

Distillation assignment



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Abstract In the following project we are discussing about distillation. The operation of the distillation is employed for the purification of liquids from non-volatile impurities. The liquid is heated to the vapor phase and then is collected and recondensed to give back the pure liquid . The non-volatile impurities are left behind in the flask. Here our main focus will be at the fractional distillation. It is the process in which we separate the different components of a mixture on the basis of the difference in their boiling points.

When their boiling points differ by more than 10?? C. It is mainly use for the mixture of components having less boiling point difference. When the liquids present in the mixture have their boiling points close to each other (i. e. less than 10?? C) the separation is best effected by fitting the distillation flask with the fractionating column. In this process a fractionating tower is used. The mixture is preheated and converted into the vapor form and then allowed to enter the fractionating tower. The temperature in fractionating tower differs with the height.

Fractionating tower is provided with the different tray like shelves where different fractions having different condensation temperatures are obtained. Although the products obtained from this technique is not 100% pure. Every fraction obtained from the distillation column still contains some impurity of the fraction lower to it. These are separated and if more purification is required the distillate is redistilled. The main application of fractional distillation is in the petroleum industry. This technique is best suited for crude oil refining. Contents 1. Basic Concepts . 1 Boiling Point

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Chapter # 1 Basic Concepts 1. 1 Boiling Point The Boiling Point of a liquid is the temperature at which vapor pressure is equal to the external pressure. The normal boiling point of a liquid is the temperature at which its vapor pressure is 760 torr, normal atmospheric pressure at sea level. 1. 2 Vapor Pressure For a liquid, at any temperature, some molecules are evaporating from the surface. As the temperature goes up, the number of molecules evaporating in a given time increases. If the liquid is in an open container, the molecules escape into the atmosphere. In a closed container, some of

the vapor molecules strike the walls of the container and return to the liquid. Soon a state of equilibrium is reached in which over any time period, the number of molecules evaporating = number of molecules condensing back to the liquid. The pressure of the vapor at this point is known as its vapor pressure. 1. 3 Condensation

Is the change of the physical state of aggregation (or simply state) of matter from gaseous phase into liquid phase and the reverse of evaporation. 1. 4

Partial pressure In a mixture of?? ideal gases, each gas has a?? partial pressure?? which is the pressure which the gas would have if it alone occupied the volume. The total?? pressure?? of a gas mixture is the sum of the partial pressures of each individual gas in the mixture. Chapter # 2

Distillation Distillation is a?? purification technique?? in which compounds with different boiling points can be separated by controlled heating.

Vapors from a sufficiently heated sample can be recondensed and collected, purer than the initial mixture. The liquid which has not vaporized is called the?? residue, and the liquid which is collected in the receiver is called the distillate An apparatus for a simple distillation During a simple distillation, the liquid is vaporized and condensed one time. The thermometer measures the temperature at which the liquid is currently boiling. The temperature remains constant throughout the distillation of a pure liquid. At the boiling point, the liquid and vapor are in equilibrium.

If the composition of each phase remains constant, the temperature will remain constant A mixture of two volatile liquids begins to distill at a temperature slightly higher than the boiling point of the lower boiling liquid,

the temperature rises steadily over time ending at a temperature slightly below that of the higher boiling component. This figure represents the LIQUID-VAPOR COMPOSITION DIAGRAM FOR a TWO COMPONENT MIXTURE. When a mixture AB is heated, the total vapor pressure (composed of the contributions of PA and PB) will rise until it is equal to the external vapor pressure.

The temperature at which this occurs for various compositions of the liquid is shown in the lower curve. In this example, the liquid having composition W boils at temperature t . The vapor in equilibrium with the liquid has composition y . The vapor condenses to give liquid of composition Z. After the first drop of liquid distills, the fraction of B in the liquid increases slightly, increasing the boiling point of the solution. The composition of both the liquid and vapor changes continuously. In case of liquid having boiling points higher than 110°C the water condenser is replaced by an air condenser.

To prevent bumping it is customary to put a few pieces of unglazed porcelain in the distillation flask. While distilling a very volatile and inflammable liquid such as ether, the distillation flask is heated on a water-bath and not on wire gauze. In case of very high boiling liquids, the flask is heated directly with a naked flame.

2. 1 Types of Distillation

There are several types of distillation depending on the procedure and the instrument setup. Each of the distillation types is used for the purification of compounds having different properties.

