LAB Manual

BSc in Industrial Chemistry

General Chemistry Lab II

CHEM 207

Physical Chemistry Department

College of Science

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LABORATORY SAFETY RULES AND GUIDELINES

All students must read and understand the information in the document entitled “General laboratory safety rules” prior to the first laboratory session. A petition containing the declaration of responsibility of the student and the lecturer responsible for the student who will be working in the laboratory must be communicated to the laboratory manager/officer before the laboratory work is started. In this petition, the student should briefly indicate the name of the project, the job description and the weekly working schedule.

General Laboratory Safety Rules

It should never be forgotten that the laboratory is a serious working environment. In this regard, every student who will work in the laboratories must attend the "Laboratory Safety" Sections.

[1]. Students must not work in the laboratories outside of regular weekly hours or on weekends without written permission from the responsible instructor and the necessary waiver petition.
[2]. All rules must be strictly followed, and any unclear issues should be directed to the laboratory technical staff.
[3]. To minimize risks due to the inherent dangers in a laboratory, all rules must be adhered to.
[4]. Lab coats must be worn at all times, and personal belongings such as coats, jackets, and bags should not be brought into the laboratory.
[5]. Approved eye protection and face shields are required at all times in the laboratory.
[6]. Contact lenses are not permitted in the laboratory.
[7]. Closed shoes must be worn at all times; open-toed shoes, backless shoes, sling backs, clogs, and sandals are not allowed.
[8]. Long hair, accessories, and loose clothing must be secured while in the laboratory.
[9]. Eating, drinking, and smoking are strictly prohibited in all laboratories.
[10]. Listening to music is not allowed, and the use of distracting devices such as mobile phones should be avoided during experiments.
[11]. Chemicals should not be smelled or tasted. They must not be touched without gloves and should be weighed and transferred using appropriate materials.
[12]. Experimental studies should only be conducted as instructed and demonstrated by laboratory technical personnel. Alternative methods should never be used.
[13]. Laboratory technical personnel should be informed about the experimental studies to be carried out in the general laboratory. If the experimental study is to be carried out in a laboratory belonging to a faculty member, the faculty member should be informed. No experimental setup, chemicals or other materials should be used unless the required permission is given.

[14]. Working alone in the laboratory, especially in an isolated area, is strongly discouraged. If it is obliged, the researcher to work alone in the laboratory should inform the laboratory technical staff in advance.

[15]. Before leaving the laboratory, make sure your work area is clean.

[16]. Before leaving the laboratory, ensure that all gas, water, vacuum, and air valves and lights are completely turned off.

[17]. Hands must be washed and cleaned at the end of the experiments. If there is an open wound in hands, they must be bandaged and appropriate gloves should be worn.

[18]. Any kind of action that may cause distraction must be avoided. It is forbidden to play games or making fun in the laboratory.

[19]. Waste containers should be kept closed with a lid.

[20]. The manuals of instruments that are going to be used in the laboratories must be read in advance and the necessary precautions should be taken.

[21]. Dangerous chemicals should be kept at minimum in the working area.

General rules to be obeyed when working with a chemical substance

[1]. All chemicals have a potential hazard therefore, they should not be touched without wearing gloves.

[2]. Solid chemicals must be transferred with a clean spatula or a spoon. The same spatula or spoon should never be used for another substance before being thoroughly cleaned.

[3]. Securely replace lids, caps, and stoppers after removing reagents from containers. Lids, caps and stoppers should not be put downwards on the bench. Otherwise, they can be contaminated with other chemicals and purity of that chemical may be spoiled.

[4]. Substances in capped or plugged containers should never be heated or boiled.

[5]. Considering that mixing chemicals randomly can cause a potential danger; it should be avoided.

[6]. All chemicals and laboratory equipments containing chemicals must be labeled;

a) The labels should be carefully read before use.
b) When chemicals are transferred from one container to another, the labeling of the new container should not be forgotten.
c) The labels should contain information about the full name of the chemical, date received or date opened, name of the responsible party and any other information required.
d) No chemicals should be placed in unlabeled bottles or a container.
e) Unlabeled chemicals should never be used.

[7]. Never return unused chemicals to stock bottles. Dispose properly. Do not insert pipette or dropper into the reagent bottles. Use the one that is designated (labeled) for that reagent.

[8]. Never use one pipette for different chemicals.

[9]. Never use your mouth pipetting a liquid. Use a rubber suction bulb, special pipette filler or

pump.

[10]. The flammable liquids should be located on the bench in closed containers only in required amounts and kept away from heat sources (burner, electric heater, etc.).

[11]. When a liquid in a test tube is to be heated, the tube should be slowly heated downward from the top with continuous shaking. Make sure that the mouth of the test tube is pointed away from you and anyone else.

[12]. Chemical wastes should be treated in accordance with the directives of the laboratory technical personnel. Chemical substances must never be spilled into sinks or other places.

[13]. Inhalation of chemicals (toxic vapors and gases) should be avoided. With organic solvents, like sulfuric acid, nitric acid, hydrochloric acid, hydrofluoric acid and with toxic gases like bromide, hydrogen sulfide, hydrogen cyanide, and chloride one should work in the fume hood.

[14]. One must be very cautious when working with concentrated acids and bases. Water should never be poured on concentrated acids.

[15]. If there is a mercury spill, it should be cleaned up immediately with a vacuum source or a foam type synthetic sponge. If the amount is too little to collect, elemental sulfur in powder form can be sprinkled on the spill site.

[16]. Broken thermometers containing mercury should never be disposed of as waste.

[17]. If chemical substances or specimens are spilled in the laboratory, the area should be cleaned and the laboratory technician should be informed.

[18]. Special care must be given when transporting chemical substances from one place to another in the laboratory.

[19]. Chemical substances should never be removed from the laboratory.

Material Safety Data Sheets (MSDS)

Many of the chemical substances used in laboratory studies are hazardous to health. Knowing the properties of these chemicals is important in terms of health as well as in determining the first aid measures after any accident that may occur during work.

Before using any chemical, MSDS should be carefully examined and experimental work should be conducted under appropriate conditions.

Material Safety Data Sheets for every chemical should contain information such as:

1. Name of the chemical;
2. Manufacturer's information;
3. Hazardous ingredients/identity information;
4. Physical/chemical characteristics;
5. Fire and explosion hazard data;
6. Health hazard data;
7. First aid measures
8. Handling and storage

Note: The safety data sheets for chemicals are available online at http://www.sigmaaldrich.com/safety-center.html. Each person should have access to the MSDS for all chemicals he/she uses.

Examples of some of the warning symbols that might appear on the labelling of a single chemical are given below:



R (Risk) factors express the hazard levels of the chemicals.

In the Regulations for Hazardous Chemicals are given some R codes and their combinations, with clear descriptions of the dangers, to be used on the tags of hazardous materials and products.

R factor	Description of the R factor
R1	Explosive in dry conditions
R2	Risk of explosion in case of impact, friction, fire or contact with other sources of
R3	High risk of explosion in case of impact, friction, fire or contact with other sources of ignition
R4	Forms very sensitive explosive metallic compounds
R5	Heating may cause explosion
R6	Explosive in contact with air
R7	May cause fire
R8	Contact with combustible materials may cause fire
R14/15	Severe reaction that led to the formation of highly flammable gas with water
R15/29	Forms toxic and flammable gases in contact with water
R20/21	Harmful by inhalation and in contact with skin
R20/22	Harmful by inhalation and if swallowed
R20/21/22	Harmful by inhalation and in contact with skin and if swallowed
R21/22	Harmful when in contact with skin and if swallowed
R23/24	Toxic by inhalation and skin contact
R23/25	Toxic by inhalation and if swallowed

Rules for Using and Handling Glassware

1. Always inspect your glassware for cracks and chips before use. Do not use broken glassware. Fire-polish any sharp edges.
2. Take special care to keep long glassware upright when carrying it.
3. Place any rolling apparatus, such as thermometers and pipettes, in appropriate holders.
4. Lubricate glass tubing, thermometers, etc., before inserting them into rubber stoppers or corks, or when placing rubber tubing on glass hose connections. Avoid applying pressure on the glass and protect your hands with gloves.
5. Do not place hot glassware on cold or wet surfaces, as it may break due to temperature changes. Use wooden tongs to hold the glassware until it cools.
6. Since cold and hot glass look the same, do not place heated glassware randomly without any warning.
7. Wash all glassware with distilled water after use.
8. Use a broom to sweep small pieces of broken glassware into a dustbin designated for broken glass.

Rules for Using and Handling Equipment

1. Inform the laboratory technician when using an instrument for the first time; researchers must be trained on proper equipment use. Carefully review manuals and standard operating procedures.
2. Pay special attention when working with an open flame. Keep hair and clothes away from the flame.
3. Always use wooden tongs when working with an open flame.
4. Never leave an open flame unattended. Turn off burners or electrical heaters when not in use.
5. Do not heat a closed container, as pressure buildup may cause it to explode.
6. Do not control the temperature of heating devices by hand.
7. Do not change temperature settings when using an oven or muffle furnace. Inform laboratory technicians if necessary.
8. Do not use plastic gloves when working with an oven or muffle furnace. Use tongs when operating at high temperatures.
9. Do not place equipment washed with solvents in a drying oven due to explosion risk.
10. Ensure sample containers and tongs do not touch the oven wall.
11. Keep the analytical balance closed when not in use.
12. In a calibrated analytical balance, check that the air bubble is in the center of the level indicator. Level the balance with foot screws until the air bubble is in the prescribed circle.
13. Do not spill chemicals inside the balance enclosure. Clean up spills immediately with a brush.
14. Operate the ventilation system before using the fume hood.
15. Perform all operations at least 15 cm inside the fume hood and keep the fume hood panel closed as much as possible.
16. Ensure all devices are electrically connected before working in a hood with explosive or flammable chemicals.
17. Make sure your hands are completely dry when working with electrical apparatus.
18. Do not work with instruments if you are not familiar with their proper use.

FIRST AID IN LABORATORY

Burns and Cuts

1. For eye and significant skin exposures, rinse the affected area with large quantities of water and seek immediate medical attention.
2. If chemicals cause burns on the skin, wash the area with water immediately to minimize the risk. Apply an ice pack to relieve pain, but seek immediate medical attention for serious burns.
3. In case of an acid spill on the skin, wash the affected area with plenty of water. If clothing is stuck to the skin, do not try to remove it. Avoid applying ointments or sprays on severe burns and do not touch the affected area. Seek immediate medical attention.
4. In the event of a fire, notify authorized personnel or the fire department immediately. Close all doors and windows on your way out. Use fire extinguishers to fight larger fires.
5. If your clothes catch fire, find a safety shower. If none is nearby, stop, drop, and roll on the floor to extinguish the flames. Use a fire blanket to extinguish burning clothes.
6. For small cuts and scratches, clean the wound, place a sterile pad over it, and apply gentle pressure. Seek immediate medical attention for serious cuts.

