Unit 8 Progress Check: FRQ

1. For parts of the free response question that require calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Examples and equations may be included in your answers where appropriate.

Answer the following questions about weak acids. Use the K_a values in the following table to help answer some of the questions.

Acid	K_a
HF	6.7×10^{-4}
$HC_2H_3O_2$	1.8×10^{-5}

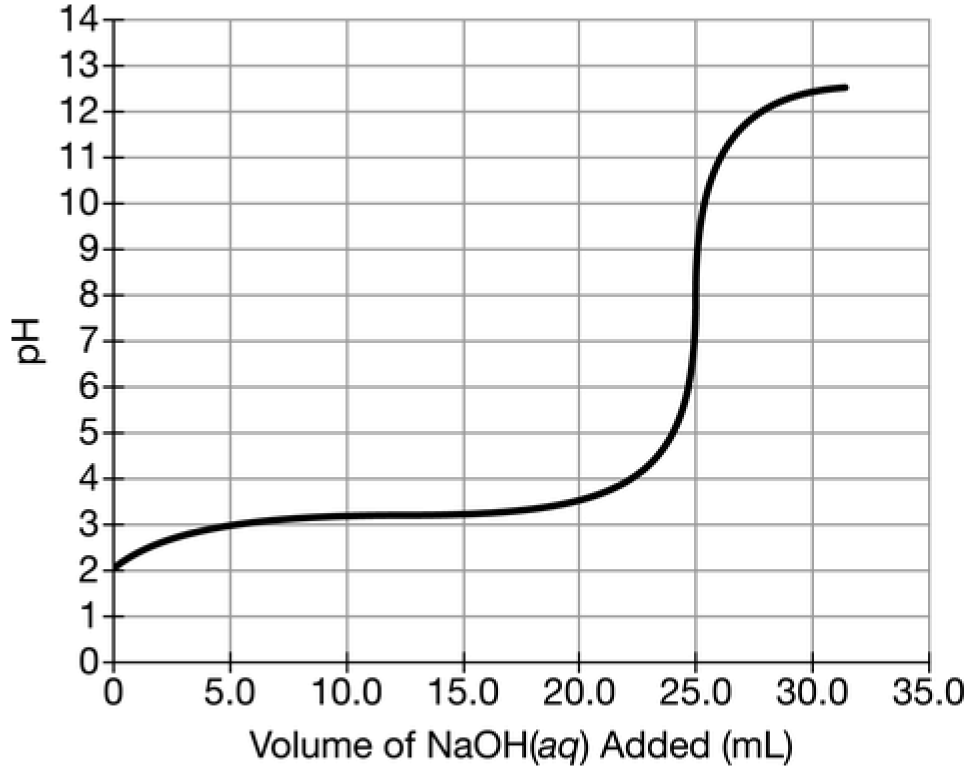
(a) Using the expression $K_a = \frac{[H^+][A^-]}{[HA]}$, explain how to determine which solution has the lower pH, $0.10\ M$ HF(aq) or $0.10\ M$ $HC_2H_3O_2(aq)$. Do not perform any numerical calculations.

Please respond on separate paper, following directions from your teacher.

(b) Which solution has a higher percent ionization of the acid, a $0.10\ M$ solution of $HC_2H_3O_2(aq)$ or a $0.010\ M$ solution of $HC_2H_3O_2(aq)$? Justify your answer including the calculation of percent ionization for each solution.

Please respond on separate paper, following directions from your teacher.

Unit 8 Progress Check: FRQ



(c) A student titrated $50.0\ mL$ of a $0.10\ M$ solution of a certain weak acid with $NaOH(aq)$. The results are given in the graph above.

(i) What is the approximate pK_a of the acid?

Please respond on separate paper, following directions from your teacher.

(ii) What specific value from the graph is needed, in addition to the information in part (c) above, to calculate the molar concentration of the $NaOH(aq)$?

Please respond on separate paper, following directions from your teacher.

(iii) Identify a pH value between 2.5 and 7.5 at which the concentration of the weak acid being titrated is less than the concentration of its conjugate base.

Please respond on separate paper, following directions from your teacher.

Unit 8 Progress Check: FRQ

(d) In another experiment, the student titrated $50.0\ \text{mL}$ of $0.100\ M\ HC_2H_3O_2$ with $0.100\ M\ NaOH(aq)$. Calculate the pH of the solution at the equivalence point.

