Chemistry Extended Essay

"Finding the oleic acid amount in 4 different types of oil by Acid – Base Titration Method."

Aysu Yıldız

D1129010

Session: May 2010

Supervisor: Serenay Tarhan Güler

TED Ankara Collage Foundation High School

Word Count: 3511

Table of Contents

ABSTRACT

Anywhere in the world most people use vegetable oil in every area of their life. Food, health, mechanic, hygiene and so on… But how people choose the kind of oil that they will use? How we choose the kind of oil that we will buy when we are in a supermarket? Depending on colour, smell or ingredient?

In this case, I became curious about the difference between different kinds of oil and wanted to search for it. After a brief research from supermarkets and Internet I realizied that the amount of oleic acid varies in different types of oil. I preferred to buy Kırlangıç and Kristal brands and 4 different types of oil which included the information about the amount of percentage oleic acid amount at the back of the bottles. This values would be my literature value which I could compare with my values.

Oleic acid is a kind of unsaturated acid which exist in different amount in each oil. As oleic acid is a type of weak acid, the most outstanding method is acid-base titration to find the amount in the oil. This experiment could have been done with other methods but I have chosen to use acid-base titration method because I wanted to do the experiment in school laboratory and school opportunities enabled me to do titration method.

In order to investigate the introduced topic and find the values of oleic acid my research question is shaped as; **what is the difference in oleic acid amounts for different types of oil?**

Related to my research topic, I also investigated the accuracy and precision of the brands Kristal and Kırlangıç.

As a consequence of this experiment, I proved that oleic acid amounts of different oils are distinct. According to this; it is seen that different oils have divergent and various affects on human health.

Word Count: 310

INTRODUCTION

Oils are used in food industry, fuel, paint, machine industry, cosmetics and lots of other areas in daily usage. Thus, oils are important for human life. This essay is an analysis of how much oleic acid amount different types of oils have.

Vegetable oils are essential for human health. Fatty acids which appear in vegetable oils is classified in two groups; unsaturated and saturated. Oleic acid is an unsaturated fatty acid which is beneficial for human health. With regard to the conclusion of my experiment, researchs on different fatty acids could be done to investigate the effect on human health. Also people should be informed about distinct typed of oils because they all include different acidity percentage.

After a brief research I found that generally vegetable oils are composed of triglycerides. Triglyceride is a type of glyceride in which the glycerol is esterified with three fatty acids. This triglyceride molecule is found as oleic acid in vegetable oils and comprise the majority of olive oil, generaly less than 2.0 %. Hence vegetable oils are acidic.

I chose this topic because I was interested in Organic Chemistry and I wondered why different types of oil have different colours, and I prepared an experiment setup in order to learn it. To investigate it I chose 4 different types of oil from 2 different brands and experimented the oleic acid amount with titration method. Besides, I investigated the affect of phenolphtalein. I used two different brands in order to have accurate results and have a chance to compare the results of both brands.

In order to investigate the introduced topic and find the values of oleic acid my research question is shaped as; **what is the difference in oleic acid amounts for different types of oil?**

This experiment requires acid-base titration and depends on two factors which are the accuracy and precision of the brands used in the experiment, and the amount of oleic acid in four different oil. I have chosen this topic to find the importance of oleic acid which affects much areas in human life.

To sum up, the aim of this experiment is to find the values of oleic acid in four different types of oil by acid-base titration and to search for the advantages and disadvantages upon different areas of human life and environment.

THE CHEMISTRY OF OLEIC ACID

Depending on containing π bonds fatty acids can be classified as saturated and unsaturated. Because of that the bonds also differ in length. As the number of bonds between two carbon atoms increase, length of bond decrease. Carbon atoms come closer to each other while the bond become stronger.

Oleic acid is a mono-unsaturated omega-9 fatty acid. A monounsaturated fatty-acid has a single double bond between carbon atoms in the chain, remaining carbon atoms have single bond between them. They are liquid/semisolid/solid at room temperature and have a high melting point. On the other hand their melting point is lower than saturated fatty acids. Oleic acid is found in some of vegetable and animal sources.[1] It has the formula; $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$. π bonding requires the overlap of two or more p orbitals on adjacent atoms. The carbon atoms having double bond between each other, which means adjacent hydrogens are on the same side of the double bond(*cis* means on the same side) and oleic acid shows cis-isomerism with polar structures. The geometry of the π bond between two sp^2-hybridized carbons forces them to be co-planar with the four attached substituent atoms. The degree of twisting about the π bond is defined in terms of the *dihedral angle*.[2] Thus, dihedral angle in cis-isomerism is 0°. The rigidity of the double bond freezes its conformation and, in the case of the *cis* isomer, causes the chain to bend and restricts the conformational movement of the fatty acid.[3] When the number of double bond increases in the chain, the flexibility decreases. Thus, the structure will be more curved when the structure has many adjacent hydrogen bonds attached to the same side of double bond.

The Formula: $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

IUPAC Name: (9*Z*)-Octadec-9-enoic acid

[1] http://en.wikipedia.org/wiki/Oleic_acid 2 February 2010
[2] Fox, Marry Anne; Whitesell, James K. , Organic Chemistry, page 218-9 (geometry of alkanes) 2 February 2010

Other names: (9*Z*)-Octadecenoic acid
(*Z*)-Octadec-9-enoic acid
cis-9-Octadecenoic acid
cis-Δ-9-Octadecenoic acid
Oleic acid
18:1 cis-9

Molar mass: 282.4614 g/mol

Density: 0.895 g/mL[3]

Oleic acid reacts with alkenes and carboxylic acids. It is soluble in basic solutions and produces salts called oleates.[4] Oleates are any salt or ester of oleic acid, containing the ion $C_{17}H_{33}COO^-$ or the group $C_{17}H_{33}COO$- ; common components of natural fats.

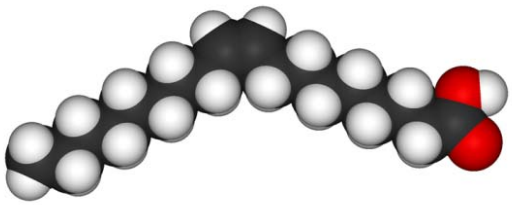


Figure 1: 3D presentation of structure of (9*Z*)-Octadec-9-enoic acid[5]

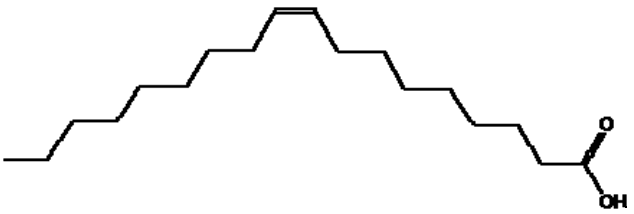


Figure 2: Chemical structure of (9*Z*)-Octadec-9-enoic acid[3][6]

[3] http://en.wikipedia.org/wiki/Oleic_acid 2 February 2010
[4] http://en.wikipedia.org/wiki/Oleic_acid#Chemistry 2 February 2010
[5] http://commons.wikimedia.org/wiki/File:Oleic-acid-3D-vdW.png 2 February 2010

[6] http://www.scienceofcooking.com/Oleic_Acid2.gif 2 February 2010

PLANNING AND DEVELOPMENT

While I was planning the experiment, I considered to use the acid-base titration for finding the amount of oleic acid in oil. As oleic acid is a type of acid, acid-base titration is the most appropriate method to find its amount. To indicate its amount in the oil it must be titrated with a strong base(KOH), which can be done with acid-base titration method.

