

## **A Proposal for**

### **Basic Chemistry Laboratory – I**

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#### **I. Objectives of the Virtual Lab**

The objective of this virtual chemistry laboratory is to apprise the students how the real experiments were done in the laboratory to develop the theory, how a hypothesis is validated using experiment, way to understand a natural phenomenon by established theory, synthesis of a drug, etc. The course will consist of experiments illustrating the principles of chemistry relevant to the study of science and engineering. All the proposed experiments are based on the topics the students learn in the theory course in chemistry in the first year.

#### **II. List of experiments**

(A Virtual Lab consists of 7-10 experiments\*)

1. Determination of percentage composition of sugar solution from viscosity measurement
2. Thin layer chromatography of ink
3. Ion exchange column for removal of hardness of water
4. Estimation of molecular weight from freezing point depression
5. Rate constant and activation energy of potassium permanganate and oxalic acid reaction
6. Kinetics of iodide-hydrogen peroxide clock reaction
7. Measurement of electrical conductance to determine the dissociation constant of acetic acid
8. Determination of saponification value of oil
9. Partition coefficient of acetic acid in water and butanol
10. Adsorption of acetic acid by charcoal

(Add more as required)

The proposed experiments are not available in [www.vlab.co.in](http://www.vlab.co.in). These experiments are designed based on the syllabus of BS106 as provided in page-8 of AICTE Jan 2018, Vol-I (see below). Most of the concept in the course curriculum is covered with the proposed experiments.

#### **(ii) Chemistry Laboratory [L : 0; T:0 ; P : 3 (1.5 credits)]**

##### **Choice of 10-12 experiments from the following:**

- Determination of surface tension and viscosity
- Thin layer chromatography
- Ion exchange column for removal of hardness of water
- Determination of chloride content of water
- Colligative properties using freezing point depression
- Determination of the rate constant of a reaction
- Determination of cell constant and conductance of solutions
- Potentiometry - determination of redox potentials and emfs
- Synthesis of a polymer/drug



- Saponification/acid value of an oil
- Chemical analysis of a salt
- Lattice structures and packing of spheres
- Models of potential energy surfaces
- Chemical oscillations- Iodine clock reaction
- Determination of the partition coefficient of a substance between two immiscible liquids
- Adsorption of acetic acid by charcoal
- Use of the capillary viscosimeters to demonstrate the isoelectric point as the pH of minimum viscosity for gelatin sols and/or coagulation of the white part of egg .

#### **Laboratory Outcomes**

- The chemistry laboratory course will consist of experiments illustrating the principles of chemistry relevant to the study of science and engineering. The students will learn to:
- Estimate rate constants of reactions from concentration of reactants/products as a function of time
- Measure molecular/system properties such as surface tension, viscosity, conductance of solutions, redox potentials, chloride content of water, etc
- Synthesize a small drug molecule and analyse a salt sample

\*Alternatively, 3-4 additional experiments (minimum) may be developed to augment existing labs ([www.vlab.co.in](http://www.vlab.co.in)).

**Note:** Please list all related experiments available on the web (vlab.co.in) and compare your proposed experiments with them. Please justify why the proposed experiments are needed and exactly what gaps they fill.

### **III. Target group of users**

- UG (1<sup>st</sup> Year/ 2<sup>nd</sup> Year) [highest priority for development]

This is a second semester course and the students from all branches will take this course.

### **IV. Mapping of proposed lab with AICTE courses as per [attached list](#) of potential labs**

- Course name and Code

BS106, Chemistry Laboratory

### **V. Mapping of proposed lab with universities (minimum 3 universities)**

- Name of University; Course code; Course name

Lovely Professional University, Analytical Chemistry Laboratory,

Amity university, CHY2204, Chemistry Laboratory

Bangalore university, General Chemistry Lab,

The University of Burdwan, CC-12, Chemistry Laboratory

West Bengal State University, CEMACOR12P, Analytical Methods in Chemistry

Chhatrapati Shahu Ji Maharaj University, BSc-II Practical

Balaji Institute of Technology & Science, Warangal, CH106BS/CH206BS, BTech Chem Lab  
University of Calcutta, Core Course-III, Practical Chemistry – I Lab  
NIT Hamirpur, CY102, Engineering Chemistry Lab

