Chem 112 - 2020
Exam # 3 Winny
Answer Key

QUESTION 1

What is the pH of a 0.33 M solution of HClO?

$K_a = 3.5 \times 10^{-8}$

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QUESTION 2

Sulfurous acid is a diprotic acid with the following K_a values:

$H_2SO_3 + H_2O \text{ ==== } HSO_3^- + H_3O^+ \quad K_{a1} = 1.4 \times 10^{-2}$

See next page

$HSO_3^- + H_2O \text{ ==== } SO_3^{2-} + H_3O^+ \quad K_{a2} = 6.3 \times 10^{-8}$

a) Determine pK_{a1} and pK_{a2}

b) Draw an alpha plot for this system

c) In what molecular form will the system exist at pH = 3?

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QUESTION 3

Equal volumes of the pairs of solutions below are mixed. Which result in buffer solutions?

- ✓ 0.3 M CH_3CO_2H + 0.1 M NaOH — React to give 0.1 M $CH_3CO_2^-$ + 0.2 M CH_3CO_2H
- ✗ 0.1 M HCl + 0.1 M $NaNO_3$ — No base
- ✓ 0.1 M HF + 0.2 M NaF
- ✓ 0.3 M CH_3CO_2H + 0.2 M KCH_3CO_2
- ✗ 0.4 M NH_4^+ + 0.4 M HNO_2 — two acids

QUESTION 4

A. Calculate the solubility of CaF_2 in pure water, in units of mol/L.

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$K_{sp} = 5.3 \times 10^{-11}$

B. Calculate the solubility of CaF_2 in a solution of 0.10 M NaF, in units of mol/L.

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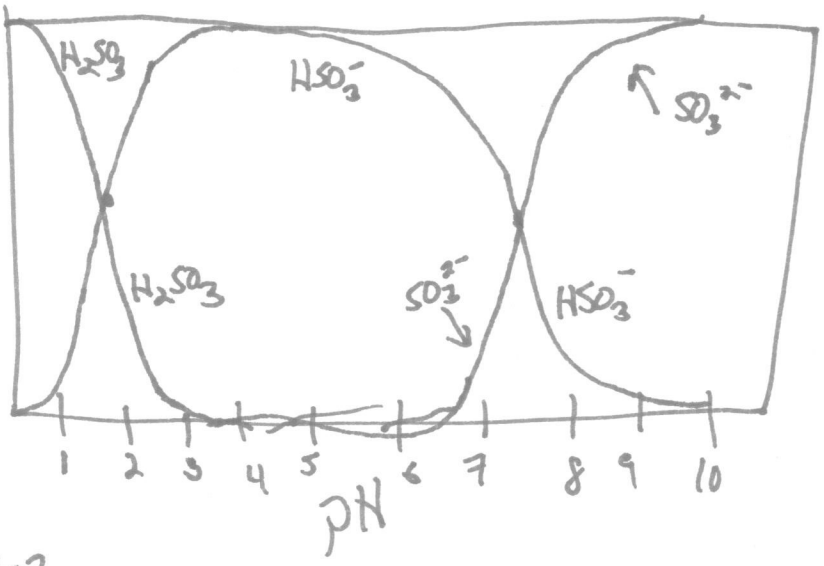
Alpha Plot

$H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+$ $K_{a1} = 1.4 \times 10^{-2}$ $pK_{a1} = \underline{1.85}$

Q2 $HSO_3^- + H_2O \rightleftharpoons SO_3^{2-} + H_3O^+$ $K_{a2} = 6.3 \times 10^{-8}$ $pK_{a2} = \underline{7.20}$



