We come across several mixtures in our daily life. Sometimes, when they are valuable not as mixtures but as individual components, we employ several methods of separation to single out the beneficial ones. For instance, to clean the dirty water, we can use the filtration method to separate the solid impurities. In the case of liquid impurities, however, filtration is incapable of purification as the significant difference between the particle size of the impurities and the solution is not much. Nonetheless, there is another physical property that can assist in the separation process, i.e., the boiling point. Distillation is a process by which we can separate a mixture of two or more liquids based on differences in their boiling points; however, simple distillation is incapable of significant purification if the difference among the boiling points of the comprising components is less than 25 ºC. 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There are several industrial applications of fractional distillations that provide us with various products that we use in our daily lives. Let' take a look at few examples of fractional distillation in our everyday life. 1. Oil Refining If you ever have the chance of visiting an oil refinery, you can witness one of the most technologically advanced fractionating columns present on our planet. The fuel that powers our vehicle's engine is found deep down beneath the earth's surface and sea-beds as crude oil, also known as petroleum. It is a naturally occurring yellowish black liquid that is composed of hydrocarbon deposits and other organic materials. These components can have several applications, but not when they are mixed. The complex mixture of hydrocarbons in crude oil can be separated into fractions by the technique of fractional distillation. In the refinery, the crude oil is fed to a furnace burning at the temperature of around 650 K. 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Surely, our notes will help you overcome the O Level Chemistry exams. But life is more than that, and Chemistry too. We will show you the exciting aspect of Chemistry through our stories on everyday applications, folk knowledge, history of science, philosophy, and the latest scientific breakthrough. Enjoy sharper detail, more accurate color, lifelike lighting, believable backgrounds, and more with our new model update. Your generated images will be more polished than ever.See What's NewExplore how consumers want to see climate stories told today, and what that means for your visuals.Download Our Latest VisualGPS ReportData-backed trends. Generative AI demos. Answers to your usage rights questions. Our original video podcast covers it all—now on demand.Watch NowEnjoy sharper detail, more accurate color, lifelike lighting, believable backgrounds, and more with our new model update. 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For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Combustion is important in everyday life because it is the process by which many essential activities are powered, such as heating homes, generating electricity, and running vehicles. It provides the energy needed for cooking, transportation, and industrial processes. However, combustion also produces emissions and pollutants that can have negative impacts on health and the environment, making it important to use cleaner and more efficient combustion technologies. We come across several mixtures in our daily life. Sometimes, when they are valuable not as mixtures but as individual components, we employ several methods of separation to single out the beneficial ones. For instance, to clean the dirty water, we can use the filtration method to separate the solid impurities. 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In this process, chemical compounds are separated by heating them to a temperature where one or more portions of the mixture evaporate. Fractional distillation is widely used to purify substances and separate mixtures to acquire their components. In oil refineries, for example, fractional distillation is used to separate crude oil into usable molecules containing distinct types of hydrocarbons with different boiling points. More carbon atoms are found in crude oil compounds or fractions with higher boiling points. Fractional distillation is used to separate the mixture of the components of the liquid into pure form in the following ways: a. Normally, the vapor of any liquid mixture does not retain the same composition as the liquid. When the specified mixture is heated, the lower boiling point liquid boils and transforms into vapor. b. The more volatile components are more likely to persist in the vapor state than in the liquid state. The mixture passes through several distillations and condensations, resulting in distinct fractions. c. The more volatile substances increase their vapor state after heating. However, as the vapor is liquefied, it becomes liquid. d. Distillation refers to the combined processes of initial vaporization and subsequent condensation. When this procedure is continued, a more volatile chemical will eventually remain in the liquid state in its pure form. In this way, the various components of the liquid-liquid mixture can be separated in a pure form by using the fractional distillation method. The fundamental concept of fractional distillation is that different liquids boil and evaporate at different temperatures. When the liquid mixture is heated, the substance with the lower boiling point starts boiling first and converts into vapor. Let us consider a liquid-liquid mixture of A and B where liquid A is more volatile than liquid B. This mixture can be separated by the following process: Fractional distillation is used for separating liquid mixtures with similar boiling points (separated by less than 70 degrees Celsius). A mixture of liquids is heated in this distillation process, and the resultant vapors rise in a glass tube known as a "fractionating column" and get separated. The fractionating column is positioned between the flask containing the mixture and the "Y" adaptor. The fractionating column has "theoretical plates" that allow vapors to condense, re-evaporate, and condense. One theoretical plate corresponds to one vaporization-condensation cycle. The more volatile liquids will rise to the top of the fractionating column, while the higher boiling point liquids will sink to the bottom. The vapor cools in the condenser before dripping into the collecting. Typically, a Vigreux column is utilized. Fractional Distillation apparatus image source: A procedure to carry out the fractional distillation process is given below: • The organic matter to be purified is placed in a round bottom flask fitted with a stir bar. • The fractional distillation equipment is set up as shown in Figure 1. • A heating mantle/block or oil bath is used to heat the organic mixture to an appropriate temperature. First, the lowest-boiling compound should be separated by adjusting the temperature. The condensate ring ascending slowly up in the fractionating column must be observed. The theoretical plates should begin to rise gradually. If the condensate ring stops, the temperature should be slightly raised. • Distillation takes place once the flask reaches an appropriate temperature. The vapor begins to condense in the liquid-cooled jacketed portion of the distillation equipment. After the first few drops of liquid start to drip down the condenser, the temperature should remain almost constant. The rate of distillation must be consistent and gradual. If the distillation takes a long time, wrap the column in aluminum foil or glass wool. The temperature of the distillate drop should be observed once the lower-boiling material is finished. • At this point, the heating element temperature can be raised to distill the next lowest-boiling compound before moving to a new, clean receiving flask. • Repeat this process until the desired compound is achieved. • Once the distillation process is finished, transfer the pure organic compound into a clean, labeled vial for preservation. Things to consider while carrying out fractional distillation: The thermometer should be placed at the intersection of the "Y" piece. Cold water should flow from the bottom of the condenser to the top. The system should be kept under nitrogen to avoid decomposition or interactions with oxygen. Keck clamps must be used on joints. If very low-boiling compounds are being distilled, the receiving flask can be placed in an ice bath. Fractional Distillation of Crude Oil: Separating the various components of crude oil is one of the frequent industrial applications of fractional distillation. Crude oil consists of gasoline, diesel, lubricating oil, kerosene, and other chemicals. Fractional distillation aids in the successful separation of these components. The chamber is filled with crude oil and then heated by high-pressure steam. The mixture then begins to boil, producing vapor. Several compounds enter the vapor phase. The vapor phase rises in the fractionating column, which is comprised of multiple plates. The plates have holes in them that allow vapor to travel through. Typically, the temperature at the top of the fractionating column is kept low. The components with the lowest boiling points will condense at the top of the fractionating column, while the compounds with the highest boiling points will condense at the bottom. The condensed vapor or liquid fractions are removed from the column's sides. The liquid fractions thus collected can then be cooled by passing them through condensers. The rate of distillation, or the speed at which a liquid is vaporized and condensed to obtain a purified substance, is influenced by several factors which are discussed below: The distillation rate rises with increasing temperature because higher temperatures cause the liquid to vaporize faster. The surface area of the liquid exposed to the air also influences the distillation rate. A larger surface area will lead to the faster evaporation rate of the liquid and thus faster will be the distillation rate. The distillation rate is inversely proportional to the pressure under which the distillation is performed. The lower the pressure, the faster will be the distillation rate, as the boiling point of liquid decrease with decreasing pressure. The boiling point of the distilled liquid also influences the distillation rate. The liquid with higher boiling points will take a longer time to vaporize and distill than the liquids with lower boiling points. The lower the volume of the liquid, the faster will be the distillation rate, and vice versa. The distillation rate is also affected by the presence of impurities in the liquid. The impurities present may alter the boiling point of the liquid and this requires the additional time to be vaporized and distilled. Some of the advantages of fractional distillation are as follows: Fractional distillation requires simple apparatus. It includes a condenser, a distillation flask, fractionating column, a thermometer, and a bunsen burner (heat source) are among. These things allow for simple fractional distillation. They are easy to handle and readily available. The fractional distillation apparatus includes a fractionating column, which facilitates the separation of two or more components of a mixture. It is positioned between the condenser and the flask to improve separation between the two liquids being distilled. They can aid in separating chemicals based on properties such as adsorption, absorption, size, and other factors. Fractional distillation is more efficient than simple distillation because it produces a purer distillate. When the temperature difference between the boiling points of the two liquids is less than 40 degrees Celsius, it is more effective to separate the two components of the mixture. The fractional distillation apparatus uses numerous simple distillation cycles to differentiate solutions with a low or high boiling point into pure components. The fractional distillation technique does not necessitate significant variations in boiling points between