Answer all questions on the Scantron answer sheet by filling in the proper bubble with a number 2 pencil. If you change your answer, please erase the previous mark thoroughly.

You are not permitted to use a programmable calculator; only non-programmable calculators can be used!

Be sure to fill in the boxes for your SID# and name; then fill in the corresponding bubbles beneath them correctly. A periodic table with atomic numbers and masses is attached to the back of this exam.

Be sure to fill out the Scantron sheet with your name and SID#.

\[ R = 0.08206 \text{ L atm/mol K} \quad K = 8.314 \text{ J/mol K} \]

\[ K = ^\circ\text{C} + 273.15 \]

\[ \text{pH} = -\log([\text{H}_3\text{O}^+]) \]

\[ K_p = K_c(\text{RT})^n \]

\[ K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]} \quad \text{pH} = \text{pK}_a + \log\frac{[\text{Base}]}{[\text{Acid}]} \quad K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]} \]

\[ K_w = 10^{-14} \text{ at } 25^\circ\text{C} \]

\[ K_c \times K_b = K_w \]

\[ K_n = K_w \text{ (strong acid-strong base)} \]

\[ = \frac{K_a}{K_w} \text{ (weak acid-strong base)} \]

\[ = \frac{K_b}{K_w} \text{ (strong acid-weak base)} \]

\[ = \frac{K_a K_b}{K_w} \text{ (weak acid-weak base)} \]

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

Strong acids: HI, HCl, HBr, HClO₄, HClO₃, H₂SO₄, HNO₃

Strong bases: any salts of group 1 metals and hydroxide ion
All problems are worth 5 points each.

1. If the equilibrium constant for the following forward reaction
   \[ 2 \text{Hg}(l) + \text{O}_2(g) \rightarrow 2 \text{HgO}(s) \]
   is 0.625, what is the equilibrium constant for the reverse reaction?
   a. \(-0.625\)
   b. 0.625
   c. 1.6
   d. 0.204
   e. none of these

2. The following pictures represent solutions at various points in the titration of a weak acid HA with aqueous KOH. Unshaded spheres represent H atoms, black spheres represent oxygen atoms, and shaded spheres represent A- ions.

Which two pictures represent the system before the titration and at the equivalence point respectively?

a. 1 and 2
b. 3 and 2
c. 2 and 4
d. 4 and 1
e. 2 and 3

3. Which of the following is a conjugate base of the Brønsted-Lowry acid H₂O in the following reaction?
   \[ \text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq) \]
   a. \(\text{NH}_3\)
   b. \(\text{NH}_4^+\)
   c. \(\text{OH}^-\)
   d. \(\text{H}_3\text{O}^+\)
   e. Both \(\text{NH}_3\) and \(\text{OH}^-\)
4. What is the neutralization constant $K_a$ of the reaction of hydrazine ($N_2H_4$) with hydrochloric acid (HCl) in water at 25 °C?

   a. $8.5 \times 10^{-21}$
   b. $8.5 \times 10^{-7}$
   c. $1.0 \times 10^{-14}$
   d. $1.2 \times 10^9$
   e. $8.5 \times 10^7$

5. When a catalyst is used to increase the rate of the reaction, which one of the following is affected?

   a. activation energy of the reaction
   b. equilibrium constant of the reaction
   c. enthalpy of the reaction
   d. energy of the reaction
   e. entropy of the reaction

6. A solution with a hydroxide ion concentration of $1.85 \times 10^{-3}$ M is ________, and has a hydronium ion concentration of ________ at 25 °C.

   a. acidic, $5.4 \times 10^{-8}$ M
   b. acidic, $2.7 \times 10^{-9}$ M
   c. basic, $5.4 \times 10^{-6}$ M
   d. basic, $2.7 \times 10^{-8}$ M
   e. basic, $1.9 \times 10^{-8}$ M

7. For the reaction shown below, which change in conditions made to the system at equilibrium will result in a shift of equilibrium toward product if the reaction takes place in a closed container?