Acid base titration is a method which allows quantitative analysis of the concentration of an unknown acid or base. In an acid-base titration an acid is titrated with a base or vice versa and neutralization occurs. The pH of equivalent point which is called end point(neutralization) can be estimated using following rules;

- A strong acid titrated with a strong base; pH=7
- A weak acid titrated with a strong base; pH>7
- A weak base titrated with a strong acid; pH<7

Acid-base titrations are done with specific indicators because of the difference of pH of solutions depending on strength of acid and base.

The main materials of acid-base titration is that;

A titrant(the solution which has a known concentration) and a analyte(unknown concentrated solution) are used. The analyte solution is put in erlenmayer flask and the solution that has a known concentration is put in burette. Besides an indicator is dropped into the erlenmeyer(the solution of unknown concentration) which gives a different colour when neutralization occurs. At the moment of neutralization the mole of acid is equal to the mole of base. According to this the unknown concentration is found by the equation;

$$n_{acid}=n_{base}$$

$$M_{acid}.V_{acid}=M_{base}.V_{base}$$

The volumes of acid and base are known and the acid/base concentration is known, so the unknown concentration can be found.

Equivalence point is the pH where amount of acid is amount of base, when the reagents have reached their stoichiometric ratio. On the other hand end point is

where the colour change happens. The closer the end point is to the equivalence point, the better the titration is done. Normally, in strong base-strong acid titration equivalence point is 7.00, but in weak acid-strong base titration it is above 8.00.

In a weak acid-strong base titration;

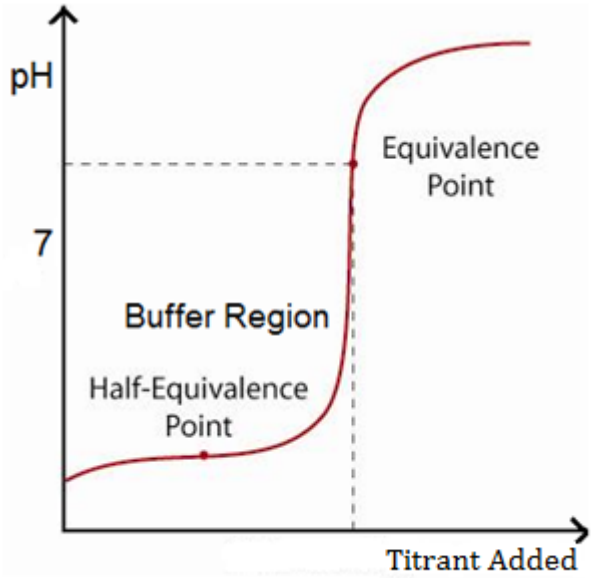
The initial pH in the erlenmeyer flask will be probably between 3-5 according to the weak acid. As the strong base is included to the flask the following reaction will occur;

$$HA(aq) + BOH(aq) \rightarrow BA(aq) + H_2O(l) \quad / \quad H^+ + OH^- \rightleftharpoons H_2O(l)$$

So that HA is gradually converted to BA^- to produce salt. In other words pH is increased gradually, and titrant(strong base) doesn't show much effect on pH. This region is called as buffer region because weak acid HA is converted to it's conjugate base A^- and it produces an absolute buffer solution on which, strong base has not much effect.

Buffer solution is an aquaeous solution of weak acid and its conjugate base or reverse which resist to sudden pH changes. It has a property of keeping the pH change at minimum level. Meaning that when an acid or base is added the pH of the solution changes very little. It is used when the pH is needed to stay constant. When half of the strong base is used to neutralize half of the weak acid, the concentration of weak acid equals to its conjugate base which is called as half-neutralisation point(half-equivalence point). At half equivalence point pH equals to pKa. pKa is -log(Ka) where Ka is the ionization constant for the partially ionized acid. At this point, half of the acid is deprotonated; so [HA]=[A-]. After that the pH of the solution increases rapidly than before half-neutralization point, but buffer region still continues. At the point of neutralization, when enough strong base is used to neutralize weak acid, pH of the solution rapidly increases because of strong base. In addition, the pH at the equivalence point is bigger than 7, which corresponds to the fact that is an aqueous solution of salt of a weak acid and strong base.[7]

[7] Green, John; Damji, Sadru, Chemistry, IBID, chapter 8, page 226 2 February 2010



Graph 1: Weak acid-strong base titration curve is shown .

In my experiment; I used 4 different types of oil; sunflower seed oil and corn oil (from the brand: Kırlangıç), virgin olive oil and genuine olive oil(from the brand: Kristal). As my research question is to find the amount of oleic acid in each one; I decided on a solution which I can titrate the acid solution(the oil) which is; 0.01 Molar(n-propanol solution including KOH. I use 0.01 Molar solution in order to gain the result more accurate and acceptable. As the n-propanol solution is an organic solution(includes C,H,O elements, molecular formula: C_3H_7OH and IUPAC name: propan-1-ol); I used glass burette because plastic ones reacts with organic solutions. I used phenolphtalein as indicator because my titrant is strong base and analyte is weak acid. Thus, the equivalent point the pH of the solution will be bigger than 7. In other words, phenolphtalein is an indicator which doesn't work in acidic solutions but gives pink colour in basic solutions because phenolphtalein is also a weak acid. I observed it from the experiment that I have done. So phenolphtalein is suitable for this titrations since it changes colour in the pH range of 8.3 to 10.0.

Why Do I used n-propanol solution including KOH?

n-propanol(propan-1-ol) is a primary alcohol which has a molecular formula of C_3H_7OH and fully miscible in water. On the other hand potassium hydroxide(KOH) is an inorganic compound which is a strong base and soluble in alcohol and glycerol.

