

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Module 5: Fluid Technology and Smart Sensors

Lubricants: Introduction, classification, ideal properties and applications. Lubricant testing: experimental determination of viscosity using Ostwald's viscometer.

Industrial Coolants: Introduction, types - water and oil-based coolants, properties and industrial applications.

Industrial effluents: Introduction, determination of COD and numerical problems.

Sensors: Introduction, potentiometric sensor - principle and its application in the estimation of iron in steel industry effluent. Conductometric sensor - principle and its application in the estimation of acid mixture in electrochemical bath effluent. pH sensor - principle and its application in the estimation of pKa of acid electrolyte.

Lubricants

The friction between metal-to-metal parts arises due to resistance across the moving surfaces in machines. Due to friction large amount of energy is liberated in the form of heat which reduces the efficiency of the machine.

Substances which apply between two moving and sliding surfaces to reduce friction between them are known as Lubricants" and the process by which friction between sliding surfaces is reduced, is known as Lubrication

Classification of Lubricants

Liquid Lubricants

1. It includes animal oils, vegetable oils, petroleum oils, synthetic lubricants.
2. Animal oils: tallow oil, whale oil etc.
3. Vegetable oils: castor oil, palm oil etc
4. Petroleum oils: petroleum fractions
5. Synthetic lubricants: polyglycol, silicones etc.

Semi-solid Lubricants (Grease)

Semi-solid Lubricants are formed by emulsifying oil and fat with thickening agents like soap of sodium, calcium, lithium, aluminum at higher temperature.

Solid Lubricants

Graphite, molybdenum disulfide (MoS_2), and boron nitride (BN), are predominantly used as solid lubricants. They are used under high temperatures and high loads (pressure)

Application of Lubricants

- **Keep moving parts apart:** Lubricants are typically used to separate moving parts in a system. This separation has the benefit of reducing friction, wear and surface fatigue, as well as heat generation, operating noise and vibrations.
- **Reduce friction:** Lower friction reduces heat generation and wear particle formation, and improves efficiency.

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- **Transfer heat:** Lubricant is constantly circulated to and from a cooler part of the system, although lubricants may be used to warm as well as to cool when a regulated temperature is required.
- **Carry away contaminants and debris:** Lubricant circulation systems benefit from carrying away internally generated debris and external contaminants introduced into the system to a filter, where they can be removed.
- **Transmit power:** Hydraulic fluids, also known as lubricants, are used as the working fluid in hydrostatic power transmission. The automatic transmission's torque converter is another essential application for power transmission with lubricants.
- **Protect against wear:** Lubricants reduce friction between two parts, preventing wear.
- **Prevent corrosion and rusting:** Many lubricants are formulated with additives that form chemical bonds with surfaces or that exclude moisture, to prevent corrosion and rust. It reduces corrosion between two metallic surfaces and avoids contact between these surfaces to avoid immersed corrosion..

Properties of Lubricants

- **Cloud Point:** The temperature at which lubricating oil becomes cloudy in appearance.
- **Pour Point:** The lowest temperature at which the lubricant oil become semi-solid and ceases to flow is called pour point. It indicates the suitability of lubricants used in cold condition. Good lubricant should possess low pour point.
- **Flashpoint:** The lowest temperature at which vapors of the material will ignite for a moment when an ignition source is brought near to it. The lubricating oil should have flash point reasonably above its working temperature.
- **Fire point:** The lowest temperature at which the vapour of that fuel will continue to burn for at least 5 seconds when an ignition source is brought near to it. The fire point is around 10°C higher than the flash point.
- **Viscosity:** It is the property of a fluid that determines its resistance to flow. It is an indicator of the flow's ability to lubricate. The lower viscosity greater will be the flow ability.
- **Viscosity Index:** The variation of viscosity of a liquid with temperature is called the viscosity index.

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- **Oxidation Stability:** Oxidation is a reaction that occurs when oxygen is combined with lubricating oil. High temperatures, water and acids will accelerate the rate of oxidation. The life of a lubricant decreases as temperatures rise, leading to varnish and sludge.
- **Demulsibility:** The ability of a lubricant to separate from water.

Viscosity

Viscosity coefficient, often simply called viscosity, is a measure of a fluid's resistance to flow or deformation. It quantifies the internal friction between adjacent fluid layers in relative motion. A higher viscosity implies a thicker fluid that flows more slowly, whereas a lower viscosity implies a thinner fluid that flows more easily.

