
## COLLEGE OF SCIENCES CHEMISTRY DEPARTMENT

# CHEM 330

# LABORATORY OF PHYSICAL CHEMISTRY OF POLYMERS

## APPROVED FOR THE ACADIMIC YEAR 2025/2026

# Course: CHEM 330 Laboratory

## Schedule of Experiments


| Experiment No. | Experiment Name | Pages |
|---|---|---|
| 1 | Identification of Polymer Type | 2 - 7 |
| 2 | Preparation of Phenol-Formaldehyde Polymer (Bakelite) | 8 - 11 |
| 3 | Preparation of Polystyrene Compound | 12 - 14 |
| 4 | Extraction of Starch from Potatoes and Preparation of Plastic Films from Starch; Study of Plasticizer Effect on Film Properties | 15 - 19 |
| 5 | Isolation of Casein from Skimmed Milk and Its Use in Adhesive Production | 20 - 22 |
| 6 | Preparation of Casein Paint | 23 - 25 |
| 7 | Preparation of Synthetic Fiber from Cellulose (Rayon) | 26 - 28 |
| 8 | Preparation of Polyvinyl Alcohol Slime | 29 - 32 |
| 9 | Determination of Polymer Molecular Weight by Viscosity Measurement | 33 - 36 |
| 10 | Measurement of Polymer Swelling Capacity and Its Applications in Liquid Absorption | 37 - 40 |
| *** | Final Exam | *** |


## Grade Distribution

| Reports | Lab Evaluation | Final Exam |
|---|---|---|
| 10 marks | 5 marks | 15 marks |

# EXP(1) : Identifying the Type of Polymer

## -Theoretical Principle

Polymers (commonly known as plastics) are long-chain molecules composed of repeating units called monomers. Depending on the type and arrangement of these monomers, polymers exhibit different physical and chemical properties. Since chemical testing of polymers may involve hazardous or toxic substances, studying their physical properties—such as density—is safer and more practical. Identifying the type of polymer based on density also helps in recycling processes. Recycling involves sorting and separating waste materials according to their properties, then reprocessing them individually.

Recycling contributes to
- conserving material and energy resources.
- reducing consumption by extending product lifetime.
- improving production efficiency.
- saving energy by reducing manufacturing processes.
- reducing landfill accumulation.
- lowering environmental pollution from harmful substances.

## -Aim of the Experiment

To identify the type of plastic polymer by determining its density using solutions of known densities.

## -Materials and Chemicals

- Different plastic samples from household and environmental sources, usually labeled with recycling codes.


- Several solutions with known densities are used (only 6–8 may be required):

| No. | Solution | Density (g/cm³) |
|---|---|---|
| 1 | 40% $CaCl_2$ (aq) | 1.3982 |
| 2 | 32% $CaCl_2$ (aq) | 1.3059 |
| 3 | 6% $CaCl_2$ (aq) | 1.0505 |
| 4 | 24% Ethanol (aq) | 0.9549 |
| 5 | 38% Ethanol (aq) | 0.9408 |
| 6 | 52% Ethanol (aq) | 0.911 |
| 7 | Butanol | 0.8 |
| 8 | Cyclohexane | 0.7 |
| 9 | Dimethylformamide | 0.94 |
| 10 | Ethanol 596 ml + deionized water 439 ml | 0.94 |
| 11 | Ethanol 448 ml + deionized water 586 ml | 0.91 |
| 12 | Pure Ethanol | 0.79 |
| 13 | Distilled/deionized water | 1.0 |
| 14 | $K_2CO_3$ (184 g in 965 ml DI water) | 1.15 |
| 15 | Dichloromethane | 1.33 |
| 16 | $K_2CO_3$ (513 g in 866 ml DI water) | 1.38 |

## -Safety Precautions

- Always wear a lab coat, gloves, and a mask.
- Ethanol and butanol: flammable liquids; may cause irritation to the eyes and skin.
- Dichloromethane: harmful, possible carcinogen, and irritant; Calcium chloride ($CaCl_2$): causes skin and eye irritation.
- Cyclohexane: highly flammable, irritant to eyes and skin; Dimethylformamide (DMF): toxic, irritant to eyes, skin, and respiratory system.
- Potassium carbonate ($K_2CO_3$): corrosive; causes serious eye and skin irritation.

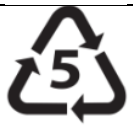
## -Experimental Procedure

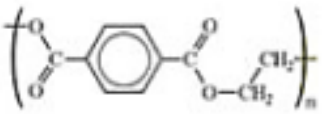
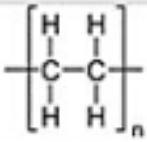
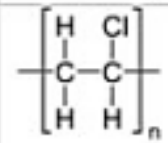
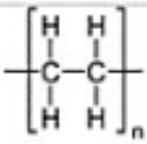
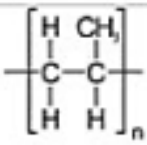
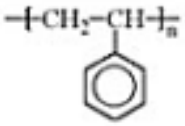
1. Cut the plastic samples into small, uniform pieces (approximately 4 × 4 mm).
2. Pour 10 mL of each solution into properly labeled test tubes.
3. Add one piece of the plastic sample into each test tube.
4. Stir gently with a glass rod and check whether the sample floats (F) or sinks (S).
    - Floating → density of polymer < density of solution.
    - Sinking → density of polymer > density of solution.
5. Record the results systematically in a data table.
6. Wash and dry the glass rod thoroughly between tests.
7. Repeat for all solutions and all polymer samples.