the various components of the liquid. The temperature difference between the boiling points of the two compounds can be less than 40 degrees Celsius for this process. This is a very useful method for separating two liquids. Fractional distillation is a common distillation technique because it provides better separation of the components of a mixture than other types of distillation like simple distillation, steam distillation, and so on. Since the distillate's composition is continuously changing, this process is also called an equilibrium process. The following are some of the disadvantages of the fractional distillation process: The solute and solvent cannot be separated by fractional distillation. The mixture, which consists of a solute dissolved in a solvent, cannot be used. The mixture must be a liquid-liquid solution that can be distilled using the fractional distillation method. For industrial purposes, the fractional distillation process necessitates complex and costly equipment such as distillation columns and reflux. They are expensive and frequently damaged by the heat. The fractional distillation process takes a long time since it repeats the simple distillation process numerous times until the required components are fully separated. The fractional distillation procedure must be repeated several times. The separation of the components is improved by subjecting the mixture to longer vaporization-condensation cycles. Industries have an ongoing requirement to separate more than one type of component, which uses a lot of energy. High pressures and temperatures are involved in the fractional distillation process. As a result, there is a probability of operational risk, which can be very serious. There is the danger of an explosion. As a result, it is damaging and dangerous for the individual. So it requires specific knowledge. The fractional distillation process is widely used in industries. Some of the major applications of fractional distillation are as follows: Fractional distillation can be used to produce high-purity silicon from chlorosilanes. Silicon is most commonly found in semiconductors. It is used to separate air into its constituents like oxygen, nitrogen, and carbon dioxide. Fractional distillation is used for water purification and also for separating ethanol and water. It is used in several industries, including oil refineries and chemical plants, to purify and separate various organic molecules. This method may separate crude oil "petroleum" into numerous petroleum products such as kerosene, petrol, diesel, and many more. The following are the differences between Steam Distillation and Fractional Distillation: S.N.Steam distillationFractional distillation1. The process of separating temperature-sensitive compounds from a mixture is known as steam distillation.The method of fractional distillation is commonly used to separate the hydrocarbon components of crude oil.2. It can be achieved through distillation, followed by condensation.It is carried out through a series of distillations and condensations.3.In this process, the chemical components are vaporized at a temperature lower than their boiling point.In this process, the chemical components are vaporized at their boiling points.4. The compound must be insoluble in water.Compounds may or may not be miscible with the liquid. . . . . About Author A solution is a homogeneous mixture that is well-mixed to form a single layer Have a solution when you want to solve a problem? Great! Have a solution when you want to separate its components? Trouble! A solution is so well-mixed that filtration and separating funnel do not provide an easy way out. Instead, we resort to simple and fractional distillations to separate and purify the liquid, through an arduous process of heating and cooling. The general process of both distillations is the same. We heat a solution in a round-bottom flask to allow the component with a lower boiling point to vaporise first. The pure vapour then passes into the condenser, where it cools and condenses to form the distillate. In fractional distillation, there is an additional fractionating column above the round-bottom flask, to condense the vapour of the liquid with a higher boiling point However, distillation gets tricky when the solution contains two or more miscible liquids. An example is a solution of water and ethanol. Ethanol and water have highly similar boiling points. Consequently, when ethanol boils first at 78 °C, a substantial amount of water vapour will also be evaporating. This contaminates the ethanol vapour. To purify the vapour, we need a fractionating column to preferentially condense the water vapour and return it to the round-bottom flask. Only ethanol vapour remains and drifts into the condenser, where it cools and condenses to form the pure ethanol distillate. Simple distillation separates a liquid from a solid-liquid solution while fractional distillation separates a liquid from a solution of two miscible liquids. The fractionating column contains a glass spiral to increase the surface area for condensation The fractionating column is so long that heat does not distribute evenly. It is hotter below and colder on top. At any point along the column, a vapour condenses if the temperature there is below its boiling point. Only when the temperature rises to match the boiling point can the vapour remain a vapour and be allowed to pass. Therefore, the first distillate will be the liquid with a lower boiling point. Its boiling point can be reached more easily at the very top of the column, allowing it to distil over first. The liquid with a high boiling point distils later, as the second fraction. As we collect the two liquids in two separate fractions, we call this modified form of distillation fractional distillation. In fractional distillation, the first distillate is the liquid with the lower boiling point. When the temperature reaches the boiling point of a liquid, its distillate forms. We can monitor the progress of fractional distillation by placing a thermometer at the very top of the column. This will tell us whether a vapour will condense or pass into the condenser. Let's examine the distillation of a solution of water and ethanol. From 10 min to 20 min, the temperature hits 78 °C and becomes equal to the boiling point of ethanol. This allows ethanol to remain as a vapour and pass into the condenser for condensation and collection. However, water has a higher boiling point of 100 °C. As the temperature is lower than its boiling point, it condenses back into water droplets, dripping down into the round-bottom flask. Summary Quiz We come across several mixtures in our daily life. Sometimes, when they are valuable not as mixtures but as individual components, we employ several methods of separation to single out the beneficial ones. For instance, to clean the dirty water, we can use the filtration method to separate the solid impurities. In the case of liquid impurities, however, filtration is incapable of purification as the significant difference between the particle size of the impurities and the solution is not much. Nonetheless, there is another physical property that can assist in the separation process, i.e., the boiling point. Distillation is a process by which we can separate a mixture of two or more liquids based on differences in their boiling points; however, simple distillation is incapable of significant purification if the difference among the boiling points of the comprising components is less than 25 ºC. For such cases, we can modify the simple distillation to fractional distillation by adding a fractionating column to the apparatus. In fractional distillation, vapors from the distilling flask are passed along the fractionating column, where plastic and glass trays improve the separation process by providing more surface area for condensation and evaporation. As the vapors rise in the fractionating column, at a certain height, components with high boiling points condense in-between the columns and return to the mixture, whereas the components with lower boiling points pass through the columns and are collected at the top. Fractional distillation also saves the loss of time and efficiency that one can encounter during multiple simple redistillations. In theory, adding more trays or plates inside the fractionating column can improve the purification process, but this can also increase the time required for separation. There are several industrial applications of fractional distillations that provide us with various products that we use in our daily lives. Let' take a look at few examples of fractional distillation in our everyday life. 1. Oil Refining If you ever have the chance of visiting an oil refinery, you can witness one of the most technologically advanced fractionating columns present on our planet. The fuel that powers our vehicle's engine is found deep down beneath the earth's surface and sea-beds as crude oil, also known as petroleum. It is a naturally occurring yellowish black liquid that is composed of hydrocarbon deposits and other organic materials. These components can have several applications, but not when they are mixed. The complex mixture of hydrocarbons in crude oil can be separated into fractions by the technique of fractional distillation. In the refinery, the crude oil is fed to a furnace burning at the temperature of around 650 K. The vapors emerging from the furnace are then fed to a 25-100m high fractionating column, where different fractions condense at certain temperature ranges. When the rising vapor reaches a tray whose temperature is below the boiling point of the vapor, it partially condenses. As some of the vapor condenses to a liquid, the dissipated latent heat then heats more liquid, and the more volatile components in the liquid evaporate joining the remaining vapor and passing up the tower. The less volatile liquid flows across the tray and down a pipe to the tray below. From hot to cold (largest hydrocarbons to smallest), the order of fractions is residue (used to make bitumen), fuel oil, diesel, kerosene, naphtha, gasoline, and refinery gas. 2. Alcohol Manufacturing Alcohol has been an important part of human culture for ages, with the earliest known evidence dating back to 9000 years ago. In fact, some human DNA studies suggest that our ancestors developed the ability to metabolize ethanol (only consumable alcohol) around 10 million years ago, long before we were even humans. From soft alcoholic beverages like beers and wines to hard alcohols like whiskey and vodka, alcohol comes in many flavors and can be found almost anywhere around the world. The basic step of making alcohol is fermentation- the process of breaking down sugars into ethanol and carbon dioxide. The carbon dioxide gas is often allowed to escape from the solution. Levels of alcohol above 18 or 19% are usually toxic to the yeast and lead to the death of the cells. Further increase in the alcohol content of the liquid is done by distillation. In fact, distilled spirits are all alcoholic beverages in which the concentration of ethyl alcohol has been increased above that of the original fermented mixture by distillation. The principle of alcoholic distillation is based upon the different boiling points of alcohol (78.5 °C, or 173.3 °F) and water (100 °C, or 212 °F). When a liquid containing ethyl alcohol is heated to a temperature above 78.5 °C but below 100 °C and the vapor coming off the liquid is condensed, the condensate will have a higher alcohol concentration or strength. Fractional distillation can further concentrate the alcohol, resulting in a stronger liquor with up to 80% v/v alcohol. 