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Allium cepa L and *Allium sativum L* as olfactory indicators for acid-base olfactory titration for visually impaired chemistry students

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Abstract
The use of *Allium cepa L* and *Allium sativum L* bulbs extract as olfactory indicators for visually impaired Chemistry students as an alternative to Methyl Orange and Phenolphthalein indicators have been established.
It is confirmed that *Allium cepa L* and *Allium sativum L* extracts are a better substitute for synthetic indicators in Strong Acid-Strong Base titration for concentrations of 0.1M, 0.5M, 1M and 2M HCl and NaOH respectively.
The mean titre values for titration of 0.1 M HCl and 0.1M NaOH using *Allium cepa L* and Methyl orange were 15.1667 and 15.1333 with S.D Error of 0.06667, signifying that *Allium cepa L* can replace Methyl orange. The mean titre values for all the indicators used for 0.5M HCl: 0.5M NaOH showed a great significant difference.
For titration of 1M HCl:1M NaOH, the mean titre values of 2.9667 for *Allium cepa L*.; 3.0667 for *Allium sativum L*; 3.2000 for Phenolphthalein and 3.1333 for Methyl orange were recorded. The results revealed an almost total concordant. Interestingly, the mean titre values of 2M HCl: 2M NaOH were *Allium cepa L* = 5.000; *Allium sativum L* = 5.000 and Phenolphthalein = 5:000, thus the two indicators can replace Phenolphthalein. The mean titre value using Methyl orange for the same 2M concentrations of HCl: NaOH was 24:000, Thus there is a very significant difference in the mean titre values. *Allium cepa L* and *Allium sativum L* bulbs extracts are of economic benefits as there are affordable, bioavailable, bioactive, ecofriendly, ease of preparation, and gives accuracy and same precision with the synthetic indicators.

Keywords: *Allium cepa L, Allium sativum L*,, Acid-Base Olfactory Titration, Methyl Orange and Phenolphthalein.

1. Introduction
In a bid to search for a better and alternative indicator for teaching acid-base titration to the inclusion of visually impaired and disadvantaged chemistry students who might have difficulties in reading end points of neutralization reaction via meniscus on burettes due to color blindness, chemists have introduced the concepts of chemistry and smell. (Kerry et al, 2005; Flair and Seltzer, 1990)
This is to ensure that color blind chemistry students who might have difficulties with visual indicators like Methyl orange and Phenolphthalein etc., are not excluded from chemistry experiments like Acid- base titration which are solely dependent on visual indicators.
In a research titled 'An Olfactory indicator for Acid-Base titration, A laboratory Technique for visually impaired, Flair and Setzer, (1990), introduced the concept of chemistry and smell otherwise known as Olfaction. This was to diversify Acid-Base titration away from the chemistry and sight which has been the norm.
Wood and Roberta, (1996), re-iterated that the Olfactory titration is carried out in the presence of both the visual and olfactory indicators respectively to enable the chemistry students compare the times at which the two very direct indicators signals the end-point of the neutralization reactions.
These novel indicators are employed to help the students detect when the neutralization of Acid- Base are completed by the olfaction rather than by the conventionally visually reading

of the meniscus in the burettes. The student employs his sense of smell to detect the end-point from the stench in the acid-base mixture in the Erlenmeyer flask.

Kerry et al, (2005), carried out an in-depth study on olfactory titration on Garlic (*Allium sativum L*), Onion (*Allium cepa L*) Vanillin as acid-base olfactory indicators. From their investigation, results showed that *Allium cepa L, Allium sativum L* and Vanillin can be employed to serve as olfactory indicators for students with color blindness. This is because their results were in tandem with visual color indicators like Methyl orange and Phenolphthalein.

In a study to compare olfactory indicator from onion bulb extract and Methyl orange and Phenolphthalein in Olfactory Titration for Visually impaired students, Andy and Gideon, 2014 reported the effectiveness of onion extracts as a good indicator that can aid students in understanding the principles of Acid-Base Volumetric analysis.