@ pH=3,

$\underline{HSO_3^-}$ predominates

Q1 pH of 0.33M HClO

$HClO + H_2O \rightleftharpoons H_3O^+ + ClO^-$

I	0.33	0	0
C	$-x$	$+x$	$+x$
E	$0.33-x$	x	x

$$K_a = 3.5 \times 10^{-8} = \frac{x^2}{0.33-x} \approx \frac{x^2}{0.33}$$

$$x = \sqrt{0.33 \times 3.5 \times 10^{-8}} = 1.07 \times 10^{-4}\ M$$

$$pH = \underline{3.97}$$

Solubility of CaF_2 Q4

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$$

$$x \qquad 2x$$

$$K_{sp} = 5.3\times10^{-11} = (x)(2x)^2 = 4x^3$$

$$x = \sqrt[3]{\frac{5.3\times10^{-11}}{4}} = 2.37\times10^{-4}\ M$$

} in H_2O

$$CaF_2(s) \rightleftharpoons Ca^{2+} + 2F^-$$

I	0	0,10
C	+x	+2x
E	x	0,10 +2x

$$K_{sp} = 5.3\times10^{-11} = (x)(0,10+2x) \approx (x)(0,10)^2$$

$$x = \frac{5.3\times10^{-11}}{(0,10)^2} = 5.3\times10^{-9}\ M$$

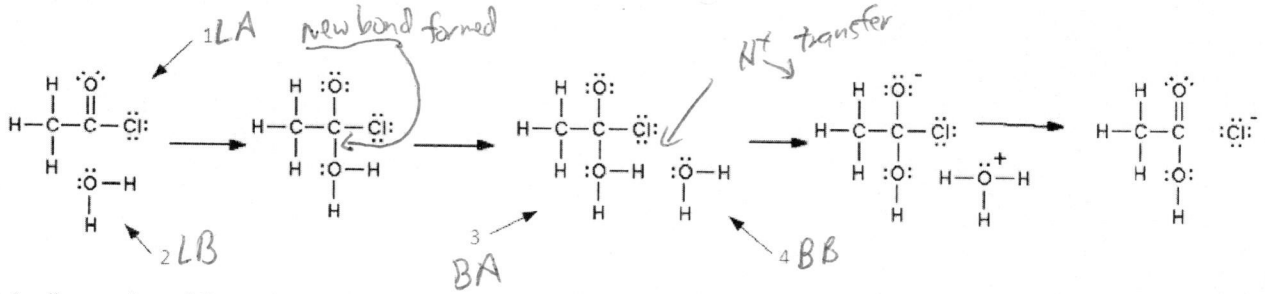
QUESTION 5

Which of the following acids has the largest K_a value?

- HBrO
- $HBrO_2$
- $HBrO_3$
- ~~$HBrO_4$~~ ← More oxygen atoms pull e^- density away from H

QUESTION 6

The mechanism for one method of producing acetic acid is shown below.



Enter the number of the compound that acts in the following ways during this reaction.

Bronsted acid: 3

Bronsted base: 4

Lewis acid: 1

Lewis base: 2

QUESTION 7

$CH_3CH_2NH_3^+$, is a weak acid. If a 0.32 M solution of the acid has a pH of 2.68, what is the value of K_a for this acid?

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$$CH_3CH_2NH_3^+ + H_2O \rightleftharpoons CH_3CH_2NH_2 + H_3O^+$$

	$CH_3CH_2NH_3^+$	H_2O	$CH_3CH_2NH_2$	H_3O^+
I	0.32		0	0
C	$-x$		$+x$	$+x$
E	$0.32 - 2.09\times10^{-3}$		x	2.09×10^{-3}

$2.09\times10^{-3} \leftarrow 10^{-2.68}$

$x = 2.09\times10^{-3}$

$$K_a = \frac{(2.09\times10^{-3})^2}{(0.32 - 2.09\times10^{-3})} = \frac{4.37\times10^{-6}}{0.3179} = 1.37\times10^{-5}$$

QUESTION 8

Co^{2+} reacts with ammonia in aqueous solution to form a complex ion.

$$Co^{2+} + 6\,NH_3 \rightleftarrows [Co(NH_3)_6]^{2+} \quad K_f = 1.3 \times 10^5$$

The reverse reaction is the dissociation of the complex ion.

$$[Co(NH_3)_6]^{2+} \rightleftarrows Co^{2+} + 6\,NH_3 \quad K_d = ?$$

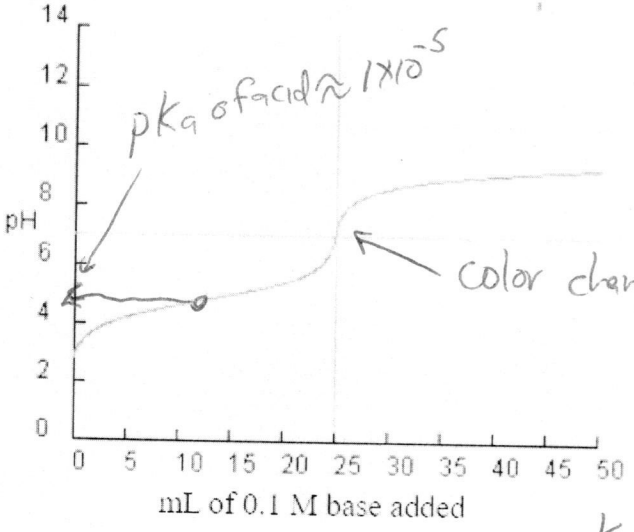
Choose two correct statements below.