A viscometer is an instrument used to measure fluid viscosity and the flow properties of liquids.

There are two distinct ways in which viscosity can be expressed:

Kinematic viscosity is measured by observing the fluid's resistance to flow under the force of gravity,

Absolute viscosity is measured by observing the fluid's resistance to flow under an external and controlled force, either through a capillary or by the movement of a body through the fluid.

Ostwald's Viscometer Method for Determining Viscosity

Ostwald's viscometer is a U-shaped glass tube used to measure the viscosity of a liquid by timing its flow under gravity through a capillary.

Apparatus

- Ostwald viscometer (U-shaped glass tube with two bulbs and a narrow capillary section)
- Stopwatch
- Sample liquid
- Reference liquid (usually water)
- Thermometer (to maintain and note the temperature)

Principle

The flow time of a liquid through the capillary is proportional to its viscosity. By comparing the flow time of the test liquid with that of a reference liquid of known viscosity, the viscosity of the test liquid can be calculated.

Procedure

1. Clean and dry the viscometer.
2. Fill the viscometer with the sample liquid so that the liquid level is above the upper mark.

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3. Draw the liquid up past the upper mark using suction, then allow it to flow down.
4. Measure the time t taken for the liquid meniscus to pass between the two engraved marks on the stem using a stopwatch.
5. Repeat the measurement several times for accuracy and take the average flow time.
6. Repeat the experiment using a reference liquid (e.g., water) whose viscosity η_1 and density ρ_1 are known, recording its flow time t_1 .

Calculation: The viscosity η_2 of the test liquid is related to the viscosity η_1 of the reference liquid by:

Rearranging

$$\frac{\eta_2}{\eta_1} = \frac{\rho_2 t_2}{\rho_1 t_1} \quad \begin{array}{l} \bullet \rho_2, \rho_1 \text{ are the densities of the test and reference liquids, respectively.} \\ \bullet t_2, t_1 \text{ are the flow times of the test and reference liquids, respectively.} \end{array} \quad \eta_2 = \eta_1 \frac{\rho_2 t_2}{\rho_1 t_1}$$

Determination of COD in waste water

“COD is the amount of oxygen required for the complete chemical oxidation of total organic and oxidizable inorganic (Ammonia & Nitrite) impurities present in water with strong oxidizing agent in acidic medium”

Chemical Oxygen Demand (COD) is a crucial parameter used to indirectly measure the amount of organic compounds (both biodegradable and non-biodegradable) in water that can be chemically oxidised.

Indicator of Pollution Load: A high COD value indicates a large quantity of organic pollutants and other reducing substances in the water.

Oxygen Depletion: When effluents with high COD are discharged into rivers or lakes, chemical oxidation consumes large amounts of the water's naturally occurring dissolved oxygen (DO).

Dissolved oxygen levels below 5 mg/L are detrimental to aquatic life, leading to the stress or death of fish and other organisms.

Toxicity Assessment: COD testing is particularly valuable for industrial wastewater because it captures organic compounds that might be toxic to the microorganisms used in the related

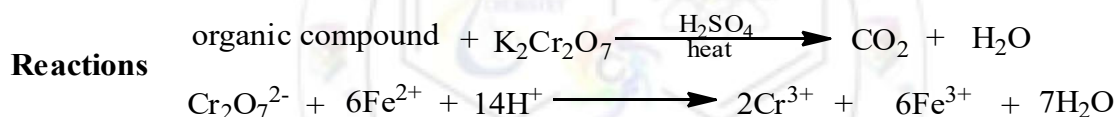
Biochemical Oxygen Demand (BOD) test, making it a more comprehensive measure of the total pollution potential.

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Treatment Efficiency: Monitoring COD levels in both the influent (incoming waste) and effluent (outgoing treated water) helps water treatment plants evaluate the efficiency of their treatment processes and ensure compliance with regulatory standards set by agencies like the

Experiment: Back titration: Pipette out 25 ml (V) of water sample and 25cm³ K₂Cr₂O₇ solutions into 250 cm³ conical flask. Add 20cm³ of 1:1 H₂SO₄ containing silver sulphate with constant stirring. Boil the mixture for half an hour and cool. Add 2 drops of ferroin indicator and titrate against std. Ferrous ammonium sulphate solution till the solution turns from blue green to reddish brown. Note down the volume of FAS required to react with remaining K₂Cr₂O₇ (Back titration = A ml). Repeat the titration for agreeing values.