Olfactory indicators aid in determination of the Acidity or basicity of a solution by changing its smell rather than it colors. (Andy and Gideon, (2014). Substances often used as olfactory indicators are Eugenol, Thymol, Vanillin and Thiophenol, (Flair and Setzer, (1990); Cloves, MPTET Varg2Science, (2019); Onions, Clove oil and Vanillin extract

1.1. The Chemistry of *Allium cepa L* (Onion)

Onion (*Allium cepa L*) is a member of the family *Amaryllidaceae* and one of the most widely cultivated species of the genus *Allium*. Onion has plentiful chemical compounds such as allicin, quercetin, fisetin, and other sulphurous compounds: diallyl disulphide and diallyl trisulphide Mahyar et al, (2021) The common bulbing onion (*Allium cepa L*) is reported to have been cultivated for the past 5000 years in part of the world. Timothy, (2007). The *Allium* genius also contain several other species commonly referred to as onion. They are cultivated as food, such as Japanese bunching Onion (*A. fistolosum*), Moses and Gideon, (2014). Onions contain phenolics and flavonoids, anti-cholesterol and anti-oxidant properties. Narshan, et al, (2021)

Chemical formula of *Allium cepa L*. C_3H_6SO Name: - Syn-propanethial-S-Oxide.

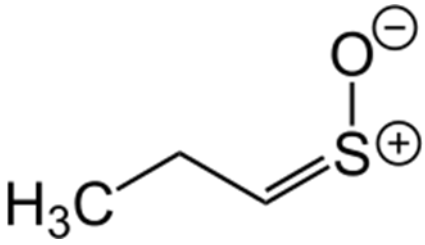


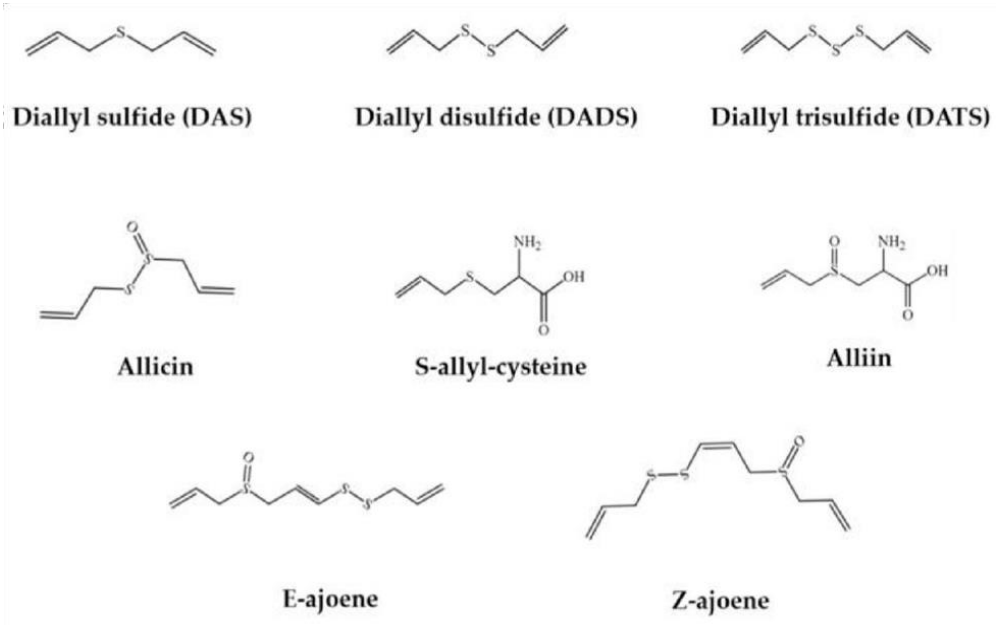
Fig 1: Structure of *Allium cepa L*. From Wikipedia, the free encyclopedia.

Allium cepa L is said to be an olfactory indicator with two and a distinct ordors in the presence of an acid and ordorless in an alkaline medium. It retains it ordor in an acidic medium. (Andy and Gideon, 2014)

1.2. The Chemistry of Garlic (*Allium sativum L)*

Garlic (*Allium sativum L)* is a member of the *Liliaceae* family. (Omar and Al-Wabel, 2010). Garlic contains diverse bioactive compounds, such as allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine. (Ao-Shang, et al, 2019). It is scientifically called *Allium sativum L* with the main compound Allicin. Chemical formula

$C_6H_{10}S_2O$ Fig. 2-9 are various chemical structures of the diverse bioactive compounds of *Allium sativum L*. Courtesy of Ao-Shang, et al, (2019)



The allicin is said to possess an ordoriferous, unstable anti-bacterial substances. Angewandte, (1992).

