Homework #11
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1. Show an equilibrium expression for hydrochloric acid (HCl) and hydronium ion in aqueous solution.

$HCl + H_2O \rightleftharpoons H_3O^+ + OH^- + Cl^-$

2. Label the acid/base and conjugate acid/base below.

a) $HNO_3\ (aq) + NaOH\ (aq) \leftrightarrow NaNO_3\ (aq) + H_2O\ (l)$
acid base conj. base conj. acid

b) $H_3PO_4\ (aq) + H_2O\ (l) \leftrightarrow H_2PO_4^-\ (aq) + H_3O^+\ (aq)$
acid base conj. base conj. acid

c) $NH_3\ (aq) + H_2O\ (l) \leftrightarrow NH_4^+\ (aq) + OH^-\ (aq)$
base acid conj. acid conj. base

3. Use $K_w = 1.0 \times 10^{-14}$ to determine $[H^+]$ in water for:

$[H^+][OH^-] = K_w$
$[H^+] = \frac{K_w}{[OH^-]}$

a) $[OH^-] = 1 \times 10^{-14}$ M $[H^+] = \frac{1.0 \times 10^{-14}}{1 \times 10^{-14}} = 1$ M

b) $[OH^-] = 1 \times 10^{-2}$ M $[H^+] = \frac{1.0 \times 10^{-14}}{1 \times 10^{-2}} = 1 \times 10^{-2}$ M

c) $[OH^-] = 5 \times 10^{-6}$ M $[H^+] = \frac{1.0 \times 10^{-14}}{5 \times 10^{-6}} = 2 \times 10^{-9}$ M

d) $[OH^-] = 8 \times 10^{-6}$ M $[H^+] = \frac{1.0 \times 10^{-14}}{8 \times 10^{-6}} = 1.25 \times 10^{-9}$ M

e) $[OH^-] = 1 \times 10^{-7}$ M $[H^+] = \frac{1.0 \times 10^{-14}}{1 \times 10^{-7}} = 1 \times 10^{-7}$ M

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4. Find the pH for:

a) $[H^+] = 1 \times 10^{-1}$ M pH = 1

b) $[H^+] = 1 \times 10^{-6}$ M pH = 6

c) $[H^+] = 1 \times 10^{-7}$ M pH = 7

d) $[H^+] = 1 \times 10^{-8}$ M pH = 8

e) $[H^+] = 1 \times 10^{-14}$ M pH = 14

need calculator

f) $[H^+] = 4.5 \times 10^{-9}$ M $pH = -\log(4.5 \times 10^{-9}) = 8.35$

g) $[H^+] = 4.0 \times 10^{-9}$ M $pH = -\log(4.0 \times 10^{-9}) = 8.40$

h) $[H^+] = 3.5 \times 10^{-9}$ M $pH = -\log(3.5 \times 10^{-9}) = 8.46$

5. Find the acid concentration $[H^+]$ for:

a) pH = 1 $[H^+] = 10^{-1}\,M = 0.1\,M$

b) pH = 6 $[H^+] = 10^{-6}\,M = 1 \times 10^{-6}\,M$

c) pH = 8.0 $[H^+] = 10^{-8.0}\,M \Rightarrow 1.0 \times 10^{-8}\,M$

calculator

b) pH = 6.63 $[H^+] = 10^{-6.63} = 2.3 \times 10^{-7}\,M$

6. Use the Henderson-Hasselbalch equation to predict the pH of a buffer solution with 0.200 M HF and 0.240 M NaF. The pK_a for HF is 3.46.

