This exam should have 20 questions. The point values are given with each question. Bubble in your answer choices on the bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam. Below are some constants you might want to use.

Acid	K_a
acetic acid	1.8×10^{-5}
chlorous acid	1.2×10^{-2}
chloroacetic acid	1.4×10^{-3}
formic acid	1.8×10^{-4}
hydrocyanic acid	6.2×10^{-10}
hydrofluoric acid	7.2×10^{-4}
hypochlorous acid	3.5×10^{-8}
hemimellitic acid	1) 1.3×10^{-3}
	2) 1.8×10^{-5}
	2) 7.4×10^{-8}
nitrous acid	4.0×10^{-4}
oxalic acid	1) 5.6×10^{-2}
	2) 5.4×10^{-5}
proprionic acid	1.3×10^{-5}
sulfurous acid	1.5×10^{-2}

Base	K_b
ammonia	1.8×10^{-5}
ethylenediamine	1) 8.5×10^{-5}
	2) 7.0×10^{-8}
hydrazine	1.7×10^{-6}
hydroxylamine	9.1×10^{-9}
methylamine	1.7×10^{-9}
pyridine	1.7×10^{-9}

1 A weak acid is found to be 15% ionized at a concentration of 0.052 M. Which one of the acids listed is the most likely identity of the weak acid? (5 points)

✓ A. chloroacetic acid

B. oxalic acid

C. formic acid

D. nitrous acid

E. sulfurous acid

Explanation: 15% ionization of 0.052M means that $0.15 \times 0.052\text{M} = 0.0078\text{M}$ is the portion of the acid that has dissociated into H^+ ions and the conjugate base, A^-. The undissociated amount remaining is 0.052 - 0.0078 = 0.0442M. $K_a = \frac{(0.0078)^2}{0.0442} = 1.4 \times 10^{-3}$ which matches chloroacetic acid.

2 Which of the following is NOT a strong base? (5 points)

A. NaOH

B. KOH

✓ C. $Be(OH)_2$

D. $Sr(OH)_2$

E. $Ba(OH)_2$

Explanation: The only hydroxides of period 2 elements that form strong bases are those of calcium, strontium, and barium.

3 Which of the following is a conjugate acid/base pair in an aqueous solution? (5 points)

✓ A. NH_3 and NH_4^+

B. HNO_3 and HNO_2

C. NaBr and Br^-

D. HCl and H^+

E. H_3O^+ and OH^-

Explanation: Conjugates differ only by the presence or absence of ONE proton, H^+, in aqueous solution.

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4 Which of the following weak acids will have the strongest conjugate base? (5 points)

A. formic acid, HCOOH

B. acetic acid, CH_3COOH

C. chloroacetic acid, $CH_2ClCOOH$

D. sulfurous acid, H_2SO_3

✓ E. propionic acid, CH_3CH_2COOH

Explanation: The weakest acid with the smallest K_a will have the strongest conjugate base with the largest K_b.

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5 Coca-Cola contains, in addition to other ingredients, appreciable amounts of orthophosphoric acid and carbonic acid. An analysis of Coke finds that the total concentration of all hydrogen ions is 3.2×10^{-3} M. What is the pH of Coke? (5 points)

A. 1.52

✓ B. 2.49

C. 3.20

D. 7.00

E. 5.74

F. 4.11

Explanation: pH = -log[H^+] = -log(3.2×10^{-3}) = -(-2.49) = 2.49

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6 A 0.25 M solution of sodium benzoate has a pH of 8.80. What is the K_b of the benzoate anion? (5 points)

A. 2.4×10^{-5}

B. 1.6×10^{-9}

C. 4.8×10^{-10}

✓ D. 1.6×10^{-10}

E. 6.3×10^{-5}

F. 6.3×10^{-6}

G. 1.0×10^{-17}

Explanation: First set up the balanced equation for the benzoate anion, "Bz^-", which undergoes hydrolysis with water to form a basic solution: $Bz^- + H_2O \rightleftharpoons HBz + OH^-$. For this equation, $K_b = \frac{[OH^-][HBz]}{[Bz^-]}$. Also, pOH = 14 - pH = 14 - 8.8 = 5.2. So $[OH^-] = 10^{-5.2} = 6.3 \times 10^{-6}$ M. The concentration of $[OH^-]$ is also equal to the equilibrium concentration of [HBz]. The 0.25 concentration is unaffected by the ionization to 3 sig figs. So Kb equals $(6.3 \times 10^{-6})^2/0.25 = 1.6 \times 10^{-10}$.