The sulphur containing compound of *Allium sativum L* are responsible for both it pungent ordor and many of its medicinal effect. Dirsh et al, (1998); Omar and Al-Wahal, 2010

1.3. Hypothesis

The following null hypothesis were stated and tested.

HO:- There is no significant difference between the mean titre values of the results obtained for Olfactory Titration using *Allium cepa L* and *Allium sativum L* olfactory indicators and those obtained for visual Acid-Base Titration using Methyl orange and Phenolphthalein with same concentrations of 0.1M, 0.5M, 1M and 2M HCl and NaOH respectively.

2.Research Methodology

The research was carried out in the Chemistry laboratory of the College of Education, Zing, Taraba State, Nigeria. The Primary method adopted for the study was the experimental design.

2.1Materials

2.1.1 Reagents, Apparatus and Equipment

The principal raw materials employed in the study was macerated bulbs of *Allium cepa L* and *Allium sativum L*. All reagents used in the experimental work were of analytical grade. These includes Hydrochloric acid (HCl, 33-36%, NaOH 98%)

Visual indicators were Methyl orange, $C_{14}H_{14}N_3NaO_3S$, Phenolphthalein ($C_{2O}H_{14}O_4$). The instruments that were used in the study were Electronic analytical balance. The following apparatus and equipment such as Erlenmeyer flask, 250ml, 250ml beakers, burette 50ml, pipette, 10ml ,25ml, graduating measuring cylinders, 10ml, 20ml, Whatman filter paper No 41, funnel, retort stand and clamp. Pestle and mortar, distilled water and a knife

2.2 Sample collection and preparation of *Allium cepa L* and *Allium sativum L.*

Ten *Allium cepa L* and *Allium Sativum L* bulbs were purchased from Zing local Market of Zing Local Government Area of Taraba State.

2.3 Extraction of *Allium cepa L* and *Allium sativum L* as Olfactory Indicators

2.3.1. *Allium cepa L* Olfactory Indicator Extraction

50 g of *Allium cepa L* bulbs were washed and weighed on a top balance. The weighed *Allium cepa L* were macerated and triturated in a mortar with pestle. The macerated and triturated samples were dissolved in 200ml of distilled water in a 250 ml beaker for aqueous extraction. The mixture was stored for 24 hours at room temperature. The extract was filtered with

Whatman filter paper and preserved in tight closed bottle and stored away from sunlight to prevent photolysis and decomposition. (Nhapi, 2016, Sintayehu and Baye, 2020), to be used as olfactory indicators for acid-base olfactory titration.

2.3.1. *Allium sativum L* Olfactory Indicator Extraction

50 g of *Allium sativum L* bulbs were washed and weighed on a top balance. The weighed *Allium sativum L* were macerated and triturated in a mortar with pestle. The macerated and triturated samples were dissolved in 200ml of distilled water in a 250 ml beaker for aqueous extraction. The mixture was stored for 24 hours at room temperature. The extract was filtered with Whatman filter paper and preserved in tight closed bottle and stored away from sunlight to prevent photolysis and decomposition. (Nhapi, 2016, Sintayehu and Baye, 2020), to be used as olfactory indicators for acid-base olfactory titration.

3.Application of *Allium cepa L and Allium sativum L* as Olfactory Indicator for HCl and NaOH Olfactory Tiration.

50 ml of 0.1M, 0.5M, 1M and 2M dil HCl from the burette were titrated with 25ml of 0.1M, 0.5M, 1M and 2M of NaOH solution in a 250ml Erlenmeyer flask and 3 drops of the indicators were added.

The results of the titrations are recorded in Tables 3.1 to 3.16 respectively.