3. Air Separation Air is a mixture made up of approximately 78% nitrogen, 21% oxygen, 0.93% argon, 0.378% carbon dioxide, and other trace gases, including water vapor and other noble gases. Most of these gases have several commercial and industrial values for which they can be extracted directly from the air by the process of liquefaction followed by fractional distillation. The process starts with ambient air filtration, in which the air goes through a filter that removes any dust particles. The filtered air is then compressed approximately up to six bars for liquefication. During compression, most of the water vapors present in the air are condensed out. The remaining water vapors are removed along with carbon dioxide when the air passes through a mesh of molecular sieves. This is done to avoid the formation of ice and dry ice during liquefaction. The purified air is then passed through a heat exchanger that includes a network of pipes carrying liquid nitrogen. The cold, compressed air is then allowed to expand rapidly, thus cooling even further to -200 °C, where most of the air is liquefied. The liquified air is then passed to a fractional distillation tower which primarily contains three distilling columns. The separation of the liquified air is based on the different boiling points of its components. After the liquefied air enters the first distillation column, the temperature is gently raised to -176 °C, which causes nitrogen to evaporate and escape the fractionating tower. Similarly, when the desired level of purity is reached, the gases can also be taken out of the fractionating column and can either be supplied to the consumer directly in the gas form or temporarily stored in the tank in liquid form. 4. Perfume Manufacturing The scents from nature have long been part of human attire, but have you ever wondered how these scents from flowers and plants end up in spray bottles? The whole process is known by the name fragrance extraction in the industrial sectors. It refers to the separation process of aromatic compounds from raw materials, using methods such as distillation, solvent extraction, expression, sieving, or enfleurage. The results of the extracts are either essential oils, absolutes, and other concretes. Raw essential oils are extracted from various plants such as mint, clove, tea tree, and patchouli. The main role of fractional distillation in the fragrance industry is to process the essential oils into isolates and aroma chemicals with a high degree of purity. Through the use of a fractionating column, different fractions distilled from a material can be selectively excluded to manipulate the scent of the final product. 5. In the Manufacturing of High-Purity Silicon Semiconductors Silicon is one of the most abundant semiconductor elements present in the world. It is found in rocks, sand, clays, and soils, combined with either oxygen as silicon dioxide or with oxygen and other elements as silicates. On the industrial scale, the lowest quality of silicon is metallurgical grade silicon (MGS). The source material for making MGS is quartzite (rock of pure silicon oxides). During the production, the silicon is purified by removing the oxides. It is achieved by moving the quartzite into a furnace where it is melted using an electrode. The quartzite is heated up to the temperature of 1900 °C and then gets mixed with carbon so that the oxygen leaves the furnace as carbon monoxide. The molten silicon is then drawn from the furnace and then purified further. The powder of MSG is exposed in the reactor with HCl at elevated temp and in the presence of a catalyst. The silicon reacts with HCl and forms trichlorosilane {SiHCl}_{3}. The TCS is liquefied and then passed through a fractional distillation tower where the impurities are removed based on their boiling point. This polycrystalline material is subsequently employed as a starting point for the production of single-crystal materials, which are eventually processed into semiconductor wafers. Because small levels of some contaminants have such a strong influence on the electric properties of semiconductors, the bulk raw material must be extremely pure (> 99.99 percent). 6. Pharmaceutical Industry The pharmaceutical industry also relies on fractional distillation to a very great extent. In the formulation of active pharmaceutical ingredients, solvent swap or solvent exchange plays a very important role. A solvent swap is performed to remove the original solvent that is used in an earlier processing step and to replace it with a more suitable solvent in the next processing step. It is achieved by fractional distillation. The swap solvent is mixed with the original solvent mixture and then loaded to the fractionating column. The original solvent is distilled off and can be collected at the top of the fractionating column, whereas the swap solvent along with the active pharmaceutical ingredient is collected at the bottom. Solvent swap processes can be made more efficient by reducing the amount of solvent used and reducing energy consumption while keeping the same level of purification. This can be accomplished by monitoring solvent concentrations in real-time during the swap. Fractional distillation is used in pharmacy for a variety of purposes, including the separation of alkanes, the production of pharma-grade alcoholic solutions, and even the breakdown of cannabis for its oil and enhancement of THC concentration. Science, Tech, Math All Science, Tech, Math Humanities All Humanities Languages All Languages Resources All Resources Photo by: mrfotos_fotolia In distillation, the more volatile component of the mixture—that is, the part that is more easily vaporized—is separated from the less volatile portion. With regard to the illustration used above, of separating water from salt, clearly the water is the more volatile portion: its boiling point is much, much lower than that of salt, and the heat required to vaporize the salt is so great that the water would be long since vaporized by the time the salt was affected. Once the volatile portion has been vaporized, or turned into distillate, it experiences condensation—the cooling of a gas to form a liquid, after which the liquid or condensate is collected. Note that in all these stages of distillation, heat is the agent of separation. This is especially important in the process of fractional distillation, discussed below. The process of removing water vapor from salt water, described earlier, is an example of what is called "single-stage differential distillation." Sometimes, however—especially when a A WATER FILTRATION PLANT IN C ONTRA C OSTA C OUNTY , C ALIFORNIA . (James A. Sugar/Corbis . Reproduced by permission.) high level of purity in the resulting condensate is desired—it may be necessary to subject the condensate to multiple processes of distillation to remove additional impurities. This process is called rectification. If distillation can be used to separate water from salt, obviously it can also be used to separate water from microbes and other impurities through a more detailed process of rectification. Distilled water, purchased for drinking and other purposes, is just one of the more common applications of the distillation process. Another well-known use of this process is the production of ethyl alcohol, made famous (or perhaps infamous) by stories of bootleggers producing homemade whiskey from "stills" or distilleries in the woods. Ethanol, the alcohol in alcoholic beverages, is produced by the fermentation of glucose, a sugar found in various natural substances. The choice of substances is a function of the desired product: grapes for wine; barley and hops for beer; juniper berries for gin; potatoes for vodka, and so on. Glucose reacts with yeast, fermenting to yield ethanol, and this reaction is catalyzed by enzymes in the yeast. The reaction continues until the alcohol content reaches a point equal to about 13%. After that point, the yeast enzymes can no longer survive, and this is where the production of beer or wine usually ends. Fortified wine or F EW INDUSTRIES EMPLOY DISTILLATION TO A GREATER DEGREE THAN DOES THE PETROLEUM INDUSTRY . S HOWN HERE IS AN OIL REFINERY . (Mark L. Stephenson/Corbis . Reproduced by permission.) malt liquor—variations of wine and beer, respectively, that are more than 13% alcohol, or 26 proof—are exceptions. These two products are the result of mixtures between undistilled beer and wine and products of distillation having a higher alcohol content. Distillation constitutes the second stage in the production of alcohol. Often, the fermentation products are subjected to a multistage rectification process, which yields a mixture of up to 95% ethanol and 5% water. This mixture is called an azeotrope, meaning that it will not change composition when distilled further. Usually the production of whiskey or other liquor stops well below the point of yielding an azeotrope, but in some states, brands of grain alcohol at 190 proof (95%) are sold. In contrast to ethanol, methanol or "wood alcohol" is a highly toxic substance whose ingestion can lead to blindness or death. It is widely used in industry for applications in adhesives, plastics, and other products, and was once produced by the distillation of wood. In this old production method, wood was heated in the absence of air, such that it did not burn, but rather decomposed into a number of chemicals, a fraction of which were methanol and other alcohols. The distillation of wood alcohol was abandoned for a number of reasons, not least of which was the environmental concern: thousands of trees had to be cut down for use in an inefficient process yielding only small portions of the desired product. Today, methanol is produced from synthesis gas, itself a product of coal gasification; nonetheless, numerous industrial processes use distillation. Distillation is employed, for instance, to separate the hydrocarbons benzene and toluene, as well as acetone from acetic acid. In nuclear power plants that require quantities of the hydrogen isotope deuterium, the lighter protium isotope, or plain hydrogen, is separated from the heavier deuterium by means of distillation. Few industries, however, employ distillation to a greater degree than the petroleum industry. Through a process known as fractional distillation, oil companies separate hydrocarbons from petroleum, allowing those of lower molecular mass to boil off and be collected first. For instance, at temperatures below 96.8°F (36°C), natural gas separates from petroleum. Other substances, including petroleum ether and naphtha, separate before the petroleum reaches the 156.2°F-165.2°F (69°C-74°C) range, at which point gasoline separates. Fractional distillation continues, with the separation of other substances, all the way up to 959°F (515°C), above which tar becomes the last item to be separated. Petroleum and petroleum-product companies account for a large portion of the more than 40,000 distillation units in operation across the country. About 95% of all industrial separation processes involve distillation, which consumes large amounts of energy; for that reason, ever more efficient forms of distillation are continually being researched. In the simplest form of filtration, described earlier, a suspension (solid particles floating in a liquid) is allowed to pass through filter paper supported in a glass funnel. The filter paper traps the solid particles, allowing a clear solution (the filtrate) to pass through the funnel and into a receiving container. There are two basic purposes for filtration: either to capture the solid material suspended in the fluid, or to clarify the fluid in which the solid is suspended. An example of the former occurs, for instance, when panning for gold: the water is allowed to pass through a sieve, leaving behind rocks that—the prospector hopes—contain gold. An example of the latter occurs in sewage treatment. Here the solid left behind is feces—as undesirable as gold is desirable. Filtration can further be classified as either gaseous or liquid, depending on which of the fluids constitutes the filtrate. Furthermore, the force that moves the fluid through the filter—whether gravity, a vacuum, or pressure—is another defining factor. The type of filter used can also serve to distinguish varieties of filtration. In liquid filtration, such as that applied in sewage treatment, a liquid can be pulled through the filter by gravitational force, as in the examples given. On the other hand, some sort of applied pressure, or a pressure differential created by the existence