Keys

Chemistry 1220, Section 1
First Hour Exam
February 4, 2002
Dr. Alexander I. Boldyrev

Instructions:

Do not begin until 8:30 AM. The exam must be turned in by 9:20 AM.

⇒ The exam has 25 questions. Each question is worth 4 points for a total of 100 points. A periodic table is located on the last page.
⇒ Use only a #2 pencil to mark the answer on the ScanTron sheet. You will turn in only the ScanTron sheet and you may keep the rest of the exam. Your exam results will be emailed to you. You can check your answers with the answer key that will be posted on-line on the next day after the exam.
⇒ On the ScanTron sheet print your name and identification number in the areas indicated.

Indicate a four character code (any combination of letters and numbers) under "version#" for the purpose of reporting final grades.
Information

For the reaction $aA + bB \rightleftharpoons cC + dD$

$$rate = -\frac{1}{a} \frac{\Delta[A]}{\Delta t} = -\frac{1}{b} \frac{\Delta[B]}{\Delta t} = +\frac{1}{c} \frac{\Delta[C]}{\Delta t} + \frac{1}{d} \frac{\Delta[D]}{\Delta t}$$

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

1st order reactions:

$$\ln[A]_t = -kt + \ln[A]_0$$

$$t_{1/2} = 0.693/k$$

2nd order reactions:

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

Arrhenius

$$\ln k = -(E_a/RT) + \ln A$$

$$\ln(k_1/k_2) = E_a/R(1/T_2 - 1/T_1)$$

$$R = 8.314 \text{ J/(mol} \cdot \text{K})$$

$$K_p = K_c(RT)^\Delta n$$

$$R = 0.0821 \text{ L} \cdot \text{atm/(mol} \cdot \text{K})$$

$$K_a = \frac{[H^+][X^-]}{[HX]}, \ K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$$K_a \cdot K_b = K_w, \ pK_a + pK_b = pK_w = 14.00$$
(1) Of the following, only ______ are not valid units for a reaction rate

a) mol/L
b) M/s
c) mol/hr
d) g/s

(2) Which substance in the reaction below either appears or disappears the fastest?

\[4\text{NH}_3 + 7\text{O}_2 \rightarrow 4\text{NO}_2 + 6\text{H}_2\text{O}\]

a) \text{NH}_3
b) \text{O}_2
c) \text{NO}_2
d) \text{H}_2\text{O}
e) The rates of appearance/disappearance are the same for all of these.

(3) The rate law of a reaction is \( \text{rate} = k[A]^n \). The units of \( k \), if the reaction is second order in \( A \), are ___.

a) \text{M/s}
b) \text{M}^{-1}\text{s}^{-1}
c) \text{1/s}
d) \text{1/M}
e) \text{s/M}^2

\[ \frac{\text{rate}}{[A]^2} = k \]

\[ k = \frac{\text{rate}}{[A]^2} \]

\[ \frac{M}{S} = k \cdot M^2 \]

\[ k = \frac{M}{S \cdot M^2} = \frac{1}{M \cdot S} \]

(4) A reaction was found to be third order in \( A \). Increasing the concentration of \( A \) by a factor 3 will cause the reaction rate to ___

a) remain constant
b) increase by a factor of 27
c) increase by a factor 9
d) triple
e) decrease by a factor of the cube root of 3

\[ \text{rate} = k[A]^3 \]

\[ \text{rate} = k \left(3 \cdot [A]\right)^3 = 27 \cdot k[A]^3 \]
(5) Use the information below to determine the order of the reaction in reactant B.

\[ A + B \rightarrow P \]

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.273</td>
<td>0.763</td>
<td>2.83</td>
</tr>
<tr>
<td>2</td>
<td>0.273</td>
<td>1.526</td>
<td>2.83</td>
</tr>
<tr>
<td>3</td>
<td>0.819</td>
<td>0.763</td>
<td>25.47</td>
</tr>
</tbody>
</table>

\[
\frac{\text{rate}_1}{\text{rate}_2} = \left( \frac{[A_1]}{[A_2]} \right)^n \left( \frac{[B_1]}{[B_2]} \right)^m
\]

\[
1 = \left( \frac{0.763}{1.526} \right)^n \quad \text{only if } n = 0
\]

(6) The reaction \( A \rightarrow B \) is first order in \([A]\). The half-life of this reaction is \[ \text{________ s.} \]

