Unit 8 Summative Assessment Practice

Show your work for each question in the space provided. Examples and equations may be included in your responses where appropriate. For 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. Pay attention to significant figures.

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1. The value of K_w is affected by changes in temperature, as shown in the table below.

Temperature (°C)	K_w	pH of Pure Water
20	6.8×10^{-15}	
25	1.0×10^{-14}	7.00
30	1.5×10^{-14}	

(a) Use the information in the table above to calculate the pH of pure water at 20°C and at 30°C. Write the pH values in the table above.

$$2\ H_2O(l) \rightleftarrows H_3O^+(aq) + OH^-(aq)$$

(b) The autoionization of water is represented by the equation shown above. Is the forward reaction classified as endothermic or exothermic? Justify your answer by describing the relationship between temperature and K_w.

(c) The pH of a sample of pure water that is at a temperature other than 25°C is determined to be 6.85. In each column of the table below, circle the correct information for this sample of pure water.

Temperature	Relative Concentrations of H_3O^+ and OH^-
less than 25°C greater than 25°C	$[H_3O^+] < [OH^-]$ $[H_3O^+] = [OH^-]$ $[H_3O^+] > [OH^-]$

For the remainder of this assessment, you can assume that the temperature is equal to 25°C.

	Volume	Substance and Concentration
Solution A	350.0 mL	0.016 M $HClO_4(aq)$
Solution B	450.0 mL	0.012 M $KOH(aq)$

2. A student combines two different solutions that are labeled as A and B. Information about these two solutions is listed in the table above.

(a) Write the net ionic equation for the acid-base reaction that occurs when solutions A and B are combined.

(b) Calculate the pH of solution A.

(c) Calculate the pH of solution B.

(d) The final volume of the combined solution is equal to 800.0 mL. Assume that the acid-base reaction that occurred in this experiment has gone to completion.

(i) Identify the excess reactant in this experiment, and calculate the number of moles of the excess reactant that remains left over at the end of the experiment.

(ii) Calculate the pH of the combined solution at the end of the experiment.

Acid	Initial Concentration of Acid	$[H_3O^+]$ at Equilibrium	pH
HX	0.050 *M*	?	3.07

3. Information about a solution of a monoprotic acid, HX, is listed in the table above.

   (a) Calculate the value of $[H_3O^+]$ in a solution of 0.050 *M* HX(*aq*).

   (b) Calculate the percent ionization of HX in a solution of 0.050 *M* HX(*aq*).

$$C_6H_5CO_2H(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_6H_5CO_2^-(aq) \qquad K_a = 6.3 \times 10^{-5}$$

4. Benzoic acid, $C_6H_5CO_2H$, ionizes according to the equation above.

   (a) Write the expression for the equilibrium constant, K_a, for the reaction.

   (b) Calculate the pH of a solution of 2.5×10^{-3} *M* $C_6H_5CO_2H(aq)$.

   A student performs a titration experiment in order to determine the concentration of the benzoate ion, $C_6H_5CO_2^-$, in a solution of potassium benzoate, $KC_6H_5CO_2$.

   (c) Write the net ionic equation for the acid-base reaction that occurs when solutions of $KC_6H_5CO_2(aq)$ and $HNO_3(aq)$ are combined in this titration experiment.

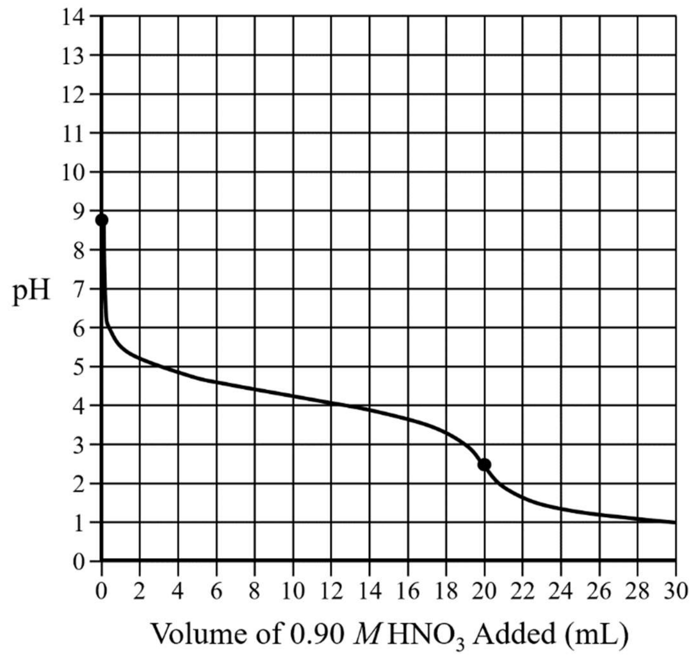
4. (continued)

The student titrated a 50.0 mL sample of $KC_6H_5CO_2(aq)$ with a solution of 0.90 M $HNO_3(aq)$. The titration curve from the experiment is shown at right.

The two data points that are marked on the titration curve represent the following pH values.

- the initial pH of the $KC_6H_5CO_2$ solution
- the pH of the reaction mixture at the equivalence point in the titration.

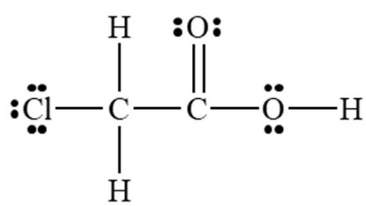
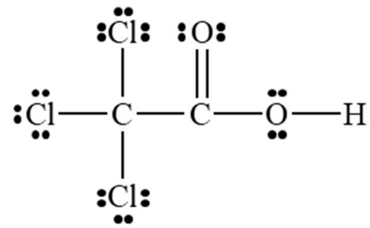
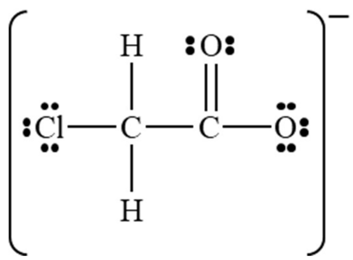
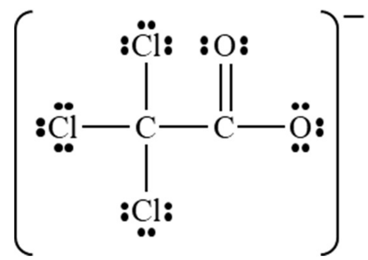
Use the information from the titration curve to answer the following questions.



(d) Calculate the concentration of the benzoate ion, $C_6H_5CO_2^-$, in the solution that was titrated in this experiment.

(e) When the pH of the reaction mixture in the titration experiment is equal to 4.80, do you predict that the benzoate ion, $C_6H_5CO_2^-$, or benzoic acid, $C_6H_5CO_2H$, should have a higher concentration in the flask? Justify your answer.

(f) A student makes the claim that bromophenol blue, an acid-base indicator with a pK_a value of 4.0, would be an appropriate indicator that could be used to determine the end point for this titration. Do you agree or disagree with the student's claim? Justify your answer.

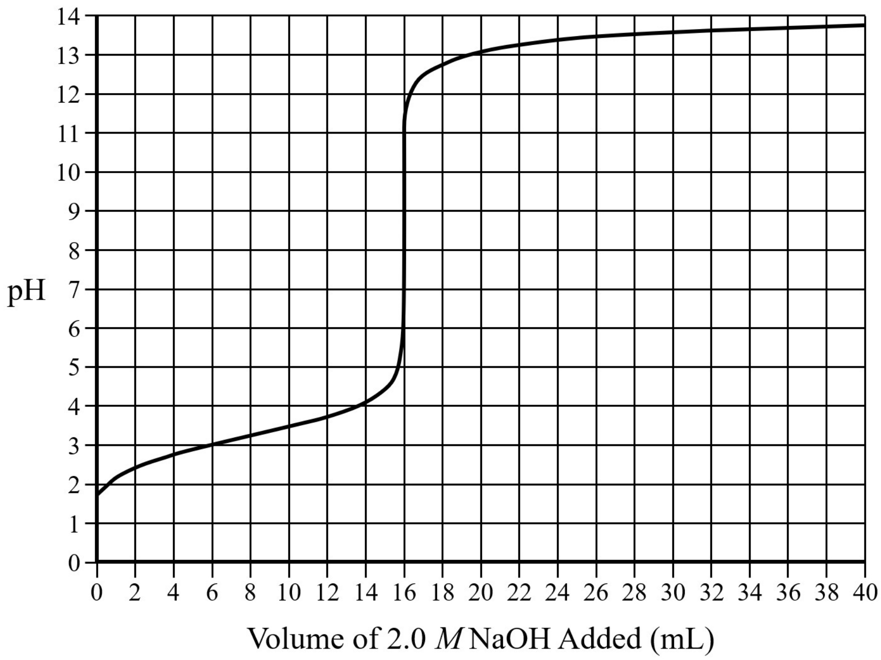
Name and Formula of Acid	Chloroacetic Acid $ClCH_2CO_2H$	Trichloroacetic Acid CCl_3CO_2H
Lewis Diagram		
pK_a of the Acid	2.86	0.66
Name and Formula of Conjugate Base	Chloroacetate $ClCH_2CO_2^-$	Trichloroacetate $CCl_3CO_2^-$
Lewis Diagram		

5. Information about chloroacetic acid ($ClCH_2CO_2H$) and trichloroacetic acid (CCl_3CO_2H) is shown in the table above.

   (a) Which substance, chloroacetic acid or trichloroacetic acid, is classified as the stronger acid? Justify your answer by comparing the pK_a values of each substance.

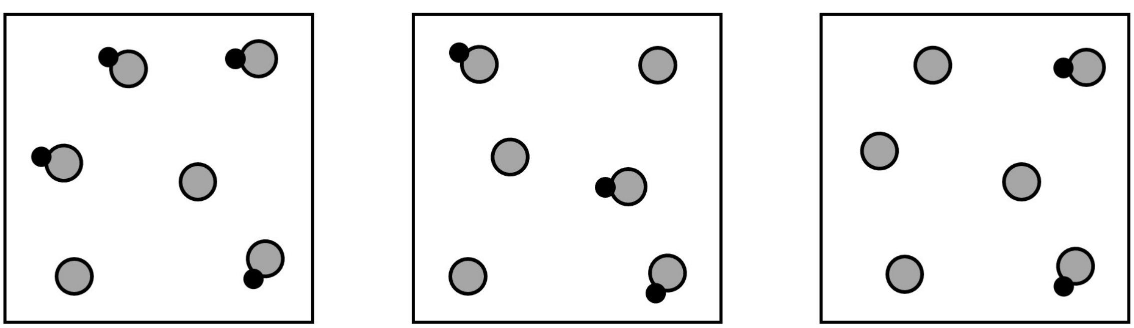
   (b) Which ion, chloroacetate ($ClCH_2CO_2^-$) or trichloroacetate ($CCl_3CO_2^-$), is classified as the weaker base? Justify your answer by using principles of chemical bonding to explain the difference in the relative stability of the two ions.

6. A student titrates 50.0 mL of 0.64 M HF(aq) with 2.0 M NaOH(aq), using a probe to monitor the pH of the solution. The data are plotted, producing the following titration curve.



(a) Using the information in the graph, estimate the pK_a of HF. ____________________________

(b) Three different particulate representations are shown below. Cations and water molecules are not shown.



(i) Circle the diagram that shows the most accurate representation of the major species present in a representative sample of the reaction mixture at the point in the titration when 12 mL of the titrant, 2.0 M NaOH, has been added.

(ii) Justify your choice in (b)(i) by comparing the pH of the reaction mixture at that particular point in the titration with the pK_a of HF.

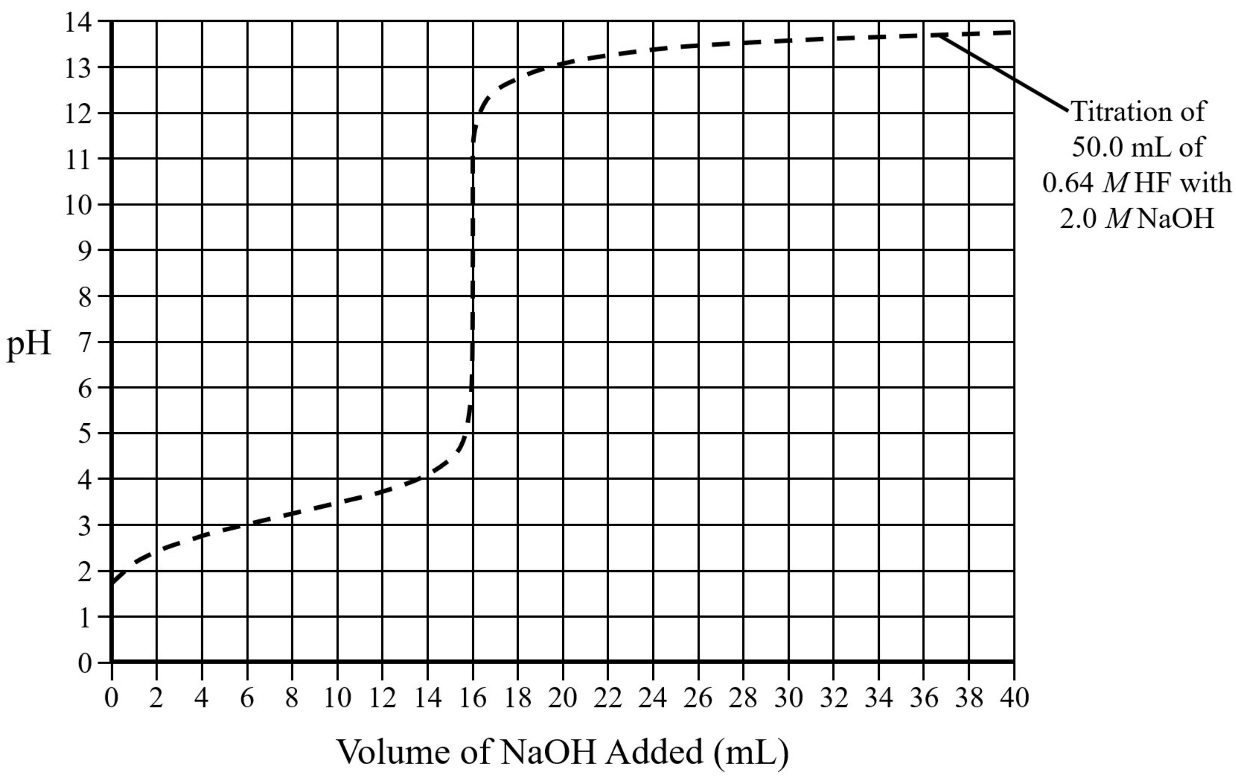
6. (continued)

(c) At the equivalence point of the titration, the pH of the reaction mixture is between 8 and 9. Circle all of the substances listed below that are present in the reaction mixture at a concentration greater than 0.10 *M* when the equivalence point is reached.

HF H_3O^+ OH^- Na^+ F^-

(d) Write the net ionic equation for the acid-base reaction that takes place between one of the substances that you circled in part (c) and $H_2O(l)$. This reaction should provide evidence to support why the pH of the reaction mixture is greater than 7 at the equivalence point.

(e) The student performs a second trial of the titration experiment, this time titrating 50.0 mL of 0.64 *M* HF(*aq*) with a solution of 1.0 *M* NaOH(*aq*) as the titrant. Sketch the curve that would result from the titration in trial 2 on the following graph, which already shows the original curve from the titration in trial 1.



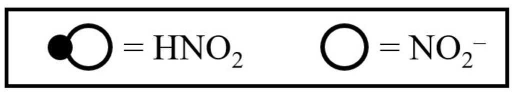
Acid	HNO_2	HOCl	NH_4^+
K_a	4.0×10^{-4}	2.9×10^{-8}	5.6×10^{-10}

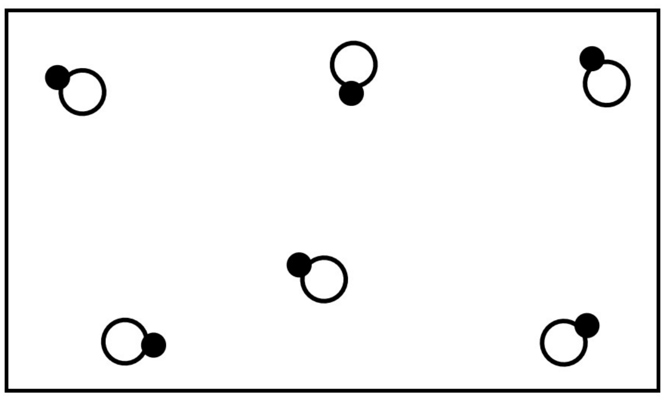
7. Information about three different weak acids is shown in the table above. Use this information to answer the following questions.

   (a) A student prepared a buffer solution by combining 500.0 mL of 2.0 *M* $HNO_2(aq)$ and 500.0 mL of 1.0 *M* KOH(*aq*).

      (i) Calculate the pH of the buffer solution prepared by the student.

      (ii) The particulate diagram shown below is incomplete. Draw in the correct number of NO_2^- ions in the box below so that the diagram shows a representative sample of the buffer solution prepared by the student.





   (b) Circle one of the following pairs of solutions which, when combined, will result in a buffer solution with a pH that is greater than the pK_a of HOCl.

50 mL of 0.10 *M* HOCl(*aq*) and 100 mL of 0.10 *M* NaOCl(*aq*)	100 mL of 0.10 *M* HOCl(*aq*) and 100 mL of 0.10 *M* NaOCl(*aq*)	100 mL of 0.10 *M* HOCl(*aq*) and 50 mL of 0.10 *M* NaOCl(*aq*)

7. (continued)

(c) Calculate the pH of the buffer solution formed from the combination of solutions that you circled in part (b).

Two different buffer solutions were prepared that each contain an equimolar mixture of NH_3 and NH_4^+. An experiment was performed in which a small amount of NaOH was added to 1.00 L of each buffer solution. The pH of each solution was measured before and after the addition of NaOH. Data from the experiment are shown in the table below.

Buffer Solution	#1	#2
Concentration of Each Component in the Buffer Solution	2.0 M $NH_3(aq)$ and 2.0 M $NH_4^+(aq)$	0.20 M $NH_3(aq)$ and 0.20 M $NH_4^+(aq)$
Volume of Buffer Solution	1.00 L	1.00 L
Initial pH of Buffer Solution	9.25	9.25
Amount of NaOH added to Each Buffer Solution	0.10 mol	0.10 mol
Final pH of the Buffer Solution after NaOH is Added (Assume that the final volume of the buffer solution remains constant at 1.00 L)	9.30	?
Magnitude of Change in pH	0.05	?

(d) Write the net ionic equation for the acid-base reaction that occurs when NaOH(aq) is added to these buffer solutions.

(e) An equal amount of NaOH (0.10 mol) was added to each buffer solution in this experiment. Do you predict that the magnitude of change in pH for buffer solution #2 will be less than, equal to, or greater than 0.05? Justify your answer by comparing the buffer capacity of solutions #1 and #2.