Eye Irritation

1. Immediately flush your eyes with running water for at least 15 minutes.
2. Care must be taken to ensure that the washing process is done in the direction of the ears from the top of the nose so that the other eye is not affected and the chemically contaminated water does not come back into the mouth.
3. Immediate transport to a medical center is advised.

Chemical Ingestion

Immediate transport of the patient to a medical center is required.

Inhalation of Gases and Vapors

1. The affected area should be evacuated and patient should be removed to fresh air.
2. If breathing has stopped, begin appropriate resuscitation at once.
3. Immediate transport to a medical center is required.

Emergency Procedures		
OCCASION	**STUDENT**	**LABORATORY TECHNICAL PERSONNEL**
FIRE	• Notify the laboratory technical personnel and the other people working in the laboratory. • Keep away flammable and explosive materials. • If a person's clothing catches on fire, lay him/her down and cover with a fire blanket.	• Call 997. • Small fires can be put out with fire extinguishers, turn off gas and electricity and evacuate the laboratory immediately. • Notify the authorized personnel (Director of the Institute, Campus Coordinator).
CHEMICAL SPILL	• Notify the laboratory technical personnel and the other people working in the laboratory. • Do not touch or inhale the chemical. • Evacuate the room immediately.	• Call 997. • Identify the chemical/s and hazards involved – check Material Safety Data sheet. • Wash the area with plenty of water or vacuum clean. • Wear protective gloves, goggles and a mask during cleaning. • If a volatile hazardous chemical is spilled, evacuate the room and ventilate the area for one day.
GAS LEAK ELECTRIC CONTACT	• Notify the laboratory technical personnel and the other people working in the laboratory.	• Call 997. • Identify the source of gas/electricity leak. • Notify the authorized personnel (Secretary and Campus Coordinator). • Turn off electrical power. • If there is a gas leak, turn it off at the source.

EXPERIMENT **1**

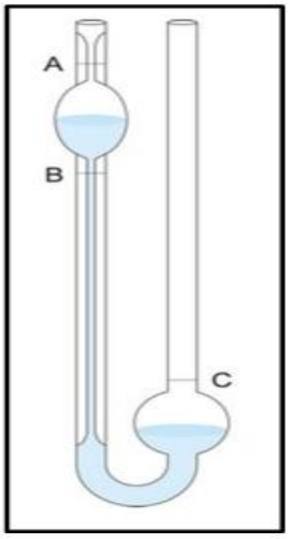
DETERMINATION OF LIQUID VISCOSITY

Aim:

To determine the viscosity of a given unknown liquid with respect to water at room temperature, by Ostwald's Viscometer.

Requirements:

Ostwald's Viscometer, specific gravity bottle, a small rubber tube with a screw pinch cork, distilled water, experimental liquid, digital timer.



Ostwald's Viscometer

Theory:

Viscosity, resistance of a fluid (liquid or gas) to a change in shape, or movement of neighboring portions relative to one another. Viscosity denotes opposition to flow. The reciprocal of the viscosity is called the fluidity. All liquids appear resistance to flow change from liquid to another, the water flow faster than glycerin, subsequently, the viscosity of water is less than glycerin at same temperature.

The absolute viscosity of a liquid is defined as the force required to move a plane of unit area at unit velocity with respect to another parallel plane separated by unit distance, the space between the planes being filled with the liquid under observation. Absolute viscosity (η) may be measured by observing the rate of flow through capillary tubes, and applying Poiseuille's law:

$$\eta = \frac{\Delta P g \pi r^4}{8vl} = \frac{\Delta P g \pi r^4 t}{8Vl} \qquad \textbf{(1)}$$

ΔP is the pressure drop across the tube in $g\ cm^{-2}$
g the acceleration due to gravity in the radius of the tube in $cm\ s^{-2}$
v the volume delivered in unit time in $ml\ s^{-1}$
V the volume delivered in ml,
l the length of the tube in cm.

To obtain the relative viscosity of a liquid at a given temperature, it is necessary to measure its time of flow at that temperature and the corresponding time of flow for the same volume of water in the same viscometer at the same temperature. Since the pressure of a liquid in a viscometer of the type used is proportional to its density, and since the terms r, V, and l in Eq. (1) are the same for both liquids, it follows that the ratio of the viscosities is given by the following equation:

$$\frac{\eta_1}{\eta_2} = \frac{d_1 t_1}{d_2 t_2} \qquad (2)$$

If substance 2 is the reference liquid, we arbitrarily assign to η_2 , the value of unity. Then η_1 is calculated by substitution of the densities and the flow times in Eq. (2). We can also use Eq. (2) to obtain the viscosity of water at a given temperature relative to the viscosity of water at 25℃ .

The factors effect on the viscosity:

1. **Effect of Temperature**: the temperature of the liquid fluid increases its viscosity decreases. In gases its opposite, the viscosity of the gases fluids increases as the temperature of the gas increases.
2. **Molecular weight**: the molecular weight of the liquid increases its viscosity increases.
3. **Pressure**: when increase the pressure on liquids, the viscosity increases because increase the attraction force between the molecules of liquid.

   The SI Unit of Viscosity is pascal-second (Pa.s).
   The CGS Unit is expressed as Poise (P).
   It is more commonly expressed as Centipoise (cP) ($1\ cP\ =\ 0.001\ Pa.s$).

Procedure:

1. Clean the Ostwald's viscometer with water and acetone, dry it in a preheated oven.
2. Attach a small piece of rubber tube having a screw pinch cock at the upper end of the Ostwald's viscometer.
3. Now fill the Ostwald's viscometer with water through pipette up to half of the bulb. Suck the water, 1 2 cm above mark A. Adjust the pinch cork, so that 1-2 drops fall per second.
4. Clamp the Ostwald's viscometer on a stand and allow the water drops to fall and start the timer when the meniscus crosses the upper mark A and stop it when the meniscus passes mark B. Note down the time taken from point A to B, in seconds.
5. Repeat the exercise to take three to four readings. Rinse the Ostwald's viscometer with alcohol and dry it.
6. Further, fill the given liquid in the Ostwald's viscometer with the help of pipette and note down the time, in seconds, as in case of water.
7. Now, take a clean dry specific gravity bottle, weigh it empty as well as with water and given liquid.

Observation Table:

Liquid Samples	Time (s)			Mean time (s)	Density (g/mL)	Viscosity (cP)
	1	2	3			
Water						
Sample						

Calculations:

Determination of the Density of the given Experimental Liquid:

Weight of empty specific gravity bottle = W_1 g.

Weight of specific gravity bottle + water = W_2 g

Weight of empty specific gravity bottle + Sample Liquid = W_3 g

Weight of Water= $(W_2 - W_1)$ g

Weight of Sample Liquid= $(W_3 - W_1)$ g

Density of Water at room temperature (ρ_w) = 0.997 g/mL

$$Density of the given Sample Liquid (\rho L) = \frac{Weight\ of\ Sample\ Liquid}{Weight\ of\ Equal\ Volume\ of\ water} \times Density\ of\ water$$

$$= \frac{(W_3 - W_1)}{(W_2 - W_1)} \times \rho_w$$

Determination of the Viscosity of the given Sample Liquid:

$Viscosity\ of\ water\ at\ room\ temperature\ (\eta_w) = 0.996\ cP$

$$Viscosity\ of\ Sample\ Liquid\ (\eta L) = \frac{\rho_L t_1}{\rho_w t_2} \times \eta_w$$

Where: t_1 : mean time of flow of sample liquid from point A to B.
t_2 : mean time of flow of water from point A to B. Result:

The Viscosity of liquid is ……cP.
Link for Simulator exp:
pcv-au.vlabs.ac.in/physical-chemistry/Determination_of_Viscosity_of_Organic_Solvents/experiment.html



Questions:

A-Choose the Correct Answer

Q1: The viscosity of liquid

A. Increases with increase in temperature

B. Decreases with increase in temperature

C. Decreases with decrease in temperature

D. Remains constant regardless of any change in the temperature

Q2: What is the relation between the viscosities of blood and water?

A. Both are equal.

B. Water is more viscous than blood.

C. They cannot be compared.

D. Blood is more viscous than water.

Q3: The factor on which viscosity depends is _____

A. Area of contact of two adjacent layers

B. Velocity difference between two adjacent layers

C. The distance between two adjacent layers

D. All of the mentioned

Q4: What is the SI unit of viscosity?

A. Poiseiulle

B. Pascal/second

C. Newton-Second

D. Newton/Second

Q5: Select the incorrect statement from the following option.

A. Viscosity helps in the selection of good lubricating oil

B. Light oils have low densities and easy flowability

C. Heavy oils are used on parts moving with high speed

D. Light oils do not impose much drag on high-speed parts

Q6. The factor on which viscosity depends is _____

A. Area of contact of two adjacent layer

B. Velocity difference between two adjacent layers

C. The distance between two adjacent layers

D. All of the mentioned

EXPERIMENT **2**

Determining the distribution coefficient for a solute between two liquids

Aim

- Determine the Distribution Coefficient (K_d) of molecular iodine between water and Ethyl Acetate.
- Determine the Stability Constant (Ks) of Iodine-Iodide complex.

Theory

The distribution Coefficient:

If an excess amount of a certain substance, is added to a mixture of two immiscible phases (i.e. liquids), it will distribute itself between the two phases so that each of them becomes saturated; provided that the substance is soluble in both phases.

If the substance is added in an amount insufficient to saturate each of the two phases, it will still become distributed between the two phases in a definite concentration ratio. This ratio is called Distribution (or Partition) Coefficient.

$$Distribution\ coefficient\ (K_d) = \frac{concentration\ in\ the\ first\ phase}{concentration\ in\ the\ second\ phase} = \frac{C1}{C2}$$

For instance; if a substance is added to ethyl acetate/water mixture, then Kd of this substance is:

$$K_d = \frac{C_{ethyl\ acetate}}{C_{water}}$$

Distribution coefficient is a function of:

- Nature of the solute.
- Type of the two immiscible phases.
- Temperature of the system. (Why?)

Distribution coefficient governs the concentration ratio of the solute species common to both phases (i.e. in the same molecular condition). To better understand this idea, suppose that we have benzoic acid added to octanol/water mixture. This weak acid will be present in the aqueous phase in two different forms, which are dissociated form $[A^-]_w$ and un-dissociated $[HA]_w$. On the other hand, it can be present in the organic phase in the un-dissociated form $[HA]_0$ and in the dimer form $[2HA]_0$.

