Set 18: Acid-base titrations 1

1. a. $H^+ + OH^- \rightarrow H_2O$

$n(H^+) = n(OH^-) = c \times V = 0.200$ mol

$c(OH^-) = 0.500$ molL^{-1}

$V(OH^-) = n/c = 0.2/0.5 = 0.400$ L $= 400$mL

b. $CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$

$n(CH_3COOH) = c \times V = 1.5 \times 0.150 = 0.225$ mol

$n(OH^-) = n(CH_3COOH) = 0.225$ mol

$V(OH^-) = n/c = 0.225/0.500 = 0.450$ L $= 450$mL

c. $H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

$n(H^+) = 2n(H_2SO_4) = 2(c \times V) = 2(0.250 \times 0.200)$

$n(OH^-) = n(H^+) = 0.0100$ mol

$V(OH^-) = n/c = 0.01/0.5 = 0.020$ L $= 20$mL

d. $H_3PO_4 + 3OH^- \rightleftharpoons 3H_2O + PO_4^{-3}$

$n(H^+) = 3n(H_3PO_4) = 3(c \times V) = 3(0.8 \times 0.075) = 0.180$ mol

$n(OH^-) = n(H^+) = 0.180$ mol

$V(OH^-) = n/V = 0.180/0.5 = 0.360$ L $= 360$mL

2. a. $H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

$n(OH^-) = n(NaOH) = cV = (0.600 \times 0.200) = 0.120$ mol

$n(OH^-) = n(H^+) = 0.120$ mol

$n(H_2SO_4) = 1/2n(H^+) = 0.060$ mol

$V(H_2SO_4) = n/c = 0.060/0.2 = 0.300$ L $= 300$mL

b. $H_2SO_4 + Ba(OH)_2 \rightarrow 2H_2O + BaSO_4(s)$

$n(OH^-) = 2n(Ba(OH)_2) = cV = 2(0.100 \times 0.050) = 0.010$ mol

$n(OH^-) = n(H^+) = 0.010$ mol

$n(H_2SO_4) = 1/2n(H^+) = 0.0050$ mol

$V(H_2SO_4) = n/c = 0.0050/0.2 = 0.0250$ L $= 25.0$ mL

3. $KOH + HC\ell \rightarrow KC\ell + H_2O$

$H^+ + OH^- \rightarrow H_2O$

$n(H^+) = n(OH^-) = c \times V = 0.105 \times 0.211 = 0.022155$ mol

$c(OH^-) = c(KOH) = n/V = 0.022155/0.0250 = 0.0886$ molL^{-1}

$c(OH^-) = 8.86 \times 10^{-3}$molL^{-1}

4. $H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

$n(OH^+) = c \times V = 2(0.0222) = 0.0444$ mol
$n(H_2SO_4) = 1/2n(H^+)$
$c(H_2SO_4) = n/V = 0.0222/0.005 = 4.44$ molL^{-1}

5. $Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$

$n(HNO_3) = cV = 1.00 \times 0.00350 = 0.00350$ mol
$n(Na_2CO_3) = 1/2n(HNO_3) = 0.00175$ mol
$c(Na_2CO_3) = n/V = 0.00175/0.025 = 0.0700$ molL^{-1} $= 7.00 \times 10^{-2}$ molL^{-1}

6. $Mg(OH)_2 + 2HC\ell \rightarrow MgC\ell_2 + H_2O$

$n(Mg(OH)_2 = m/M = 0.450/[(24.31)+2(17.008)] = 0.450/58.33 = 0.0077147$
$n(HC\ell) = 2n(Mg(OH)_2 = 0.0077147 \times 2 = 0.015429$
$V(HC\ell) = n/c = 0.014844/0.150 = 0.103$ L $= 103$ mL

7. $CaO + 2HC\ell \rightarrow CaC\ell_2 + H_2O$

$n(HC\ell) = cV = (1.50 \times 0.250) = 0.375$ mol
$n(CaO) = 1/2n(HC\ell) = 0.1875$ mol
$m(CaO) = nxM(CaO) = (0.1875)(56.08) = 10.5$g