8. Compare the observed density ranges with standard reference values to identify the type of polymer.

---

## Reference Table for Polymer Identification

| Polymer Name | Abbreviation | Density Range ($g/cm^3$) | Recycling Code |
|---|---|---|---|
| Poly(ethylene terephthalate) | PET | 1.38 – 1.45 |   |
| High-density polyethylene | HDPE | 0.94 – 0.96 |   |
| Polyvinyl chloride | PVC | 1.20 – 1.55 |   |
| Low-density polyethylene | LDPE | 0.91 – 0.93 |   |
| Polypropylene | PP | 0.89 – 0.91 |   |
| Polystyrene | PS | 1.04 – 1.11 |   |

| Resin Code | Polymer Resin | Structure | General Applications |
|---|---|---|---|
| 1 PET | Polyethylene Terephthalate |  | • Plastic drinking bottles<br>• Food jars |
| 2 HDPE | High Density Polyethylene |  | • Shampoo, dish, laundry and house cleaning bottles<br>• Shipping containers |
| 3 PVC | Polyvinyl Chloride |  | • Packaging materials<br>• Pipes, fencing<br>• Blood bags, medical tubing |
| 4 LDPE | Low Density Polyethylene |  | • Bags for dry cleaning & newspapers<br>• Shrink wrap, film |
| 5 PP | Polypropylene |  | • Medicine bottles<br>• Bottle caps<br>• Automotive parts<br>• Carpeting |
| 6 PS | Polystyrene |  | • Disposable cups, utensils, food containers<br>• Foam packaging |

## Results Instructions

- Fill in the results table, indicating whether each plastic sample floated (F) or sank (S) in the corresponding solution.
- Determine the density range of each unknown plastic sample based on the observations.
- Compare the obtained density ranges with the reference table to identify the type of polymer.

- What is the aim of the experiment?

**Results table:**

| unknown plastic | solutions with known densities | | | | | | | | polymer type |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | Indicate which samples floated (F) and which sank (S) in each solution. | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

# EXP (2) :Preparation of Polyphenol-Formaldehyde (Bakelite)

## -Theoretical Principle

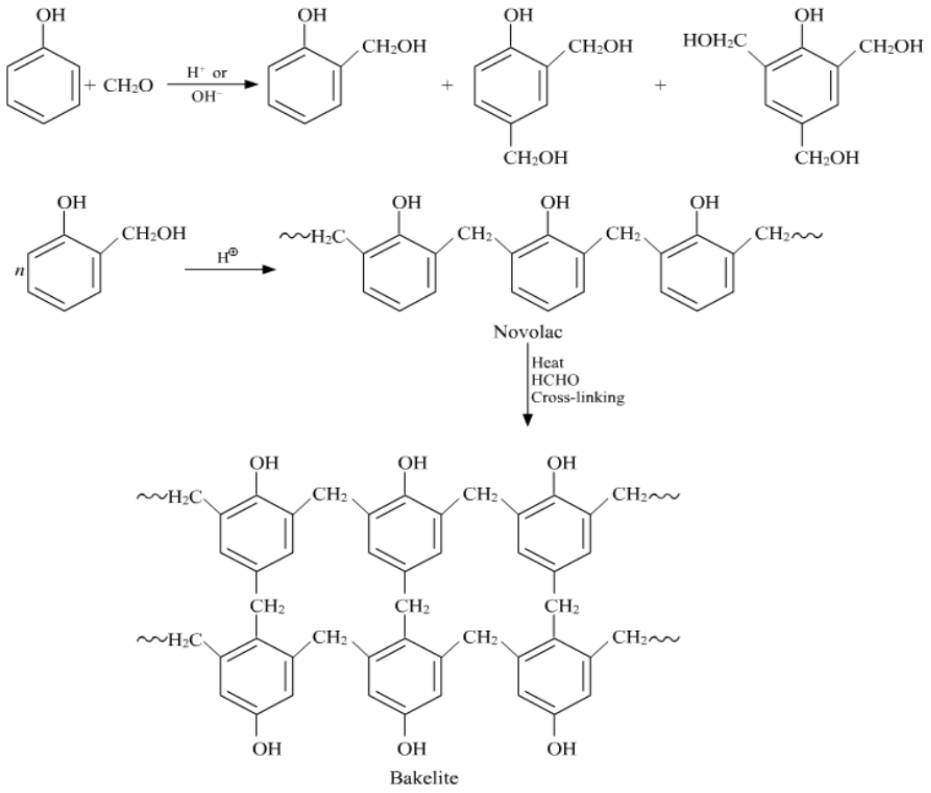
Bakelite is a polymer produced from the condensation reaction between phenol and formaldehyde in either an acidic or a basic medium.

The reaction occurs in two stages:

1. In the first stage, low-molecular-weight resin is formed (Novolac) in acidic medium, which can be melted or dissolved. while in alkaline medium, it's called (Resole).
2. In the second stage, the resin is further treated to form a cross-linked product, resulting in a thermosetting polymer (Bakelite).

Bakelite is used as an insulating material in electrical devices, adhesives, and as a binder in various applications.

Preparation of Bakelite



## -Aim of the Experiment

To prepare Bakelite polymer in an acidic medium and study some of its properties.

## -Materials and Chemicals

The following material are required:

- Phenol (5 g)
- Formaldehyde solution (30–40%, freshly prepared, 13.75 mL)
- Glacial acetic acid (6.25 mL)
- Concentrated hydrochloric acid (HCl)

## -Safety Precautions

- Always wear a lab coat, gloves, safety goggles, and a face mask.
- Hydrochloric acid: corrosive, harmful to skin and eyes.
- Phenol: toxic, corrosive, and carcinogenic; causes severe burns to skin and eyes.
- Glacial acetic acid: flammable, corrosive, causes serious skin and eye burns.
- Formaldehyde: toxic, irritating to skin, eyes, and mucous membranes.
- Work inside a fume hood to avoid inhaling harmful vapors.