I used n-propanol solution including KOH because KOH is soluble in alcohol, since n-propanol is a primary alcohol. Besides n-propanol and KOH doesn't react, thus chemical properties of KOH and n-propanol doesn't change. I didn't use water because water and oil makes an heterogenous solution so that KOH and oleic acid can not react effectively.

I used KOH as my titrant because it is one of the strongest bases and it can deprotonate very weak acids, even very weak acidic C-H groups in the absence of water.[5] Meaning that, KOH is the most aproppriate base to titrate oleic acid as oleic acid is a weak acid including C-H groups.

Why did I seperated procedures from each other?

As the experiment is accomplished with 4 different types of oil of 2 brands; I wanted to group each brand in itself. Different hpothesis and aim are also forced me to seperate the procedures. With Kırlangıç brand I only examined the oleic acid amounts in oils, but with Kristal brand I also searched if phenophtalein amount affects titration.

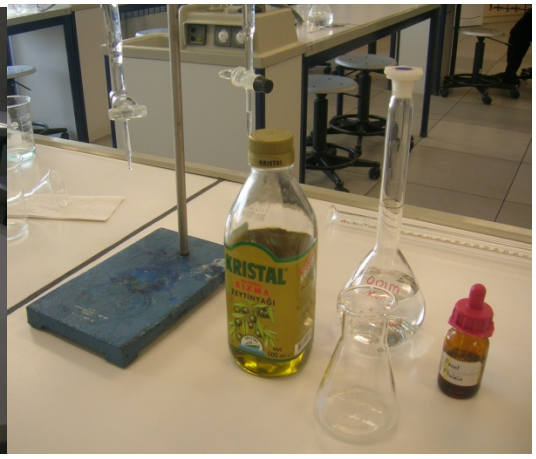
METHOD

Materials:

- 500.0 ml (±0.2 ml) of n-propanol solution including 0.01 M KOH
- 20 Erlenmayer flask(seperate for each trial-100 ml)
- Beaker(250 ml)
- 1 Glass Burette(50.0 ml±0.5)
- 4 plastic burette(50.0 ml±0.5)
- Phenolphtalein(25.0 ml±0.5/ 3-4 drops for each trial)
- 4 different types of oil(250.0 ml±0.5)
- Pipette(50.0 ml±0.2)
- Distilled water
- Thermometer(with a range of ± 0.5 °C)
- Barometer(±0.05 kPa)

I didn't indicate uncertainties of erlenmayer flask and beaker because I did all my volume measurements with burette. Erlenmayer flask and beaker was not important for measurements.

Picture 1: Some of the materials are shown.



Picture 2: The experiment setup and some materials are shown

Experiment 1: Determination of oleic acid amount in Sunflower Seed Oil.

- **Aim** of the experiment is to find the volume of n-propanol solution including KOH which neutralizes oleic acid in sunflower seed oil.
- **Hypothesis:** The oleic acid amount in sunflower seed oil will be the least between the four oils.
- **Constant Values:** Temperature, pressure, Molarity of n-propanol solution used as titrant, Volume of the oil, amount of the indicator, type of base, type of indicator.
- **Independent Variable(s):** the amount of n-propanol solution and pH of the solution.
- **Dependent variable(s):** amount of oleic acid.

Experiment 2: Determination of oleic acid amount in Corn Oil.

- **Aim** of this experiment is to find the volume of n-propanol solution including KOH which neutralizes oleic acid in the corn oil.
- **Hypothesis:** The oleic acid amount in Corn oil will be more than oleic acid amount in Sunflower seed oil.
- **Constant values:** Molarity of the solutions, temperature, volume of the oil, pressure, amount of the indicator, type of base, type of indicator, temperature, pressure.
- **Independent variable(s):** acid the amount of n-propanol solution and Ph of the solution.
- **Dependent variable(s):** amount of oleic.

Experiment 3: Determination of amount of oleic acid in Virgin Olive Oil and the effect of different amount of phenolphtalein.

- **Aim** of this experiment is to find the volume of n-propanol solution including KOH which neutralizes oleic acid in virgin olive oil and find if the amount of phenolphtalein affects the result.
- **Hypothesis:** Amount of oleic acid in virgin olive oil will be the less between 4 oils.
- **Constant values:** Molarity of the solutions, temperature, volume of the oil, pressure, type of base, type of indicator.
- **Independent variable(s):** the amount of n-propanol solution and the amount of phenolphtalein.
- **Dependent variables:** amount of oleic acid

Experiment 4: Determination of amount of oleic acid in Genuine Olive Oil and the effect of different amount of phenolphtalein.

- **Aim** of this experiment is to find the volume of n-propanol solution including KOH which neutralizes oleic acid in genuine olive oil and find if the amount of phenolphtalein affects the result.
- **Hypothesis:** The oleic acid amount in genuine olive oil will be more than in corn oil and sunflower oil but less than in virgin olive oil.
- **Constant values:** Molarity of the solutions, temperature, volume of the oil, pressure, type of base, type of indicator.
- **Independent variable(s):** the amount of n-propanol solution and the amount of phenolphtalein.
- **Dependent variables:** amount of oleic acid

NOTE THAT; PROCEDURES OF EACH OIL IS SEPERATED BY THEIR BRANDS ACCORDING TO COMMON HYPOTHESIS AND AIM, AND ALSO SHOWED IN 'APPENDIX 1' PART.

DATA COLLECTION

As I did the volumetric measurements just with burette I indicated the uncertainty of burette in each table.

EXPERIMENT 1: Sunflower seed oil (Brand: Kırlangıç)

Molarity of n-propanol solution including KOH: 0.01 M

Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Amount of Phenolphtalein (drops)	3	3	3	3	3
Used volume of KOH solution (ml, ± 0.05)	3.70	4.05	4.20	3.97	3.48

Table 1: Values of Phenolphtalein dropped into the oil and used volume of n-propanol solution including KOH are shown.

Temperature: 22.5± 0.5 °C

Pressure: 94.40 ±0.05 kPa

EXPERIMENT 2: Corn Oil (Brand: Kırlangıç)

Molarity of n-propanol solution including KOH: 0.01 M

Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Amount of Phenolphtalein (drops)	3	3	3	3	3
Used volume of KOH solution (ml, ± 0.05)	6.20	6.02	5.55	5.55	5.57

Table 2: Values of Phenolphtalein dropped into the oil and used volume of n-propanol solution including KOH are shown.

Temperature: 22.5± 0.5 °C

Pressure: 94.40 ±0.05 kPa

EXPERIMENT 3: Virgin Olive Oil (Brand: Kristal)

Molarity of n-propanol solution including KOH: 0.01 M

Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Amount of Phenolphtalein (drops)	3	3	4	4	4
Used volume of KOH solution (ml, ± 0.05)	44.40	44.80	45.20	45.12	44.65

Table 3: Values of Phenolphtalein dropped into the oil and used volume of n-propanol solution including KOH are shown.

