THE USE OF DIFFERENT PLANT PIGMENTS FROM FLOWERS AND FRUITS AS ACID-BASE TITRATION INDICATORS

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DECLARATION

I Opolot Henry Joseph declare that this research project report is my original work and has not been submitted anywhere for the award of a degree where other people's work was used, this has been acknowledged and cited according to the University policy

Signature: ……………………… Date: 20th/08/2024……………………

OPOLOT HENRY JOSEPH

APPROVAL

This research project report has been submitted for examination with my approval as his University supervisor.

Signature: ……………………… Date: 20/08/2024……………………

DR. KAMOGA OMAR

DEDICATION

This report is dedicated to my mother Mrs Omoding Racheal and my father Mr Omoding Francis, who have supported and guided me spiritually, physically, emotionally and financially in achieving my academic vision. Special thanks also to Dr Kamoga Omar (My Supervisor), for his tirelessly support in my academic journey. Not forgetting Mrs Akantorana Precious for having always guided me in my academic life. This research is also dedicated to fellow chemistry students for their special time, support and cooperation exhibited for the success of my research.

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I give special thanks to God Almighty for the far he has brought me through academic career due to His might and grace. Thank you, Lord!

To Dr. Kamoga Omar, I am very grateful for the hard work you put into this study and the sacrifices that you made to see me finish this work. Thank you very much Dr. Kamoga Omar for your endless support, motivation and encouragement through continuous guidance. This motivated me to work tirelessly to complete the study. Thank you for always availing yourself to see this work progressing. May God bless you more wisdom to serve nations.

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ABSTRACT

This study aimed to determine the pKa values of plant pigments extracted from selected fruits and flowers and evaluate their suitability as natural pH indicators in various acid-base titrations. The research involved extracting pigments from species such as Peacock flower, Mexican Sunflower, Cascabela, Spectabilis, Eggplant, Apple, Tomato, and Lantana, followed by their application in titrations involving NaOH vs. HCl, NaOH vs. CH_3COOH, NH_4OH vs. HCl, and NH_4OH vs. CH_3COOH. The pH of neutralization was determined for each titration, and the corresponding pKa values were calculated. The effectiveness of each pigment as an indicator was assessed based on the alignment of the pKa values with the pH at the point of neutralization and the clarity of the observed color changes.

The results revealed that pigments from the Mexican Sunflower, Cascabela, and Apple were particularly effective as natural indicators, exhibiting clear color transitions such as brown to colorless and yellow to colorless, with pKa values closely matching the titration endpoints. In contrast, Lantana pigments were found unsuitable for all titrations due to significant discrepancies between their pKa values and the neutralization points, resulting in unclear color changes. The study highlights the potential of these natural pigments as eco-friendly alternatives to synthetic indicators, especially in educational and environmentally conscious applications.

Based on these findings, the study recommends further research into additional plant species to expand the pool of effective natural indicators and refine extraction methods to optimize yield and purity. The potential for wider application of these pigments in areas such as pH-sensitive packaging, food, and cosmetics is also suggested. This research underscores the viability of using natural substances in chemical processes, contributing to more sustainable laboratory practices and offering valuable teaching tools in educational settings.

CHAPTER 1.0: INTRODUCTION

1.1 Background

In Uganda, the greatest problem faced by the science education department is the increasing scarcity and high costs of science teaching materials. This has made implementation of practicals/experiments in secondary schools and universities difficult which has reduced on the potential of students' science knowledge (Nannyonjo, 2007).

Acid-base titration is very important in science education mostly in the Chemistry practical syllabus. It involves the determination of concentration of sample acid or base by neutralizing either the acid or base and are carried out using a piece of equipment called a burette. In acid-base titrations, the analyte (titrand) is the solution with unknown molarity and the reagent (titrant) is the solution with a known molarity that will react with the analyte(Ayodele, Hawa, & Tawakalitu, 2020). During acid-base titrations, indicators are used to determine the equivalent points between the reacting reagents. The major indicators used today are synthetic meaning they are man-made chemical substances made in the laboratory of which are used to determine pH of a substance. They include phenol red, methyl red, methyl yellow, bromophenol blue, thymol blue, methyl orange and phenolphthalein(S. Sharma, 2007). These indicators are expensive and slightly have toxic effects to the people using them and the environment as well. Therefore due to this, scientists are embarking on using natural indicators from plants pigments which are readily available, easy to prepare and environment friendly. Some of these plant extracts have worked as indicators and have been found to be accurate and precise at equivalent points in acid-base titrations(Ntoi, 2016). However, knowing the pKa values of these plant extracts is very paramount so as to come up with the right choice of indicator for a given acid-base titration since these indicators are generally weak acids. Their pKa values can be obtained using the titration method(LaManna, 1987).

1.2 Problem Statement

The pKa values of plant pigments derived from flowers and fruits are a significant aspect of Chemistry. These Ka values can offer important information about the chemical characteristics of these pigments which are beneficial in the field of producing natural indicators. However, the lack of extensive data on the pKa values of these plant pigments poses a challenge/threat to further research and utilization in this field. As a result, there is pressing need for a systematic exploration and determination of the pKa values of the variety of plant pigments that can be used to make indicators to bridge this knowledge gap as these flower extracts have very simple, cost-effective, environment friendly extraction procedure and excellent performance with sharp colour change in end points of the titrations, it would be possible to replace the standard indicators being used in conventional laboratories with natural flower indicators.

1.3 Hypothesis

1.3.1 Null Hypothesis

The selected fruits and flowers are acid-base indicators.

1.3.2 Alternative Hypothesis

The selected fruits and flowers are not acid-base indicators.

1.4 Objective of the study

1.4.1 General objective

To determine the pKa values of the plant pigments found in the selected fruits and flowers.

1.4.2 Specific objectives

1. To extract the pigments of the selected plant flowers and fruits.
2. To determine the pH at the point of neutralization of different acid-base titrations.
3. To calculate the pKa value for the different extracts obtained from the selected plant fruits and flowers.

1.5 Scope of the study

1.5.1 Geographical scope

This research was done in Nagongera village, Tororo district in Uganda.

1.5.2 The content scope

This research focused on the determination of the pKa values of plant pigments found in the selected fruits and flowers. That is, four flowers (*Thevetia cascabela*, *Senna spectabilis, Mexican sunflower* & *peacock flower*) and four fruits *(eggplant, apple, tomato & lantana berries).*

1.5.3 Time scope

This research was carried out in a period of three months that is to say from November, 2023 to April, 2024.

1.6 Significance of the study

This research gave information about the pKa values of the plant pigments of the selected plant fruits and flowers which can be helpful to the scientists who produce indicators to come up with indicators suitable to a given acid-base titration with ease having known their pH working ranges.

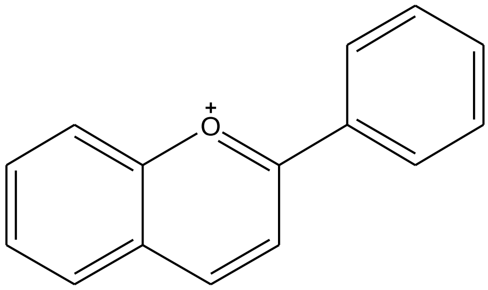
1.7 Justification

There are challenges faced during acid-base titrations by an individual carrying out an experiment if he/she carried out an experiment without choosing the right indicator suitable for the titration. He/she is most likely to obtain inaccurate results. Therefore knowing the pKa value of an indicator is very paramount before choosing an indicator to use for a given acid-base titration.

CHAPTER 2.0: LITERATURE REVIEW

Both flowers and fruits have pigments that are responsible for their colouration and these pigments are mainly flavonoids and anthocyanins. These pigments are very sensitive to pH and due to such they show different colours at different pH because they are very unstable. They exhibit different colours in acidic or alkaline medium(Martín, Navas, Jiménez-Moreno, & Asuero, 2017).

Anthocyanins are water soluble pigments which are responsible for the attractive colours of plant fruits and flowers. They have the given chemical structure;



Anthocyanins are acidic aromatic compounds and the most common phenolic acids in anthocyanin molecules are malonic, acetic, malic, succinic, and oxalic acids(Wrolstad, 2004).

Thus these substances (anthocyanins& lycopenes) give a sharp distinct and stable colour change on a change from acid to alkaline medium. Therefore, they can be used acid-base indicators in volumetric analysis(Nuryanti, Matsjeh, Anwar, Raharjo, & Hamzah, 2013). These pigments can be extracted from the plant fruits; *Solanum melongena*(eggplant), *Malus domestica* (apple), *Solanum lycopersicum* (tomato) and lantana berries and flowers; *Caesalpinia pulcherrima*(peacock) flower, *Tithona diversifolia* (Mexican sunflower), *Senna spectabilis*(cassia) flower and *Thevetia cascabela*(yellow oleander)flower.

2.1 Fruits

2.1.1 Apple

The plant is known as *Malus domestica* cultivated worldwide and are the most widely grown species in the genus *Malus(Kellerhals, 2009)*. It originated in Central Asia, where its wild ancestor, *Malus sieversii* is still existing. It is a flowering plant that is deciduous mostly standing about 2-5 metres tall on land where it is cultivated. It bears fruits classified under pomes which mature in late summer or autumn. The fruits are typically round or spherical and some are more elongated(Velasco et al., 2010). They are green at an early stage and become red on ripening due to the presence of anthocyanin (the red pigmentation all over the skin of the apple is due to accumulation of anthocyanin). An apple fruit when ripe can be eaten and it does need to be cooked for it to be eaten by man.

Figure 2.1: *Showing raw apples*

Figure 2.2: *Showing ripe apples*

2.1.2 Egg plant

This plant is commonly known as *Solanum melongena* which grows about 40 to 150 cm tall, with large, coarsely lobed leaves that are about 10 cm long and 5 cm broad and grow to a height of about 200 cm on cultivated land(Rubatzky, Yamaguchi, Rubatzky, & Yamaguchi, 1997). It is a flowering plant that bears fruits which are eaten while raw or while cooked just like tomatoes by man(Ghosh, 2022). Its fruits botanically classified as berries that are green while young and become white to purple in colour while mature. The fruits are spongy, long and cylindrical in shape with a broad base and a narrow top(Ghosh).

Figure 2.3: *Showing raw eggplants*

Figure 2.4: *Showing ripe eggplants*

2.1.3 Tomato

It is botanically known *as Solanum lycopersicum*. Tomato is a perennial herbaceous plant but it is often grown as an annual crop even if biennial and perennial forms exist. Tomato is cultivated in tropical and temperate climates in open field or under greenhouse in temperate climate(Gopalakrishnan, 2007).

The tomato is a flowering plant whose fruit is globular or ovoid. Botanically, the fruit exhibits all of the common characteristics of berries; a simple fleshy fruit that encloses its seed in the pulp. The outer skin is a thin and fleshy tissue that comprises the remainder of the fruit wall as well as the placenta. The fruit turns into red colour when it matures(Bangerth, 2009).

Figure 2.5**:** *Showing Ripe Tomatoes*

2.1.4 Lantana Camara berries

The fruit is a berry-like drupe which are small, fleshy and turn from green to dark purple when mature(Singh, Singh, Meghwal, Singh, & Swamy, 2014). They are 5-8mm in diameter and very numerous on one head, each one seeded.

Figure 2.6: *Showing raw lantana berries*

Figure 2.7: *Showing ripe lantana berries*

2.2 Flowers

2.2.1 Mexican Sunflower.

It is botanically known as *Tithona diversifolia*. T diversifolia is a woody herb or succulent shrub, 1.2-3 m tall(Githinji, 2018). Opposite leaves (3-5), attenuate base, acute apex, crenate margin. Leaf size is 5-17 x 5-12 cm, densely pubescent beneath, palmate venation. Occasionally upper leaves are unloaded. Flowers are yellow, their ray size is 306 cm x 5-18 mm. The flower heads are solitary on a peduncle 6-13 cm long. Each mature stem may bear several flowers at the top of branches(Githinji, 2018).

*Figure 2.8**:** Showing Mexican Sunflower*

2.2.2 Senna spectabilis

Senna spectabilis, also known as the golden wonder tree, American cassia, popcorn tree, golden shower tree, or Archibald's cassia, is a medium to large tree with bright yellow flowers that bloom in the summer(Rauk, 2019). The flowers are 1.5 inches wide and appear in dense racemes up to two feet long(Minnesota, 1913). The plant has pinnately compound leaflets that are three inches long and have fuzzy undersides. The cylindrical seedpods are 12 inches long.

Figure 2.9: *Showing Senna spectabilis*

2.2.3 Thevetia Cascabela

Cascabela thevetia is an evergreen tropical shrub or small tree. Its leaves are willow-like, linear-lanceolate, and glossy green in colour(Sahu, Nayak, Sahu, & Roul, 2022). They are covered in waxy coating to reduce water loss (typical of oleanders). Its stem is green turning silver/gray as it ages. Flowers bloom from summer to fall. The long funnel-shaped sometimes-fragrant yellow (less commonly apricot, sometimes white) flowers are in few-flowered terminal clusters. Its fruit is deep red-black in colour(Boddupalli, 2021).

Figure 2.10: Showing *Thevetia Cascabela*

2.2.4 Peacock Flower

It is botanically known as *Caesalpinia pulcherrima*. It is Shrub to 3-4 m tall, the branches with short scattered prickles(Davison, 1989). Leaves alternate bipinnate, pinnae 4-8 pairs, each with 7-11 pairs of elliptic, obtuse, obliquely inequilateral light green leaflets about 2-2.5 cm long; flowers are red-and-yellow, the petals crinkly-edged, in long terminal racemes and it is several-seeded where seeds are compressed, brown and usually 6-8 per pod(V. Sharma, 2010). It is a flowering plant whose flowers are red-and-yellow, bowl-shaped, and 2–3 inches across. They have five crinkled, unequal red and orange petals, and ten prominent bright red stamens(Alamgir & Alamgir, 2017).

Figure 2.11: *Showing Peacock Flower*

CHAPTER 3.0: METHODS AND MATERIALS

3.1 Research design

This research involved the use of four flowers (*Senna spectabilis*, *Thevetia cascabela*, *Mexican sunflower and peacock flower*) and four fruits (*apple, tomato, lantana berries and eggplant*) with the determination of the pKa values of the extracts got from the selected plant fruits and flowers.

3.2 Sampling

Four flowers (*Senna spectabilis*, *Thevetia cascabela*, *Mexican sunflower and peacock flower*) and four fruits (*apple, tomato, lantana berries and eggplant*) were selected where they were freshly obtained in a period of one week from the villages of Tororo District and were prepared for laboratory work.

3.3 Study area

The study area covered Tororo district in Eastern Uganda because it is where the Faculty of science and education, Nagongera campus was located(Matthysse & Colbo, 1987).

Figure 3.12: *Showing the location of villages in Tororo District.*

3.4 Materials

The apparatus that were used in this research are; filter papers, beakers, test tubes, pestle and motor, kitchen knife, filter funnels, pH meter, stirrer, and test tube racks. The main reagents that were used include; sodium hydroxide, ammonium hydroxide, hydrochloric acid, ethanoic acid, ethanol and distilled water.

3.5 Sample collection

Sample collection was done for one week from the gardens, bushes and markets. Samples of fresh flowers and fruits were got directly from the garden and bushes by detaching the flowers from their stalks using a knife.

