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**Chemistry IA23**

**Aim**

To determine the concentration and identity of a wek monoprotic organic acid.

**Apparatus with Uncertainty Table**

|  |  |  |
| --- | --- | --- |
| **Apparatus** | **Uncertainty** | **Justification** |
| Burette | ±0.10 | Human reaction had to be accounted for. The stopwatch may have been pressed earlier or later than the actual timed value. This error happened twice; at the beginning of the timed oscillations and at the end of the oscillations. There was an approximated error of ±0.15s at each reading, resulting in an overall error of ±0.3s. |
| Datalogger with pH probe | ±0.02 pH | This is the smallest increment in the datalogger, a digital instrument. |
| Pipette | ±0.06 ml | The uncertainty was stated on the instrument. |

Raw Data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Volume of acid added (V) /cm3 (±0.10) | pH of mixture (pH) (±0.02) | | | Average pH (pHave) (±0.02) |
| 1 | 2 | 3 |
| 0.0 | 14.00 | 14.00 | 14.00 | 14.00 |
| 5.0 | 13.85 | 13.80 |  | 13.83 |
| 10.0 | 13.67 | 13.63 |  | 13.65 |
| 15.0 | 12.87 | 12.90 |  | 12.89 |
| 15.5 |  | 12.55 | 12.69 | 12.62 |
| 15.6 |  |  | 12.53 | 12.53 |
| 15.7 |  |  | 12.45 | 12.45 |
| 15.8 |  |  | 12.32 | 12.32 |
| 15.9 |  |  | 12.12 | 12.12 |
| 16.0 |  |  | 11.56 | 11.56 |
| 16.1 |  |  | 10.64 | 10.64 |
| 16.2 |  |  | 9.94 | 9.94 |
| 16.3 |  |  | 8.38 | 8.38 |
| 16.4 |  |  | 7.00 | 7.00 |
| 16.5 |  |  | 6.75 | 6.75 |
| 16.6 |  |  | 6.66 | 6.66 |
| 16.7 | . |  | 6.50 | 6.50 |
| 16.8 |  |  | 6.40 | 6.40 |
| 16.9 |  |  | 6.28 | 6.28 |
| 17.0 |  |  | 6.22 | 6.22 |
| 18.0 |  | 5.73 |  | 5.73 |
| 19.0 |  | 5.50 |  | 5.50 |
| 20.0 | 5.37 | 5.35 |  | 5.36 |
| 25.0 | 4.95 |  |  | 4.95 |
| 30.0 | 4.75 | 4.74 |  | 4.75 |
| 35.0 | 4.60 |  |  | 4.60 |
| 40.0 | 4.47 | 4.48 |  | 4.48 |
| 45.0 | 4.40 |  |  | 4.40 |

Volume of NaOH = (20.0 ± 0.06) cm3

Quantitative Observations

* The acid has a pungent smell, similar to vinegar.
* During titration, no visible change was observed.

Processed Data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mean Volume/ cm3 | | dV/cm3 | dpH |  |
| 2.5 |  | 5.0 | -0.18 | 0.035 |
| 7.5 |  | 5.0 | -0.17 | 0.035 |
| 12.5 |  | 5.0 | -0.77 | 0.16 |
| 15.3 |  | 0.5 | -0.26 | 0.53 |
| 15.6 |  | 0.1 | -0.09 | 0.9 |
| 15.7 |  | 0.1 | -0.08 | 0.8 |
| 15.8 |  | 0.1 | -0.13 | 1.3 |
| 15.9 |  | 0.1 | -0.20 | 2.0 |
| 16.0 |  | 0.1 | -0.56 | 5.6 |
| 16.1 |  | 0.1 | -0.92 | 9.2 |
| 16.2 |  | 0.1 | -0.70 | 7.0 |
| 16.3 |  | 0.1 | -1.56 | 15.6 |
| 16.4 |  | 0.1 | -1.38 | 13.8 |
| 16.5 |  | 0.1 | -0.25 | 2.5 |
| 16.6 |  | 0.1 | -0.09 | 0.9 |
| 16.7 |  | 0.1 | -0.16 | 1.6 |
| 16.8 |  | 0.1 | -0.10 | 1.0 |
| 16.9 |  | 0.1 | -0.12 | 1.2 |
| 17.0 |  | 0.1 | -0.06 | 0.6 |
| 17.5 |  | 1.0 | -0.49 | 0.49 |
| 18.5 |  | 1.0 | -0.23 | 0.23 |
| 19.5 |  | 1.0 | -0.14 | 0.14 |
| 22.5 |  | 5.0 | -0.41 | 0.082 |
| 27.5 |  | 5.0 | -0.21 | 0.041 |
| 32.5 |  | 5.0 | -0.15 | 0.029 |
| 37.5 |  | 5.0 | -0.13 | 0.025 |
| 42.5 |  | 5.0 | -0.07 | 0.015 |
| 47.5 |  | 5.0 | -0.09 | 0.017 |