of a vacuum, can force the liquid through the filter. Water filtration for purification purposes is often performed by means of gravitation. Usually, water is allowed to run down through a thick layer of granular material such as sand, gravel, or charcoal, which removes impurities. These layers may be several feet thick, in which case the filter is known as a deep-bed filter. Water purification plants may include fine particles of charcoal, known as activated carbon, in the deep-bed filter to absorb unpleasant-smelling gases. For separating smaller volumes of solution, a positive-pressure system—one that uses external pressure to push the liquid through the filter—may be used. Fluid may be introduced under pressure at one end of a horizontal tank, then forced through a series of vertical plates covered with thick filtering cloths that collect solids. In a vacuum filter, a vacuum (an area virtually devoid of matter, including air) is created beneath the solution to be filtered, and as a result, atmospheric pressure pushes the liquid through the filter. When the liquid is virtually freed of impurities, it may be passed through a second variety of filter, known as a clarifying filter. This type of filter is constructed of extremely fine-mesh wires or fibers designed to remove the smallest particles suspended in the liquid. Clarifying filters may also use diatomaceous earth, a finely powdered material produced from the decay of marine organisms. Gas filtration is used in a common appliance, the vacuum cleaner, which passes a stream of dust-filled air through a filtering bag inside the machine. The bag traps solid particles, while allowing clean air to pass back out into the room. This is essentially the same principle applied in air filters and even air conditioning and heating systems, which, in addition to regulating temperature, also remove dust, pollen, and other impurities from the air. Various industries use gas filtration, not only to purify the products released into the atmosphere, but also to filter the air in the workplace, as for instance in a factory room where fine airborne particles are a hazard of production. The gases from power plants that burn coal and oil are often purified by passing them through filtering systems that collect particles. Sewage treatment is a complex, multistage process whereby waste water is freed of harmful contents and rendered safe, so that it can be returned to the environment. This is a critical part of modern life, because when people congregate in cities, they generate huge amounts of wastes that contain disease-causing bacteria, viruses, and other microorganisms. Lack of proper waste management in ancient and medieval times led to devastating plagues in such cities as Athens, Rome, and Constantinople. Indeed, one of the factors contributing to the end of the Athenian golden age of the fifth century B.C. was a plague, caused by lack of proper sewage-disposal methods, that felled many of the city's greatest figures. The horrors created by improper waste management reached their apogee in 1347-51, when microorganisms carried by rats brought about the Black Death, in which Europe's population was reduced by one-third. Small amounts of sewage can be dealt with through aerobic (oxygen-consuming) decay, in which microorganisms such as bacteria and fungi process the toxins in human waste. With larger amounts of waste, however, oxygen is depleted and the decay mechanism must be anaerobic, or carried out in the absence of oxygen. For people who are not connected to a municipal sewage system, and therefore must rely on a septic tank for waste disposal, waste products pass through a tank in which they are subjected to anaerobic decay by varieties of microorganisms that do not require oxygen to survive. From there, the waste goes through the drain field, a network of pipes that allow the water to seep into a deep-bed filter. In the drain field, the waste is subjected to aerobic decay by oxygen-dependant microorganisms before it either filters through the drain pipes into the ground, or is evaporated. Municipal waste treatment is a much more involved process, and will only be described in the most general terms here. Essentially, large-scale sewage treatment requires the separation of larger particles first, followed by the separation of smaller particles, as the process continues. Along the way, the sewage is chemically treated as well. The separation of smaller solid particles is aided by aluminum sulfate, which causes these particles to settle to the bottom more rapidly. Through continual processing by filtration, water is eventually clarified of biosolids (that is, feces), but it is still far from being safe. At that point, all the removed biosolids are dried and incinerated; or they may be subjected to additional processes to create fertilizer. The water, or effluent, is further clarified by filtration in a deep-bed filter, and additional air may be introduced to the water to facilitate aerobic decay—for instance, by using algae. Through a long series of such processes, the water is rendered safe to be released back into the environment. However, wastes containing extremely high levels of toxins may require additional or different forms of treatment. "Case Study: Petroleum Distillation" (Web site). < (June 6, 2001). "Classification of Matter" (Web site). < 98/smith/smith2. ht ml (June 6, 2001). "Fractional Distillation" (Web site). < (June 6, 2001). "Introduction to Distillation" (Web site). < (June 6, 2001). Kellert, Stephen B. and Matthew Bleck. The Encyclopedia of the Environment. New York: Franklin Watts, 1999. Oxlade, Chris. Chemistry. Illustrated by Chris Fairclough. Austin, TX: Raintree Steck-Vaughn, 1999. Seuling, Barbara. Drip! Drop! How Water Gets to Your Tap. Illustrated by Nancy Tobin. New York: Holiday House, 2000. "Sewage Treatment" (Web site). < (June 6, 2001). Zumdahl, Steven S. Introductory Chemistry: A Foundation, 4th ed. Boston: Houghton Mifflin, 2000. Combustion is important in everyday life by which so many essential activities are powered, such as heating homes, generating electricity, and running vehicles. It provides the energy needed for cooking, transportation, and industrial processes. However, combustion also produces emissions and pollutants that can have negative impacts on health and the environment, making it important to use cleaner and more efficient combustion technologies. We come across several mixtures in our daily life. Sometimes, when they are valuable not as mixtures but as individual components, we employ several methods of separation to single out the beneficial ones. For instance, to clean the dirty water, we can use the filtration method to separate the solid impurities. In the case of liquid impurities, however, filtration is incapable of purification as the significant difference between the particle size of the impurities and the solution is not much. Nonetheless, there is another physical property that can assist in the separation process, i.e., the boiling point. Distillation is a process by which we can separate a mixture of two or more liquids based on differences in their boiling points; however, simple distillation is incapable of significant purification if the difference among the boiling points of the comprising components is less than 25 °C. For such cases, we can modify the simple distillation to fractional distillation by adding a fractionating column to the apparatus. In fractional distillation, vapors from the distilling flask are passed along the fractionating column, where plastic and glass trays improve the separation process by providing more surface area for condensation and evaporation. As the vapors rise in the fractionating column, at a certain height, components with high boiling points condense in-between the columns and return to the mixture, whereas the components with lower boiling points pass through the columns and are collected at the top. Fractional distillation also saves the loss of time and efficiency that one can encounter during multiple simple redistillations. In theory, adding more trays or plates inside the fractionating column can improve the purification process, but this can also increase the time required for separation. There are several industrial applications of fractional distillation that provide us with various products that we use in our daily lives. Let' take a look at few examples of fractional distillation in everyday life. 1. Oil Refining If you ever have the chance of visiting an oil refinery, you can witness one of the most technologically advanced fractionating columns present on our planet. The fuel that powers our vehicle's engine is found deep down beneath the earth's surface and sea-beds as crude oil, also known as petroleum. It is a naturally occurring yellowish black liquid that is composed of hydrocarbon deposits and other organic materials. 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From hot to cold (largest hydrocarbons to smallest), the order of fractions is residue (used to make bitumen), fuel oil, diesel, kerosene, naphtha, gasoline, and refinery gas. 2. Alcohol Manufacturing Alcohol has been an important part of human culture for ages, with the earliest known evidence dating back to 9000 years ago. In fact, some human DNA studies suggest that our ancestors developed the ability to metabolize ethanol (only consumable alcohol) around 10 million years ago, long before we were even humans. From soft alcoholic beverages like beers and wines to hard alcohols like whiskey and vodka, alcohol comes in many flavors and can be found almost anywhere around the world. The basic step of making alcohol is fermentation- the process of breaking down sugars into ethanol and carbon dioxide. The carbon dioxide gas is often allowed to escape from the solution. Levels of alcohol above 18 or 19% are usually toxic to the yeast and lead to the death of the cells. Further increase in the alcohol content of the liquid is done by distillation. In fact, distilled spirits are all alcoholic beverages in which the concentration of ethyl alcohol has been increased above that of the original fermented mixture by distillation. The principle of alcohol distillation is based upon the different boiling points of alcohol (78.5 °C, or 173.3 °F) and water (100 °C, or 212 °F). When a liquid containing ethyl alcohol is heated to a temperature above 78.5 °C but below 100 °C and the vapor coming off the liquid is condensed, the condensate will have a higher alcohol concentration or strength. Fractional distillation can further concentrate the alcohol, resulting in a stronger liquor with up to 80% v/v alcohol. 3. Air Separation Air is a mixture made up of approximately 78% nitrogen, 21% oxygen, 0.93% argon, 0.378% carbon dioxide, and other trace gases, including water vapor and other noble gases. Most of these gases have several commercial and industrial values for which they can be extracted directly from the air by the process of liquefaction followed by fractional distillation. The process starts with ambient air filtration, in which the air goes through a filter that removes any dust particles. The filtered air is then compressed approximately up to six bars for liquefaction. During compression, most of the water vapors present in the air are condensed out. The remaining water vapors are removed along with carbon dioxide when the air passes through a mesh of molecular sieves. This is done to avoid the formation of ice and dry ice during liquefaction. The purified air is then passed through a heat exchanger that includes a network of pipes carrying liquid nitrogen. The cold, compressed air is then allowed to expand rapidly, thus cooling even further to -200 °C, where most of the air is liquefied. The liquefied air is then passed to a fractional distillation tower which primarily contains three distilling columns. The separation of the liquefied air is based on the different boiling points of its components. After the liquefied air enters the first distillation column, the temperature is gently raised to -176 °C, which causes nitrogen to evaporate and escape the fractionating tower. Similarly, when the desired level of purity is reached, the gases can also be taken out of the fractionating column and can either be supplied to the consumer directly in the gas form or temporarily stored in the tank in liquid form. 4. Perfume Manufacturing The scents from nature have long been part of human attire, but have you ever wondered how these scents from flowers and plants end up in spray bottles? The whole process is known by the name fragrance extraction in the industrial sectors. 