# VAISHNO COLLEGE OF ENGINEERING

**Affliated to HPTU, Hamirpur and approved by AICTE**

# Applied Chemistry

# Lab Manual

# CH-111P (NEP Syllabus)

**Department of Applied sciences**

**VillThapkour, PO Bhardoya, Tehsil Indora,Distt. Kangra (HP)-176403**

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**Vision of Institute**

To emerge as an institute of eminence in the fields of engineering, technology and management in serving the industry and the nation by empowering students with a high degree of technical managerial and practical competence.

**Mission of Institute**

M1 To strengthen the theoretical, practical and ethical dimensions of the learning process by fostering a cultural of research and innovation among faculty members and students.

M2 To encourage long term interaction between academia and industry through the involvement of industry for hands on implementation of the curriculum.

M3 To strengthen and molding students in professional ethical, social and environmental dimensions by encouraging participation in co-curricular extracurricular and CSR activities.

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## Lab Syllabus & List of Experiments

| CHM-111P Applied Chemistry Lab | | | | | | | |
|---|---|---|---|---|---|---|---|
| Teaching Scheme | | | Credit | Marks Distribution | | | Duration of End Semester Examination |
| L | T | P | | Internal Assessment | End Semester Examination | Total | |
| 0 | 0 | 2 | 1 | Maximum Marks: 30 | Maximum Marks: 20 | 50 | 2 Hours |
| | | | | Minimum Marks: 12 | Minimum Marks: 8 | 20 | |

Following is the list of experiments/ jobs. Minimum 08 number of practicals are to be performed from following list. The additional experiments may be performed by the respective institution depending on the infrastructure available.

**Laboratory Work:**

1. To determine the pH and conductivity of five different water samples.
2. To determine total alkalinity in a given sample of water using standard acid.
3. To determine total hardness of water using complexometric titration method.
4. To determine the amount of Chlorine (residual) in given sample of water using N/20 Sodium thio sulphate solution.
5. To determine the percentage of Chlorine in sample of bleaching powder, 10 g of which are dissolved in 500ml of water.
6. To determine the amount of Chromium in given sample of water.
7. To determine dissolved oxygen in given sample of water.
8. To determine the coefficient of viscosity of the given unknown liquids by using Ostwald‘s Viscometer
9. To determine the coefficient of viscosity of the given lubricating oil using Red Wood Viscometer.
10. To determine surface tension of given liquid by drop number method using Stalagmometer.
11. To determine % age of moisture, volatile matter, ash and fixed carbon in given sample of coal by proximateanalysis method.
12. To verify Beer's Law and apply it to find the concentration of given unknown solution by using UV-visiblespectra-photometer.
13. Estimation of Copper/Iron.
14. Preparation of any of the following polymers: Phenol formaldehyde resins/Urea formaldehyde resins
    /Biodegradable /conducting polymer.
15. To synthesize a polymer using synthetic monomer via free radical polymerization and characterize thepolymer using FTIR spectra-photometer.
16. To synthesize a semisynthetic polymer via grafting of monomer on polymeric backbone and

characterize thepolymer using FTIR spectra-photometer.

17. Synthesis of nano-particles of Au/Ag/NiO/ZnO/Iron Oxide

## Evaluation Scheme

**Internal Assessment: 30 marks (pass marks:12)**

Distribution of marks for internal assessment:

- Written/presentation/Demonstration: 05
- Viva-voice: 05
- Teacher assessment: Lab Work performance/Report/File Work:15
- Attendance: 05

**External Assessment: 20 marks (pass marks: 08)**

**Total marks 30+20=50, Pass marks = 20**

**Note: Student has to pass internal & external assessment separately.**



## GENERAL GUIDELINES AND SAFETY INSTRUCTIONS

1. Sign in the log register as soon as you enter the lab and strictly observe your lab timings.

2. Strictly follow the written and verbal instructions given by the teacher / Lab Instructor. If you do not understand the instructions, the handouts and the procedures, ask the instructor or teacher.