3.6 Preparation of the collected sample

3.6.1 For flowers

The petals of collected flowers were rinsed with distilled water and then sundried.

The dried petals were then blended into powder form using the lab mill.

10g of powder of each flower were poured in four different beakers and in each beaker was added 50ml of ethanol and the solutions were kept for 72 hours in a cool dark place.

After the 72 hours, the solution from each beaker was added into other four beakers each filled with 5ml of distilled water.

The resultant solution from each beaker was then filtered into a clean and dry beaker. The filtrates in each beaker were the acid-base indicators required(Ayodele et al., 2020).

3.6.2 For fruits

3.6.2.1 Case I: Apples and Eggplants

The apples (4) and eggplants (4) were thoroughly cleaned with distilled water.

They were peeled and the peelings were chopped into small pieces and were put in two different beakers where one beaker had apple peelings and the other had eggplant peelings.

To each beaker 100ml of distilled water was added and then boiled at $90^{o}C$ for 1 hour.

After 1 hour, the solutions were then cooled after which the peelings were carefully removed and the solutions were filtered using a filter paper.

The resultant coloured solutions in the filtrate were the acid-base indicators required and now were ready to be used(Ayodele et al., 2020).

3.6.2.2 Case II: Tomato

Four ripe tomatoes were cleaned with distilled water and then chopped into small pieces.

The chopped pieces were then crushed using a clean mortar and a pestle then filtered using a sieve to obtain the filtrate which was the acid-base indicator.

3.6.2.3 Case III: Lantana Berries

20g of Lantana berries were thoroughly cleaned with distilled water, then put in a clean dry beaker and 100ml of distilled water was added and then heated at 90°C for 1 hour.

The solution was then cooled, filtered using a filter paper into a clean- dry beaker to obtain the filtrate which was the acid-base indicator required for acid-base titrations.

3.6.3 Procedure:

0.1M of HCl, NaOH, NH_4OH and CH_3COOH were prepared as follows;

Preparation of 0.1M Hydrochloric Acid (HCl)

To prepare 0.1M HCl, 8.33 mL of concentrated HCl (12M) was measured and diluted to 1 liter with distilled water in a volumetric flask. The solution was mixed thoroughly.

Preparation of 0.1M Sodium Hydroxide (NaOH)

4 grams of NaOH pellets were dissolved in distilled water and diluted to 1 liter in a volumetric flask to prepare the 0.1M NaOH solution. The solution was mixed thoroughly.

Preparation of 0.1M Acetic Acid (CH3COOH)

5.75 mL of glacial acetic acid (17.4M) was measured and diluted to 1 liter with distilled water in a volumetric flask to obtain 0.1M CH3COOH. The solution was mixed thoroughly.

Preparation of 0.1M Ammonium Hydroxide (NH4OH)

To prepare 0.1M NH4OH, 6.76 mL of concentrated NH4OH (14.8M) was measured and diluted to 1 liter with distilled water in a volumetric flask. The solution was mixed thoroughly.

Thereafter,

10ml of 0.1M NaOH was pipetted into a clean beaker and the burette was filled up to the zero mark with 0.1M HCl.

The initial pH of NaOH in beaker was read from the pH meter and recorded.

5 drops of the Peacock flower indicator were added into the beaker and the colour change was noted.

From the burette was released $0.5cm^3$ of 0.1M HCl into the beaker, shaken gently as the pH of the solution was read and recorded together with the colour.

$0.5cm^3$ of the acid was continually added into the beaker while shaking gently as the pH of the solution was read and recorded together with the colour.

The titration was done until the solution became acidic.

The steps above were repeated for the titration of 0.1M CH_3COOH & 0.1M NaOH, 0.1M CH_3COOH & 0.1M NH_4OH and 0.1M HCl & 0.1M NH_4OH using the peacock flower as an indicator.

The same procedure was used for the remaining flower extracts (*Mexican sunflower*, *Senna spectabilis* & *Thevetia cascabela*) and fruit extracts (*apple*, *eggplant*, *tomato* & *lantana*) indicators.

CHAPTER 4.0: RESULTS AND DISCUSSION

4.1 Results for Flower Extracts

The pKa was obtained by taking the average of the pH values where the colour change occurred.

4.1.1For the Peacock Flower Extract

Table 4.1: Peacock extract as an indicator in the titration of 0.1M HCl & 0.1M NaOH

Volume of Pipette used= 10ml

Volume of acid added(cm^3)	pH	Colour-Change
0	12.24	Green
0.5	11.21	Green
1	4.82	Brown
2	2.51	Brown
2.5	1.64	Brown

pKa = $\frac{11.21 + 4.82}{2}$

Hence, pKa = 8.02

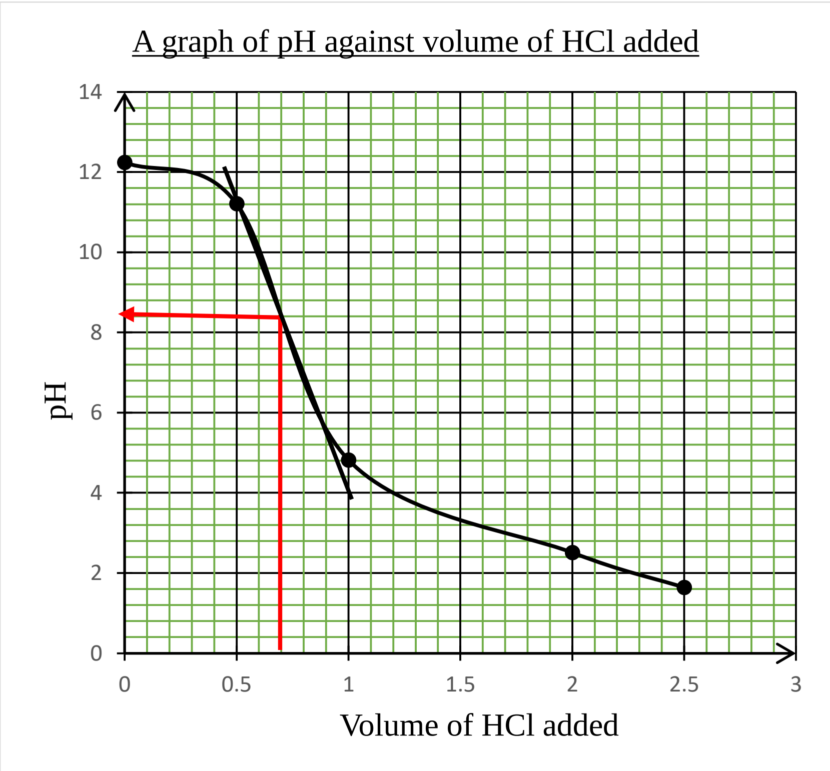


Figure 4.1: A graph of pH against volume of HCl added for peacock flower extract indicator

From the graph, pH= 8.2

Table 4.2: Peacock extract as an indicator in the titration of 0.1M CH_3COOH & 0.1M NaOH

Volume of pipette used= 10ml

Volume of acid added(cm3)	pH	Colour-Change
0	12.29	Green
0.5	12.16	Green
1	12.06	Green
1.5	11.93	Green
2	11.75	Brown
2.5	11.44	Brown
3	11.02	Brown
3.5	10.6	Brown
4	9.98	Brown
4.5	8.35	Brown
5	6.41	Brown
5.5	5.79	Brown
6	5.64	Brown

$$pKa = \frac{11.93 + 11.75}{2}$$

Hence pKa = 11.84

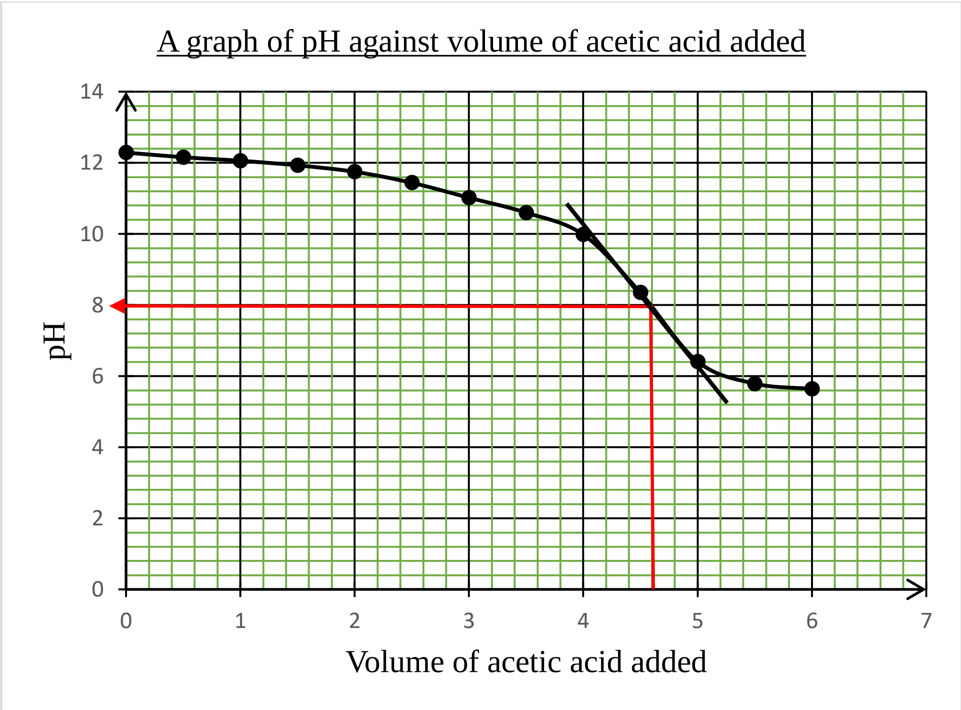


***Figure 4.2**: A graph of pH against volume of Acetic acid added for peacock flower extract indicator*

From the graph, pH = 8.0

Table 4.3: ***Peacock extract as an indicator in titration of 0.1M NH4OH & 0.1M HCl***

Volume of pipette used= 10ml

Volume of acid added(cm^3)	**pH**	**Colour-Change**
0	11	Green
0.5	10.48	Green
1	10.24	Green
1.5	10.03	Green
2	9.85	Green
2.5	9.67	Green
3	9.5	Green
3.5	9.37	Green
4	9.24	Green
4.5	9.11	Green
5	8.98	Green
5.5	8.85	Green
6	8.73	Green
6.5	8.54	Green
7	8.39	Green
7.5	8.18	Green
8	7.9	Green
8.5	7.34	Brown
9	5.83	Brown
9.5	3	Brown
10	1.75	Brown

pKa = $\frac{7.9+ 7.34}{2}$

Hence pKa = 7.62

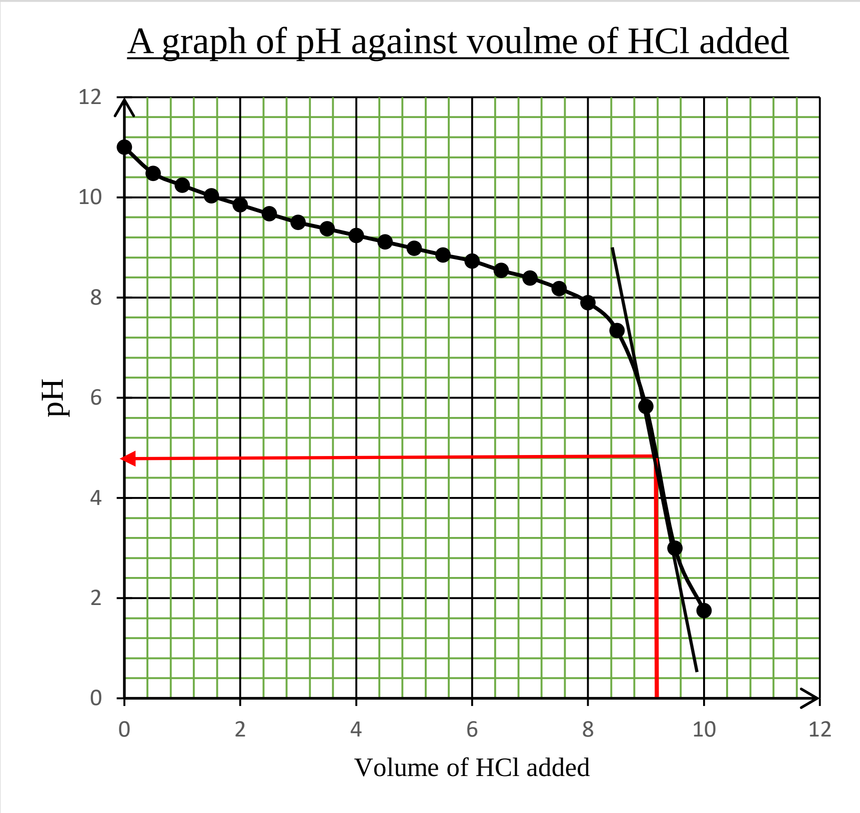


Figure 4.3: *A graph of pH against volume of HCl added for peacock flower extract indicator*

From the graph, pH = 4.8

Table 4.4: Peacock extract as indicator in the titration of 0.1M NH_4OH & 0.1M CH_3COOH

Volume of pipette used= 10ml

Volume of acid added	pH	colour change
0	10.51	Green
0.5	10.03	Green
1	9.88	Green
1.5	9.72	Green
2	9.43	Green
2.5	9.39	Green
3	9.24	Green
3.5	9.13	Green
4	8.86	Green
4.5	8.67	Green
5	8.63	Green
5.5	8.51	Green
6	8.24	Green

6.5	7.61	Brown
7	6.97	Brown
7.5	6.21	Brown
8	5.54	Brown
8.5	5.3	Brown
9	5.04	Brown
9.5	4.87	Brown
10	4.71	Brown
10.5	4.6	Brown

PKa = $\frac{8.24 + 7.61}{2}$

Hence, pKa = 7.93

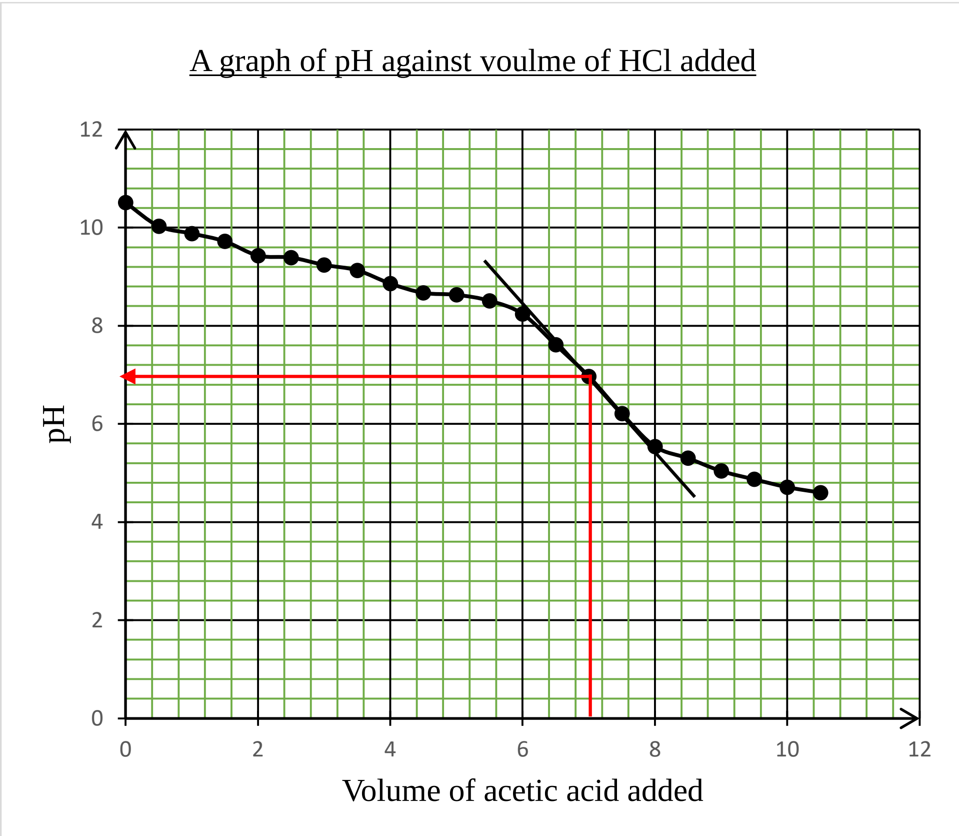


Figure 4.4: *A graph of pH against volume of Acetic acid added for peacock flower extract indicator*