## VI. Expected timelines

Presentation of proposal to domain experts' committee – 31<sup>st</sup> March 2022

Demo of First 3 Expts and Review – 30<sup>th</sup> June 2022

Demo of 5-6 Expts and review – 31<sup>st</sup> August 2022

Demo of 7-10 Expts and review – 31<sup>st</sup> October 2022

Final demo of 7-10 Expts – 15<sup>th</sup> November 2022

Hosting of lab (7-10 Expts) – 30<sup>th</sup> November 2022

Note 1: The [LDC](#) will coordinate the [reviews](#) and [hosting](#)

Note 2: The lab is supposed to be developed and hosted within 6 - 9 months from the date of approval

## VII. Budget (Max. Rs 2 Lakhs per experiment with a ceiling of Rs 20 Lakhs per Lab)

**Table I. Budget for Chemistry Laboratory, BS106**

S. No.	Equipment/Activity	Budget # (In Rupees)
1	Laptop / Machine	5,20,000
2	Manpower	3,94,200
3	Consumables	8,00,000
4	Contingency	1,00,000
5	Honorarium for Lab Developer (Rs 20k per experiment; Ceiling of Rs 2 Lakhs per lab)	1,00,000
6	Miscellaneous	60,000
<b>TOTAL</b>		<b>19,74,200</b>

# To be released based on the recommendation of the review committee

**Note:** Institute overheads not to be included in the budget

## VIII. Justification of the budget requirements

### (a) Details of Laptop/Machine

Computer (one), Rs. 60,000/-

Temperature dependent viscometer, Rs. 4,00,000/-

Conductivity meter, Rs. 60,000/-

(b) Details of Manpower (number, cost per man-months, etc.)

a. Total man-months required

18

b. No. of project staff, cost per man-months

Project Scientist: One (1), Rs. 35,000/- per month

Project Attendant: One (1), Rs. 8,800/- per month

c. Honoraria for other staff associated with the project

Honoraria for chemistry laboratory staffs Rs. 10,000/- per experiments.

(c) Details of Consumables

Varieties of consumables are needed to optimize and develop the proposed experiments. For example, chemicals, solvent, light source, optical components, etc.

(d) Details of Miscellaneous cost

a. Internal Review (Optional, Rs 1000 per experiment)

Internal review by faculty members will be done for each experiment. For a total 10 experiments, the cost will be Rs. 10,000/-

b. Field Trials

Not applicable

c. Others

Video recording of laboratory experiments for giving the students an in-laboratory experience. The cost is Rs. 5,000/- per hour. For 10 experiments of approximately 1 hr each, the total cost will be Rs. 50,000/-.

**IX. Student Feedback and Learning**

- How will you collect feedback and use them?

The feedback will be collected in terms of google form for each experiments. After receiving a few of them, or periodically, the inputs will be analyzed by the PI. If needed, a modification in the virtual lab will be done and will be updated in the system.

- What is the actual learning component provided by the Virtual Lab?

The take home learning of the proposed virtual lab are as follows:

- Experiment 1:** Students will understand how to measure viscosity using Ostwald viscometer and determine the concentration of an unknown sugar solution by measuring the viscosity by comparison method.
- Experiment 2:** To acquaint the students the chromatographic technique.
- Experiment 3:** Students will learn how ion exchange column soften hard water.
- Experiment 4:** Students will learn how to measure the molecular weight using colligative property.
- Experiment 5:** To apprise the students the power of Arrhenius theory and how to measure activation energy.
- Experiment 6:** Students will learn how to determine the order of a reaction.
- Experiment 7:** To teach students how to measure conductance and to use conductance value for the determination of dissociation constant of a weak acid.
- Experiment 8:** To show how to determine the saponification value of oil using saponification reaction.
- Experiment 9:** To teach students how to determine partition coefficient.
- Experiment 10:** Students will learn the adsorption phenomenon.