3. Never work alone! You should be accompanied by your laboratory partner and / or the instructors / teaching assistants all the time.

4. It is mandatory to come to lab in uniform and wear your ID cards.

5. Do not wear loose-fitting clothing or jewellery in the lab. Rings and necklaces are usual excellent conductors of electricity.

6. Mobile phones should be switched off in the lab.

7. Keep the labs clean at all times, no food and drinks allowed inside the lab.

8. Intentional misconduct will lead to expulsion from the lab.

9. Do not handle any equipment without reading the safety instructions. Read the handout and procedures in the Lab Manual before starting the experiments.

10. Immediately report dangerous or exceptional conditions to the Lab instructor / teacher: Equipment that is not working as expected.

11. Be sure of location of fire extinguishers and first aid kits in the laboratory.

12. Observation book and lab record should be carried to each lab. Readings of current lab experiment are to be entered in Observation book and previous lab experiment should be written in Lab record book. Both the books should be corrected by the faculty in each lab.

## Experiment No: 1

**Aim:**

Determine the surface tension of a given liquid at room temp using stalgmometer by drop number method

## Requirements:

Stalgmometer, specific gravity bottle, a small rubber tube with a screw pinch cork, distilled water, experimental liquid.

## Theory:

In the drop number method, the number of drops formed by equal volumes of two liquid is counted. If $m_1$ and $m_2$ is the mass of one drop of each of the liquid having densities $d_1$ and $d_2$ respectively. If $n_1$ and $n_2$ is the number of drops formed by volume v of the two liquids, then their surface tensions are related as

$$¥_1/¥_2 = (d_1/d_2)*(n_2/n_1)$$

One of the liquid is water its surface tension and density are known.Then te surface tension of the given liquid can be calculated.

## Procedure:

1. Clean the stalgmometer with chromic acid mix, wash with water and dry it
2. Attach a small piece of rubber tube having a screw pinch cock at the upper end of the stalgmometer.
3. Immerse the lower end of the stalgmometer in distilled water and suck the water 1-2cm above mark A. adjust the pinch cork so that 10-15 drops fall per minute

4. Clamp the stalgmometer allow the water drops to fall and start counting the number of drops when the meniscus crosses the upper mark A and stop counting when the meniscus passes mark B
5. Repeat the exercise to take three to four readings
6. Rinse the stalgmometer with alcohol and dry it
7. Suck the given liquid in the stalgmometer and count the drops as in case of water
8. Take a clean dry weighing bottle weighs it with water as well as with liquid.
9. Note the temp of water taken in a beaker.

## Observations:

Room temp=$t^0C$

Density of water=$d_w$

Surface tension of water=¥ dynes/cm

| | No of drops From a Fixed Volume | | | Mean |
|---|---|---|---|---|
| Liquid | 1…. | 2…… | 3….. | $n_l$= |
| Water | 1…. | 2……. | 3…… | $n_w$= |

Weight of empty specific gravity bottle=$w_1$gram

Weight of specific gravity bottle+water=$w_2$ gram

Weight of empty sp.gravity bottle+liquid=$w_3$gram

Weight of water= ($w_2$-$w_1$)gram

Weight of liquid= ($w_3$-$w_1$)gram

## Calculations:

Density of the liquid

$D_l = (w_3 - w_1)/(w_2 - w_1) * d_w$

Surface tension of liquid=

$¥_l/¥_w = (d_l/d_w)*(n_w/n_l)* ¥_w$

## Result

The surface tension of liquid is ……dynes/cm.

