F}_2(g) \)
(b) \( \text{rate} = k[\text{H}_2][\text{FCl}] \)
(c) 
\[
\begin{align*}
&\text{E}_{\text{act}1} \\
&\Delta H \\
&\text{E}_{\text{act}2}
\end{align*}
\]
(d) Catalyst(s): None
Intermediate(s): HF
(e) T T T F

2. (6 pts) Write the \( K_c = [\text{H}_2\text{O}(g)]^4/[\text{H}_2(g)]^4 \) and \( K_p = \frac{P_{\text{H}_2\text{O}}}{P_{\text{H}_2}}^4 \)

3. 3(a) \( K_c = 1.78 \)
3(b) \( Q_c = 1.56 \) so the reaction must shift RIGHT in order to reestablish equilibrium.

4. \([\text{H}_2] = 0.084 \ \text{M} \) and \([\text{H}_2\text{S}] = 0.36 \ \text{M} \)

5. 
\[
\begin{align*}
\text{Fe}_3\text{O}_4(s) + 4 \text{H}_2(g) & \rightleftharpoons 3 \text{Fe}(s) + 4 \text{H}_2\text{O(g)} \\
\text{H}_2(g) + \text{S(s)} & \rightleftharpoons \text{H}_2\text{S(g)}
\end{align*}
\]
6. \( K_c = 6.50 \)

7. F F F T F

CHAPTER 14. AQUEOUS EQUILIBRIA: ACIDS & BASES

8. 
\[
\begin{align*}
\text{HCl(aq)} + \text{H}_2\text{O(l)} & \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{Cl}^-(aq) \\
\text{HC}_2\text{H}_3\text{O}_2(aq) + \text{H}_2\text{O(l)} & \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{C}_2\text{H}_6\text{O}_2^-(aq) \\
\text{NaOH(aq)} & \rightleftharpoons \text{OH}^-(aq) + \text{Na}^+(aq) \\
\text{NH}_3(aq) + \text{H}_2\text{O(l)} & \rightleftharpoons \text{OH}^-(aq) + \text{NH}_4^+(aq)
\end{align*}
\]

9. 
<table>
<thead>
<tr>
<th></th>
<th>Solution A</th>
<th>Solution B</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>pH = 5.2</td>
<td>pH = 5.2</td>
</tr>
<tr>
<td>(b)</td>
<td>pH = 2.5</td>
<td>pH = 2.5</td>
</tr>
<tr>
<td>(c)</td>
<td>pH = 4.0</td>
<td>pH = 4.0</td>
</tr>
<tr>
<td>(d)</td>
<td>[OH(^-)] = 1.0 x 10(^{-9})</td>
<td>[OH(^-)] = 1.0 x 10(^{-9})</td>
</tr>
<tr>
<td>(e)</td>
<td>pOH = 5.5</td>
<td>pOH = 5.5</td>
</tr>
</tbody>
</table>