- After the Virtual Lab experience, would the student be able to perform the experiment in the real lab?

Along with the virtual lab, a short video of performing the experiment in real laboratory will be provided. This will give the students an idea about the real life in-hand experience virtually. Care will be taken to introduce each equipment.

## 1. Determination of percentage composition of sugar solution from viscosity measurement

### Objective:

To familiarize students how to measure viscosity using Ostwald viscometer and determine the concentration of an unknown sugar solution by measuring the viscosity by comparison method.

### Theory:

The coefficient of viscosity ( $\eta$ ) of a liquid is defined as the tangential force per unit area required maintaining unit velocity gradient between two successive layers of a liquid, which are unit distance apart from each other. The unit of coefficient of viscosity is dyne s cm<sup>2</sup> (poise). The co-efficient of viscosity of liquid can be determined by comparing with a liquid with known coefficient of viscosity using Poiseuille's equation.

$$\eta = \frac{\pi P r^4 t}{8 V l} \quad (1)$$

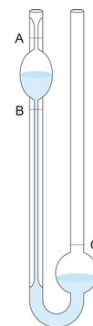
where  $V$  = volume of the liquid following through a capillary tube of length ( $l$ ) in  $t$  second. The radius of the capillary is  $r$  cm and  $P$  is the driving pressure in dyne cm<sup>-2</sup>.  $P$  can be replaced by  $h\rho g$ , where  $h$  is the difference in height between the levels of the liquid in the two limbs,  $g$  = acceleration due to gravity and  $\rho$  is the density of the liquid. Now if the same capillary and the same volume of liquids are used, then for the two liquids the following equation can be deduced.

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2} \quad (2)$$

In the above equation,  $\rho_1$  and  $\rho_2$  are the densities and  $t_1$  and  $t_2$  are time of flow for the two liquids. Thus, if  $\eta_2$  is known, then by determining  $t_1$ ,  $t_2$ ,  $\rho_1$  and  $\rho_2$ ,  $\eta_1$  can be determined.

In the present experiment we will determine the relative viscosity in comparison of viscosity of water. So as  $\eta_2$  the viscosity of water and its density ( $\rho_2$ ) is known (from the chart), then by measuring  $t_2$  its time of flow and  $\rho_1$ ,  $t_1$  the density and time of flow of other liquids, viscosity can be calculated. The flow time of the liquids are determined using Ostwald's viscometer (Fig. 1.) and stopwatch. Densities are determined using specific gravity bottle.

In this experiment several glucose solution in water is prepared having different concentration of sucrose among which one solution has unknown concentration. Using equation (2), coefficient of viscosity ( $\eta$ ) is measured for each solution. Now  $\eta$  is plotted against the known concentration of sucrose that gives a straight line. From this plot the concentration of unknown solution is determined as the  $\eta$  value of this solution will be measured.



**Figure 1.** Schematic diagram of Ostwald viscometer.

## 2. Thin layer chromatography of ink

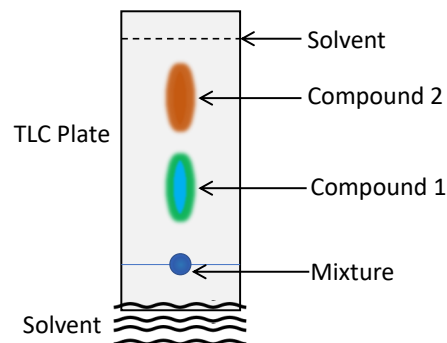
### Objective:

To acquaint the students the chromatographic technique.

### Theory:

Chromatography is extensively used by the chemists to separate compounds in a mixture.

Although many types of chromatography have been developed, all methods use a mobile phase and a stationary phase. In this experiment, we will be using thin layer chromatography, or TLC. In TLC, a mobile phase (i.e. solvent) migrates up a thin layer of solid particles attached to a glass plate (called the stationary phase). Chromatography works because of the differences in polarity between the stationary phase, the solvent, and the components of the mixture being studied. When using a solvent with low polarity, the majority of the components of the mixture, if not all of them, will be held more strongly to the stationary phase than the solvent molecules, so the solvent will not displace them and carry them along with it. If a more polar solvent is chosen, it will displace the majority of the molecules in the sample. Depending on the polarity of each of the components, some may travel farther with the solvent than others, resulting in separation of each of the components (see Fig 1).