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On the industrial scale, the lowest quality of silicon is metallurgical grade silicon (MGS). The source material for making MGS is quartzite (rock of pure silicon oxides). During the production, the silicon is purified by removing the oxides. It is achieved by moving the quartzite into a furnace where it is melted using an electrode. The quartzite is heated up to the temperature of 1900 °C and then gets mixed with carbon so that the oxygen leaves the furnace as carbon monoxide. The molten silicon is then drawn from the furnace and then purified further. The powder of MSG is exposed in the reactor with HCl at elevated temp and in the presence of a catalyst. The silicon reacts with HCl and forms trichlorosilane (SiHCl}_{3}). The TCS is liquefied and then passed through a fractional distillation tower where the impurities are removed based on their boiling point. 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The original solvent is distilled off and can be collected at the top of the fractionating column, whereas the swap solvent along with the active pharmaceutical ingredient is collected at the bottom. Solvent swap processes can be made more efficient by reducing the amount of solvent used and reducing energy consumption while keeping the same level of purification. This can be accomplished by monitoring solvent concentrations in real-time during the swap. Fractional distillation is used in pharmacy for a variety of purposes, including the separation of alkanes, the production of pharma-grade alcoholic solutions, and even the breakdown of cannabis for its oil and enhancement of THC concentration. Purification of alcohol, desalination, crude oil refining, and creating liquefied gases from air are just a few examples of uses for distillation. Where does distilled come from? Distillation is used to separate liquids from nonvolatile solids, such as alcoholic liquors and fermented materials, or two or more liquids with different boiling points, such as in the separation of gasoline, kerosene, and lubricating oil from crude oil. In everyday life, how does simple distillation work? In the production of hard liquor, simple distillation is used to separate salt from seawater, sugar from water, and ethanol from water. What is the purpose of distilled water? Making ice cubes, soup, coffee, tea, pasta, rice, baby formula, juices, Kool-Aide®, and simply healthy drinking water are among the other uses of distilled water. Unfortunately, unless you use pure distilled water on a regular basis, the contaminants found in tap water will continue to enter your body. In everyday life, what are some examples of separating mixtures? Answer: Decanting oil and vinegar is a common example. The oil will float on top of the water as a mixture of the two liquids settles, allowing the two components to be separated. Decantation can also be used to separate kerosene and water. Why is distillation so important in our daily lives? Production of Gasoline The production of fuel is one of the most common industrial uses of distillation. Fractional distillation, which involves separating all of the components in a mixture, can help refine crude oils to make fuel from usable components, such as gasoline and diesel. What are some examples of distillation? Distillation ExamplesSalt water is transformed into fresh water by distillation. Distillation separates various types of fuel from crude oil, such as gasoline. Distillation is the process of making alcohol. The alcohol is separated from the rest of the mixture before being collected in a concentrated form. What exactly is normal distillation? Simple distillation is a method of separating two liquids with different boiling points. The vapors that form in the component of the mixture that boils at the lowest temperature will be richest as the liquid being distilled is heated. Which distillation-based mixtures can be separated? Fractional distillation is a process of separating a liquid from a mix of two or more liquids. Fractional distillation, for example, can separate liquid ethanol from a mixture of ethanol and water. Because the liquids in the mixture have different boiling points, this method works. What are the advantages of distillation? Distillation has both advantages and disadvantages, as it is a water softening process that involves heating the water to be softened. It's a cost-effective water softening technique for smaller spaces. It's fairly inexpensive. It can also be repurposed. The distilled water may contain some of the undesirable elements. What are the advantages of distillation? Metals (lead), nitrate, and other inorganic particles like iron and hardness are effectively removed from a con- taminated water supply by distillation. Microorganisms, such as bacteria and viruses, are also killed by the boiling process. Oxygen and some trace metals are removed from water by distillation. What is the purpose of distillation? Distillation is the process of purifying a compound by distinguishing it from non-volatile or less volatile materials. When a mixture is distilled, the components frequently separate from a pure distillate. In the context of distillation, what are the significance of distilled water? : water that has been devoid of dissolved or suspended solids, as well as from organisms, by distillation (for medical or chemical purposes) What is distillation's basic principle? Distillation's principle entails heating the liquid to form a vapour, then cooling it to return the liquid. It's used to separate components of a mixture made up of two miscible liquids that boil without decomposition but have enough difference in boiling points to be separated. What is the most common use for simple distillation? Simple distillation is used to purify drinking water of undesirable chemicals and minerals like salt, which is the most common purpose. What are the three distillation steps? Fermentation, distillation, and finishing are the three parts of the alcohol distillation process. What are the five advantages of distillation? 7 Health Benefits of Using a Water Distiller Bacteria and Vibrations are exempt from distillation. Carcinogenic chemicals are not present in distilled water. Pure water is distilled water. Distilled water aids in the body's self-cleaning. What are the drawbacks of distillation? Simple Distillation Impurities' Disadvantages Because the simple distillation process is only boiled and recondensed once, the product's final composition will match that of the vapor, resulting in significant impurities. Azeotropic Mixtures, Energy Consumption, and Chemical Reactions Is drinking distilled water beneficial to your kidneys? Distilled water purifies the body and promotes healthy kidney function. What are the advantages of multistage flash distillation? A multi-stage flash distillation system has the following advantages: 1) a low operating cost when waste heat is used in the distillation process; 2) feedwater quality is less important when compared to reverse osmosis system technology; and 3) the multi-stage flash system has a high gain output ratio. What impact does distillation have on the environment? Cryogenic distillation is a commercially viable separation, but it consumes more than 20 Gigajoules of energy per ton of ethylene produced. This energy consumption is linked to a significant reduction in greenhouse gas emissions and the depletion of non-renewable energy resources. What is the name of the pure liquid collected after distillation? The distillation device, also known as a still, consists of a reboiler or pot that heats the source material, a condenser that cools the heated vapor back to its liquid state, and a receiver where the concentrated or purified liquid, known as the distillate, is collected. Iodine and salt are separated using which method. The sublimation process separates it. When the iodine and salt mixture is heated, the iodine sublimates while the salt is left. Fractional distillation is a significant separation technique widely used in chemistry and industrial applications. It is crucial in separating a mixture of liquids into its individual components based on differences in boiling points. This article delves into the principles underlying fractional distillation, its processes, equipment involved, and its diverse applications across various industries.Principles of Fractional DistillationAt the core of fractional distillation is the fundamental principle that different substances have distinct boiling points, which is the temperature at which a substance transitions from a liquid to a gas. In a mixture of liquids, the component with the lowest boiling point will vaporize first when heat is applied. By carefully controlling temperature and pressure during the heating process, it becomes possible to separate and collect these vapors.Boiling PointThe boiling point of a liquid is influenced by several factors, including atmospheric pressure. At higher pressures, boiling points increase; conversely, reducing pressure lowers boiling points. This concept allows for fractional distillation to be adapted for different conditions, making it versatile in various applications. Additionally, the purity of the components can be enhanced through multiple distillation cycles.Vapor-Liquid EquilibriumThe separation process is governed by vapor-liquid equilibrium (VLE), which describes the balance between the vapor phase and liquid phase of a substance at a given temperature and pressure. When a liquid mixture is heated, some components vaporize while others remain in liquid form. The composition of the vapor phase will differ from that of the liquid phase based on the relative volatility of each component, allowing for effective separation during condensation.The Process of Fractional DistillationThe fractional distillation process typically involves several steps:Heating: The liquid mixture is heated in a distillation flask or column until it reaches its boiling point.Vaporization: As components vaporize, they ascend through a column packed with materials (known as packing) designed to facilitate multiple condensation-vaporization cycles.Separation: As vapors rise through the column, they cool slightly due to interactions with cooler surfaces or packing material causing them to condense back into liquid at various heights within the column.Collection: The condensed liquids (distillates) are collected at different collection points based on their boiling points.Repetition: This cycle may be repeated multiple times to achieve higher purity levels for each component.Equipment UsedSeveral key pieces of equipment are integral to conducting fractional distillation effectively:Distillation Flask: The initial container where the liquid mixture is heated.Fractionating Column: A vertical column connected to the distillation flask, packed with materials that promote efficient separation.Condenser: A cooling apparatus that allows vapors to condense back into liquids after they exit the fractionating column.Receiving Flask: Containers placed at various collection points to collect separated liquids.Applications of Fractional DistillationFractional distillation finds extensive application across many sectors due to its effectiveness in separating mixtures with close boiling points. Here are some prominent examples:1. Petroleum RefiningOne of the most significant uses of fractional distillation occurs in petroleum refining. Crude oil consists of numerous hydrocarbons with varying boiling points. During refining, crude oil undergoes fractional distillation in large columns known as crude