**Experiment No: 2**

**Aim: To determine the coefficient of viscosity of a given unknown liquid, by using Ostwalds viscometer.**

**Requirements:** Ostwald viscometer, rubber tube with screw pinch cock, stand, beaker, unknown liquid, distilled water. specific gravity bottle

**Theory:** The force of friction which one part of the liquid offers to another part of the liquid is called viscosity. For measuring the viscosity coefficient, Ostwald viscometer method is used which is based on Poiseuille's law. According to this law, the rate of flow of liquid through a capillary tube having viscosity coefficient, η, can be expressed as

$$\eta = \pi \cdot r^4 Tp / 8vl$$

where, v= vol. of liquid (in ml)

t= flow time (in sec.) through capillary r= radius of the capillary (in cm)

l= length of the capillary (in cm)

P= hydrostatic pressure (in dyne/sq.cm)

η= viscosity coefficient (in poise).

Since, the hydrostatic pressure (the driving force) of the liquid is given by P = dg h (where h is the height of the column and d is the density of the liquid);

$$\eta \propto P\ t\ ; \quad \text{or,} \quad \eta \propto d\ g\ h\ t$$

If, η1 and η2 are the viscosity coefficients of the liquids under study, d1, d2 , are their densities and t1 and t2 are their times of flow of *equal volume* of liquids through the same capillary respectively, then

$$\eta 1 \propto d1\ g\ h\ t1 \text{ and } \eta 2 \propto d2\ g\ h\ t2$$

*Hence,*

$$\eta_1/\eta 2 = d_1 t_{1/d2t2}$$

viscosity of one **Pa·s** is placed between two plates, and one plate is pushed sideways with a shear stress of one pascal, it moves a distance equal to the thickness of the layer between the plates in one second. The cgs unit for the same is the **poise** (P), (named after J. L. Marie Poiseuille). It is more commonly expressed, as **centipoise** (**cP**). [1 cP = 0.001 Pa·s]. Water at 20

°C has a viscosity of 1.0020 cP.

## Procedure:

1. Note the laboratory temperature.
2. Wash the specific gravity bottle with distilled water and dry.
3. Take the weight of the empty & filled (with distilled water) specific gravity bottle (with stopper). Then, weigh the filled with specific gravity bottle h unknown given liquid. Use the data for measuring the densities.
4. Clean and rinse the viscometer properly with distilled water. Fix the viscometer vertically on the stand and filled with specific amount (say 20ml) of mixture (every time take the same volume).
5. Time of flows were recorded for each solutions (water and the given liquid).
6. Take 3 to 4 readings.

## Observations:

1. Laboratory temperature=…. ˚C
2. Density measurement:

Weight of empty R.D.bottle (w1) =…g.

Weight of R.D.bottle with water (w2) =…g.

Weight of R.D. bottle with liquid (w3) =…g.

So, weight of water (ww) = (w2-w1) =…g.

| Sl no. | Flow times (sec) | | | |
|---|---|---|---|---|
| | t1 | t2 | t3 | mean |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

## Calculations:

**1.** Determination of the density of the liquid (dl):

$$\frac{\text{Density of liquid (dl)}}{\text{Density of water (dw)}} = \frac{\text{Weight of liquid}}{\text{Weight of water}}$$

Determination of the viscosity of the liquid ($\eta_l$)

Viscosity of the liquid, $\eta$ = dl/dw x tl/tw x viscosity of water

**Result:** The viscosity of the given liquid with respect to water at laboratory temperature was found to be cP.

**Experiment No: 3**

**AIM -** To determine the hardness of water using complexometric titration method.

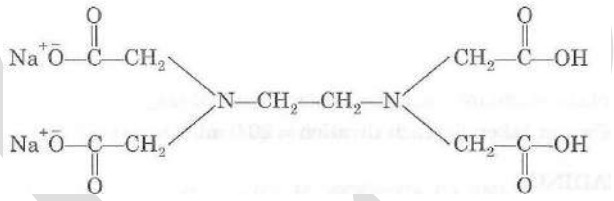
**APPRATUS REQUIRED** - Burette, pipette, conical flask, Beaker, test tube.

