# Thought Lab 16.1: Finding an Equilibrium Law Answer Key



## Answers to Analysis Questions

**2.** The data should be entered in a spreadsheet program and show calculated values for the initial [$CH_3COOH(aq)$], the initial [$CH_3CH_2OH(aq)$], and the equilibrium [$CH_3COOH(aq)$]. Calculated values should show three decimal places to reduce round-off errors later.

| Experiment | Initial $CH_3COOH$ (mol) | Initial $CH_3CH_2OH$ (mol) | Equilibrium $CH_3COOH$ (mol) | Total volume (mL) | Initial $[CH_3COOH]$ (mol/L) | Initial $[CH_3CH_2OH]$ (mol/L) | Equilibrium $[CH_3COOH]$ (mol/L) |
|---|---|---|---|---|---|---|---|
| **1** | 0.22 | 0.114 | 0.125 | 38.1 | 5.774 | 2.992 | 3.281 |
| **2** | 0.184 | 0.115 | 0.0917 | 40.3 | 4.566 | 2.854 | 2.275 |
| **3** | 0.152 | 0.121 | 0.0631 | 39.4 | 3.858 | 3.071 | 1.602 |
| **4** | 0.214 | 0.132 | 0.11 | 42.6 | 5.023 | 3.099 | 2.582 |
| **5** | 0.233 | 0.137 | 0.122 | 41.5 | 5.614 | 3.301 | 2.940 |

**4.** The five ICE tables are shown below.

**Experiment 1**

| | $CH_3COOH(aq) + CH_3CH_2OH(aq) \leftrightarrow CH_3COOCH_2CH_3(aq) + H_2O(aq)$ | | | |
|---|---|---|---|---|
| | $[CH_3COOH(aq)]$ (mol/L) | $[CH_3CH_2OH(aq)]$ (mol/L) | $[CH_3COOCH_2CH_3(aq)]$ (mol/L) | $[H_2O(aq)]$ (mol/L) |
| **I**nitial | 5.774 | 2.992 | 0 | 0 |
| **C**hange | –2.493 | –2.493 | 2.493 | 2.493 |
| **E**quilibrium | 3.281 | 0.499 | 2.493 | 2.493 |

**Experiment 2**

| | $CH_3COOH(aq) + CH_3CH_2OH(aq) \leftrightarrow CH_3COOCH_2CH_3(aq) + H_2O(aq)$ | | | |
|---|---|---|---|---|
| | $[CH_3COOH(aq)]$ (mol/L) | $[CH_3CH_2OH(aq)]$ (mol/L) | $[CH_3COOCH_2CH_3(aq)]$ (mol/L) | $[H_2O(aq)]$ (mol/L) |
| **I**nitial | 4.566 | 2.854 | 0 | 0 |
| **C**hange | –2.291 | –2.291 | 2.291 | 2.291 |
| **E**quilibrium | 2.275 | 0.563 | 2.291 | 2.291 |

**Experiment 3**

| | $CH_3COOH(aq) + CH_3CH_2OH(aq) \leftrightarrow CH_3COOCH_2CH_3(aq) + H_2O(aq)$ | | | |
|---|---|---|---|---|
| | $[CH_3COOH(aq)]$ (mol/L) | $[CH_3CH_2OH(aq)]$ (mol/L) | $[CH_3COOCH_2CH_3(aq)]$ (mol/L) | $[H_2O(aq)]$ (mol/L) |
| **I**nitial | 3.858 | 3.071 | 0 | 0 |
| **C**hange | –2.256 | –2.256 | 2.256 | 2.256 |
| **E**quilibrium | 1.602 | 0.815 | 2.256 | 2.256 |

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**Experiment 4**

| | $CH_3COOH(aq) + CH_3CH_2OH(aq) \leftrightarrow CH_3COOCH_2CH_3(aq) + H_2O(aq)$ | | | |
|---|---|---|---|---|
| | $[CH_3COOH(aq)]$ (mol/L) | $[CH_3CH_2OH(aq)]$ (mol/L) | $[CH_3COOCH_2CH_3(aq)]$ (mol/L) | $[H_2O(aq)]$ (mol/L) |
| **I**nitial | 5.023 | 3.099 | 0 | 0 |
| **C**hange | –2.441 | –2.441 | 2.441 | 2.441 |
| **E**quilibrium | 2.582 | 0.658 | 2.441 | 2.441 |

**Experiment 5**

| | $CH_3COOH(aq) + CH_3CH_2OH(aq) \leftrightarrow CH_3COOCH_2CH_3(aq) + H_2O(aq)$ | | | |
|---|---|---|---|---|
| | $[CH_3COOH(aq)]$ (mol/L) | $[CH_3CH_2OH(aq)]$ (mol/L) | $[CH_3COOCH_2CH_3(aq)]$ (mol/L) | $[H_2O(aq)]$ (mol/L) |
| **I**nitial | 5.614 | 3.301 | 0 | 0 |
| **C**hange | –2.674 | –2.674 | 2.674 | 2.674 |
| **E**quilibrium | 2.940 | 0.627 | 2.674 | 2.674 |

**5.** The calculated values for $K_c$ are shown below.

$$K_c = \frac{[CH_3COOCH_2CH_3(aq)][H_2O(aq)]}{[CH_3COOH(aq)][CH_3CH_2OH(aq)]}$$

Experiment

**1** 3.80 **2** 4.10 **3** 3.90 **4** 3.51 **5** 3.88

**6.** At this point, you should round your calculated values to three significant digits. The average value for $K_c$ is 3.84 and the values are reasonably close. The value furthest from the average is 3.51, but without further details on the experiment, you cannot determine if Experiment 4 had different experimental or procedural errors compared with the other experiments.

**7.** Other mathematical relationships among the equilibrium concentrations include the following:

$$K_c = \frac{[CH_3COOCH_2CH_3(aq)] + [H_2O(aq)]}{[CH_3COOH(aq)] + [CH_3CH_2OH(aq)]}$$

$$K_c = \frac{[CH_3COOCH_2CH_3(aq)] + [H_2O(aq)]}{[CH_3COOH(aq)]\,[CH_3CH_2OH(aq)]}$$

$$K_c = \frac{[CH_3COOCH_2CH_3(aq)] \div [H_2O(aq)]}{[CH_3COOH(aq)] \div [CH_3CH_2OH(aq)]}$$

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Other mathematical combinations are possible, but the only combination that will give a reasonably constant value for the five experiments is

$$K_c = \frac{[CH_3COOH(aq)]\,[CH_3CH_2OH(aq)]}{[CH_3COOCH_2CH_3(aq)]\,[H_2O(aq)]}$$

This is the inverse of $K_c$.