Year 12 Chemistry
Semester One Calculations Revision

1. Heather, a consumer research chemist, is involved in checking the ammonia levels in various household cleaners. The analytical process she used involved several stages with the results for one of the household cleaners set out below:

   (i) Preparation of a sodium carbonate primary standard. In preparing this, 2.230g of sodium carbonate was transferred to a 100mL volumetric flask and filled to the mark with distilled water.

   (ii) Standardisation of an approximately 0.5 mol L^{-1} solution of hydrochloric acid using the previously prepared sodium carbonate standard. On average 22.82mL of standard sodium carbonate solution is used to titrate 20.00mL samples of hydrochloric acid solution.

   (iii) Preparation of a diluted solution of household ammonia, in which 20.00mL of household ammonia is diluted to 100.0mL

   (iv) Titrating the diluted ammonia with the standardised hydrochloric acid solution. In this step 20.00mL samples of diluted ammonia required 24.51mL of the hydrochloric acid from (ii) for equivalence.

   Using Heather's results determine the following:

   a) the concentration in mol L^{-1} of ammonia in the diluted household cleaner.

   b) the percentage of ammonia (by mass) in the household cleaner if the density of household cleaning solution is 1.080g mL^{-1}.

2. Spirits of salts is used in the building industry to dissolve excess mortar from new brickwork. The active ingredient is hydrochloric acid with a concentration of around 13 mol L^{-1}. In order to precisely determine the concentration of hydrochloric acid in some spirits of salts an analyst takes a 20.00mL sample and makes this up to 500.0mL in a volumetric flask. The diluted spirits of salts solution is then analysed by taking 20.00mL samples and titrating this with 0.4590 mol L^{-1} sodium hydroxide solution. An average of 21.25mL of base was required for end point. Use this information to determine the following:

   a) the moles of sodium hydroxide used in the titration.

   b) the concentration of hydrochloric acid in the diluted spirits of salts.

   c) the percentage by mass of hydrochloric acid in the original undiluted spirits of salts if this solution has a density of 1.18g mL^{-1}.

3. A brand of premium red wine vinegar claims to contain 6% ethanoic acid by mass. Analysis of this vinegar involved titration of 20.00mL samples with

0.7240 mol L^{-1} sodium hydroxide solution. An average of 28.75mL of sodium hydroxide solution was required for end point. Further analysis showed the vinegar has a density of 1.060g mL^{-1}.

The titration reaction is shown below

$$CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$$

a) Determine the moles of sodium hydroxide used in the titration.

b) Determine the moles of ethanoic acid involved in each titration.

c) Calculate the concentration of ethanoic acid in the vinegar samples of mol L^{-1}.

d) Calculate the mass of ethanoic acid in 1.00L of vinegar.

e) Calculate the mass of 1.00L of vinegar.

f) Determine the percentage by mass of ethanoic acid in the vinegar.

g) Comment on the claim made on the label.

4. Limewater used for testing $CO_2(g)$ is a saturated solution of $Ca(OH)_2(aq)$. Such a solution is made by leaving solid $Ca(OH)_2$ in contact with water until no further $Ca(OH)_2$ dissolves.

A 20.00mL samples of limewater was titrated with standardised 3.190×10^{-2} mol L^{-1} HCl and on average 20.31mL of acid was needed to achieve equivalence. Determine the solubility of $Ca(OH)_2$ in gL^{-1}.

Q1. (i)

$$n_{Na_2CO_3} = \frac{2.230}{2\times22.99 + 12.01 + 3\times16} = \frac{2.230}{105.99} = 0.0210\,mol$$

$$c_{Na_2CO_3} = \frac{n}{V} = \frac{0.0210}{0.1} = 0.210\,M$$

(ii) $Na_2CO_3 + 2HCl \rightarrow CO_2 + H_2O + 2NaCl$

$c = 0.210$, $V = 22.82mL$

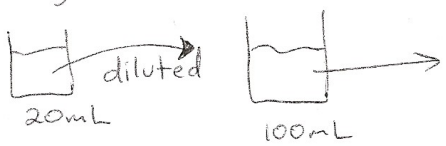
$n = cV = (0.210)(0.02282) = 0.0048\,mol$

$V = 20mL$

$$n_{HCl} = \frac{2}{1} \times n_{Na_2CO_3} = \frac{2}{1} \times 0.0048 = 0.00$$

$$c_{HCl} = \frac{n}{V} = \frac{0.0096}{0.02} = 0.48M$$

(iii) NH_3



(iv) $NH_3 + HCl \rightarrow NH_4Cl$

$V = 20mL$ $V = 24.51mL$, $c = 0.48M$

$n = cV = (0.48)(0.02451) = 0.01177\,mol$

$n_{NH_3} = n_{HCl} = 0.01177\,mol$

$$c_{NH_3} = \frac{n}{V} = \frac{0.01177}{0.02} = 0.5885\,M$$ is the concentration of the diluted cleaner