**CHEMICAL REQUIRED -**

1. EDTA solution
2. Water sample
3. Erichrome Black – T (EBT)
4. Buffer solution of pH = 10

## THEORY -

The concentration of hardening ions in water can be determined by a titration technique, the titrant is the disodium salt of ethylene-diamine-tetraacetic acid



Disodium salt of ethylene diamine-tetracetic acid.

*(Abbreviated as $Na_2H_2Y$ or EDTA)*

In aqueous solution, $Na_2H_2Y$ dissociates into $Na^+$ and $H_2Y^{2-}$ ions. $Ca^{2+}$ and $Mg^{2+}$ react with $H_2Y^{2-}$ to form stable complexes in a solution having pH of

about 10. A buffer solution containing ammonia and ammonium ions is used to maintain the pH of the solution around 10.

For the detection of the end point Erichrome Black T (EBT) is used as indicator. EBT forms complex ions with $Ca^{2+}$ and $Mg^{2+}$ ions, but binds more strongly to $Mg^{2+}$ ions. Since only a small amount of EBT is added, only a small amount of $Mg^{2+}$ ions is used in formation of complex and no $Ca^{2+}$ ions are used. EBT indicator is sky-blue in solution but its complex with $Mg^{2+}$ ions, $[Mg\text{- }EBT]^{2+}$, is wine-red.

$$Mg^{2+}(aq) + EBT(aq) \rightarrow [Mg\text{-}EBT]^{2+}(aq)$$

Sky-blue Wine-red

Thus, during titration when indicator is added to hard water, the initial colour is wine red. When the titrant is added, $H_2Y^{2-}$ complexes with free $Ca^{2+}$ and $Mg^{2+}$ present in water and finally removes $Mg^{2+}$ ions from the $[Mg\text{-}EBT]^{2+}$ complex ions. As a result the colour of the solution changes from wine-red to sky blue

$$[Mg\text{-}EBT]^{2+}(aq) + H_2Y^{2-}(aq) \rightarrow MgY^{2-}(aq) + 2H^{+}(aq) + EBT(aq)$$

Wine-red Sky blue

It may be mentioned here that for the end point to appear, $Mg^{2+}$ ions must be present in the solution. Therefore, a small amount of $Mg^{2+}$ ions (as some salt) is added to the buffer solution and an equivalent amount of $Na_2H_2Y$ is also added so that the added $Mg^{2+}$ ions do not affect the amount of $H_2Y^{2-}$ used during titration.

## PROCEDURE -

1. Rinse Burette with EDTA solution & fill it upto the mark.

2. Rinse pipette with sample A solution & pipette out 10 ml of it into water washed conical flask.
3. Add about half tube of buffer solution having pH-10 to conical flask.
4. Add 2 or 3 drops of Erichrome Black T indicator of solution in conical flask. Wine colour is obtained.
5. Titrate solution with EDTA solution till the colour changes from wine red to original blue colour with single drops of EDTA solution.
6. Note down the reading.
7. Repeat the above process till the similar readings are obtained.

## OBSERVATION :-

A. Sample "A" or known hard water

| S.No. | Volume of Sample "A" (in ml) | EDTA of Burette reading | | Volume of EDTA (in ml) |
|---|---|---|---|---|
| | | Initial | Final | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

Calculation: - $N_1N_1 = N_2V_2$

RESULT:- The total harness of given unknown water sample is found to be ppm

## PRECAUTIONS:-

1. Reading should be taken carefully.
2. The end print should be checked.
3. Note that there should be no air bubble in nozzle of burette

**Experiment No: 4**

**AIM** -To determine %age of moisture, volatile matter, ash and fixed carbon in given sample of coal by proximate analysis method.

## PROCEDURE -

1. Moisture – It is determined by heating a known quantity of air dried coal from $105^0$C-$110^0$C for one hour and calculating the loss in weight as percentage. Heat a silica crucible with lid, cool it in a desiccator and weigh. Take 1 gram of coal sample in it and again weigh, heat the crucible without lid in an air oven at $105^0$C-$110^0$C for 1 hour, cool the crucible in a desiccator and weigh it again.

