Chemistry 1A, Fall 2012

Midterm Exam #2
October 17, 2012
(90 min, closed book)

Name:_____

SID:_____

GSI Name:_____ Discussion Day/Time: _____

- The test consists of 5 short answer questions and 22 multiple choice questions.
- Put your written answers in the boxes provided. Answers outside the boxes may not be considered in grading.
- Write your name on every page of the exam.

Question	Page	Points	Score
Multiple Choice (1-22)	2-7	88	
Titration Short Answer		6	
Soda (1) Short Answer		4	
Soda (2) Short Answer		4	
Ocean Acidification Short Answer		4	
Indicators Short Answer		4	
Total		110	

Useful Equations and Constants:

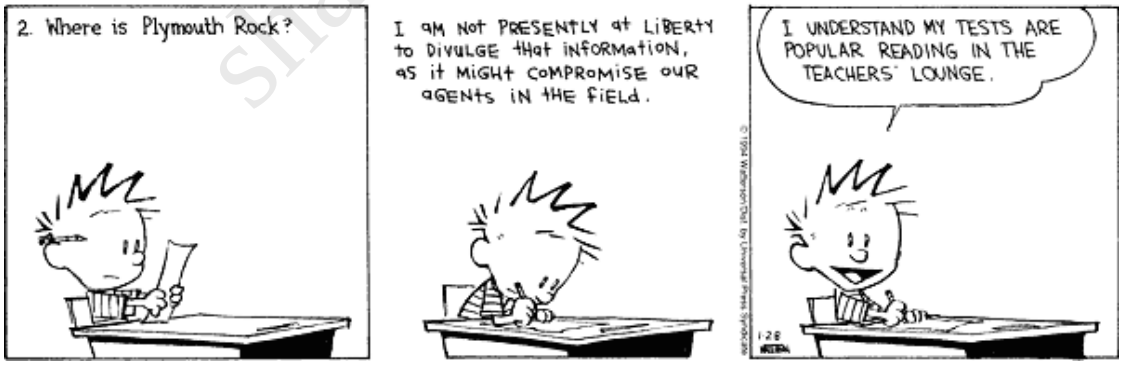
$pH = - \log[H^+]$
$pX = - \log X$
$X = 10^{-pX}$
$K_w = 1 \times 10^{-14}$ at 25°C
$PV = nRT$
$K_w = K_a K_b$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$R = 0.0821$ L atm mol^{-1} K^{-1}
$T(K) = T(°C) + 273$

Strong acids and bases:

HCl	LiOH
HNO_3	NaOH
H_2SO_4	KOH
$HClO_4$	
HBr	
HI	



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WEAK BASES

The equilibrium constants for several weak bases are given in the table and will be referred to in Questions 1 through 9.

Name	Formula	K_b	pK_b
ammonia	NH_3	2×10^{-5}	4.7
sodium azide	NaN_3	4.0×10^{-10}	9.4
sodium nitrite	$NaNO_2$	2.5×10^{-11}	10.6
chloramine	NH_2Cl	10^{-14}	14
sodium nitrate	$NaNO_3$	10^{-16}	16

1. Which reaction best describes what happens when $NaNO_2$ is dissolved in water?

   A) $NaNO_2\,(aq) + H_2O\,(l) \leftrightarrows Na^+(aq) + NO_2^-(aq)$

   B) $NO_2^-(aq) + H_2O\,(l) \leftrightarrows NO_3^-(aq) + 2H^+(aq)$

   C) $NaNO_2\,(aq) + H^+(l) \leftrightarrows HNO_2\,(aq) + Na^+(aq)$

   D) $NO_2^-(aq) + H_2O\,(l) \leftrightarrows HNO_2\,(aq) + OH^-(aq)$

2. Which solution is the most basic?

   A) 0.10 M NaN_3 B) 0.10 M $NaNO_2$ C) 0.10 M NH_3 D) 0.10 M NH_4Cl

3. Which statement best explains the difference in K_b between NH_3 and NH_2Cl?

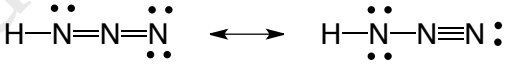
   A) NH_2Cl has fewer H atoms so it is more basic.

   B) The hydrogen bonding is stronger in NH_2Cl so it is more basic.

   C) Cl withdraws electron density from the N atom making NH_2Cl more basic.

   D) Cl withdraws electron density from the N atom making NH_2Cl less basic.

4. Two resonance forms of hydrazoic acid, HN_3, are shown below. Which statement best explains why HN_3 is an acid?



   A) HN_3 is an acid because there are two resonance structures.

