Chemistry Department
Christ Church Grammar School

Year 12
2020

Volumetric Analysis/Titration Validation Test 2020

Time allowed: 45 minutes

Instructions
Please ensure you enter your name and circle your teacher's initials below.
Scientific calculators only. Chemistry Data Sheet will be provided

Name: ANSWERS

Teacher: (circle)

CEM NMO KLD MXC

Mark: _____ / ~~44~~

Question 1 **17 marks**

A bottle of store bought cloudy ammonia was analysed to determine the concentration of ammonia present.

25.00 (± 0.03) mL of cloudy ammonia was pipetted into a 250 (± 0.15) mL volumetric flask and made up to the mark with distilled water.

The mass of the 25.00 mL aliquot of cloudy ammonia was 23.42 (± 0.05) g.

A standard solution of hydrochloric acid was used, with a concentration of 0.103 (± 0.002) mol L^{-1}.

The standardised HCℓ was titrated against 20.00 (± 0.03) mL aliquots of diluted cloudy ammonia, each with 3-5 drops of bromophenol blue added.

The average titre volume obtained was 16.23 (± 0.10) mL.

a) Write an ionic equation for the reaction between the household ammonia and the hydrochloric acid. (1 mark)

$NH_{3(aq)} + H^+_{(aq)} \rightarrow NH_4^+{}_{(aq)}$

b) The cloudy ammonia advertises its ammonia concentration as 15-20 g/L. Calculate the concentration of ammonia in the cloudy ammonia solution and determine whether it fits within this range. Note: Error analysis not required here. (6 marks)

$n(H^+) = 0.01623 \times 0.103 = 0.0016717$ moles (1)

$n(NH_3)$ in 20mL diluted = $n(H^+) = 0.0016717$ moles (1)

$n(NH_3)$ in 250 mL diluted = $0.0016717 \times \frac{250}{20}$

$= 0.020896$ moles (1)

$n(NH_3)$ in 25mL undiluted cloudy ammonia

$= 0.020896$ moles (1)

$m(NH_3)$ in 25mL undiluted = $n \times M$

$= 0.020896 \times 17.034$

$= 0.3559$ g (1)

$[NH_3] = \frac{0.3559}{0.025} = 14.24$ gL^{-1} (1)

∴ not within range

c) Complete the table below, calculating the % error in each measurement.

Measurement	Value	% error
25mL pipette	25.00 (± 0.03)	0.12
20 mL pipette	20.00 (± 0.03)	0.15
burette	16.23 (± 0.10)	0.62
Volumetric flask	250 (± 0.15)	0.06
[HCℓ]	0.103 (± 0.002)	1.94

(1 mark)

d) Hence or otherwise, express your answer calculated in part b) to the correct number of significant figures in the box provided below.

(3 marks)

total error = 2.89 % (1)

2.89 % of 14.24 g = $\frac{2.89}{100} \times 14.24 = 0.411$ g (1)

Concentration of NH_3 in cloudy ammonia:

14.2 ± 0.4 g/L (1)

e) If you had rinsed the burette with distilled water only, what effect would it have on the calculated concentration of ammonia? Fully explain your answer. (3 marks)

- the HCl would be diluted (1)
- meaning a higher titre volume is needed (1)
- resulting in a higher calculated [NH_3] (1)

f) Bromophenol blue is an indicator that changes colour in the range of pH 3-4.6. With the use of an appropriate equation, explain why this indicator was used.

(3 marks)

At equivalence, NH_4^+ is present
This is the conjugate acid of a weak base, so hydrolyses to form a weakly acidic solution (1)

$NH_4^+(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NH_3$ (1)

- bromophenol blue is appropriate as its end point occurs close to the equivalence point (1)

Question 2 14 ~~15~~ marks

Acid 'X' is a weak, diprotic, organic acid found naturally in many fruits. It is often used in a concentrated form as a flavouring to give food a sour taste.

A student wanted to set up a titration to determine the concentration of 'Acid X' present in various samples of grapefruit juice to compare their quality and flavour.