Following are the common types of distillation:

2. 1. 1 Simple Distillation

Simple distillation is practiced for a mixture in which the boiling point of the

components differs by at least 70°C. It is also followed for the mixtures contaminated with in volatile particles (solid or oil) and those that are nearly pure with less than 10 percent contamination. Double distillation is the process of repeating distillation on the collected liquid in order to enhance the purity of the separated compounds.

2. 1. 2 Fractional Distillation

Those mixtures, in which the volatility of the components is nearly similar or differs by 25°C (at 1 atmosphere pressure), cannot be separated by simple distillation. In such cases, fractional distillation is used whereby the constituents are separated by a fractionating column. In the fractionating column, the plates are arranged and the compound with the least boiling point is collected at the top while those with higher boiling point are present at the bottom. A series of compounds are separated simultaneously one after another.

Fractional distillation is used for the alcohol purification and gasoline purification in petroleum refining industries.

2. 1. 3 Steam Distillation

Steam distillation is used for the purification of mixtures, in which the components are temperature or heat sensitive; for example, organic compounds. In the instrument setup, steam is introduced by heating water, which allows the compounds to boil at a lower temperature. This way, the temperature sensitive compounds are separated before decomposition. The vapors are collected and condensed in the same way as other distillation types.

The resultant liquid consists of two phases, water and compound, which is then purified by using simple distillation. Steam distillation is practiced for the large scale separation of essential oils and perfumes.

2. 1. 4 Vacuum

Distillation Vacuum distillation is a special method of separating compounds at pressure lower than the standard atmospheric pressure. Under this condition, the compounds boil below their normal boiling temperature. Hence, vacuum distillation is best suited for separation of compounds with higher boiling points (more than 200°C), which tend to decompose at their boiling temperature.

Vacuum distillation can be conducted without heating the mixture, as usually followed in other distillation types. For the separation of some aromatic compounds, vacuum distillation is used along with steam distillation. 2. 1. 5 Short Path Distillation Thermal sensitive compounds can also be separated by following short path distillation. In this technique, the separated compounds are condensed immediately without traveling the condenser. The condenser is configured in a vertical manner between the heating flask and the collecting flask. Similar to vacuum type, the pressure is maintained below the atmospheric pressure.

Short path distillation is used for the separation of organic compounds with high molecular weight, especially in the pharmaceutical industries. 2. 2

Raoult's Law For a mixture of two miscible liquids (A and B), the total vapor pressure is the sum of the individual vapor pressures (Dalton's Law) $P_{total} = P_A + P_B$ The vapor pressures of the individual components are given by Raoult's Law. $P_A = X_A P_A^0$ and $P_B = X_B P_B^0$ Where P_A^0 is the vapor pressure of pure A and P_B^0 is the vapor pressure of pure B and X_A and X_B are the mole fractions of A and B in the liquid Where $X_A = \frac{n_A}{n_A + n_B}$ and $X_B = \frac{n_B}{n_A + n_B}$

Where n_A and n_B are the number of moles of each component in the liquid.

2.3 Dalton Law According to Dalton's Law of Partial Pressures $P_A = X_A' P_t$ $P_B = X_B' P_t$ Where P_A and P_B are the partial pressures of the two gases And P_t is the total pressure ($P_t = P_A + P_B$) And X_A' and X_B' are the mole fractions of A and B respectively in the vapor. And $X_A' = n_A' / (n_A' + n_B')$, $X_B' = n_B' / (n_A' + n_B')$ Where n_A' and n_B' are the number of moles of each component in the vapor.

2.4 Vapor Enrichment Combining Raoult's Law and Dalton's law, we can obtain the following relationship: If A is more volatile than B, $P_A^* > P_B^*$ and $P_A > P_B$ and $P_A > P_B$

A ; $P_A^* > P_B^*$ Then $X_A' / X_B' > X_A / X_B$ The ratio of A/B in the vapor is greater than the ratio of A/B in the liquid. The vapor is enriched In the more volatile (lower boiling) component relative to the liquid. During the distillation, since the vapor always contains more A than B, the fraction of B in the Liquid increases continuously causing the boiling point of the solution to increase.

Chapter # 3 Fraction Distillation Distillation to separate volatile chemical substances in which the products are collected in a series of separate fractions, each with a higher boiling point than the previous fraction.