From the graph, pH = 7.0

4.1.2 Mexican Sunflower

***Table 4.5*: Mexican Sunflower extract as an indicator in the titration of 0.1M HCl & 0.1M NaOH**

volume of acid	pH	colour change
0	12.32	Yellow
0.5	12.27	Yellow
1	9.7	Yellow
1.5	6.41	Colourless
2	4.79	Colourless

$$pKa = \frac{9.7 + 6.41}{2}$$

Hence pKa = 8.06

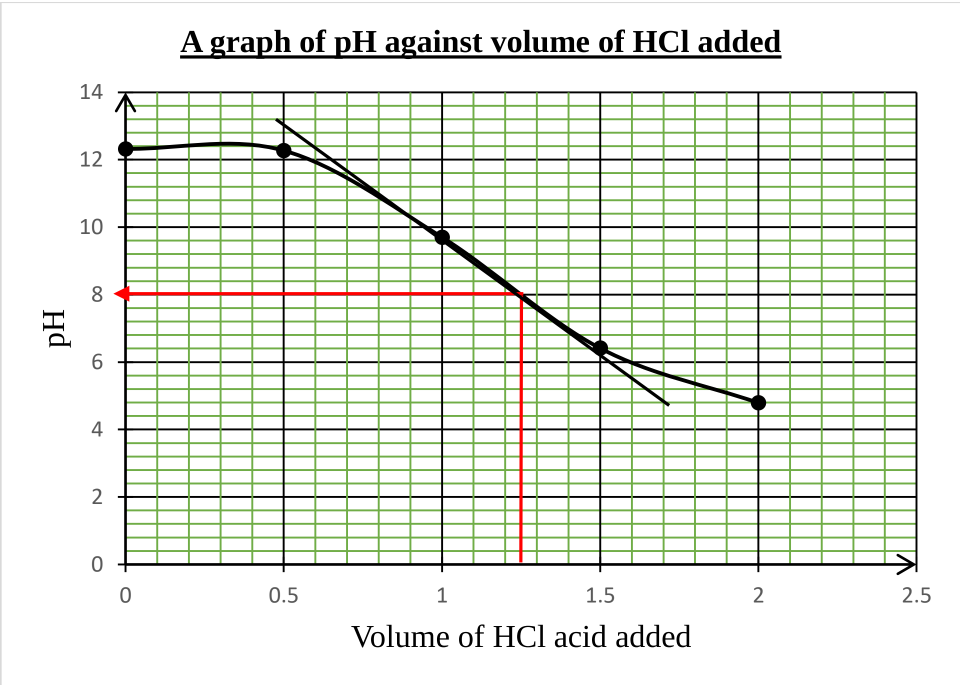


Figure 4.5*:* *A graph of pH against volume of HCl acid added for Mexican Sunflower extract indicator*

From the graph, pH = 8.0

Table 4.6: Mexican Sunflower extract as an indicator in the titration of 0.1M NaOH & 0.1M CH_3COOH

Volume of pipette used = 10ml

Volume of acid added	pH	colour change
0	12.22	Yellow
0.5	12.09	Yellow
1	12	Yellow
1.5	11.85	Yellow
2	11.64	Yellow
2.5	11.35	Yellow
3	10.85	Yellow
3.5	10.35	Yellow
4	9.67	Yellow
4.5	8.6	Yellow
5	6.51	Colourless
5.5	5.83	Colourless
6	5.42	Colourless
6.5	5.14	Colourless
7	4.85	Colourless

pKa = $\frac{8.6+6.51}{2}$

Hence pKa = 7.56

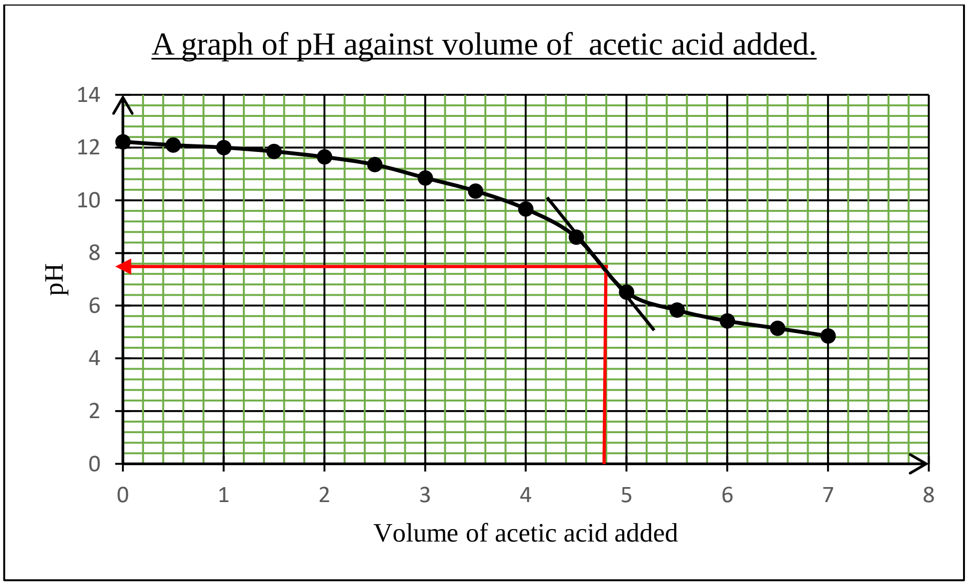


Figure 4.6: *A graph of pH against volume of Acetic acid added for Mexican Sunflower extract indicator*

From the graph, pH = 7.6

Table 4.7: Mexican Sunflower extract *as an* indicator in the titration of HCl against NH_4OH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	10.91	Yellow
0.5	10.51	Yellow
1	10.29	Yellow
1.5	10.08	Yellow
2	9.87	Yellow
2.5	9.7	Yellow
3	9.39	Yellow
3.5	9.27	Yellow
4	9.15	Yellow
4.5	9.01	Yellow
5	8.88	Yellow
5.5	8.78	Yellow
6	8.62	Yellow
6.5	8.47	Yellow
7	8.29	Yellow
7.5	8.07	Yellow
8	7.71	Colourless
8.5	6.86	Colourless
9	4.6	Colourless
9.5	1.79	Colourless
10	1.47	Colourless

pKa = $\frac{8.07 + 7.71}{2}$

Hence pKa = 7.89

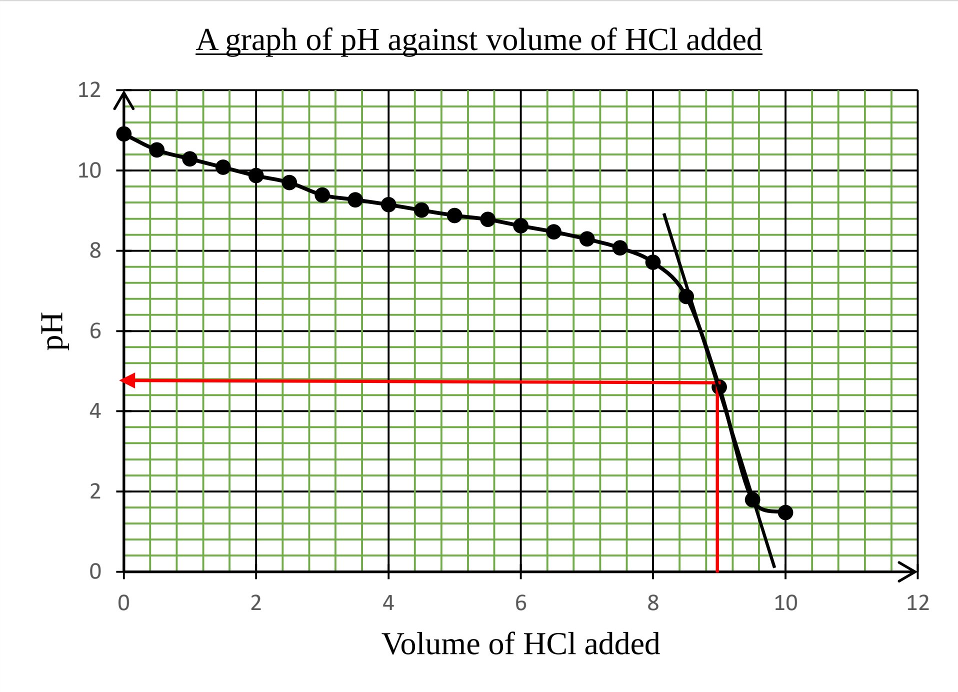


Figure 4.7: *A graph of pH against volume of HCl acid added for Mexican Sunflower extract indicator*

From the graph, pH = 4.8

Table 4.8: Mexican Sunflower extract *as an indicator in the titration of acetic acid against* NH_4OH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	10.08	Yellow
0.5	9.34	Yellow
1	8.9	Yellow
1.5	8.16	Yellow
2	6.58	Yellow
2.5	5.19	Colourless
3	4.62	Colourless
3.5	4.38	Colourless
4	4.18	Colourless
4.5	4.06	Colourless
5	3.94	Colourless
5.5	3.87	Colourless

pKa = $\frac{6.58 + 5.19}{2}$

Hence pKa = 5.89

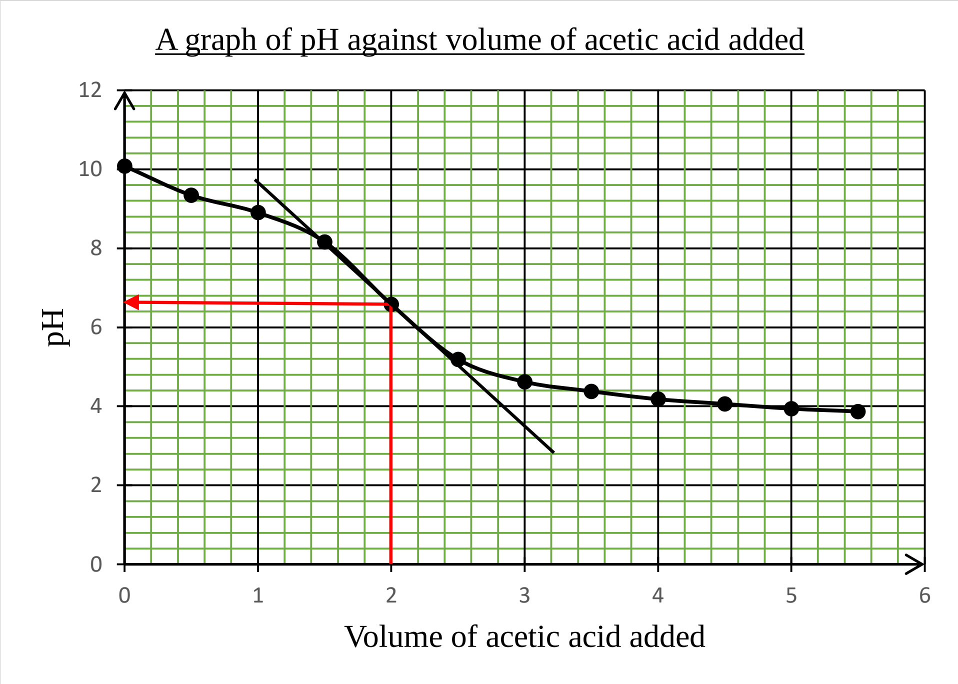


Figure 4.8: *A graph of pH against volume of Acetic acid added for Mexican Sunflower extract indicator*

From the graph, pH = 6.6

4.1.3 Cascabela Thevetia

Table 4.9: Cascabela Thevetia extract as an indicator in the titration of HCl against NaOH

Volume of pipette used = 10ml

volume of acid added	pH	Colour-Change
0	12.37	Brown
0.5	12.31	Brown
1	12.22	Brown
1.5	12.06	Brown
2	11.84	Brown
2.5	11.49	Brown
3	8.17	Colourless
3.5	4.64	Colourless
4	2.98	Colourless

pKa = $\frac{11.49+8.17}{2}$

Hence pKa = 9.83

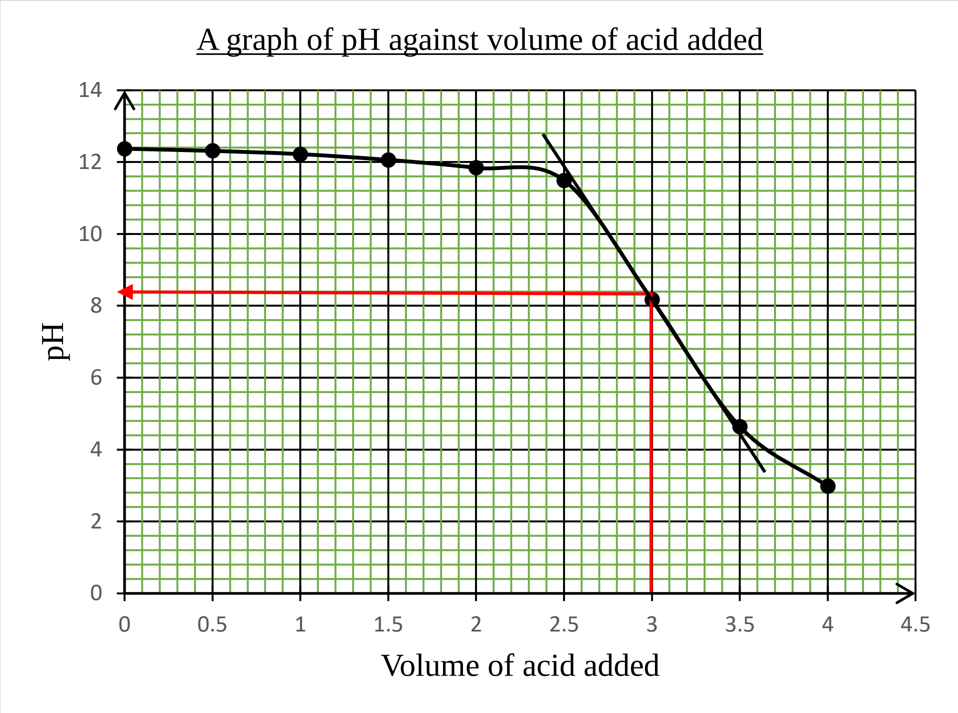


Figure 4.9: *A graph of pH against volume of HCl acid added for Cascabela thevetia extract indicator*