In this case: $K_d = \frac{[HA]_0}{[HA]_w}$

Distribution phenomenon is involved in several areas of pharmaceutical interest, which includes:

1. Preservation of oil-water systems (i.e. emulsions).
2. Drug actions at nonspecific sites.
3. The absorption and distribution of drugs throughout the body.
4. Chromatographic separation technique.
5. Extraction purposes.
6. Determination of complex stability constant.

The stability constant:

Complexes are structures that result from a donor-receptor interaction between two or more different chemical constituents.

Intermolecular forces involved in the formation of these complexes are:

1. Covalent bonds.
2. Van der Waal forces.
3. Dipole or induced Dipole bonds.
4. Hydrogen bonds.
5. Charge transfer and hydrophobic interactions.

Complexes can be divided into three broad classes, which are:

a) Metal Ion Complexes.

In which a central metal ion is bonded to one or more ligands by a coordinate bond, for example: chelate complexes.

b) Organic Molecular Complexes.

Molecular complexes consist of constituents held together by weak forces. For example: Caffeine with acidic drugs.

c) Inclusion/Occlusion Compounds.

In which one of the constituents is trapped in the open lattice or cage-like structure of the other to yield a stable arrangement. For example: Cyclodextrins with hydrophobic drugs.

Determination of the stoichiometric ratio of ligand-to-metal or donor-to-acceptor, and of a quantitative expression of the stability constant (K_s) for complex formation are important in the study and application of complexes.

In this experiment, we are going to use the 'Distribution Method' to determine the stability constant (K_s) of iodine-iodide complex.

The complex stability constant determined at equilibrium is given by: $I_2 + I^- \leftrightarrow I_3^-$

$$K_s = \frac{[\ I_3^-]_{complex}}{[I_2]_{free}\,[I^-]_{free}}$$

The concentrations of the above species can be determined from the initial concentrations, the distribution coefficient (Kd) of molecular iodine between two immiscible solvents, and from the fact that only molecular iodine will be present in the organic phase, while both ionized and molecular iodine will be present in the aqueous phase

Experimental Part

Materials and apparatus:

- 0.04 M I_2/Ethyl Acetate,
- 0.1M NaI,
- Distilled water,
- Pure Heptane,
- 0.1M $Na_2S_2O_3$,
- Conical flasks,
- Burets,
- Volumetric pipets (10 ml and 25 ml),
- Beakers,
- separatory funnel,
- Measuring cylinder,
- Pipette filler.

Procedure

Important Note: during the titration of organic phase, very good shaking is required after each addition of $Na_2S_2O_3$ in order to extract I_2 from the organic phase; because the interaction between them takes place in the aqueous medium.

K_d Determination:

1. Take 20 ml of 0.04 M I_2/Ethyl Acetate solution (organic phase), place in separatory
2. funnel, add 100 ml distilled water (aqueous phase).
3. Shake at intervals for about 10 min.
4. Allow the equilibrium to establish in the system at room temperature.
5. Separate the two layers.

Titration of organic layer:

1. Using a pipet transfer 10 ml of the organic layer to a conical flask containing 10 ml of 0.1M NaI.
2. Titrate with 0.1 M $Na_2S_2O_3$ until the disappearance of color.
3. Note that the chemical reaction that occurs is:
   $2Na_2S_2O_3 + I_2 \rightarrow 2\,NaI + Na_2S_4O_6$

Titration of aqueous layer:

1. Transfer 25 ml of aqueous layer to an Erlenmeyer flask containing 10 ml of 0.1M NaI.
2. Add 1 ml of Heptane, which will act as an indicator, and shake the solution (heptane will
3. extract I_2 and appear as pink droplets).
4. Titrate with 0.01 M $Na_2S_2O_3$ until the disappearance of pink color (of heptane droplets).

K_s Determination:

Repeat the previous procedures using 0.1 M NaI instead of distilled water as an aqueous phase and 0.04 M I_2/ ethyl acetate as an organic phase.

Results and calculations

K_d Determination:

End point		$[I_2]$, M		K_d
Organic	Aqueous	Organic	Aqueous	

K_s Determination:

End point		$[I_2]$, M				K_s
Organic	Aqueous	Organic	Aqueous			
		$[I_2]_{free}$	$[I_2]_{free}$	$[I^-]_{complex}$	$[I^-]_{free}$	



Questions

1. **What is the primary objective of this experiment?**
   a) To measure the boiling point of ethyl acetate
   b) To determine the distribution coefficient (Kd) of iodine between water and ethyl acetate
   c) To synthesize iodine-iodide complexes
   d) To purify water using ethyl acetate

2. **The distribution coefficient (Kd) is defined as:**
   a) The ratio of the solute's concentration in the aqueous phase to the organic phase
   b) The ratio of the solute's concentration in the organic phase to the aqueous phase
   c) The total concentration of solute in both phases
   d) The temperature of the system

3. **Which factor does NOT affect the distribution coefficient (Kd)?**
   a) Nature of the solute
   b) Type of immiscible phases
   c) Volume of the conical flask
   d) Temperature of the system

4. **In the experiment, what role does heptane play during the titration of the aqueous layer?**
   a) It reacts with iodine to form a complex
   b) It acts as an indicator by extracting iodine and showing a pink color
   c) It neutralizes $Na_2S_2O_3$
   d) It dissolves ethyl acetate

5. **What chemical reaction occurs during the titration with $Na_2S_2O_3$?**
   a) $I_2 + Na_2S_2O_3 \rightarrow NaI + Na_2SO_4$
   b) $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$
   c) $I_2 + NaI \rightarrow I_3^-$
   d) $Na_2S_2O_3 + H_2O \rightarrow NaOH + H_2SO_3$

6. **What type of intermolecular force is NOT listed as being involved in complex formation?**
   a) Covalent bonds
   b) Ionic bonds
   c) Hydrogen bonds
   d) Van der Waals forces

7. **For Ks determination, what is added to the aqueous phase instead of distilled water?**
   a) Ethyl acetate
   b) 0.1 M NaI
   c) 0.1 M $Na_2S_2O_3$

d) Pure heptane

8. **Which of the following is an application of the distribution phenomenon?**
   a) Freezing point depression
   b) Chromatographic separation
   c) Electrolysis of water
   d) Polymer synthesis

9. **What is the purpose of shaking the separatory funnel during Kd determination?**
   a) To heat the solution
   b) To ensure equilibrium distribution of iodine between phases
   c) To evaporate excess water
   d) To dissolve $Na_2S_2O_3$

10. **The stability constant (Ks) is calculated for which complex in this experiment?**
    a) I_2 + Ethyl acetate
    b) $I_2 + H_2O$
    c) $Na_2S_2O_3 + I_2$
    d) $I_2 + I^- \leftrightarrow I_3^-$

True/False Questions

1	The distribution coefficient (Kd) depends only on the nature of the solute	
2	In this experiment, only molecular iodine (I_2) is present in the organic phase.	
3	The stability constant (Ks) is determined using the distribution method in this experiment.	
4	Ethyl acetate and water are miscible liquids in this experiment	
5	Shaking is not required during the titration of the organic phase with $Na_2S_2O_3$.	
6	The reaction $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$ is used to quantify iodine concentration.	
7	The distribution coefficient (Kd) remains constant regardless of temperature changes.	
8	Inclusion compounds involve a ligand-to-metal coordinate bond	
9	The aqueous layer is titrated with 0.01 M $Na_2S_2O_3$ in the Kd determination procedure.	
10	The experiment can be used to study drug absorption in the body.	

EXPERIMENT **3**

Measurement of Gas Diffusion (Graham's Law of Diffusion)

Aim: measurement of Gas diffusion

Kinetic Molecular Theory assumes that the molecules of gases are in rapid random motion and their average velocities are proportional to the absolute temperature. It also assumes that at the same temperature, the average kinetic energies of the molecules of different gases are equal. Graham's Law of Diffusion is based on the above assumptions of Kinetic Molecular Theory. The theory can be stated in the following form: The rates of diffusion of different gases are inversely proportional to the square roots of their molar masses.

The diffusion rate (r) of a molecule is inversely related to the square root of its molecular weight (MW),

$$r = \frac{1}{\sqrt{Mwt}}$$

and the ratio of the distances traveled by NH_3 (d_1) and HCl (d_2) should be close to the ratio of the diffusion rates:

$$\frac{r_1}{r_2} = \frac{1}{\sqrt{Mwt_1}} / \frac{1}{\sqrt{Mwt_2}} = \frac{\sqrt{Mwt_2}}{\sqrt{Mwt_1}} \cong \frac{d_2}{d_1}$$

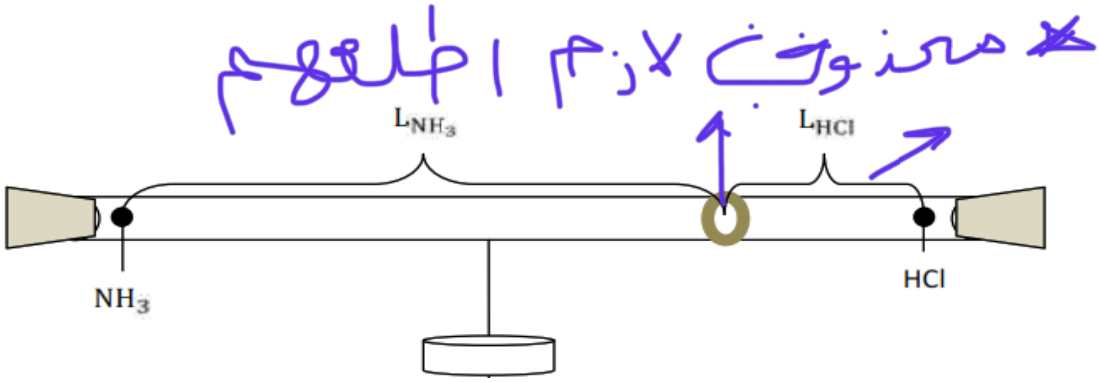
It would be difficult to make experimental measurements of the velocities of individual gas molecules without the aid of sophisticated laboratory equipment. But the relative molecular velocities of certain gases can be compared using some very simple equipment. Problem: In this exercise you will determine the relative molecular velocities of ammonia gas and hydrogen chloride gas. This information will be used to calculate experimental values for (1) the ratio of the average molecular velocity of ammonia gas to that of hydrogen chloride gas and (2) the theoretical rate of diffusion between ammonia and hydrogen chloride. Ammonia and hydrogen chloride gases react, upon contact, to form a white cloud of microscopic particles of solid ammonium chloride. This fact makes it fairly easy to experimentally measure the relative rates of diffusion of these gases. This is accomplished by simultaneously introducing ammonia and hydrogen chloride gases into the opposite ends of a glass tube and noting the time needed for the appearance of the faint white precipitate of ammonium chloride. Experimental values for the relative rates of diffusion of NH_3 and HCl through the air in the tube can then be obtained by

measuring the distance traveled by each gas and dividing by the time required for the appearance of the ammonium chloride precipitate.