**Figure 1.** Principle of thin layer chromatography

After the solvent reaches the top of the TLC plate, the plate is removed from the solvent and dried. The positions of noticeable components will be marked. The  $R_f$  value is then calculated as:

$$R_f = \frac{\text{Distance travelled by the solute}}{\text{Distance travelled by the solvent}} \quad (1)$$

Different components of ink have own characteristic  $R_f$  values that depends on the solvent and this make the identification possible. A solvent much more polar than the components of the mixture will displace all of the molecules and carry them all very easily on the solvent front, yielding no separation that would be useful in identification. Finding a solvent suitable for separation of a mixture or identification of a sample usually requires trying several solvents with different polarities.

### 3. Ion exchange column for removal of hardness of water

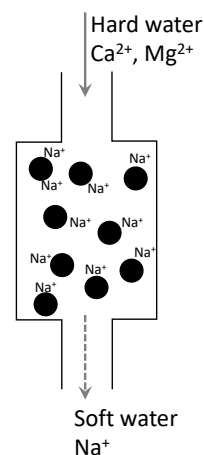
#### Objective:

Students will learn how ion exchange column soften hard water.

#### Theory:

The presence of calcium ( $\text{Ca}^{2+}$ ) and/or magnesium ( $\text{Mg}^{2+}$ ) in water results in water being considered “hard”. Calcium and magnesium ions in water react with soap to produce insoluble component and decrease the effectiveness of the soap for cleaning. Hard water can be softened using an ion exchange softening process.

The ion exchange water softening process can remove nearly all calcium and magnesium from water. During ion exchange treatment, water is passed through a resin containing exchangeable ions. Stronger binding ions displace weaker binding ions and are removed from the water. There are two types of ion exchange - anion exchange and cation exchange. Anion exchange resins generally exchange chloride for anionic contaminants. Cationic ion exchange involves removing the hardness ions calcium and magnesium and replacing them with non-hardness ions, typically sodium supplied by dissolved sodium chloride salt, or brine. The ion exchange column contains a microporous exchange resin, usually sulfonated polystyrene beads that are supersaturated with sodium to cover the bead surfaces. As water passes through this resin bed, calcium and magnesium ions attach to the resin beads and the loosely held sodium is released from the resin into the water. The softening process is illustrated in Fig. 1. After softening a large quantity of hard water, the column become saturated with calcium and magnesium ions. When this occurs, the exchange resin must be regenerated, or recharged. To regenerate, the ion exchange resin is flushed with a brine or sodium hydroxide solution. The sodium ions in the solution are exchanged with the calcium and magnesium ions on the resin and excess calcium and magnesium is flushed out with wastewater.



**Figure 1.** The water softening and recharge Process.



#### 4. Estimation of molecular weight from freezing point depression

##### Objective:

Students will learn how to measure the molecular weight using colligative property.

##### Theory:

When some solute is added to a solvent, the freezing point of the resulting solution is found to be less than that of pure solvent. This is known as freezing point depression. It is a colligative property i.e. the extent of the dropping of the freezing point is proportional to the number of solute molecules present in the solution.

The magnitude of the freezing-point depression ( $\Delta T_f$ ) is directly proportional to the molality of the solution as

$$\Delta T_f = K_f \times \text{molality} \quad (1)$$

where,  $K_f$  is a parameter called the freezing-point depression constant or cryoscopic constant and  $i$  is the van 't Hoff factor, the number of particles the solute splits into or forms when dissolved. This constant corresponds to the value of  $\Delta T_f$  when molality = 1, and is characteristic of the solvent.