From the graph, pH = 8.4

Table 4.10: Cascabela Thevetia extract as an indicator in the titration acetic acid against NaOH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	12.28	Yellow
0.5	12.26	Yellow
1	12.19	Yellow
1.5	12.12	Yellow
2	12.01	Yellow
2.5	11.87	Yellow
3	11.7	Yellow
3.5	11.45	Yellow
4	10.96	Yellow
4.5	10.33	Yellow
5	9.48	Yellow
5.5	6.65	Colourless
6	5.73	Colourless
6.5	5.19	Colourless
7	4.96	Colourless
7.5	4.72	Colourless

pKa = $\frac{9.48 + 6.65}{2}$

Hence pKa = 8.07

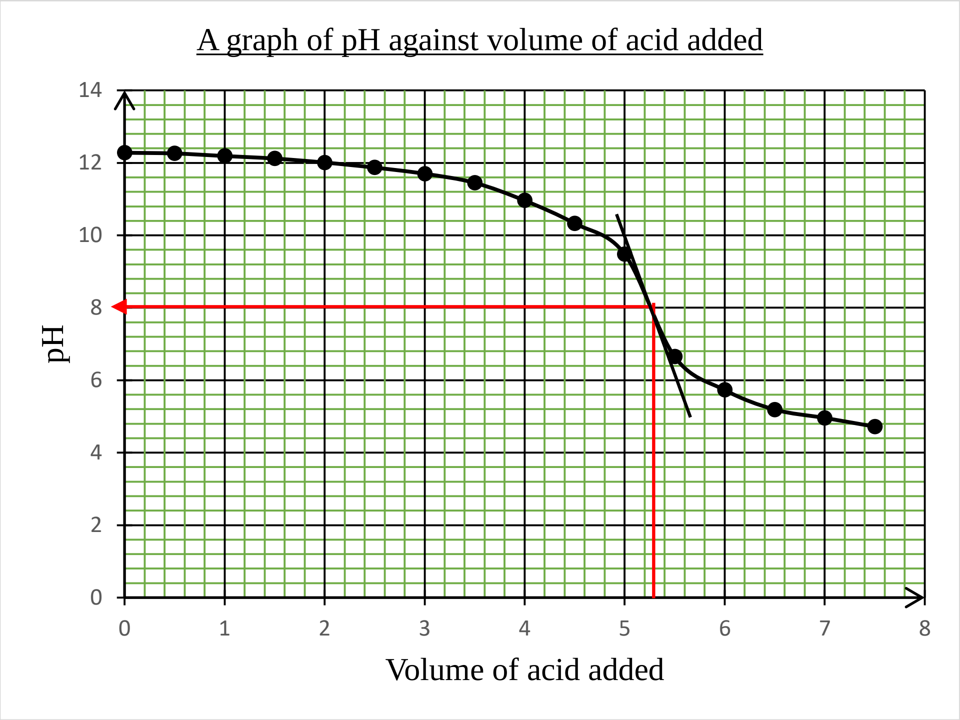


Figure 4.10: *A graph of pH against volume of Acetic acid added for Cascabela Thevetia extract indicator*

From the graph, pH = 8.0

Table 4.11: Cascabela Thevetia extract as an indicator in the titration of HCl against NH_4OH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	10.83	Yellow
0.5	10.49	Yellow
1	10.2	Yellow
1.5	9.98	Yellow
2	9.82	Yellow
2.5	9.63	Yellow
3	9.48	Yellow
3.5	9.31	Yellow
4	9.2	Yellow
4.5	9.05	Yellow
5	8.93	Yellow
5.5	8.8	Yellow
6	8.67	Yellow
6.5	8.53	Yellow

7	8.32	Yellow
7.5	8.04	Yellow
8	7.73	Colourless
8.5	6.73	Colourless
9	3.48	Colourless
9.5	1.84	Colourless
10	1.5	Colourless

pKa = $\frac{8.04 + 7.73}{2}$

Hence pKa = 7.89

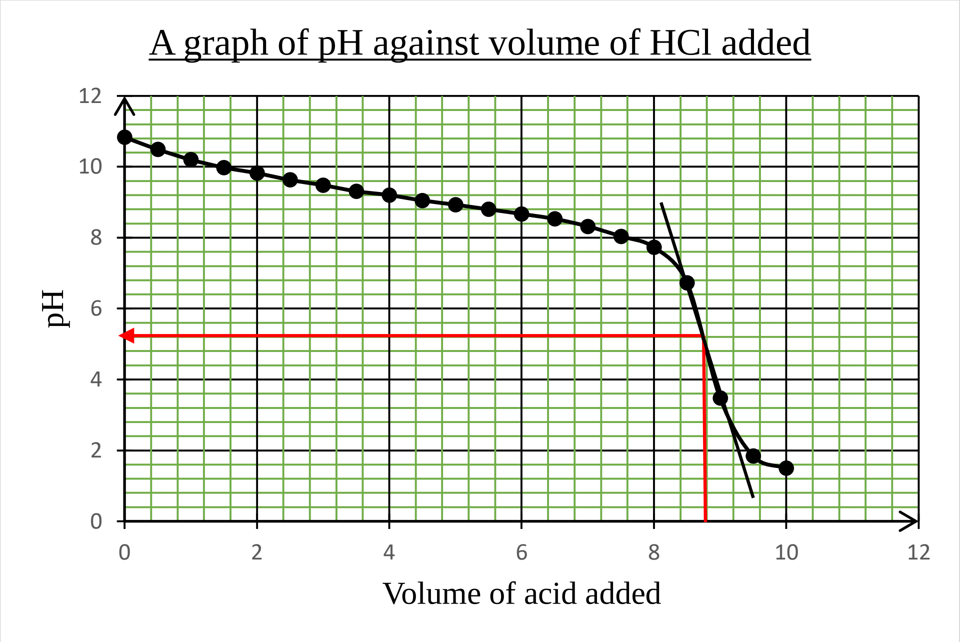


Figure 4.11: *A graph of pH against volume of HCl acid added for Cascabela Thevetia extract indicator*

From the graph, pH = 5.2

Table 4.12: Cascabela Thevetia extract as an indicator in the titration of 0.1M NH_4OH against CH_3COOH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-change
0	10.05	Yellow
0.5	9.29	Yellow
1	8.73	Yellow
1.5	8.07	Yellow
2	6	Colourless
2.5	4.84	Colourless
3	4.48	Colourless
3.5	4.25	Colourless
4	4.07	Colourless

4.5	3.94	Colourless
5	3.87	Colourless
5.5	3.77	Colourless
6	3.72	Colourless
6.5	3.61	Colourless
7	3.6	Colourless
7.5	3.56	Colourless
8	3.51	Colourless
8.5	3.47	Colourless
9	3.44	Colourless
9.5	3.4	Colourless
10	3.37	Colourless

pKa = $\frac{8.07+6}{2}$

Hence pKa = 7.03

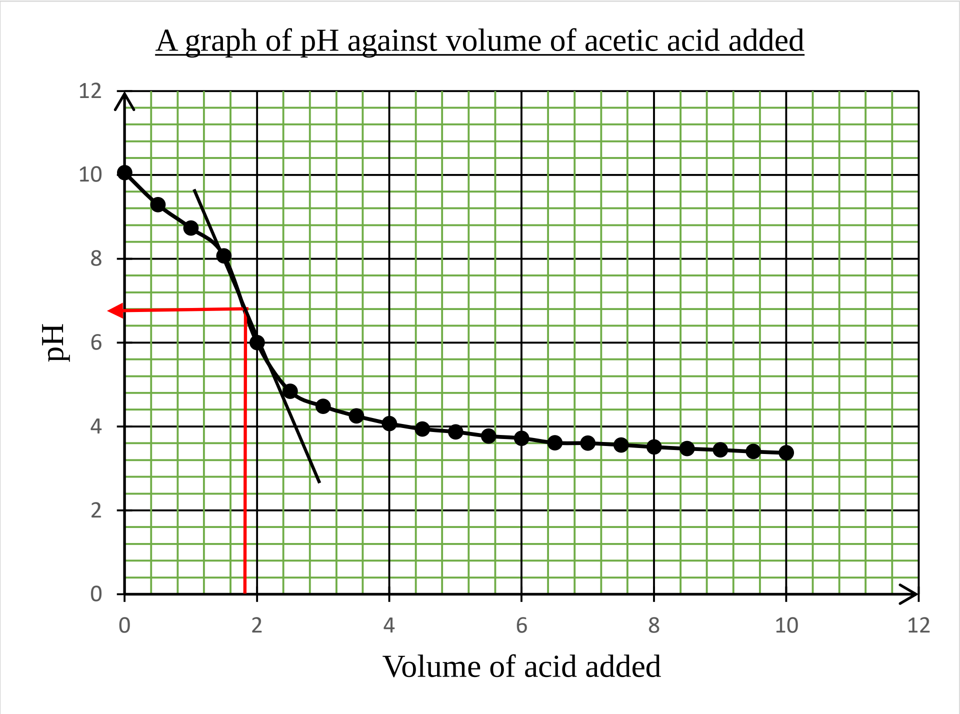


Figure 4.12: *A graph of pH against volume of Acetic acid added for Cascabela Thevetia extract indicator*

From the graph, pH = 6.8

4.1.4 Senna Spectabilis

Table 4.13: Senna Spectabilis extract as an indicator in the titration of 0.1M HCl and 0.1M NaOH.

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	12.38	Brown
0.5	12.21	Brown
1	12.13	Brown
1.5	11.92	Brown
2	11.64	Brown
2.5	11.1	Brown
3	9.83	Brown
3.5	7.56	Colourless
4	5.39	Colourless
4.5	4.84	Colourless

pKa = $\frac{9.83+7.56}{2}$

Hence pKa = 8.70

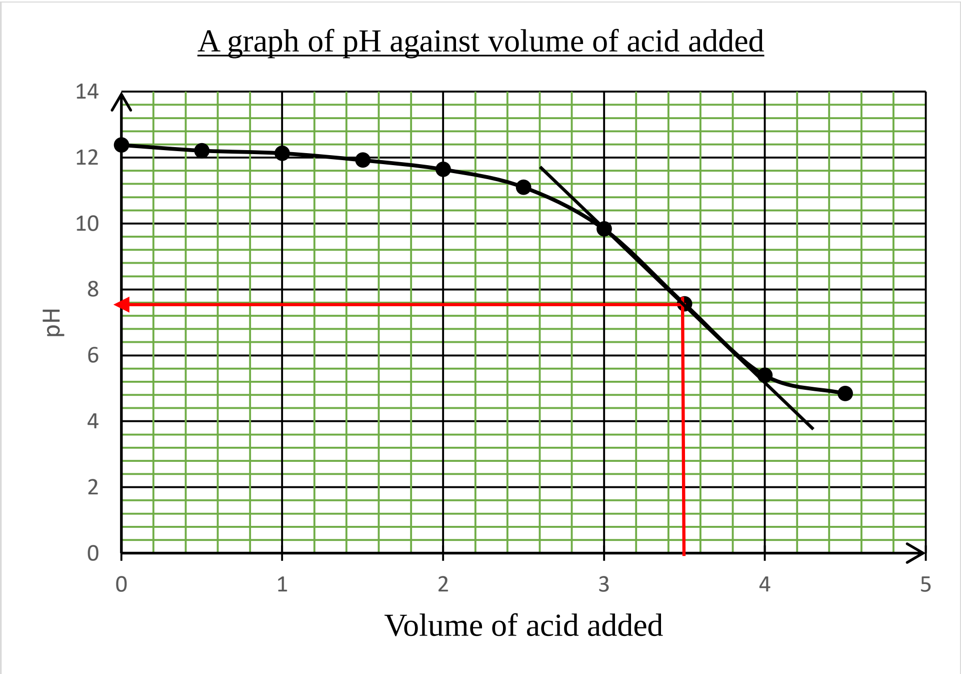


Figure 4.13: *A graph of pH against volume of HCl acid added for Senna Spectabilis extract indicator*

From the graph, pH = 7.6

Table 4.14: Senna Spectabilis extract as an indicator in the titration of 0.1M CH_3COOH against 0.1M NaOH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	12.27	Brown
0.5	12.23	Brown
1	12.15	Brown
1.5	12.04	Brown
2	11.93	Brown
2.5	11.57	Brown
3	11.19	Brown
3.5	10.67	Brown
4	9.89	Brown
4.5	8.8	Brown
5	6.43	Colourless
5.5	5.53	Colourless
6	5.13	Colourless
6.5	4.87	Colourless
7	4.65	Colourless

pKa = $\frac{6.43 + 8.8}{2}$

Hence pKa = 7.62

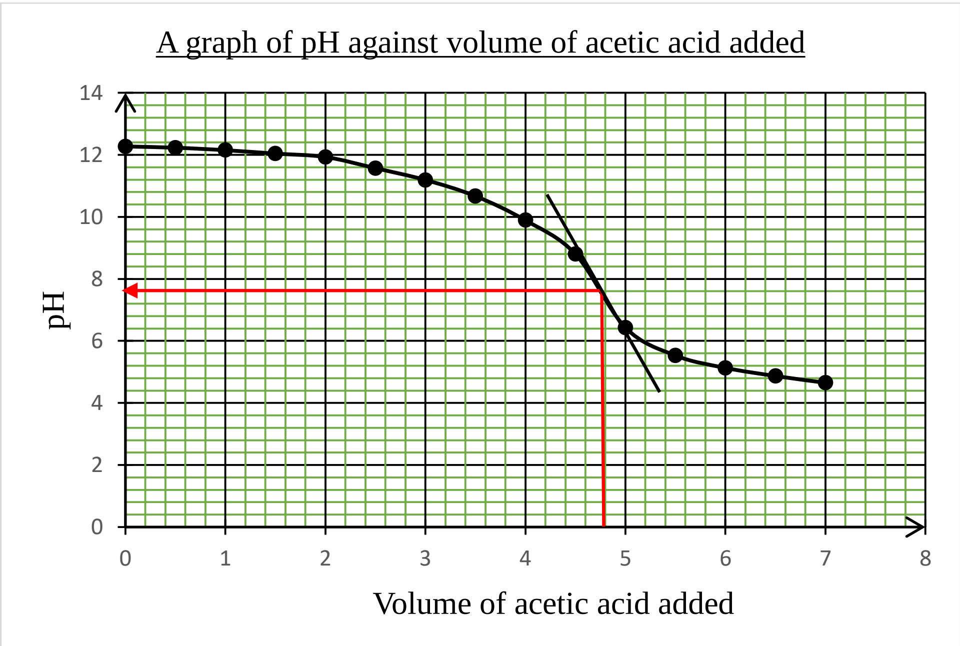


Figure 4.14: A graph of pH against volume of acetic acid added for *Senna Spectabilis extract* indicator

From the graph, pH = 7.6

Table 4.15: Senna Spectabilis extract as an indicator in the titration of 0.1M HCl and 0.1M NH_4OH.