distillation units (CDUs). This process separates crude oil into valuable fractions such as gasoline, kerosene, diesel fuel, and lubricating oils based on their boiling ranges.2. Chemical ProductionIn chemical manufacturing, fractional distillation plays an essential role in producing high-purity solvents and chemicals. For example, acetone and ethanol can be isolated from their mixtures through fractional distillation processes within chemical plants. Achieving high levels of purity ensures that chemicals meet industry standards for quality and safety.3. Alcohol DistillationThe production of alcoholic beverages employs fractional distillation to separate ethanol from fermentation mixtures. Distillers use pot stills or column stills to achieve varying levels of alcohol content depending on desired beverage characteristics. By controlling temperature and pressure during this process, manufacturers can create spirits such as whiskey, rum, and vodka with distinct flavors and aromas.4. Essential Oil ExtractionIn the fragrance industry, fractional distillation assists in extracting essential oils from plants while maintaining their complex chemical structures. This method allows for obtaining high-quality oils used in perfumes and cosmetics while preserving their aromatic properties.5. Air SeparationAir separation plants utilize fractional distillation to produce industrial gases like oxygen, nitrogen, and argon from air. By cooling air to extremely low temperatures until it liquefies, operators can separate these gases based on their different boiling points utilizing large-scale fractionating columns.6. Pharmaceutical IndustryThe pharmaceutical sector also benefits from fractional distillation to purify compounds used in drug development and manufacturing processes. High-purity solvents are vital for creating pharmaceuticals that could affect efficacy or safety.Advantages and LimitationsAdvantagesHigh Purity: Fractional distillation can yield highly pure components when executed correctly.Scalability: This technique can be scaled up or down depending on production needs—from laboratory settings to large industrial operations.Versatility: It can be adapted for various applications across multiple industries.LimitationsEnergy Intensive: The process requires significant energy input for heating and maintaining specific temperature controls.Complexity: Achieving effective separations may require complex setups with precise control over conditions.Not Effective for All Mixtures: Fractional distillation is most efficient for mixtures containing components with significantly different boiling points; closely boiling substances may require additional purification steps.ConclusionFractional distillation is an indispensable technique with vast implications across industries ranging from energy production to food and beverage processing. Its ability to accurately separate complex mixtures based on boiling point differences makes it essential for producing high-purity chemicals critical for various applications. As technology advances, further innovations may enhance efficiency and broaden its applications even more—ultimately solidifying its status as a cornerstone method in both industrial chemistry and daily life pursuits alike. Chemical processing industries face complex challenges in separating liquid mixture components. As equipment manufacturers, we understand the technical demands of separation processes. Our years of manufacturing experience reveal the importance of reliable separation units. Fractional distillation offers a reliable solution for separating components in industrial processes. Modern manufacturing incorporates advanced control systems to maintain optimal separation efficiency. This comprehensive guide explores working principles, equipment setup, and operational procedures. Readers will discover essential components, maintenance requirements, and industry-specific applications of fractional distillation units.Understanding the Separation ProcessThe separation process involves heating a mixture until it reaches different boiling points. Industries employ this technique to separate complex mixtures into their components.How does Fractional Distillation Work?The process begins when heat transforms liquid components into vapor at specific temperatures. Understanding how fractional distillation works requires knowledge of vapor pressure and boiling point differences. The vapor rises through a column while cooler components condense and flow downward. Different components separate based on their unique molecular weights and boiling points.Temperature gradients inside the column enable efficient component separation at each level.Components of a Fractional Distillation UnitA reboiler maintains a consistent heat supply at the bottom of the unit. The fractionating column contains trays or packing material for vapor-liquid contact enhancement. The condenser at the top converts purified vapor back into liquid form.Collection vessels gather separated components at different height levels of the column.The Fractional Distillation ProcessContinuous cycles of vaporization and condensation occur within the distillation column. Extraction in chemistry principles guides these separation cycles for optimal results. The process repeats until the desired separation purity levels meet industry standards. The plates in the column act as steps where separation occurs repeatedly.Precise temperature control ensures consistent product quality throughout the separation operation.Essential Components and SetupThe setup consists of specialized components designed to achieve precise separation of mixtures. Modern facilities integrate advanced control systems to maintain optimal performance during the separation.Primary Fractional Distillation EquipmentThe fractionating column serves as the heart of fractional distillation equipment systems. The column height determines the degree of separation achieved during the process.Reboilers provide controlled heat input to maintain steady vapor flow upward.Trays or packing materials create surface area for vapor-liquid contact inside the columns.Supporting EquipmentHeat exchangers maintain proper temperature gradients throughout the entire fractional distillation equipment. The reflux drum collects condensed vapors before redistributing them back into the column.Pumps circulate liquids between different sections of the distillation unit.Control valves regulate flow rates to ensure stable operation conditions.Safety EquipmentRelief valves protect the system from dangerous pressure buildup during operation. Modern units incorporate emergency shutdown systems to prevent equipment damage or failure.Pressure monitoring devices alert operators to abnormal operating conditions.Temperature sensors detect unexpected changes in different column sections.Operational ProceduresProper operational procedures ensure the safe and efficient separation of complex liquid mixtures. The setup phase requires careful attention to equipment conditions and safety protocols. Operators must verify all connections and seals before starting the distillation process.Setting Up the Fractional Distillation UnitSystem preparation begins with a thorough inspection of all components for potential damage. The feed mixture enters the column at a predetermined point based on design specifications. Initial heating starts gradually to prevent thermal shock to the system components.All valves must be checked for proper positioning before introducing the feed.Temperature controllers require calibration to maintain precise heating throughout the process.Pressure gauges need verification to ensure they display accurate readings.Monitoring and ControlOperators track multiple parameters through advanced control systems during the distillation process. Regular sampling helps maintain product quality and optimization of operating conditions. The control room displays real-time data from various sensors throughout the unit.Temperature profiles must stay within specified ranges at different column heights.Pressure readings require constant monitoring to prevent system instability.Flow rates need adjustment based on product quality requirements.Operators document all parameter changes for process optimization and troubleshooting.Applications and BenefitsIndustries worldwide rely on fractional distillation for separating complex mixtures into pure components. This technique enables the production of essential products used in daily life.Industrial Uses of Fractional DistillationThe petroleum industry separates crude oil into gasoline, diesel, and other valuable products. Chemical manufacturers purify raw materials for producing plastics, pharmaceuticals, and other chemicals.Oil refineries process millions of barrels daily through large distillation columns.Beverage producers create spirits of specific alcohol content using this method.Food industries separate essential oils and flavoring compounds for various products.Laboratory ApplicationsResearch laboratories use smaller distillation units to purify compounds for experimental work. Universities teach distillation principles using specialized glass apparatus for hands-on learning.Scientists analyze unknown mixtures by separating their individual components.Quality control labs verify product purity through precise distillation techniques.Process AdvantagesThe process allows continuous operation without interruption for extended production periods. Companies achieve high product purity while maintaining consistent quality standards.Multiple products can be obtained from a single separation process.The method reduces waste by recovering valuable components from mixtures.Maintenance and SafetyRegular maintenance schedules ensure reliable operation and prevent unexpected equipment failures. Safety protocols protect operators while maintaining optimal performance of the distillation system.Operating the Fractional Distillation UnitThe unit requires proper startup procedures to maintain consistent product quality standards. Operators monitor critical parameters to ensure safe operation within design specifications.Temperature gauges need regular calibration to maintain accurate readings during operation.Pressure relief valves undergo periodic testing to ensure proper emergency response.Best Practices for the Fractional Distillation ProcessRegular cleaning prevents fouling and maintains efficient heat transfer in system components. Maintenance teams inspect seals and gaskets to prevent potential leaks.Equipment inspection schedules must align with manufacturer recommendations.Documentation helps track maintenance history and identify recurring issues.Troubleshooting GuideOperators check specific indicators when product quality deviates from standard specifications. System alarms provide early warning signs of potential operational problems.Unusual pressure readings often indicate blockages in the column.Temperature fluctuations may signal problems with heating element performance.Sudden changes in flow rates require immediate investigation of pump conditions.ConclusionFractional distillation remains essential for modern industrial processes across various manufacturing sectors. In a chemical process plant, the process delivers high-purity products while maintaining efficiency in production operations.Industries continue to improve distillation technology for better separation and energy efficiency.Regular maintenance and operator training ensure safe and reliable system operation.Modern control systems enhance process automation and product quality consistency.Understanding proper procedures and safety protocols maximizes the benefits of distillation units. This separation method will continue evolving to meet future industrial production demands.FAQs1. What is fractional distillation? Fractional distillation separates liquid mixtures based on different boiling points of components. The process uses a column with internal trays to achieve pure component separation.2. What is the principle of fractional distillation? The principle relies on heating mixtures until