Molality of a solution is given by:

$$\text{molality} = \frac{\text{moles of solute}}{\text{Mass of the solvent in kg}} \quad (2)$$

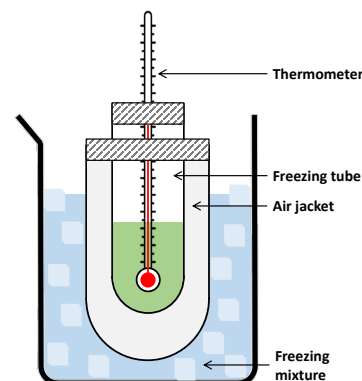
$$\text{moles of solute} = \frac{\text{weight of solute (w}_{\text{solute}})}{\text{Molecular weight of solute (M)}} \quad (3)$$

$$\text{mass of the solvent in kg} = \frac{\text{mass of the solvent in gm (w}_{\text{solvent}})}{1000} \quad (4)$$

Now plugging all the information into equation (1), we finally get:

$$M = \frac{K_f \times w_{\text{solute}} \times 1000}{\Delta T_f \times w_{\text{solvent}}} \quad (5)$$

Using equation (5) we can calculate the molecular weight of the solute provided a solution is prepared containing known masses of solute and solvent ( $w_{\text{solute}}$  and  $w_{\text{solvent}}$ ), the measured freezing-point depression of the solution, and the value of  $K_f$  for the solvent is known. This is a fairly common method for determining the molecular weights of non-volatile substances and it forms the basis for this experiment. We will dissolve an accurately weighed quantity of an unknown solute in an accurately weight quantity of solvent and measure the freezing-point depression for the resulting solution. Then, using the provided  $K_f$  value for solvent and equation (5), we will calculate the molecular weight of the unknown solute.



**Figure 1.** Measurement of freezing point depression

## 5. Rate constant and activation energy of potassium permanganate and oxalic acid reaction

### Objective:

To apprise the students the power of Arrhenius theory and how to measure activation energy.

### Theory:

The activation energy of a reaction is the amount of energy required to initiate the reaction. It represents the minimum energy needed to form an activated complex during collisions between reactant molecules. In slow reactions, the fraction of molecules in the system to form an activated complex is low, and most of the collisions are unsuccessful for the reaction. In 1889, Arrhenius demonstrated that the rate constant of a chemical reaction varies with temperature. For a given reaction, the rate constant  $k$  is related to the temperature of the system by the Arrhenius equation

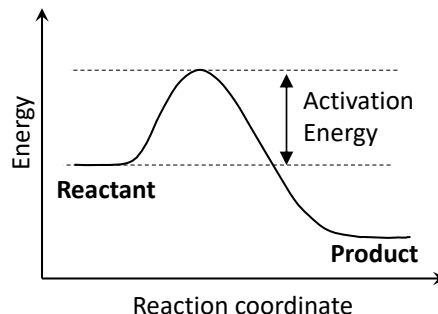
$$k = Ae^{-\frac{E_a}{RT}} \quad (1)$$

where  $R$  is the ideal gas constant,  $T$  is the temperature in Kelvin,  $E$  is the activation energy and  $A$  is a constant called the frequency factor, which is related to the fraction of collisions between reactants having the proper orientation to form an activated complex. Taking natural logarithm of the above equation we get

$$\ln k = -\frac{E_a}{RT} + \ln A \quad (2)$$

Thus, a plot of  $\ln k$  vs  $1/T$  yields a straight line with negative slope  $= -E_a/R$ .

In this experiment, a reaction between potassium permanganate and dilute oxalic acid will be carried out at different temperatures. The permanganate ion converted to  $MnO_2$  in this reaction. The rate constant ( $k$ ) is measured at different temperatures and  $\ln k$  is plotted against  $(1/T)$  to determine Activation energy ( $E_a$ ). Given that the reaction is first order in permanganate and oxalate, the rate constant can be measured by measuring the completion time of the reaction, which accompany a change in colour from deep purple to light brown.



**Figure 1.** Activation energy of a reaction.

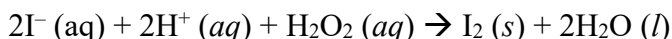
## 6. Kinetics of iodide-hydrogen peroxide clock reaction

### Objective:

The students will learn how to determine the order of a reaction.

