McCord CH302

unique: 49175 and 49190

Exam 2

Mar 13, 2019

Wednesday 7:30 - 9:00 PM

A-L in UTC 2.112A

M-Z In BUR 106

Remember to refer to the Periodic Table handout that is separate from this exam copy.

NOTE: Please keep this exam copy intact (all pages still stapled - including this cover page). You must turn in ALL the materials that were distributed. This means that you turn in your exam copy (name and signature included), bubble sheet, periodic table handout, and all scratch paper. Please also have your UT ID card ready to show as well.

This print-out should have 20 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001　5.0 points
Calculate the pH of a 0.018 M $Ba(OH)_2$ solution.

1. 1.44

2. 12.56 **correct**

3. 5.26

4. 8.44

5. 1.74

6. 12.26

Explanation:
0.018 M $Ba(OH)_2$ is a strong base that dissociates completely, resulting in a 0.036 M hydroxide ion concentration.

$$pOH = -\log(0.036\,M)$$

$$pH = 14 - pOH = 12.56$$

002　5.0 points
A rection has an equilibrium constant equal to 1.36×10^{-4}. You place only reactants into a container. Which of the following statements is/are true?

　I. $\Delta G > 0$

　II. $\Delta G^\circ > 0$

　III. The reaction will occur spontaneously until $K = 1$

　IV. The reaction will not occur spontaneously because $Q > K$

　V. The reaction will occur spontaneously until $Q = K$

1. II and IV only

2. I, II, and III only

3. I, II, and IV only

4. I and III only

5. I, II, and V only

6. V only

7. II and V only **correct**

8. II and III only

Explanation:
There are two key pieces of information. First, the K value indicates that ΔG° is positive, but the fact that the reaction begins with only reactants suggests that the reaction needs to run forward until $Q = K$. Because this is the case, ΔG is negative at first. Statements II and V are the only true choices.

003　5.0 points
The molecule below is diprotic with pK_a values equal to 3.90 and 5.95.
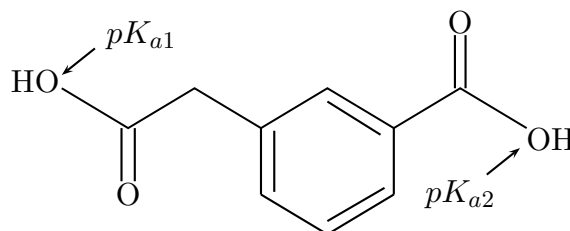
What is the charge on the overall molecule if it is placed into a 0.05 M NaOH solution?

1. -1

2. -2 **correct**

3. 0

4. +2

5. +1

Explanation:
The NaOH solution will be more basic than the two acidic functional groups. Therefore, the pH will be greater than the pK_a. This means both acid groups will be deprotonated, resulting in an overall -2 charge.

004   5.0 points

Consider the free energy diagram:
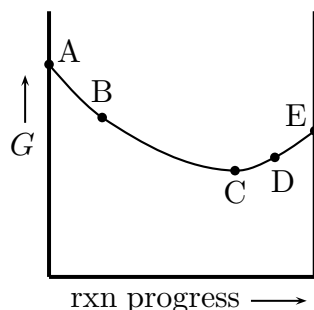
If the reaction depicted above is exothermic, which of the following statements is false?

1. The ΔG_{rxn} for this reaction is negative at all points to the right of C **correct**

2. Point C is simultaneously the lowest free energy value on this diagram and the point in which ΔG_{rxn} is equal to zero