The student researched that grapefruit juice can have a percentage by mass of 'Acid X' in the range of 2.5 – 5.0 %. The molar mass for Acid 'X' is 134 $gmol^{-1}$.

The average mass of 20.00 mL samples of grapefruit juice was found to be 20.80 g.

The student had standardised a solution of sodium hydroxide and determined its concentration to be 0.105 $molL^{-1}$.

a) Using the information above, perform appropriate calculations to determine if the grapefruit juice needs to be diluted prior to the titration. Explain your decision.

(6 marks)

Assuming a % of Acid X of 5 %, and aliquots of 20 mL being analysed.

$m(H_2X)$ in 20mL $= 20.8\,g \times \frac{5}{100} = 1.04\,g$ (1)

$n(H_2X)$ in 20 mL $= \frac{1.04}{134} = 0.00776$ moles (1)

diprotic, so $n(OH^-)$ needed to react with 20 mL

$= 2 \times n(H_2X) = 0.01552$ moles (1)

$V(NaOH)$ needed $= \frac{n}{C} = \frac{0.01552}{0.105} = 0.148\,L = 148\,mL$. (1)

(If % Acid X = 2.5 %, then a volume of 74 mL required)

∴ Dilution required (1)

(1) mark for explanation

eg. Dilution is required, so that the titre volume is within an appropriate range (fits within burette & is large enough to minimise % error)

* 1 mark removed from 26.

b) In the laboratory, the student had access to a 20 mL and 25 mL pipette, as well as volumetric flasks of 125 mL, 250 mL and 500 mL. Using this equipment, give the procedure you would follow to perform the dilution. (2 marks)

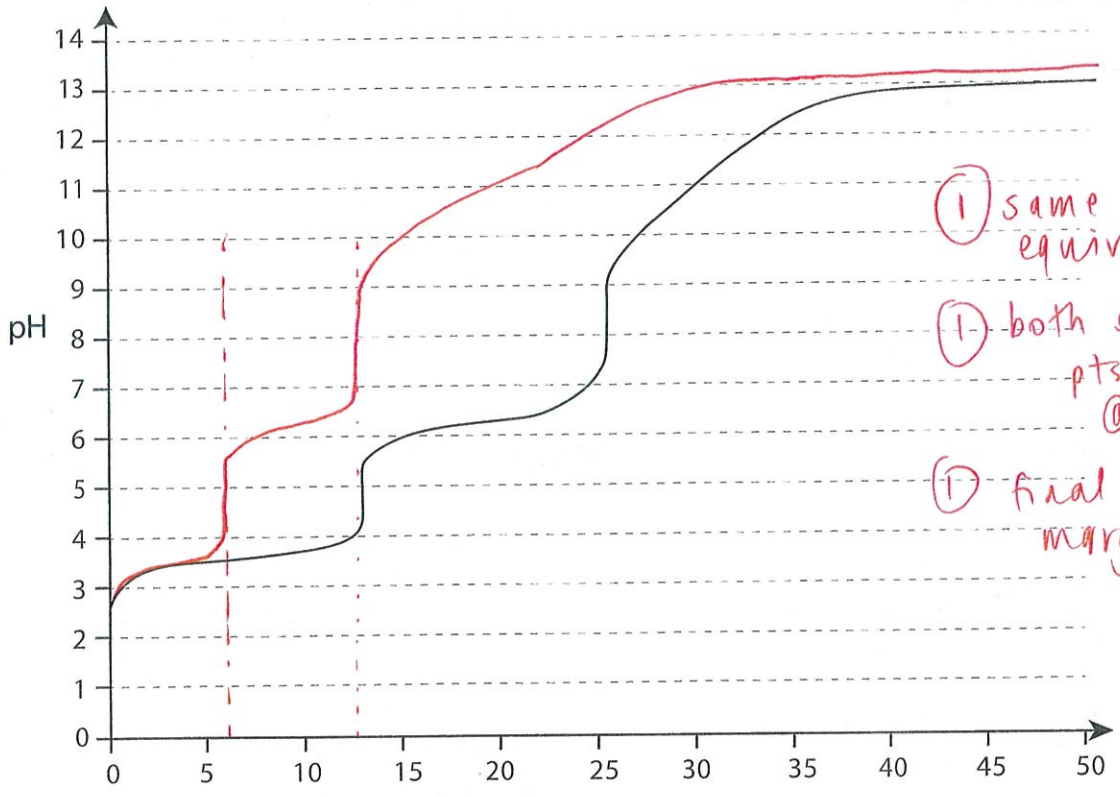
- titre range ~ 75 - 150 mL
∴ either a 5 or 6.25 fold dilution appropriate, using 20mL or 25mL pipette & 125 mL volumetric flask