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7 Determine the pH of a solution of 0.0196 M $HClO_4$. (5 points)

✓ A. 1.71

B. 1.77

C. 2.01

D. 7.01

E. 12.29

F. 0.71

Explanation: $HClO_4$ is a strong acid that dissociates completely. The concentration of the acid is therefore equal to the concentration of the H^+ ions. pH = -log$[H^+]$ = -log(0.0196) = 1.71.

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8 Determine the pH of a solution of pyridine with a concentration of 0.23 M. (5 points)

A. 8.58

B. 10.70

✓ C. 9.30

D. 4.71

E. 9.93

Explanation: First set up the balanced equation for pyridine, a weak base: $B + H_2O \rightleftharpoons BH^+ + OH^-$. For this equation, $K_b = \frac{[OH-][BH^+]}{[B]}$, which for pyridine is equal to 1.7×10^{-9}. You can use the shortcut/assumption here where [OH-] = $\sqrt{K_b \cdot C_B} = 1.98 \times 10^{-5}$ M. This is a pOH of 4.70, and a pH of 9.30.

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9 An aqueous solution of hydrocyanic acid, HCN, has a pH of 5.91. What is the concentration of HCN in the solution? (5 points)

A. 1.2×10^{-6} M

✔ B. 2.4×10^{-3} M

C. 5.9×10^{-10} M

D. 4.6×10^{7} M

E. 4.1×10^{2} M

F. 7.8×10^{-2} M

Explanation: First set up the balanced equation for the weak acid: $HCN \rightleftharpoons H^+ + CN^-$. For this equation, $K_a = \frac{[H^+][CN^-]}{[HCN]} = 6.2 \times 10^{-10}$. Use the pH to find $[H^+] = 10^{-5.91}$, which equals $[CN^-]$. Solving for HCN you get $(10^{-5.91})^2/6.2 \times 10^{-10} = 2.4 \times 10^{-3}$.

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10 What is the conjugate base of acetic acid? (5 points)

✔ A. acetate anion

B. acetaldehyde

C. acetic anyhydride

D. arsenic

E. sodium acetic acid

Explanation: none

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11 Solid sodium acetate is dissolved into water to make an aqueous solution with a concentration of 0.44 M. Determine the pH of this solution. (5 points)

A. 10.81

B. 11.99

C. 7.00

D. 4.81

✔ E. 9.19

Explanation: First set up the balanced equation for the acetate ion, which acts as a weak base: $A^- + H_2O \rightleftharpoons HA + OH^-$. Determine the value of K_b for the acetate ion by using its conjugate acid, acetic acid, $K_a = 1.8 \times 10^{-5}$. $K_w/K_a = K_b = 5.56 \times 10^{-10}$. You can use the shortcut/assumption here and get [OH-] $= \sqrt{5.56 \times 10^{-10} \cdot .44} = 1.56 \times 10^{-5}$. That gives a pOH of 4.81 and a pH of 9.19.

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12 Neutral pH will always be exactly 7.00 by definition. (5 points)

A. True

✔ B. False

Explanation: Definition of neutrality is $[H^+] = [OH^-]$. Only at 25°C will that condition give a pH of 7.00. Other temperatures can raise and lower the value of neutral pH.

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13 The protons on a polyprotic acid will (5 points)

A. all come off at the same pH.

✓ B. come off sequentially at higher and higher pH's.

Explanation: none

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14 What is the pH of solution that is made by mixing 700 mL of 0.070 M NaOH and 800 mL of 0.060 M HCl? (5 points)

A. 12.21

B. 3.18

C. 7.10

D. 11.10

✓ E. 10.82

F. 5.92

G. 8.55

Explanation: strong acid + strong base will make water + salt. 700(.07) = 49 mmol of H+. 800(.06) = 48 mmol of OH-. Limiting reactant is H+. You make 48 mmol of H2O with 1 mmol of OH- left over in 1500 mL of solution. That is 6.66×10^{-4} M OH-. pOH = 3.18 and pH = 10.82

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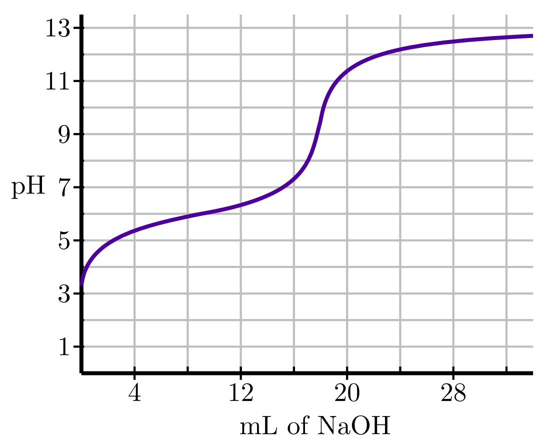
15 (1 of 2 parts) The titration of 50 mL of a weak acid is carried out and the pH curve shown to the right is produced. Interpret the pH curve and figure out what the value of K_a is for the weak acid. What is the value of K_a? (5 points)