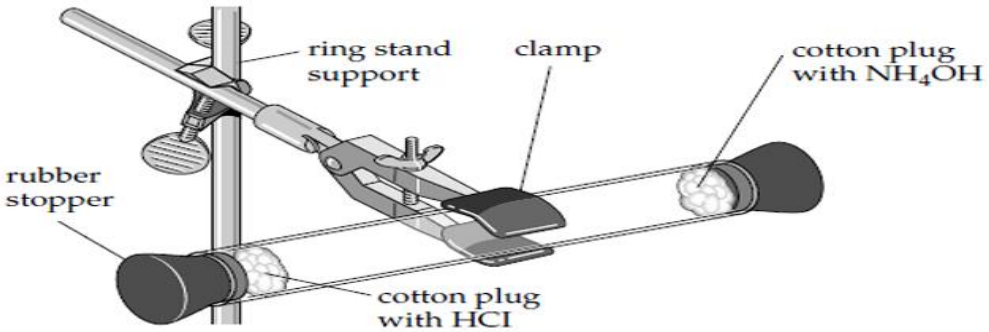
Materials

- glass tubing
- cotton balls (4)
- NH3 (aq) (conc.)
- metric ruler
- cotton swabs (4)
- HCl (aq) (conc.)
- safety goggles
- Vis-a-vis marker

Procedure: EYE PROTECTION MUST BE WORN AT ALL TIMES!!!



$$\frac{r_{NH_3}}{r_{HCl}} = \frac{\frac{L_{NH_3}}{time}}{\frac{L_{HCl}}{time}} \quad \text{and} \quad \frac{L_{NH_3}}{L_{HCl}} = \frac{\sqrt{Mwt_{NH_3}}}{\sqrt{Mwt_{HCl}}}$$



1. You will be using concentrated ammonia and concentrated hydrochloric acid (source of hydrogen chloride gas) in a sealed dropper bottle. Keep these containers tightly closed when not in use.
2. BE CERTAIN NOT TO SWITCH THE CAPS - YOU WILL CONTAMINATE THE SOLUTIONS AND RUIN YOUR RESULTS!

3. Lay the glass tubing on the lab bench. Be sure that the tube is completely dry inside. The tubing must remain on the table top at all times!
4. Mark the tube on one side to indicate where the Hydrochloric acid will be inserted.
5. Wrap a cotton ball around the stem of each swab. The cotton ball will be used to stopper the ends of the tubing.
6. Place one or two drops of the hydrochloric acid on one of the swab ends. Place one or two drops of the ammonia on the other swab. Do not touch the acid or the base! If any solution comes into contact with your skin or clothing, immediately rinse with cold water for at least 30 seconds.
7. Simultaneously insert the moistened ends of the swabs into the ends of the glass tubing. Your results will be off if this step is not done correctly!
8. Mark the position of the tip of each swab with the Vis-a-vis marker on the outside of the tube.
9. After several minutes, a white ring will form where the gases meet and react with each other. Mark the position of the ring with the Vis-a-vis marker. This ring may be very difficult to see. Leaving the tube on the black counter top will enable you to better see the ring.
10. Measure the distance traveled by each gas.
11. Carefully follow the directions of your instructor when disposing of the cotton swabs.
12. Clean the tubes according to your instructor's directions and repeat.
13. The procedure may be repeated if you have time (you should have time for at least two trials). Take the average of the distances for your calculations.

Calculations:

1. Write a balanced equation for the reaction between Hydrochloric acid + ammonia. Start with a word equation, then translate and balance into a complete equation.
2. Determine the experimental distance ratio.
3. Determine the average of the distances for each gas before you calculate the experimental value for this lab.
4. Determine the theoretical distance ratio by using Graham's Law. Be sure to review Graham's Law before performing these calculations!
5. Determine the experimental error (% error).

Questions

1. Which gas will diffuse faster, oxygen (O_2) or methane (CH_4)? How many times faster? Show all work.
2. In an experiment similar to the one which you performed, substance X was substituted for HCl. Ammonia was found to have a diffusion rate of 5.0 cm/minute, and substance X at a rate of 4.6 cm/minute. Calculate the molar mass of substance X. Show all work.

EXPERIMENT 4

Determination of the distribution coefficient of ethanoic acid between water and 2-butanol

Aim: To examine the dissolution and distribution of a solute in two immiscible liquids

Pre lab questions

What does the "distribution coefficient" mean? Explain your answer by providing the equilibrium equation.

Introduction

As we know when two immiscible solvents A and B are placed in a beaker, they will not mix and instead form separate layers. At a constant temperature, when a solute X is added which is soluble in both solvents remains in the same molecular–form in both and does not react with either of them and the system is shaken vigorously, the solute X gets dissolved in both solvents depending on its solubility in each solvent. This nature is mainly used in solvent extraction where a crude (impure) product is obtained in an experiment. For example, the reaction would have been carried out in an aqueous solution and at the end of the reaction there may be unreacted starting materials and unwanted side-products. The aqueous solution is shaken with another immiscible solvent that does not mix with water. The immiscible solvent can be chosen such that the substances that are wanted will dissolve in it, leaving the other substance in the water layer. This procedure can be repeated by adding more of the organic solvent to the aqueous layer, shaking the solutions together, separating them and running of the solution containing the required product. In the cases when a given amount of a solute dissolves between two immiscible liquids at a given temperature, it is necessary to determine the amounts/ concentrations of the solute in both the solvents. Such a situation is described by the partition law in which the ratio of concentrations of the solute is expressed as the equilibrium constant or the partition coefficient, K_D .
This experiment illustrates the distribution of ethanoic acid between two solvents that may be considered to be immiscible, but-1-ol and water. Solutions of the acid in the two solvents are shaken together, allowed to separate and analyzed by titrating a sample of each layer with sodium hydroxide solution.

The procedure is repeated several times, using different concentration of acid and you will then be able to see whether there is any simple relationship between the concentrations of the acid in each solvent.

Equipment and chemicals required:

Equipment	Chemicals
Pipette (10/25 cm^3)	But-1-ol 150 cm^3
Burette	2 mol dm^{-3} ethanoic acid 150 cm^3
Separating funnels	~ 0.50 mol dm^{-3} NaOH 150 cm^3
Reagent bottles (250 cm^3)	Phenolphthalein indicator
Titration flasks (250 ml)	
Beakers	
Measuring cylinder (10/25ml)	

Procedure

1. Prepare the following mixtures by measuring required volumes of ethanoic acid (CH_3 COOH), butanol and distilled water into a separating funnel/ reagent bottle

Mixture	But-1-ol / cm^{-3}	ethanoic acid / cm^{-3}	Water / cm^{-3}	Volume of 0.5moldm-3 NaOH / cm^{-3}	
				Organic Layer	Aqueous Layer
1	20	10	25		
2	20	15	20		
3	20	20	15		
4	20	25	10		
5	20	30	5		

2. Shake the mixture(s) vigorously for about 5 minutes to allow ethanoic acid to dissolve and distribute in both layers. After shaking, rest the separating funnel/ reagent bottle on an experimental bench (table) and allow the layers to separate. At this stage, the top layer is but-1-ol and the bottom layer is water.

3. Using the pipette (use a pipette filler) transfer 10 cm^3 of the upper layer (but 1-ol) into a titration flask. Using a measuring cylinder, add about 25 cm^3 of water to the flask, followed by 3 drops of phenolphthalein indicator. Titrate the resulting mixture against the 0.50 mol dm^{-3} NaOH solution.

4. Using a second pipette, withdraw 10 cm3 of the aqueous layer from the bottom layer (aqueous) through the top layer and transfer into a titration flask, add 25 cm^3 of distilled water and titrate it against the 0.50 mol dm^{-3} NaOH solution as before.

5. Repeat steps 3 and 4 above with other mixtures prepared and record the results in the corresponding columns in the table.

NOTE: Steps 3 and 4 can be done as follows if the pipette fillers are not available in the laboratory). After allowing the separation of layers in step 2 just after vigorous shaking of the mixture in a reagent bottle, transfer the mixture into a burette and allow the layers to separate. Now from this you may withdraw the required volume of water layer (which is in the bottom) first. After the completion of titration of that aqueous layer, you may remove remaining water layer and then the samples from the organic layer can be collected and titrated

Calculate the concentrations of ethanoic acid in each of the respective titrations and record the results in the table below.

Estimate the ratio of

$[CH_3\ COOH]_{butanol}$

$[CH_3\ COOH]_{water}$

Mixture	$[CH_3\ COOH]_{butanol}$	$[CH_3\ COOH]_{water}$	$\frac{[CH_3\ COOH]_{butanol}}{[CH_3\ COOH]_{water}}$
1			
2			
3			
4			
5			

Comment on the values obtained for

$$\frac{[CH_3\ COOH]butanol)}{[CH_3\ COOH]\ water\ )}$$

for the distribution coefficient K_D for the ethanoic acid in butanol and water. and hence give the value

Post lab questions:

1. Why the immiscible solution has to be separated before the ethanoic acid is titrated?

EXPERIMENT 5

Determining the boiling point of some liquids - and the solubility product of various substances

Determination of Boiling Points of Selected Liquids and Solubility Products of Sparingly Soluble Salts

Aim

1. To determine the boiling points of ethanol, acetone, and water under controlled conditions.
2. To calculate the solubility product constants (K_{sp}) of salts such as barium sulfate ($BaSO_4$) and silver chloride (AgCl) using conductivity and titration methods.

Introduction

Boiling point is a fundamental physical property that reflects intermolecular forces in liquids. It is the temperature at which the vapor pressure equals atmospheric pressure. Solubility product (Ksp) is an equilibrium constant for the dissolution of sparingly soluble salts. Understanding these properties is essential in fields ranging from pharmaceuticals to environmental chemistry.
Boiling point trends help predict volatility and purity, while Ksp values guide precipitation reactions and solubility behavior in aqueous systems.

Tools and Chemicals

Equipment:

- Thermometer (0–100 °C)
- Hot plate or Bunsen burner
- Beakers (100 mL, 250 mL)
- Test tubes
- Conductivity meter
- Stirring rod
- Pipettes
- Analytical balance
- Safety goggles and gloves

Chemicals:

- **Liquids for boiling point**: Ethanol, Acetone, Distilled Water
- **Salts for K_{sp}**: Barium sulfate ($BaSO_4$), Silver chloride (AgCl)
- **Solutions**: 0.1 M Na_2SO_4, 0.1 M $AgNO_3$
- Distilled water

Procedure

Part A: Boiling Point Determination

1. Pour 50 mL of each liquid into separate clean beakers.
2. Insert a thermometer into each liquid without touching the bottom.
3. Heat gently using a hot plate or Bunsen burner.
4. Record the temperature at which steady bubbling occurs throughout the liquid.
5. Repeat for each liquid and average the readings.

