Chemistry 20 – Lesson 28
Acid/Base Stoichiometry

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Practice problems

1. $HCl_{(aq)} \quad + \quad NaOH_{(aq)} \longrightarrow NaCl_{(aq)} \quad + \quad HOH_{(l)}$

$c_{HCl} = 0.250\,{}^{mol}\!/\!_{L} \qquad c_{NaOH} = ?$

$v_{HCl} = 0.0165L \qquad v_{NaOH} = 0.100L$

A. calculate moles

$n_{HCl} = 0.250\,{}^{mol}\!/\!_{L}(0.0165L)$

$n_{HCl} = 0.004125mol$

B. mole ratio

$$\frac{n_{NaOH}}{1} = \frac{n_{HCl}}{1}$$

$n_{HCl} = 0.004125mol$

C. calculate concentration

$$[NaOH_{(aq)}] = \frac{.004125\,mol}{0.100\,L}$$

$$\boxed{[NaOH_{(aq)}] = 0.0413\,{}^{mol}\!/\!_{L}}$$

2. The hydrochloric acid in a solution of kettle-scale remover is titrated with a 0.974 mol/L solution of sodium hydroxide. 10.00 mL samples of the acid solution were used. The color change of bromothymol blue indicator to green indicates the endpoint.

Trial	**1**	**2**	**3**	**4**
Final burette reading (mL)	15.6	29.3	43.0	14.8
Initial burette reading (mL)	0.6	15.6	29.3	1.2
Volume of NaOH added (mL)	**15.0**	**13.7**	**13.7**	**13.6**
Color at endpoint	blue	green	green	green

$HCl_{(aq)} \quad + \quad NaOH_{(aq)} \longrightarrow NaCl_{(aq)} \quad + \quad HOH_{(l)}$

$c_{HCl} = ? \qquad c_{NaOH} = 0.974\,{}^{mol}\!/\!_{L}$

$v_{HCl} = 0.01000L \qquad v_{NaOH} = \dfrac{13.7mL + 13.7mL + 13.6mL}{3} = 13.667mL$

We ignore trial 1 since the volume is substantially more than the other trials. In addition, the color at endpoint is blue rather than green.

A. calculate moles

$n_{NaOH} = 0.974\,{}^{mol}\!/\!_{L}(0.013667L)$

$n_{NaOH} = 0.013311mol$

B. mole ratio

$$\frac{n_{NaOH}}{1} = \frac{n_{HCl}}{1}$$

$n_{HCl} = 0.013311mol$

C. calculate concentration

$$[HCl_{(aq)}] = \frac{.013311\,mol}{0.01000\,L}$$

$$\boxed{[HCl_{(aq)}] = 1.33\,{}^{mol}\!/\!_{L}}$$

Assignment

1.

/3 **The indicator should change at around pH = 7. Possible indicators are chorophenol red, bromothymol blue, phenol red, and phenolphthalein. In terms of indicating the exact equivalence point they would all work quite well since even a drop or two of acid or base in neutral water can change the pH by one or two points.**

2. $HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + HOH_{(l)}$

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$c_{HCl} = 2.00\ ^{mol}/_{L}$ $\quad m_{NaOH} = 1.20g$

$v_{HCl} = ?$

A. calculate moles

$$n_{NaOH} = \frac{1.20g}{40.00\ ^{g}/_{mol}}$$

$$n_{NaOH} = 0.0300mol$$

B. mole ratio

$$\frac{n_{NaOH}}{1} = \frac{n_{HCl}}{1}$$

$$n_{HCl} = 0.0300mol$$

C. calculate volume

$$v_{HCl} = \frac{0.0300\,mol}{2.00\ ^{mol}/_{L}}$$

$$\boxed{v_{HCl} = 15.0\,mL}$$

3. $2\ LiOH_{(aq)} + HOOCCOOH_{(aq)} \longrightarrow 2\ HOH_{(l)} + LiOOCCOOLi_{(aq)}$

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$c_{LiOH} = ?$ $\quad m_{HOOCCOOH} = 3.78g$