A. 3.2×10^{-10}

B. 6.0×10^{-5}

C. 1.6×10^{-7}

D. 3.2×10^{-4}

✓ E. 1.0×10^{-6}

Explanation: The endpoint is at 18mL at a pH of 9.5. The 1/2 way point on the titration curve is at 9 mL at a pH of 6.0. pKa = pH at 1/2 way point, therefore pKa = 6 and Ka is 1.0×10^{-6}.

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16 (2 of 2 parts) The NaOH used in the titration was 0.0625 M. What was the original concentration of the weak acid? (5 points)

A. 0.0250 M

B. 0.113 M

C. 0.0450 M

D. 0.0625 M

✓ E. 0.0225 M

F. 0.0125 M

Explanation: The endpoint is 18 mL, multiply by .0625 and you get 1.125 mmol of base which equals the acid amount as well. Divide by the volume of acid (50 mL) and you get 0.0225 M.

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17 Benzene-1,2,3-tricarboxylic acid is commonly known as hemimellitic acid. The formula, $C_6H_3(COOH)_3$, can more easily be thought of and depicted as a triprotic acid, H_3A. A small sample of hemimellitic acid is dissolved into an aqueous buffer with a pH of 6.00. Which protonated/deprotonated form is this acid in at this pH? (5 points)

A. H_3A

B. H_2A^-

✓ C. HA^{2-}

D. A^{3-}

E. A^{4-}

F. H_4A^+

Explanation: The pKa's for hemimellitic acid are 2.88, 4.75, and 7.13. If the pH is 6, then the acid must be in the HA^{2-} state.

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18 You mix 240 mL of 0.075 M hydroxylamine (NH_2OH) with 100 mL of 0.060 M hydrochloric acid. What is the pH of the resulting solution? (5 points)

✓ A. 6.26

B. 7.74

C. 5.96

D. 8.34

E. 7.00

F. 5.66

Explanation: In the mixed solution you have added 18 mmol of hydroxylamine (240mL·0.075M) and 6.0 mmol (100mL·0.06M) of H^+ 340mL of solution. The acid is the limiting reactant and you therefore make 6 mmol of the hydroxylammonium ion (NH_3OH^+) and leave behind (in excess) 12 mmol of the hydroxylamine. So this is just a base buffer with the conjugates in a 6/12 or 1/2 ratio. Using the basic form of the H-H equation you get: pOH = 8.04 + log(1/2) = 8.04 - 0.301 = 7.74. The pH is 14-pOH, or 14-7.74 = 6.26.

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19 Which of the following reactions represents the “buffering action” when hydroxide is added to a buffer of formic acid and formate? (5 points)

✓ A. $HCOOH + OH^- \rightarrow HCOO^- + H_2O$

B. $HCOO^- + H^+ \rightarrow HCOOH$

C. $HCOOH + H_2O \rightarrow HCOO^- + H_3O^+$

D. $HCOO^- + OH^- \rightarrow HCOOH + O^{2-}$

E. $H_2O + OH^- \rightarrow OH^- + H_2O$

Explanation: The acid part of the buffer (HCOOH, formic acid) will react and neutralize the incoming hydroxide (base).

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20 Which of the following mixtures will result in a buffer solution? (5 points)

✓ A. 80 mL of 0.12M KOH and 80 mL of 0.24 M CH_3CH_2COOH

B. 90 mL of 0.13M HBr and 90 mL of 0.26M NaOH

C. 100 mL of 0.22M KOH and 200 mL of 0.11M HCOOH

D. 50 mL of 0.16M HNO_3 and 100 mL 0.080M NH_3

E. 200 mL of 0.25M KOH and 100 mL of 0.25M HF

Explanation: To make a buffer solution you need to have substantial concentrations of both the acid and base forms of a conjugate pair. This can be most easily produced by neutralizing half of the concentration of a weak acid (or base) with strong base (or acid). In this case 80mL of 0.12 KOH will neutralize 9.6 mmol of acid. 80mL of a 0.24M solution of CH_3CH_2COOH is 19.2 mmol of acid. Neutralizing half of it (19.2 - 9.6 = 9.6) you will end up with a buffer: 1/2 is HA and 1/2 is A^-.

Remember to bubble in ALL your answers BEFORE time is called. Sign your bubblesheet AND your exam. Then turn in BOTH your exam copy and your bubblesheet.