8. $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$

a. $n(H_2SO_4) = 1/2n(NaHCO_3) = 1/2(m/M) = 1/2(600.0/132) = 2.273$ mol

$m(H_2SO_4) = nM = 3.571 \times 98 = 222.7$ g

b. $n(H_2SO_4) = 2.273$ mol

$V(H_2SO_4) = n/c = 2.273/12.0 = 0.189$ L $= 189$ mL

9. $HC\ell + NaOH \rightarrow NaC\ell + H_2O$

$n(NaOH) = cV = (0.104)(0.025) = 0.0026$ mol
$n(NaOH) = n(HC\ell)$

a. (i) $c(HC\ell) = n/V = 0.0026/0.0244 = 0.107$ molL^{-1}

(ii) $c(HC\ell) = (nM)g/1$ L $= (0.1066)(36.508)/1 = 3.89$ gL^{-1}

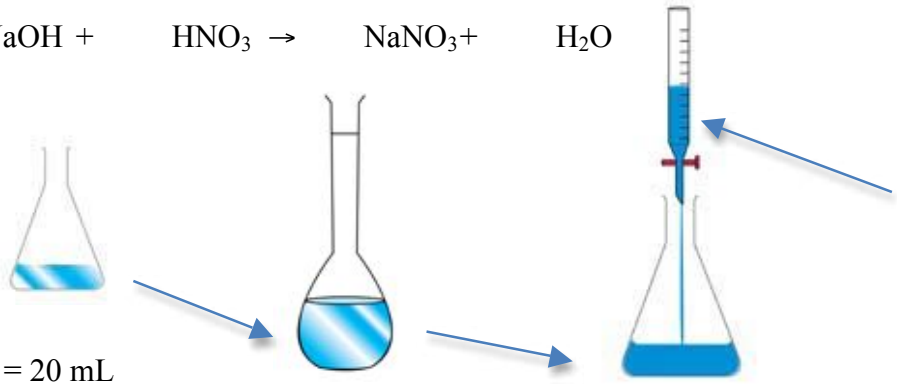
9. b. n(before) = n(after)

(0.107)(V) = (0.100)(1)
V = 0.100/0.107 = 0.935 L = 935 mL

c. cV = cV = 0.107×2.0 = (0.100)V

V = (0.107×2.0)/0.100 = 2.14L
$V_{H2O\ added}$ = 2.14-2.0 = 0.140 L = 140 mL

10. $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$



v = 20 mL
c = 2.00 $molL^{-1}$

V = 500 mL

v = 20 mL

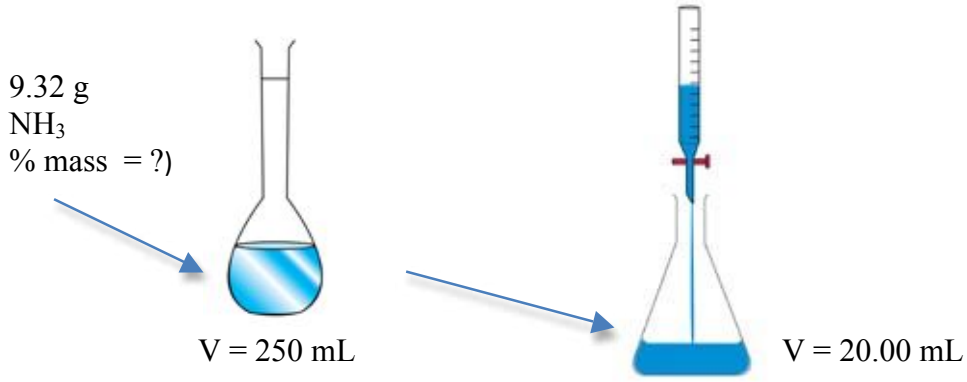
HNO_3
V = 21.80 mL
c = ?)

$n(HNO_3) = n(NaOH) = cV$
$c(NaOH) = c_1V_1/V_2 = ((2.00)(0.0200))/0.500 = 0.0800\ molL^{-1}$
$n(NaOH)_{20mL\ aliquot} = cV = 0.0800×0.0200 = 0.0016$ mol
$n(HNO_3) = n(NaOH) = 0.0016$ mol
$c(HNO_3) = n/V = 0.0016/0.0218 = 0.0734\ molL^{-1}$