3. The standard reaction represented by this diagram is product preferred

4. ΔG° is represented by the difference in free energy between points A and E

5. Point C is lower in free energy than E due to the entropy of mixing products and reactants

Explanation:
All statements are true except that the ΔG_{rxn} is negative at all points to the right of C. At this point, $Q > K$, meaning the reaction is reactant preferred.
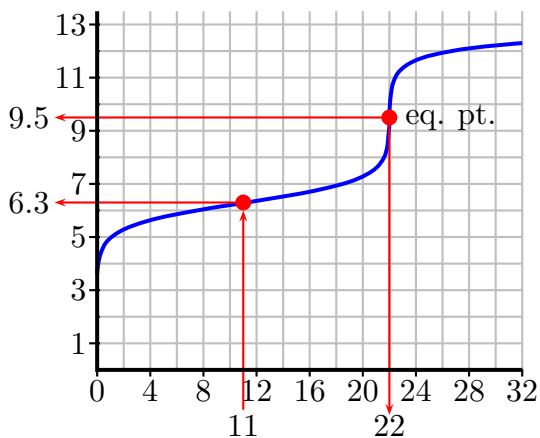
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005 (part 1 of 3) 5.0 points
A sample of 30 mL of a weak acid (HA) solution was titrated with 0.075 M NaOH. The pH curve for this titration is shown.
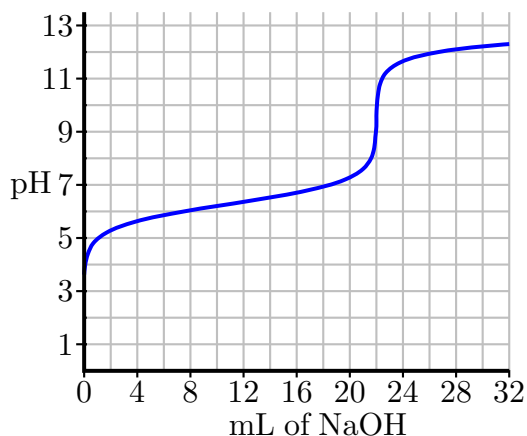
What is the concentration of the original weak acid solution (the 30 mL) ?

1. 0.055 M **correct**

2. 0.048 M

3. 0.022 M

4. 0.075 M

5. 0.032 M

Explanation:

equivalence point is 22 mL of NaOH
$\times$ 0.075 M = 1.65 mmol OH-
mmol acid = mmol base
1.65 mmol / 30 mL = 0.055 M HA

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006 (part 2 of 3) 5.0 points
Which of the following is the value of K_a for the weak acid, HA ?

1. 1.2×10^{-7}

2. 5.0×10^{-7} **correct**

3. 7.6×10^{-5}

4. 3.2×10^{-10}

5. 1.3×10^{-6}

Explanation:
The half titration point is at 11 mL and the pH = pKa there which is 6.3. That would match a K_a of 5.0×10^{-7}.

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007 (part 3 of 3) 5.0 points
Below is a listing of five indicators and their associated pK_a values. Which indicator would be the best one to use for this titration?

1. methyl red, 5.0

2. bromophenol blue, 4.1

3. thymol blue, 9.3 **correct**

4. alizarin yellow, 10.9

5. phenol red, 7.4

6. bromocresol purple, 6.4

Explanation:
The equivalence point is at a pH of 9.5. Only thymol blue in this listing covers that pH during the color transition.

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008   5.0 points
Combining which two solutions will result in an ideal buffer where pH = 8.23?

1. 80 mL 0.2 M HCl and 160 mL 0.2 M NH_2NH_2 **correct**

2. 160 mL 0.2 M HCl and 160 mL 0.2 M C_5H_5N

3. 80 mL 0.2 M HCl and 160 mL 0.2 M C_5H_5N

4. 80 mL 0.2 M HCl and 80 mL 0.2 M

NH_2NH_2

Explanation:
Find the two solutions that will result in an ideal buffer at the proper pH. For a perfect buffer, the pK_a equal the pH OR the pK_b matches the pOH. The buffer should consist of 80 mL 0.2 M HCl and 160 mL 0.2 M NH_2NH_2 because this matches both the definition of the buffer and the pH of the solution

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009   5.0 points
A reaction is at equilibrium and then the entire mixture is compressed to half the original volume. As expected, the pressure initially doubles, but then falls slightly to a lower pressure. Which of the following generic reactions listed is the only one capable of this response?

1. $C(g) + J(s) \rightleftharpoons Y(g)$

2. $A(g) + C(g) \rightleftharpoons 3D(g)$ **correct**

3. $B(g) \rightleftharpoons Z(g)$

4. $A(g) + B(g) \rightleftharpoons 2C(g)$

Explanation:
When gases are a part of a reaction, Le Chatelier's principle will effectively shift a reaction that is at equilibrium to the side of the reaction with the fewest moles of gas when the volume is decreased. This is to lower the pressure of the applied stress. The only choice of the five listed with differing moles of gas on each side is
$A(g) + C(g) \rightleftharpoons 3D(g)$

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010   5.0 points
What is the correct equilibrium relation for the following reaction beginning with 1.2 atm dicobalt octacarbonyl, $Co_2(CO)_8$?
$$Co_2(CO)_8(g) \rightleftharpoons 2Co(s) + 8CO(g)$$

1. $K = \frac{(2x)^2(8x)^8}{1.2-x}$

2. $K = \frac{1}{1.2-x}$

3. $K = \frac{(8x)^8}{1.2-x}$

correct

4. $K = \frac{8x}{1.2-x}$

5. $K = \frac{-8x}{1.2+x}$

Explanation:
Construct a RICE table to demonstrate that there is a 1:8 relationship between the gaseous $Co_2(CO)_8$ and CO. Using the variable x, it can be determined that the pressure of dicobalt octacarbonyl is $1.2-x$ and the pressure of carbon monoxide is $8x$. Lastly, create the mass action expression relationship at equilibrium:

$$K = \frac{(8x)^8}{1.2-x}$$

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011   5.0 points
What is the pH of a 0.12 M solution of hydroxylammonium bromide (NH_3OHBr)?