This investigation will show that the identity of the acid can be determined graphically, and will show that the pKa of the acid can be found at the point where the volume of the acid titrated is twice that of the volume titrated at the equivalence point.

Given that the titrant is a weak monoprotic acid, and the analayte is a strong base, a basic buffer is formed in excess of the base. At equivalence point, there is only salt. However, at the point where

According to the Henderson-Hasselbalch equation,

We can find this point when there is 2n the mols of weak acid have been added to the solution, where n is the mols of weak acid at the equivalence point. Since

by the formula

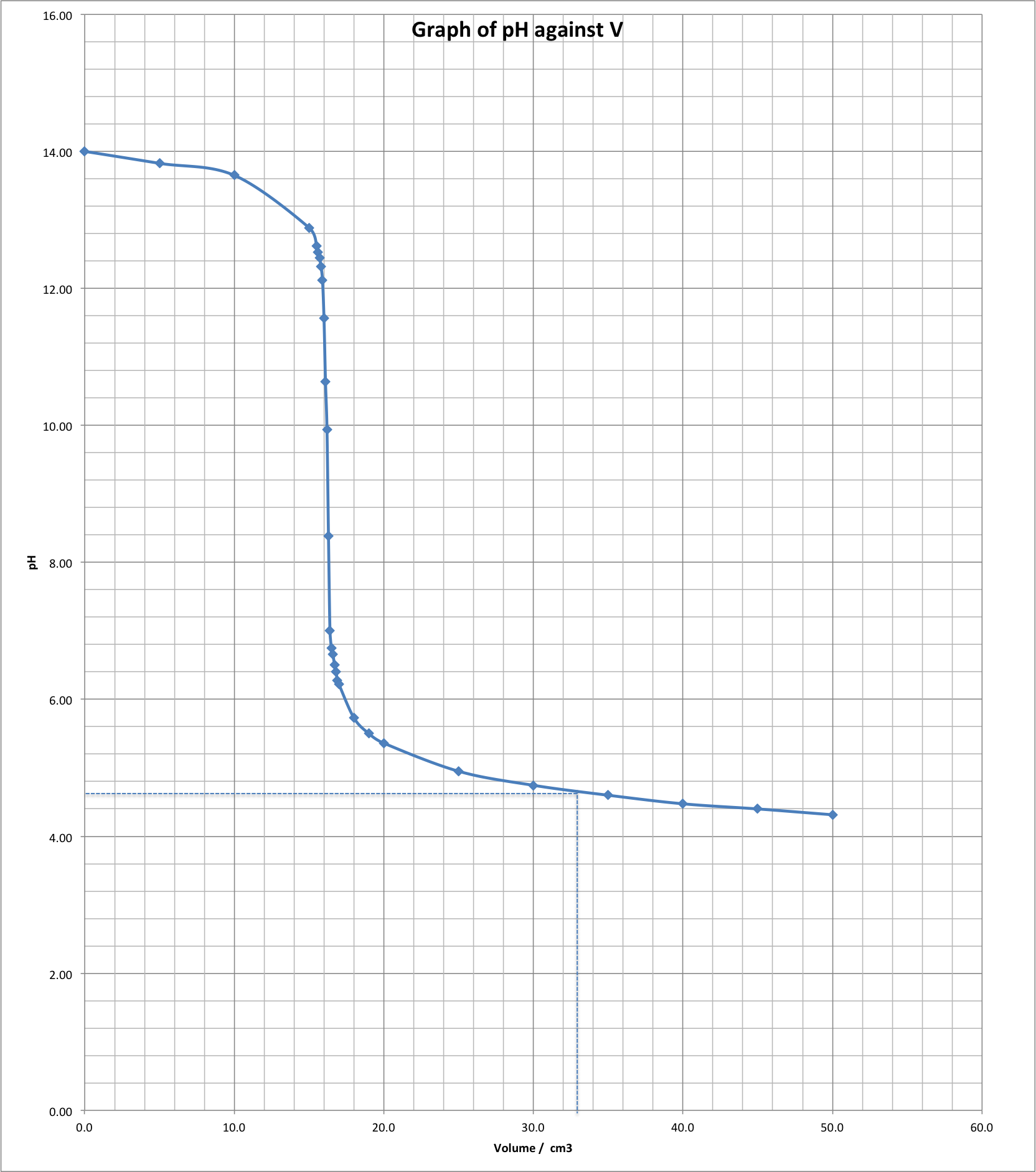
So we can state that at the point where the volume of acid added is twice the volume added at the equivalence point, we can find the corresponding value of pH where .