Table 3.1:- 0.1MHCl:0.1MNaOH with 3 drops *Allium cepa L* Olfactory Indicator (ACLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	13.10	26.20	39.50
Initial Reading	0.00	13.10	26.20
Vol of HCl used	13.10	13.10	13.30

Mean Titre Value (MTV)= $\frac{13.10+13.10}{2}$ =26.20/2 = 13.10 cm^3

Table 3.2:- 0.1MHCl:0.1MNaOH with 3 drops Allium sativum L Olfactory Indicator (ASLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	13.20	26.40	39.80
Initial Reading	0.00	13.20	26.40
Vol of HCl used	13.20	13.20	13.40

Mean Titre Value (MTV)= $\frac{13.20+13.20}{2}$ =26.40/2 = 13.20 cm^3

Table 3.3:- 0.1MHCl:0.1MNaOH with 3 drops Methyl orange Indicator (MOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	15.20	30.00	45.20
Initial Reading	0.00	15.20	30.00
Vol of HCl used	15.20	14.80	15.20

Mean Titre Value (MTV)= $\frac{15.20+15.20}{2}$ =30.40/2 = 15.20 cm^3

Table 3.4:- 0.1MHCl:0.1MNaOH with 3 drops Phenolphthalein Indicator (PhPhI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	15.10	30.60	46.00
Initial Reading	0.00	15.10	35.50
Vol of HCl used	15.10	15.50	15.50

Mean Titre Value (MTV)= $\frac{15.50+15.50}{2}$ =31.00.20/2 = 15.50 cm^3

Table 3.5:-0.5MHCl:0.5MNaOH with 3 drops *Allium cepa L* Olfactory Indicator (ACLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	18.10	36.20	36.00
Initial Reading	0.00	18.10	18.20
Vol of HCl used	18.10	18.10	17.80

Mean Titre Value (MTV)= $\frac{18.10+18.10}{2}$ =36.20/2 = 18.10 cm^3

Table 3.6:- 0.5MHCl:0.5MNaOH with 3 drops *Allium sativum L* Olfactory Indicator (ASLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	17.30	34.00	34.00
Initial Reading	0.00	17.30	17.30
Vol of HCl used	17.30	16.70	16.70

Mean Titre Value (MTV)= $\frac{16.70+16.70}{2}$ =33.40/2 = 16.70 cm^3

Table 3.7:- 0.5MHCl:0.5MNaOH with 3 drops Methyl Orange Indicator (MOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	28.10	28.30	28.30
Initial Reading	0.00	0.00	0.00
Vol of HCl used	28.10	28.30	28.30

Mean Titre Value (MTV)= $\frac{28.30+28.30}{2}$ =56.60/2 = 28.30 cm^3

Table 3.8:- 0.5MHCl:0.5MNaOH with 3 drops Phenolphthalein Indicator (PhPhI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	34.10	34.10	34.20
Initial Reading	0.00	0.00	0.00
Vol of HCl used	34.10	34.10	34.20

Mean Titre Value (MTV)= $\frac{34.10+34.10}{2}$ =68.20/2 = 34.10 cm^3

Table 3.9:- 1MHCl:1MNaOH with 3 drops *Allium cepa L* Olfactory Indicator (ACLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	2.90	5.90	8.90
Initial Reading	0.00	2.90	5.90
Vol of HCl used	2.90	3.00	3.00

Mean Titre Value (MTV)= $\frac{3.00+3.00}{2}$ =6.00/2 = 3.00 cm^3

Table 3.10:- 1MHCl:1MNaOH with 3 drops *Allium sativum L* Olfactory Indicator (ASLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	3.10	6.10	9.20
Initial Reading	0.00	3.10	6.10
Vol of HCl used	3.10	3.00	3.10

Mean Titre Value (MTV)= $\frac{3.10+3.10}{2}$ =6.20/2 = 3.10 cm^3

Table 3.11:- 1MHCl:1MNaOH with 3 drops Methyl Orange Indicator (MOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	3.40	6.40	9.40
Initial Reading	0.00	3.40	6.40
Vol of HCl used	3.40	3.00	3.00

Mean Titre Value (MTV)= $\frac{3.00+3.00}{2}$ =6.00/2 = 3.00 cm^3

Table 3.12:- 1MHCl:1MNaOH with 3 drops Phenolphthalein Indicator (PhPhI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	3.00	6.30	9.60
Initial Reading	0.00	3.00	6.30
Vol of HCl used	3.00	3.30	3.30