## -Experimental Procedure

1. Take 25 ml of freshly prepared reaction mixture (phenol + formaldehyde + acetic acid) in a 100 ml beaker.
2. Place the beaker on a white sheet of paper for easy observation.
3. Slowly add about 10 mL of concentrated hydrochloric acid while stirring.

4. Continue adding ~2 mL of HCl drop by drop until polymerization begins (appearance of a white precipitate).
5. Continue stirring while the polymer forms and changes into a pinkish color.
6. Wash the polymer several times with water before transferring.
7. Record and describe the physical properties of the prepared polymer.

fig(1):polymer prepared in acidic medium .

## Results and Discussion

- What is the aim of the experiment?

- What type of polymerization occurred in the reaction?

- What are the common applications of Bakelite polymers?

- Is Novolac a **thermoplastic**, **thermosetting**, or **elastomer**?

- Is Bakelite a **thermoplastic**, **thermosetting**, or **elastomer**?

- Record the characteristics of the prepared polymer in terms of:

| in acidic medium | |
|---|---|
| Color | |
| Solubility in water | |
| Physical state (solid/rubbery) | |

- Write the **reaction equation for (**phenol with formalin). then write **name of the polymer** obtained in acidic medium.

# EXP (3) :Polystyrene Synthesis

## -Theoretical Principle

Polystyrene (PS) is a polymer prepared through addition polymerization of styrene monomers. Styrene is an organic compound, a colourless liquid with a distinctive smell. Polystyrene is one of the most widely used plastics, employed in packaging, insulation, trays, tableware, and many other applications.

## -Aim of the Experiment

To synthesize polystyrene polymer by addition polymerization and study some of its properties.

## -Materials and Chemicals

- Styrene monomer
- Benzoyl peroxide (BPO) as an initiator

## -Safety Precautions

- Always wear a lab coat, gloves, mask, and safety goggles during the experiment.
- Styrene: flammable, irritating to skin, eyes, and respiratory system.
- Benzoyl peroxide: flammable, irritating to skin, eyes, and respiratory system.
- Conduct the reaction inside a fume hood to avoid inhalation of vapours.

## -Experimental Procedure

1. Prepare two 50 ml glass beakers, label them as 'Polymer 1' and 'Polymer 2'.
2. Add different amounts of benzoyl peroxide initiator (e.g., 0.1 g in one beaker and 0.4 g in the other).
3. Add 15 ml of styrene monomer into each beaker and stir until the initiator dissolves completely.
4. Heat both mixtures on a hot plate at 80–90 °C with continuous stirring (inside the fume hood).
5. The mixture with higher initiator content will start polymerization first, indicated by bubble formation and white fumes.
6. As the reaction proceeds, the viscosity of the solutions increases gradually.
7. To check polymerization completion, remove a small drop of solution with a glass rod, cool it, and observe fibre formation (brittle fibres indicate the reaction is complete).
8. Once complete, the two beakers are removed from the hot plate, and quickly, the contents of the beaker are poured into a glass dish before it hardens inside the cup, making it difficult to remove.
9. Allow the polymer to cool and harden.

## -Results and Discussion

Answer the following questions based on the experiment:

- What is the aim of the experiment?

- What is the structural formula of styrene monomer and polystyrene polymer?

▪ What are the steps of the polymerization process, and what type of reaction is it?

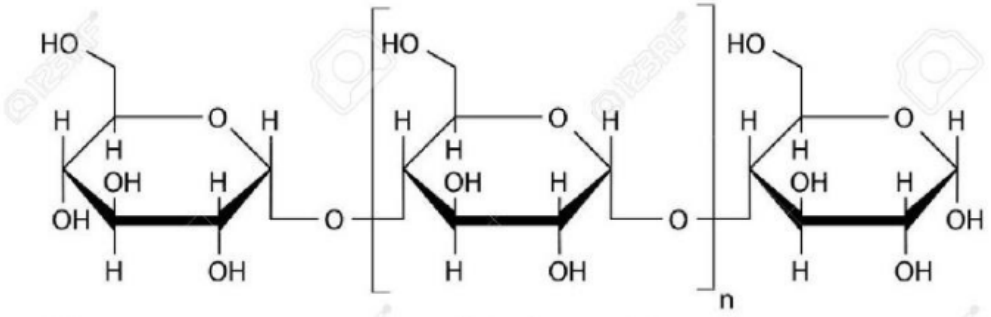
▪ Is the resulting polymer a thermoplastic or a thermoset? (Hint: reheating test can be tried).

▪ Compare the properties of the polymer with high initiator content vs. low initiator content.

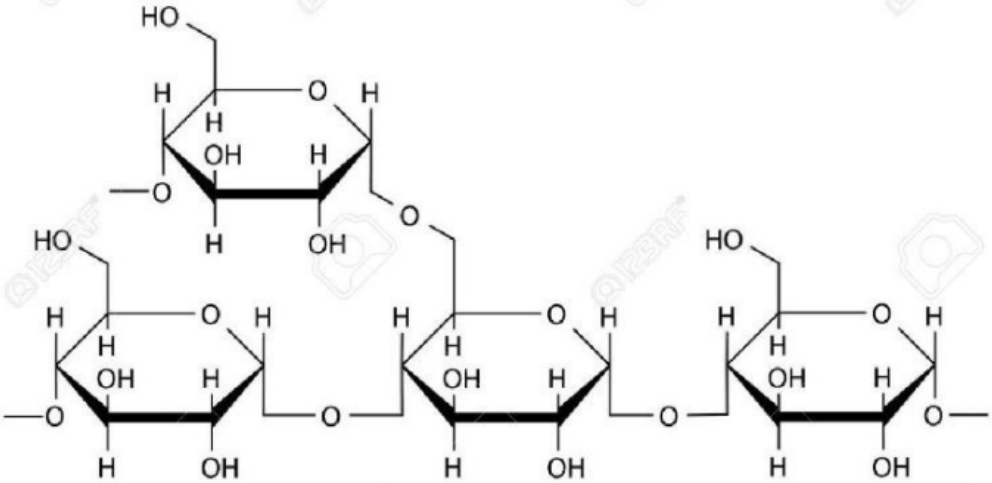
# EXP (4) : Extraction of starch from potatoes and prepare plastic film from starch and study the effect of plasticizers on the characteristics of the film

## Theoretical Principle

Starch is a polysaccharide polymer composed mainly of two glucose polymers: amylose (linear) and amylopectin (branched).