- [ ] The value of K_d is 1.3×10^{-5}
- [ ] The value of K_d is 1.3×10^{5}
- [x] The dissociation is highly favored. ← K_f is large
- [x] The value of K_d is 7.7×10^{-6}
- [ ] The formation reaction is highly favored.

$$K_d = \frac{1}{K_f} = \frac{1}{1.3 \times 10^5} = 7.7 \times 10^{-6}$$

QUESTION 9

A weak acid is titrated with a strong base and the following pH titration curve is obtained.



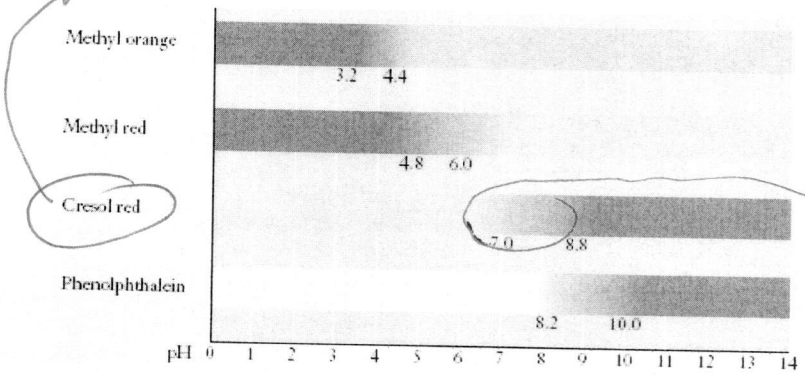
$$K_a = 10^{-pK_a} = 1 \times 10^{-5}$$

What is the value of Ka for the weak acid?

1×10^{-5}

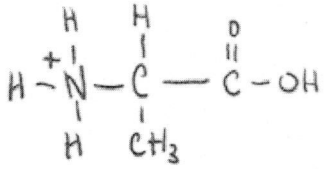
Which of the pH indicators below would be the best choice for this titration?

Cresol red



QUESTION 10

The fully acidic structure of the amino acid alanine is shown here:



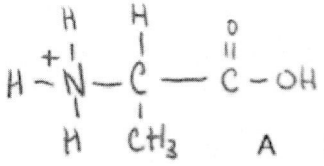
The pK_a for the -COOH group on the right is 2.34.

The pK_a for the - NH_3^+ group on the left is 9.69

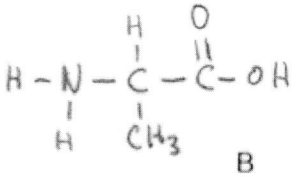
Larger pKa means weaker acid

As pH increases, which group loses an H^+ ion first (enter COOH or NH3)?

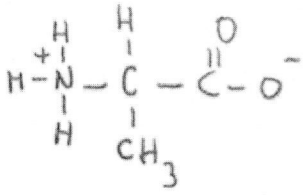
COOH



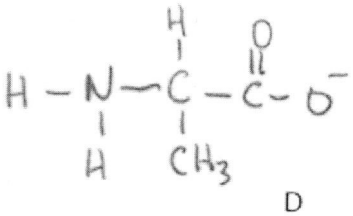
A



B



C



D

Which of the structures above represents the state of alanine in a pH = 5 solution? Enter the letter.

C

above 2.34, so COOH has lost its H^+; below pH 9.69, NH_3^+ keeps its H^+

Which of the structures above represents the state of alanine in a pH = 11 solution? Enter the letter.

D

Both COOH and NH_3^+ have lost H^+ above pH 9.69

QUESTION 11

Write the chemical reaction equation described by the K_a value for H_3PO_4.

$H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + H_3O^+(aq)$

Write the chemical reaction equation described by the K_b value for NO_2^-.

