Christ Church
Grammar School

Year 12 Chemistry

Volumetric Analysis
Validation Test
2018

Time allowed: 45 minutes

Name: Solutions

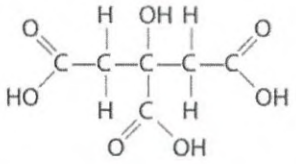
Marks: _____ / 46

Question 1 **(20 marks)**

Citric acid is a weak organic acid occuring naturally in many fruits, especially citrus fruits. It is very soluble and is often used as an additive to improve flavour and as a preservative. To determine the exact citric acid content in a popular energy drink, a titration with sodium hydroxide solution was used. The average citric acid content in energy drinks is 11.7 gL^{-1}.

The standardised sodium hydroxide had a concentration of 0.0204 $molL^{-1}$.

The formula for citric acid is $C_6H_8O_7$ and the structure of citric acid is shown below. It is triprotic and contains three carboxylic acid groups;



a) Using a calculation, determine if the energy drink requires dilution before titration. If dilution is required, provide a brief procedure outlining how you would perform this dilution using standard laboratory equipment.

m (citric acid) in 20mL = 11.7 x (20/1000)
= 0.234g ✓

n (citric acid) in 20mL = 0.234 / 192.124
= 0.001218 moles ✓

n(NaOH) required = n (citric) x 3 = 0.003659 moles ✓

V = n / c
V = 0.003659 / 0.0204
= 179 mL ✓

Based on undiluted energy drink, a titre volume of 179mL would be needed which is too high. ✓
Take a 25mL aliquot of energy drink and transfer to a 250mL volumetric flask (10x dilution) ✓

(6 marks)

b) In a separate experiment, a student carried out a titration on some lemonade using standardised sodium hydroxide (concentration 0.097 $molL^{-1}$). He found that 25.00 mL of lemonade had a mass of 27.90 g. He carried out the analysis on 25.00 mL aliquots of undiluted lemonade and obtained the following results using phenolphthalein as the indicator:

	Volume of sodium hydroxide (mL)				
	Rough	1	2	3	4
Initial volume (mL)	0.90	1.55	0.70	0.20	1.45
Final volume (mL)	19.35	19.75	19.00	18.80	19.70
Titre volume (mL)	18.45	18.20	18.30	18.60	18.25

c) Using the results above, calculate the average titre volume: 18.25

(1 mark)

d) Assuming all the acid present is citric acid and using your average titre volume, calculate the acid content of the lemonade in gL^{-1} and as a percentage by mass. Use the appropriate number of significant figures to express your final answer.

$n(NaOH) = cV = 0.097 \times 0.01825 = 0.00177$ moles ✓

$n(\text{citric acid})$ in 25mL $= 0.00177 \times (1/3)$

$= 0.000590008$ ✓

$m(\text{citric acid}) = n \times M = 0.000590008 \times 192.124$

$= 0.11337g$ ✓

$c = m/v = 0.11337 / 0.025 = 4.53 gL^{-1}$ ✓

$\% = 0.11337 / 27.90 \times 100 = 0.41\%$ ✓

✓ +1 for s.f.

(6 marks)

e) Given that the lemonade is carbonated with CO_2, is this a valid experiment? Use equations to justify your answer.

carbon dioxide dissolves in water to produce carbonic acid, H_2CO_3. H_2CO_3 undergoes hydrolysis in water ✓ $H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$. As there is carbonic and citric acid, the calculated acid is higher than the actual citric acid concentration. ✓

(2 mark)

f) State the effect of rinsing the following equipment with the solution given on the apparent % acid in the lemonade.

	Equipment	Rinsed with	Effect on apparent acid content
(i)	Burette	distilled water	Increase ✓
(ii)	Pipette	distilled water	Decrease ✓
(iii)	Conical flask	lemonade	Increase ✓

(3 marks)

g) Explain your response to part f) (iii)

A known volume from pipette is transferred into conical flask. Rinsing with lemonade would increase the n(citric acid) present thus increasing the apparent % acid. ✓

(2 marks)

Question 2 **(10 marks)**

An average titre volume of 14.85 mL was obtained when 0.204 (± 0.001) $molL^{-1}$ of NaOH was used to standardise a 20.00 (± 0.03) mL hydrochloric acid solution.

a) Calculate the percentage uncertainty associated with the average titre volume.

% = 0.1 / 14.85 × 100 = 0.673 %.

(1 mark)

b) Calculate the percentage uncertainty of the pipette used.

% = 0.03 / 20.00 × 100 = 0.150 %.

(1 mark)

c) Calculate the concentration of the hydrochloric acid and the absolute error uncertainty associated with the determined concentration.

$n(NaOH) = cV = 0.204 \times 0.01485$

$= 0.0030294$ moles ✓

$n(HCl) = n(NaOH) = 0.0030294$ moles ✓

$c(HCl) = n/V = 0.0030294 / 0.02$

$= 0.15147$ mol L^{-1} ✓

% error in concentration of NaOH = $0.001 / 0.204 \times 100$

$= 0.490\%$ ✓

Total % error in conc. of HCl = $0.490 + 0.673 + 0.150$

$= 1.31\%$ ✓

Absolute error = $(1.31/100) \times 0.15147 = 0.00199$ mol L^{-1} ✓

$\therefore c(HCl) = 0.151 \pm 0.002$ mol L^{-1}

(6 marks)

d) The sodium hydroxide in the above experiment was not a primary standard. It had to be prepared and then standardised. Give 2 reasons why NaOH is a poor primary standard.