Amylose




Amylopectin

Starch exists as a white powder in plant cells (e.g., corn, wheat, rice, potato tubers) and is an important energy source. When mixed with plasticizers such as glycerol, starch can form films with improved

flexibility and mechanical properties. Plasticizers increase flexibility and reduce brittleness of the resulting bioplastic film.

## -Aim of the Experiment

1. To extract starch from potatoes.
2. To prepare a plastic film from the extracted starch and study the effect of plasticizers on the film's characteristics.

## -Materials and Chemicals

- Potatoes (clean and free of soil)
- Distilled water
- Hydrochloric acid 0.1 M
- Sodium hydroxide 0.1 M
- Glycerol (propane-1,2,3-triol) as plasticizer
- Optional: food coloring (for visual observation)

## Safety Precautions

- Wear lab coat, gloves, and a mask throughout the experiment.
- Glycerol: eye and skin irritant.
- Handle acids and bases with care; they may be corrosive.
- Work in a well-ventilated area and follow standard laboratory safety procedures.

## -Experimental Procedure

**Part A** — Extraction of Starch from Potatoes:

1. Peel and grate approximately (155 g) ≃ 2 pieces of clean potatoes (**no need to peel the potatoes)**.
2. Place the grated potato in a mortar and add about 140 ml of distilled water; grind to release starch.

3. Pour the liquid mixture slowly through a fine strainer into a 500 ml glass beaker to separate the starch-rich liquid from the solid potato fibers (**leave the potatoes in the mortar)**.
4. Repeat step 3 for 2 or 3 times.
5. Allow the starch-rich liquid to settle for about 5 minutes.
6. Decant the supernatant carefully, leaving the white starch sediment.
7. Wash the starch by adding ~100 ml distilled water, stirring, and allowing it to settle; repeat washing 2–3 times.
8. Collect the wet starch (clay-like consistency) and set aside for film preparation.

**Part B** — Preparation of Starch-Based Plastic Film and Study of Plasticizer Effect:

1. Weigh 4 g of the wet starch (slurry starch) and add ~22 ml distilled water into a 100 ml beaker.
2. Add 3 ml of 0.1 M HCl.
3. Add 2 ml of glycerol and mix thoroughly.
4. Heat the mixture gently on a hot plate ( place a watch glass on the beaker); avoid boiling. Continue heating until the mixture thickens (~15 minutes).
5. Check pH using litmus paper and adjust gradually with 0.1 M NaOH if needed to neutralize (max. 3 ml as the acid used) until the equilibrium is reached.
6. Optionally add a drop of food coloring and mix well for visualization.
7. Pour the resulting mixture as a thin layer onto a glass plate using a glass rod and spread uniformly.

8. Allow to dry in sunlight for one day or at room temperature for 1–2 days until fully dried.
9. Repeat the process for a control film **without glycerol** to compare mechanical properties.

## Results and Discussion

Answer the following questions based on the experiment:

▪ What is the aim of the experiment?

▪ What is the structural formula of starch (amylose/amylopectin)?

▪ What is a plasticizer name and what role does it play in the film?

▪ What effect does adding HCl during preparation have on the film?

▪ Compare the film without glycerol (plasticizers) and the film containing glycerol in terms of:

- Hardness an Flexibility / elasticity

- Transparency and appearance

▪ How does the amount of glycerol affect the mechanical and physical properties of the starch film?

▪ Propose possible applications for the starch-based films prepared in this experiment.

▪ Describe any observations and record the drying time and any defects (cracks, stickiness, etc.) observed in the films.

# EXP (5) : Isolation of Casein from low-fat or Skimmed Milk and Its Use in Adhesive Manufacturing

## 1- Theoretical principle:

Casein, which belongs to the group of phosphoproteins, can be precipitated from milk in several ways. When an acid is added to milk at around 20°C, the casein separates completely, leaving behind a yellow solution of whey. The precipitation process is delicate: if too much acid is added, if the acid is added too quickly, or if the acid is too strong, part of the casein may re-dissolve with lactose (milk sugar).

Casein is amphoteric, meaning it reacts with acids and bases to form salts due to the presence of acidic groups (–COOH)and basic groups (–$NH_2$).

Casein protein is used in a number of applications such as in the manufacture of adhesives, paints, cosmetics, and pharmaceuticals.

## Aim of experiment:

Separation of casein from skimmed milk and use it in the manufacture of adhesives

## 2- The experimental:

### 2.1. Chemicals:

1. Glacial acetic acid
2. Isopropanol
3. Ether
4. Ethanol

## 2.2. Safety precautions:

- Wear lab coat, gloves, mask, and safety goggles during the experiment.
- Glacial acetic acid is flammable and corrosive to the skin and eyes.
- Alcohols used in this experiment should be handled in a fume hood.