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	10.7	Brown
0.5	10.15	Brown
1	9.94	Brown
1.5	9.76	Brown
2	9.59	Brown
2.5	9.43	Brown
3	9.23	Brown
3.5	9.12	Brown
4	8.96	Brown
4.5	8.83	Brown
5	8.66	Brown
5.5	8.49	Brown
6	8.26	Brown
6.5	8.03	Brown
7	7.65	Colourless
7.5	6.33	Colourless
8	4.01	Colourless
8.5	1.87	Colourless
9	1.45	Colourless
9.5	1.28	Colourless
10	1.16	Colourless

pKa = $\frac{8.03 + 7.65}{2}$

Hence pKa = 7.84

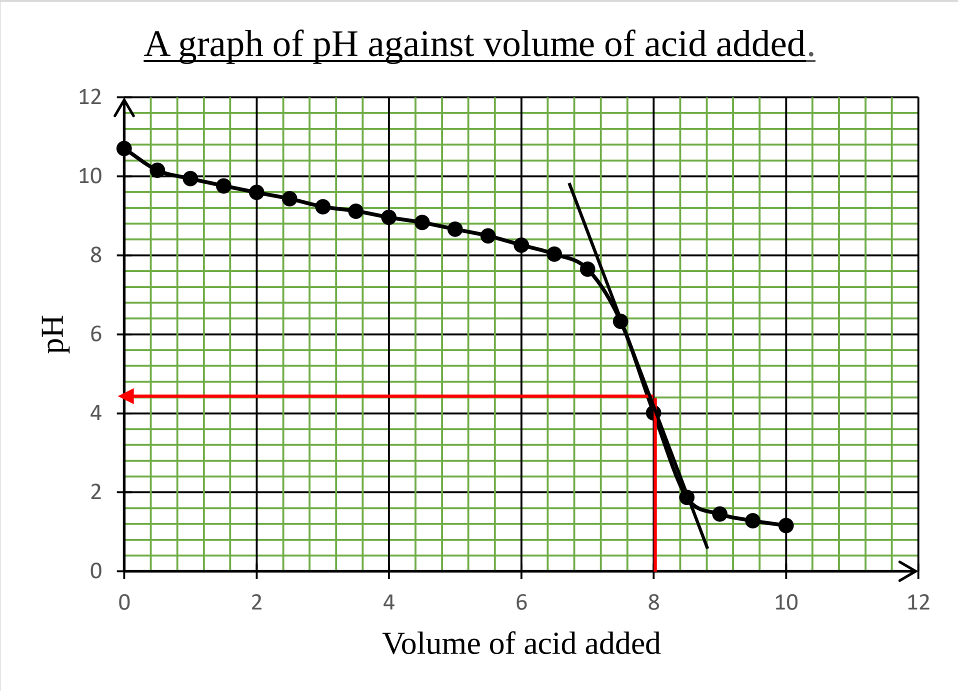


Figure 4.15: A graph of pH against volume of HCl acid added for *Senna Spectabilis extract* indicator

From the graph, pH = 4.40

Table 4.16: Senna Spectabilis as an indicator in the titration of 0.1M CH_3COOH and NH_4OH

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	9.95	Brown
0.5	8.58	Brown
1	8.32	Brown
1.5	8.09	Brown
2	5.87	Colourless
2.5	4.16	Colourless
3	3.62	Colourless
3.5	3.6	Colourless
4	3.56	Colourless
4.5	3.49	Colourless
5	3.44	Colourless
5.5	3.38	Colourless
6	3.37	Colourless
6.5	3.27	Colourless
7	3.24	Colourless
7.5	3.19	Colourless
8	3.16	Colourless
8.5	3.14	Colourless
9	3.1	Colourless
9.5	3.07	Colourless

10	3.05	Colourless

pKa = $\frac{11.21 + 4.82}{2}$

Hence pKa = 8.02

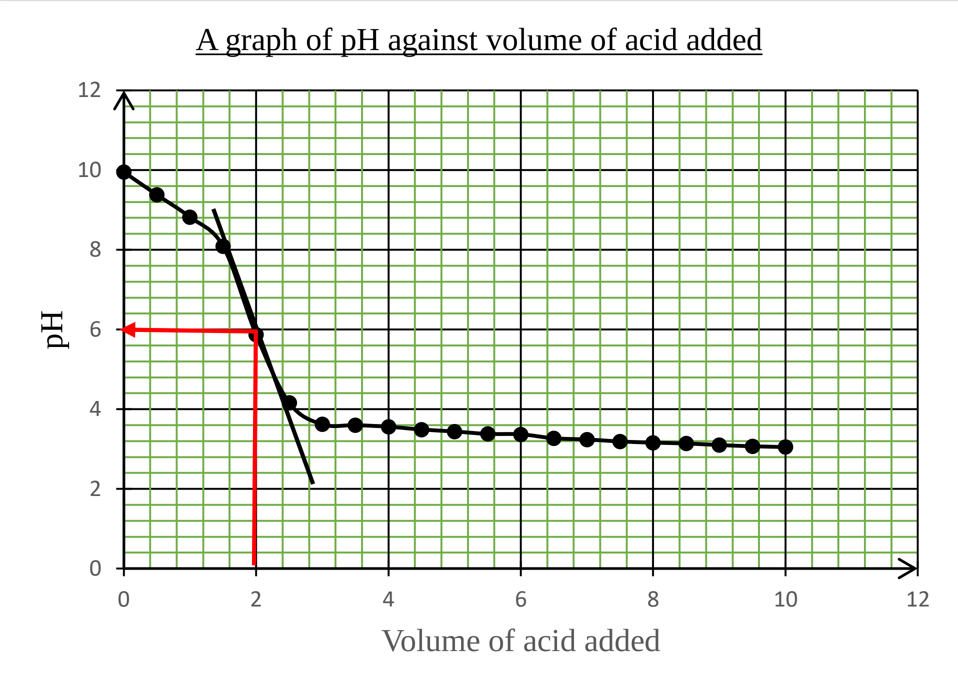


Figure 4.16: A graph of pH against volume of CH_3COOH acid added for Senna Spectabilis extract indicator

From the graph, pH = 6.0

4.2 Results for Fruit Extracts

The pKa was obtained by taking the average of the pH values where the colour change occurred.

4.2.1 For an egg plant

Table 4.17: Eggplant as an indicator in the titration of 0.1M NaOH & 0.1M HCl

Volume of pipette used = 10ml

Volume of acid added	pH	Colour-Change
0	12.35	Yellow
0.5	12.3	Yellow
1	12.23	Yellow
1.5	12.07	Yellow
2	11.78	Yellow
2.5	10.19	Yellow
3	7.04	Colourless
3.5	3.66	Colourless
4	3.24	Colourless
4.5	2.49	Colourless
5	1.95	Colourless
5.5	1.42	Colourless

pKa = $\frac{10.19 + 7.04}{2}$

Hence pKa = 8.62

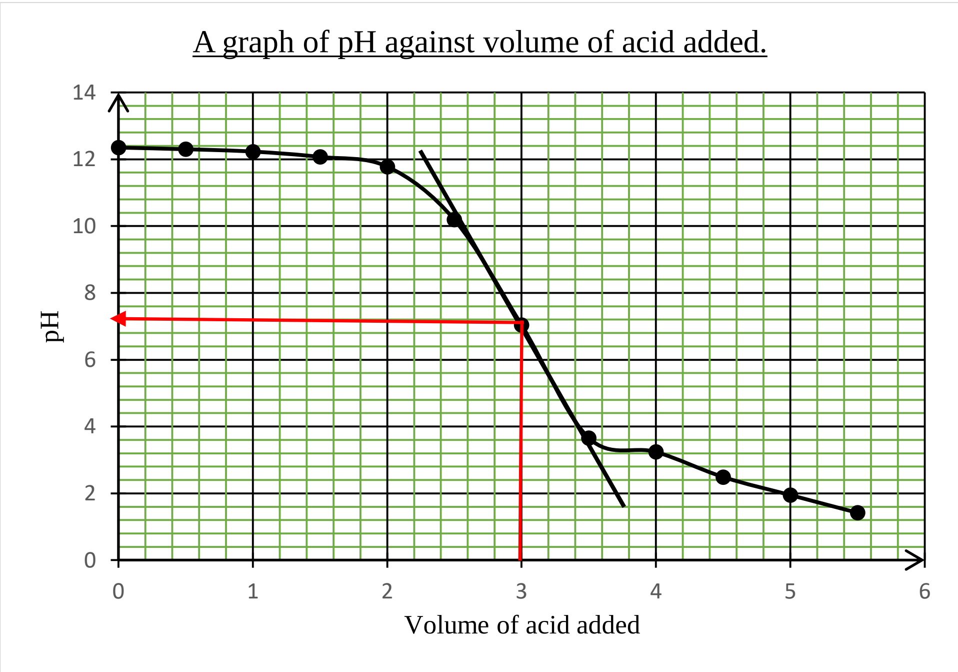


Figure 4.17: *A graph of pH against volume of HCl acid added for eggplant extract indicator*

From the graph, pH = 7.2

Table 4.18: Eggplant as an indicator in the titration of 0.1M NaOH & 0.1M CH_3COOH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	12.4	Yellow
0.5	12.38	Yellow
1	12.31	Yellow
1.5	12.23	Yellow
2	12.11	Yellow
2.5	11.25	Yellow
3	10.32	Yellow
3.5	6.36	Colourless
4	5.19	Colourless
4.5	4.81	Colourless
5	4.52	Colourless
5.5	4.36	Colourless
6	4.26	Colourless
6.5	4.15	Colourless
7	4.06	Colourless

$$pKa = \frac{10.32 + 6.36}{2}$$

Hence pKa = 8.34

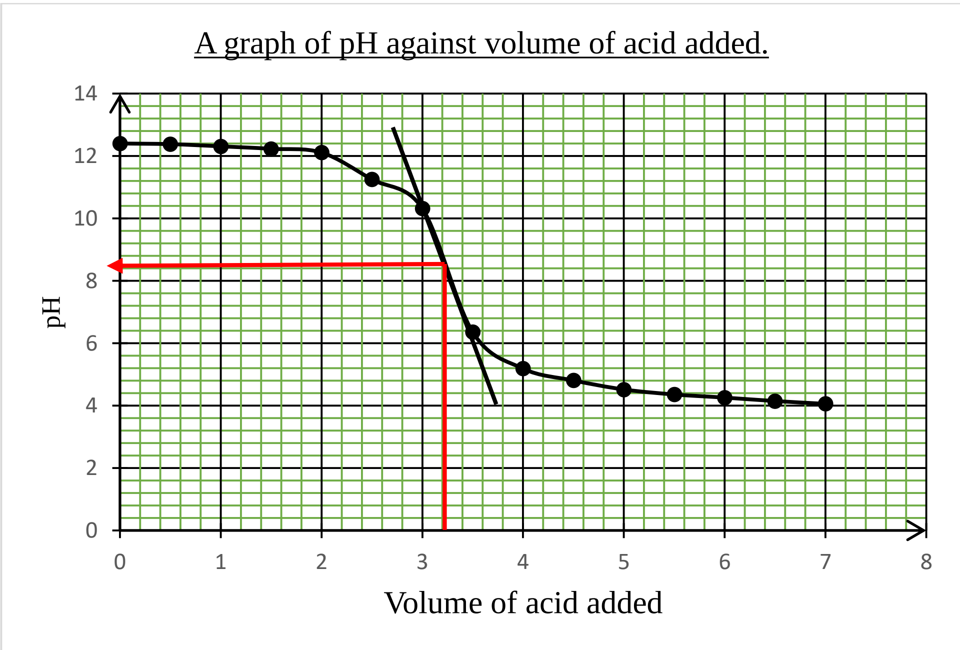


Figure 4.18: *A graph of pH against volume of CH_3COOH acid added for eggplant extract indicator.*

From the graph, pH = 8.20

Table 4.19: Eggplant as an indicator in the titration of 0.1M HCl & 0.1M NH_4OH

Volume of acid added = 10ml

Volume of acid added	pH	Colour-Change
0	10.22	Yellow
0.5	10.05	Yellow
1	7.84	Colourless
1.5	2.01	Colourless
2	1.95	Colourless
2.5	1.92	Colourless
3	1.33	Colourless
3.5	1.02	Colourless
4	0.96	Colourless

pKa = $\frac{10.05 + 7.84}{2}$

Hence pKa = 8.95

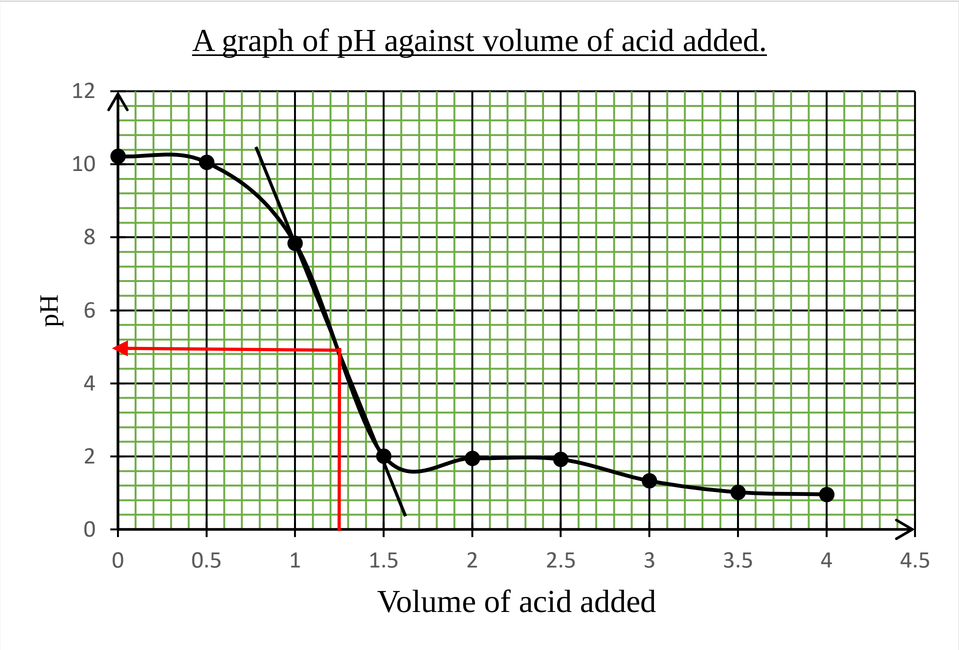


Figure 4.19: *A graph of pH against volume of HCl acid added for eggplant extract indicator.*