$$pH = pka + \log\left(\frac{[F^-]}{[HF]}\right) = 3.46 + \log\left(\frac{0.240}{0.200}\right)$$

$$= 3.54$$

$NaF \rightarrow Na^+ + F^-$

pH = 3.54

7. Complete and balance the following gas evolution reactions

a) $2HCl\ (aq) + CaCO_3\ (s) \rightarrow H_2CO_3 + CaCl_2$

$\hookrightarrow H_2O(l) + CO_2(g)$

c) $2HNO_3\ (aq) + CaCO_3\ (s) \rightarrow H_2CO_3 + Ca(NO_3)_2$

$\hookrightarrow H_2O(l) + CO_2(g)$

a) $H_2SO_4\ (aq) + CaCO_3\ (s) \rightarrow H_2CO_3 + CaSO_4$

$\hookrightarrow H_2O(l) + CO_2(g)$

8. A 25.00 mL sample of HNO_3 of unknown concentration is titrated to an endpoint using 18.3 mL of 0.115 M NaOH. Find the acid molarity.

$HNO_3 + NaOH \rightarrow H_2O + NaNO_3(aq)$

$$M = \frac{\#\text{ mol acid}}{\text{vol acid}} = \frac{(0.0183\text{ L NaOH})\left(0.115\ \frac{\text{mol NaOH}}{\text{L NaOH}}\right)\left(\frac{1\text{ mol HNO}_3}{1\text{ mol NaOH}}\right)}{0.02500\text{ L}}$$

$$= 0.0842\text{ M}$$

9. A 25.00 mL sample of HCl of unknown concentration is titrated to an endpoint using 11.7 mL of 0.088 M KOH. Find the acid molarity.

$HCl + KOH \rightarrow H_2O + KCl(aq)$

$$M = \frac{\#\text{ mol acid}}{\text{vol. acid}} = \frac{(0.0117\text{ L KOH})\left(0.088\ \frac{\text{mol KOH}}{\text{L KOH}}\right)\left(\frac{1\text{ mol HCl}}{1\text{ mol KOH}}\right)}{0.02500\text{ L}}$$

$$= 0.041\text{ M}$$

10. A 5.00 mL sample of NaOH of unknown concentration is titrated to an endpoint using 24.1 mL of 0.155 M HCl. Find the base molarity.

$HCl + NaOH \rightarrow H_2O + NaCl(aq)$

$$M = \frac{\#\text{ mol base}}{\text{vol base}} = \frac{(0.0241\text{ L HCl})\left(0.155\ \frac{\text{mol HCl}}{\text{L HCl}}\right)\left(\frac{1\text{ mol NaOH}}{1\text{ mol HCl}}\right)}{0.0050\text{ L}}$$

$$= 0.747\text{ M}$$

diprotic acid

11. A 25.00 mL sample of H_2SO_4 of unknown concentration is titrated to an endpoint using 11.7 mL of 0.088 M NaOH. Find the acid molarity.

$$H_2SO_4 + 2\ NaOH \rightarrow 2H_2O + Na_2SO_4(aq)$$

$$M = \frac{\#\text{mol acid}}{\text{vol acid}} = \frac{(0.0117\ \text{L NaOH})\left(0.088\ \frac{\text{mol NaOH}}{\text{L NaOH}}\right)\left(\frac{1\ \text{mol } H_2SO_4}{2\ \text{mol NaOH}}\right)}{0.02500\ \text{L}}$$

$$= 0.021\ \text{M}$$

$$2\ HNO_3 + Mg(OH)_2 \rightarrow 2H_2O + Mg(NO_3)_2\ (aq)$$

12. A 5.00 mL sample of $Mg(OH)_2$ of unknown concentration is titrated to an endpoint using 28.8 mL of 0.0055 M HNO_3. Find the ~~acid~~ base molarity.

$$M = \frac{\#\text{mol acid}}{\text{vol acid}} = \frac{(0.0288\ \text{L } HNO_3)\left(0.0055\ \frac{\text{mol } HNO_3}{\text{L } HNO_3}\right)\left(\frac{1\ \text{mol } Mg(OH)_2}{2\ \text{mol } HNO_3}\right)}{0.00500\ \text{L}}$$

$$= 0.016\ \text{M}$$