Temperature: 22.5± 0.5 °C

Pressure: 94.40 ±0.05 kPa

EXPERIMENT 4: Genuine Olive Oil

Molarity of n-propanol solution including KOH: 0.01 M

Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Amount of Phenolphtalein (drops)	3	3	4	4	4
Used volume of KOH solution (ml, ± 0.05)	25.40	23.50	23.50	23.60	23.60

Table 4: Values of Phenolphtalein dropped into the oil and used volume of n-propanol solution including KOH are shown.

Temperature: 22.5± 0.5 °C

Pressure: 94.40 ±0.05 kPa

Qualitative Observations for all experiments:

All 4 oil has a different colour so that they can be distinguished from each other. They can be ranged lightest to darkest as sunflower seed oil, corn oil, genuine olive oil, virgin olive oil. When I started to titrate the oils they became blurred and had a lighter colour. Near to neutralization pink colour appeared but dissapeared immediately; but

after some drops of KOH solution pink colour stayed. The solution had a colour of light pink on the yellow phase. Also it was blurred. The initial colour concentration of the oils differ from each other. Genuine olive oil and Virgin olive oil have more concentrated colour with respect to corn oil and sunflowerseed oil.

DATA PROCESSING AND ANALYSIS

$M_{KOH} * V_{KOH} = n_{oleic}$ (mole of oleic acid in the oil)

1 mole oleic acid is→ 282.4614 g/mol[6]

n_{oleic} mole oleic acid is→ x grams

$$x = \frac{282.4614 \frac{g}{mole} * \text{n mole oleic}}{1} \text{grams (mass of oleic acid in n mole oleic)}$$

20 ml → x grams of oleic acid

1000 ml → y grams of oleic acid

$$y = \frac{1000ml * x\ grams}{20\ ml} grams(mass\ of\ oleic\ acid\ in\ one\ liter)$$

$$\frac{y\ grams}{mass\ of\ monounsaturated\ fatty\ acid\ in\ the\ oil} = \%\ percentage\ of\ oleic\ acid$$

Note that all calculations of all experiments are in 'Appendix 2' part.

Experiment 1: Sunflower seed Oil

	Mole of oleic acid in the oil ($*10^{-5}$ mole, ±0.05)	Amount of oleic acid per liter ($*10^{-1}$ grams)	Mean value ($*10^{-1}$ grams)	Percentage amount of oleic acid ($*10^{-3}$ grams)
Trial 1	3.70	5.22 ± %0.26	5.47 ± %0.22	5.90%
Trial 2	4.05	5.71 ± %0.26	5.47 ± %0.22	6.40%
Trial 3	4.20	5.93 ± %0.26	5.47 ± %0.22	6.70%
Trial 4	3.97	5.60 ± %0.26	5.47 ± %0.22	6.30%
Trial 5	3.48	4.91 ± %0.04	5.47 ± %0.22	5.50%

Table 5: The processed values of sunflower seed oil are shown in the table with their uncertainties and units. The numbers written before units(like $*10^{-3}$) are generalized to the column and should be noticed.

Example Calculation for Experiment 1:

Trial 1:

$(0.01)M*(3.70\pm 0.05)liter*10^{-3}=(3.70\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(3.70\pm 0.05)*10^{-5}$ mole x

$x=(1.04\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.04\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(5.22*10^{-1})\pm$ %0.26 grams

Experiment 2: Corn Oil

	Mole of oleic acid in the oil ($*10^{-5}$ mole, ±0.05)	Amount of oleic acid per liter ($*10^{-1}$ grams)	Mean value ($*10^{-1}$ grams)	Percentage amount of oleic acid ($*10^{-3}$ grams)
Trial 1	6.20	8.76± %0.27	8.16± %0.27	10.1%
Trial 2	6.02	8.50± %0.27	8.16± %0.27	9.80%
Trial 3	5.55	7.83± %0.27	8.16± %0.27	9.10%
Trial 4	5.55	7.83± %0.27	8.16± %0.27	9.10%
Trial 5	5.57	7.86± %0.27	8.16± %0.27	9.20%

Table 6: The processed data of corn oil are shown in the table with uncertainties and units. The numbers written before units(like $*10^{-3}$) are generalized to the whole column and should be noticed.

Example Calculation for Experiment 2:

Trial 3:

$(0.01)M*(5.55\pm 0.05)liter*10^{-3}=(5.55\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(5.55\pm 0.05)*10^{-5}$ mole x

$x=(1.56\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.56\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(7.83*10^{-1})\pm$ %0.27 grams

Experiment 3: Virgin Olive Oil

	Mole of oleic acid in the oil ($*10^{-5}$ mole, ±0.05)	Amount of oleic acid per liter ($*10^{-1}$ grams)	Mean value ($*10^{-1}$ grams)	Percentage amount of oleic acid ($*10^{-2}$ grams)
Trial 1	4.44	6.27± %0.26	6.33± %0.26	62.7%
Trial 2	4.48	6.33± %0.26	6.33± %0.26	63.3%
Trial 3	4.52	6.38± %0.26	6.33± %0.26	63.8%
Trial 4	4.51	6.37± %0.26	6.33± %0.26	63.7%
Trial 5	4.46	6.30± %0.26	6.33± %0.26	63.0%

Table 7: The processed data of virgin olive oil are shown in the table with uncertainties and units. The numbers written before units(like $*10^{-3}$) are generalized to the whole column and should be noticed.

Example Calculation for Experiment 4:

Trial 5:

$(0.01)M*(44.65 \pm 0.05)liter*10^{-3}=(4.46\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(4.46\pm 0.05)*10^{-4}$ mole x

$x=(1.26\pm0.05)*10^{-1}$ grams

20±0.05 ml $(1.26\pm0.05)*10^{-1}$ grams

1000 ml y

y= $6.30 \pm \%0.26$ grams

Experiment 4: Genuine Olive Oil

	Mole of oleic acid in the oil ($*10^{-5}$ mole, ±0.05)	Amount of oleic acid per liter ($*10^{-1}$ grams)	Mean value ($*10^{-1}$ grams)	Percentage amount of oleic acid ($*10^{-2}$ grams)
Trial 1	2.54	3.59± %0.34	3.38± %0.33	35.8%
Trial 2	2.35	3.32± %0.33	3.38± %0.33	33.1%
Trial 3	2.35	3.32± %0.33	3.38± %0.33	33.1%
Trial 4	2.36	3.33± %0.33	3.38± %0.33	33.0%
Trial 5	2.36	3.33± %0.33	3.38± %0.33	33.0%

Table 7: The processed data of virgin olive oil are shown in the table with uncertainties and units. The numbers written before units(like $*10^{-3}$) are generalized to the column and should be noticed.