Part B: Solubility Product Determination

Method 1: Saturated Solution Conductivity

1. Prepare saturated solutions of $BaSO_4$ and AgCl by adding excess salt to distilled water.
2. Filter the solutions to remove undissolved solids.
3. Measure the conductivity of the filtrate.
4. Use molar conductivity values to estimate ion concentrations.
5. Calculate K_{sp} using:

$$K_{sp} = [Ba^{2+}][SO_4{}^{2-}] or [Ag^{+}][Cl^{-}]$$

Method 2: Titration (for AgCl)

1. Mix known volumes of $AgNO_3$ and NaCl to form AgCl precipitate.
2. Filter and collect the supernatant.
3. Titrate the remaining Ag^+ ions with NaCl.
4. Calculate equilibrium concentrations and K_{sp}.

Results Tables

Table 1: Boiling Point Data

Liquid	Trial 1 (°C)	Trial 2 (°C)	Trial 3 (°C)	Average (°C)
Water				
Ethanol				
Acetone				

Table 2: Solubility Product Data

Salt	[Cation] (mol/L)	[Anion] (mol/L)	K_{sp} (mol²/L²)
$BaSO_4$			
AgCl			

Equations and Laws Used

Boiling Point:

- **Clausius-Clapeyron Equation** (optional for advanced analysis):

$$ln\,P = -\frac{\Delta H_{vap}}{RT} + C$$

Solubility Product:

- For a salt AB ⇌ $A^+ + B^-$:

$$K_{sp} = [A^+][B^-]$$

- For salts with different stoichiometry:

e.g., $Ca(OH)^2 \rightleftharpoons Ca^{2+} + 2OH^- \rightarrow K_{sp} = [Ca^{2+}][OH^-]^2$

Questions

1. What is the primary purpose of determining the boiling point of a liquid?

2. Which of the following liquids has the lowest boiling point based on the experiment?

3. What equipment is used to measure the temperature during boiling point determination?

4. What does the solubility product constant (Ksp) represent?

5. Which method is used to determine the Ksp of $BaSO_4$ in the experiment?

6. What is the chemical equation used to calculate the Ksp of AgCl?

7. Which of the following tools is essential for titration in the solubility product experiment?

8. Why is it important to filter the saturated solution before measuring conductivity?

9. What is the average boiling point of ethanol based on the experiment?

10. Which law or equation is optionally used to analyze boiling point data in advanced studies?

EXPERIMENT 6

Determining the Coefficient of Effectiveness of a Precipitation

Aim

To determine the coefficient of effectiveness of the reaction between calcium chloride ($CaCl_2$) and sodium carbonate (Na_2CO_3) by calculating the percentage yield of calcium carbonate ($CaCO_3$) precipitate formed.

Introduction

The "coefficient of effectiveness" (CoE) is defined here as the ratio of the actual yield of a product obtained in a chemical reaction to the theoretical yield, expressed as a percentage. In this experiment, we'll use a precipitation reaction where $CaCl_2$ and Na_2CO_3 react to form insoluble $CaCO_3$ and soluble NaCl. This is a cost-effective alternative to silver-based reactions, using readily available chemicals. The reaction's effectiveness will be assessed by isolating and weighing the $CaCO_3$ precipitate.

The reaction is:

$$CaCl_2\,(aq) + Na_2CO_3\,(aq) \rightarrow CaCO_3\,(s) + 2NaCl\,(aq)$$

Theory

The theoretical yield is calculated based on the limiting reactant and stoichiometry, while the actual yield is measured experimentally. The CoE is:

$$CoE = \frac{Actual\ Yield}{Theoretical\ Yield} \times 100\%$$

Molar masses:

- $CaCl_2$: 110.98 g/mol
- Na_2CO_3: 105.99 g/mol
- $CaCO_3$: 100.09 g/mol For a 1:1 mole ratio, the limiting reactant determines the maximum $CaCO_3$ produced.

Apparatus and Tools

Chemicals:

0.1 M $CaCl_2$ solution,

0.1 M Na_2CO_3 solution,

distilled water

- **Equipment**:
  - 100 mL beakers (2)
  - 50 mL graduated cylinder
  - Stirring rod
  - Filter paper (pre-weighed)
  - Funnel
  - Analytical balance (precision ±0.01 g)
  - Drying oven or heat lamp
  - Safety gear (goggles, gloves, lab coat)

Procedure

1. ***Preparation***:
   - Measure 50 mL of 0.1 M $CaCl_2$ solution using a graduated cylinder and pour it into a beaker.
   - Measure 50 mL of 0.1 M Na_2CO_3 solution and pour it into another beaker.
2. ***Reaction:***
   - Slowly pour the Na_2CO_3 solution into the $CaCl_2$ solution while stirring. Observe the formation of a white $CaCO_3$ precipitate.
3. ***Filtration:***
   - Weigh a piece of filter paper and record its mass.
   - Set up a funnel with the filter paper and pour the reaction mixture through it to collect the $CaCO_3$ precipitate.
   - Rinse the beaker with a small amount of distilled water to transfer any remaining precipitate.
4. ***Drying:***
   - Place the filter paper with the precipitate in a drying oven (or under a heat lamp) at 80°C for 30 minutes or until dry.
   - Weigh the dried filter paper with $CaCO_3$ and subtract the filter paper's mass to get the actual yield.
5. ***Cleanup:***
   - Dispose of the filtrate (NaCl solution) safely per lab guidelines.

Calculations (Theoretical Yield)

- Moles of $CaCl_2$ = 0.1 mol/L×0.050 L=0.005 mol
- Moles of Na_2CO_3 = 0.1 mol/L×0.050 L=0.005
- Limiting reactant: 1:1 ratio, so both are fully consumed.

- Theoretical yield of $CaCO_3$ = 0.005 mol×100.09 g/mol=0.50045 g (≈ 0.50 g)

Results and Discussion

Sample Data

Mass of filter paper	g
Mass of filter paper + dry $CaCO_3$	g
Actual yield of $CaCO_3$	g
Theoretical yield	g
Coefficient of Effectiveness: CoE	%

Question:

1- Give reason: why the CoE <100%?

2- In certain experiment the following results are obtained

Sample Data (Hypothetical):

- Mass of filter paper: 1.20 g
- Mass of filter paper + dry $CaCO_3$: 1.67 g
- Calculate:
  A. Actual yield of $CaCO_3$
  B. Theoretical yield
  C. Coefficient of Effectiveness: CoE

EXPERIMENT 7

Freezing point dispersion

Aim:

Upon completion of this lab, the student will be able to:

1) Relate freezing point depression to molality of the solution.
2) Measure the freezing point depression constant for water.

Introduction

Properties of a solution that only depend on the amount of solute in the solution and are independent of the chemical identity of the solute are referred to as *Colligative Properties.* Examples of colligative properties include:

1. boiling point elevation
2. freezing point depression
3. lowering of vapor pressure and
4. osmotic pressure.

In this experiment the freezing point depression of water due to the presence of a solute will be studied.

When solutes such as salt or glucose are added to water, the freezing point of water decreases. The extent to which the freezing point is lowered or depressed depends on the amount of the solute that is added. The amount of solute in the solution is measured in terms of molality. Molality (m) is defined as the moles of solute per kilogram of the solvent. Molality is used instead of molarity in these instances, as the volume of the solvent changes slightly with variations in temperature while mas does not. This allows for consistency over a range of temperatures without additional calculations to account for thermal expansion of solvents.

Therefore, the depression in the freezing point, ΔT_f is proportional to the molality, m, of the solution.

$$\Delta T_f \, \alpha \, m$$

$$\Delta T_f = K_f \bullet m$$

In the above equation K_f, the proportionality constant, is referred to as the freezing point depression constant. The freezing point depression constant for water is 1.86 °C/m. This value will be confirmed experimentally.

Experimental Design

In this experiment, different amounts of a non-volatile and non-ionic solute, glycerol, will be added to water. The freezing point of water will be measured for each amount of glycerol added. A plot of the molality vs. the freezing point depression will be used to determine the freezing point depression constant.

Reagents and Supplies

Glycerol, rock salt (NaCl), thermometer

Procedure

1. Place an empty beaker on the electronic balance and tare the balance.
2. Place a large empty test tube inside the beaker in step 1 and record the mass.
3. Add about 12 grams of deionized water to the test tube in step 2 and record the mass.
4. Add about 1 gram of glycerol into the test tube in step 3 and record the mass. Use a dropper to add the glycerol. Glycerol is highly viscous and may not flow easily in and out of the dropper. Care must be taken to avoid glycerol spills on the balance pan. In case of spills, use paper towels to immediately clean the glycerol and discard the paper towel in the trash container. Make sure that the glycerol is completely dissolved before beginning the cooling process.
5. Repeat steps 1 through 4 with the following amounts of glycerol.

Test Tube	Water (grams)	Glycerol (grams)
1	12	1.0
2	12	1.4
3	12	1.8
4	12	2.4
5	12	3.0
6	12	3.8
7	12	4.5
8	12	5.2

6. Determine the freezing point of water in each of the test tube using the following method.

   a) Clamp the test tube containing the water/glycerol solution.
   b) Prepare a cold-water bath by combining water, rock salt, and ice in the following proportion in a 600-mL beaker: 25% water, 25% rock salt, and 50% ice. The temperature of the bath should be at least −8°C.
   c) Place the test tube inside containing the water/glycerol solution in the cold-water bath. Make sure that the solution inside the test tube is completely submerged into the ice mixture.
   d) Place a thermometer inside the test tube and lightly stir the contents, taking care to avoid breaking the test tube.
   e) When the mixture becomes a thick slurry, remove the test tube from the ice bath.
   f) Remove the test tube from ice bath and begin stirring to melt the ice crystals. Dip the test tube into a room temperature water bath immediately in order to facilitate melting. Do not leave the test tube inside the room temperature bath as this might lead to artificially high melting points.
   g) Stir the contents of the test tube gently, using the thermometer. Record the temperature at which the last crystal has melted. This is the melting point (NOTE: this is the same as the freezing point).

7. Once the freezing points of the water in all the test tubes have been measured, discard the solutions as directed by the instructor.