components vaporize at specific temperatures. Components with lower boiling points rise first through the distillation column.3. What are applications of fractional distillation? Primary applications include:Petroleum refineries separate crude oil into fuels and other productsChemical industries produce pure solvents and raw materialsPharmaceutical companies purify medical compounds and ingredientsResearch laboratories separate compounds for analysis and study We come across several mixtures in our daily life. Sometimes, when they are valuable not as mixtures but as individual components, we employ several methods of separation to single out the beneficial ones. For instance, to clean the dirty water, we can use the filtration method to separate the solid impurities. In the case of liquid impurities, however, filtration is incapable of purification as the significant difference between the particle size of the impurities and the solution is not much. Nonetheless, there is another physical property that can assist in the separation process, i.e., the boiling point. Distillation is a process by which we can separate a mixture of two or more liquids based on differences in their boiling points; however, simple distillation is incapable of significant purification if the difference among the boiling points of the comprising components is less than 25 °C. For such cases, we can modify the simple distillation to fractional distillation by adding a fractionating column to the apparatus. In fractional distillation, vapors from the distilling flask are passed along the fractionating column, where plastic and glass trays improve the separation process by providing more surface area for condensation and evaporation. As the vapors rise in the fractionating column, at a certain height, components with high boiling points condense in-between the columns and return to the mixture, whereas the components with lower boiling points pass through the columns and are collected at the top. Fractional distillation also saves the loss of time and efficiency that one can encounter during multiple simple redistillations. In theory, adding more trays or plates inside the fractionating column can improve the purification process, but this can also increase the time required for separation. There are several industrial applications of fractional distillation that provide us with various products that we use in our daily lives. Let' take a look at few examples of fractional distillation in everyday life. 1. Oil Refining If you ever have the chance of visiting an oil refinery, you can witness one of the most technologically advanced fractionating columns present on our planet. 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It is achieved by fractional distillation. The swap solvent is mixed with the original solvent mixture and then loaded to the fractionating column. The original solvent is distilled off and can be collected at the top of the fractionating column, whereas the swap solvent along with the active pharmaceutical ingredient is collected at the bottom. Solvent swap processes can be made more efficient by reducing the amount of solvent used and reducing energy consumption while keeping the same level of purification. This can be accomplished by monitoring solvent concentrations in real-time during the swap. Fractional distillation is used in pharmacy for a variety of purposes, including the separation of alkanes, the production of pharma-grade alcoholic solutions, and even the breakdown of cannabis for its oil and enhancement of THC concentration. Distillation is a method for separating components from a liquid mixture by taking advantage of their boiling point differences. It is a liquid-gas separation and involves the vaporization and subsequent condensation of each liquid.Here are some benefits of fractional distillation over simple distillation. Common types of distillation are simple distillation, fractional distillation, vacuum distillation and steam distillation. They differ mainly in the apparatus setup and their applications. Fractional distillation is more efficient than simple distillation in separation due to a high number of theoretical plates. It is an important process in chemistry, industry and food science. Uses of fractional distillation include processes such as desalination, crude oil refining and chemical purification. Simple distillation is effective only for liquids whose boiling points differ by more than 30 °C. On the contrary, fractional distillation is suitable for more challenging separations, where the boiling point difference is less than 30 °C. To understand how fractional distillation works, one needs to know Raoult's law, which states the vapor pressure of a solution is dependent on the vapor pressure of each component and the mole fraction of the component in the solution. While keeping the pressure constant, one can generate a temperature-composition diagram. For a pentane-hexane mixture at one atmospheric pressure, an initial liquid mixture (L1) of hexane (bp = 69°C) and pentane (bp = 36°C) boils at 48 °C to produce vapor V1, which condenses to form L2. After the first vaporization-condensation cycle, the percentage of pentane has increased from 48 percent to 73 percent. L2 then vaporizes into V2, resulting in a further enrichment in pentane. L5, which is the liquid obtained after four cycles, is almost pure pentane. Each vaporization-condensation cycle, also called theoretical plate, yields a purer solution of the more volatile component. In a fractional distillation setup, a fractionating column is typically placed between the distilling flask and head to increase the separation of liquids from the mixture. These columns have a larger surface area on which liquid-vapor equilibria can occur and thus more theoretical plates. Examples of fractionating columns are Vigreux and glass beads columns, which have six to eight theoretical plates. In a simple distillation, a fractionating column is not used, and vapor from the distilling flask goes straight into condensation. It only has one or two theoretical plates, so it would not be effective for the separation of mixtures like L1, which requires more than four vaporization-condensation cycles to purify. Fractional distillation is used in oil refineries to separate crude oil into hydrocarbons, which have different carbon numbers, boiling points and applications. Some of the isolated products include gasoline, diesel, oils and waxes. This method is also used in chemical plants, natural gas processing and cryogenic air separation plants. Fractional distillation is also a common technique in organic chemistry laboratories. For example, cyclopentadiene is usually sold as dicyclopentadiene because cyclopentadiene can spontaneously dimerize to form dicyclopentadiene. Fractional distillation is often used to revert dicyclopentadiene back to cyclopentadiene. Fractional distillation alone is not harmful to the environment. In fact, fractional distillation converts crude oil, otherwise unusable, into more valuable products. However, petroleum refineries, where fractional distillation of crude oil is performed, can be a source of pollution if the side products are not treated properly according to regulations. Refineries are a major source of air pollutants such as particulate matter, nitrogen oxides and carbon monoxide. Wastewater from the refineries also causes water and land pollution as it settles down in aquifers, soil and groundwater. Encyclopedia Britannica: Distillation LibreTexts: Fractional Distillation Luo, Lan. "The Advantages Of Fractional Distillation" sciencing.com, . 30 March 2020. APA Luo, Lan. (2020, March 30). The Advantages Of Fractional Distillation. sciencing.com. Retrieved from Chicago Luo, Lan. The Advantages Of Fractional Distillation last modified March 24, 2022. , the free encyclopedia that anyone can edit. 110,331 active editors 7,023,126 articles in English School in Sketty, Swansea, photographed in 1854 The period between 1701 and 1870 saw an expansion in access to formal education in Wales, though schooling was not yet universal. Several philanthropic efforts were made to provide education to the poor during the 18th century. In the early to mid-19th century, charitable schools were established to provide a basic education. Private schools aimed at the working classes also existed. State funding was introduced to schools from 1833. Some use of the Welsh language was made in 18th-century philanthropic education, at a time when most agricultural workers in Wales spoke only Welsh. In the 19th century, public opinion was keen for children to learn English, and many schools punished children for speaking Welsh, though studies found such methods ineffective. The government did little to promote bilingual education. Grammar schools experienced difficulties and, by the end of the period, secondary education was limited. Dissenter academies and theological colleges offered higher education. (Full article...) Recently featured: White dwarf Battle of Groix Scott Carpenter Archive By email More featured articles About T. brachyglossum seedheads ... that Taraxacum brachyglossum (pictured) can reproduce both sexually and asexually, depending on environmental conditions? ... that although Frederick Rondel was taught to paint by a French king's court painter, he chose to depict American landscapes like the Adirondack Mountains? ... that a 19th-century water-pumping station is now a wedding venue? ... that Washington University in St. Louis holds one of the few surviving printed broadsides of the United States Declaration of Independence? ... that Jerzy Broszkiewicz, a louse-feeder during World War II, later became a writer of youth literature and drama? ... that Lorde wrote a song about herself titled "Man of the Year" the day after attending GQ's "Men of the Year" party in 2023? ... that American football player Curtis Burrow, the fourth different kicker used by the Green Bay Packers in 1988, played one game before being released? ... that Bukit Brown Cemetery is believed to be the largest Chinese cemetery outside of China, with over 100,000 burials? ... that an eight-week UK number-one single co-written by Audrey Hobert has a sexually explicit version? Archive Start a new article Nominate an article Vera Rubin Observatory The Vera C. Rubin Observatory (pictured) in Chile releases the first light images from its new 8.4-meter (28 ft) telescope. In basketball, the Oklahoma City Thunder defeat the Indiana Pacers to win the NBA Finals. An attack on a Greek Orthodox church in Damascus, Syria, kills at least 25 people. The United States conducts military strikes on three nuclear facilities in Iran. In rugby union, the Crusaders defeat the Chiefs to win the Super Rugby Pacific final. Ongoing: Gaza war Iran–Israel war Russian invasion of Ukraine timeline Sudanese civil war timeline Recent deaths: Lucien Nedzi Anne Burrell Frederick W. Smith Ron Taylor Mohammad Kazemi Marita Camacho Quirós Nominate an article June 25 Original rainbow flag 1658 – Anglo-Spanish War: The largest battle ever fought on Jamaica, the three-day Battle of Rio Nuevo, began. 1910 – The United States Congress passed the Mann Act, which prohibited the interstate transport of females for "immoral purposes". 1944 – World War II: U.S. Navy and Royal Navy ships bombarded Cherbourg, France, to support U.S. Army units engaged in the Battle of Cherbourg. 1978 – The rainbow flag (original version pictured) representing gay pride was first flown at the San Francisco Gay Freedom Day parade. 