A process by which a chemical compound is separated into components by distillation. in fractional distillation the compound is heated and, as each of its constituent components comes to a boil, its vapors are separated and cooled, so it can be removed in its pure form Fraction distillation is done on two scales. 1. Laboratory scale 2. Industrial scale 3. 1 Fraction distillation on laboratory scale Fractional distillation in a laboratory makes use of common laboratory glassware, as well as some single-purpose items such as a?? fractionating column. The apparatus is assembled as in the diagram. The

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diagram represents a batch apparatus, as opposed to a continuous apparatus.) The mixture is put into the round bottomed flask along with a few anti-bumping granules (or a Teflon coated magnetic stirrer bar if using magnetic stirring), and the fractionating column is fitted into the top. As the mixture boils, vapor rises up the column. The vapor condenses on the glass platforms, known as trays, inside the column, and runs back down into the liquid below, refluxing distillate. The column is heated from the bottom. The efficiency in terms of the amount of heating and time required to get fractionation can be improved by insulating the outside of the column in an insulator such as wool, aluminum foil or preferably a vacuum jacket. The hottest tray is at the bottom and the coolest is at the top. At steady state conditions, the vapor and liquid on each tray are at equilibrium only the most volatile of the vapors stays in gaseous form all the way to the top. The vapor at the top of the column then passes into the condenser, which cools it down until it liquefies. The separation is more pure with the addition of more trays (to a practical limitation of heat, flow, etc. The condensate that was initially very close to the azeotrope composition becomes gradually richer in water. The process continues until all the ethanol boils out of the mixture. This point can be recognized by the sharp rise in temperature shown on the thermometer. Example As an example, consider the distillation of a mixture of water and ethanol. Ethanol boils at 78.4 °C while water boils at 100 °C. So, by gently heating the mixture, the most volatile component will concentrate to a greater degree in the vapor leaving the liquid. Some mixtures form azeotropes, where the mixture boils at a lower temperature than either component.

In this example, a mixture of 96% ethanol and 4% water boils at 78.2 °C, being more volatile than pure ethanol. For this reason, ethanol cannot be completely purified by direct fractional distillation of ethanol-water mixtures.

3.1.1 Applications Chemical separation (in analysis (physics and chemistry)) : Distillation column is a tube that provides surfaces on which condensations and vaporizations can occur before the gas enters the condenser in order to concentrate the more volatile liquid in the first fractions and the less volatile Components in the later fractions.

The analyte typically goes through several vaporization-condensation steps prior to arriving at the condenser. Separation and purification (chemistry) Molecular weight of the substance, distillation separates on the basis of weight (or size) of molecules. If the boiling points are close together, a multistage operation, which can most conveniently be achieved by placing a column above the boiling liquid solution, is required. This glass column contains some loosely packed material (e. g.

Hydrogen isotopes research (in hydrogen (H) (chemical element): Isotopes of hydrogen) Who from theoretical principles predicted a difference in the vapor pressures of hydrogen (H₂) and hydrogen deuteride (HD) and thus the possibility of separating these substances by distillation of liquid hydrogen. In 1931 Urey and two collaborators detected deuterium by its atomic. 3.2 Fractional distillation on industrial scale. Fractionating columns are widely used in the chemical process industries where large quantities of liquids have to be distilled.

Such industries are the?? petroleum processing,?? petrochemical?? production,?? natural gas processing ,?? coal tar?? processing,?? brewing, liquified air?? separation, and?? hydrocarbon solvent?? production and similar industries but it finds its widest application in?? petroleum refineries. In such refineries, the crude oil feedstock is a very complex multicomponent mixture that must be separated and yields of pure chemical compounds are not expected, only groups of compounds within a relatively small range of boiling, also called?? fractions?? and that is the origin of the name?? fractional distillation?? or fractionation.

It is often not worthwhile separating the components in these fractions any further based on product requirements and economics. 3. 2. 1 Fractionating column. Industrial distillation is typically performed in large, vertical cylindrical columns known as “ distillation or fractionation towers” or “ distillation columns” with diameters ranging from about 65 centimeters to 6 meters and heights ranging from about 6 meters to 60 meters or more. The distillation towers have liquid outlets at intervals up the column which allow for the withdrawal of different?? fractions?? or products having different?? boiling points?? or boiling ranges.