$v_{LiOH} = 0.125L$

A. calculate moles

$$n_{HOOCCOOH\cdot 2H_2O} = \frac{3.78g}{126.08\ ^{g}/_{mol}}$$

$$n_{HOOCCOOH\cdot 2H_2O} = 0.02998mol$$

B. mole ratio

$$\frac{n_{LiOH}}{2} = \frac{n_{HOOCCOOH}}{1}$$

$$n_{LiOH} = 2(0.02998mol)$$

$$n_{LiOH} = 0.05996\,mol$$

C. calculate concentration

$$[LiOH_{(aq)}] = \frac{.05996\,mol}{0.125L}$$

$$\boxed{[LiOH_{(aq)}] = 0.480\ ^{mol}/_{L}}$$

4. $HNO_{3\,(aq)} + NaOH_{(aq)} \longrightarrow NaNO_{3\,(aq)} + HOH_{(l)}$

/6

$c_{HNO_3} = 3.00\ ^{mol}/_{L}$ $\quad c_{NaOH} = 0.10\ ^{mol}/_{L}$

$v_{HNO_3} = ?$ $\quad v_{NaOH} = 0.0600\,L$

A. calculate moles

$$n_{NaOH} = 0.10\ ^{mol}/_{L}(0.0600L)$$

$$n_{NaOH} = 0.00600mol$$

B. mole ratio

$$\frac{n_{NaOH}}{1} = \frac{n_{HNO_3}}{1}$$

$$n_{HNO_3} = 0.00600mol$$

C. calculate volume

$$v_{HNO_3} = \frac{0.00600\,mol}{3.00\ ^{mol}/_{L}}$$

$$\boxed{v_{HNO_3} = 2.00\,mL}$$

5. $H_2SO_{4\,(aq)} + 2\,RbOH_{(aq)} \longrightarrow Rb_2SO_{4\,(aq)} + 2\,HOH_{(l)}$

/6

$c_{H_2SO_4} = 1.00\,\text{mol/L}$ $\quad c_{RbOH} = 0.35\,\text{mol/L}$

$v_{H_2SO_4} = ?$ $\quad v_{RbOH} = 0.0600\,\text{L}$

A. calculate moles

$n_{RbOH} = 0.35\,\text{mol/L}\,(0.0600\text{L})$

$n_{RbOH} = 0.0210\text{mol}$

B. mole ratio

$\frac{n_{RbOH}}{2} = \frac{n_{H_2SO_4}}{1}$

$\frac{0.0210\,\text{mol}}{2} = \frac{n_{H_2SO_4}}{1}$

$n_{H_2SO_4} = 0.0105\text{mol}$

C. calculate volume

$v_{H_2SO_4} = \frac{0.0105\,\text{mol}}{1.00\,\text{mol/L}}$

$\boxed{v_{H_2SO_4} = 10.5\,\text{mL}}$

6. $2\,CH_3COOH_{(aq)} + Ba(OH)_{2\,(aq)} \longrightarrow Ba(CH_3COO)_{2\,(aq)} + 2\,HOH_{(l)}$

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$m_{CH_3COOH} = 3.78\text{g}$ $\quad c_{Ba(OH)_2} = ?$

$v_{Ba(OH)_2} = 0.125\,\text{L}$

A. calculate moles

$n_{CH_3COOH} = \frac{3.78\text{g}}{60.06\,\text{g/mol}}$

$n_{CH_3COOH} = 0.062937\text{mol}$

B. mole ratio

$\frac{n_{Ba(OH)_2}}{1} = \frac{n_{CH_3COOH}}{2}$

$\frac{n_{Ba(OH)_2}}{1} = \frac{0.062937\,\text{mol}}{2}$

$n_{Ba(OH)_2} = 0.0314685\text{mol}$

C. calculate volume

$\left[Ba(OH)_{2(aq)}\right] = \frac{0.0314685\,\text{mol}}{0.125\,\text{L}}$

$\boxed{\left[Ba(OH)_{2(aq)}\right] = 0.252\,\text{mol/L}}$

7. $HBr_{(aq)} + NaOH_{(aq)} \longrightarrow NaBr_{(aq)} + HOH_{(l)}$

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$c_{HBr} = ?$ $\quad c_{NaOH} = 1.000\,\text{mol/L}$