(1.)

b) first find conc of household cleaner

$C_1V_1 = C_2V_2$

$(0.5885)(100) = C_2(20)$

$\Rightarrow C_2 = 2.94M$

$n_{NH_3} = cv = (2.94)(0.02) = 0.05885$

mass NH_3 $= 0.05885 \times (14.01 + 3\times1.008)$

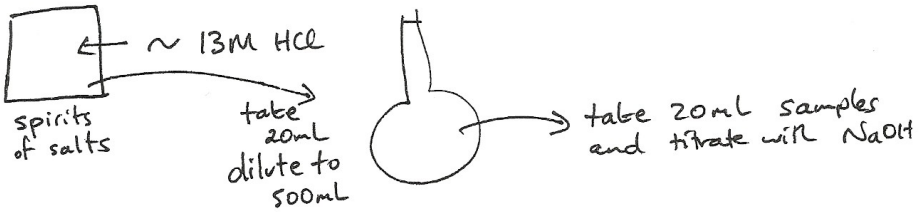
$= 0.05885 \times 17.034 = 1.002g$

mass of 20 mL household cleaner $= 20 \times 1.08$

$= 21.6g$

$\% NH_3 = \frac{1.002}{21.6} \times 100 = 4.64\%$

Q2



a) $HCl + NaOH \longrightarrow H_2O + NaCl$

$V = 20mL$

$V = 21.25mL$

$c = 0.4590M$

$n = cv = (0.459)(0.02125)$

$= 0.00975 mol$

b) $n_{HCl} = n_{NaOH} = 0.00975mol$ $\quad c_{HCl\ (diluted)} = \frac{n}{V} = \frac{0.00975}{0.02} = 0.488M$

c) $C_1V_1 = C_2V_2$

$C_1(20) = (0.488)(500)$

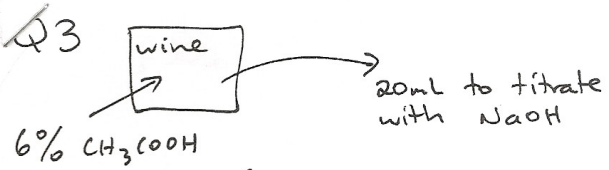
$\Rightarrow C_1 = 12.19M$ (conc of undiluted HCl)

$n = cv = (12.19)(0.02) = 0.2438$ mol HCl in 20mL spirits of salt

$\% HCl = \frac{\text{mass HCl}}{\text{mass solution}} \times 100 = \frac{8.89}{(1.18\times20)} \times 100 = 37.7\%$

(2)

Q3



a) $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

$V = 20mL$ $\quad c = 0.7240M$, $V = 28.75mL$

$n = cV = (0.7240)(0.02875) = 0.0208$

b) $n_{CH_3COOH} = n_{OH^-} = 0.0208 mol$

c) $c_{CH_3COOH} = \frac{n}{V} = \frac{0.0208}{0.02} = 1.04M$

d) $n = cV = (1.04)(1) = 1.04 mol$

$mass_{CH_3COOH} = 1.04 \times (2\times12.01 + 4\times1.008 + 2\times16)$

$= 1.04 \times 60.052 = 62.45g$

e) $density = \frac{mass\ solution}{volume\ of\ solution}$

$1.060 = \frac{mass\ solution}{1000} \Rightarrow mass\ solution = 1060g$

f) $\%\ ethanoic\ acid = \frac{mass\ ethanoic\ acid}{mass\ vinegar} \times 100$

$= \frac{62.45}{1060} \times 100 = 5.89\%$

g) the label claims 6%, the wine actually contains 5.89% – a lesser amount.

% error in label claim $\frac{0.11}{6} \times 100 = 1.8\%$

Q4

$$Ca(OH)_2 + 2HCl \rightarrow H_2O + CaCl_2$$

$V = 20\,mL$

$c = 3.19 \times 10^{-2}$

$V = 20.31\,mL$

$n = cV = (3.19 \times 10^{-2})(0.02031)$

$= 6.48 \times 10^{-4}$

$$n_{Ca(OH)_2} = \frac{1}{2} \times n_{HCl} = \frac{1}{2} \times 6.48 \times 10^{-4} = 3.24 \times 10^{-4}\ mol$$

$$C_{Ca(OH)_2} = \frac{n}{V} = \frac{3.24 \times 10^{-4}}{0.02} = 1.62 \times 10^{-2}\ M$$

to convert $mol\,L^{-1}$ to $g\,L^{-1}$ multiply by molar mass

$$C_{Ca(OH)_2} \text{ in } g\,L^{-1} = 1.62 \times 10^{-2} \times (40.08 + 2 \times 16 + 2 \times 1.008)$$

$$= 1.62 \times 10^{-2} \times 74.096$$

$$= 1.20\ g\,L^{-1}$$