11. $CH_3COOH + KOH \rightarrow KCH_3COO + H_2O$

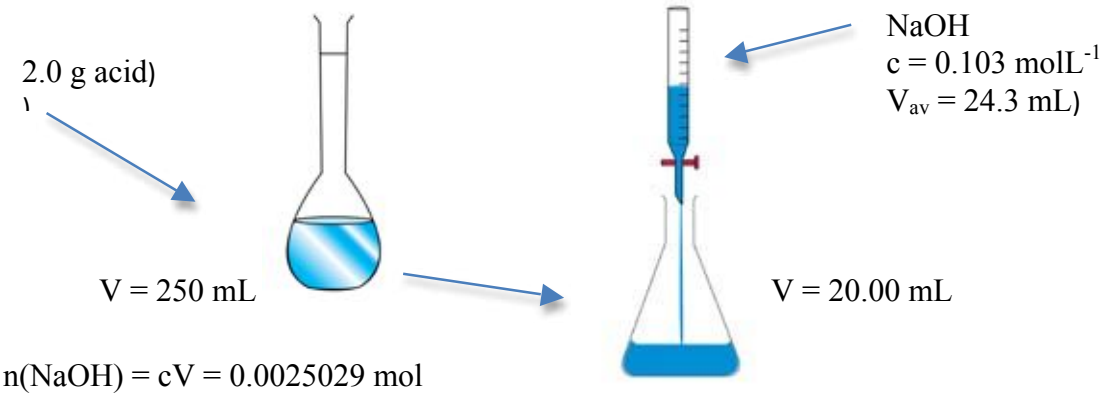
$\rho = m/V = 1.01 gmL^{-1}$
3% CH_3COOH by mass therefore in 1mL 3/100×1.01 = 0.0303g
in 1L=30.3g
$n(CH_3COOH)=m/M=30.3/60 = 0.505$ mol
$c = 0.505\ molL^{-1}$
$n(CH_3COOH) = cV = 0.505x0.0250 = 0.0126$ mol
$n(CH_3COOH) = n(KOH)$
V(KOH) = n/c = 0.0126/0.500 = 0.02525 L = 25.26 mL

12. $HC\ell$ + NH_3 → $NH_4^+{}_{(aq)}$ + $Cl^-{}_{(aq)}$



$n(HC\ell) = cV = (0.980)(0.0258) = 0.025284$ mol
$n(NH_3) = n(HC\ell)$
dilute $c(NH_3) = n/V = 0.25284/0.0200 = 1.2642$ molL^{-1}
n in 250mL = cV = (1.2642)(0.250) = 0.316 mol
n((NH3) in 9.32g = 0.316 mol
$m(NH_3)$ in 9.32g = nM = (0.316 ×17.01) = 5.38g
$\%NH_3$ = (mass NH_3/mass cloudy) × 100 = (5.380/9.32)×100 = 57.5%

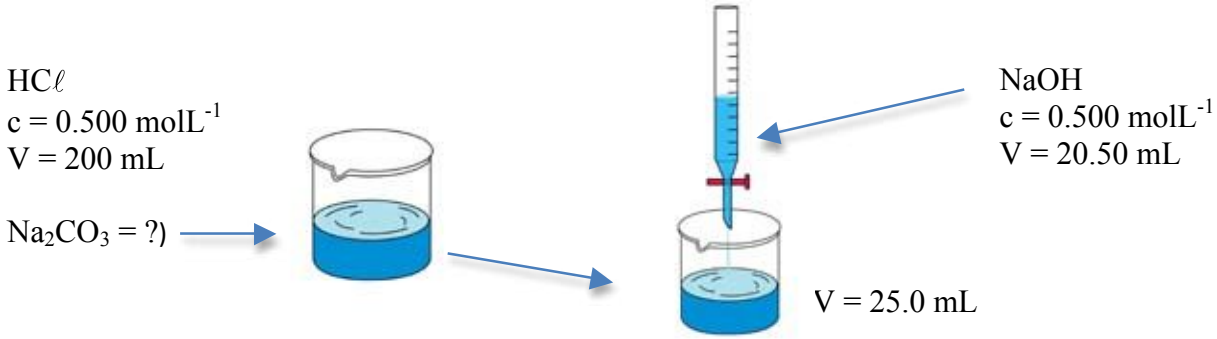
13. H_3X + 3NaOH → Na_3X + H_2O



n(NaOH) = cV = 0.0025029 mol
$n(H_3X) = 1/3n(H^+) = 0.0005343$
$c(H_3X) = n/V = 0.008343/0.020 = 0.041715$ molL^{-1}

$n(H_3X)$ in 250mL and hence 2g = cV = (0.041715)(0.250) = 0.01043 mol
n = m/M therefore M = m/n = 2.00/0.01043 = 191.8gmol = 192 gmol^{-1}

14.



$n(NaOH) = cV = (0.5)(0.0205) = 0.01025$

$n(HC\ell) = n(NaOH)$
$c(HC\ell) = n/V = 0.01025/0.025 = 0.410\ molL^{-1}$
$n(HC\ell)$ in 200mL solution $= cV = 0.410 \times 0.2 = 0.0820$ mol
Original moles in 0.5 $molL^{-1}$ 200mL $HC\ell = cV = 0.500 \times 0.2 = 0.100$ mol
$n(HC\ell)$ consumed by $Na_2CO_3 = 0.100\text{-}0.0820 = 0.0180$ mol
$n(Na_2CO_3) = 1/2n(HC\ell) = 0.0090$ mol
$m(Na_2CO_3) = nM = (0.0090) \times 106 = 0.954$ g