Mean Titre Value (MTV)= $\frac{3.30+3.30}{2}$ =6.60/2 = 3.30 cm^3

Table 3.13:- 2MHCl:2MNaOH with 3 drops *Allium cepa L* Olfactory Indicator (ACLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	5.00	10.10	15.10
Initial Reading	0.00	5.00	10.00
Vol of HCl used	5.00	5.10	5.10

Mean Titre Value (MTV)= $\frac{5.10+5.10}{2}$ =10.20/2 = 5.10 cm^3

Table 3.14:- 2MHCl:2MNaOH with 3 drops *Allium sativum L* Olfactory Indicator (ASLOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	4.00	8.00	12.00
Initial Reading	0.00	4.00	8.00
Vol of HCl used	4.00	4.00	4.00

Mean Titre Value (MTV)= $\frac{4.00+4.00}{2}$ =8.00/2 = 4.00 CM^3

Table 3.15:- 2MHCl:2MNaOH with 3 drops Methyl Orange Indicator (MOI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	24.00	48.00	24.00
Initial Reading	0.00	24.00	0.00
Vol of HCl used	24.00	24.00	24.00

Mean Titre Value (MTV)= $\frac{24.00+24.00}{2}$ =48.00/2 = 24.00 cm^3

Table 3.16:- 2MHCl:2MNaOH with 3 drops Phenolphthalein Indicator (PhPhI).

Burette	Aliquot 1 cm^3	Aliquot 2 cm^3	Aliquot 3 cm^3
Final Reading	2.00	4.00	6.00
Initial Reading	0.00	2.00	4.00
Vol of HCl used	2.00	2.00	2.00

Mean Titre Value (MTV)= $\frac{2.00+2.00}{2}$ =4.00/2 = 2.00 cm^3

4.0 Results and Discussion

4.1 Application of olfactory indicators of *Allium cepa L* and *Allium sativum L* extracts in Acid-Base Olfactory titration and Comparing with Methyl Orange and Phenolphthalein visual indicators.

Table 3.1 to Table 3.16 shows the results of the olfactory Titration of 0.1M, 0.5 M, 1M and 2M HCl and 0.1M, 0.5M 1M, and 2M NaOH respectively, and using *Allium cepa L* and *Allium sativum L* olfactory indicators and Methyl Orange and Phenolphthalein. The mean titre values obtained from the studies coincided with that of visual synthetic indicators, Methyl Orange and Phenolphthalein. They indicated colorless solution at the end-points just as Phenolphthalein. These results concurred with Flair and Setzer, (1990), Wood and Roberts, (1996), Kerry et al, (2005) and Andy and Sofeme, (2015)

4.2 Test of Hypothesis

HO There is no significant difference between the mean titre values of results obtained for Olfactory titrations of 0.1M, 0.5M, 1M and 2M HCl and 0.1M, 0.5M, 1M and 2M NaOH using *Allium cepa L* and *Allium sativum L* Olfactory indicators and those obtained using Methyl orange and Phenolphthalein visual indicators respectively.

Tables 4..2.1 to Table 4.2.4 shows the mean titre values of titration of 0.1M, 0.5M, 1M and 2M HCl and 0.1M, 0.5M, 1M and 2M NaOH using ACLOI, ASLOI, MeO and PhPh, S.D, and S.D Error

The results from these tables gives the test for the Hypothesis.

Table 4.2.1: - The Mean titre values of titration of 0.1M HCl: 0.1M NaOH Using ACLOI, ASLOI, MeO, PhPh, S.D and S.D Error.

S/N	No of Titration	Conc M	Indicator	MTV	S.D	S.D Erro
1	3	0.1	ACLOI	15.1667	0.11547	0.06667
2	3	0.1	ASLOI	13.0000	0.00000	0.00000
3	3	0.1	MeO	15.3667	0.23094	0.13333

4	3	0.1	PhPh	15.1333	0.11547	0.06667

From the results in the table 4.2.1 above the MTV of Olfactory titration of 0.1M HCl: 0.1M NaOH using ACLOI and PhPh indicators are 15.1667 and 15.1333 with and S.D of 0.11547 shows that there is no difference in the mean titre values of olfactory titration using ACLOI and PhPh for Concentrations of 0.1M of HCl and NaOH respectively. The hypothesis is accepted. Therefore, ACLOI can be used in place of Phenolphthalein.