## 2.3Procedure:

1. Prepare a 10% solution of glacial acetic acid by mixing 7 ml of it in 50 ml of water. This solution will be used later for precipitation.
2. Place 200 ml of low-fat or skimmed milk in a 300 ml beaker and heat it on the hot plate to 40–50°C with continuous stirring (using a glass rod or magnetic stirrer).
3. Add the prepared acetic acid10% solution drop by drop while stirring gently. Allow enough time between additions to ensure stable precipitation. Avoid adding excess acid.
4. At a certain point, the casein will separate from the solution, forming a white curd, while the solution becomes nearly clear or pale yellow. Leave the mixture for 5 minutes to stabilize.
5. Collect the casein curd by decanting most of the liquid and scooping the solid with a glass rod.
6. Wash the precipitate several times with distilled water (about 100 ml each time).
7. Filter the casein using a Buchner funnel to remove excess water (the precipitate may also be pressed to remove water as much as possible).
8. Break the dried casein into small pieces using a glass rod or spatula.
9. Wash the pieces with 30 ml of a 1:1 mixture of isopropanol and ethanol (if isopropanol is not available, ether may be used). Repeat washing if needed to remove fats. This step should be performed in a fume hood.
10. Leave the casein to dry in air and weigh the final product.

## -Manufacturing Adhesive from Casein:

- Neutralize the wet casein with sodium bicarbonate after separating it from the acidic liquid.
- The final material will be a white paste-like substance that, once dried, forms an adhesive.

## 3- Results and discussion :

1. What is the aim of the experiment?

2. What is casein?

3. What is the purpose of adding acid to milk?

4. What other methods can be used to precipitate casein?

5. Calculate the following:

a) Weight of low-fat or skimmed milk used in the experiment, assuming density = 1.026 g/cm³.

b) Percentage yield of casein.

# EXP (6) : Preparation of Casein Paint

## -Aim of the Experiment:

. The aim of this experiment is to prepare a paint (emulsion) from milk protein (casein) using the borax-casein method.

## -Theoretical Principle:

Casein is considered a natural polymer that precipitates from milk through various methods, including the use of acids such as acetic acid (vinegar). It precipitates at a specific point known as the isoelectric point (IEP), which is the pH level at which the net electric charge of the protein is zero.

Milk coating can be prepared by mixing measured amounts of casein with a solution of borax, ammonium bicarbonate or calcium hydroxide. To enhance the properties of the coating, chemical additives can be included, such as glycerol to prolong the drying time, calcium carbonate (chalk) as a thickening agent, and coloring agents.

## Safety Precautions:

1. Wear a lab coat, gloves, mask and goggles.
2. Acetic acid glacial is a corrosive substance and its vapor causes irritation to the eyes.
3. The chemical compounds in this experiment are handled in the gas cabinet.

## Procedure:

### 1. Isolating Casein from Milk:

-Pour 200 ml of low-fat or skimmed milk into a suitable beaker and heat it using an electric heater between 45-50°C. Stir continuously using magnetic stirrer or glass rod.

-Gradually add 10% acetic acid solution dropwise while stirring, allowing the mixture to stabilize between additions. When the mixture reaches the isoelectric point, casein precipitates, and the solution turns from milky to clear or pale yellow.

-Let it sit for 5 minutes, then filter the precipitate and wash it twice with distilled water. Dry the precipitate using a filter or cloth, pressing to remove excess water.

-Crush the dried casein into small particles, then wash with 30 ml of isopropanol or a 1:1 mixture of ether and ethanol for five minutes to remove fats. Repeat if necessary.

### 2. Preparing Borax Solution:

Heat 30 ml of distilled water to approximately 60°C, then gradually add (5) grams of borax while stirring until fully dissolved.

### 3. Preparing Casein Paint:

-Mix (5) grams of wet casein with 10 ml of distilled water to form a suspension. Gradually add the borax solution to this suspension with stirring until achieving the desired consistency.

-Grind two colored chalks into fine powder, form a mound, moisten with a little distilled water, and knead into a medium consistency paste. Add the borax-casein mixture gradually to the colored paste while stirring to produce the final paint with the desired density and color.

- Divide the paint into two portions: one with 1.5 ml glycerin and one without.

Apply the paint onto suitable surfaces using a brush for testing and comparison.

## Results and Discussion:

1-What is the purpose of the experiment?

2- Define the isoelectric point of Proteins (IEP).

3-What are your observations on the (casein-borax) coating containing glycerin and the one that does not contain glycerin?

# EXP (7) : Preparation of Synthetic Fabric from Cellulose (Rayon Fibers)

## Aim of the experiment:

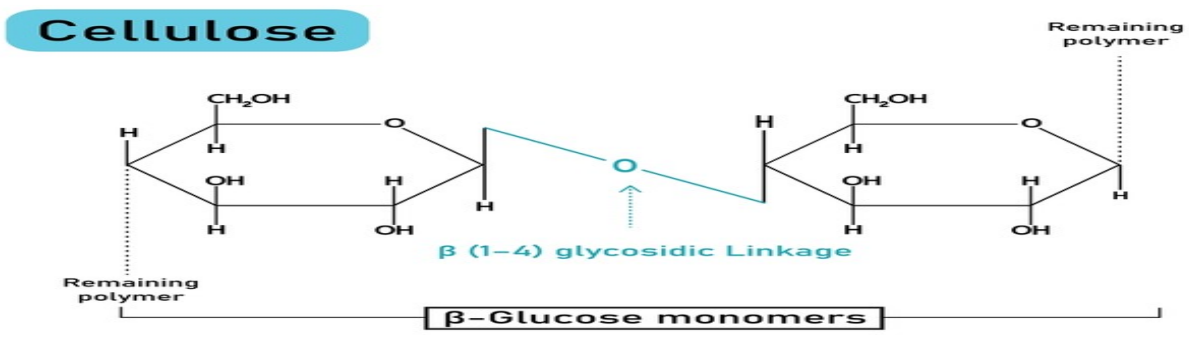
Preparation of rayon fibers from cotton using the cuprammonium process.