$v_{HBr} = 0.00500\,\text{L}$ $\quad v_{NaOH} = 0.00186\,\text{L}$

A. calculate moles

$n_{NaOH} = 1.000\,\text{mol/L}\,(0.00186\text{L})$

$n_{NaOH} = 0.00186\text{mol}$

B. mole ratio

$\frac{n_{HBr}}{1} = \frac{n_{NaOH}}{1}$

$n_{HBr} = 0.00186\text{mol}$

C. calculate concentration

$\left[HBr_{(aq)}\right] = \frac{0.00186\,\text{mol}}{0.00500\,\text{L}}$

$\boxed{\left[HBr_{(aq)}\right] = 0.372\,\text{mol/L}}$

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

$pH = -\log[0.372\,\text{mol/L}]$

$\boxed{pH = 0.429}$

8.

$2\,HA_{(aq)} + Zn_{(s)} \rightarrow ZnA_{2\,(aq)} + H_{2\,(g)}$	**(non–ionic)**
$2\,H_3O^+_{(aq)} + 2\,A^-_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2\,A^-_{(aq)} + H_{2\,(g)} + 2\,H_2O_{(l)}$	**(total ionic)**
$2\,H_3O^+_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + H_{2\,(g)} + 2\,H_2O_{(l)}$	**(net ionic)**

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$c_{H_3O^+} =$ $\quad m_{Zn} = 3.27\,g$

$v_{H_3O^+} = 0.200\,L$

A. calculate moles

$$n_{Zn} = \frac{3.27g}{65.41\,{}^{g}\!/\!_{mol}}$$

$$n_{Zn} = 0.0500mol$$

B. mole ratio

$$\frac{n_{H^+}}{2} = \frac{n_{Zn}}{1}$$

$$\frac{n_{H^+}}{2} = \frac{0.0500\,mol}{1}$$

$$n_{H^+} = 0.100mol$$

C. calculate concentration & pH

$$[H^+_{(aq)}] = \frac{0.100\,mol}{0.200\,L}$$

$$[H^+_{(aq)}] = 0.500\,{}^{mol}\!/\!_{L}$$

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

$$pH = -\log[0.500\,{}^{mol}\!/\!_{L}]$$

$$\boxed{pH = 0.301}$$

9.

/2 **The following indicators change colour at 4.4 (approximately): methyl orange, bromocresol green, methyl red.**

10.

Trial	**1**	**2**	**3**	**4**
Final burette reading (mL)	17.9	35.0	22.9	40.1
Initial burette reading (mL)	0.3	17.9	5.9	22.9
Volume of $HCl_{(aq)}$ added (mL)	**17.6**	**17.1**	**17.0**	**17.2**
Color at endpoint	red	orange	orange	orange

$$Na_2CO_{3\,(aq)} + 2\,HCl_{(aq)} \longrightarrow H_2CO_{3\,(aq)} + 2\,NaCl_{(aq)}$$

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$c_{Na_2CO_3} = 0.120\,{}^{mol}\!/\!_{L}$ $\quad c_{HCl} = ?$

$v_{Na_2CO_3} = 0.01000L$ $\quad v_{HCl} = \dfrac{17.1mL + 17.0mL + 17.2mL}{3} = 17.1mL$

We ignore trial 1 since the volume is substantially more than the other trials. In addition, the color at endpoint is red rather than orange.