Data Table

NOTE: Normal freezing point of water = 0°C

ΔT_f = Measured freezing pint – Normal freezing point

Test Tube	Mass of Empty Test Tube (grams)	Mass of Test Tube + Water (grams)	Mass of Test Tube + Water + Glycerol (grams)	ΔT_f (°C)
1				
2				
3				
4				
5				
6				
7				
8				

Data Analysis

Mass of water = (Mass of test tube + water) – (Mass of empty test tube)

Mass of glycerol = (Mass of test tube + water + glycerol) – (Mass test tube + water) Mass of

solution = Mass of water + Mass of glycerol
Molar mass of glycerol = 92.1 g/mol

$$Molality = \frac{moles\ of\ glycerol}{mass\ of\ solvent\ (kg)}$$

Test Tube	Mass of water (grams)	Mass of water (kg)	Mass of glycerol (grams)	Moles of glycerol	Molality	ΔT_f (°C)
1						
2						
3						
4						
5						
6						
7						
8						

Data Analysis

Plot a graph of molality (x-axis) vs. ΔT_f (y-axis).

Obtain the equation of the best-fit line. Be sure to set the y-intercept to zero. The slope of this line is the K_f.

Multiple-Choice Questions (MCQs)

1. **What property of a solution is directly related to freezing point depression?**
   a) Volume
   b) Molality
   c) Density
   d) Temperature

2. **Freezing point depression is an example of a:**
   a) Colligative property
   b) Physical property
   c) Chemical property
   d) Intensive property

3. **The freezing point of a solution is always:**
   a) Higher than the pure solvent
   b) Lower than the pure solvent
   c) Equal to the pure solvent
   d) Unpredictable

4. **What unit is used to express molality?**
   a) Moles per liter
   b) Moles per kilogram
   c) Grams per liter
   d) Grams per kilogram

5. **The freezing point depression constant (K_f) depends on:**
   a) The solute
   b) The solvent
   c) The concentration
   d) The temperature

6. **For water, the freezing point depression constant (K_f) is approximately:**
   a) 0.512 °C/m
   b) 1.86 °C/m
   c) 3.14 °C/m
   d) 4.18 °C/m

7. **What happens to the freezing point of water when sugar is dissolved in it?**
   a) It increases
   b) It decreases

c) It remains the same
d) It becomes zero

8. **Which of the following will cause the greatest freezing point depression in water?**
   a) 0.1 m NaCl
   b) 0.1 m Glucose
   c) 0.1 m $CaCl_2$
   d) 0.1 m Sucrose

9. **The equation for freezing point depression is:**
   a) $\Delta T_f = K_f \times m$
   b) $\Delta T_f = K_f / m$
   c) $\Delta T_f = m / K_f$
   d) $\Delta T_f = K_f + m$

10. **What is the purpose of measuring the freezing point depression in this experiment?**
    a) To calculate the boiling point
    b) To determine the molality of the solution
    c) To find the freezing point depression constant
    d) Both b and c

11. **If the molality of a solution increases, the freezing point depression:**
    a) Decreases
    b) Increases
    c) Remains constant
    d) Becomes zero

12. **Which instrument is commonly used to measure the freezing point of a solution?**
    a) Barometer
    b) Thermometer
    c) Hydrometer
    d) Spectrophotometer

13. **The van't Hoff factor (i) accounts for:**
    a) The temperature of the solution
    b) The number of particles formed by the solute
    c) The volume of the solvent
    d) The pressure of the solution

14. **For a non-electrolyte solute, the van't Hoff factor (i) is:**
    a) 0
    b) 1
    c) 2
    d) 3

15. **What is the freezing point of pure water at standard pressure?**
    a) 0 °C
    b) 32 °C
    c) 100 °C
    d) -1.86 °C

16. **If a solution has a molality of 1 m and K_f = 1.86 °C/m, what is the freezing point depression?**
    a) 0.93 °C
    b) 1.86 °C
    c) 3.72 °C
    d) 0 °C

17. **Which solute will dissociate into the most particles in water?**
    a) NaCl
    b) $MgCl_2$
    c) Glucose
    d) KBr

18. **The freezing point depression constant is unique to:**
    a) Each solute
    b) Each solvent
    c) Each solution
    d) Each temperature

19. **In the experiment, if the measured freezing point depression is 3.72 °C, and molality is 2 m, what is K_f?**
    a) 1.86 °C/m
    b) 0.93 °C/m
    c) 3.72 °C/m
    d) 7.44 °C/m

20. **Why does adding a solute lower the freezing point of a solvent?**
    a) It increases the vapor pressure

b) It disrupts the solvent's crystal lattice formation
c) It decreases the solvent's density
d) It increases the boiling point

Short-Answer Questions

1. **What is freezing point depression?**

2. **How is freezing point depression related to molality?**

3. **What is the freezing point depression constant (Kf) for water?**

4. **Define molality.**

5. **Why is molality used instead of molarity in freezing point depression calculations?**

6. **What is the van't Hoff factor (i)?**

7. **Calculate the freezing point depression for a 0.5 m NaCl solution in water (Kf = 1.86 °C/m)..**
8. **What is the freezing point of a 1 m glucose solution in water?**

9. **Why does NaCl cause a greater freezing point depression than glucose at the same molality?**

10. **What is a colligative property?**

11. **If a solution's freezing point is -3.72 °C, what is the freezing point depression?**

12. **How do you experimentally determine the freezing point of a solution?**

13. **What is the freezing point of a 0.2 m $CaCl_2$ solution in water?**

14. **Why is the freezing point depression constant specific to the solvent?**

15. **What happens to the freezing point depression if the solute concentration doubles?**

16. **Calculate Kf if ΔTf = 5.58 °C and molality = 3 m.**

17. **What is the purpose of Experiment C1?**

18. **Why does the solvent's freezing point decrease with solute addition?**

19. **What would happen to the freezing point if no solute were added to water?**

20. **If ΔT_f = 0.93 °C and Kf = 1.86 °C/m, what is the molality?**

EXPERIMENT **8**

Determining the molecular weight using the freezing point Depression

Aim:

1. To determine the freezing point of a substance from its cooling curve.
2. To study the effect of foreign substance content on the freezing point of a solvent.
3. To determine the molecular weight by using the freezing point depression method.

Introduction:

When non-volatile solute is added into a pure solvent, the freezing point of the solvent is depressed. This phenomenon is called the freezing point depression. In other word, the solution possesses a lower freezing point than the pure solvent. The freezing point depression can be explained as solvent molecules leaves the liquid phase and join to form the solid phase; they leave behind a lesser volume of solution where the solute particles may present. This results in the decrease of entropy of the solute particles. Thus, we can say that freezing point depression depends on the concentration of the solute particles present and it is called colligative properties. The colligative properties are solution that depends on the number of molecules in a constant volume of solvent but not the properties of the molecules. However, when the concentration of the solute becomes larger, where the interaction of solute becomes more important, therefore, the freezing point depression may depend on certain properties of the solute rather than the concentration.

In this experiment, we will investigate the phenomenon of freezing point depression and determine the molar mass of substance X. The relationship between the lowering of the freezing point and the concentration of the solution is given by the following:

$$\Delta T = K_f m = K_f \times \frac{mass\ of\ material}{Molecular\ weight\ \times kg\ solvent}$$

where; $\Delta T = freezing\ point\ depression,$

$K_f\ is\ the\ freezing\ point\ molar\ constant\ of\ solvent\ \ and$

$$m\ is\ the\ \frac{mass\ of\ material}{Molecular\ weight\ \times kg\ solvent} = \frac{no\ of\ moles\ of\ solute}{kg\ of\ solvent}$$

Methods:

A) *Determination of the Freezing Point of Naphthalene*

1. A weighing boat was weighed.
2. 5g of naphthalene was added to the weighing boat and weighted again.
3. The naphthalene was transferred into a test tube.

4. The naphthalene was melted using the water bath.
5. When all had melted, the test tube from the water bath was dried and clamped on a retort stand and the initial temperature was recorded.
6. The liquid naphthalene was stirred continuously and the temperature was recorded every 15 seconds until no more change in the gradient for the temperature vs. time graph.
7. A graph of temperature versus time was plotted.
8. The freezing point of naphthalene was determined.

B) Determination of the Freezing Point and Molecular Weight of a Substance

1. Approximately 0.5g of substance X was weighed.
2. The substance was added to the naphthalene in a test tube which was used in part A.
3. The melting and cooling steps were carried out.
4. The molecular weight of substance X was calculated.

[K_f for naphthalene is 6.8]

Apparatus and Materials:

- Naphthalene
- Substance X
- Test tubes
- Stopwatch
- Beaker
- Thermometer
- Glass rod
- Retort stand
- Water bath

Results:

Part 1

Mass of weighing boat 1 = g
Mass of naphthalene + weighing boat 1 = g
Mass of naphthalene = g – g = g

Part 2

Mass of weighing boat 2 = g
Mass of substance X + weighing boat 2 = g
Mass of substance X = g

Table 1: The temperature readings for naphthalene.

Time(s)	T(°C)	Time(s)	T(°C)	Time(s)	T(°C)	Time(s)	T(°C)
0		135		270		405	
15		150		285		420	
30		165		300		435	
45		180		315		450	
60		195		330			
75		210		345			
90		225		360			
105		240		375			
120		255		390			

Plot Temperature vs Time

Based on the graph plotted for the pure solvent (naphthalene), the freezing point obtained is °C.

Table 2: The temperature readings for naphthalene and substance X.

Time(s)	T(°C)	Time(s)	T(°C)	Time(s)	T(°C)	Time(s)	T(°C)
0		135		270		405	
15		150		285		420	
30		165		300		435	
45		180		315		450	
60		195		330			
75		210		345			
90		225		360			
105		240		375			
120		255		390			

Plot Temperature vs Time

Based on the graph plotted the freezing point obtained for solution of substance X and naphthalene is °C.

Calculations:

$$\Delta T = K_f m = K_f \times \frac{mass\ of\ material}{Molecular\ weight\ \times kg\ solvent}$$

$\Delta T = \Delta T_{(pure\ solvent)} - \Delta T_{(solution)}$

$K_f\ for\ naphthalene\ = 6.8\ kg\ mol^{-1}$
$Mass\ of\ substance\ X\ =\quad g$
$Mass\ of\ solvent\ in\ kg\ (naphthalene)\ =\quad kg$

Solve to find molecular weight

Molecular weight of substance X = **g mol^{-1}**

EXPERIMENT 9

Measuring the surface tension of liquids

Aim:

To determine a surface tension of a liquid by dripping.

Theory

Surface tension

Surface of a liquid behaves like a thin flexible membrane that tries to achieve an equilibrium state (state with minimum energy). With increasing surface, the energy of the surface layer increases. The surface of the liquid hence tries to take the smallest and smoothest area. The value of surface tension decreases with increasing temperature.

Surface tension measurement

One of the methods to measure surface tension of a liquid is to let the liquid drip. Liquid in a capillary tube form drops at the bottom of the tube. The drops will gradually grow and, when they reach a sufficient size, they will separate from the liquid.