## Theoretical principle :

Rayon is a semi-natural fiber produced from cellulosic fibers, often referred to as artificial silk or rayon. It can be produced from cotton or wood pulp and is used in textiles, clothing, and even in tire manufacturing. Rayon preparation process can be classified into three types: viscose process, cuprammonium process, and acetate process.

Rayon produced by viscose and cuprammonium processes has similar chemical properties and is easily manufactured, but both lose strength and roughness when wet, regaining strength when dry. Acetate rayon, however, reacts differently to heat.
Exposure to boiling water removes its luster and may even damage or burn it. Nevertheless, it has unique characteristics such as purity, smoothness, color stability, and long-lasting ironing quality.

Cellulose is an organic compound with the molecular formula $(\sim C_6H_{10}O_5 \sim)_n$ , a polysaccharide consisting of hundreds or thousands of glucose units in a linear chain. It is present in all plant tissues, mainly in the plant cell wall, and is the main component of cotton fibers. Like starch, cellulose is a complex carbohydrate.



## Aim of the experiment:

Preparation of rayon fibers from cotton using the cuprammonium process.

## 2- Experimental :

### 2.1. Chemicals:

1. Copper (II) sulfate pentahydrate (1M)
2. Concentrated ammonia
3. Dilute sulfuric acid 5%

### 2.2. Safety Precautions:

- Wear lab coat, gloves, mask, and safety goggles during the experiment.
- Wash hands thoroughly after handling copper(II) sulfate pentahydrate.
- Ammonia vapors are irritating and harmful, so work in a well-ventilated area such as a fume hood.

### 2.3. Procedure:

1. Take 50 ml of copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) in beaker.
2. Add concentrated ammonia dropwise with stirring until a light blue-green $Cu(OH)_2$ forms, then precipitation occurs and the solution turns light blue.
3. Ensure complete precipitation by adding 1–2 extra drops of ammonia (avoid excess).
4. Separate the precipitate by filtration and wash it twice with 5 mL cold distilled water.
5. Transfer the precipitate to beaker, add 40 mL concentrated ammonia, and stir until the precipitate dissolves to give the dark blue copper-ammonia solution that called "Schweitzer's reagent" $\mathbf{[Cu(NH_3)_4(H_2O)_2](OH)_2}$.

6. Cut a piece of cotton into small pieces, weigh it, and add to the solution while stirring with a glass rod until it dissolves completely, forming the cellulose-copper-ammonia solution.
7. Prepare 100 mL of 5% dilute sulfuric acid in a 250 mL beaker.
8. Fill a plastic dropper or syringe with the cellulose solution and inject slowly into the dilute sulfuric acid solution, forming dark blue fibers.
9. The fibers gradually lose their blue color and turn white in the sulfuric acid solution.
10. Repeat the injection process for the remaining cellulose solution.
11. Wash the resulting rayon fibers with distilled water and preserve them for weighing.

## 3- Results and discussion:

- What is the aim of the experiment?

- What is the chemical formula of cellulose?

- What are the uses of rayon?

- Fill in the following table:

| Weight of cotton used (g) | Weight of rayon fibers produced (g) | % yield |
|---|---|---|
| | | |

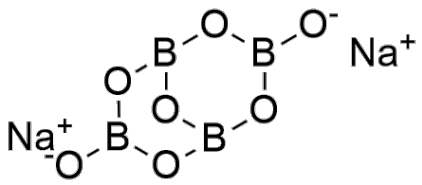
# EXP (8) : Preparation of Polyvinyl Alcohol Slime

## 1- Theoretical principle:

Polyvinyl alcohol (PVA) is a synthetic polymer that is supplied as odorless white granules. It is soluble in water—slowly at room temperature or in cold water, and more rapidly at higher temperatures. PVA fibers are used in paper and textile industries, for reinforcement of concrete, and in chemical-resistant protective gloves.

boron compound. It consists of soft, white, multi-faceted crystals that dissolve quickly in water but tend to clump when exposed to humid air. Its molecular formula is $Na_2B_4O_7 \cdot 10H_2O$. Borax is widely used in detergents, water softeners, and soaps.

Borax, chemically known as sodium tetraborate or sodium borate, is important In slime preparation, borax acts as a cross-linker between polymer chains.



Borax

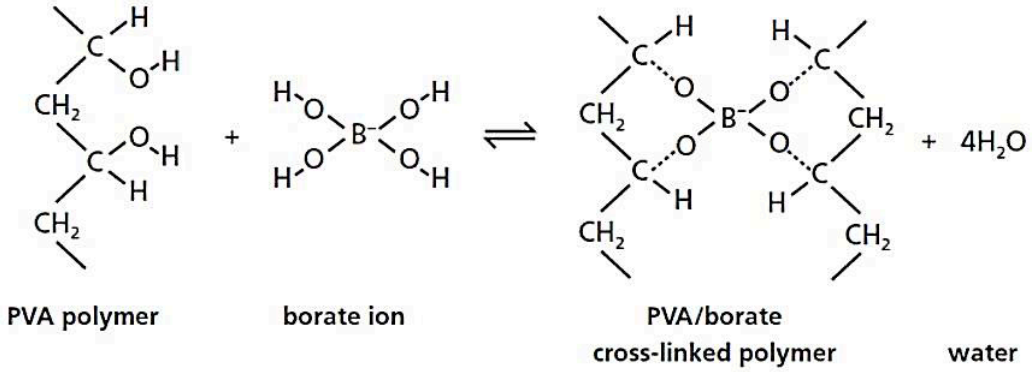
Polyvinyl alcohol (slime) formation equations:
Formation of boric acid:

(1) $Na_2B_4O_7 + 7H_2O \rightarrow 4B(OH)_3 + 2NaOH$

Boric acid accepts ($OH^-$) from water:

(2) $B(OH)_3 + 2H_2O \leftrightarrow B(OH)^-_4 + H_3O^+$

The borate ion $B(OH)^-_4$ has four hydroxyl groups capable of forming hydrogen bonds between PVA polymer chains, creating cross-links that produce the slime.