From the graph, pH = 5.0

Table 4.20: Eggplant as an indicator in the titration of 0.1M CH_3COOH & 0.1M NH4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	10.18	Yellow
0.5	9.25	Yellow
1	8.81	Yellow
1.5	7.49	Colourless
2	5.55	Colourless
2.5	4.11	Colourless
3	3.68	Colourless
3.5	3.45	Colourless
4	3.36	Colourless

pKa = $\frac{8.81 + 7.49}{2}$

Hence pKa = 8.15

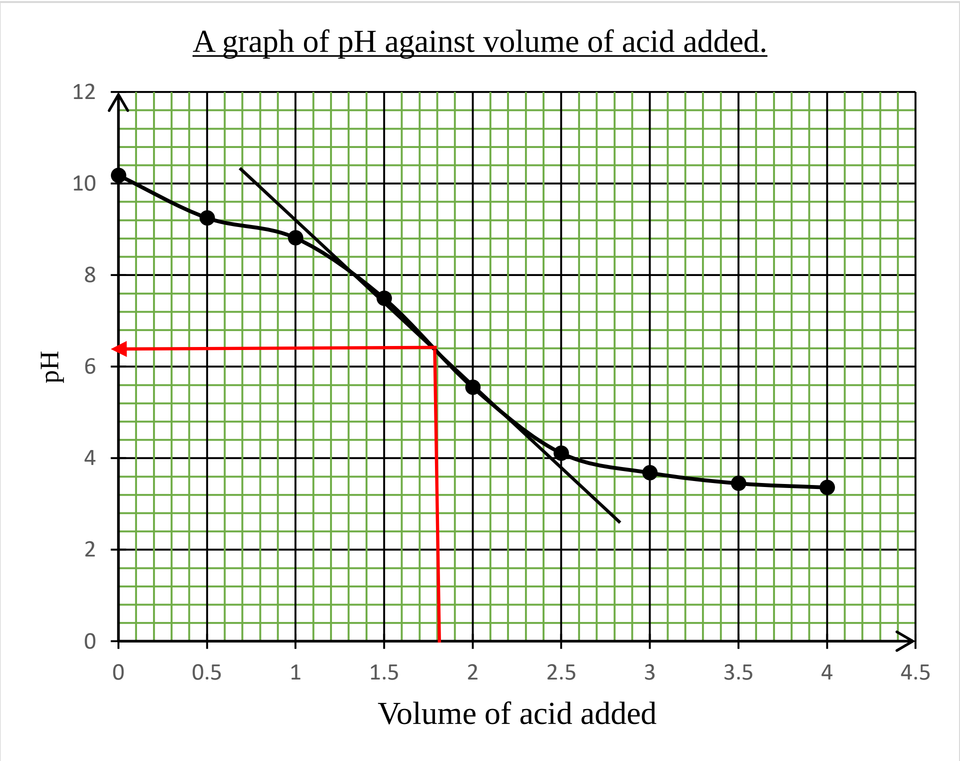


Figure 4.20: *A graph of pH against volume of CH_3COOH acid added for eggplant extract indicator.*

From the graph, pH = 6.40

4.2.2 An apple

Table 4.21: An apple as an indicator in the titration of 0.1M HCl & O.1M NaOH

Volume of acid added = 10ml

Volume of acid added(ml)	pH	colour-change
0	12.34	green
0.5	12.32	green
1	12.23	green
1.5	12.01	green
2	11.79	green
2.5	11.33	green
3	9.81	green
3.5	2.64	Colourless
4	1.57	Colourless
4.5	1.32	Colourless

pKa = $\frac{9.81+2.64}{2}$

Hence pKa = 6.23

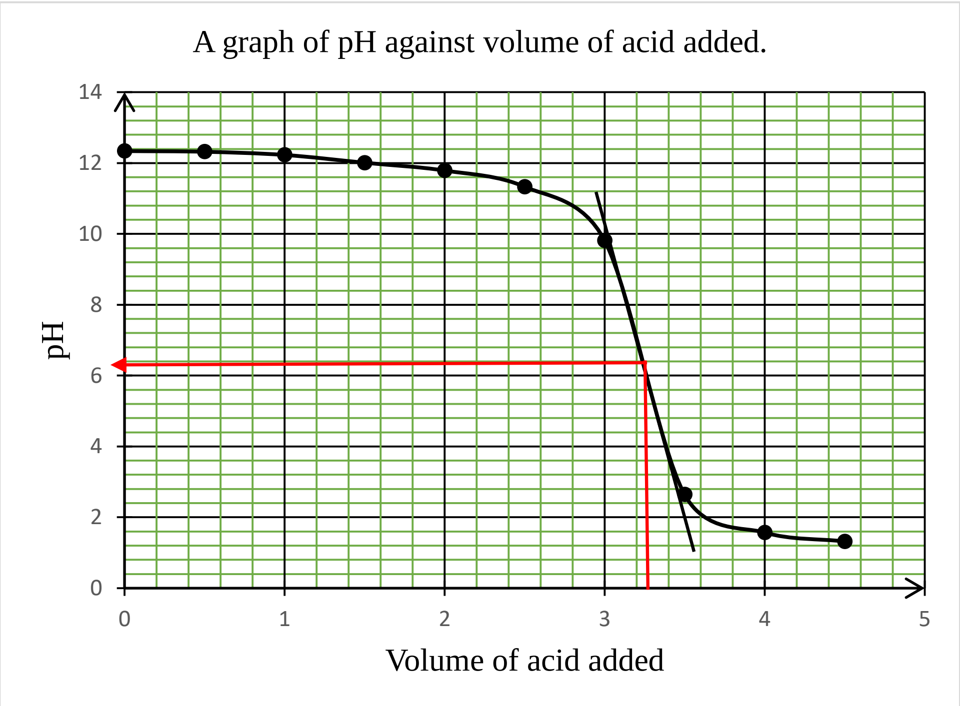


Figure 4.131: **A graph of pH against volume of HCl acid added for an apple extract indicator.**

From the graph, pKa = 6.2

Table 4.22: An apple as an indicator on the titration of 0.1M NaOH & 0.1M CH_3COOH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	12.42	Green
0.5	12.28	Green
1	12.16	Green
1.5	12.04	Green
2	11.76	Green
2.5	11.37	Green
3	10.44	Green
3.5	6.26	Colourless
4	5.36	Colourless
4.5	5.06	Colourless
5	4.71	Colourless
5.5	4.52	Colourless
6	4.39	Colourless
6.6	4.25	Colourless
7	4.14	Colourless

pKa = $\frac{10.44 + 6.26}{2}$

Hence pKa= 8.35

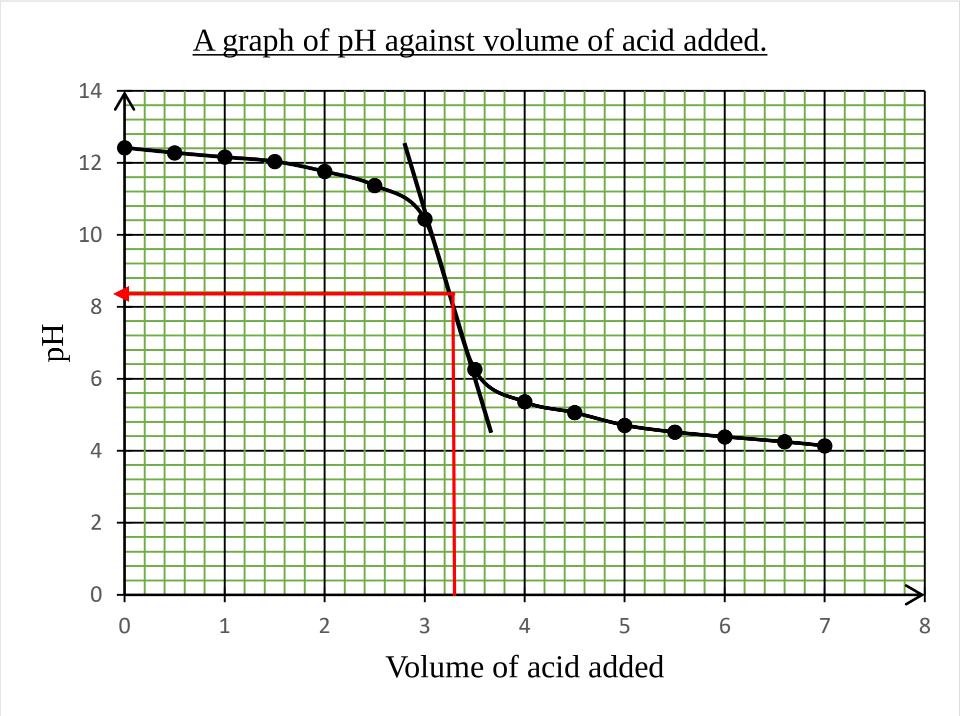


Figure 4.22: *A graph of pH against volume of acetic acid added for an apple extract indicator.*

From the graph pH = 8.4

Table 4.23: An apple as an indicator in the titration of 0.1M HCl & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	10.19	Green
0.5	9.77	Green
1	9.43	Green
1.5	6.79	Colourless
2	4.32	Colourless
2.5	3.39	Colourless
3	2.18	Colourless
3.5	1.89	Colourless

pKa = $\frac{9.43 + 6.79}{2}$

Hence pKa = 8.11

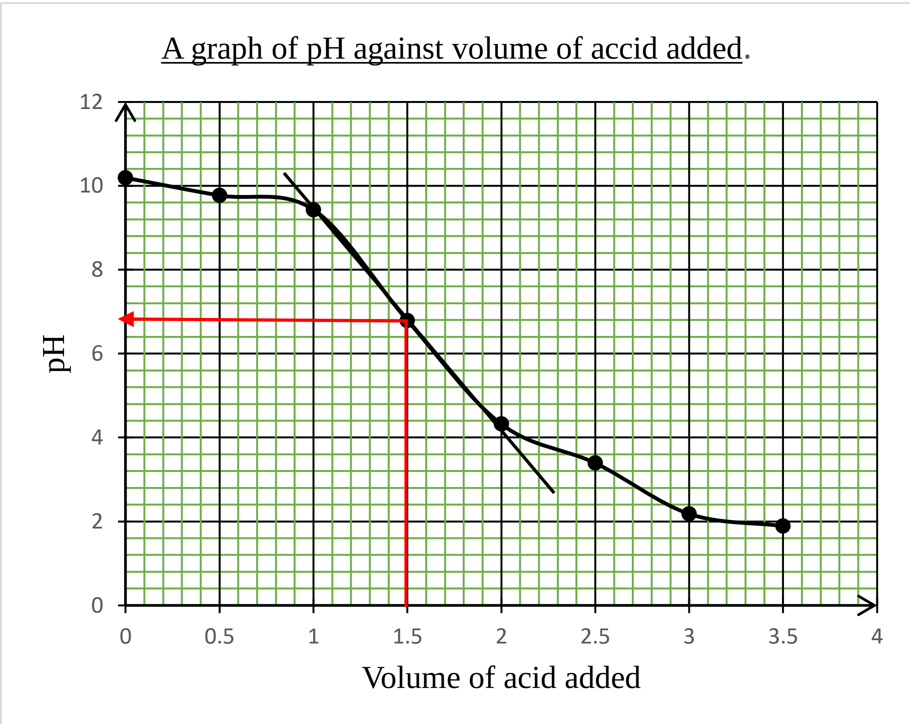


Figure 4.23: *A graph of pH against volume of HCl acid added for an apple extract indicator.*

From the graph, pH = 6.80

Table 4.24: An apple as an indicator in the titration of 0.1M CH3COOH & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour-Change
0	10.17	Green
0.5	9.65	Green
1	9.39	Green
1.5	8.82	Green
2	8.55	Green
2.5	7.96	Colourless
3	5.05	Colourless
3.5	3.99	Colourless
4	3.76	Colourless
4.5	3.54	Colourless
5	3.12	Colourless
5.5	2.98	Colourless
6	2.76	Colourless
6.5	2.55	Colourless
7	2.01	Colourless

$$pKa = \frac{8.55 + 7.96}{2}$$

Hence pKa = 8.23

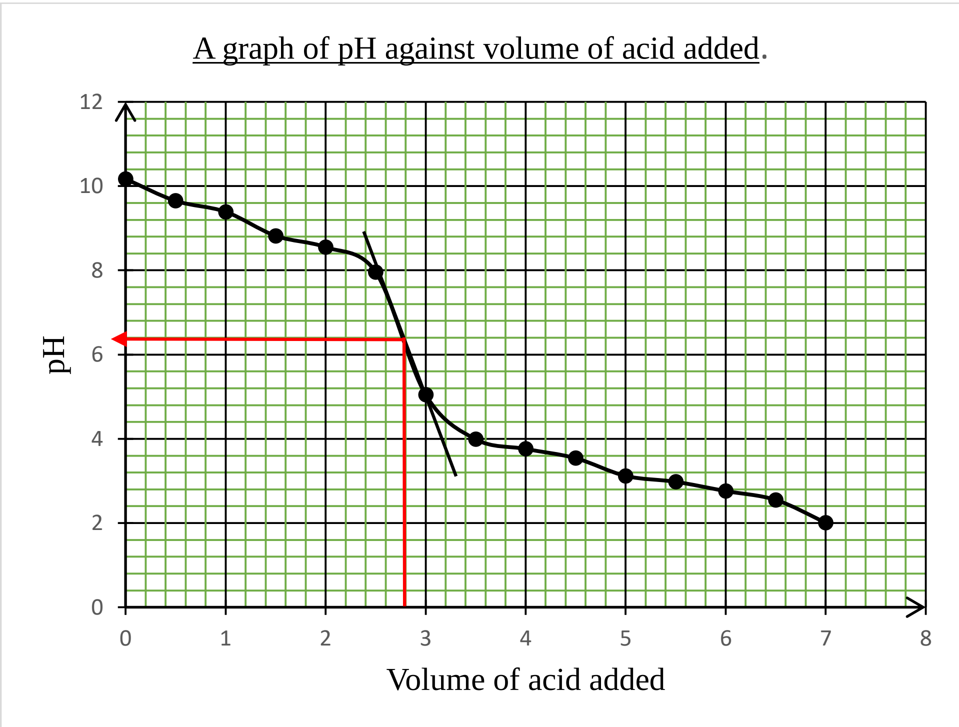


Figure 4.24: *A graph of pH against volume of NH_4OH acid added for an apple extract indicator.*

From the graph, pH = 6.40

4.2.3 Tomato

Table 4.25: Tomato as an indicator in the titration of 0.1M HCl & 0.1M NaOH

Volume of pipette used = 10ml

Volume of acid used(ml)	pH	Colour-Change
0	12.39	Brown
0.5	12.2	Brown
1	12.05	Brown
1.5	11.76	Brown
2	11.38	Brown
2.5	9.81	Brown
3	6.49	Colourless
3.5	2.88	Colourless
4	1.75	Colourless
4.5	1.42	Colourless

pKa = $\frac{9.81 + 6.49}{2}$

Hence pKa = 8.15

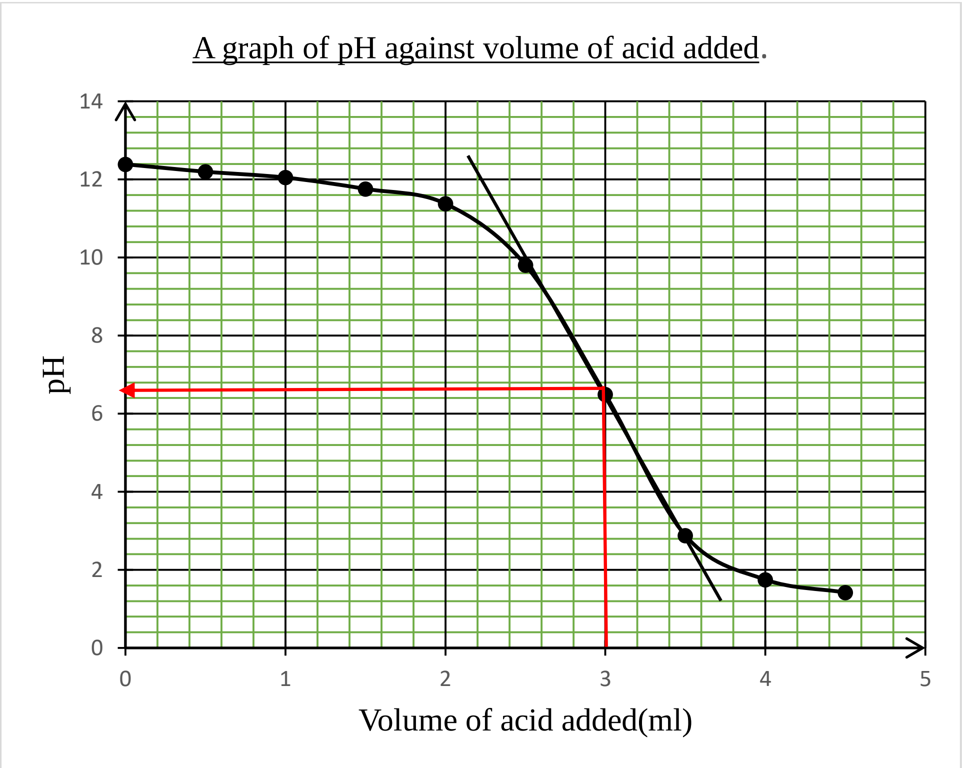


Figure 4.25: *A graph of pH against volume of HCl acid added for a tomato extract indicator.*