The “ lightest” products (those with the lowest boiling point) exit from the top of the columns and the “ heaviest” products (those with the highest boiling point) exit from the bottom of the column. 3. 2. 2 Reflux Large-scale industrial towers use?? reflux?? to achieve a more complete separation of products. Reflux refers to the portion of the condensed overhead liquid product from a distillation or fractionation tower that is returned to the upper

part of the tower as shown in the schematic diagram of a typical, large-scale industrial distillation tower.

Inside the tower, the reflux liquid flowing downwards provides the cooling needed to condense the vapors flowing upwards, thereby increasing the effectiveness of the distillation tower. The more reflux is provided for a given number of?? theoretical plates, the better the tower's separation of lower boiling materials from higher boiling materials. Alternatively, the more reflux provided for a given desired separation, the fewer theoretical plates are required. 3. 2. 3 Bubble caps There is no difference whatsoever in the theory involved.

All that is different is what the fractionating column looks like. The diagram shows a simplified cross-section through a small part of a typical column. The column contains a number of trays that the liquid collects on as the vapor condenses. The up-coming hot vapor is forced through the liquid on the trays by passing through a number of?? bubble caps. This produces the maximum possible contact between the vapor and liquid. This all makes the boiling-condensing-reboiling process as efficient as possible. The overflow pipes are simply a controlled way of letting liquid trickle down the column.

If you have a mixture of lots of liquids to separate (such as in petroleum fractionation), it is possible to tap off the liquids from some of the trays rather than just collecting what comes out of the top of the column. That leads to simpler mixtures such as gasoline, kerosene and so on. 3. 2. 4

Condenser For?? fractional distillation, an air or Vigreux condenser is usually used to slow the rate at which the hot vapors rise, giving a better separation

between the different components in the distillate. An air condenser is the simplest sort of condenser.

There is only one tube, and the heat of the fluid is conducted to the glass, which is cooled by air. It is related to the retort used by alchemists. The air condenser is usually used for fractional distillation and high-temperature condensation, and it can be packed with some material such as glass beads, metal pieces, or Raschig rings to increase the number of effective plates. A Vigreux condenser is a modification of the air condenser. It is usually used as a fractionating column for fractional.

Unlike straight-walled columns, a Vigreux column has a series of downward-pointing indentations on the inside wall which serve to dramatically increase the surface area without increasing the length of the condenser. Because of their added complexity, Vigreux columns also tend to be considerably more expensive than traditional straight-walled designs. Chapter # 4 Fractional Distillation of Crude Oil Crude oil, also called petroleum, is a complex mixture of carbon and hydrogen (hydrocarbons), which exist as a liquid in the earth's crust.

Crude oil has many compositions; some is black, thick and tar like, while other crude oils are lighter in color and thinner. The carbon and hydrogen in crude oil are thought to have originated from the remains of microscopic marine organisms that were deposited at the bottom of seas and oceans and were transformed at high temperature and pressure into crude oil and natural gas. This oil and gas migrates upward through the porous rock, as it

is less dense than the water which fills the pores. The oil and gas is trapped by a layer of impermeable rock through which they can't flow.

Several different types of oil and gas "traps" exist; a common dome formed by folded sedimentary rocks. Crude oil is obtained by drilling a hole into the reservoir rock (sandstone, limestone etc.) and pumping it out. | Petroleum refining?? is the process of separating the many compounds present in crude petroleum. This process is called fractional distillation where the crude oil is heated; the several of the compounds boil at different temperatures and change to gases; and are later recondensed back into liquids. 4. 1

Boiling point and hydrocarbons The principle which is used is that the longer the carbon chain, the higher the temperature at which the compounds will boil. Hydrocarbons have different boiling points, and can either be solids, liquids or gases at room temperature. | Molecules which strongly interact or bond with each other through a variety of intermolecular forces cannot move easily or rapidly and therefore, do not achieve the kinetic energy necessary to escape the liquid state. Therefore, molecules with strong intermolecular forces will have higher boiling points.

This is a consequence of the increased kinetic energy needed to break the intermolecular bonds so that individual molecules may escape the liquid as gases. The bigger the hydrocarbon molecule and the more carbon atoms it contains, * the higher is its boiling point * the less easily it turns into a vapour (I. e. , it is less volatile) * the less easily it flows (I. e. , it is more viscous) and * the less easily it ignites (I. e. , it is less flammable) This means that large hydrocarbon molecules are less useful as fuels. 4. 2 Basic Process.