   The loss of weight corresponds to the moisture.
2. Volatile Matter:- It is determined by heating 1 gram of air dried coal for 1 minute in a translucent silica crucible at a steady temperature of $925^0$C in a muffle furnace.
3. Ash :- Take one gram of powdered air dried sample in previously weighed crucible having 5 cm diameter and 1 cm depth. Place a crucible on a claypipe triangle and heat over a Bunsen burner with a wavy flame. Place the crucible without lid in muffle furnace at $750^0$C and heat for 1 hour cool it in a desiccators to room temperature and weigh with lid.
4. Fixed carbon :- The sum of total of percentages of volatile matter, moisture and ash subtracted from 100 gives the percentage of fixed carbon.

## CALCULATION:-

1. Moisture –

Weight of empty crucible = $W_1$ gm

Weight of crucible + sample = $W_2$ gm

Weight of crucible + sample after heating = $W_3$ gm

$$\% \text{ moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

2. Volatile matter –

Weight of empty crucible = $W_4$ gm

Weight of crucible + sample = $W_5$ gm

Weight of crucible + sample after heating = $W_6$ gm

$$\% \text{ (moisture + Volatile matter)} = \frac{W_5 - W_6}{W_5 - W_4} \times 100$$

$$\% \text{ of Volatile matter} = \left( \frac{W_5 - W_6}{W_5 - W_4} \times 100 \right) - (\% \text{ moisture})$$

3. Ash –

Weight of empty crucible = $W_7$ gm

Weight of crucible + sample = $W_8$ gm

Weight of crucible + ash = $W_9$ gm

$$\% \text{ Ash} = \frac{W_9 - W_8}{W_8 - W_7} \times 100$$

4. Fixed carbon :-

$$\% Fc = 100 - ( \% \text{ Moisture} + \% \text{ Volatile matter} + \% \text{ Ash} )$$

**Experiment No: 5**

**Aim:** Determine the Alkalinity of given water using standard acid.

**Introduction:** The alkalinity of the water is a measure of its capacity to neutralize acids. The alkalinity of natural waters is due primarily to the salts of week acids. Bicarbonates represent the major form of alkalinity. Alkalinity can be expressed as follows: Alkalinity (mol/L) = $[HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. As alkalinity of many surface waters constitute of carbonates, bicarbonate and hydroxide contents, it is assumed to be an indicator of these constituents as well. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes. Raw domestic wastewater has an alkalinity less than or only slightly greater than that of the water supply.

## Requirements:

Apparatus: Burette, conical flask, pipette, measuring cylinder

Reagents: $H_2SO_4$ solution, Phenolpthalein indicator, Methyl Orang indicator

## Procedure:

1. Fill the burette to $H_2SO_4$ solution.
2. Take a 100ml water sample in flask. Add few drop of Phenolphthalein indicator.
3. Note the initial reading on burette scale. Titrate against $H_2SO_4$ till the pink colour disappear.

**4.** Note the end point reading and get volume of used $H_2SO_4$ in ml (P) (Concordant value I).

5. Add 1-3 drop of Methyl Orange in same sample flask.
6. Titrate it, till the appearance of light orange colour.
7. Note down the final reading and find the volume of used $H_2SO_4$.
8. Repeat the steps of using the sample to get concordant value (Concordant value II).
9. Calculate the total alkanity of sample.

## Observation:


**Observation table:**

For Concordant value I: Determination of phenolphthalein end point

| S.No. | Water sample | Initial Value | Final Value | Ml of $H_2SO_4$ (P) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

For Concordant value II: Determination of methyl orange end point

| S.No. | Water sample | Initial Value | Final Value | Ml of $H_2SO_4$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

## Calculations:

Total volume of standard $H_2SO_4$ used for the titration: T = Concordant value I + Concordant value II

Thus, Phenolpthalein alkalinity = P*1000/ml sample Total alkalinity (mg/lit of $CaCO_3$) = T*1000/ml sample

# Experiment No: 6

**Aim:** To determine the percentage of chlorine in sample of bleaching powder,10 g of which are dissolved in 500 ml of water.

