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 M SO_2Cl_2, what will the concentrations of SO_2 and Cl_2 be at equilibrium?

- $[SO_2]$ = **0.0323** M
- $[Cl_2]$ = **0.0323** 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 $[SO_2] = x$.

$[SO_2] = x$
$[Cl_2] = x$; *(a Cl_2 molecule is formed whenever an SO_2 molecule is)*
$[SO_2Cl_2] = 0.0555 - x$; *(we start with 0.0555 M SO_2Cl_2, and lose one molecule of SO_2Cl_2 whenever an SO_2 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

$$x = \frac{-0.045 \pm \sqrt{(0.045^2 - (4 \times 1 \times -0.024975))}}{2 \times 1} = 0.0323$$

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!

- $[SO_2]$ = 0.0323 M
- $[Cl_2]$ = 0.0323 M
- $[SO_2Cl_2]$ = 0.0232 M ; *(it wasn't necessary for this problem to calculate this one. It's for your reference)*

3) For the equilibrium $\boldsymbol{HC_3H_5O_2(aq) \leftrightarrow H^+(aq) + C_3H_5O_2^-(aq)}$ where K = 1.3×10^{-5}, calculate the equilibrium concentration of H^+ if you were to dissolve 0.13 moles $HC_3H_5O_2$ in 500.0 mL of water. *[Hint: compare the value of K with your initial concentration!]*

- $[H^+]$ at equilibrium is **0.0018** M

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

$[HC_3H_2O_2]_{initial}$ = 0.13 moles / 0.5000 L = 0.26 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.

$$K=\frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}=1.3\times10^{-5}$$

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

$[H^+] = x$
$[C_3H_5O_2^-] = x$
$[HC_3H_5O_2] = 0.26 - x$

Plugging into the equilibrium expression, we get:

$$\frac{x^2}{(0.26-x)}=1.3\times10^{-5}$$

Rearranging into quadratic form:

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

We solve using the quadratic equation:

a = 1
b = 0.000013
c = -0.00000338

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

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!

- $[H^+]$ = 0.0018 M
- $[C_3H_5O_2^-]$ = 0.0018 M
- $[HC_3H_5O_2]$ = 0.26 – 0.0018 = 0.2582 = 0.26 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, $\boldsymbol{N_2O_3(g) \leftrightarrow NO_2(g) + NO(g)}$, with K = 0.193. If a reaction vessel contains 0.250 M N_2O_3, 0.225 M NO, and 0.147 M NO_2, will the reaction proceed to the left or right, or is the reaction already at equlibrium?

- 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.

$$Q = \frac{[NO_2][NO]}{[N_2O_3]} = \frac{(0.147) \times (0.225)}{0.250} = 0.132$$

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:

A) $Fe^{3+}(aq) + SCN^-(aq) \leftrightarrow Fe(SCN)^{2+}(aq)$

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

B) $Cu(NO_3)_2(aq) + Zn(s) \leftrightarrow Cu(s) + Zn(NO_3)_2(aq)$

- $$K = \frac{[Zn(NO_3)_2]}{[Cu(NO_3)_2]}$$

C) $H_3PO_4(aq) \leftrightarrow 3H^+(aq) + PO_4^{3-}(aq)$

- $K = \frac{[H^+]^3[PO_4^{3-}]}{[H_2PO_4]}$

D) $2H_2(g) + O_2(g) \leftrightarrow 2H_2O(g)$

- $K = \frac{[H_2O]^2}{[H_2]^2[O_2]}$