Via examination of the graph (figure 1),

Equivalence point is at V = 16.3 cm3

Thus, the volume of acid when the ( pH = pKa ) = 32.6 cm3

To find the pH at that point, by examination of the graph of pH against V (figure 2)



Thus, the pH of the solution at that point is about pH 4.7.

By referencing the IB Chemistry Data booklet, the identity of the acid is **ethanoic acid**.

METHOD 1   
  
To find the concentration of the acid,

The equation for the dissociation of the weak acid is:

The measured value of the acid is

Since the pKa of ethanoic acid is 4.76[[1]](#footnote-1)

To find the uncertainty of ,

Thus, maximum deviance from original value is

So, to determine the uncertainty of the acid:

= 9.67%

Thus, the final concentration of ethanoic acid:

METHOD 2  
  
Another way to calculate the uncertainty of the acid is shown:

Since the reaction of the acid to the base is:

Thus the ratio of at equivalence point.

The initial pH of NaOH = (14.00

Thus, [OH-] = = 1.00 M

Inserting values of concentration and volume at equivalence point:

To calculate uncertainty of M,

Thus, maximum deviance from original value is

Thus, the value of concentration of acid is

Conclusion & Evaluation

We know that the solution is ethanoic acid from graphical analysis. This is confirmed by qualitative observations, as the liquid gives off a pungent aroma similar to vinegar, which suggests that the liquid is ethanoic acid. Since there is no way to determine the uncertainty of the value of pH from a graphical reading, there will be none given.

The percentage deviation from the literature value cannot be calculated, as the literature value of the concentration of the liquid is not known. Thus, we are unable to comment on the accuracy of the experimental value.

For both method 1 and 2, since the value of [acid] falls within the value for the percentage inaccuracy of the value of [acid], which is and respectively. The high random error in the graph (>5%) shows that the result of the concentration of the acid is not precise.

We can observe as well that the second method has a smaller percentage uncertainty than the other one. Thus, the method 2 is more precise.

Sources of random error can be traced to the uncertainty of the pH. One reason for the presence of the uncertainty in the concentration is fluctuations in temperature. Since pH is affected by temperature, fluctuations in the temperature of the setup due to changes in the surroundings will cause the pH reading to be affected in unpredictable directions, causing the equivalence point to shift. This will affect the experimental value of the concentration of the acid in unpredictable directions.

In addition, the burette reading may not have been straight. Thus, this will cause the reading of the burette to be skewed higher or lower than expected, depending on how the burette is read. This causes the value of V to be affected in unpredictable directions, causing the equivalence point to shift. This will affect the experimental value of the concentration of the acid in unpredictable directions.

Finally, the

1. IB Chemisty Data Booklet, table 15, pg 13 [↑](#footnote-ref-1)