

**CHM 111**  
**Take-Home Quiz 3                      SOLUTIONS**

**Answer each question. If a calculation is required, show your work.**

1,2) For the equilibrium  $SO_2Cl_2(g) \leftrightarrow SO_2(g) + Cl_2(g)$  with  $K = 0.045$ , if you start with a reaction vessel containing  $0.0555 \text{ M } SO_2Cl_2$ , what will the concentrations of  $SO_2$  and  $Cl_2$  be at equilibrium?

- $[SO_2] = \underline{0.0323 \text{ M}}$
- $[Cl_2] = \underline{0.0323 \text{ M}}$

*To solve this problem, you must first set up an equilibrium expression:*

$$K = \frac{[SO_2][Cl_2]}{[SO_2Cl_2]} = 0.045$$

*Now, express concentrations at equilibrium in terms of a single variable. For convenience, we'll let  $[SO_2] = x$ .*

$$[SO_2] = x$$

$$[Cl_2] = x ; \text{ (a } Cl_2 \text{ molecule is formed whenever an } SO_2 \text{ molecule is)}$$

$$[SO_2Cl_2] = 0.0555 - x ; \text{ (we start with } 0.0555 \text{ M } SO_2Cl_2, \text{ and lose one molecule of } SO_2Cl_2 \text{ whenever an } SO_2 \text{ molecule is formed)}$$

*Plugging into the equilibrium expression, we get:*

$$\frac{x^2}{(0.0555 - x)} = 0.045$$

*Rearranging into quadratic form:*

$$x^2 + 0.045x - 0.0024975 = 0$$

*We solve using the quadratic equation:*

$$a = 1$$

$$b = 0.045$$

$$c = -0.0024975$$

$$x = \frac{-0.045 \pm \sqrt{(0.045)^2 - (4 \times 1 \times -0.0024975)}}{2 \times 1} = 0.0323$$

*There are two solutions to this quadratic, but since  $x$  represents a concentration, we can throw out the negative solutions. Negative concentrations do not make physical sense!*

- $[\text{SO}_2] = 0.0323 \text{ M}$
- $[\text{Cl}_2] = 0.0323 \text{ M}$
- $[\text{SO}_2\text{Cl}_2] = 0.0232 \text{ M}$ ; (it wasn't necessary for this problem to calculate this one. It's for your reference)

3) For the equilibrium  $\text{HC}_3\text{H}_5\text{O}_2(\text{aq}) \leftrightarrow \text{H}^+(\text{aq}) + \text{C}_3\text{H}_5\text{O}_2^-(\text{aq})$  where  $K = 1.3 \times 10^{-5}$ , calculate the equilibrium concentration of  $\text{H}^+$  if you were to dissolve 0.13 moles  $\text{HC}_3\text{H}_5\text{O}_2$  in 500.0 mL of water. [Hint: compare the value of  $K$  with your initial concentration!]

- $[\text{H}^+]$  at equilibrium is **0.0018 M**

First, we must calculate the concentration of the starting species (propionic acid):

$$[\text{HC}_3\text{H}_5\text{O}_2]_{\text{initial}} = 0.13 \text{ moles} / 0.5000 \text{ L} = 0.26 \text{ M}$$

Now that we know the initial concentration, we can set up the equilibrium expression and define equilibrium concentrations in terms of one variable as we did in the previous problem.

$$K = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_2^-]}{[\text{HC}_3\text{H}_5\text{O}_2]} = 1.3 \times 10^{-5}$$

Now, express concentrations at equilibrium in terms of a single variable. For convenience, we'll let  $[\text{H}^+] = x$ .

$$\begin{aligned} [\text{H}^+] &= x \\ [\text{C}_3\text{H}_5\text{O}_2^-] &= x \\ [\text{HC}_3\text{H}_5\text{O}_2] &= 0.26 - x \end{aligned}$$

Plugging into the equilibrium expression, we get:

$$\frac{x^2}{(0.26 - x)} = 1.3 \times 10^{-5}$$

Rearranging into quadratic form:

$$x^2 + 0.000013x - 0.00000338 = 0$$

We solve using the quadratic equation:

$$\begin{aligned} a &= 1 \\ b &= 0.000013 \\ c &= -0.00000338 \end{aligned}$$

$$x = \frac{-0.000013 \pm \sqrt{(0.000013)^2 - (4 \times 1 \times -0.00000338)}}{2 \times 1} = 0.00183$$

There are two solutions to this quadratic, but since  $x$  represents a concentration, we can throw out the negative solutions. Negative concentrations do not make physical sense!

- $[\text{H}^+] = 0.0018 \text{ M}$
- $[\text{C}_3\text{H}_5\text{O}_2^-] = 0.0018 \text{ M}$
- $[\text{HC}_3\text{H}_5\text{O}_2] = 0.26 - 0.0018 = 0.2582 = 0.26 \text{ M}$  (to two significant figures)

Note that the concentration of acetic acid did not change significantly. This will become important in Chapter 17!

4) In an equilibrium between oxides of nitrogen,  $\text{N}_2\text{O}_3(\text{g}) \leftrightarrow \text{NO}_2(\text{g}) + \text{NO}(\text{g})$ , with  $K = 0.193$ . If a reaction vessel contains  $0.250 \text{ M}$   $\text{N}_2\text{O}_3$ ,  $0.225 \text{ M}$   $\text{NO}$ , and  $0.147 \text{ M}$   $\text{NO}_2$ , will the reaction proceed to the left or right, or is the reaction already at equilibrium?

- The reaction **proceeds to the right**.

To solve this problem, you must calculate the reaction quotient  $Q$  and compare it to the value of the equilibrium constant  $K$ . The reaction quotient takes the same form as  $K$ .

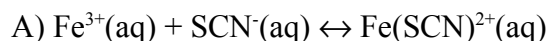
$$Q = \frac{[\text{NO}_2][\text{NO}]}{[\text{N}_2\text{O}_3]} = \frac{(0.147) \times (0.225)}{0.250} = 0.132$$

$$Q = 0.132$$

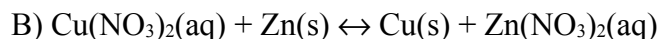
$$K = 0.193$$

- $Q < K$ , so the reaction will proceed to the right to produce more products.

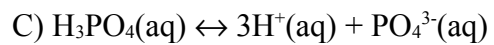
5) Write the concentration-based equilibrium constant expressions for the following:



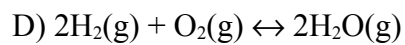
- $$K = \frac{[\text{Fe}(\text{SCN})^{2+}]}{[\text{Fe}^{3+}][\text{SCN}^-]}$$



- $$K = \frac{[\text{Zn}(\text{NO}_3)_2]}{[\text{Cu}(\text{NO}_3)_2]}$$



$$\bullet \quad K = \frac{[\text{H}^+]^3 [\text{PO}_4^{3-}]}{[\text{H}_2\text{PO}_4]}$$



$$\bullet \quad K = \frac{[\text{H}_2\text{O}]^2}{[\text{H}_2]^2 [\text{O}_2]}$$