   B) HN_3 is an acid because the negative charge can spread out on the N_3^- anion.

   C) HN_3 is an acid because there is a negative charge on the N atom next to the H atom.

   D) HN_3 is an acid because it does not attract H^+ to form H_2N_3.

5. You are given a mixture of 0.10 M $NaNO_3$ and 0.10 M NH_4Cl. The solution is:

   A) acidic B) basic C) neutral D) none of these

6. What is the pH of 0.10 M $NaNO_2$? [K_b (NO_2^-)= 2.5×10^{-11}]

A) 2.2 B) 5.3 C) 5.8 D) 8.2 E) 10.4

7. What is the pH of 100 mL of 0.10 M $NaNO_2$ solution after adding 50 mL of 0.10 M HCl?

A) 3.4 B) 5.8 C) 8.1 D) 8.2 E) 10.6

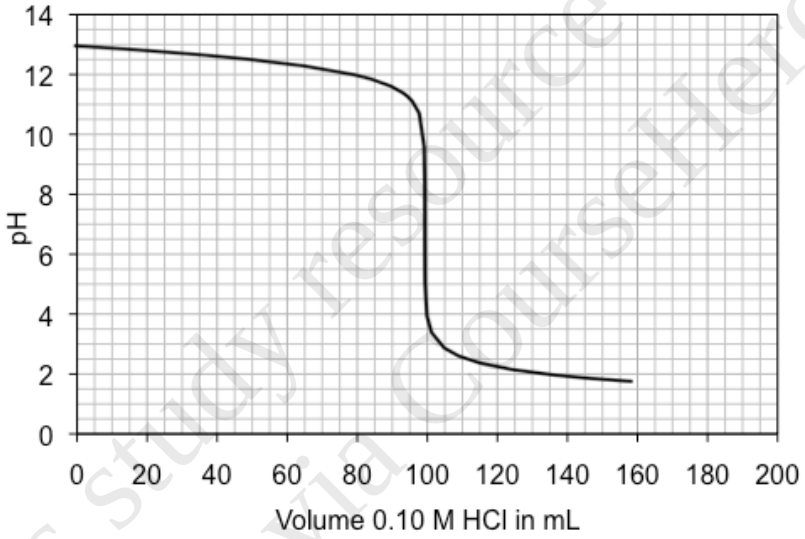
8. What is the pH of 100 mL of 0.10 M $NaNO_2$ solution after adding 100 mL of 0.10 M HCl? [K_a (HNO_2) = 4.0×10^{-4}]

A) 1.0 B) 1.3 C) 2.2 D) 2.3 E) 6.1

SHORT ANSWER: The graph for the titration of 100 mL of 0.10 M NaOH solution with 0.10 M HCl solution is shown below.

Sketch the graph for the titration of 100 mL of 0.10 M $NaNO_2$ with 0.10 M HCl.

- Specify the value of the initial pH
- Specify the value of the pH halfway to the equivalence point
- Specify the value of the pH at the equivalence point.



9. What is/are the dominant species in the solution besides water at the equivalence point?

A) HNO_2 B) NO_2^- C) $[HNO_2] = [NO_2^-]$ D) $[HNO_2] = [H^+]$

CARBONATED BEVERAGES

In order to make carbonated water, soda makers dissolve carbon dioxide gas, CO_2 (g), in water.

$$CO_2\,(g) \leftrightarrows CO_2\,(aq) \qquad K_H = \frac{[CO_2]}{p_{CO_2}} = 0.033\ \text{M/atm at 25°C}$$

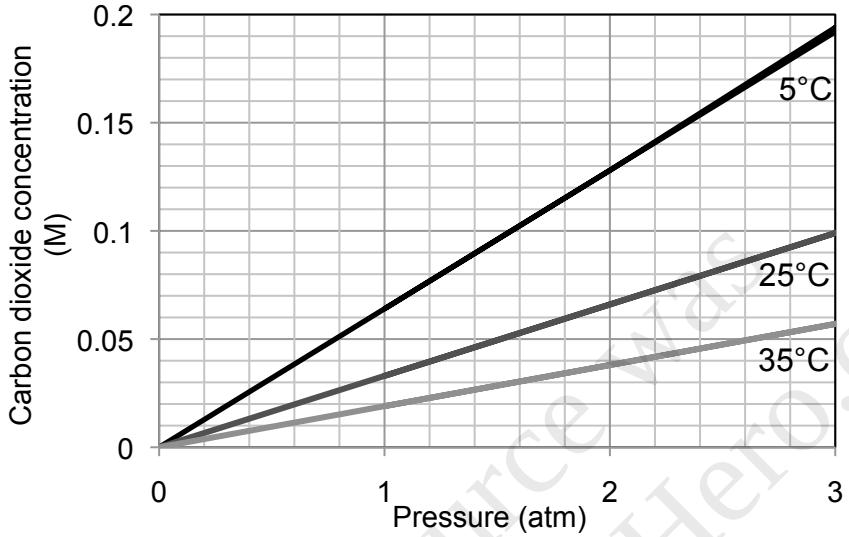
10. What is the equilibrium concentration of CO_2 in water at 25°C if the partial pressure of CO_2 (g) above the water is 2.0 atm?