### Theory:

When hydrogen peroxide is added to a solution of potassium iodide, the iodide ions are oxidized to form iodine



The rate of the reaction can be expressed as

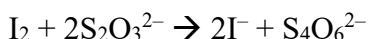
$$\text{Rate} = k [\text{I}^{-}]^n [\text{H}_2\text{O}_2]^m [\text{H}^{+}]^p \quad (1)$$

where,  $k$  is the rate constant,  $n$ ,  $m$  and  $p$  are the order of the reaction with respect to iodide, hydrogen peroxide and acid, respectively. However, if the concentration of  $\text{H}^{+}$  is held constant throughout the experiment then its effect will not appear in the rate law, which simplifies to

$$\text{Rate} = k' [\text{I}^{-}]^n [\text{H}_2\text{O}_2]^m \text{ where } k' = k[\text{H}^{+}]^p \quad (2)$$

The rate law for the reaction between iodide and hydrogen peroxide can be determined by carrying out experiments in which the initial concentrations of iodide and peroxide are varied. In this way we can measure the value of  $m$  and  $n$  once the initial rate for each experiment is known.

The addition of thiosulfate ions ( $\text{S}_2\text{O}_3^{2-}$ ) allows an accurate measurement of the rate at which the peroxide-iodide reaction is taking place. Suppose that a small and known amount of thiosulfate ion is added to the original mixture of peroxide and iodide. Iodine is produced slowly by the reaction between peroxide and iodide ions and the thiosulfate ions immediately consumes iodine as



As long as excess thiosulfate ions are present in the solution, no free iodine can accumulate because it is immediately turned into iodide ions which are colorless. The thiosulfate is the limiting reagent. So once all the thiosulfate ions are consumed, iodine starts to form in the solution. Iodine is a pale yellow. If starch is added to the solution then a more dramatic blue solution is formed by the complex of starch-iodine. The color change is sharp, and the time elapsed to this point is determined simply by use of a stopwatch. The time from the addition of the peroxide solution to the appearance of the blue color is  $\Delta t$  for the reaction. Since the stoichiometry of the thiosulfate-iodine and the peroxide-iodide reactions is known, it is possible to calculate how many moles of peroxide were reduced in the known interval of time. Consequently, the average rate (moles of hydrogen peroxide consumed per liter per second) of the reaction during this period can be calculated as

$$\text{Rate} = - \frac{\Delta[\text{H}_2\text{O}_2]}{\Delta t} \quad (3)$$

Using equation (3), the initial rate for different experiments is determined and consequently the rate equation can be obtained.

## 7. Measurement of electrical conductance to determine the dissociation constant of acetic acid

### Objective:

To teach students how to measure conductance and to use conductance value for the determination of dissociation constant of a weak acid.

### Theory:

Materials are usually classified as conductors, semiconductors, or insulators in terms of their behavior toward the flow of current. Conductors have very little resistance to the passage of current. Ohm's law states that,

$$V = i R \quad (1)$$

where  $V$  is the potential,  $i$  is the current and  $R$  is the resistance. The resistance depends upon the nature and geometry of the conductor.

$$R = \rho \frac{l}{A} \quad (2)$$

In the above equation,  $l$  is the distance,  $A$  is the area and  $\rho$  is the specific resistance. It is more convenient to focus attention on the conductance,  $L$ , which is inverse of the resistance,  $R$ , for when the conductor is in liquid state, and is expressed in mhos or  $\text{ohms}^{-1}$ . In terms of conductance equation (2) is written as

$$L = \kappa \frac{A}{l} \quad (3)$$

where  $\kappa$  is the specific conductance, i.e., the conductance of a tube of material 1 cm long having a cross section of  $1 \text{ cm}^2$ . The equivalent conductance ( $\Lambda$ ) is defined as the conductance of a solution containing 1 gram equivalent of electrolyte such that the entire solution is placed between two electrodes 1 cm apart. The specific conductance of an electrolyte solution is related to equivalent conductance as

$$\Lambda = \frac{\kappa}{c} \quad (4)$$

where  $c$  is the electrolyte concentration ( $\text{moles cm}^{-3}$ ). The equivalent conductance of an electrolyte can be measured by using a conductivity cell. For any conductivity cell, the ratio  $l/A$  is a constant known as the cell constant,  $X$ , which is determined in every experiment.