1. 6.04

2. 9.56

3. 4.44

4. 3.33

5. 3.61

6. 3.48 **correct**

7. 3.72

8. 3.24

Explanation:
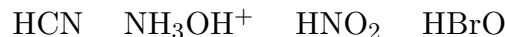$M_{NH_3OHBr} = 0.12$ M $K_b = 1.1 \times 10^{-8}$
It's a salt of a weak base (BHX). This means you need a K_a for the weak acid BH^+. Use $K_a = \frac{K_w}{K_b}$ and you'll get the $K_a = 9.09091 \times 10^{-7}$. You CAN use the approximation for the equilibrium which means that

$$[H^+] = \sqrt{K_a \cdot C_{BH^+}} = 0.000330289 \text{ M}$$

$$pH = -\log(0.000330289) = 3.48111$$

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012   5.0 points
Rank the following acids in increasing order of acidity.

$$HCN \quad NH_3OH^+ \quad HNO_2 \quad HBrO$$

1. $HCN < HBrO < NH_3OH^+ < HNO_2$ **correct**

2. $HNO_2 < HBrO < HCN < NH_3OH^+$

3. $HNO_2 < NH_3OH^+ < HBrO < HCN$

4. $NH_3OH^+ < HNO_2 < HBrO < HCN$

5. $NH_3OH^+ < HBrO < HCN < HNO_2$

6. $HCN < NH_3OH^+ < HNO_2 < HBrO$

Explanation:
Look at the coversheet for the values of pK_a.

$HCN = 9.21$

$NH_3OH^+ = 14 - 7.96 = 6.04$

$HNO_2 = 3.40$

$HBrO = 8.20$

$HCN < HBrO < NH_3OH^+ < HNO_2$

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013   5.0 points
What is the dominant species in solution at the equivalence point of a weak base-strong acid titration?

1. Strong base

2. Weak base

3. Equal parts weak acid and weak base

4. Neutral salt

5. Strong acid

6. Weak acid **correct**

Explanation:
The dominant species in solution at the equivalence point will be the conjugate of the analyte. In this case, the dominant species in

solution will be the conjugate of the weak base, which is just a weak acid.

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014   5.0 points
What is the ratio of potassium acetate to acetic acid necessary to make a buffer with a pH equal to 5.12?

1. 0.42

2. 9.86

3. 2.4 **correct**

4. 2.9

5. 3.1

6. 0.38

Explanation:
You can solve for the ratio using the H-H equation and knowledge of log rules:

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

$$5.12 = 4.74 + \log\left(\frac{[A^-]}{[HA]}\right)$$

$$10^{5.12-4.74} = \frac{[A^-]}{[HA]}$$

$$= 2.4$$

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015   5.0 points
What is the pH after 250 mL of 0.25 M HNO_3 is added to 350 mL of 0.50 M CH_3NH_2 (methylamine) ?

1. 10.64

2. 3.62

**3.** 3.36

4. 10.38

5. 6.21

6. 2.29

7. 5.05

8. 10.90 **correct**

Explanation:
This is a simple Henderson-Hasselbach calculation.

$$pH = pK_a + \log\left(\frac{C_B}{C_{BH^+}}\right)$$

The pK_b for methylamine (the base, B) is 3.36 which means the pK_a for the methylammonium ion (BH^+) is 10.64. You may use the ratio of moles because this is a partial neutralization (buffer) problem. The weak base methylamine, B, is converted to the conjugate acid, BH^+ via the reaction with the strong acid.

$$B + H^+ \rightarrow BH^+$$
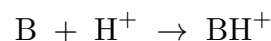
The acid is the limiting reactant and determines the amount of BH^+ made. Remember, volume times concentration equals amount (moles).

mol $BH^+ = 0.25(0.250) = 0.0625$ mol

mol B = .50(0.350) - 0.0625 mol = .1125 mol

Now solve for pH using the H-H equation:

$$pH = 10.64 + \log\left(\frac{0.1125}{0.0625}\right)$$

$$pH = 10.64 + 0.26$$

$$pH = 10.90$$

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016   5.0 points
A weak acid, HA, ionizes 7.65% at a 0.250 M concentration. What is the hydroxide ion concentration in this solution?