## Aim of the experiment:

Preparation of polyvinyl alcohol (slime) by adding borax as a cross-linking agent to the polyvinyl alcohol solution.

## 2- The experimental :

### 2.1 Chemicals:

1. Polyvinyl alcohol (PVA)(8%)
2. 4% aqueous borax solution
3. 0.5M hydrochloric acid solution
4. 0.5M sodium hydroxide solution

### 2.2 Safety Precautions:

- Wear lab coat, gloves, mask, and safety goggles during the experiment.
- Both borax and polyvinyl alcohol can irritate eyes and skin. Avoid direct contact.
- Wash hands thoroughly after the experiment.

## 2.3 Procedure:

### Part 1: Preparation of 8% PVA aqueous solution

1. Measure 92 mL of distilled water in a 150 mL beaker.
2. Add 8 g of PVA slowly while stirring with a glass rod.
3. Heat gently with occasional stirring to dissolve completely (avoid boiling).
4. Allow solution to cool. The solution can be stored indefinitely once cooled.

### Part 2: Preparation of Polyvinyl Alcohol Slime

1. Place 40 mL of the prepared 8% PVA solution into a plastic cup.
2. Add one drop of food coloring or fluorescein dye while stirring with a glass rod (optional).
3. Add 10 mL of 4% borax solution gradually while stirring vigorously until slime forms.
4. Using disposable gloves, knead the slime thoroughly to mix and press out air bubbles. Alternatively, place it in a plastic bag and knead until slime is fully formed (about 2 minutes).

## 3- Results and discussion:

- What is the aim of the experiment?

- What are the chemical formulas of polyvinyl alcohol and borax?

- What is the chemical equation for slime formation?

- Record observations for the following:
  * Stretch slime slowly with hands – what happens?

  * Stretch slime quickly with hands – what happens?

  * Roll slime into a ball and drop it on a table – what happens?

  * Place a small piece of slime on the table and strike it hard – what happens?

  * Add drops of 0.5M HCl to slime while stirring – how many drops, and what happens?

  * Add drops of 0.5M NaOH to slime while stirring – how many drops, and what happens?

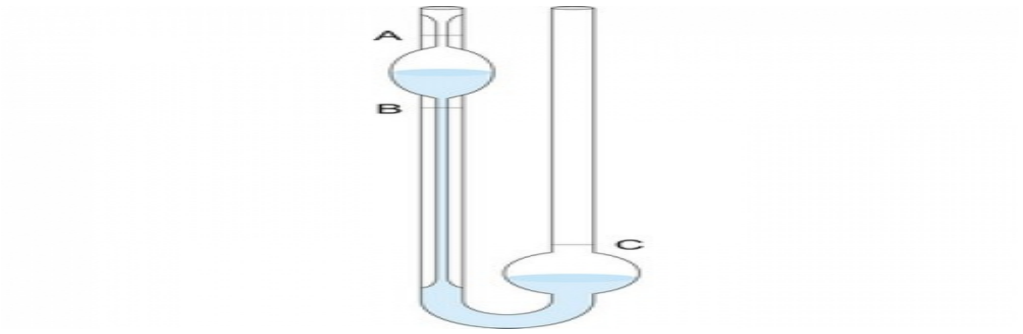
# EXP (9) : The average molecular weight of a polymer by viscometry

## Theoretical Principle:

The molecular weight of a polymer can be determined in several ways, including viscosity. Viscosity is an intrinsic property of a liquid that resists flow due to internal friction between the molecules. Viscosity depends primarily on the nature and temperature of the liquid.

To measure the viscosity of a liquid, a viscometer can be used. This device is used to determine viscosity, i.e., the resistance of a liquid to movement. There are several methods available for measuring the viscosity of a polymer solution, and this experiment relies on the capillary tube viscometer method. Two well-known types of viscometers fall under this category: the Ubbelohde viscometer and the Ostwald viscometer.

The Ostwald method is considered one of the simplest methods. In this method, the flow time of the same volume of different concentrations of a polymer solution is measured between the lines (A and B) shown on the tube of an Ostwald Viscometer. Therefore, this method will be used in this experiment.




Ostwald Viscometer

## Aim of the Experiment:

Determination of the average molecular weight of a polymer by measuring viscosity.

## The Chemicals :

The following Chemical are required:

| (α) &( K) at 25°C Value | Solvents | The Polymer |
|---|---|---|
| $K=1.2x10^{-4}$ α=0.73 | $CHCl_3$ | Polystyrene |
| $K=3.7\ x10^{-4}$ α=0.62 | Toluene | |
| $K=4.53x10^{-4}$ α=0.64 | $H_2O$ (distilled) | Polyvinyl alcohol |
| $K=1.49x10^{-4}$ α=0.82 | Acetone | Cellulose acetate |

## Safety Precautions:

- Make sure to wear lab- coat , gloves, and a mask throughout the experiment .
- Chloroform is a toxic substance, irritating to the eyes, skin, and respiratory system.
- Toluene is a flammable substance, irritating to the eyes, skin, and respiratory system.
- Acetone is a volatile substance, causing irritation upon exposure.