Blank titration: Pipette out 25cm³ of standard potassium dichromate solution. Add 20cm³ of dilute 1:1 sulphuric acid followed by 2-3 drops of ferroin indicator. Titrate against standard FAS solution till the color turns from blue - green to reddish brown. Note down the volume of FAS solution added (Blank titre value = B ml)



5.7.3 Calculations:

Normality of Standard FAS solution _____ N

$$\text{COD of a sample} = \frac{N(B - A)}{V} \times 8 \times 1000 \text{ mg/lit}$$

Problem 1: Define COD. Calculate the COD of the effluent sample when 25cm³ of the effluent sample requires 8.5cm³ of 0.001N K₂Cr₂O₇ solution for complete oxidation.

COD is the amount of oxygen required for the complete chemical oxidation of total organic and inorganic (Ammonia & Nitrite) impurities present in water with strong oxidizing agent in acidic medium

Given

- Back Titration – Blank ($B-A$) = 8.5cm³
- Volume of water sample taken $V = 25 \text{ cm}^3$
- Normality of FAS Solution $N = 0.001\text{N}$
- COD?

$$\text{COD of a sample} = \frac{N(B - A)}{V} \times 8 \times 1000 \text{ mg/lit}$$

$$\text{COD of a sample} = \frac{0.001(8.5)}{25} \times 8 \times 1000$$

$$\text{COD of a sample} = 27.2 \text{ mg/lit}$$

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Let us see a problem to calculate COD

Problem 1: Define COD. Calculate the COD of the effluent sample when 25cm^3 of the effluent sample requires 8.5cm^3 of $0.001\text{N K}_2\text{Cr}_2\text{O}_7$ solution for complete oxidation.

COD is the amount of oxygen required for the complete chemical oxidation of total organic and inorganic (Ammonia & Nitrite) impurities present in water with strong oxidizing agent in acidic medium

Given

- Back Titration – Blank (B-A) = 8.5cm^3
- Volume of water sample taken $V = 25\text{ cm}^3$
- Normality of FAS Solution $N = 0.001\text{N}$
- COD?

$$\text{COD of a sample} = \frac{N(B-A)}{V} \times 8 \times 1000 \text{ mg/lit}$$

$$\text{COD of a sample} = \frac{0.001(8.5)}{25} \times 8 \times 1000$$

$$\text{COD of a sample} = 27.2 \text{ mg/lit}$$

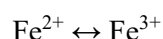
POTENTIOMETRY

Theory:

The principle involved in the potentiometer is that when a pair of electrodes is placed in the sample solution, it shows the potential difference by the addition of the titrant or by the change in the concentration of the ions. The potential developed depends upon the concentration of the ions, given by Nernst's equation,

$$E = E^0 + \frac{RT}{nF} \ln [M^{n+}]$$

For example in the redox reaction



The Nernst's equation is given by $E = E^0 + \frac{RT}{nF} \ln \frac{[\text{Fe}^{3+}]}{[\text{Fe}^{2+}]}$

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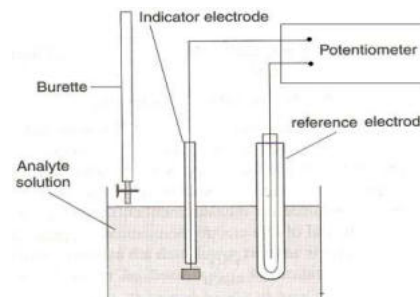
The equivalence point can be determined by using characteristic graph.

Instrumentation:

The basic components of potentiometer are

1. An indicator electrode
2. A reference electrode
3. A salt bridge if necessary
4. A potentiometer to measure the variation of potential.

A typical electrochemical cell for potentiometric studies is constructed by coupling two half cells, one is a reference electrode and the other is indicator electrode. The potential of the analyte solution is observed with the variation of concentration of ions during titration. The variation of concentration of ions can be controlled by adding titrant. Generally saturated calomel electrode is coupled with inert platinum electrode during titration.



Applications

- Determine thermodynamic constants like K_a , K_b etc
- Determine the accurate end point of a titration.
- Measure of pH of a solution.
- Determine Fluoride concentration in a solution or underground water.

Potentiometric Determination of FAS

Procedure:

Pipette out 25ml of FAS solution in to a 100ml beaker. Add 2 test tube of dilute H_2SO_4 . Immerse calomel electrode and platinum electrode assembly of the potentiometer and measure the potential.