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>[A] (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rightarrow 0.0 )</td>
<td>1.60</td>
</tr>
<tr>
<td>( \rightarrow 5.0 )</td>
<td>0.80 ( \rightarrow ) ( \frac{1}{2} ) initial</td>
</tr>
<tr>
<td>10.0</td>
<td>0.40</td>
</tr>
<tr>
<td>15.0</td>
<td>0.20</td>
</tr>
<tr>
<td>20.0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

a) 23
b) 10.0
c) 5.0
d) 0.20
e) -5.0

(7) In the potential energy profile of a reaction, the species that exists at the maximum on the curve is called the \[ \text{________} \]

a) product
b) activated complex
c) activation energy
d) enthalpy of reaction
e) atomic state
(8) In general, as temperature goes up, reaction rate ___

a) goes up if the reaction is exothermic  
b) goes up if the reaction is endothermic  
c) goes up regardless of whether the reaction is exothermic or endothermic  
d) stays the same regardless of whether the reaction is exothermic or endothermic  
e) stays the same if the reaction is first order

(9) The mechanism for formation of the product X is:

\[ A + B \rightarrow C + D \]
\[ B + D \rightarrow X \]

The intermediate reactant in the reaction is ___

a) A  
b) B  
c) C  
d) D  
e) X

(10) At equilibrium, ___

a) all chemical processes have ceased  
b) the rate of the forward reaction equals that of the reverse  
c) the rate constant for the forward reaction equals that of the reverse  
d) none of the above

(11) Which is the correct equilibrium constant expression for the Haber process (production of ammonia gas from nitrogen and hydrogen gases)?

\[
\begin{align*}
\text{a)} & \quad \frac{[NH_3]^2}{[N_2][H_2]^3} \\
\text{b)} & \quad \frac{[NH_3]}{[N_2][H_2]^2} \\
\text{c)} & \quad \frac{[H_2]^3}{[N_2][NH_3]^2} \\
\text{d)} & \quad \frac{[N_2][H_2]}{[NH_3]^2} \\
\text{e)} & \quad \frac{[N_2]^2[H_2]^3}{[NH_3]} \\
\end{align*}
\]

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \]
(12) Consider the gaseous equilibrium: \(2A \rightleftharpoons 2B + C\)
Determine the value of the missing B concentration at equilibrium

<table>
<thead>
<tr>
<th>Exp#</th>
<th>[A] at equilibrium</th>
<th>[B] at equilibrium</th>
<th>[C] at equilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10 M</td>
<td>0.15 M</td>
<td>0.20 M</td>
</tr>
<tr>
<td>2</td>
<td>0.20 M</td>
<td>0.50 M</td>
<td>0.072 M</td>
</tr>
<tr>
<td>3</td>
<td>0.35 M</td>
<td>?</td>
<td>0.15 M</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\kappa_c &= \frac{[B]^2[C]}{[A]^2}, \\
\kappa_c &= \frac{(0.15)^2}{(0.20)} = 0.45 \\
\end{align*}
\]

\[
[B] = \sqrt{0.37} = 0.61
\]

(13) Which of the reactants and/or products do not appear in the properly written heterogeneous \(K_c\) expression for the reaction:

\[
\text{NiCO}_3 (s) + 2\text{H}^+ (aq) \rightleftharpoons \text{Ni}^{2+} (aq) + \text{CO}_2 (g) + \text{H}_2\text{O} (l)
\]

a) \(\text{NiCO}_3 (s)\) only
b) \(\text{CO}_2 (g) + \text{H}_2\text{O} (l)\)
c) \(\text{H}^+ (aq)\) and \(\text{Ni}^{2+} (aq)\)
d) \(\text{CO}_2 (g)\) only
e) \(\text{NiCO}_3 (s)\) and \(\text{H}_2\text{O} (l)\)

(14) Consider the following reaction at equilibrium:

\[
2\text{NH}_3 (g) \rightleftharpoons \text{N}_2 (g) + 3\text{H}_2 (g) \quad \Delta H^\circ = 92.4 \text{ kJ/mol}
\]

Adding \(\text{N}_2 (g)\) to the system at equilibrium will _____

a) decrease the concentration of \(\text{NH}_3 (g)\) at equilibrium
d) decrease the concentration of \(\text{H}_2 (g)\) at equilibrium
e) increase the value of the equilibrium constant
c) cause the reaction to shift to the right
e) remove all of the \(\text{H}_2 (g)\)
(15) Consider the following reaction at equilibrium:

\[ 2\text{SO}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2\text{SO}_3 (g) \quad \Delta H^\circ = -99 \text{ kJ/mol} \]

If the temperature is increased, then ___ when the total pressure is held constant

a) the concentration of \text{SO}_3 will decrease
b) the partial pressure of \text{SO}_2 will decrease
c) the total volume of the system will decrease
d) the partial pressure of \text{O}_2 will decrease

(16) The effect of a catalyst on a chemical reaction is to ___

a) lower the energy of the transition state
b) accelerate the forward reaction only
c) make reactions more exothermic
d) increase the entropy change associated with a reaction
e) react with product, effectively removing it and shifting the equilibrium to the right