~~(1) identification of dilution factor~~
(1) identification of correct glassware
(1) description of procedure.

c) Describe an assumption the student needed to make when planning their analysis of the grapefruit juice. (1 mark)

- that all the acid present is acid X.

d) The pH was monitored throughout the titration and the following curve was obtained.



(1) same pH @ equivalence points
(1) both equivalence pts occur @ ½ volume
(1) final pH is marginally higher

i) Explain why there are two equivalence points. (1 mark)

- Acid X is diprotic

ii) Using the formula H_2X to denote Acid 'X', write an ionic equation to describe the reaction that has gone to completion at the first equivalence point (12.5 mL of NaOH added).

$H_2X + OH^- \longrightarrow HX^- + H_2O$

(1 mark)

iii) On the titration curve, draw the curve you would expect to obtain if the concentration of the standard NaOH solution was doubled and a total of 50 mL of was added.

(3 marks)

Question 3 **13 marks**

Antacids are medications that treat heartburn, indigestion and acid reflux. The active ingredients are carbonate containing compounds. A standardised solution of hydrochloric acid (1.13 $molL^{-1}$) was used to determine the percentage by mass of magnesium carbonate in a common antacid tablet using a back titration procedure. The assumption was made that all the carbonate present was in the form of magnesium carbonate.

Step 1: A 1.67 g sample of the antacid tablet was placed in a conical flask;

Step 2: 50.0 mL of the standardized hydrochloric acid was added to the conical flask;

Step 3: At the completion of the reaction, the mixture in the conical flask was added to a 500 mL volumetric flask and made up to the mark with distilled water;

Step 4: A 25.00 mL aliquot of the diluted mixture was titrated with 0.0530 $molL^{-1}$ sodium hydroxide, using phenolphthalein as the indicator.

The scientists performed a rough titration and then recorded the results of a further 4 titrations in the table below:

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**
Final volume (mL)	33.80	37.90	31.70	28.80
Initial volume (mL)	5.25	9.50	3.20	0.30
Volume titrated (mL)	28.55	28.40	28.50	28.50

a) Calculate the average volume of sodium hydroxide used in the titration sequence.

Vav = 28.52 mL (1 mark)

b) Write an equation for the reaction of magnesium carbonate with hydrochloric acid in Step 2.

$MgCO_3 + 2H^+ \rightarrow H_2O + CO_2 + Mg^{2+}$

(1 mark)

c) Write an ionic equation for the reaction taking place in Step 4.

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

(1 mark)

d) Calculate the percentage by mass of magnesium carbonate in the antacid tablet.

(8 marks)

n(H+) added initially = C x V

= 1·13 x 0·05 = 0·0565 moles (1)

titration

n(OH-) needed = 0·053 x 0·02852 = 0·00151156 moles (1)

n(H+) in 25 mL = 0·00151156 moles (1)

n(H+) in 500 mL = 0·00151156 x 500/25 = 0·03023 moles (1)

n(H+) that reacted with $MgCO_3$

= 0·0565 - 0·03023

= 0·02627 (1)

$n(MgCO_3) = 1/2\ n(H^+) = 0·013135$ (1)

$m(MgCO_3) = n \times M = 0·013135 \times 84·32$

= 1·1075 g (1)

$\%\ MgCO_3 = \frac{1·1075}{1·67} \times 100 = 66·3\ \%$ (1)

e) When conducting the titration above, give the solutions that you would use to wash the following pieces of equipment with: (2 marks)

Equipment	Solution to be rinsed with
burette	standard NaOH
500 mL volumetric flask	distilled water