   $$\text{NH}_4\text{Br}(s) \rightleftharpoons \text{NH}_3(g) + \text{HBr}(g) \quad \Delta H^\circ = 188.3 \text{ kJ.}$$

   a. Adding more NH$_4$Br
   b. Adding more NH$_3$
   c. Decreasing the volume of the container
   d. Increasing the temperature
   e. Adding a catalyst
8. What is the percent dissociation of a 0.2 M solution of benzoic acid?

a. 1.1%
b. 1.4%
c. 1.8%
d. 2.1%
e. 4.5%

9. For the reaction: 4 HCl(g) + O₂(g) ⇌ 2 Cl₂(g) + 2 H₂O(l), the equilibrium constant is 0.0825 at 400 K. If the concentrations are as follows:

[HCl] = 0.25 M  [O₂] = 0.2 M  [Cl₂] = 0.005 M

What will happen to the reaction?

a. It will shift to the left.
b. It will shift to the right.
c. It will stay the same.
d. The equilibrium constant will go up.
e. The equilibrium constant will go down.

10. What is the equilibrium constant, $K_c$, for the reaction

FeS(s) + 2 H₂O+ (aq) ⇌ Fe²⁺(aq) + H₂S (aq) + 2 H₂O (l)

if the amounts of reactants and products at equilibrium are: 1.758 g of FeS(s), 0.1 M of H₂O⁺(aq), 2.50×10⁻¹⁰ M of Fe²⁺(aq), 2.00×10⁻¹¹ M of H₂S and 100 ml of H₂O?

a. 0.80 × 10⁻²⁴  b. 5.00 × 10⁻²²  c. 2.50 × 10⁻²²  d. 2.50 × 10⁻²⁰  e. 5.00 × 10⁻¹⁹
11. The equilibrium concentrations at 336°C for the gas-phase reaction \(2\text{NH}_3 \rightarrow \text{N}_2 + 3\text{H}_2\) are:

\[
\begin{align*}
\text{[NH}_3\text{]} &= 0.5 \text{ M} \\
\text{[N}_2\text{]} &= 0.05 \text{ M} \\
\text{[H}_2\text{]} &= 0.1 \text{ M}
\end{align*}
\]

What is \(K_p\) for this reaction?

a. 0.0002  
b. 5000  
c. 2.0  
d. 0.5  
e. 0.005

12. What is the pH when 0.1 M CH₃COOH (acetic acid) is mixed with an equal volume of 0.05 M NaCH₃COO (sodium acetate)?

a. 4.14  
b. 4.44  
c. 4.74  
d. 5.04  
e. 5.34

13. What is the change in pH when 40.0 mL of 6 M RbOH is added to 2.0 L of a solution that is 0.1 M in HBr and 0.1 M in KBr?

a. It increases by 10.6  
b. It increases by 10.3  
c. It increases by 11.3  
d. It increases by 11.6  
e. It increases by 12.3
17. At 50°C the value of $K_w$ is $5.5 \times 10^{-14}$. Calculate the pH for a neutral aqueous solution at 50°C.
   a. 6.26 
   b. 6.63 
   c. 7.00 
   d. 7.37 
   e. 7.74

18. At 50°C the value of $K_w$ is $5.5 \times 10^{-14}$. Calculate the pH for an aqueous solution at 50°C that contains $2.50 \times 10^{-4}$ M in hydroxide ion.
   a. 3.60
   b. 9.66
   c. 10.34
   d. 10.40
   e. 11.14

19. Many pools use chlorine compounds to kill bacteria and viruses. Chlorine is usually added as hypochlorous acid (HOCl). What is the pH of the solution at equilibrium when you add 15.7 g of hypochlorous acid to 2.00 L of water?
   a. 3.72
   b. 3.39
   c. 4.14
   d. 4.55
   e. 7.45
20. Given a solution of 50.00 mL of 0.4 M oxalic acid (H₂C₂O₄), how many mL of 0.5 M NaOH would you need to add for the pH to be equal to 4.40?
   a. 49.7
   b. 55.3
   c. 60.2
   d. 64.7
   e. 69.3