1. 1.91×10^{-16} M

2. 1.31×10^{-13} M

3. 5.23×10^{-13} M **correct**

4. 1.00×10^{-14} M

5. 1.91×10^{-2} M

Explanation:
Percent ionization quickly gives you the dissociation of a weak electrolyte at a particular

concentration:

$$[H^+] = 0.0765 \times 0.25\,\text{M}$$

$$[H^+] = 0.019125\,\text{M}$$

Use K_w to convert this into $[OH^-]$:

$$[OH^-] = \frac{1 \times 10^{-14}}{0.019125\,\text{M}}$$

$$[OH^-] = 5.23 \times 10^{-13}\,\text{M}$$

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017   5.0 points

Although difficult to obtain, chlorous acid is a powerful oxidizing agent in its pure form. What is the pH of a 0.15 M $HClO_2$ solution?

1. 1.92

2. 1.43 **correct**

3. 2.00

4. 0.82

5. 2.02

6. 1.37

Explanation:
Due to the large size of K_a (or simply that the ratio of concentration to K_a is less than 1000), you will need to solve the full quadratic equation to get the correct answer. Use a RICE table to create an equilibrium relation for a weak acid:

$$K_a = \frac{x^2}{0.15 - x}$$

The variable x represents the $[H^+]$. Therefore, the correct root of the quadratic will help you solve for pH. Rearrange the mass action expression to obtain a quadratic:

$$0 = x^2 + 0.012x - 0.0018$$

Solve for both roots

$$x = \frac{-0.012 + \sqrt{0.012^2 - 4(1)(-0.0018)}}{2(0.012)}$$

$$x = -0.0488486$$

$$x = \frac{-0.012 - \sqrt{0.012^2 - 4(1)(-0.0018)}}{2(0.012)}$$

$$x = 0.0368486$$

As seen above, this will give you a negative and positive root. Use the positive root. Take the negative log to obtain pH:
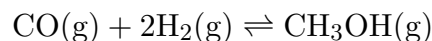
$$pH = -\log(0.0368486)$$

$$pH = 1.43$$

Do note: the answer of 1.43 is significantly different than the approximation answer of 1.37.

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018 (part 1 of 2) 5.0 points
Consider the following reaction for the next two questions:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Beginning at equilibrium, which of the following will result in a shift toward the right of this reaction?

1. Adding an inert gas at constant pressure

2. Removing CO gas

3. Adding CH_3OH gas

4. Reducing the volume of the container **correct**

5. Adding an inert gas at constant volume

Explanation:
The only option that will cause a shift to the right of this reaction is reducing the volume of the container. By reducing the volume of the container, the pressure is increased. Increasing the overall pressure results in a shift way from the side of the reaction with the most gas moles.

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019 (part 2 of 2) 5.0 points
If this reaction is exothermic, lowering the temperature will cause the reaction to...

$$K_p = \frac{0.435^3}{1.37067^2 \cdot .83333} = 0.05258$$

1. shift right due to a larger K value **correct**

2. shift left due to a smaller K value

3. remain at equilibrium

4. shift left due to a smaller Q value

5. shift right due to a decreased Q value

Explanation:
Reducing the temperature of an exothermic reaction will cause the reaction to shift to the right. This is because an exothermic reaction will have a larger K value when the temperature is decreased.

020　5.0 points

0.834 atm A, 0.565 atm B, and 1.24 atm C are placed into a container to run the following reaction:

$$2A(g) + B(g) \rightleftharpoons 3C(g)$$
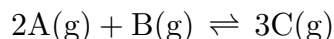
At equilibrium, 0.435 atm C remains. What is K_p for this reaction?

1. 0.0526 **correct**

2. 0.107

3. 18.8

4. 8.12

5. 0.0230

Explanation:
The first thing to observe in this question is that the reaction runs in reverse, because C is consumed over the course of the reaction. Running a RICE table, you will see that the change in C is equal to $-3x = 0.435 - 1.24 = -0.805$; therefore, $x = 0.2683$.

$$P_A = 0.834 + 2x = 1.37067$$

$$P_B = 0.565 + x = .83333$$

Now you can solve for the equilibrium constant, K_p: