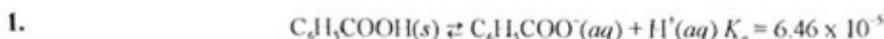


Acids and Bases Practice Quiz



Benzoic acid, $\text{C}_6\text{H}_5\text{COOH}$, dissociates in water as shown in the equation above. A 25.0 mL sample of an aqueous solution of pure benzoic acid is titrated using standardized 0.150 M NaOH.

- After addition of 15.0 mL of the 0.150 M NaOH, the pH of the resulting solution is 4.37. Calculate each of the following.
 - $[\text{H}^+]$ in the solution
 - $[\text{OH}^-]$ in the solution
 - The number of moles of NaOH added
 - The number of moles of $\text{C}_6\text{H}_5\text{COO}^-$ (aq) in the solution
 - The number of moles of $\text{C}_6\text{H}_5\text{COOH}$ in the solution
- State whether the solution at the equivalence point of the titration is acidic, basic, or neutral. Explain your reasoning. In a different titration, a 0.7529 g sample of a mixture of solid $\text{C}_6\text{H}_5\text{COOH}$ and solid NaCl is dissolved in water and titrated with 0.150 M NaOH. The equivalence point is reached when 24.78 mL of the base solution is added.
- Calculate each of the following.
 - The mass, in grams, of benzoic acid in the solid sample
 - The mass percentage of benzoic acid in the solid sample



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

Part A

1 point is earned for the correct answer.

$$[\text{H}^+] = 10^{-4.37} \text{ M} = 4.3 \times 10^{-5} \text{ M}$$

1 point is earned for the correct answer.

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{4.3 \times 10^{-5} \text{ M}} = 2.3 \times 10^{-10} \text{ M}$$

1 point is earned for the correct answer.

$$\text{mol OH}^- = 0.0150 \text{ L} \times 0.150 \text{ mol L}^{-1} = 2.25 \times 10^{-3} \text{ mol}$$

1 point is earned for the correct answer.

$$\text{mol OH}^- \text{ added} = \text{mol C}_6\text{H}_5\text{COO}^- \text{ (aq) generated, thus}$$

$$\text{mol C}_6\text{H}_5\text{COO}^- \text{ (aq) in solution} = 2.25 \times 10^{-3} \text{ mol}$$

1 point is earned for the correct molarity.



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$$K_a = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]} \Rightarrow [\text{C}_6\text{H}_5\text{COOH}] = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{K_a}$$

$$[\text{C}_6\text{H}_5\text{COOH}] = \frac{(4.3 \times 10^{-5} \text{ M}) \times \frac{2.25 \times 10^{-3} \text{ mol}}{0.040 \text{ L}}}{6.46 \times 10^{-5}} = 3.7 \times 10^{-2} \text{ M}$$

1 point is earned for the correct answer.

$$\text{thus, mol C}_6\text{H}_5\text{COOH} = (0.040 \text{ L})(3.7 \times 10^{-2} \text{ M}) = 1.5 \times 10^{-3} \text{ mol}$$

OR

1 point is earned for the correct molarity.

$$\text{pH} = \text{p}K_a + \log \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$$

$$\Rightarrow \text{pH} - \text{p}K_a = \log [\text{C}_6\text{H}_5\text{COO}^-] - \log [\text{C}_6\text{H}_5\text{COOH}]$$

$$\Rightarrow \log [\text{C}_6\text{H}_5\text{COOH}] = \log [\text{C}_6\text{H}_5\text{COO}^-] - (\text{pH} - \text{p}K_a)$$

$$= \log \left(\frac{2.25 \times 10^{-3} \text{ mol}}{0.040 \text{ L}} \right) - (4.37 - 4.190)$$

$$= -1.25 - 0.18 = -1.43$$

$$\Rightarrow [\text{C}_6\text{H}_5\text{COOH}] = 10^{-1.43} = 3.7 \times 10^{-2} \text{ M}$$

1 point is earned for the correct answer.

$$\text{thus, mol C}_6\text{H}_5\text{COOH} = (0.040 \text{ L})(3.7 \times 10^{-2} \text{ M}) = 1.5 \times 10^{-3} \text{ mol}$$

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6

The student response earns six of the following points:

1 point is earned for the correct answer.

$$[\text{H}^+] = 10^{-4.37} \text{ M} = 4.3 \times 10^{-5} \text{ M}$$

1 point is earned for the correct answer.

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{4.3 \times 10^{-5} \text{ M}} = 2.3 \times 10^{-10} \text{ M}$$



Acids and Bases Practice Quiz

1 point is earned for the correct answer.

$$\text{mol OH}^- = 0.0150 \text{ L} \times 0.150 \text{ mol L}^{-1} = 2.25 \times 10^{-3} \text{ mol}$$

1 point is earned for the correct answer.

mol OH⁻ added = mol C₆H₅COO⁻(aq) generated, thus

$$\text{mol C}_6\text{H}_5\text{COO}^-(\text{aq}) \text{ in solution} = 2.25 \times 10^{-3} \text{ mol}$$

1 point is earned for the correct molarity.

$$K_a = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]} \Rightarrow [\text{C}_6\text{H}_5\text{COOH}] = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{K_a}$$

$$[\text{C}_6\text{H}_5\text{COOH}] = \frac{(4.3 \times 10^{-5} \text{ M}) \times \frac{2.25 \times 10^{-3} \text{ mol}}{0.040 \text{ L}}}{6.46 \times 10^{-5}} = 3.7 \times 10^{-2} \text{ M}$$

1 point is earned for the correct answer.

$$\text{thus, mol C}_6\text{H}_5\text{COOH} = (0.040 \text{ L})(3.7 \times 10^{-2} \text{ M}) = 1.5 \times 10^{-3} \text{ mol}$$

OR

1 point is earned for the correct molarity.

$$\text{pH} = \text{p}K_a + \log \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$$

$$\Rightarrow \text{pH} - \text{p}K_a = \log [\text{C}_6\text{H}_5\text{COO}^-] - \log [\text{C}_6\text{H}_5\text{COOH}]$$

$$\Rightarrow \log [\text{C}_6\text{H}_5\text{COOH}] = \log [\text{C}_6\text{H}_5\text{COO}^-] - (\text{pH} - \text{p}K_a)$$

$$= \log \left(\frac{2.25 \times 10^{-3} \text{ mol}}{0.040 \text{ L}} \right) - (4.37 - 4.190)$$

$$= -1.25 - 0.18 = -1.43$$

$$\Rightarrow [\text{C}_6\text{H}_5\text{COOH}] = 10^{-1.43} = 3.7 \times 10^{-2} \text{ M}$$

1 point is earned for the correct answer.

$$\text{thus, mol C}_6\text{H}_5\text{COOH} = (0.040 \text{ L})(3.7 \times 10^{-2} \text{ M}) = 1.5 \times 10^{-3} \text{ mol}$$

Part B



Acids and Bases Practice Quiz

1 point is earned for the prediction and the explanation.

At the equivalence point the solution is basic due to the presence of $\text{C}_6\text{H}_5\text{COO}^-$ (the conjugate base of the weak acid) that hydrolyzes to produce a basic solution as represented below.



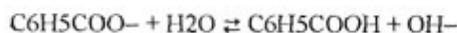
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The student response earns one of the following points:

1 point is earned for the prediction and the explanation.

At the equivalence point the solution is basic due to the presence of $\text{C}_6\text{H}_5\text{COO}^-$ (the conjugate base of the weak acid) that hydrolyzes to produce a basic solution as represented below.



Part C

1 point is earned for the correct answer.

$$\text{mol C}_6\text{H}_5\text{COOH} = (0.02478 \text{ L}) \times (0.150 \text{ mol OH}^- \text{ L}^{-1}) \times \frac{1 \text{ mol C}_6\text{H}_5\text{COOH}}{1 \text{ mol OH}^-}$$

$$= 3.72 \times 10^{-3} \text{ mol C}_6\text{H}_5\text{COOH}$$

$$\text{mass C}_6\text{H}_5\text{COOH} = 3.72 \times 10^{-3} \text{ mol C}_6\text{H}_5\text{COOH} \times \frac{122 \text{ g C}_6\text{H}_5\text{COOH}}{1 \text{ mol C}_6\text{H}_5\text{COOH}}$$

$$= 0.453 \text{ g C}_6\text{H}_5\text{COOH}$$

1 point is earned for the correct answer.

$$\text{mass \% C}_6\text{H}_5\text{COOH} = \frac{0.453 \text{ g C}_6\text{H}_5\text{COOH}}{0.7529 \text{ g}} \times 100$$

$$= 60.2\%$$



Acids and Bases Practice Quiz

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2

The student response earns two of the following points:

1 point is earned for the correct answer.

$$\text{mol C}_6\text{H}_5\text{COOH} = (0.02478 \text{ L}) \times (0.150 \text{ mol OH}^- \text{ L}^{-1}) \times \frac{1 \text{ mol C}_6\text{H}_5\text{COOH}}{1 \text{ mol OH}^-}$$

$$= 3.72 \times 10^{-3} \text{ mol C}_6\text{H}_5\text{COOH}$$

$$\text{mass C}_6\text{H}_5\text{COOH} = 3.72 \times 10^{-3} \text{ mol C}_6\text{H}_5\text{COOH} \times \frac{122 \text{ g C}_6\text{H}_5\text{COOH}}{1 \text{ mol C}_6\text{H}_5\text{COOH}}$$

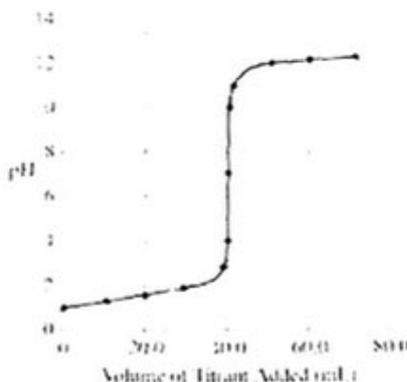
$$= 0.453 \text{ g C}_6\text{H}_5\text{COOH}$$

1 point is earned for the correct answer.

$$\text{mass \% C}_6\text{H}_5\text{COOH} = \frac{0.453 \text{ g C}_6\text{H}_5\text{COOH}}{0.7529 \text{ g}} \times 100$$

$$= 60.2\%$$

2.



A solution of 0.100 M HCl and a solution of 0.100 M NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.

- a. Identify the solution that was initially added to the beaker. Explain your reasoning.



Acids and Bases Practice Quiz

- On the titration curve above, circle the point that corresponds to the equivalence point.
- At the equivalence point, how many moles of titrant have been added?
- The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.
- What is the difference between the equivalence point of a titration and the end point of a titration?
- On the grid provided on the next page, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).



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

Part A

1 point is earned for the correct identification with rationale.

The solution in the beaker was the 0.100 M HCl because the initial pH was 1 (the pH of 0.100 M HCl).

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1

The student response earns one of the following points:

1 point is earned for the correct identification with rationale.

The solution in the beaker was the 0.100 M HCl because the initial pH was 1 (the pH of 0.100 M HCl).

Part B

1 point is earned for the correct choice of point.

The point with coordinates (40.0, 7) is circled.

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The student response earns one of the following points:

1 point is earned for the correct choice of point.



Acids and Bases Practice Quiz

The point with coordinates (40.0, 7) is circled.

Part C

1 point is earned for the correct numerical answer.

$$0.0400 \text{ L} \times \frac{0.100 \text{ mol NaOH}}{1.00 \text{ L}} = 0.00400 \text{ mol NaOH}$$

0

1

The student response earns one of the following points:

1 point is earned for the correct numerical answer.

$$0.0400 \text{ L} \times \frac{0.100 \text{ mol NaOH}}{1.00 \text{ L}} = 0.00400 \text{ mol NaOH}$$

Part D

1 point is earned for the correct selection of indicator.

1 point is earned for the explanation.

Methyl red would be best because its color change will occur closest to the equivalence point (when the pH changes from about 4 to 10).

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2

The student response earns two of the following points:

1 point is earned for the correct selection of indicator.

1 point is earned for the explanation.

Methyl red would be best because its color change will occur closest to the equivalence point (when the pH changes from about 4 to 10).

Part E

Acids and Bases Practice Quiz

1 point is earned for each correct definition (for a maximum of 2 points).

The equivalence point in a titration occurs when the number of moles of titrant added is exactly sufficient to react completely with the number of moles of the titrated species present in the sample being titrated.

The end point of a titration is the point in a titration at which the indicator undergoes its color change.

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2

The student response earns two of the following points:

1 point is earned for each correct definition (for a maximum of 2 points).

The equivalence point in a titration occurs when the number of moles of titrant added is exactly sufficient to react completely with the number of moles of the titrated species present in the sample being titrated.

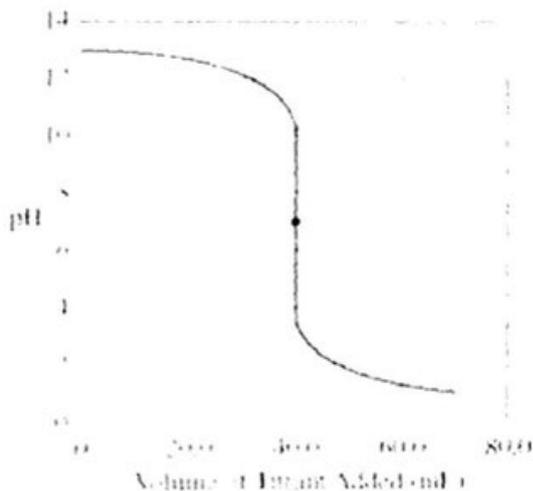
The end point of a titration is the point in a titration at which the indicator undergoes its color change.

Part F

1 point is earned for starting between pH 12 and 14 and for finishing below pH 2.

1 point is earned for locating the equivalence point at pH 7 and volume 40.0 mL.

1 point is earned for the overall shape of the curve.



Acids and Bases Practice Quiz

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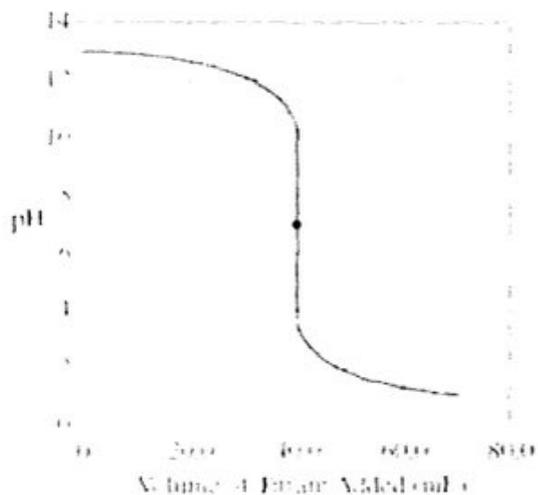
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The student response earns three of the following points:

1 point is earned for starting between pH 12 and 14 and for finishing below pH 2.

1 point is earned for locating the equivalence point at pH 7 and volume 40.0 mL.

1 point is earned for the overall shape of the curve.



Refer to the following.