ACLOI can also be used in place of Methyl orange. The mean titre values of ASLOI are way below those of Methyl orange and Phenolphthalein. The hypothesis is rejected for ASLOI.

Table 4.2.2: - The Mean titre values of titration of 0.5M HCl: 0.5M NaOH Using ACLOI, ASLOI, MeO, PhPh, S.D and S.D Error.

S/N	No of Titration	Conc M	Indicator	MTV	S.D	S.D Erro
1	3	0.5	ACLOI	18.0667	0.05774	0.03333
2	3	0.5	ASLOI	17.3000	0.00000	0.00000
3	3	0.5	MeO	28.2333	0.11547	0.06667
4	3	0.5	PhPh	13.1667	0.04557	0.03333

Table 4.2.2 shows a marked difference in the mean titre values obtained from Olfactory titration using 0.5M HCl: 0.5M NaOH, signifying that there is a significant difference between the mean titre values obtained using ACLOI, ASLOI, MeO and PhPh in 0.5M HCl:0.5M NaOH Olfactory titration respectively. Thus, the Hypothesis is rejected for concentrations of HCl and NaOH 0.5M.

Table 4.2.3: - The Mean titre values of titration of 1M HCl: 1M NaOH Using ACLOI, ASLOI, MeO, PhPh, S.D and S.D Error.

S/N	No of Titration	Conc M	Indicator	MTV	S.D	S.D Erro
1	3	1	ACLOI	2.9667	0.05774	0.03333
2	3	1	ASLOI	3.0667	0.05774	0.03333
3	3	1	MeO	3.2000	0.17321	0.10000
4	3	1	PhPh	3.1333	0.23094	0.13333

Table 4.2.3 shows that the mean titre values for the olfactory titration of 1MHCl:1M NaOH using both the two olfactory indicators and the two visual indicators are almost the same. Thus, signifying that there is no difference between the mean titre values using ACLOI, ASLOI, MeO and PhPh indicators. Therefore, the Null Hypothesis is rejected when using the 1M HCl: 1M NaOH concentrations. Thus, ACLOI and ASLOI can be used in place of MeO and PhPh for concentrations of 1M HCl and 1M NaOH

Table 4.2.4: - The Mean titre values of titration of 0.5M HCl: 0.5M NaOH Using ACLOI, ASLOI, MeO, PhPh, S.D and S.D Error.

S/N	No of Titration	Conc M	Indicator	MTV	S.D	S.D Erro
1	3	2	ACLOI	5.0000	0.00000	0.00000
2	3	2	ASLOI	5.0000	0.00000	0.00000
3	3	2	MeO	5.0000	0.00000	0.00000
4	3	2	PhPh	13.166	0.00000	0.00000

Results from Table 4.2.4 shows that the mean titre values for olfactory titration of 2M HCl and 2M NaOH using ACLOI, ASLOI and PhPh indicator are the same. This shows that there is no mean difference between the mean titre values obtained using ACLOI and ASLOI and that obtain using PhPh. The null Hypothesis is rejected.

Conclusion

Acid-base titration in Chemistry laboratory is often carried out using visual indicators like Methyl orange, Methyl red and Phenolphthalein etc. These synthetic indicators have their short comings. For instance, end points of titrations are determined by colour change in the reaction mixture of the Acid-base. Students with visual impairment will always have difficulties reading the endpoint from the meniscus of the burette. Therefore, the address this anomaly, the research adapts an alternative indicator for such students known as the olfaction indicators where such students will deploy their sense of smell to determine the end point of Acid-Base neutralization reaction. The study was to investigate whether *Allium cepa L* and *Allium sativum L* can be used as alternative to Methyl orange and Phenolphthalein indicators respectively. From the results of the study, Allium *cepa L* and *Allium Sativum L* are better Olfactory indicators. They can be used in the absence of Methyl orange and Phenolphthalein.

Appreviation:-*MTV-Mean titre vaue *S.D –Standard Deviation *S.D Error- Standard Deviation Error *ACLOI-*Allium cepa* L Olfactory Indicator *ASLOI-*Allium sativum L* Olfactory Indicator *MeO- Methyl orange *PhPh- Phenolphthalein

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