A) 0.0156 M B) 0.033 M C) 0.066 M D) 30.3 M

11. What is the equilibrium concentration of CO_2 in water at 25°C if there is a gas pressure of 1.0 atm above the water, and it consists of the equimolar mixture of CO_2 and N_2?

A) 0.0156 M B) 0.033 M C) 0.066 M D) 30.3 M

The data in the graph below show the solubility of CO_2 (g) in water as a function of gas pressure at three temperatures. Use the data to answer the questions below.



12. What is the equilibrium constant, K_H, for the dissolution of CO_2 in water at 5°C if the CO_2 pressure is 1.4 atm?

A) 0.064 M/atm B) 0.09 M/atm C) 1.4 M/atm D) 15.6 M/atm

13. Which of the following conditions would be most optimal for making carbonated water?

A) High pressure CO_2, high temperature
B) Low pressure CO_2, high temperature
C) High pressure CO_2, low temperature
D) Low pressure CO_2, low temperature

SHORT ANSWER: You open a bottle of soda that was equilibrated at 2.0 atm CO_2 (g) at 5°C. After the bottle is opened to the atmosphere where the partial pressure of CO_2 (g) is 3.9×10^{-4} atm and the temperature is 25°C, you find that the concentration of CO_2 (aq) is 0.06 M. Explain this observation.

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SHORT ANSWER: Suppose you have a 2 liter container with 1 atm CO_2 (g) at 25°C. You inject 1.0 L of a 0.033 M CO_2 solution. The solution takes up half the volume. Explain why the concentration of CO_2 in the solution increases when equilibrium is reached.

OCEAN ACIDIFICATION

Dissolved CO_2 reacts with water to produce HCO_3^- and CO_3^{2-} according to the equations below.

$CO_2\,(aq) + H_2O\,(l) \leftrightarrows H^+(aq) + HCO_3^-(aq)$ $\quad K_{a1} = 4.5\times10^{-7}$

$HCO_3^-(aq) \leftrightarrows H^+(aq) + CO_3^{2-}(aq)$ $\quad K_{a2} = 4.7\times10^{-11}$

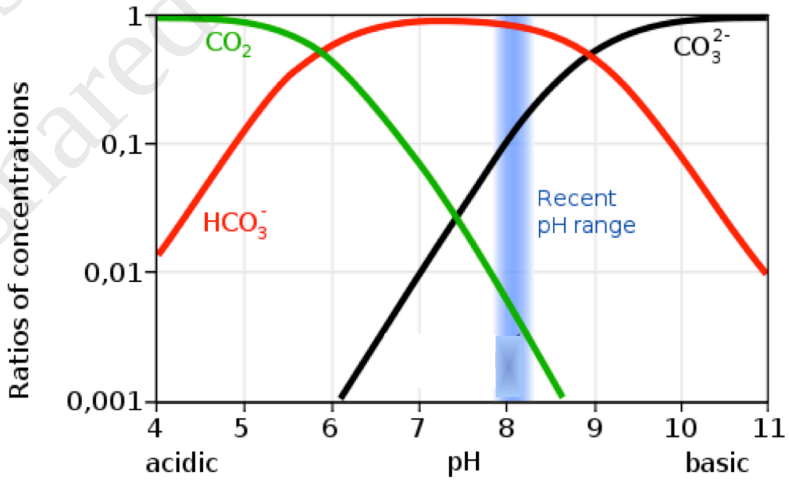
14. In view of the equilibria above, what is the conjugate acid of HCO_3^- (aq)?

A) H_2O B) CO_2 C) H^+ D) CO_3^{2-}

15. What volume of 0.010 M NaOH must be added to a 100 mL solution that is a mixture of 0.010 M $NaHCO_3$ and 0.010 M Na_2CO_3 in order to completely eliminate its buffering properties?

A) 50 mL B) 100 mL C) 150 mL D) 200 mL E) 250 mL

Use the equations above and the data in the graph to answer questions below about the acidity of the ocean.