Kohlrausch proposed that when complete dissociation exists in infinite dilution, each ionic species migrates independently. The  $\Lambda_0$  value can be then considered to be the sum of equivalent ionic conductance at infinite dilution

$$\Lambda_0 = \lambda_0^+ + \lambda_0^- \quad (9)$$

Kohlrausch additivity law can be used to obtain  $\Lambda_0$  for a weak electrolyte, which can be further connect to the degree of dissociation of the same.

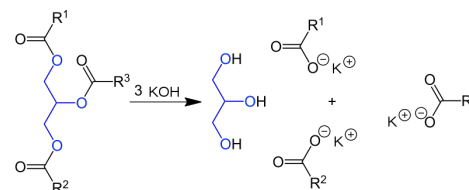
## 8. Determination of saponification value of oil

### Objective:

To show how to determine the saponification value of oil using saponification reaction.

### Theory:

Saponification is a type of reaction in which ester molecules are broken to create carboxylic acid ( $-\text{COOH}$ ) and alcohol ( $-\text{OH}$ ), in presence of base (e.g.  $\text{KOH}$ ,  $\text{NaOH}$ , etc.). Vegetable oils and animal fats are the triesters (also called triglycerides) as these have three ester groups derived from long chain fatty acids. These are the traditional materials for saponification and can be converted to soap in either a one- or a two-step process. In traditional one-step process, the triglyceride is treated with a strong base (e.g.  $\text{KOH}$ ), which cleaves the ester bond; releasing fatty acid salts (soaps) and poly-alcohol (glycerol) (see Fig. 1.).



**Figure 1.** Schematic of saponification reaction.

Saponification value is determined as the number of milligrams of  $\text{KOH}$  required to completely saponify one gram of the oil or fat. In this experiment we will take a known amount of the oil or fat and reflux it with excess of a standard  $\text{KOH}$  solution. Then we will measure the amount of unreacted  $\text{KOH}$  by titrating the solution with a standard acid. An identical blank experiment will be performed where there is no fat or oil.

## 9. Partition coefficient of acetic acid in water and butanol

### Objective:

To teach students how to determine partition coefficient.

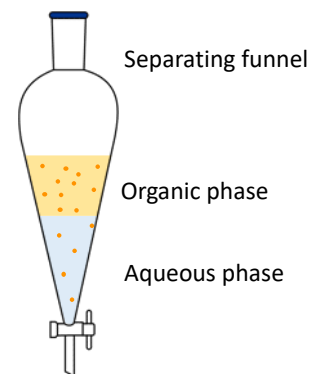
### Theory:

Nernst distribution law states that at constant temperature, when a solute is allowed to distribute between two immiscible solvents in contact with each other, at equilibrium the ratio of the concentration of the solute in two solvent layers is constant. When a solute is shaken in two immiscible liquids, then the solute is found to be distributed between the liquids in a definite manner, if the solute is soluble in each of the solvent. According to distribution law, the distribution co-efficient ( $k_d$ ) at a particular temperature is given by

$$k_d = \frac{C_1}{C_2} \quad (1)$$

where  $C_1$  and  $C_2$  represent concentration of solute in water and organic layer respectively. The partition coefficient relates to the same molecular species in each phase i.e. the solute molecules in each solution phase are in the same state of association.

In this experiment, acetic acid will be partitioned between butanol (organic solvent) and water. The concentration of the acid in both the phases will be determined by taking out some small portion and titrating against a standard base using an acid base indicator. One can either use a separating funnel to separate the two phases or carefully pipette out a specific quantity from both the layer of solvents. The concentration of the solvent is varied by adding additional equal quantities of fresh butanol and water and re-distributing the distribution coefficients. In this case, equation (1) will be exactly same where  $C_1$  and  $C_2$  are the concentration of acetic acid in water and butanol respectively and hence the partition can be successfully determined.