## Apparatus Required:

Conical flask, Burette, Pipettes .

## Principle:

Chlorine is a strong oxidizing agent and liberates Iodine from Iodide ions. $Cl2 + 2\ KI \longrightarrow I2 + 2KCl$

Starch gives blue colour with

Iodine i.e., $I_2$ + starch ⟶

Blue Colour

The liberated Iodine is titrated against standard Sodium

Thiosulphate-reducing agent $I_2 + 2Na_2S_2O_2 \longrightarrow Na_2S_4O_6\ 2NaI$

The disappearance of blue colour indicates the completion of reaction with free iodine converted black to iodine.

**Reagents**:

1. Conc.Acetic Acid
2. Potassium Iodide Crystals
3. Sodium Thiosulphate
4. Starch Indicator

**Procedure:**

1. 1 gm of fresh bleaching powder is taken and is added to a small quantity of water and made into a fine paste. Some more water is added, stirred well and allowed to settle for a few minutes. It is diluted with distilled water to make upto 1 L and the container is stoppered.
2. 25 ml of the bleaching powder solution is taken in a conical flask and a pinch of Potassium Iodide is added.
3. 2 ml of acetic acid is added and is allowed for the reaction to complete.
4. 1 ml of starch solution is added and the titration is continued till the disappearance of blue colour.

**Tabulation:**

| Sl.No | Volume of water sample (ml) | Burette Reading (ml) | | Concurrent Burette Reading (ml) | Volume of Sodium Thiosulphate (ml) |
|---|---|---|---|---|---|
| | | Initial Reading | Final Reading | | |
| | | | | | |

**Calculation:**

Concentration of chlorine, mg/l = (V1-V2) x Normality of titrant x 1000 x Eq.wt of chlorine

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Volume of Sample

Percentage of chlorine = Concentration of chlorine x 100

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**Result:** 1. The available chlorine in the given sample of bleaching powder is = ---------- mg/l

2. Percentage of chlorine content in bleaching powder is = ----------
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**Inference:**

If the bleaching powder consisted wholly of Ca(OCl)Cl it contains 55% of available chlorine—that is, chlorine which can be liberated by treatment with dilute acid; but the commercial variety generally contains other substances, and does not yield more than 36% available chlorine.

**Experiment No: 7**

**Aim:**

To find the amount of residual chlorine present in the given water sample.

## Apparatus Required:

Burette, Conical flask, Pipette, Measuring jar.

## Principle:

Chlorine is primarily added to the water for destroying the harmful micrororganisms. Presence of excess chlorine intensifies the taste and odour of any other compounds in combination with ammonia.

Chlorine is a strong oxidizing agent and liberates Iodine from Potassium Iodide. The liberated Iodine is equivalent to the amount of chlorine and can be titrated against Sodium thiosulphate using starch as an indicator.

## Reagents:

1. Acetic Acid
2. Potassium Iodide
3. Sodium Thiosulphate.

## Procedure:

1. Take 100ml water sample in a conical flask and add 5ml acetic acid. The pH after addition of acetic acid should be between 3 and 4.
2. Add approximately 1 gm of KI crystals and mix thoroughly with a stirring rod for about 15 minutes keeping it away from the direct sunlight.
3. Add a few drops of starch indicator and titrate against 0.025N sodium thiosulphate until the contents turn colourless from blue.

## Result:

The amount of residual chlorine present in the given water sample is ----------

## Inference:

Residual chlorine is the low level amount of chlorine remaining in the water after a certain period or contact time after its initial application. It constitutes an important safeguard against the risk of subsequent microbial contamination after treatment—a unique and significant benefit for public health.