Example Calculation for Experiment 4:

Trial 2:

$$(0.01)M*(23.50\pm 0.05)liter*10^{-3}=(2.35\pm 0.05)*10^{-4}\ mole$$

1 mole 282.4614 g/mol

$(2.35\pm 0.05)*10^{-4}$ mole x

$$x=(6.64\pm0.05)*10^{-1}\ grams$$

20±0.05 ml $(6.64\pm0.05)*10^{-1}$ grams

1000 ml y

$$y= 3.32 \pm \%0.33\ grams$$

CONCLUSION AND EVALUATION

With regard of having suspicions on acidity of oils, I have generated a research question of finding the oleic acid amount of 4 different oils, as oleic acid determines the acidity of oil, by using acid-base titration. The results of the experiment supported my hypothesis.

Considering the chemical properties of oleic acid and my research question, I have formed an acid-base titration method which helped me to find the amount and percentage of oleic acid in the oil after a few calculations. I used n-propanol solution including KOH to indicate the amount of oleic acid, such that oleic acid is a weak acid and KOH is a strong base, thus it brings me to the method; acid base titration. Because of having an unknown analyte oil including a weak acid(oleic acid) acid-base titration was the most appropriate method which is explained in detail in Planning part.

To find the difference of oleic acid amounts in different oils, I took 4 different types of oils, the two from 2 different brands; Kırlangıç and Kristal, and investigated the acidities of them. To have more accurate and precise values I took 0.01 M n-propanol solution including KOH and 20 mililiters of each oil. When the experiment is done with 0.1 M n-propanol solution the results become very small such could not accepted as scientific. As I used two different brands, I have analyzed the accuracy of the brands which have indicated certain literature values of oleic acid amounts on their information part at the back.

I prefferred to use 20 mililiters of each oil in order to have enough KOH solution to titrate oleic acid in the oil. On the other hand I used phenolphtalein as indicator of acid-base titration because titration of a weak acid and strong base concludes with a equivalence point of pH bigger than 7, thus phenolphtalein is the most approppriate indicator with the range of 8.3 to 10.0.

In addition I used phenolphtalein not much as it is also a weak acid and can affect the titration of oleic acid and KOH, causing errors.

After I titrated each oil by 5 trials, I observed that I used KOH solution to neutralize oleic acid in the increasing order of; sunflower seed oil, corn oil, genuine olive oil and virgin olive oil. Also I observed qualitatively that the colour of the oil darkens when

oleic acid amount increases in the oil. After calculating the values the percentages of oleic acid proved the qualiitative observations quantitatively.

The literature values of the oils about fatty acid percentage with respect to oleic acid, written on the back of the bottles, are;

Sun flower seed oil(Brand:Kırlangıç): maximum %0.3
Corn Oil(Brand:Kırlangıç): maximum %0.3
Virgin Olive Oil(Brand:Kristal): maximum %0.8
Genuine Olive Oil(Brand:Kristal): maximum %1

The summary of experimental data

	Average Percentage of Experimental Value (grams)	Literature Value (maximum)	Error
Sunflower seed oil	6.16%(*10^{-3})	0.30%	6.02%
Corn Oil	9.46%(*10^{-3})	0.30%	4.66%
Virgin Olive Oil	63.30%(*10^{-2})	0.80%	0.57%
Genuine Olive Oil	34.60%(*10^{-2})	1.00%	2.55%

Table 8: Average values of experimental values, literature value and errors are shown.

In comparison with the results of the experiment, the values supported the literature values, meaning that the results are accurate with respect to the literature values. In addition to error propagation ı also calculated the accuracy of experimental procedure.

According to error propagation, the values of all experiments are mostly precise. The errors of Virgin Olive Oil are the least, thus data of this oil is most precise.

The percentage errors of the four experiment showed that the results are mostly accurate with respect to literature value and mean value. On the other hand percentage errors are calculated as approximately %10 in some trials. This could be because of the systematic and random errors.

As phenolphtalein is a weak acid, it could have affected the acidity of the oil(in response to oleic acid). Because of this, another acid-base indicator which had a

basic pH range could have been used in order to prevent interaction between indicator and weak acid. This can be another research question for further investigation.

As n-propanol is a type of alcohol it is much more volatile with respect to other liquids. Because of this it could have vapourized while I was performing the experiment. Thus, vapourization of n-propanol could have caused errors on results. Due to this error source, a non-volatile solution could be used. KOH is soluble in alcohol and glycerine. Glycerine could have been used instead of n-propanol.

My percentage errors could have been because of;

- My sensitivity to the colour change, meaning that I could have stopped to drop KOH solution late. This causes more KOH to drop into the oil causing excess amount of KOH(darker pink). To prevent this I prepared a solution having standard pink colour and compared all my solutions with it by using white paper to have a better observation.
- Misreading the volume of KOH solution after neutralization. Also n-propanol solution including KOH could have vapourized a little amount, so I could not have read the exact value.
- The phenolphtalein and oil solution in the erlenmeyer flask could not have mixed enough causing neutralization at wrong time.
- Even though I used cold water bath the temperature could have changed. The equilibrium could have changed because of this. The reaction rate could have increased, disabling met o observe the changes during titration.

The results showed that the percentage amount of oleic acid is;
Virgin olive oil>Genuine olive oil>Corn oil>Sunflower seed oil

According to these results oil selection in daily usage has outshined, meaning that different oleic acid amounts in different oils can cause or provide disadvantages or advantages. Oleic acid has positive and negative effects on human health. It can hinder the progression of ADL, Adrenoleukodystrophy, a fatal disease that affects brain and adrenal glands. On the other hand, great amount of oleic acid, like oleic acid amount in Virgin Olive Oil, can be responsible for hypothensive(blood pressure

reducing) effects of olive oil and breast cancer.[8] Oleic acid amount higher than %2.0 in oil makes it inedible, whereas grape seed oil and sea buckthorn oil includes 15-20% of oleic acid.[9]

Another effects of oleic acid on human health are; it can lower cholesterol level and increase levels of HDL, while decreasing level of LDL, known as bad cholesterol. Also it prevents development of heart disease and it is used in production of antioxidants. Oleic acid is used in soap and some cosmetics.[10]

[8] http://en.wikipedia.org/wiki/Oleic_acid#Health_effects 2 February 2010
[9] http://en.wikipedia.org/wiki/Oleic_acid#Occurrence 2 February 2010
[10] http://www.wisegeek.com/what-is-oleic-acid.htm 2 February 2010