16. The ocean has a pH ~ 8. What are the major species in solution?

A) $[HCO_3^-] = [H^+] > [CO_3^{2-}] > [CO_2]$

B) $[HCO_3^-] > [H^+] > [CO_3^{2-}] > [CO_2]$

C) $[HCO_3^-] > [CO_3^{2-}] > [H^+] > [CO_2]$

D) $[HCO_3^-] > [CO_3^{2-}] > [CO_2] > [H^+]$

17. About 35% of the CO_2 released by humans into the atmosphere by burning fossil fuels dissolves into the oceans, rivers, and lakes. How does this affect the pH of the ocean?

A) The pH will stay the same because of the HCO_3^- / CO_3^{2-} buffer.

B) The pH will stay the same because of the CO_2 / HCO_3^- buffer.

C) The pH will decrease because CO_2 (aq) is an acid.

D) The pH will increase because CO_2 (aq) is a base.

The main component of shells of marine organisms is calcium carbonate, $CaCO_3$ (s).

$$CaCO_3\ (s) \leftrightarrows Ca^{2+}\ (aq) + CO_3^{2-}\ (aq) \qquad K_{sp} = 4.8\times10^{-9}$$

Use the information on the preceding page to consider the effect of ocean pH on shellfish.

18. The concentration of Ca^{2+} (aq) in seawater is about 1.0×10^{-2} M. What concentration of CO_3^{2-} (aq) is necessary to have a saturated solution of $CaCO_3$?

A) 4.8×10^{-11} M B) 4.8×10^{-9} M C) 6.9×10^{-5} M D) 4.8×10^{-7} M

SHORT ANSWER: As the oceans take up CO_2(g) released by humans, scientists predict negative effects on shellfish. Explain the effect on shellfish on the basis of changes in the ocean acidity, concentration of CO_3^{2-}(aq), and solubility of $CaCO_3$(s).

19. Scientists are considering injection of CO_2 (g) into sandstone, $CaAl_2Si_2O_8$ (s), to remove CO_2 (g) from the atmosphere according to the reaction:

$$CaAl_2Si_2O_8\ (s) + CO_2\ (g) + 2H_2O\ (l) \leftrightarrows CaCO_3\ (s) + Al_2Si_2O_5(OH)_4\ (s)$$

Is this reaction an oxidation-reduction reaction?

A) Yes, because CO_2 (g) is converted to $CaCO_3$ (s).

B) Yes, because $2H_2O$ (l) is converted to OH^- (s).

C) No, because the oxidation states of the atoms do not change.

D) No, because oxygen gas is not released.

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INDICATORS

A mixture of methyl orange, methyl red, and phenolphthalein are dissolved in an aqueous solution at pH = 8. A small volume of this solution is placed on an anion exchange column. The stationary phase is a polymer with fixed positively charged groups initially ion-paired with Cl^- anions. Anions in the solution exchange with the Cl^- anions, and thus are temporarily retained on the column. Use the data in the table to answer the questions below.

Indicator	**HA color**	**A^- color**	**K_a**
methyl orange	red	yellow	3.4×10^{-4}
methyl red	yellow	red	7.9×10^{-6}
phenolphthalein	colorless	pink	4.0×10^{-10}

20. What colors do you predict for methyl orange and methyl red in a solution in which the pH is set independently at pH = 8? Phenolphthalein is colorless in this solution.

A) Methyl orange is yellow and methyl red is red.

B) Methyl orange is red and methyl red is red.

C) Methyl orange is yellow and methyl red is yellow.

D) Methyl orange is red and methyl red is yellow.

21. The equilibrium, K_{eq}, between the polymer and the A^- form of an indicator is:

$$\text{polymer}^+ Cl^- + A^-(aq) \leftrightarrows \text{polymer}^+ A^- + Cl^-(aq)$$

What happens as a concentrated solution of NaCl (aq) is poured down the column?

A) There is no change because the system is at equilibrium.

B) There is no change because Na^+ (aq) and Cl^- (aq) are spectator ions.

C) The equilibrium shifts to the left and the indicator moves down the column.

D) The equilibrium shifts to the right and the indicator remains attached to the polymer.

22. For the equilibrium, K_{eq}, between the indicators and the polymer shown above, which indicator is most predominantly retained by the stationary phase?

A) methyl orange B) methyl red C) phenolphthalein D) all three

SHORT ANSWER: When a concentrated solution of NaCl (aq) is poured down the column, the first indicator to move down the column is phenolphthalein. Explain why. Frame your explanation in terms of the relative position of the chemical equilibria on the column.