This MC portion of the exam should have 17 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 ionization constants you will find useful.

Acid	K_a
acetic acid	1.8×10^{-5}
benzoic acid	6.4×10^{-5}
chlorous acid	1.2×10^{-2}
formic acid	1.8×10^{-4}
hypochlorous acid	3.5×10^{-8}
malonic acid	1) 1.4×10^{-3}
	2) 2.0×10^{-6}
oxalic acid	1) 5.6×10^{-2}
	2) 5.4×10^{-5}

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

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1 The following reaction is at equilibrium at 250 K:

$I_2(g) + C_5H_8(g) \rightleftharpoons C_5H_6(g) + 2HI\ (g) \qquad \Delta H^\circ = 92.5$ kJ

You increase the temperature to 500 K. How will the equilibrium concentration of $I_2(g)$ change? (4 pts)

A. It will increase.
• B. It will decrease.
C. It will not change.

Explanation: For this endothermic reaction, you can consider the reaction to be:

heat + $I_2(g) + C_5H_8(g) \rightleftharpoons C_5H_6(g) + 2HI\ (g)$

At increased tempertures, the equilibrium constant increases and our reaction will shift to make more products.

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2 At equilibrium at a certain temperature, you find concentrations of 0.600 M $SO_2(g)$, 0.300 M $O_2(g)$, and 3.28 M $SO_3(g)$. Given the reaction:

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

Calculate K_c at this temperature. (4 pts)

• A. 99.6
B. 18.2
C. 1.00 x 10^{-2}
D. 54.6
E. 2.36 x 10^{-4}

Explanation: $K_c = [SO_3]^2/([SO_2]^2[O_2]) = (3.28)^2/((.6)^2(.3))$

3 Consider the reaction: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

Calculate ΔG_{rxn} for this reaction at 230°C knowing that K_p is equal to 50 at this temperature. (4 pts)

- • A. -16.3 kJ/mol rxn
- B. -7.44 kJ/mol rxn
- C. -0.0733 kJ/mol rxn
- D. +7.44 kJ/mol rxn
- E. + 16.3 kJ/mol rxn

Explanation: $\Delta G_{rxn} = -RT \ln K$, where R is the gas constant 8.314 J/mol K; T is the absolute temperature and K is the thermodynamic equilibrium constant. Plugging given values into this equation and converting to kJ will give the correct answer -16.3 kJ/mol rxn

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4 Which of the following weak bases will have the strongest conjugate acid? (4 pts)

- • A. $(CH_3)_3N$; $K_b = 6.5 \times 10^{-5}$
- B. CH_3NH_2; $K_b = 3.6 \times 10^{-4}$
- C. $(CH_3)_2NH$; $K_b = 5.4 \times 10^{-4}$
- D. $C_2H_5NH_2$; $K_b = 6.5 \times 10^{-4}$

Explanation: For every conjugate acid base pair, $K_a \times K_b = K_w$. Therefore, the weakest base will have the strongest conjugate acid partner. The larger the value of the equilibrium constant the greater the extent of ionization.

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5 It is possible to make a solution of a weak acid that has a lower pH than a solution of a strong acid. (4 pts)

- • A. This statement is true because a very high concentration of a weak acid can yield a more acidic solution than an very dilute solution of a strong acid.
- B. This statement is false because as long as the concentration of the strong acid is the same as the concentration of the weak acid, the pH of the solutions will be identical.
- C. This statement is true because a very low concentration of a weak acid will have the same pH as a moderately high concentration of a strong acid.
- D. This statement is false because a strong acid will always have a lower pH than a weak acid regardless of the concentration of the acid.

Explanation: The pH is dependent on the extent of ionization and the concentration of the acid. It is possible to have a very dilute solution of a strong acid that has a higher pH than a very concentrated solution of a weak acid.

