College of science

Department of chemistry

Course code: CHEM 353

Third practical experiment:

Potentiometric titration of a mixture of acids (Hydrochloric acid (HCl) and acetic acid (CH$_3$COOH)) with a Strong base (Sodium hydroxide (NaOH))

The work and contribution of this practical report is done by the following students:

1-Faisal Mansour (442105660)

2-TALAL ALOSAIMI (437103019)

Under the supervision of the teaching assistant: Abdulaziz Alsalman

*Introduction

- Potentiometric titrations are fundamentally based upon measuring the pH of a given solution by availing electrochemical techniques or approaches rather than the usual and classical use of the general logarithmic rule of finding the pH of any solution, that is, $pH=-Log[H^+]$. Potentiometric titrations are ubiquitously applied for measuring the pH of a solution by the presence of a voltage difference, which is yielded due to the movement of charged ions around the membrane of a pH meter. Additionally, and typically, a pH meter comprises of a reference (Standard) electrode, in addition to a wire within that is made up of silver (Ag) in combination to silver chloride (AgCl) altogether, that is Ag/AgCl. And finally, a membrane that consists of 70% glass (SiO_2) + 20% sodium (Na)+ 10% of enhancing impurities such as calcium oxide (CaO), and that contains an internal solution. While potentiometric titrations work upon the utilization of electrochemical cells, there exists another type of a cell within the study of chemistry in general that contrarily works to that of a typical electrochemical cell, and that is a galvanic cell. Galvanic cells are basically cells that work opposite to that of a electrochemical cell in which there is a gain or loss of electrons within solutions where, additionally, the anode, which is where the oxidation process takes place, that has an abundance of electrons is to be the negative electrode (Where within an electrochemical cell, that would oppositely be the cathode) in addition to its solution which oxidizes by itself (Reducing agent) and reduces the other solution at the positive electrode, which is to be the cathode (Oppositely in an electrochemical cell, that would be the anode) that has a deficiency in electrons. The cathode is where the reduction process takes place within its solution that reduces by itself (Oxidizing agent) and oxidizes the other solution at the anode within a galvanic cell. We can calculate the voltage difference within a galvanic cell by using an equation called "Nernst equation" in which it states that "$E_{(Cell)}=E_{(R)}-E_{(L)}$" where "$E_{(Cell)}$" is the voltage difference, and "$E_{(R)}$" is to be the right electrode, which is the anode (Negative electrode), as assumed from the letter "R", and "$E_{(L)}$" is to be the left electrode, which is the cathode (Positive electrode), as assumed from the letter "L". The spontaneity of a reaction within a galvanic cell depends on the voltage difference, which is "$E_{(Cell)}$", as to be greater than or equal to 0.2 (V) (Equivalent to 200 (mV)) or

otherwise, the reaction in a galvanic cell wouldn't be spontaneous. A typical and classical example of a galvanic cell would be Daniell's cell in which a solution of zinc sulfate ($ZnSO_4$) is used at the anode (Negative electrode) where the oxidation process takes into effect into the zinc (Zn) which is considered as a reducing agent as it reduces the other oxidizing agent solution of copper (II) sulfate ($CuSO_4$) at the cathode (positive electrode) where the reduction process takes its effect into the copper (Cu).