The crude petroleum is heated and changed into a gas. The gases are passed through a distillation column which becomes cooler as the height increases. See the figure on the left. When a compound in the gaseous state cools below its boiling point, it condenses into a liquid. The liquids may be drawn off the distilling column at various heights. | Although all fractions of petroleum find uses, the greatest demand is for?? gasoline. One barrel of crude petroleum contains only 25-35% gasoline. Transportation demands require that over 50% of the crude oil be converted into gasoline.

To meet this demand some petroleum fractions must be converted to gasoline. This may be done by “ cracking” - breaking down large molecules of heavy heating oil; “ reforming” - changing molecular structures of low quality gasoline molecules; or “ polymerization” - forming longer molecules from smaller ones. For example if decane is heated to about 500C the covalent carbon-carbon bonds begin to break during the cracking process. Many kinds of compounds including alkenes are made during the cracking process.

Alkenes are formed because there are not enough hydrogen's to saturate all bonding position after carbon-carbon bonds are broken. 4. 3 How the Distillation Tower WorksThe way the Distillation Tower works is by becoming progressively cooler from the base to the top. All the Hydrocarbon fractions start off in gas form, as they have been heated to that point. The gases then rise up the tower. The gas mixture then encounters a barrier through which there are are only openings into the bubble caps. The gas mixture is then forced to go through a liquid before continuing upwards.

The liquid in the first tray is at a cool enough temperature to get the heaviest gas fractions to condense into liquid form, while the lighter fractions stay gaseous. In this way the heaviest hydrocarbon fractions are separated out from the mixed gas. The remaining gas continues its journey up the tower until it reaches another barrier. Here the bubble cap process is repeated but at a lower temperature than before, which then filters out the next lightest set of fractions. This process continues until only the very lightest fractions, those of 1 to 4 Carbon atoms, are left. These stay in gas form and are collected at the top of the tower.

The separation of the heavier elements in the second tower follows exactly the same process but at lower pressure.

4. 4 Products of Fraction Distillation of crude oil.

| Name of Fraction | Boiling Point | Uses of Fraction |
|------------------|--------------------|---------------------------|
| Petroleum gases | 25oc | Bottled gas and chemicals |
| Gasoline | 40oc - 75oc | Petrol |
| Naphtha | 75oc - 150oc | Chemicals |
| Kerosene | 150oc - 240oc | Jet Fuel |
| Diesel Oil | 220oc - 250oc | Diesel Fuel |
| Lubricating Oil | 250oc - 350oc | Lubricants and chemicals |
| Fuel Oil | 350oc | Fuels for ships |
| Bitumen | stays solid/liquid | Roads and Roofing Felt |

4. 1. 1 Advantages

To understand the diversity contained in crude oil, and to understand why refining crude oil is so important in our society, look through the following list of products that come from crude oil:

- Petroleum gas??- used for heating, cooking, making plastics
- * small alkanes (1 to 4 carbon atoms)
- * commonly known by the names methane, ethane, propane, butane
- * boiling range = less than 104 degrees Fahrenheit / 40 degrees Celsius
- * often liquified under pressure to create LPG (liquified petroleum gas)
- * Naphtha?? or?? Ligroin??- intermediate that will be further processed to make gasoline
- * mix of 5 to 9

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carbon atom alkanes boiling range = 140 to 212 degrees Fahrenheit / 60 to 100 degrees Celsius * Gasoline??- motor fuel * liquid * mix of alkanes and cycloalkanes (5 to 12 carbon atoms) * boiling range = 104 to 401 degrees Fahrenheit / 40 to 205 degrees Celsius * Kerosene??- fuel for jet engines and tractors; starting material for making other products * liquid * mix of alkanes (10 to 18 carbons) and aromatics * boiling range = 350 to 617 degrees Fahrenheit / 175 to 325 degrees Celsius * Gas oil?? or?? Diesel distillate??- used for diesel fuel and heating oil; starting material for making other products * liquid alkanes containing 12 or more carbon atoms * boiling range = 482 to 662 degrees Fahrenheit / 250 to 350 degrees Celsius * Lubricating oil??- used for motor oil, grease, other lubricants * liquid * long chain (20 to 50 carbon atoms) alkanes, cycloalkanes, aromatics * boiling range = 572 to 700 degrees Fahrenheit / 300 to 370 degrees Celsius * Heavy gas?? or?? Fuel oil??- used for industrial fuel; starting material for making other products * liquid