From the graph, pH = 6.60

Table 4.26: *Tomato as an indicator in the titration of 0.1M CH_3COOH & 0.1M NaOH*

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	colour-change
0	12.4	Brown
0.5	11.94	Brown
1	11.73	Brown
1.5	11.41	Brown
2	10.69	Brown
2.5	9.5	Brown
3	7.58	Colourless
3.5	5.46	Colourless
4	4.99	Colourless
4.5	4.7	Colourless
5	4.48	Colourless
5.5	4.33	Colourless
6	4.24	Colourless
6.5	4.14	Colourless
7	4.06	Colourless

$$pKa = \frac{9.5 + 7.58}{2}$$

Hence pKa = 8.54

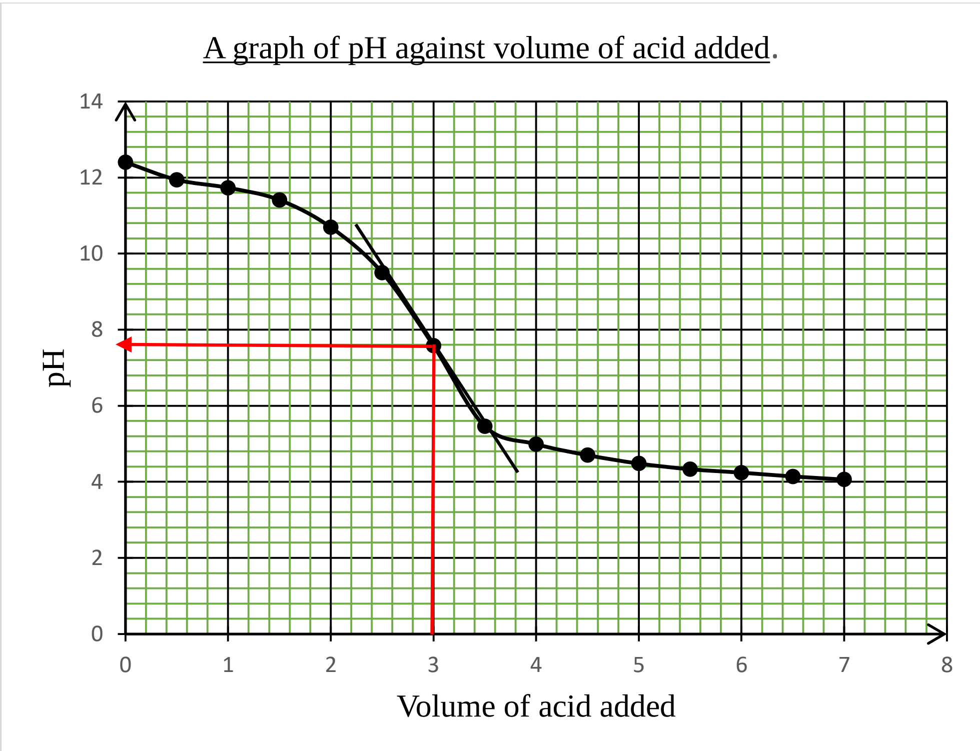


Figure 4.26: *A graph of pH against volume of acetic acid added for a tomato extract indicator.*

From the graph, pH = 7.60

Table4. 27: Tomato as an indicator in the titration of 0.1M HCl & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	colour change
0	10.25	Brown
0.5	9.8	Brown
1	8.87	Brown
1.5	6.41	Colourless
2	5.89	Colourless
2.5	5.02	Colourless
3	4.67	Colourless
3.5	4.03	Colourless
4	3.75	Colourless
4.5	3.24	Colourless
5	2.91	Colourless

pKa = $\frac{8.87 + 6.41}{2}$

Hence pKa = 7.64

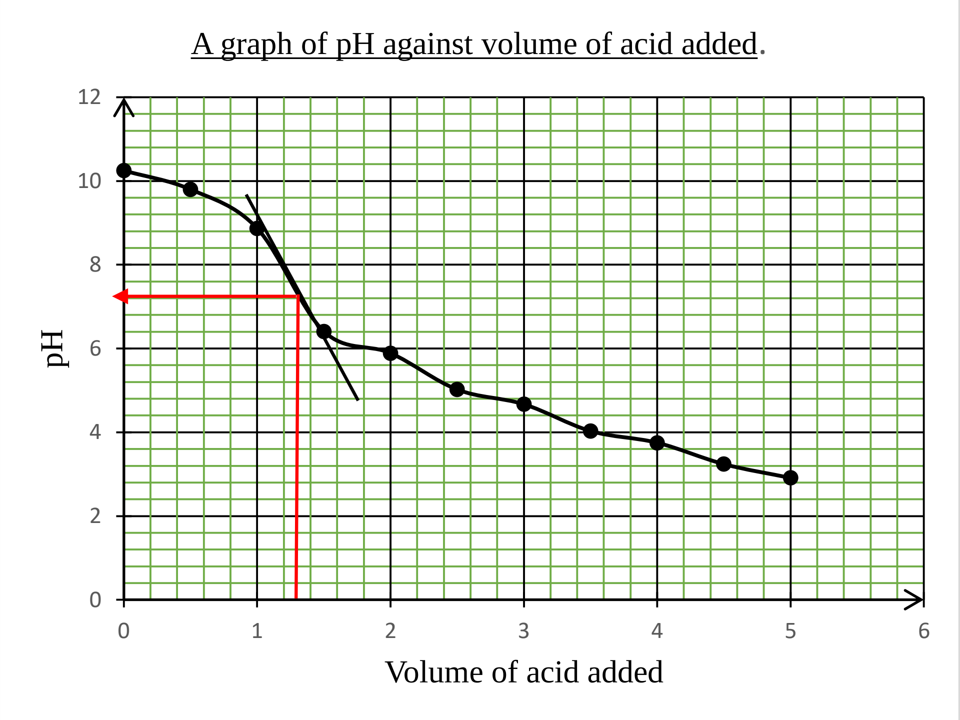


Figure 4.27: *A graph of pH against volume of HCl acid added for a tomato extract indicator.*

From the graph, pH = 7.20

Table 4.28: Tomato as an indicator in the titration of 0.1M CH3COOH & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	colour-change
0	10.14	Brown
0.5	9.78	Brown
1	9.28	Brown
1.5	8.83	Brown
2	6.64	Colourless
2.5	4.59	Colourless
3	3.98	Colourless
3.5	3.71	Colourless
4	3.56	Colourless
4.5	3.46	Colourless

pKa = $\frac{8.83 + 6.64}{2}$

Hence pKa = 7.74

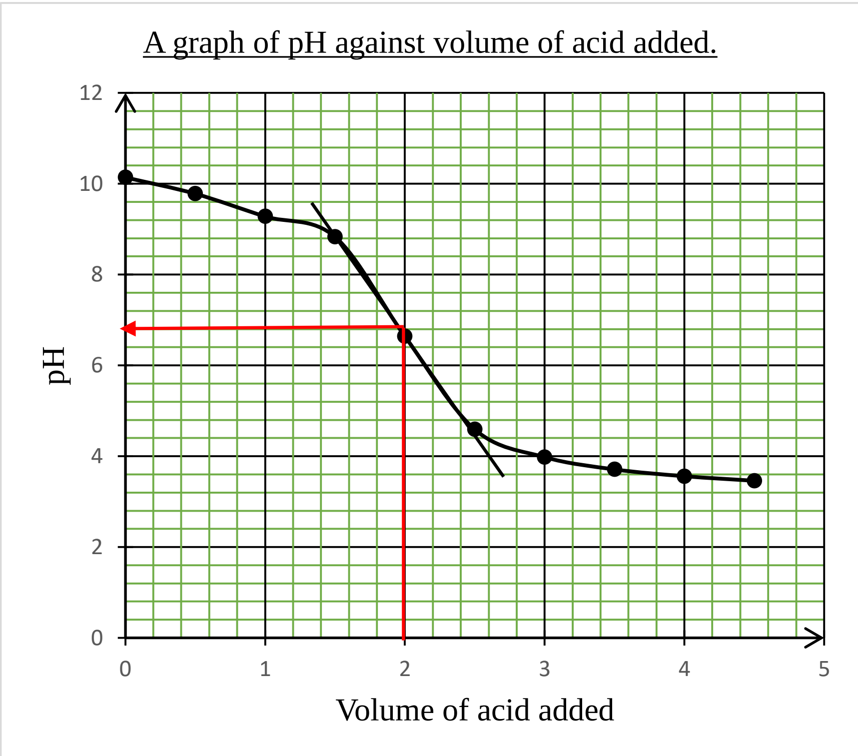


Figure 4.28: *A graph of pH against volume of acetic acid added for a tomato extract indicator.*

From the graph, pKa = 6.80

4.2.4 Lantana

Table 4.29: Lantana as an indicator in the titration of 0.1M HCl & 0.1M NaOH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	Colour change
0	12.36	Black
0.5	12.34	Black
1	12.21	Black
1.5	12.03	Black
2	11.72	Black
2.5	11.16	Black
3	8.64	Brown
3.5	2.1	Brown
4	1.5	Brown
4.5	1.23	Brown
5	1.09	Brown

pKa = $\frac{11.16 + 8.64}{2}$

Hence pKa = 9.90

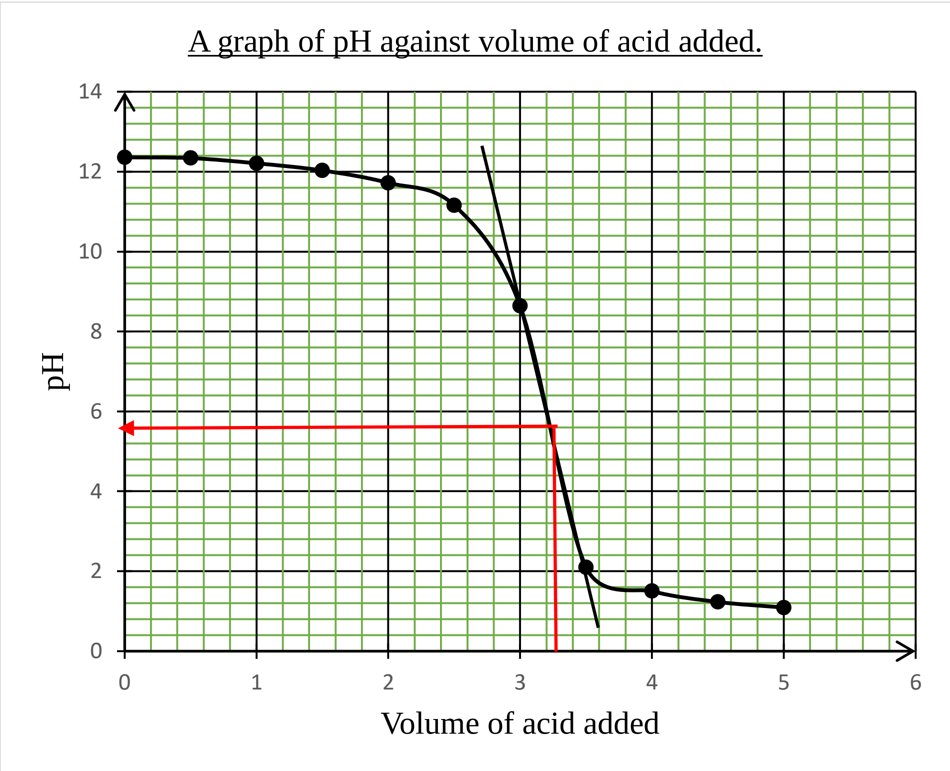


Figure 4.29: *A graph of pH against volume of HCl acid added for a lantana extract indicator.*

From the graph, pH = 5.60

Table 4.30: Tomato as an indicator in the titration of 0.1M CH3COOH & 0.1M NaOH

Volume of pipette = 10ml

Volume of acid added(ml)	pH	colour change
0	12.38	Black
0.5	12.25	Black
1	12.12	Black
1.5	11.94	Black
2	11.61	Black
2.5	11.13	Black
3	9.91	Brown
3.5	6.23	Brown
4	5.25	Brown
4.5	4.82	Brown
5	4.55	Brown
5.5	4.39	Brown
6	4.25	Brown
6.5	4.14	Brown
7	4.07	Brown
7.5	4.01	Brown
8	3.94	Brown

pKa = $\frac{11.13 + 9.91}{2}$

Hence pKa = 10.52

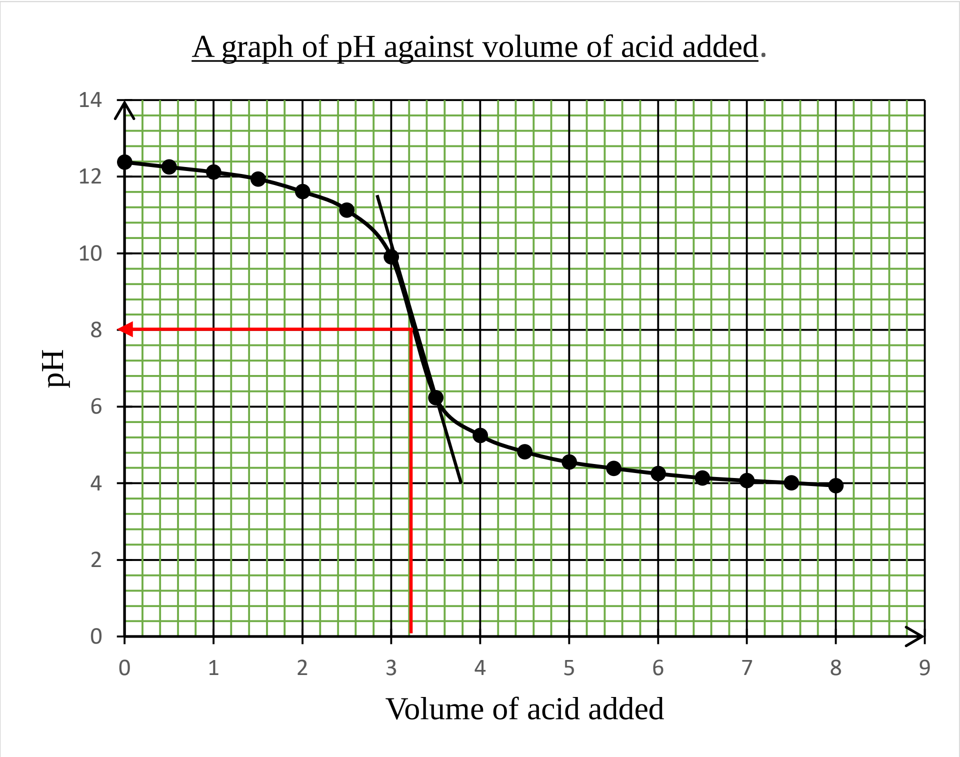


Figure 4.30: A graph of pH against volume of acetic acid added for a lantana extract indicator.