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6 Determine the pH of a 0.0146 M solution of HBr. (4 pts)

- • A. 1.84
- B. impossible, K_a was not given
- C. 12.2
- D. 3.67
- E. 4.23

Explanation: HBr is a strong acid. Strong acids ionize 100% in solution. Therefore, the concentration of the hydronium ion is the same as the stated concentration of the strong acid. pH = - log(0.0146)

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7 Determine the pH of a 0.42 M solution of hypochlorous acid, HClO.
(4 pts)

A. 4.95
B. 0.38
• C. 3.92
D. 2.88
E. 5.61

Explanation: $K_a = 3.5 \times 10^{-8}$. [H+] $\approx \sqrt{K_a(.42)}$. This gives you [H+] $= 1.21 \times 10^{-4}$ M. The pH = -log[H+] = 3.92

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8 Determine the pH of a 0.19 M solution of hydrazine, NH_2NH_2.
(4 pts)

• A. 10.75
B. 9.66
C. 4.34
D. 3.25
E. 13.28

Explanation: Hydrazine is a weak base. $K_b = 1.7 \times 10^{-6}$. [OH-] $\approx \sqrt{K_b(.19)}$. This gives you [OH-] $= 5.68 \times 10^{-4}$ M. The pOH = -log[OH-] = 3.25 The pH = 14 - 3.25 = 10.75.

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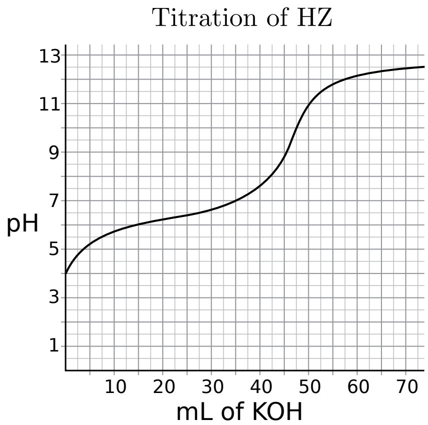
9 A sample of 25.0 mL of a weak acid (HZ) was titrated with a 0.038 M solution of KOH. The resulting pH curve for this titration is shown in the figure to the right. Using this data, determine the original concentration of the weak acid HZ.
(4 pts)



A. 0.055 M
B. 0.060 M
C. 0.065 M
• D. 0.070 M
E. 0.075 M
F. 0.080 M
G. 0.085 M

Explanation: Analysis of the pH curve reveals that the endpoint of the titration corresponds to a volume of approximately 46 mL of the KOH solution. 46mL(0.038M) = 1.748 mmol of OH^-. There is the same number of mmol of the weak acid HZ. Divide mmol by volume to get concentration of the HZ: 1.748/25 = 0.70 M HZ.

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10 Please refer to the titration curve shown in the previous problem. Analyze the titration curve and determine the value of K_a for the weak acid HZ. (4 pts)

A. 1.0×10^{-6}
• B. 5.0×10^{-7}
C. 2.5×10^{-7}
D. 1.2×10^{-8}
E. 4.5×10^{-10}
F. 3.1×10^{-9}
G. 8.5×10^{-6}

Explanation: The endpoint of the titration is about 46 mL. Half of that value is 23 mL. The pH from the curve at 23 mL is about 6.3 which will be the same as the pK_a for the weak acid. So that $K_a = 10^{-6.3} = 5.0 \times 10^{-7}$.