Add potassium dichromate solution from the microburette in increments of 0.5ml and measure the potential after each addition. Plot a graph of $\Delta E/\Delta V$ against volume of $K_2Cr_2O_7$ as shown in the figure. And calculate the amount of FAS in the solution.

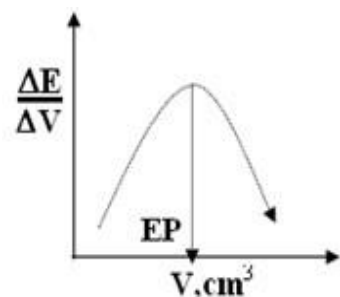


Figure: First Derivative Curve

CONDUCTOMETRY

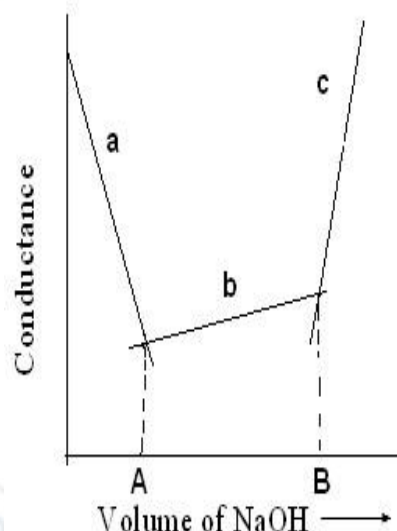
Theory:

Conductometry deals with the measurement of conductance in a solution. The conductivity of an electrolyte solution depends upon,

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- Distance b/n the electrodes. (**Greater the distance conductivity is lesser**)
- Number of ions present in the solution. (**Higher the concentration high is the conductivity**)
- The mobility of the ions. (**Smaller the ion greater is the mobility and hence conductivity**)
- The temperature of the solution. (**Higher the temperature, increases the mobility and hence conductivity increases**)

Principle: Conductivity of an electrolytic solution depends on the concentration of the ions present when the distance between the electrodes and temperature is kept constant.

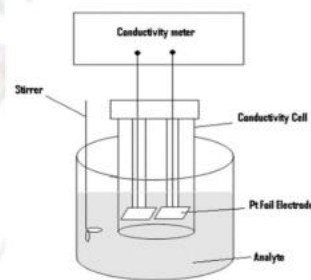


Instrumentation:

Two platinized foil placed at 1cm apart is immersed in the test solution at constant temperature and is connected to a conductivity meter. The conductivity is varied by the addition of titrants.

Application:

- Colored solution can be titrated
- Accuracy is high compared to conventional method.
- It can be used for very weak acids and bases.



Mixture of strong acid and a weak acid with a strong base (HCl+CH₃COOH)

In the titration of acid mixture containing strong and weak acid, The strong acid gets completely neutralized first and then the weak acid neutralization starts. The initial conductivity will be very high due to the presence of small H⁺ ions. On addition of NaOH the conductivity decreases due to the formation of H₂O and NaCl. This decrease in conductance is observed till all the strong acid is completely neutralized (First equivalence point A). Thereafter the conductivity slowly increases till equivalence point due to the presence of Sodium acetate which is a strong electrolyte (Second Equivalence point B). After the 2nd equivalence point, the NaOH added adds more Na⁺ ions to the solution thereby increasing the conductance rapidly.

Determination of pKa using pH sensor

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Principle: The strength of an acid is experimentally measured by determining its equilibrium constant or dissociation constant (K_a). Since strong acids are strong electrolytes, they ionize almost completely in aqueous solution. It is not meaningful to study the ionic equilibrium of strong acids and calculate their equilibrium constants, as the unionized form is present to a very small extent. Hence, the study of ionic equilibria and the calculation of K_a apply only to weak acids.

Fill the standard NaOH solution into the micro burette. Pipette 50 cm³ of the vinegar into a clean 100 cm³ beaker. Immerse a combined electrode (glass-calomel electrode assembly) into the acid and connect the cell to the pH meter. The initial pH of the solution is noted down, and also after the subsequent addition of 0.5 cm³ of NaOH. Plot a first derivative graph (graph 1) with the volume of NaOH along the x-axis and $\Delta pH/\Delta V$ along the y-axis, and determine the equivalence point. Plot another titration graph (graph 2) with the volume of NaOH along the x-axis and pH along the y-axis, and determine the pK_a of vinegar (i.e., pH at half equivalence point [HEP]).

