SCH4U

TITRATION PROBLEMS

1. Calculate the volume of 0.500 mol/L $NaOH_{(aq)}$ required to titrate 300.0 mL of 0.200 mol/L $HCl_{(aq)}$?

NaOH	HCl
V = ?	V = 300.0 mL or 0.300 L
C = 0.500 mol/L	C = 0.200 mol/L
$n_{NaOH} = n_{OH^-}$	$n_{HCl} = n_{H^+}$

$n_{HCl} = C \times V = (0.200)(0.300) = 0.0600$ mol

$n_{H^+} = 0.0600$ mol = $n_{OH^-} = n_{NaOH}$ at equivalence point

$V_{NaOH} = n/c = 0.0600$ mol/0.500mol/L = 0.120 L or 120 mL

OR

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$n_{HCl} = C \times V = (0.200)(0.300) = 0.0600$ mol

$n_{HCl} = n_{NaOH}$

$V_{NaOH} = n/c = 0.0600$ mol/0.500mol/L = 0.120 L or 120 mL

2. If 250.0 mL of 0.300M $Ca(OH)_2$ is required to titrate 600.0 mL of $HNO_{3(aq)}$, what is the concentration of $HNO_{3(aq)}$?

$\underline{Ca(OH)_2}$	$\underline{HNO_3}$
V = 250.0 mL or 0.250 L	v = 600.0 mL or 0.600 L
C = 0.300 mol/L	c = ?
$n_{OH^-} = 2 \times n_{Ca(OH)2}$	$n_{HCl} = n_{H^+}$
($2\ OH^-$ in 1 $Ca(OH)_2$)	($1\ H^+$ in 1 HCl)

$n_{Ca(OH)2} = C \times V = (0.300)(0.250) = 0.0750$ mol

$n_{OH^-} = 2(0.0750) = 0.150$ mol $= n_{H^+} = n_{HNO3}$ at equivalence point

$C_{HNO3} = 0.150 mol/0.600\ L = 0.250\ M$

OR

$$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO3)_2 + 2H_2O$$

$n_{Ca(OH)2} = C \times V = (0.300)(0.250) = 0.0750$ mol

$n_{HNO3} = 2(0.0750) = 0.150$ mol

$C_{HNO3} = 0.150 mol/0.600\ L = 0.250\ M$

3. Calculate the mass of NaOH required to titrate 400.0 mL of 0.50 M $HBr_{(aq)}$.

NaOH	HBr
m = ?	V = 400.0 mL or 0.400 L
	C = 0.50 M

$n_{HBr} = (.400)(0.50) = 0.200 \text{ mol} = n_{H^+} = n_{OH^-} = n_{NaOH}$

$m_{NaOH} = n \times mm = (0.200 \text{ mol})(40.00 \text{ g/mol}) = 8.00 \text{ g}$

OR

$$NaOH + HBr \rightarrow NaBr + H_2O$$

$n_{HBr} = (.400)(0.50) = 0.200 \text{ mol}$

$n_{HBr} = n_{NaOH}$

$m_{NaOH} = n \times mm = (0.200 \text{ mol})(40.00 \text{ g/mol}) = 8.00 \text{ g}$

4. If 8.75 g of $Ba(OH)_2$ neutralizes 8.00 L of $HCl_{(aq)}$, what is the concentration of $HCl_{(aq)}$?

$\underline{Ba(OH)_2}$	$\underline{HCl}$
m = 8.75 g	V = 8.00 L
	C = ?

$n_{Ba(OH)2}$ = m/mm = 8.75 g / 171.31 g/mol = 0.511 mol

n_{OH^-} = 2 (0.0511) = 0.102 mol = n_{H^+} = n_{HCl}

C_{HCl} = n/v = 0.102 mol/8.00 l = 0.0128 mol/L

OR

$$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$$

$n_{Ba(OH)2}$ = m/mm = 8.75 g/171.31 g/mol = 0.511 mol

n_{HCl} = 2(0.511) = 0.102 mol

C_{HCl} = n/v = 0.102 mol/8.00 l = 0.0128 mol/L

5. Calculate the volume of calcium hydroxide required to titrate 500.0 mL of 0.030 M phosphoric acid.

$Ca(OH)_2$	H_3PO_4
C = 0.10 M	V = 500.0 mL or 0.500 L
V = ?	C = 0.030 M

n_{H3PO4} = (0.030)(.500) = 0.0150 mol

n_{H^+} = 3(0.0150) = 0.0450 mol since 3 mol of H^+ will be released from 1 mol of H_3PO_4

n_{OH^-} = 0.0450 mol since at equivalence point

$n_{Ca(OH)2}$ = 0.0450/2 = 0.0225 mol since 2 mol of OH are in 1 mol of $Ca(OH)_2$

i.e. $Ca(OH)_2 - Ca^{2+} + 2OH^-$

$V_{Ca(OH)2}$ = n/c = 0.0225 mol/0.020 mol/L = 1.13 L

OR

$$3Ca(OH)_2 + 2H_3PO_4 \text{ -- } Ca_3(PO_4)_2 + 6H_2O$$

n_{H3PO4} = (0.030)(.500) = 0.0150 mol

$n_{Ca(OH)2}$ = 0.0150/2 x 3 = 0.0225 mol

$V_{Ca(OH)2}$ = n/c = 0.0225 mol/0.020 mol/L = 1.13 L

6. A 8.24 g sample of a solid organic acid is dissolved in water. It is found that 47.3 mL of 0.100 M NaOH are needed to titrate the acidic solution. Assuming that there is only one hydrogen in the acidic solid, determine the molar mass of the solid acid. What would the molar mass be if the acid has two hydrogens?

Acid	NaOH
m = 5.25 g	V = 47.3 mL = 0.0473 L
Formula: HA	C = 0.100 M

n_{NaOH} = cxv = (0.0473)(0.100) = 0.00473 mol

n_{OH^-} = 0.00473 mol

n_{H^+} = 0.00473 mol

n_{HA} = 0.00473 mol if acid is monoprotic

mm = m/n = 8.24 g/0.00473 mol = 1742 g/mol

If acid is Diprotic H_2A then n_{acid} = 0.00473/2 = 0.00237 mol
And mm = 8.24g/0.00237 mol = 3477 g/mol

OR

$$HA + NaOH \text{ -- } NaA + H_2O$$

n_{NaOH} = cxv = (0.0473)(0.100) = 0.00473 mol
n_{HA} = 0.00473 mol
mm = m/n = 8.24 g/0.00473 mol = 1742 g/mol

If acid is diprotic:

$$H_2A + 2NaOH \text{ -- } Na_2A + 2H_2O$$

n_{NaOH} = cxv = (0.0473)(0.100) = 0.00473 mol
n_{HA} = 0.00473/2 = 0.00237 mol
mm = 8.24g/0.00237 mol = 3477 g/mol