-The following image portrays Daniell's cell
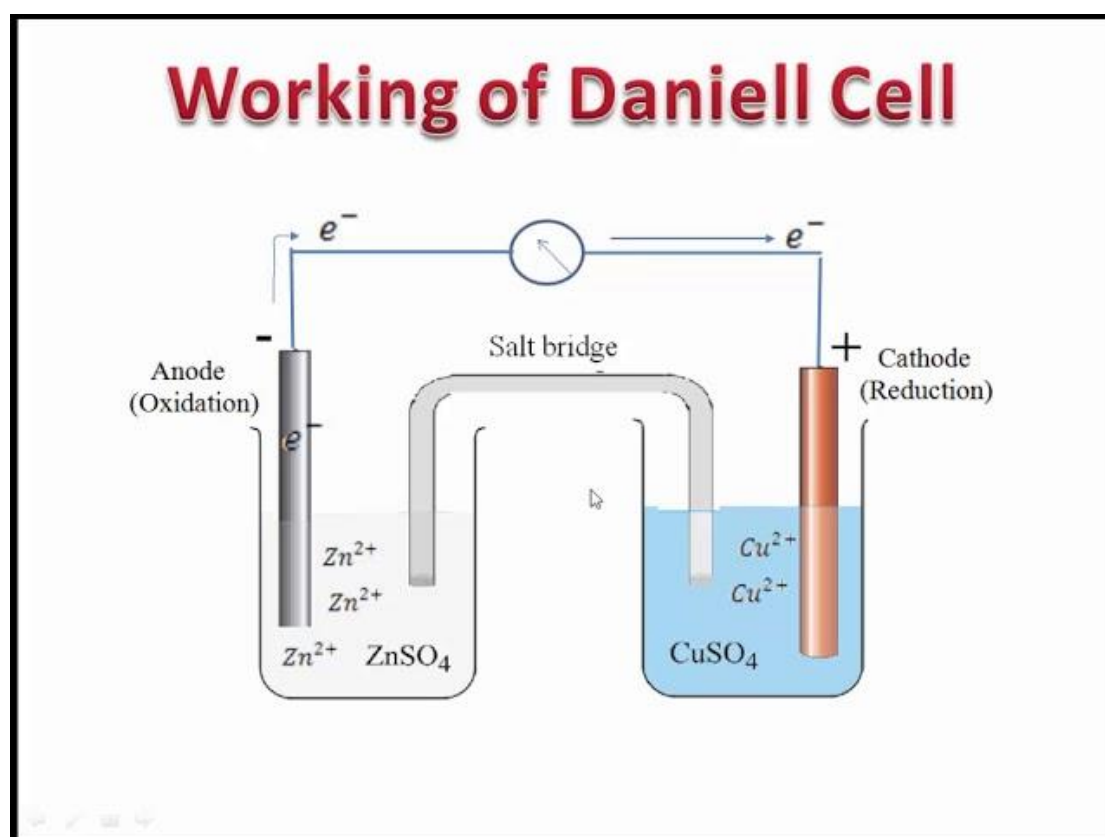
*Aim of the experiment

- Finding the molar concentration for each of hydrogen chloride (HCl) and acetic acid (CH₃COOH) that make up the acidic mixture using potentiometric titration.

*Laboratory substances/materials/tools that'll be used

1) Three different buffer solutions of distinct pH (10-7-4) for examining and calibrating the pH meter efficiency

2) Sodium hydroxide (NaOH)=>As a solid pellet initially from which we would then prepare a solution of it

3)A volumetric flask of 100 (mL) to be filled up by the strong base

4)Burette for the strong base (Sodium hydroxide (NaOH))

5)An acidic mixture that contains hydrochloric acid (HCl), and acetic acid (CH₃COOH)

6)A beaker to be filled up to 15 (mL) volume by the acidic mixture

7)pH meter

8)Distilled water

*Practical work methodology

- We start by preparing a solution of sodium hydroxide (NaOH) that exactly requires a mass of 2.4 (g) of (NaOH) pellets for a concentration of 0.6 (M) in a 100 (mL) volumetric flask, meaning that, 0.6 (M)=100 (mL) in order to be put into a burette by filling it to 30 (mL). when this step is done, a separate beaker is neatly prepared by water washing and cleaning for the purpose of pouring in the 15 (mL) acidic mixture of hydrochloric acid (HCl) and acetic acid (CH₃COOH) into it. We then proceed to calibrate a pH meter that can be found near to a bench within the laboratory which firstly must be cleanly