1. Can't be obtained in pure form ✓
2. Has a relatively low molar mass ✓
3. Is deliquescent
4. Reacts with CO_2 in the air

(2 marks)

(any 2).

Question 3 **7 marks**

Marble is composed mainly of calcium carbonate, $CaCO_3$, with some impurities.

A 1.20 g sample of marble was dissolved in 500.0 mL of 0.150 $molL^{-1}$ standardised hydrochloric acid. The mixture fizzed as carbon dioxide was produced. After the mixture finished reacting, the solution was then titrated with 20.00 mL of 0.100 $molL^{-1}$ NaOH solution. The average titre volume required was determined as 18.6 mL.

Calculate the percentage by mass of calcium carbonate in the sample of marble.

$n(NaOH) = cV = 0.1 \times 0.02 = 0.002$ moles ✓

$n(HCl) = n(NaOH) = 0.002$ moles of HCl in 18.6mL

$n(HCl)$ in 500mL $= (500/18.6) \times 0.002$

$= 0.05376$ moles ✓

$n(HCl)$ added $= cV = 0.150 \times 0.5$

$= 0.075$ moles ✓

$n(HCl)$ reacted with the marble $= 0.075 - 0.05376$

$= 0.02124$ moles ✓

$2HCl + CaCO_3 \rightarrow CaCl_2 + CO_2 + H_2O$

$n(CaCO_3) = 1/2 \times n(CaCO_3) = 0.01062$ moles ✓

$m(CaCO_3) = 0.01062 \times 100.09 = 1.063$ g ✓

% $= 1.063 / 1.20 \times 100$

$= 88.6\%$ ✓

Question 4 **4 marks**

A sample of river water has a density of 1.01 gmL^{-1} and contains 3.50% by mass of ethanoic acid. What volume of 0.600 $molL^{-1}$ sodium hydroxide is required to neutralise 20.00 mL of the river water?

m (20mL of river water) = $20 \times 1.01 = 20.2g$ ✓

m (eth. acid) = $20.2 \times (3.5/100)$

= $0.707g$ in 20mL sample. ✓

n (eth. acid) = m / M

= $0.707 / 60.052$

= 0.01177 moles ✓

n (NaOH) = n (eth. acid)

= 0.01177 moles

& $V = n / c$

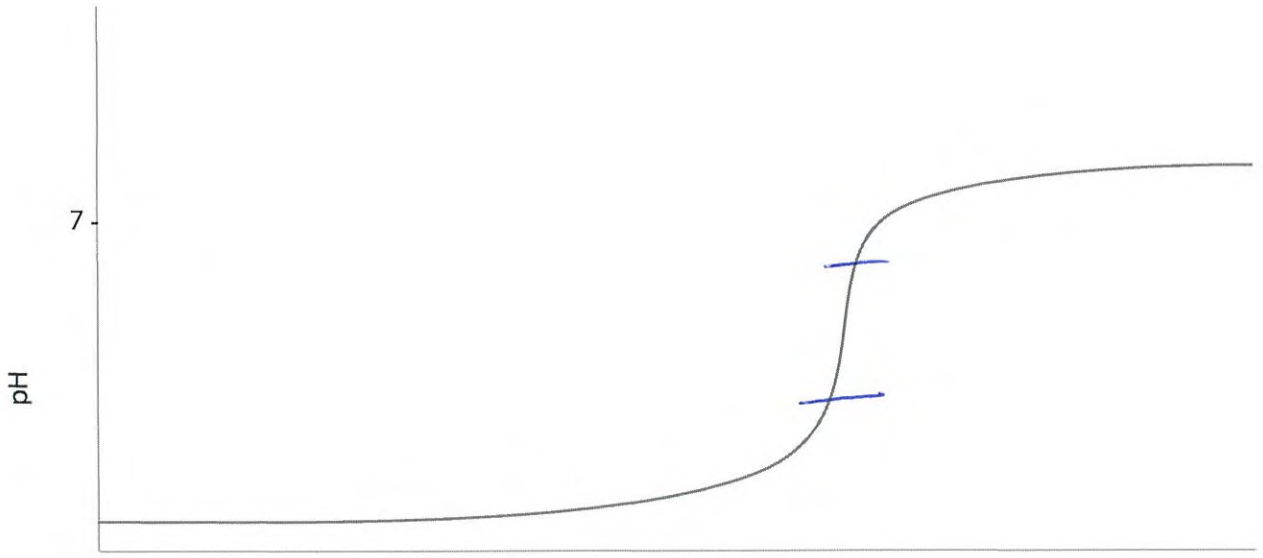
= $0.01177 / 0.6$

= $0.01961L$

= $19.6mL$ ✓

Question 5 **5 marks**

A known concentration of ammonia solution is added to a nitric acid solution to determine the concentration of acid present.
The titration curve of the reaction is shown below.



a) Methyl orange was correctly chosen as an appropriate indicator for the titration. Mark an approximate range for its colour change on the graph above. (1 mark)

b) Using chemical equations to support your answer, explain why methyl orange is an appropriate choice for this reaction. Include the term 'equivalence point' and 'end point' in your response.

The end point range of methyl orange is close to the equivalence point for this titration. ✓
Ammonia reacts with acid according to the equation; $NH_3 + H^+ \rightleftharpoons NH_4^+$ ✓
The NH_4^+ undergoes hydrolysis according to the equation; $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$ ✓
The $[H_3O^+]$ increases, thus the pH at equivalence is less than 7. ✓

(4 marks)

END OF TEST