BIBLIOGRAPHY AND REFERENCES

1. Oleic acid, Wikipedia <http://en.wikipedia.org/wiki/Oleic_acid> 2 February 2010
2. Fox, Marry Anne; Whitesell, James K. , Organic Chemistry, 3rd Edition, London: Jones and Barltett, 2004
3. Oleic acid, Wikipedia,< http://en.wikipedia.org/wiki/Oleic_acid >2 February 2010
4. Chemistry of Oleic Acid, Wikipedia, <http://en.wikipedia.org/wiki/Oleic_acid#Chemistry> 2 February 2010
5. Structure of Oleic Acid, Wikipedia, <http://commons.wikimedia.org/wiki/File:Oleic-acid-3D-vdW.png> 2 February 2010
6. Chemical structure of oleic acid, <http://www.scienceofcooking.com/Oleic_Acid2.gif> 2 February 2010
7. Green, John; Damji, Sadru, Chemistry, 3rd Edition. IBID Press, Victoria: 2008
8. Oleic acid, health, Wikipedia, <http://en.wikipedia.org/wiki/Oleic_acid#Health_effects> 2 February 2010
9. Oleic acid, occurence, Wikipedia, <http://en.wikipedia.org/wiki/Oleic_acid#Occurrence> 2 February 2010
10. Effects of Oleic acid on health, <http://www.wisegeek.com/what-is-oleic-acid.htm >2 February 2010

Appendix 1:

Procedures Of Kırlangıç And Kristal Brands

- **Procedure: For Kırlangıç brand**
  (For Sunflower seed oil and Corn oil)
  1. I checked the pressure from Local Meteorology Institute in order to control the pressure variable and at the beginning of each experiment and during the experiment I controlled pressure values from school lab barometer.
  2. I took one of the plastic burettes and put the sunflower seed oil into it up to 0. To have 20 ml of each oil I used 4 different plastic burettes for each oil, because oil is not very fluent liquid so that obtaining oil in erlenmeyer by using burette was the easiest way and this also decreases error.
  3. I put one of the erlenmayer of 100 ml±20 under the burette and opened the stopcock.
  4. I poured 20.0 ml±0.5 of the sunflower seed oil/corn oil and closed the stopcock.
  5. I took the glass burette and fill it with n-propanol solution including 0.01 M KOH up to 0. I used glass burette in order to prevent reaction between plastic and n-propanol solution. I have paid attention to use glass burette for n-propanol solution because of the basic solution which includes organic compund, n-propanol, reacts with plastic when they are contacted.
  6. I measured temperature by using thermometer. I recorded them. The temperature must be kept constant as neutralization is an exothermic reaction. If temperature is increased or lowered equilibrium would be affected.
  7. As neutralization is an exothermic reaction I prepared a cold water bath setup to keep the tempreature constant.
  8. I kept the room temperature and pressure constant by preventing airflow.
  9. I dropped 3 drops of phenolphtalein into the oil(erlenmeyer flask) and mixed the phenolphtalein with the oil by shaking the erlenmeyer. Be careful not to slop the mixture. Place the tap of the burette in erlenmayer flask in order to avoid the solution spill outside. At the beginning the solution is colourless as phenolphtalein doesn't react with acid. Phenolphtalein takes reaction with basic solutions. The full neutralization doesn't occur so the solution hasn't become basic.
  10. After that I put the erlenmeyer under the burette. After the mechanism is ready, I opened the stopcock of the burette narrow and the solution of known concentration starts to pour by small drops into the erlenmayer.

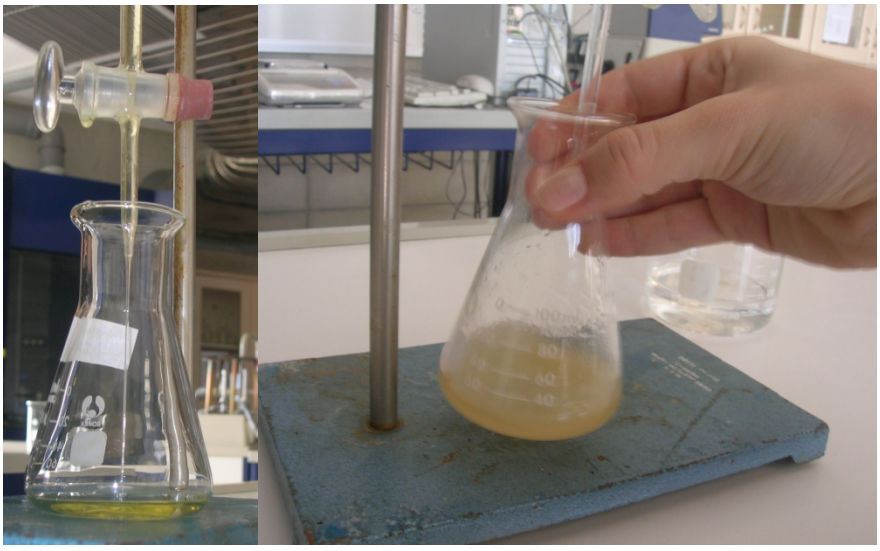
11. While the solution is pouring drop by drop swing the erlenmeyer continually under the burette in order to mix the drop with the oil fastly.
12. When some light pink is observed in the erlenmeyer, close the stopcock immediately but continue to swing the flask.
13. If the colour dissappeared open the stopcock again and continue to drop n-propanol solution.(the colour must stay at least 20 seconds to record the value)
14. When pink colour appears and stays while you swing it, it means that it is the point of neutralization. The change in colour must be observed fast to close the stopcock at the exact moment of neutralization. The change in colour must stay at least 20 seconds in order to record the data.
15. Read the value from the burette and I record the value.
16. I repeated the steps 4 times with new erlenmeyer filled with same amount of sunflower seed oil.
17. Be sure you have 5 different trials.
18. Repeat steps 1 to 16 for corn oil.

Picture 3: Burettes are shown. One of them is filled with n-propanol solution, the other one is filled with oil.

- **Procedure: For Kristal brand**
  (For Virgin Olive Oil and Genuine Olive Oil)
  1. I took a plastic burette and put virgin olive oil in it up to 0.
  2. I took an erlenmeyer flask and fill it with 20.00±0.05 ml of virgin olive oil in it by using the burette. To have 20 ml of each oil I used 4 different plastic burettes for each oil, because oil is not very fluent liquid so that obtaining oil in erlenmeyer by using burette was the easiest way.
  3. I took the glass burette and put n-propanol solution including KOH up to 0. I used glass burette in order to prevent reaction between plastic and n-propanol solution. I have paid attention to use glass burette for n-propanol solution because of the basic solution which includes organic compund, n-propanol, tooks reaction with plastic when they are contacted.
  4. I put 3 drops of phenolphtalein in the erlenmeyer flask and shake it. At the beginning the solution is colourless as phenolphtalein doesn't react with acid. The solution hasn't become basic yet.
  5. I measured temperature by using thermometer. I recorded it. The temperature must be kept constant as neutralization is an exothermic

reaction. If temperature is increased or lowered equilibrium would be affected.