washed and rinsed by distilled water where later on with the aim for it to properly work and produce fruitful, accurate results, it needs to be examined by the use of the three buffer solutions of differing pH, which can range about 10 to 7 to 4 (10-7-4), that can be found on the top within the same bench. Once this process is nicely finished in which we would then measure and take the read from the pH meter initially of the acidic mixture that is within the 15 (mL) beaker without any additions of (NaOH) from the burette, we then gradually titrate 1 (mL) exactly within each time from the burette that contains the strong base (NaOH) into the 15 (mL) beaker that has the acidic mixture to measure the pH where it primarily gives low reads due to having the mixture of acids, and then it yields reads that are slowly, increasingly going within each gradual titration where higher generated reads can be observed later on. We proceed on making this approach till we reach our first equivalence point, and since this is an acidic mixture of hydrogen chloride (HCl) and acetic acid (CH$_3$COOH), then there would exist two equivalence points in which the first equivalence point is for (HCl) since it's the strong acid, and the second, final equivalence point is surely for the weak acid of (CH$_3$COOH). The equivalence points are, generally, hardly noticed by the reads from the pH meter within this practical experiment specifically (Especially concerning the read from the pH meter from first equivalence point from the strong acid of (HCl)) since the other amount that is in the 15 (mL) beaker is an acidic mixture of a strong acid (HCl) and a weak acid (CH$_3$COOH). However, we keep on progressively adding and titrating each 1 (mL) exactly from the burette having the (NaOH) until we reach the second equivalence point for (CH$_3$COOH) that gives out a greatly massive difference within the reads to be taken from the pH meter since in this current case, the solution entirely should have more [OH$^-$] ions (from the (NaOH) solution that's within the burette) than to have the [H$^+$] ions (From the mixture of acids; (HCl) and (CH$_3$COOH)) from the beginning.

# *Calculations and results

-According to the prior whole data that was practically and experimentally accomplished and generated effectually in addition to the benefit of Microsoft excel, a scatter plot that has an increasingly varying pH that represents the Y-axis, and has a progressively increasing by 1 (mL) exactly of volume in milliliters (mL) from the additions of the strong base (Sodium hydroxide; NaOH) solution within the burette that makes up the X-axis can be created in the interest of graphically indicating the information before.
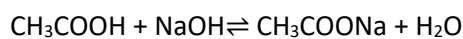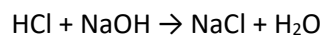
Practically performed data for the volume of strong base (Sodium hydroxide (NaOH)) with each corresponding pH
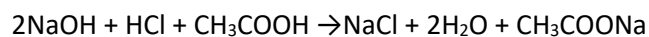
V(NaOH) (mL)	pH
0	0.81
1	0.91
2	1.02
3	1.15
4	1.3
5	1.56
6	2.09
7	3.37
8	3.82
9	4.09
10	4.28
11	4.43
12	4.58
13	4.71
14	4.48
15	4.98
16	5.13
17	5.32
18	5.57
19	6
20	11.04
21	12.51
22	12.8

Potentiometric titration for a mixture of acids (Hydrochloric acid (HCl) and acetic acid (CH_3COOH)) with a strong base (Sodium hydroxide (NaOH))
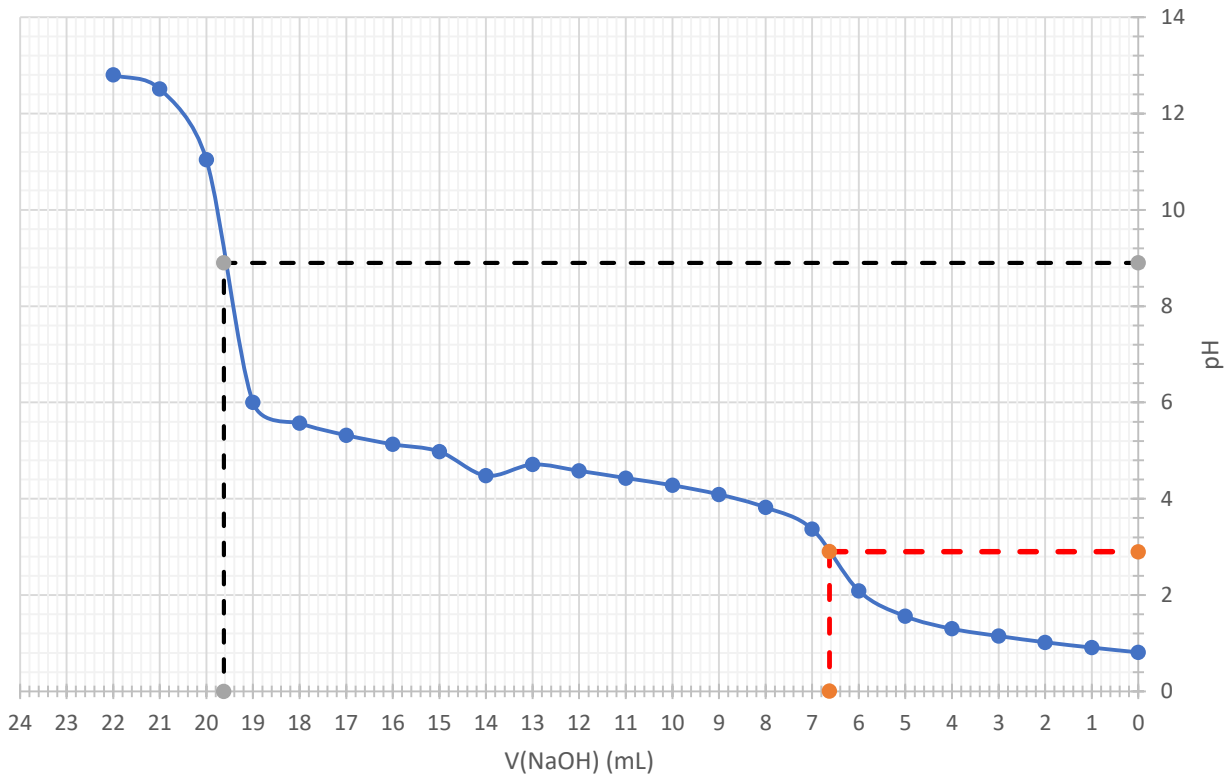
-The following transitional chemical equations describe the total and balanced chemical equations where the first chemical; equation makes up for the first Equivalence point, and the last chemical equation stands for the second Equivalence point