The gravitational force acts upon a drop with mass m:

$$F_g = m_g$$

The drop is held at the end of the capillary tube by surface forces. The net force of these forces acts upwards and its magnitude is calculated from relationship

$$F_p = \sigma l = \sigma \pi d,$$

where σ is the surface tension of the liquid, l is the circumference of the drop dripping from the capillary and d its diameter.

The drop will separate from the tube when the gravitational force is greater than the net force of the surface forces. Therefore:

$$F_p = F_g$$

After substituting from the equations above:

$$\sigma \pi d = mg.$$

The surface tension is then calculated from the relationship

$$\sigma = \frac{mg}{\pi d}$$

Using this formula, it would be possible to determine the surface tension. The accuracy of this measurement is negatively affected by the fact that only a part of the drop is separated from the tube when the drop drips; part of it stays on the end of the capillary. Before separating, the drop is narrowed and its diameter is smaller than *d*. Therefore, the dripping method is used mainly as a reference method. If we work with the same capillary, the diameter of the narrowed drop is approximately the same with all wetting liquids.

We use two different liquids in this experiment. We measure the surface tension σ_1 of one liquid; we must know the surface tension σ_2 of the second liquid (which can be looked up). We then determine the ratio of the surface tensions of these liquids

$$\frac{\sigma_1}{\sigma_2} = \frac{\frac{m_1 g}{\pi d}}{\frac{m_2 g}{\pi d}} = \frac{m_1}{m_2}$$

First we determine the mass of one drop of each liquid (weigh more drops and divide the result by the number of drops). We substitute these masses m_1 and m_2 into the relationship

$$\sigma_1 = \frac{m_1}{m_2}\sigma_2.$$

Tools

- liquid with unknown surface tension we want to measure
- liquid with surface tension we know (e.g. water)
- laboratory stand
- funnel
- cork with a hole (of a size to fit the capillary and the funnel firmly into it)
- capillary
- container into which we drop the measured liquid
- laboratory scales
- thermometer

Note: If you do not have these tools, you can use a capillary or pipette to drip the liquid **(see Technical notes).**

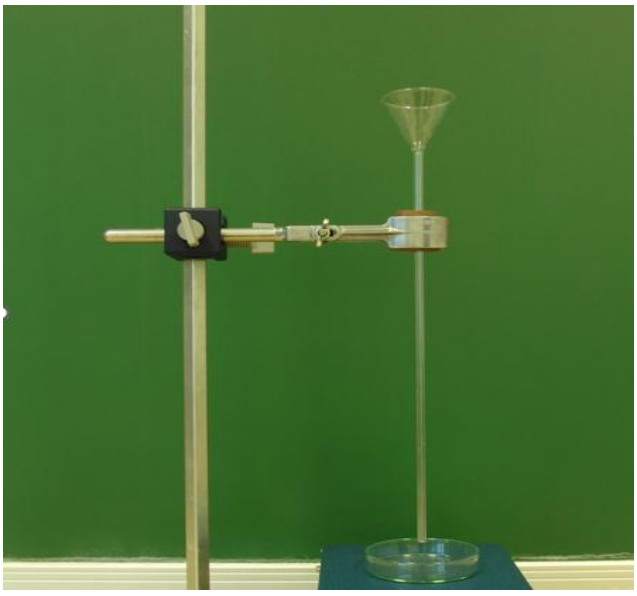
Fig 1: Tools for dripping



Procedure

1. Insert the funnel in one side of the hole in the cork and the capillary in the other. Fasten the cork in the laboratory stand.
2. Weigh the empty container which you later use to catch the drops.
3. Measure the temperature of both liquids.
4. Pour the liquid in the funnel.
5. Drip 100 drops (if we want to measure more accurately, we can drip more drops).
6. Weigh the container with 100 drops.
7. Determine the mass of 100 drops and then the mass of one drop.
8. Use the same procedure to determine the mass of one drop of water (second liquid).
9. Calculate the surface tension of the liquid from the relationship

$$\sigma_1 = \frac{m_1}{m_2}\sigma_2$$



Technical notes

We can use a pipette or a capillary to perform this experiment.

Draw the measured liquid into the pipette or the capillary, block the upper end with your finger and let the liquid drip.

We can influence the drip rate by pushing the top of the pipette.

Question :
Sample result

We made the measurements with water, alcohol and kerosene. We weighed the container and let all the liquids drip into it.
The temperature of both liquids was 20 °C.
We used water as the reference liquid with known surface tension ($\sigma_1 = 72.75 \cdot 10^{-3}$ N/m at temperature 20 °C).
Table 1 summarizes the mass of 100 drops of each liquid m_{100}, find the mass of one drop of each liquid m_1 and the surface tension σ.

	water	alcohol	kerosene
m_{100} [g]	3.984	1.333	1.497
m_1 [g]			
σ [N·m^{-1}]	$72.75 \cdot 10^{-3}$		

For comparison, the table values for alcohol and kerosene at 20 °C:

alcohol	$22.55 \cdot 10^{-3}$ N/m
kerosene	$27.00 \cdot 10^{-3}$ N/m

Purification of Solids by Recrystallization

Objective

To purify solid organic compounds using recrystallization techniques, identify a suitable recrystallization solvent through solubility tests, and determine the purity and percent recovery of the purified product.

Introduction

Recrystallization is a fundamental technique used to purify solid organic compounds. It relies on the differential solubility of a compound and its impurities in a solvent at different temperatures. A suitable recrystallization solvent should dissolve the compound at high temperatures but not at low temperatures. Impurities may be soluble, insoluble, or colored, and each is removed in a separate step during the recrystallization process.
The success of recrystallization depends on careful technique: using minimal hot solvent for dissolution, slow cooling to form pure crystals, and minimal ice-cold solvent for rinsing. The purified product is isolated via suction filtration, dried, and analyzed by melting point and percent recovery.

Materials

- Unknown solid compound
- Possible solvents: water, methanol, ethanol, 70% ethanol, hexanes, toluene
- Phthalic acid (for practice)
- Activated charcoal (if needed for colored impurities)
- Boiling sticks
- Glassware: test tubes, 10 mL Erlenmeyer flasks, Hirsch funnel, filter flasks, neoprene adapter
- Suction filtration apparatus
- Hot plate with aluminum block
- Melting point apparatus
- Balance, spatula, Pasteur pipets, test tube tongs

Safety Precautions

- Wear safety goggles and gloves.
- Work in a fume hood when using volatile or flammable solvents.
- Do not heat closed containers.
- Avoid skin contact with solvents and chemicals.
- Dispose of waste in designated containers.

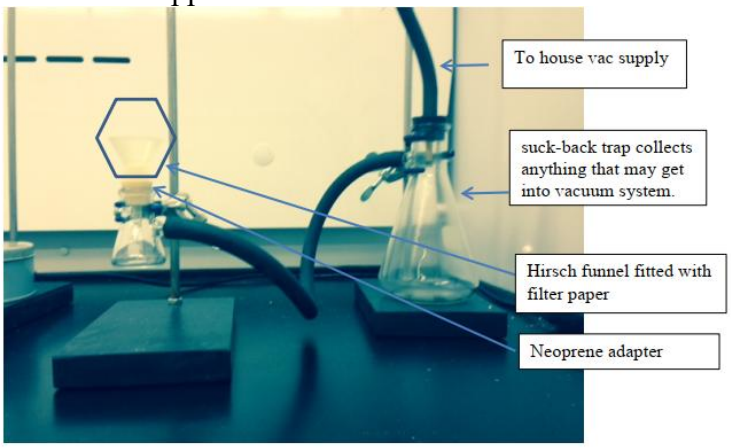
Procedure

Part 1: Solvent Selection for Unknown

1. Turn on the hot plate to ~225°C upon entering the lab.
2. Obtain an unknown solid from your TA.
3. Test solubility in each available solvent (water, methanol, ethanol, 70% ethanol, hexanes, toluene) using ~10 mg of unknown and 0.25 mL solvent.
    - If soluble at room temperature, discard.
    - If insoluble at room temperature, heat to boiling.
    - If still insoluble, discard.
    - If soluble when hot, cool slowly and observe crystal formation.
4. Record observations in a table (1).
5. Identify the best solvent based on crystal quality and recovery.

Part 2: Macroscale Recrystallization of Phthalic Acid (Practice)

1. Weigh ~325 mg of phthalic acid into a 10 mL Erlenmeyer flask.
2. Boil 5–6 mL water in a test tube with a boiling stick.
3. Add hot water dropwise to the flask until the solid just dissolves.
4. Cool slowly to room temperature, then in an ice bath.
5. Set up suction filtration apparatus.



6. Filter crystals, rinse with ice-cold water, and dry on a tared filter paper.
7. Weigh dried crystals and calculate percent recovery.

Part 3: Recrystallization of Unknown

1. Weigh ~250 mg of unknown.
2. Recrystallize using the best solvent identified in Part 1.
3. Filter, rinse, and dry crystals as in Part 2.
4. Weigh product and determine melting point.
5. Compare with melting point of impure unknown.

Data and Results

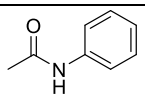
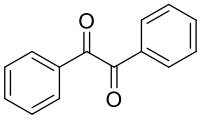
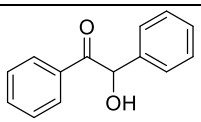
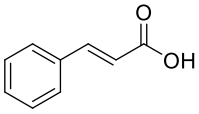
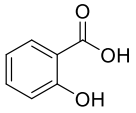
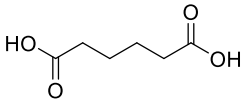
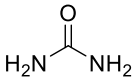
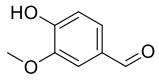
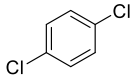
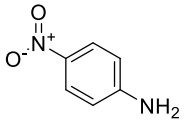
***Table 1**: Solubility Tests for Unknown*

Solvent	Cold (0.25 mL)	Hot (0.25 mL)	Hot (0.50 mL)	Observations
Water				
Methanol				
Ethanol				
70% Ethanol				
Hexanes				
Toluene				

Table 2: Recrystallization Results

Compound	Mass Used (mg)	Mass Recovered (mg)	% Recovery	MP (Impure)	MP (Pure)	Identity
Phthalic Acid						
Unknown						

Unknown Table

Compound Name	Structure	Melting Point (°C)	Notes
Acetanilide	 *N*-phenylacetamide	114 - 116	Neutral compound. Forms colorless plates or scales.
Benzil	 1,2-diphenylethane-1,2-dione	94 - 96	α-Diketone. Yellow crystalline solid.
Benzoin	 2-hydroxy-1,2-diphenylethanone	134 - 136	Hydroxy ketone. Yellowish or white crystals.
trans-Cinnamic Acid	 (E)-3-phenylprop-2-enoic acid	132 - 135	Unsaturated carboxylic acid. White crystalline powder.
Salicylic Acid	 2-hydroxybenzoic acid	158 - 160	Ortho-hydroxybenzoic acid. White crystalline powder.
Adipic Acid	 hexanedioic acid	151 - 153	Dicarboxylic acid. White crystalline powder.
Urea	 urea	132 - 135	Neutral, hydrogen-bonding solid. Colorless crystals.
Vanillin	 4-hydroxy-3-methoxybenzaldehyde	81 - 83	Aldehyde, phenol, and ether. White to off-white needles.
p-Dichlorobenzene	 1,4-dichlorobenzene	52 - 54	Neutral, non-polar hydrocarbon. White volatile crystals.
p-Nitroaniline	 4-nitroaniline	147 - 149	Strongly polarized due to -NO_2 and -NH_2 groups. Yellow crystals.