A. calculate moles

$$n_{Na_2CO_3} = 0.120\,{}^{mol}\!/\!_{L}(0.01000L)$$

$$n_{Na_2CO_3} = 0.00120mol$$

B. mole ratio

$$\frac{n_{HCl}}{2} = \frac{n_{Na_2CO_3}}{1}$$

$$\frac{n_{HCl}}{2} = \frac{0.00120\,mol}{1}$$

$$n_{HCl} = 0.00240mol$$

C. calculate concentration

$$[HCl_{(aq)}] = \frac{0.00240\,mol}{0.0171L}$$

$$\boxed{[HCl_{(aq)}] = 0.140\,{}^{mol}\!/\!_{L}}$$

11. $NH_{3\,(aq)}$ + $HCl_{(aq)}$ $\longrightarrow$ $NH_4Cl_{\,(aq)}$

$c_{NH_3} = ?$ $\quad c_{HCl} = 1.48\,{}^{mol}\!/\!_{L}$

$v_{NH_3} = 0.01000\text{L}$ $\quad v_{HCl} = \dfrac{14.1\text{mL} + 13.9\text{mL} + 14.0\text{mL}}{3} = 14.0\text{mL}$

We ignore trial 1 since the volume is substantially more than the other trials. In addition, the color at endpoint is yellow rather than green.

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A. calculate moles

$n_{HCl} = 1.48\,{}^{mol}\!/\!_{L}\,(0.0140\text{L})$

$n_{HCl} = 0.02072\text{mol}$

B. mole ratio

$\dfrac{n_{NH_3}}{1} = \dfrac{n_{HCl}}{1}$

$\dfrac{n_{NH_3}}{1} = \dfrac{0.02072\,\text{mol}}{1}$

$n_{NH_3} = 0.02072\text{mol}$

C. calculate concentration

$[NH_{3(aq)}] = \dfrac{0.02072\,\text{mol}}{0.01000\,\text{L}}$

$\boxed{[NH_{3(aq)}] = 2.07\,{}^{mol}\!/\!_{L}}$

12.

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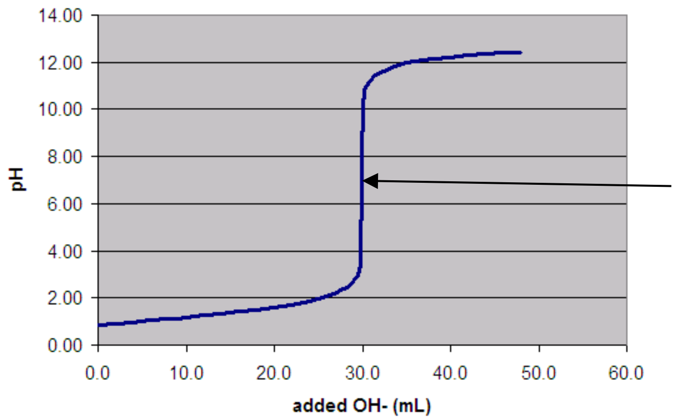

$HCl_{(aq)}$ + $NaOH_{\,(aq)}$ $\longrightarrow$ $NaCl_{\,(aq)}$ + $HOH_{\,(l)}$

$c_{HCl} = ?$ $\quad c_{NaOH} = 0.10\,{}^{mol}\!/\!_{L}$

$v_{HCl} = 0.0200\text{L}$ $\quad v_{NaOH} = 0.0300\text{L}$

A. calculate moles

$n_{NaOH} = 0.10\,{}^{mol}\!/\!_{L}\,(0.0300\text{L})$

$n_{NaOH} = 0.00300\text{mol}$

B. mole ratio

$\dfrac{n_{NaOH}}{1} = \dfrac{n_{HCl}}{1}$

$n_{HCl} = 0.00300\text{mol}$

C. calculate concentration

$[HCl_{(aq)}] = \dfrac{.00300\text{mol}}{0.0200\,\text{L}}$

$\boxed{[HCl_{(aq)}] = 0.150\,{}^{mol}\!/\!_{L}}$

13.

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curve	volume of titrant	pH	indicator(s)
a	20 mL	7	bromothymol blue, phenolphthalein
b	20 mL	9	phenolphthalein, thymolphthalein
c	20 mL	5	bromocresol green, methyl red
d	20 mL	7	bromothymol blue, phenolphthalein