## Experimental Procedure:

1. Accurately weigh (1) gram of the selected polymer and place it in a dry 100 ml standard flask.
2. Add 80 ml of solvent to the flask until the polymer is completely dissolved. Then, add the solvent to the mark. (If the polymer is not completely dissolved, the flask can be placed in a water bath at 25°C to accelerate the dissolution process.)

3. Prepare the following solutions: (0.02, 0.04, 0.06, 0.08, 0.1 g/100 ml) in standard flasks by diluting the original polymer solution. (The standard flask should be 25 ml or 50 ml.
4. Measure the viscosity of the solvent using a viscometer (Ostwald). The device must be washed with solvent before use. A quantity of solvent is placed inside the viscometer, and the solvent flow time ($t_0$) is measured. (10) ml of solvent is placed if the previous solutions were prepared in (25) ml of volumetric flasks, and 20 ml of solvent is placed if they were prepared in 50 ml of standard flasks.)
5. The device(viscometer) is washed with the solvent, then with the desired polymer solution (using 10 or 20 ml of solvent), and the solution flow time ($t_0$) is measured.
6. The time required for the remaining solutions to flow is calculated, starting with the diluted solution and then the highest concentration. The device is washed twice with solvent after each solution, and the same volume is used for each measurement.

## Results and Discussion:

- What is the aim of the experiment?

- What is the chemical formula of the selected polymer, and state its name?

- What are other methods available for measuring the viscosity of solutions?

- What factors affect the viscosity of a polymer?

- Record the results in the following table:

| (In $\eta_r$/C) | ($\eta_{sp}$/C) | $(\frac{\eta}{\eta o}) - 1] =$ $[(\eta sp]$ | $\eta_r = \frac{\eta}{\eta o} =$ $\frac{t}{to}$ | t (sec) | $t_0$(sec) | C (g/100ml) |
|---|---|---|---|---|---|---|
| | | | | | | **0.002** |
| | | | | | | **0.04** |
| | | | | | | **0.06** |
| | | | | | | **0.08** |
| | | | | | | **0.1** |

-Draw a graph of ($\eta_{sp}$/C) or (In ($\eta_r$/C) with ( C) .

The y-intercept represents the intrinsic viscosity value [η]

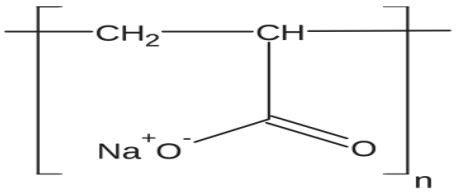
-Calculate the average molecular weight (Mw) of the polymer using the following Mark-Houwink equation:

$$\eta = K \times (Mw)^{\alpha}$$

# EXP (10) : The Swelling Capacity of Polymers and Their Uses in Liquid Absorption

## Theoretical Principle:

Sodium polyacrylate is a polymer characterized by its superior water absorption capacity, with its ability to absorb water approximately 200 to 300 times its mass. It has the following structural formula:




It is used to produce artificial snow and in cleaning materials. It can also be used in agriculture due to its ability to retain water for long periods under plants and trees. Its most important application is in baby diapers, where it is used to prevent water leakage. The more sodium polyacrylate it contains, the greater the absorbency of the diaper. However, the polymer's absorption capacity decreases when salts are present in the water or solution used.

## Aim of Experiment:

Measuring the swelling capacity of sodium polyacrylate polymer by calculating the amount of water absorbed at equilibrium and the absorption rate constant.

## Chemical Materials :

. Sodium polyacrylate.

. Distilled Water

## Safety Precautions:

- Be sure to wear a lab coat, gloves, and a mask throughout the experiment

## Experimental Procedure:

1-Weigh exactly (0.1) grams of sodium polyacrylate and place it inside an empty tea bag or another bag that serves a similar purpose. The bag and the polymer inside will then be weighed and recorded as (Wo).

2-Place five bags prepared in step (1) in suitable beaker containing distilled water.

3-Remove one bag every (3) minutes. Then, gently remove the excess water from the surface of the bag with a tissue, avoiding pressing the bag.

4-Weigh each bag after it has absorbed water and record each weight as (Wt).

## Calculations:

Calculate the amount of water absorbed (degree of swelling) as follows:

$$A = (W_t - W_o)/W_o$$

Where (Wt) represents the weight of the sample with the absorbed water at time (t) and (Wo) represents the initial weight.

Second: Swelling Kinetics Studies:

To study the concentrated absorption of a polymer, the kinetic equation for a second-order reaction is used, as shown in the equation:

$$\frac{dA}{dt} = k(A_{eq} - A)^2$$

Where (k) = the absorption rate constant, (A)eq = the amount of water absorbed at equilibrium, and (A) = the amount of water absorbed at time( t).

Integrating the previous equation, we obtain the following equation:

$$t/A = t/A_{eq} + 1/k_{eq}$$

Where: $K_{eq} = KA^2_{eq}$ , and $K_{eq}$ = the absorption rate constant at equilibrium.

When the absorption kinetics corresponds to second-order kinetics, the previous relationship is linear. When plotted graphically, it produces a straight line. ( Aeq ). from its slope, and the absorption rate constant (K) can be calculated from the y-axis cut (intercept)

## Results and Discussion :

-What is the purpose of the experiment?

-What is the structural formula of sodium polyacrylate polymer?

-What are the uses of sodium polyacrylate polymer?

-Record the results in the following table:

| No. Bag | $w_o$ | $time_{(min)}$ | $w_t$ | A | t/A |
|---|---|---|---|---|---|
| 1 | | 3 | | | |
| 2 | | 6 | | | |
| 3 | | 9 | | | |
| 4 | | 12 | | | |
| 5 | | 15 | | | |

-From Graph relationship.

1-Find the slope of the straight line and calculate ($A_{eq}$) from it.
2-Find the y-intercept and calculate the value of (K) from it.