Questions

1. Solubility Behavior
   - Draw a solubility (y) vs. temperature (x) plot showing the three common solubility behaviors. Indicate which is ideal for recrystallization.

2. Removal of Soluble Impurities
   - Briefly describe how soluble impurities are separated from the desired compound at the molecular level.

3. Phthalic Acid Solubility
   - How many mL of boiling water are required to dissolve 4.2 g of phthalic acid? *(Assume solubility is 5 g per 100 mL at 99°C)*

4. Crystallization and Percent Recovery
   - If the solution from Question 3 is cooled to 14°C, how many grams of phthalic acid crystallize out? What is the percent recovery? *(Solubility at 14°C is 0.5 g per 100 mL)*

5. Structural Solubility
   - What structural property of sodium 4-amino-1-naphthalenesulfonate makes it very soluble in water?

6. Additional Questions

a. Why is it important to use a minimum amount of solvent during recrystallization?

b. What is the purpose of using a boiling stick?

c. Why should the recrystallization solution be cooled slowly?

d. How does suction filtration help in isolating crystals?

e. Why might a sample not dry completely, and how does this affect the melting point?

General Questions for safety

1. **What must students wear at all times in the laboratory?**

a) Open-toed shoes
b) Lab coats
c) Contact lenses
d) Loose clothing

2. **Which of the following is NOT allowed in the laboratory?**

a) Closed shoes
b) Eating and drinking
c) Eye protection
d) Lab coats

3. **What should be done with long hair in the laboratory?**

a) Left loose
b) Secured
c) Covered with a hat
d) Cut short

4. **What is required for eye protection in the laboratory?**

a) Sunglasses
b) Approved eye protection and face shields
c) Contact lenses
d) No protection needed

5. **What should be avoided in the laboratory to prevent distractions?**

a) Listening to music
b) Wearing lab coats
c) Using gloves
d) Washing hands

6. **What should be done before leaving the laboratory?**

a) Leave the gas valves open
b) Ensure the work area is clean
c) Leave chemicals unlabeled
d) Leave the lights on

7. **What should be done with waste containers in the laboratory?**

a) Left open

b) Kept closed with a lid
c) Placed near heat sources
d) Used for storing chemicals

8. **What should be done with unlabeled chemicals?**
a) Used immediately
b) Disposed of properly
c) Returned to stock bottles
d) Ignored

9. **What should be done with broken glassware?**
a) Left on the bench
b) Swept into a dustbin designated for broken glass
c) Used again
d) Thrown in regular trash

10. **What should be done with flammable liquids in the laboratory?**
a) Kept near heat sources
b) Located on the bench in closed containers
c) Stored in open containers
d) Poured down the sink

11. **What should be done before using any chemical?**
a) Taste it
b) Read the MSDS
c) Smell it
d) Touch it without gloves

12. **What should be done with solid chemicals?**
a) Transferred with bare hands
b) Transferred with a clean spatula or spoon
c) Poured directly from the container
d) Smelled before use

13. **What should be done with lids, caps, and stoppers after removing reagents from containers?**
a) Left on the bench
b) Securely replaced
c) Thrown away

d) Used for other chemicals

14. **What should be done with substances in capped or plugged containers?**
a) Heated or boiled
b) Left as is
c) Never heated or boiled
d) Poured down the sink

15. **What should be done with chemical wastes?**
a) Spilled into sinks
b) Treated in accordance with laboratory directives
c) Left on the bench
d) Used again

16. **What should be done when working with concentrated acids and bases?**
a) Pour water on concentrated acids
b) Be very cautious
c) Use bare hands
d) Ignore safety precautions

17. **What should be done with mercury spills?**
a) Left as is
b) Cleaned up immediately with a vacuum source or sulfur
c) Poured down the sink
d) Ignored

18. **What should be done with broken thermometers containing mercury?**
a) Disposed of as waste
b) Left on the bench
c) Never disposed of as waste
d) Used again

19. **What should be done with chemical substances or specimens spilled in the laboratory?**
a) Left as is
b) Cleaned and the laboratory technician informed
c) Poured down the sink
d) Ignored

20. **What should be done when transporting chemical substances in the laboratory?**
a) Special care must be given

b) No care needed
c) Poured down the sink
d) Left on the bench

21. **What should be done with glassware before use?**
a) Inspected for cracks and chips
b) Used as is
c) Left on the bench
d) Ignored

22. **What should be done with long glassware when carrying it?**
a) Kept upright
b) Left on the bench
c) Used as is
d) Ignored

23. **What should be done with rolling apparatus like thermometers and pipettes?**
a) Left on the bench
b) Placed in appropriate holders
c) Used as is
d) Ignored

24. **What should be done with glass tubing, thermometers, etc., before inserting them into rubber stoppers or corks?**
a) Lubricated
b) Used as is
c) Left on the bench
d) Ignored

25. **What should be done with hot glassware?**
a) Placed on cold or wet surfaces
b) Held with wooden tongs until it cools
c) Left on the bench
d) Ignored

26. **What should be done with glassware after use?**
a) Left on the bench
b) Washed with distilled water
c) Used as is

d) Ignored

27. **What should be done with small pieces of broken glassware?**
a) Left on the bench
b) Swept into a dustbin designated for broken glass
c) Used again
d) Ignored

28. **What should be done when using an instrument for the first time?**
a) Inform the laboratory technician
b) Use it without training
c) Left on the bench
d) Ignored

29. **What should be done when working with an open flame?**
a) Keep hair and clothes away from the flame
b) Use bare hands
c) Left on the bench
d) Ignored

30. **What should be done with an open flame when not in use?**
a) Left unattended
b) Turned off
c) Used as is
d) Ignored

31. **What should be done for eye and significant skin exposures?**
a) Rinse with large quantities of water and seek immediate medical attention
b) Left as is
c) Used as is
d) Ignored

32. **What should be done if chemicals cause burns on the skin?**
a) Wash the area with water immediately
b) Left as is
c) Used as is
d) Ignored

33. **What should be done in case of an acid spill on the skin?**
a) Wash the affected area with plenty of water

b) Left as is
c) Used as is
d) Ignored

34. **What should be done in the event of a fire?**
a) Notify authorized personnel or the fire department immediately
b) Left as is
c) Used as is
d) Ignored

35. **What should be done if your clothes catch fire?**
a) Find a safety shower
b) Left as is
c) Used as is
d) Ignored

36. **What should be done for small cuts and scratches?**
a) Clean the wound, place a sterile pad over it, and apply gentle pressure
b) Left as is
c) Used as is
d) Ignored

37. **What should be done for eye irritation?**
a) Immediately flush your eyes with running water for at least 15 minutes
b) Left as is
c) Used as is
d) Ignored

38. **What should be done for chemical ingestion?**
a) Immediate transport of the patient to a medical center
b) Left as is
c) Used as is
d) Ignored

39. **What should be done with chemical substances or specimens spilled in the laboratory?**
a) Cleaned and the laboratory technician informed
b) Left as is
c) Used as is

d) Ignored

40. **What should be done with chemical substances when transporting them in the laboratory?**

a) Special care must be given
b) No care needed
c) Poured down the sink
d) Left on the bench

Put True and False foe each of the following

Students must wear lab coats at all times in the laboratory.	
Eating and drinking are allowed in the laboratory.	
Long hair must be secured while in the laboratory.	
Approved eye protection and face shields are required at all times in the laboratory.	
Contact lenses are permitted in the laboratory.	
Closed shoes must be worn at all times in the laboratory	
Chemicals should not be smelled or tasted	
Experimental studies should only be conducted as instructed by laboratory technical personnel	
All chemicals have a potential hazard and should not be touched without wearing gloves.	
Solid chemicals must be transferred with a clean spatula or spoon.	
Substances in capped or plugged containers should never be heated or boiled.	
All chemicals and laboratory equipment containing chemicals must be labeled.	
Listening to music is allowed in the laboratory.	
Lids, caps, and stoppers should be left on the bench after removing reagents from containers.	
Working alone in the laboratory is encouraged.	
Mixing chemicals randomly is safe and should be done frequently.	
Unused chemicals should be returned to stock bottles.	
Pipettes should never be used for different chemicals.	
Flammable liquids should be kept near heat sources.	
Mouth pipetting is allowed in the laboratory.	
Glassware should be inspected for cracks and chips before use.	
Long glassware should be carried upright.	
Rolling apparatus like thermometers and pipettes should be placed in appropriate holders.	
Glass tubing, thermometers, etc., should be lubricated before inserting them into rubber stoppers or corks.	
Hot glassware should be placed on cold or wet surfaces.	

Glassware should be washed with distilled water after use.	
Small pieces of broken glassware should be swept into a dustbin designated for broken glass.	
Researchers must be trained on proper equipment use before using an instrument for the first time.	
Hair and clothes should be kept away from an open flame.	
Open flames should be left unattended when not in use.	
For eye and significant skin exposures, rinse the affected area with large quantities of water and seek immediate medical attention	
If chemicals cause burns on the skin, wash the area with water immediately.	
In case of an acid spill on the skin, wash the affected area with plenty of water.	
In the event of a fire, notify authorized personnel or the fire department immediately.	
If your clothes catch fire, find a safety shower.	
For small cuts and scratches, clean the wound, place a sterile pad over it, and apply gentle pressure.	
For eye irritation, immediately flush your eyes with running water for at least 15 minutes.	
For chemical ingestion, immediate transport of the patient to a medical center is required.	
Chemical substances or specimens spilled in the laboratory should be cleaned and the laboratory technician informed	
Special care must be given when transporting chemical substances in the laboratory	

References

1. Susan A. Weiner and Blaine Harrison, 2010, Introduction to Chemical Principles, A Laboratory Approach, 7ed. Brooks/Cole, ISBN-13: 978-0-495-11479-6
2. Vickie Williamson and Larry Peck, 2009, Experiments in General Chemistry: Inquiry and Skill Building, Brooks/Cole, ISBN-13: 978-0-495-11479-6, ISBN-13: 978-0-495-55300-7