$HCl + NaOH \rightarrow NaCl + H_2O$

$CH_3COOH + NaOH \rightleftharpoons CH_3COONa + H_2O$

$2NaOH + HCl + CH_3COOH \rightarrow NaCl + 2H_2O + CH_3COONa$

-From the benefit of Microsoft excel graphical scatter plot, we can determine the unknown molar concentration for the mixture of acid in which the first one is definitely to be for the strong acid of (HCl) having the first equivalence point and the second one is certainly to be for the weak acid of (CH_3COOH) having the second

equivalence point. This operation can be established by availing the dilution equation twice as for the first Equivalence point for (HCl) and the second Equivalence point for (CH_3COOH) …

-For the first equivalence point for (HCl) that's based upon the first balanced chemical equation above, we have…

$(M{\times}V)/n=(M'{\times}V')/n'$ ("n" and "n'" are particularly within this case to be n=1=n')

-Where…

-M=>Unknown molar concentration of the strong acid (hydrogen chloride (HCl)) solution

-V=>Volume of the strong acid (Hydrogen chloride (HCl)) that is within the 15 (mL) beaker

-M'=>Molar concentration of the strong base solution (Sodium hydroxide (NaOH)), which is 0.6 (mol/L)

-V'=>Volume of the strong base (Sodium hydroxide (NaOH)) according to its correspondence within the graphical Microsoft excel scatter plot from the pH as the Y-axis to the volume of sodium hydroxide (NaOH) in (mL)

$\Leftrightarrow M=(M'{\times}V')/V$
$\Leftrightarrow M'=(0.6{\times}6.625)/(15)$
$\Leftrightarrow M'{\approx}0.27(M)$

-For the second equivalence point for (CH_3COOH), we'll be performing the same basic concept by availing the dilution equation, but in addition to the use of the stoichiometric coefficients, which tells the number of moles in a provided chemical equation, within the chemical equation since that the second equivalence point is based on the last balanced chemical equation…

$$(M{\times}V)/n=(M'{\times}V')/n'$$

-Where…

-n=>Stiochiometric coefficient, or the number of moles, for the weak acid (acetic acid (CH_3COOH)) within the last balanced chemical equation, which is "1"

-n'=> Stiochiometric coefficient, or the number of moles, for the strong base (Sodium hydroxide ($NaOH$)) within the last balanced chemical equation, which is "2"

$$\Leftrightarrow M=(n{\times}M'{\times}V')/(V{\times}n')$$
$$\Leftrightarrow M'=(1{\times}0.6{\times}19.625)/(15{\times}2)$$
$$\Leftrightarrow M'{\approx}0.393\ (M)$$

*Conclusion

-We practically and experimentally performed a potentiometric titration of an acidic mixture that contains a strong acid of hydrochloric acid (HCl) and of acetic acid (CH_3COOH) with a strong base of sodium hydroxide (NaOH).

*References

-The last practical lecture of course CHEM 353

The end of the practical experiment