$NO_2^-(aq) + H_2O \rightleftharpoons HNO_2(aq) + OH^-(aq)$

QUESTION 12

$Fe(OH)_2$ is sparingly soluble, with $K_{sp} = 4.9 \times 10^{-17}$

Solid $Fe(OH)_2$ is added to three different solutions:

a. pure water

b. 0.010 M NaOH

c. 0.010 M HCl

$Fe(OH)_2(s) \rightleftharpoons Fe^{2+}(aq) + 2OH^-(aq)$

In which solution is the $Fe(OH)_2$ most soluble?

C

HCl reacts with OH^-, shifting equilibrium to the dissolved side

In which solution is the $Fe(OH)_2$ least soluble?

B

OH^- addition pushes equilibrium left, toward the solid

QUESTION 13

Calculate the pH of a 1.0 L buffer solution containing

22.6 g $NaHCO_3$

27.0 g Na_2CO_3

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QUESTION 14

You have a 1.0- L solution of 0.25 M CH_3CO_2H. How many grams of $NaCH_3CO_2$ must be added to prepare a buffer of pH = 5.00?

Molar mass of $NaCH_3CO_2$ = 82.03 g/mol

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Buffer pH

n / 22.6 g $NaHCO_3 \times \frac{1\,mol}{84.01\,g} = 0.269\,mol$

$27.0\,g\ Na_2CO_3 \times \frac{1\,mol}{105.98\,g} = 0.255\,mol$

$K_a = 4.8 \times 10^{-11}$

HCO_3^-

$pK_a = 10.318$

$pH = 10.318 + \log \frac{0.255}{0.269}$

$= 10.318 + (-0.0236)$

$= 10.294$

Create a buffer

$0.250\,mol\ CH_3CO_2H$

$K_a = 1.8 \times 10^{-5}$

$pK_a = 4.745$

$5.00 = 4.745 + \log \frac{[B]}{0.25M}$

$0.255 = \log \frac{[B]}{0.25\,mol}$

$1.8 = \frac{[B]}{0.25}$

$[B] = 0.45\,mol$

$\uparrow mol/L$

$0.45\,mol\ NaCH_3CO_2 \times \frac{82.03\,g}{mol} =$

$36.9\,g\ NaCH_3CO_2$

QUESTION 15

Phenol, C_6H_5OH, is a weak acid with $K_a = 1.6 \times 10^{-10}$.

What is pK_a for phenol?

9.80

$pK_a = -\log(K_a) = -\log(1.6 \times 10^{-10}) = 9.80$

What is K_b for the phenolate anion, $C_6H_5O^-$?

6.25×10^{5}

$K_a \times K_b = 1.0 \times 10^{-14}$ $K_b = \frac{1.0 \times 10^{-14}}{1.6 \times 10^{-10}} = 6.25 \times 10^{-5}$

QUESTION 16

Which of the following acid-base pairs would be used to create a buffer of pH = 6.95?

Weak Acid	Conjugate Base	K_a	pK_a
$HC_2O_4^-$	$C_2O_4^{2-}$	6.4×10^{-5}	4.19
$H_2PO_4^-$	HPO_4^{2-}	6.2×10^{-8}	7.21
HCO_3^-	CO_3^{2-}	4.8×10^{-11}	10.32

Choose acid-base pair with pK_a near desired pH

Enter the formula of the acid.

$H_2PO_4^-$

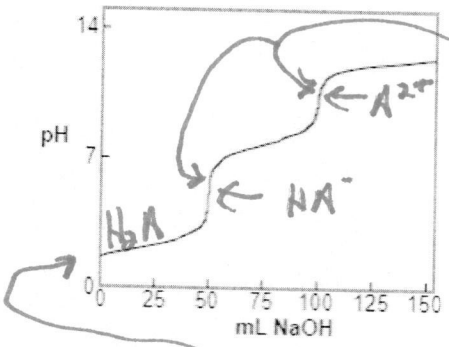
Which will be in higher concentration, the conjugate acid or the conjugate base?
Enter "acid" or "base."

acid

Since desired pH (6.95) is less than pK_a (7.21), buffer will have more acid than base.

QUESTION 17

Consider the pH titration curve below. What type of species was being titrated?



look for end points (two of them)

- monoprotic acid
- diprotic acid
- triprotic acid
- monoprotic base
- diprotic base
- triprotic base

pH starts low, so starting with an acid