Practice Problems (solutions with answers are on the website)

1. Write the equilibrium expression (K_{eq}) for the following reactions:

a. $N_{2\,(g)} + O_{2\,(g)} <-> 2\,NO_{(g)}$

$$K_{eq} = \frac{[NO]^2}{[N_2][O_2]}$$

b. $Zn(H_2O)_4^{2+}{}_{(aq)} + 4\,CN^-{}_{(aq)} <-> Zn(CN)_4^{2-}{}_{(aq)} + 4\,H_2O_{(l)}$

$$K_{eq} = \frac{[Zn(CN)_4^{2-}]}{[Zn(H_2O)_4^{2+}][CN^-]^4}$$

c. $H_2CO_{3\,(aq)} + H_2O_{(l)} <-> HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$

$$K_{eq} = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]}$$

d. $2\,CO_{(g)} <-> C_{(s)} + CO_{2\,(g)}$

$$K_{eq} = \frac{[CO_2]}{[CO]^2}$$

2. In the reaction in part a of #1, when will the concentration of N_2 be the highest: When K_{eq} is equal to 1.36×10^{-7}, or when K_{eq} is equal to 12.6? Explain

↳ K_{eq} of less than one will favor the reactants (reverse reaction)

3. If the reaction below is at equilibrium, will the forward or reverse reaction be favored (and why) under the following conditions:

$2\,CO_{(g)} \leftrightarrow C_{(s)} + CO_{2\,(g)} + \text{Heat}$

a. increase in the amount of CO

forward, excess CO will decompose to form more product to return the reaction to equilibrium

b. decrease amount of CO_2

forward

more reactant will convert to product to increase the $[CO_2]$ and return to equilibrium

c. Adding carbon

No effect → solids do not affect the equilibrium

d. increasing the pressure

forward → increase in pressure favors the side with fewer moles of gas

e. decreasing the pressure

reverse → decrease in pressure favors the side with more moles of gas

f. decreasing the temperature

forward → the reaction is exothermic

lowering the temperature will favor the reaction that produces heat

4. In the reaction of ammonia in water: $NH_{3\,(aq)} + H_2O_{(l)} <-> NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

If the K_{eq} for the reaction is 1.8×10^{-5} and the concentrations for NH_4^+ and OH^- are 3.5×10^{-4}, what is the $[NH_3]$?

$$K_{eq} = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$$1.8\times10^{-5} = \frac{[3.5\times10^{-4}][3.5\times10^{-4}]}{[NH_3]}$$

$$[NH_3] = 0.0068$$

5. How many moles of HNO_3 are contained in 89.0L of a 0.45M solution?

$$M = \frac{\text{moles solute}}{\text{L of solution}}$$

$$0.45M = \frac{x \text{ moles } HNO_3}{89.0\,L}$$

40. moles HNO_3

6. What is the new concentration of a NaOH solution that was made from 75 mL of a 5.5 M NaOH solution and diluted to 250 mL with distilled water?

$M_1V_1 = M_2V_2$

$M_1 = 5.5M$ $\quad M_2 = ?$

$V_1 = 75mL$ $\quad V_2 = 250mL$

$$\frac{M_1V_1}{V_2} = M_2$$

$$1.65 = M_2 \quad (1.7 \text{ w/ S.F.})$$

7. What is the $[H_3O^+]$ of a 0.0659M solution of HNO_3? What is the pH of the solution?

$[H_3O^+]$ is **0.0659 M**

$pH = -\log [H_3O^+]$

$pH = -\log [0.0659]$

$pH = 1.18$

8. If a solution contains 9.0×10^{-5} M of $[OH^-]$ ions, what is the $[H_3O^+]$? What is the pOH of the solution?

$pOH = -\log [OH^-]$

$= -\log [9.0 \times 10^{-5}]$

$= 4.05 \rightarrow 4.1$

$[H_3O^+] = \frac{1.0 \times 10^{-14}}{9.0 \times 10^{-5}}$

$[H_3O^+] = 1.1 \times 10^{-10}$ M

more than one way to solve this

9. If a solution of $Ca(OH)_2$ has a pH of 9.44, what is the $[OH^-]$?

$pOH + pH = 14.0$

$pOH + 9.44 = 14.0$

$pOH = 4.56$

$[OH^-] = 10^{-pOH}$

$= 10^{-4.56}$

$[OH^-] = 2.75 \times 10^{-5}$ M

10. A 300 mL solution of NaOH with a concentration of 0.0459M was diluted with 450 mL of water. What is the pH of the new solution?

$V_1 = 0.300$ L

$M_1 = 0.0459$ M

$V_2 = 300$ mL $+ 450$ mL $= 750$ mL $= 0.750$ L

$M_2 = ?$

$M_1V_1 = M_2V_2$

$M_2 = 0.0184$ M → since this is the molarity of a NaOH solution it is also the $[OH^-]$

$-\log [OH] = pOH$

$-\log [0.0184] = pOH$

$1.74 = pOH$

$pOH + pH = 14.0$

$1.74 + pH = 14.0$

$pH = 12.26 \rightarrow 12.3$ (s.f.)

(11) $\underset{\text{acid}}{HCN} + \underset{\text{base}}{H_2O} \rightarrow \underset{\text{conj. acid}}{H_3O^+} + \underset{\text{conj. base}}{CN^-}$

(12) Conjugate acids → add a proton

$NH_3 \rightarrow NH_4^+$

$H_2PO_4^- \rightarrow H_3PO_4$

$H_2O \rightarrow H_3O^+$

(13) conjugate bases → take away a proton

$HCO_3^- \rightarrow CO_3^{2-}$

$H_2O \rightarrow OH^-$

(14) $Li_2CO_3 + 2HNO_3 \rightarrow 2LiNO_3 + CO_2 + H_2O$

* carbonates react with acids to form CO_2, H_2O + a salt

$0.75\,M \times 0.15 = 0.11$

↓

actual $[H_3O^+]$

since HF is a weak acid
and only partially dissociates

$pH = -\log[H_3O^+]$

$= -\log[0.11]$

$\boxed{pH = 0.96}$