6. As neutralization is an exothermic reaction I prepared a cold water bath setup to keep the tempreature constant.
7. I kept the room temperature and pressure constant by preventing airflow.
8. I took the solution under the burette. After the mechanism is ready, I opened the stopcock of the burette narrow and the solution of known concentration starts to pour by small drops into the erlenmayer.
9. While the KOH solution is dropping shake the erlenmeyer flask continually.
10. When light pink colour is observed I close the stopcock immediately and continue to shake the erlenmeyer. If the colour dissappeared after 20-25 seconds I put the erlenmeyer under the burette and continue to drop n-propanol solution. If not I stopped dropping n-propanol from the burette.
11. When the pink colour stays steady I read the value from the burette and I recorded. the change in colour must be observed fast to close the stopcock at the exact moment of neutralization. The change in colour must stay at least 20 seconds in order to record the data.
12. I repeated the steps one more time.
13. After 2nd trial put 4 drops of phenolphtalein in the virgin olive oil(in erlenmeyer flask) and observed if there is a change in results in 3rd,4th and 5th trials. Do the same steps except phenolphtalein amount. I took down the values.
14. Repeat steps 1 to 13 for Genuine olive oil.



Picture 4 and 5: The burette and erlenmeyer flask is shown while pouring and mixing.

APPENDIX 2:

Calculations:

Experiment 1: Sunflower seed oil (Brand: Kırlangıç)

Trial 1:

$(0.01)M*(3.70\pm 0.05)liter*10^{-3}=(3.70\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(3.70\pm 0.05)*10^{-5}$ mole x

$x=(1.04\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.04\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(5.22*10^{-1})\pm$ %0.26 grams

Trial 2:

$(0.01)M*(4.05\pm 0.05)liter*10^{-3}=(4.05\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(4.05\pm 0.05)*10^{-5}$ mole x

$x=(1.14\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.14\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(5.71*10^{-1})\pm$ %0.26 grams

Trial 3:

$(0.01)M*(4.20\pm 0.05)liter*10^{-3}=(4.20\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(4.20\pm 0.05)*10^{-5}$ mole x

$x=(1.18\pm0.05)*10^{-2}$ grams

20 ± 0.05 ml $(1.18\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(5.93*10^{-1})\pm$ %0.26 grams

Trial 4:

$(0.01)M*(3.97\pm 0.05)liter*10^{-3}=(3.97\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(3.97\pm 0.05)*10^{-5}$ mole x

$x=(1.12\pm0.05)*10^{-2}$ grams

20 ± 0.05 ml $(1.12\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(5.60*10^{-1})\pm$ %0.26 grams

Trial 5:

$(0.01)M*(3.48\pm 0.05)liter*10^{-3}=(3.48\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(3.48\pm 0.05)*10^{-5}$ mole x

$x=(9.82\pm0.05)*10^{-2}$ grams

20±0.05 ml $(9.82\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(4.91*10^{-1})\pm$%0.037grams

Experiment 2: Corn Oil (Brand: Kırlangıç)

Trial 1:

$(0.01)M*(6.20\pm 0.05)liter*10^{-3}=(6.20\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(6.20\pm 0.05)*10^{-5}$ mole x

$x=(1.75\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.75\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(8.76*10^{-1})\pm$ %0.27 grams

Trial 2:

$(0.01)M*(6.02\pm 0.05)liter*10^{-3}=(6.02\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(6.02\pm 0.05)*10^{-5}$ mole x

$x=(1.70\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.70\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(8.50*10^{-1})\pm$ %0.27 grams

Trial 3:

$(0.01)M*(5.55\pm 0.05)liter*10^{-3}=(5.55\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(5.55\pm 0.05)*10^{-5}$ mole x

$x=(1.56\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.56\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(7.83*10^{-1})\pm$ %0.27 grams

Trial 4:

$(0.01)M*(5.55\pm 0.05)liter*10^{-3}=(5.55\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(5.55\pm 0.05)*10^{-5}$ mole x

$x=(1.56\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.56\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(7.83*10^{-1})\pm$ %0.27 grams

Trial 5:

$(0.01)M*(5.57\pm 0.05)liter*10^{-3}=(5.57\pm 0.05)*10^{-5}$ mole

1 mole 282.4614 g/mol

$(5.57\pm 0.05)*10^{-5}$ mole x

$x=(1.57\pm0.05)*10^{-2}$ grams

20±0.05 ml $(1.57\pm0.05)*10^{-2}$ grams

1000 ml y

$y=(7.86*10^{-1})\pm$ %0.27 grams

Experiment 3: Virgin Olive Oil (Brand: Kristal)

Trial 1:

$(0.01)M*(44.40\pm 0.05)liter*10^{-3}=(4.44\pm 0.05)*10^{-4}$ mole

1 mole	282.4614 g/mol
$(4.44\pm 0.05)*10^{-4}$ mole	x

$x=(1.25\pm0.05)*10^{-1}$ grams

20±0.05 ml	$(1.25\pm0.05)*10^{-1}$ grams
1000 ml	y

y= 6.27 ± %0.26 grams

Trial 2:

$(0.01)M*(44.80\pm 0.05)liter*10^{-3}=(4.48\pm 0.05)*10^{-4}$ mole

1 mole	282.4614 g/mol
$(4.48\pm 0.05)*10^{-4}$ mole	x

$x=(1.26\pm0.05)*10^{-1}$ grams

20±0.05 ml	$(1.26\pm0.05)*10^{-1}$ grams
1000 ml	y

y= 6.33 ± %0.26 grams

Trial 3:

$(0.01)M*(45.20\pm 0.05)liter*10^{-3}=(4.52\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(4.52\pm 0.05)*10^{-4}$ mole x

$x=(1.28\pm0.05)*10^{-1}$ grams

20 ± 0.05 ml $(1.28\pm0.05)*10^{-1}$ grams

1000 ml y

y= $6.38 \pm$ %0.26 grams

Trial 4:

$(0.01)M*(45.12\pm 0.05)liter*10^{-3}=(4.51\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(4.51\pm 0.05)*10^{-4}$ mole x

$x=(1.27\pm0.05)*10^{-1}$ grams

20 ± 0.05 ml $(1.27\pm0.05)*10^{-1}$ grams

1000 ml y

y= $6.37 \pm$ %0.26 grams

Trial 5:

$(0.01)M*(44.65 \pm 0.05)liter*10^{-3}=(4.46 \pm 0.05)*10^{-4}$ mole

1 mole	282.4614 g/mol
$(4.46 \pm 0.05)*10^{-4}$ mole	x

$x=(1.26 \pm 0.05)*10^{-1}$ grams

20±0.05 ml	$(1.26 \pm 0.05)*10^{-1}$ grams
1000 ml	y

$y = 6.30 \pm \%0.26$ grams

Experiment 4: Genuine Olive Oil (Brand:Kristal)

Trial 1:

$(0.01)M*(25.40 \pm 0.05)liter*10^{-3}=(2.54 \pm 0.05)*10^{-4}$ mole

1 mole	282.4614 g/mol
$(2.54 \pm 0.05)*10^{-4}$ mole	x

$x=(7.17 \pm 0.05)*10^{-1}$ grams

20±0.05 ml	$(7.17 \pm 0.05)*10^{-1}$ grams
1000 ml	y

$y = 3.59 \pm \%0.34$ grams

Trial 2:

$(0.01)M*(23.50\pm 0.05)liter*10^{-3}=(2.35\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(2.35\pm 0.05)*10^{-4}$ mole x

$x=(6.64\pm0.05)*10^{-1}$ grams

20±0.05 ml $(6.64\pm0.05)*10^{-1}$ grams

1000 ml y

y= 3.32 ± %0.33 grams

Trial 3:

$(0.01)M*(23.50\pm 0.05)liter*10^{-3}=(2.35\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(2.35\pm 0.05)*10^{-4}$ mole x

$x=(6.64\pm0.05)*10^{-1}$ grams

20±0.05 ml $(6.64\pm0.05)*10^{-1}$ grams

1000 ml y

y= 3.32 ± %0.33 grams

Trial 4:

$(0.01)M*(23.60\pm 0.05)liter*10^{-3}=(2.36\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(2.36\pm 0.05)*10^{-4}$ mole x

$x=(6.66\pm0.05)*10^{-1}$ grams

20±0.05 ml $(6.66\pm0.05)*10^{-1}$ grams

1000 ml y

---

y= 3.33 ± %0.33 grams

Trial 5:

$(0.01)M*(23.60\pm 0.05)liter*10^{-3}=(2.36\pm 0.05)*10^{-4}$ mole

1 mole 282.4614 g/mol

$(2.36\pm 0.05)*10^{-4}$ mole x

$x=(6.66\pm0.05)*10^{-1}$ grams

20±0.05 ml $(6.66\pm0.05)*10^{-1}$ grams

1000 ml y

---

y= 3.33 ± %0.33 grams

APPENDIX 3:

Error Propagation:

Experiment 1: Sunflower seed oil (Brand: Kırlangıç)

$$\frac{(5.22*10^{-1})+(5.71*10^{-1})+(5.93*10^{-1})+(5.60*10^{-1})+(4.91*10^{-1})}{5}$$

$$=\frac{27.4*10^{-1}}{5} = 5.47*10^{-1}\ \text{gr (mean value)}$$

ERROR CALCULATIONS

$$\frac{|\text{expected}|-|\text{observed}|}{|\text{expected}|}*100$$

1) $\frac{5.47*10^{-1} - 5.22*10^{-1}}{5.47*10^{-1}}*100 = 4.57\%$

2) $\frac{5.71*10^{-1} - 5.47*10^{-1}}{5.47*10^{-1}}*100 = 4.38\%$

3) $\frac{5.93*10^{-1} - 5.47*10^{-1}}{5.47*10^{-1}}*100 = 8.41\%$

4) $\frac{5.60*10^{-1} - 5.47*10^{-1}}{5.47*10^{-1}}*100 = 2.38\%$

5) $\frac{5.47*10^{-1} - 4.91*10^{-1}}{5.47*10^{-1}}*100 = 10.20\%$

Experiment 2: Corn Oil (Brand: Kırlangıç)

$$\frac{(8.76*10^{-1})+(8.50*10^{-1})+(7.83*10^{-1})+(7.83*10^{-1})+(7.86*10^{-1})}{5}$$

$$= \frac{40.78*10^{-1}}{5} = 8.16*10^{-1}\ \text{gr (mean value)}$$

ERROR CALCULATIONS

$$\frac{|\text{expected}|-|\text{observed}|}{|\text{expected}|}*100$$

1) $\frac{8.76*10^{-1} - 8.16*10^{-1}}{8.16*10^{-1}}*100 = 7.35\,\%$

2) $\frac{8.50*10^{-1} - 8.16*10^{-1}}{8.16*10^{-1}}*100 = 4.17\,\%$

3) $\frac{8.16*10^{-1} - 7.83*10^{-1}}{8.16*10^{-1}}*100 = 4.04\%$

4) $\frac{8.16*10^{-1} - 7.83*10^{-1}}{8.16*10^{-1}}*100 = 4.04\,\%$

5) $\frac{8.16*10^{-1} - 7.86*10^{-1}}{8.16*10^{-1}}*100 = 3.68\,\%$

Experiment 3: Virgin olive oil (Brand: Kristal)

$$\frac{6.27 + 6.33 + 6.38 + 6.37 + 6.30}{5}$$

$$= \frac{31.65}{5} = 6.33 \text{ gr (mean value)}$$

ERROR CALCULATIONS

$$\frac{|\text{expected}| - |\text{observed}|}{|\text{expected}|} * 100$$

1) $\frac{6.33 - 6.27}{6.33} * 100 = 0.94\,\%$

2) $\frac{6.33 - 6.33}{6.33} * 100 = 0\ \%$

3) $\frac{6.38 - 6.33}{6.33} * 100 = 0.79\,\%$

4) $\frac{6.37 - 6.33}{6.33} * 100 = 0.63\,\%$

5) $\frac{6.33 - 6.30}{6.33} * 100 = 0.47\,\%$

Experiment 4: Genuine olive oil (Brand: Kristal)

$$\frac{3.59 + 3.32 + 3.32 + 3.33 + 3.33}{5}$$

$$= \frac{16.89}{5} = 3.38 \text{ gr (mean value)}$$

ERROR CALCULATIONS

$$\frac{|\text{expected}| - |\text{observed}|}{|\text{expected}|} * 100$$

1) $\frac{3.59 - 3.38}{3.38} * 100 = 6.21\%$

2) $\frac{3.38 - 3.32}{3.38} * 100 = 1.80\ \%$

3) $\frac{3.38 - 3.32}{3.38} * 100 = 1.80\ \%$

4) $\frac{3.38 - 3.33}{3.38} * 100 = 1.48\ \%$

5) $\frac{3.38 - 3.33}{3.38} * 100 = 1.48\ \%$