From the graph, pH = 8.00

Table 4.31: Lantana as an indicator in the titration of 0.1M HCl & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	colour-change
0	10.21	Black
0.5	9.9	Black
1	8.99	Black
1.5	7.74	Brown
2	2.94	Brown
2.5	1.51	Brown
3	1.21	Brown
3.5	1.08	Brown

pKa = $\frac{8.99+7.74}{2}$

Hence pKa = 8.37

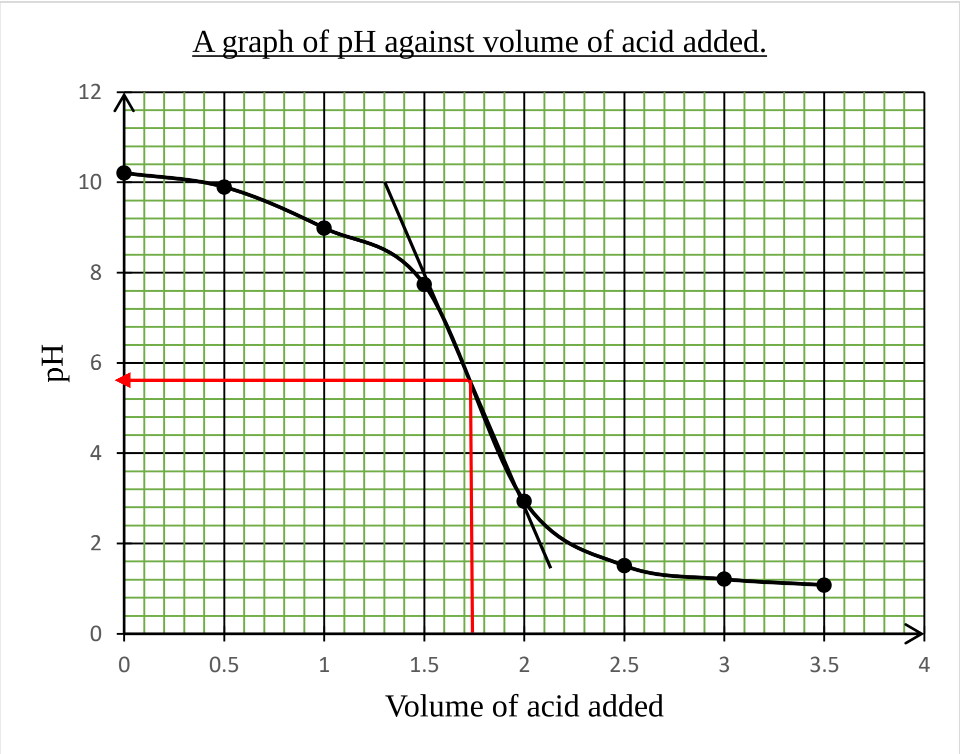


Figure 4.31: *A graph of pH against volume of HCl acid added for a lantana extract indicator.*

From the graph, pH = 5.60

Table 4.32: Lantana as an indicator on the titration of 0.1M CH3COOH & 0.1M NH_4OH

Volume of pipette used = 10ml

Volume of acid added(ml)	pH	colour change
0	10.16	Black
0.5	9.98	Black
1	8.76	Black
1.5	6.94	Brown
2	5.45	Brown
2.5	4.01	Brown
3	3.73	Brown
3.5	3.54	Brown
4	3.42	Brown
4.5	3.34	Brown
5	3.24	Brown

pKa = $\frac{8.76 + 6.94}{2}$

Hence pKa = 7.85

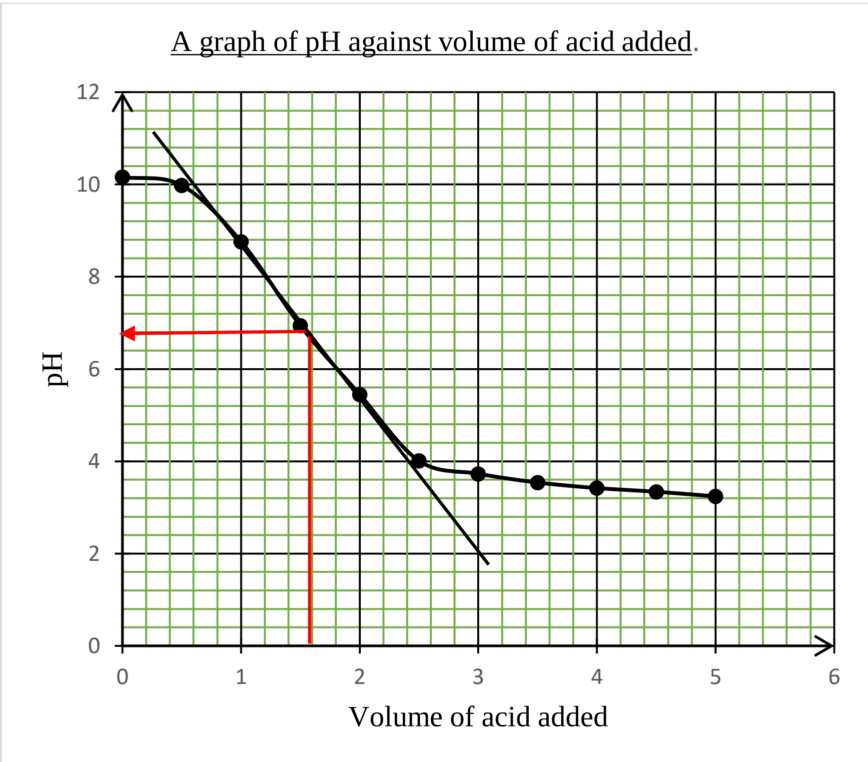


Figure 4.32: *A graph of pH against volume of acetic acid added for a lantana extract indicator.*

From the graph, pH = 6.80

TABLE OF RESULTS

Indicator	Type of titration	pKa	pH range (pKa±1)	pH of neutralization point	Colour-Change	Comment (suitable/not suitable for the titration)
Peacock	NaOH Vs. HCl	8.02	7.02 - 9.02	7.6	Green - Brown	Suitable
	NaOH Vs. CH3COOH	11.84	10.84 -12.84	8.0	Green - Brown	Not suitable
	NH4OH Vs. HCl	7.62	6.62 - 8.62	4.8	Green - Brown	Not suitable
	NH4OH Vs. CH3COOH	7.93	6.93 - 8.93	7.0	Green - Brown	Suitable
Mexican sunflower	NaOH Vs. HCl	8.06	7.06 - 9.06	8.0	Brown - Colourless	Suitable
	NaOH Vs. CH3COOH	7.56	6.56 - 8.56	7.6	Brown - Colourless	Suitable
	NH4OH Vs. HCl	7.89	6.89 - 8.89	4.8	Brown - Colourless	Not suitable
	NH4OH Vs. CH3COOH	5.89	4.89 - 6.89	6.66	Brown - Colourless	Suitable
Cascabela						
	NaOH Vs. HCl	9.83	8.83 - 10.83	8.4	Yellow - colourless	Suitable
	NaOH Vs. CH3COOH	8.07	7.07 - 9.07	8.0	Yellow - colourless	suitable
	NH4OH Vs. HCl	7.89	6.89 - 8.89	5.2	Yellow - colourless	Not suitable
	NH4OH Vs. CH3COOH	7.03	6.03 - 8.03	6.8	Yellow - colourless	suitable
Spectabilis	NaOH Vs. HCl	8.70	7.70 - 9.70	7.6	Brown - colourless	Not suitable
	NaOH Vs. CH3COOH	7.62	6.62 -8.62	7.6	Brown - colourless	Suitable
	NH4OH Vs. HCl	7.84	6.84 - 8.84	4.4	Brown - colourless	Not suitable
	NH4OH Vs. CH3COOH	8.02	7.02 - 9.02	6.0	Brown - colourless	Not suitable
Eggplant	NaOH Vs. HCl	8.62	7.62 - 9.62	7.2	Yellow - colourless	Not suitable
	NaOH Vs. CH3COOH	8.34	7.34 - 9.34	8.2	Yellow - colourless	Suitable
	NH4OH Vs. HCl	8.95	7.95 - 9.95	5.0	Yellow - colourless	Not suitable
	NH4OH Vs. CH3COOH	8.15	7.15 - 9.15	6.4	Yellow - colourless	Not suitable
Apple	NaOH Vs. HCl	6.23	5.23 - 7.23	6.2	Green - colourless	Suitable
	NaOH Vs. CH3COOH	8.35	7.35 - 9.35	8.4	Green - colourless	Suitable
	NH4OH Vs. HCl	8.11	7.11 - 9.11	6.8	Green - colourless	Not suitable
	NH4OH Vs. CH3COOH	8.23	7.23 - 9.23	6.4	Green - colourless	Not suitable
Tomato	NaOH Vs. HCl	8.15	7.15 - 9.15	6.6	Brown - colourless	Not suitable
	NaOH Vs. CH3COOH	8.54	7.54 - 9.54	7.6	Brown - colourless	Suitable
	NH4OH Vs. HCl	7.64	6.64 - 8.64	7.2	Brown - colourless	Suitable
	NH4OH Vs. CH3COOH	7.74	6.74 - 8.74	6.8	Brown - colourless	Suitable
Lantana	NaOH Vs. HCl	9.90	8.90 - 10.90	5.6	Black - Brown	Not suitable
	NaOH Vs. CH3COOH	10.52	9.52 - 11.52	8.0	Black - Brown	Not suitable
	NH4OH Vs. HCl	8.37	7.37 - 9.37	5.6	Black - Brown	Not suitable
	NH4OH Vs. CH3COOH	7.83	6.83 - 8.83	6.0	Black - Brown	Not suitable

Peacock flower extract

The pigments extracted from the Peacock plant exhibit a green to brown color change across different titrations.

The pH at the point of neutralization varies significantly depending on the titration, with the most suitable pKa values aligning with NaOH vs. HCl (pKa = 8.02) and NH_4OH vs. CH_3COOH (pKa = 7.93).

The indicator is suitable for titrations where the pH of neutralization is close to the pKa, such as NaOH vs. HCl and NH_4OH vs. CH_3COOH. In these cases, the color change is distinct, making it useful as an indicator.

It is not suitable for NaOH vs. CH_3COOH and NH_4OH vs. HCl, where the pKa values are significantly different from the neutralization points, leading to less clear or ineffective color changes.

Mexican Sunflower extract

The Mexican Sunflower pigment exhibits a brown to colorless transition during titrations.

It shows consistent pKa values across different titrations, with pKa values ranging from 5.89 to 8.06.

The indicator is suitable for most titrations, especially NaOH vs. HCl and NaOH vs. CH_3COOH, where the pH of neutralization aligns well with the pKa values, resulting in a clear brown to colorless transition.

It is not suitable for NH_4OH vs. HCl due to a significant difference between the pKa value and the pH of neutralization, which would make the color change less clear.

Cascabela flower extract

The pigment from Cascabela turns from yellow to colorless during titrations.

The pKa values observed range from 7.03 to 9.83, with the most suitable being NaOH vs. HCl (pKa = 9.83).

It is suitable for titrations such as NaOH vs. HCl and NaOH vs. CH_3COOH, where the pKa values are close to the neutralization points, resulting in a distinct color change.

The indicator is not suitable for NH_4OH vs. HCl due to the pKa not aligning well with the neutralization point, making the yellow to colorless transition less effective.

Spectabilis flower extract

The Spectabilis plant pigment changes from brown to colorless during titrations.

It has pKa values ranging from 7.62 to 8.70, but the neutralization points vary significantly, especially in NaOH vs. HCl.

It is suitable for NaOH vs. CH_3COOH, where the pKa is closely aligned with the neutralization point, leading to a clear brown to colorless transition.

It is not suitable for other titrations, such as NaOH vs. HCl and NH_4OH vs. HCl, where the pKa and neutralization points differ significantly.

Eggplant extract

The pigment from Eggplant changes from yellow to colorless during titrations.

The pKa values are relatively high, ranging from 8.15 to 8.95, but there is variability in the pH of neutralization.

It is suitable for NaOH vs. CH_3COOH, where the pKa value is close to the neutralization point, resulting in a distinct yellow to colorless change.

The indicator is not suitable for NaOH vs. HCl and NH_4OH vs. HCl, as the pKa values do not align well with the neutralization points, making the transition less effective.

Apple extract

Apple pigments exhibit a green to colorless change.

The pKa values range from 6.23 to 8.35, with some close alignment to the neutralization points.

It is suitable for NaOH vs. HCl and NaOH vs. CH_3COOH, where the pKa values align well with the neutralization points, producing a clear green to colorless transition.

It is not suitable for NH_4OH vs. HCl and NH_4OH vs. CH_3COOH, where the pKa values differ significantly from the neutralization points.

Tomato extract

The Tomato pigment changes from brown to colorless during titrations.

The pKa values are within the range of 7.64 to 8.54, with varying suitability across different titrations.

It is suitable for NaOH vs. CH3COOH and NH4OH vs. CH3COOH, where the pKa values align with the neutralization points, resulting in a distinct brown to colorless change.

The indicator is not suitable for NaOH vs. HCl and NH4OH vs. HCl due to significant differences between the pKa and neutralization points.

Lantana extract

Lantana pigments change from black to brown, with relatively high pKa values ranging from 7.83 to 10.52.

However, the neutralization points are significantly lower than the pKa values.

The indicator is generally not suitable for any of the titrations due to the large difference between the pKa values and the pH of neutralization. This misalignment results in unclear or ineffective color changes, making it unsuitable for titration.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, the study successfully identified effective natural pH indicators from certain plant species, with pigments showing suitability depending on their pKa values in relation to the pH of neutralization. The color changes observed in these pigments, such as green to brown or yellow to colorless, were clear when the pKa values were closely aligned with the titration endpoint. This variability highlights the importance of selecting appropriate natural indicators for specific titrations. The research supports the broader use of natural substances as sustainable alternatives to synthetic chemicals and opens up new possibilities for their application in educational and industrial contexts. Further exploration into more plant species and optimization of the extraction process could enhance the practical use of natural indicators, contributing to greener chemical practices.

5.2 RECOMMENDATION

From this study, it is recommended to focus on pigments from the Mexican Sunflower, Cascabela, and Apple as effective natural indicators for acid-base titrations, particularly in reactions involving strong bases like sodium hydroxide and weak acids like ethanoic acid. These pigments demonstrated a close alignment between their pKa values and the pH of neutralization, resulting in clear color changes. Conversely, pigments from the Lantana plant were consistently unsuitable and should be avoided for titration purposes. Further research is encouraged to explore additional plant species that could serve as natural pH indicators, and to refine the extraction methods for higher yield and purity. Expanding the use of these natural indicators beyond the laboratory to applications such as pH-sensitive packaging or eco-friendly colorants in food and cosmetics could provide sustainable alternatives to synthetic chemicals. These findings also suggest a valuable role for natural indicators in educational settings, promoting environmental sustainability.

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