Please respond on separate paper, following directions from your teacher.

Part (a)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1 ✓

The response indicates that if [HA] is equal for the two acids, the acid with the larger K_a will have the larger concentration of H^+ (which is equal to the concentration of A^-) and the lower pH , so $0.10\ M\ HF(aq)$ will have the lower pH .

Part (b)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response. The choice of which solution has a higher percent ionization should be consistent with the calculations.

0	1	2	3 ✓

The response meets all three of the following criteria:

- ☐ The response includes a calculation of the percent ionization for $0.10\ M\ HC_2H_3O_2$ as follows.

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$1.8 \times 10^{-5} = \frac{x^2}{0.10-x} \text{ (Assume } x << 0.10\ M\text{ .)}$$

$$x^2 = 1.8 \times 10^{-6}$$

$$x = 1.3 \times 10^{-3}$$

$\frac{0.0013}{0.10} \times 100 = 1.3\%$

- ☐ The response includes a calculation of the percent ionization for $0.010\ M\ HC_2H_3O_2$ as follows.

  $1.8 \times 10^{-5} = \frac{x^2}{0.010-x}$ (Assume $x << 0.010\ M$.)

  $x^2 = 1.8 \times 10^{-7}$

  $x = 4.2 \times 10^{-4}$

  $\frac{0.00042}{0.010} \times 100 = 4.2\%$

- ☐ The response includes a conclusion consistent with the calculations.

Part (c)(i)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1 ✓

The response indicates that the $\mathrm{p}K_a$ is $3.2\ (\pm 0.1)$.

Part (c)(ii)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1 ✓

The response indicates that the value $25.0\ \mathrm{mL}$ is needed.

Part (c)(iii)

Unit 8 Progress Check: FRQ

Select a point value to view scoring criteria, solutions, and/or examples and to score the response. If the student chose a pK_a near 3.2 in part (c)(i), the response to part (c)(iii) must be greater than that value.

0	1 ✓

The response indicates a pH greater than 3.2 and less than or equal to 7.5.

Part (d)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response. If the student uses incorrect results in a later step, the point can be earned for the later step. Note: It is not possible to determine the H^+ (or OH^-) in one step because a weak acid is reacting with a strong base, yielding a basic solution. However, it is possible to calculate OH^- by imagining that $HC_2H_3O_2$ and OH^- react completely to form a solution of pure $C_2H_3O_2{}^-$, which then hydrolyzes to form $HC_2H_3O_2$ and OH^- . From the calculation of OH^- , H^+ and pH can be determined.

0	1	2	3 ✓

The response includes all three groups of calculations below (or variations):

- ☐ Calculate the initial molarity of $C_2H_3O_2{}^-$ in the titrated solution.

$$\frac{0.100 \text{ mol } HC_2H_3O_2}{1000 \text{ mL } HC_2H_3O_2} \times 50.0 \text{ mL } HC_2H_3O_2 = 0.00500 \text{ mol } HC_2H_3O_2$$

$$0.00500 \text{ mol } HC_2H_3O_2 \rightarrow 0.00500 \text{ mol } C_2H_3O_2{}^- \text{ at complete reaction}$$

$$\frac{0.00500 \text{ mol } C_2H_3O_2{}^-}{0.1000 \text{ L}} = 0.0500\ M\ C_2H_3O_2{}^- \text{ at complete reaction}$$

- ☐ Calculate OH^- at the equivalence point using the hydrolysis of $C_2H_3O_2{}^-$

First calculate K_b for $C_2H_3O_2{}^-$:

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} = 5.6 \times 10^{-10}$$

Then calculate $[OH^-]$ and pH .

$$C_2H_3O_2{}^- + H_2O \rightleftarrows HC_2H_3O_2 + OH^-$$

$$K_b = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2{}^-]} = \frac{x^2}{0.0500 - x}$$

Assume that $0.0500 - x \approx 0.0500$, then $K_b = 5.6 \times 10^{-10} = \frac{x^2}{0.0500}$

$x^2 = 2.8 \times 10^{-11}$,$x = 5.3 \times 10^{-6} = [OH^-]$

☐ Calculate $pH = 14.0 - pOH = 14.0 - (-\log(5.3 \times 10^{-6}) = 8.7$