**Figure 1.** Partitioning of a solute in water and organic phase.

## 10. Adsorption of acetic acid by charcoal

### Objective:

In this experiment students will learn the adsorption phenomenon.

### Theory:

Adsorption is a process that occurs when a gas or liquid solute (adsorbate) accumulates on the surface of a solid or a liquid (adsorbent), forming a molecular or atomic film. It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The reverse process is called desorption. Similar to surface tension, adsorption is a consequence of surface energy. In a bulk material, all the bonding requirements (be they ionic, covalent or metallic) of the constituent atoms of the material are filled. But atoms on the (clean) surface experience a bond deficiency, because they are not wholly surrounded by other atoms. Thus it is energetically favorable for them to bond with the adsorbate. The exact nature of the bonding depends on the nature of the species involved, and broadly classified as physisorption or chemisorption.

Physisorption or physical adsorption is a type of adsorption in which the adsorbate adheres to the surface only through Van der Waals (weak intermolecular) interactions, which are also responsible for the non-ideal behaviour of real gases. Chemisorption is a type of adsorption whereby a molecule adheres to a surface through the formation of a chemical bond, as opposed to the Van der Waals forces which cause physisorption.

Adsorption is usually described through adsorption isotherms, that is, functions which connect the amount of adsorbate on the adsorbent, with its pressure (if gas) or concentration (if liquid). Several models are used to describe the process of adsorption, namely Freundlich isotherm, Langmuir isotherm, BET isotherm, etc. Here we will deal with Langmuir isotherm.

For liquids (adsorbate) adsorbed on solids (adsorbent), the Langmuir isotherm can be expressed by:

$$m = \frac{A_{\max}kc}{1+kc} \quad (1)$$

Where;  $m$  is the substance amount of adsorbate adsorbed per gram (or kg) of the adsorbent, the unit is  $\text{mol g}^{-1}$  (or  $\text{mol.kg}^{-1}$ ).  $A_{\max}$  is the maximal substance amount of adsorbate per gram (or kg) of the adsorbent, the unit is  $\text{mol g}^{-1}$  (or  $\text{mol kg}^{-1}$ ),  $k$  is the adsorption constant ( $\text{mol}^{-1} \text{dm}^3$ ) and  $c$  is the concentration of adsorbate in liquid ( $\text{mol dm}^{-3}$ ).

In practice, activated carbon is used as an adsorbent for the adsorption of mainly organic compounds. It is a material with an exceptionally high surface area. Just one gram of activated carbon has a surface area of approximately  $500 \text{ m}^2$  (for comparison, a tennis court is about  $260 \text{ m}^2$ ).

In this experiment we will measure  $k$  and  $A_{\max}$  for the acetic acid (adsorbate) adsorption by activated charcoal (adsorbent). We will perform two set of experiments. In the first set we will determine the concentration of several acetic acid solution having different strength without charcoal by titrating with standard NaOH. In the second experiment, we will add known amount of charcoal in each solution and shake well to let the adsorption happen. After that we will measure the concentration of unadsorbed acetic acid in each solution by the titration. Then,  $k$  and  $A_{\max}$  will be determined.

### **ANNEXURE-I**

Important information for the development of Virtual Labs

(A Virtual Lab consists of 7-10 experiments)

**X. Link to some sample virtual labs**

<https://python-iitk.vlabs.ac.in/>      <https://cs-iitd.vlabs.ac.in/>      <https://plchla-coep.vlabs.ac.in/>

**XI. Technology Used**

- For Web interface (should be Free and Open-Source Software)
- For back-end (should be Free and Open-Source Software)

**XII. Required Components for virtual experiments**

- Step-by-step procedure
- Online manual
- Pre-test
- Simulator
- Post-test
- Related resources
- Additional help

All the above requirements will be fulfilled on sanction of the project.