## Tabulation:

| Sl.No | Volume of water sample (ml) | Burette Reading (ml) | | Concurrent Burette Reading (ml) | Volume of Sodium Thiosulphate (ml) |
|---|---|---|---|---|---|
| | | Initial Reading | Final Reading | | |
| | | | | | |

**Calculation:**

$$\text{Residual chlorine, mg/l} = \frac{\text{ml of titrate} \times \text{Normality of Titrate} \times 1000 \times \text{Eq.wt of chlorine}}{\text{Volume of Sample}}$$

**VIVA QUESTIONS:-**

**VIVA QUESTIONS:-**

1. Define surface tension.
2. What are the units of surface tension?
3. Which phenomena is responsible for the shape of liquid droplets?
4. Define viscosity.
5. What are the units of viscosity?
6. What do you mean by fluidity?
7. How viscosity of a liquid varies with temperature?
8. What is the significance of determination of moisture content, volatile matter, ash content?
9. What is the source of alkalinity in water?
10. What is hardness?
11. What are the disadvantages of hard water ?
12. What is full form of EDTA and EBT?
13. Why chlorine is added to water?
14. What is the chemical formula of bleaching powder?
15. What are the disadvantages of excess of chlorine present in water?
16. What is equivalent weight ?
17. What is normality?

## Laboratory Experiment Evaluation Rubric

| Category | Outstanding (Up to 100%) | Accomplished (Up to 75%) | Developing (Up to 50%) | Beginner (Up to 25%) |
|---|---|---|---|---|
| **Written/Presentation/Demonstration** | The write-up is clear, well-organized, and follows the prescribed format. All required sections (aim, apparatus, theory, procedure, diagram, etc.) are present and well-written. Demonstration is clear and thorough. | The report follows the specified format, but some sections (like the diagram or theory) are missing or incomplete. The demonstration is understandable but lacks depth. | The report includes most sections but lacks clarity, coherence, or completeness in some parts (e.g., diagram missing, unclear theoretical explanation). The demonstration is incomplete or unclear. | The report is poorly written and organized. Many sections are missing or incorrect (e.g., no diagram, incomplete procedure). The demonstration lacks clarity or is missing. |
| **Viva-Voice** | Demonstrates a deep understanding of the experiment, underlying principles, and outcomes. Answers questions confidently | Demonstrates a general understanding of the experiment and principles but struggles with some aspects. Provides correct answers to | Struggles with some fundamental concepts and principles. Answering questions requires additional prompts, with a few errors in | Lacks a basic understanding of the experiment. Unable to answer most questions accurately. Demonstrates significant gaps in knowledge. |

| Category | Outstanding (Up to 100%) | Accomplished (Up to 75%) | Developing (Up to 50%) | Beginner (Up to 25%) |
|---|---|---|---|---|
| | and accurately. | most questions. | understanding. | |
| **Performance/Report/File Work** | Performs the experiment accurately and efficiently. The report is thorough, with correct observations, calculations, and analysis. Data is recorded neatly and with appropriate units. All relevant calculations and interpretations are included. | Performs the experiment well with minor errors or delays. The report is complete but may contain some inaccuracies or missing components in calculations or observations. | Completes the experiment but with notable mistakes, either in the setup or the data. The report has several missing or inaccurate components, including incorrect or incomplete calculations. | Struggles to perform the experiment correctly. Significant errors in setup, data collection, and analysis. The report is poorly structured with major inaccuracies or missing sections. |
| **Attendance** | Consistently attends all lab sessions, actively participates, and engages with the experiment | Attends most lab sessions with occasional absences. Participation is generally good but lacks | Attends some lab sessions but has frequent absences or minimal participation. | Misses several lab sessions and shows minimal to no participation in class or |

| Category | Outstanding (Up to 100%) | Accomplished (Up to 75%) | Developing (Up to 50%) | Beginner (Up to 25%) |
|---|---|---|---|---|
| | and group discussions. | consistency or depth. | | group activities. |