(17) According to Arrhenius, an acid is a substance that ___

a) is capable of accepting one or more \text{H}^+

b) causes an increase in the concentration of \text{H}^+ in aqueous solutions
c) can accept a pair of electrons to form a coordinate covalent bond
d) reacts with the solvent to form the cation formed by autoionization of that solvent
e) tastes bitter

(18) Which one of following is not a Bronsted-Lowry acid?

a) \((\text{CH}_3)_3\text{NH}^+\)
b) \(\text{CH}_3\text{COOH}\)
c) \(\text{HF}\)
d) \(\text{HNO}_2\)
e) \(\text{ClO}_4^-\)
A substance that is capable of acting as both acid and as base is __________

a) autosomal  
b) conjugated  
\(\text{c) amphoteric}  
d) autocratic  
e) contrapunctual

The concentration of water in pure water is approximately ______ M

\[
\frac{\text{mol}}{\text{L}} = \frac{1000 \text{ g}}{18 \text{ g/mol}} = \frac{1000}{18} M \approx 55 M
\]

The conjugate base of \(\text{HSO}_4^-\) is

a) \(\text{OH}^-\)  
b) \(\text{H}_2\text{SO}_4\)  
\(\text{c) SO}_4^{2-}\)  
d) \(\text{HSO}_4^-\)  
e) \(\text{H}_3\text{SO}_4^+\)

The molar concentration of hydroxide ion (\(\text{HO}^-\)) in pure water at 25° C is

a) 1  
b) 0  
\(\text{c) } 1\times10^{-14}\)  
d) \(1\times10^{-7}\)  
e) 7

What is the pH of a 0.015 M solution of \(\text{Ca(OH)}_2\)

\[
\text{Ca(OH)}_2(\text{aq}) \rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})  
\]

\[
\text{pH} = 14.00 - 1.52 = 12.48
\]

\[
\text{pOH} = -\log [\text{OH}^-] = 1.52
\]
(24) The $K_a$ of HF is $6.8 \times 10^{-4}$. What is the pH of a 0.35 M solution of HF?

\[
\begin{align*}
\text{a)} & \quad 3.17 \\
\text{b)} & \quad 1.81 \\
\text{c)} & \quad 3.62 \\
\text{d)} & \quad 0.46 \\
\text{e)} & \quad 12.19
\end{align*}
\]

\[
K_a = \frac{[H^+][F^-]}{[HF]} = \frac{(x)(0.35-x)}{(0.35-x)} = 6.8 \times 10^{-4}
\]

\[
x^2 = 0.35 \times 6.8 \times 10^{-4} = 2.38 \times 10^{-4}, \quad x = 0.0151, \quad \log x = 1.81
\]

(25) Which one of the following is the weakest acid?

\[
\begin{align*}
\text{a)} & \quad \text{HF} \ (K_a = 6.8 \times 10^{-4}) \\
\text{b)} & \quad \text{HClO} \ (K_a = 3.0 \times 10^{-8}) \\
\text{c)} & \quad \text{HNO}_2 \ (K_a = 4.5 \times 10^{-4}) \\
\text{d)} & \quad \text{HCN} \ (K_a = 4.9 \times 10^{-10}) \\
\text{e)} & \quad \text{Acetic acid} \ (K_a = 1.8 \times 10^{-5})
\end{align*}
\]
### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Period</th>
<th>Group</th>
<th>Element</th>
<th>Atomic Number</th>
<th>Atomic Mass</th>
<th>Electron Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>H</td>
<td>1</td>
<td>1.008</td>
<td>1s^1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>He</td>
<td>2</td>
<td>4.003</td>
<td>1s^2</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>Al</td>
<td>13</td>
<td>26.982</td>
<td>1s^22s^22p^63s^23p^1</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>Si</td>
<td>14</td>
<td>28.085</td>
<td>1s^22s^22p^63s^23p^2</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>P</td>
<td>15</td>
<td>30.974</td>
<td>1s^22s^22p^63s^23p^3</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>S</td>
<td>16</td>
<td>32.06</td>
<td>1s^22s^22p^63s^23p^4</td>
</tr>
</tbody>
</table>

**Main Groups**

1A - Alkaline Earth Metals
1B - Alkaline Metals
2A - Alkaline Earth Metals
2B - Alkaline Metals
3A - Noble Gases
13A - Chalcogens
14A - Halogens
15A - Alkaline Earth Metals
16A - Alkaline Metals
17A - Noble Gases
18A - Noble Gases

**Transition Metals**

23-32

**Actinide Series**

29-38

**Lanthanide Series**

57-71