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11 A 0.019 M solution of 2-chloroproprionic acid is 21.3% ionized at 25°C. What is the ionization constant (K_a) for this organic weak acid? (4 pts)

A. 2.1×10^{-1}
B. 3.5×10^{-2}
• C. 1.1×10^{-3}
D. 6.3×10^{-2}
E. 4.2×10^{-3}
F. 2.1×10^{-4}
G. 8.6×10^{-4}

Explanation: 21.3% of .019 is 0.00405 M which is the amount ionized (the H+ and the A-). This leaves 0.019-.00405 = 0.0150 M of the unionized acid (HA) in solution. Now plug in those numbers in the mass action expression for Ka:

$$K_a = [H+][A-]/[HA] = (0.00405)^2/0.015 = 1.1 \times 10^{-3}$$

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12 What is the pOH of a 0.0048 M solution of chloric acid, $HClO_3$? (4 pts)

A. 1.36
B. 3.23
C. 2.32
D. 12.74
• E. 11.68
F. 10.77

Explanation:

$$[OH-] = K_w/[H+] = 1.0 \times 10^{-14}/0.0048 = 2.0833 \times 10^{-12}$$

Take the -log for pOH and get 11.68.

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13 75 mL of 0.015 M HNO_3 is added to 100 mL of 0.012 M KOH. What is the final concentration of H^+ (or H_3O^+ if you prefer)? (4 pts)

- • A. 2.33×10^{-11} M
- B. 1.71×10^{-5} M
- C. 1.33×10^{-11} M
- D. 7.5×10^{-4} M
- E. 7.5×10^{-11} M

Explanation: 75(0.015) = 1.125 mmol H+. 100(.012) = 1.200 mmol OH-. Limiting reactant is the acid and 1.2 - 1.125 = 0.075 mmol of OH- left over in 175 mL of solution which means the concentration of OH- is 4.29×10^{-4} M. This makes the H+ concentration equal to 2.33×10^{-11} M.

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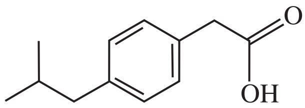
14 Ibuprofen is a nonsteroidal anti-inflammatory drug with the the chemical structure that is shown. The K_a for ibuprofen is 1.2×10^{-5}. Stomach acid has a pH around 1.5. When ibuprofen is dissolved in stomach acid what is the charge on the structure? (4 pts)



ibuprofen

- A. negative
- • B. neutral
- C. positive
- D. neutral, but with one positive and one negative charge

Explanation: The pK_a for ibuprofen is 4.91. The pH of the solution is more acidic than this. Therefore the carboxylic acid group on the ibuprofen will be protonated and the molecule will be neutral.

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15 Which of the following is not a conjugate acid/base pair? (4 pts)

- • A. H_3O^+ , OH^-
- B. HF , F^-
- C. NH_3 , NH_4^+
- D. CN^- , HCN
- E. CH_3COOH , CH_3COO^-

Explanation: Conjugated acid/base pairs differ in formula by a single proton. H_3O^+ is the conjugate acid of H_2O; OH^- is the conjugate base of H_2O. These are not a conjugate pair with respect to each other.

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16 What is the majority species of malonic acid ($H_2C_3H_2O_4$) in a solution with a pH = 9? (4 pts)

- • A. $C_3H_2O_4^{2-}$
- B. $HC_3H_2O_4^-$
- C. $H_2C_3H_2O_4$
- D. $H_3C_3H_2O_4^+$
- E. $H_4C_3H_2O_4^{2+}$

Explanation: pH of 9 is more basic than both of the pKa's for the acid. Therefore both protons will be "off". The molecule will be doubly-deprotonated and in the form $C_3H_2O_4^{2-}$.

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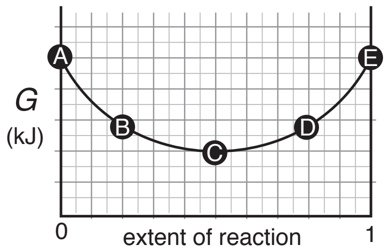
17 For this reaction, $\Delta G°$ is ______ and the equilibrium mixture is represented by spot ______ . (4 pts)



- A. zero ; C
- B. negative ; D
- C. negative ; B
- D. zero ; A
- E. zero ; E

Explanation: The equilibrium position is the lowest point on the diagram which is spot C. The start and finish free energies are identical which means that $\Delta G°$ is zero.

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 you bubblesheet.