2009 – Singer Michael Jackson died as a result of the combination of drugs in his body. Giovanni Battista Riccioli (d. 1671)Eloísa Díaz (b. 1866)George Michael (b. 1963)Farrah Fawcett (d. 2009) More anniversaries: June 24 June 25 June 26 Archive By email List of days of the year About 1795 Turban Head eagle with original reverse 1797 Turban Head eagle with heraldic eagle reverse The Turban Head eagle was a ten-dollar gold piece, or eagle, struck by the United States Mint from 1795 to 1804. The piece was designed by Robert Scot, and was the first in the eagle series, which continued until the Mint ceased striking gold coins for circulation in 1933. The common name is a misnomer; Liberty does not wear a turban but a cap, believed by some to be a pileus or Liberty cap: her hair twisting around the headgear makes it appear to be a turban. The number of stars on the obverse was initially intended to be equal to the number of states in the Union, but with the number at 16, that idea was abandoned in favor of using 13 stars in honor of the original states. The initial reverse, featuring an eagle with a wreath in its mouth, proved unpopular and was replaced by a heraldic eagle. Increases in the price of gold made it profitable for the coins to be melted down, and in 1804, President Thomas Jefferson ended coinage of eagles; the denomination was not struck again for circulation for more than 30 years. These Turban Head eagles are in the National Numismatic Collection at the National Museum of American History. Coin design credit: United States Mint; photographed by Jaclyn Nash Recently featured: Springbok Geraldine Ulmar Shah Mosque (Isfahan) Archive More featured pictures Community portal – The central hub for editors, with resources, links, tasks, and announcements. Village pump – Forum for discussions about Wikipedia itself, including policies and technical issues. Site news – Sources of news about Wikipedia and the broader Wikimedia movement. Teahouse – Ask basic questions about using or editing Wikipedia. Help desk – Ask questions about using or editing Wikipedia. Reference desk – Ask research questions about encyclopedic topics. Content portals – A unique way to navigate the encyclopedia. Wikipedia is written by volunteer editors and hosted by the Wikimedia Foundation, a non-profit organization that also hosts a range of other volunteer projects: CommonsFree media repository MediaWikiWiki software development Meta-WikiWikimedia project coordination WikibooksFree textbooks and manuals WikidataFree knowledge base WikinewsFree-content news WikiquoteCollection of quotations WikisourceFree-content library WikispeciesDirectory of species WikiversityFree learning tools WikivoyageFree travel guide WiktionaryDictionary and thesaurus This Wikipedia is written in English. Many other Wikipedias are available; some of the largest are listed below. 1,000,000+ articles العربية Deutsch Español فارسی Français Italiano Nederlands 日本語 Polski Português Русский Svenska Українська Tiếng Việt 中文 250,000+ articles Bahasa Indonesia Bahasa Melayu Bân-lâm-gú Български Català Čeština Dansk Eesti Ελληνικά Esperanto Euskara עברית Հայերեն Magyar Norsk bokmål Română Simple English Slovenčina Srpski Srpskohrvatski Suomi Türkçe Oʻzbekcha 50,000+ articles Asturianu Azərbaycanca [illegible] Bosanski کوردی Frysk Gaeilge Galego Hrvatski ქართული Kurdî Latviešu Lietuvių [illegible] Македонски [illegible] Norsk nynorsk [illegible] Shqip Slovenščina [illegible] [illegible] اردو Retrieved from " 2 This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "1658" – news · newspapers · books · scholar · JSTOR (January 2016) (Learn how and when to remove this message) Calendar year Years Millennium 2nd millennium Centuries 16th century 17th century 18th century Decades 1630s 1640s 1650s 1660s 1670s Years 1655 1656 1657 1658 1659 1660 1661 vte January 30: Swedish troops cross the frozen waters of the Danish straits on foot in the March Across the Belts 1658 by topic Arts and science Architecture Art Literature Music Science Leaders State leaders Colonial governors Religious leaders Birth and death categories Births – Deaths Establishments and disestablishments categories Establishments – Disestablishments Works category Works vte 1658 in various calendarsGregorian calendar1658MDCLVIIIAb urbe condita2411Armenian calendar1107ԹՎ ՌՃԷAssyrian calendar6408Balinese saka calendar1579–1580Bengali calendar1064–1065Berber calendar2608English Regnal year9 Cha. 2 – 10 Cha. 2(Interregnum)Buddhist calendar2202Burmese calendar1020Byzantine calendar7166–7167Chinese calendar丁酉年 (Fire Rooster)4355 or 4148 — to —戊戌年 (Earth Dog)4356 or 4149Coptic calendar1374–1375Discordian calendar2824Ethiopian calendar1650–1651Hebrew calendar5418–5419Hindu calendars - Vikram Samvat1714–1715 - Shaka Samvat1579–1580 - Kali Yuga4758–4759Holocene calendar11658Igbo calendar658–659Iranian calendar1036–1037Islamic calendar1068–1069Japanese calendarMeireki 4 / Manji 1(万治元年)Javanese calendar1580–1581Julian calendarGregorian minus 10 daysKorean calendar3991Minguo calendar254 before ROC民前254年Nanakshahi calendar190Thai solar calendar2200–2201Tibetan calendar阴火鸡年(female Fire-Rooster)1784 or 1403 or 631 — to —阳土狗年(male Earth-Dog)1785 or 1404 or 632 June 14: Battle of the Dunes 1658 (MDCLVIII) was a common year starting on Tuesday of the Gregorian calendar and a common year starting on Friday of the Julian calendar, the 1658th year of the Common Era (CE) and Anno Domini (AD) designations, the 658th year of the 2nd millennium, the 58th year of the 17th century, and the 9th year of the 1650s decade. As of the start of 1658, the Gregorian calendar was 10 days ahead of the Julian calendar, which remained in localized use until 1923. Calendar year January 13 – Edward Sexby, who had plotted against Oliver Cromwell, dies in the Tower of London.[1] January 30 – The "March Across the Belts" (Tåget över Bält), Sweden's use of winter weather to send troops across the waters of the Danish straits at a time when winter has turned them to ice, begins. Within 17 days, Sweden's King Karl X Gustav leads troops across the ice belts to capture six of Denmark's islands as Swedish territory. February 5 – Prince Muhi al-Din Muhammad, one of the sons of India's Mughal, Emperor Shah Jahan, proclaims himself Emperor after Jahan names Muhi's older brother, Dara Shikoh, as regent, and departs from Aurangabad with troops. February 6 – Swedish troops of Charles X Gustav of Sweden cross The Great Belt in Denmark, over frozen sea.[2] March 8 (February 26 OS) – The peace between Sweden and Denmark-Norway is concluded in Roskilde by the Treaty of Roskilde, under which Denmark is forced to cede significant territory. This leads to Sweden reaching its territorial height during its time as a great power. April 15 – In India, the Battle of Dharmat is fought in the modern-day state of Madhya Pradesh between rival claimants to the throne of the Mughal Empire. Prince Muhi al-Din Muhammad, the son of the Emperor Shah Jahan, leads 30,000 men in a triumph over 22,000 troops led by Jaswant Singh of Marwar and Ratan Singh Rathore. Despite heavy losses, with more than 11,000 casualties, Prince Muhi, who has adopted the name Aurangzeb, continues toward Samugarh and Agra and captures the throne at the end of July. April 16 – In Skåneland, a region recently ceded by Denmark to the Swedish Empire, representatives of the nobility of the provinces of Blekinge, Halland and Scania gather at the Scanian city of Malmö to swear their allegiance to King Charles X Gustav of Sweden. May 1 – Hydriotaphia, Urn Burial and The Garden of Cyrus are published by Thomas Browne in England. May 29 – Aurangzeb wins the Battle of Samugarh as Indian Mughal regent Dara Shikoh makes a last effort to defend the Mughal capital Agra. June 3 – Pope Alexander VII appoints François de Laval vicar apostolic of New France. June 14 – Anglo-Spanish War (1654–60) and Franco-Spanish War (1635–59): In the Battle of the Dunes, a Spanish force attempting to lift a siege of Dunkirk is defeated by the French and English. England is then given Dunkirk, for its assistance in the victory. June 25–27 – In the Battle of Rio Nuevo, part of the Anglo-Spanish War, a Spanish invasion force fails to recapture Jamaica from the English. July 2 – The Siege of Toruń begins in Poland as troops of the Polish–Lithuanian Commonwealth and of Austria seek to recapture the city of Toruń from a garrison of the Swedish Army. Within six months, the Swedish occupiers surrender. July 18 – Prince Leopold of the House of Habsburg, son of the late Ferdinand III, is elected as the new Holy Roman Emperor. July 31 – After Shah Jahan completes the Taj Mahal, his son Aurangzeb deposes him as ruler of the Mughal Empire. July – Šarhūda's Manchu fleet annihilates Onufriy Stepanov's Russian flotilla, on the Amur River. August 1 – The coronation of Leopold I takes place in Frankfurt. August 5 – Just six months after winning territory from Denmark-Norway in war and subsequent treaty, Sweden's King Charles X Gustav declares a second war against Denmark. By August 11, the King's troops have surrounded Denmark's capital, Copenhagen, while the Swedish Navy blocks the harbor to prevent the city from being resupplied, and begins bombardment. August 14 – The League of the Rhine (Rheinische Allianz) is formed by 50 German princes whose cities are on the Rhine river. September 3 – Oliver Cromwell dies and his son Richard assumes his father's position as Lord Protector of England, Scotland and Ireland. September 17 – Portuguese Restoration War: In the Battle of Vilanova, a Spanish army, having crossed the Minho, defeats the Portuguese. October 7 – The Netherlands enters the Dano-Swedish War to come to the rescue of Denmark, sending a 45-ship fleet from Vlie. October 29 – The 45-ship fleet of the Netherlands arrives at Denmark and begins its counterattack on Sweden's army and navy with three squadrons. November 6 – The Mexican Inquisition carries out the execution, by public burning, of 14 men convicted of homosexuality, while another 109 arrested are either released or given less harsh sentences. November 8 (October 29 old style) – The Battle of the Sound takes place between the navies of the Dutch Republic (with 41 warships) and of Sweden (with 45) at the Øresund, a strait between Denmark and Sweden's newly-acquired territory, the former Danish island of Scania. The Dutch Republic is successful at breaking the Swedish Navy's blockade of Copenhagen, and Sweden is forced to retreat, bringing an end to the attempted conquest of Denmark. November 23 – The elaborate funeral of Lord Protector of England Oliver Cromwell (who had died on September 3 and was buried at Westminster Abbey two weeks later) is carried out in London. A little more than two years later (in January 1661), his body will be disinterred and his head severed and placed on a spike. December 11 – Abaza Hasan Pasha, an Ottoman provincial governor who is attempting to depose the Grand Vizier, wins a battle at the Turkish city of Ilgin, defeating loyalist forces led by Murtaza Pasha. The victory is the last for the rebels. Two months later (February 16, 1659) Abaza Hasan is assassinated after being invited to peace negotiations by the loyalists. December 20 – Representatives of the Russian Empire and the Swedish Empire sign the Treaty of Valiesar at the Valiesar Estate near Narva, part of modern-day Estonia. In return for ceasing hostilities between the two empires in the Second Northern War, Russia is allowed to keep captured territories in Livonia (part of modern-day Latvia) for a term of three years. December 25 – Polish and Danish forces defeat a Swedish Army in the Battle of Kolding in Denmark. December 30 – The Siege of Toruń ends almost six months after it started, with Poland recapturing the city from Sweden. Portuguese traders are expelled from Ceylon by Dutch invaders. The Dutch in the Cape Colony start to import slaves from India and South-East Asia (later from Madagascar). Mary of Modena January 9 – Nicolas Coustou, French artist (d. 1733)[3] January 17 – Samson Wertheimer, European rabbi (d. 1724) January 17 – Francis Seymour, 5th Duke of Somerset (d. 1678) February 18 – Charles-Irénée Castel de Saint-Pierre, French writer (d. 1743) March 5 – Antoine de la Mothe Cadillac, French explorer (d. 1730) March 8 – Thomas Trevor, 1st Baron Trevor, British Baron (d. 1730) March 23 – Jean-Baptiste Santerre, French painter (d. 1717) March 30 – Muro Kyūsō, Japanese Neo-Confucian scholar (d. 1734) April 11 – James Hamilton, 4th Duke of Hamilton, Scottish peer (d. 1712) April 19 – Johann Wilhelm, Elector Palatine, German noble (d. 1716) April 22 – Giuseppe Torelli, Italian violist, violinist, pedagogue and composer (d. 1709) May 30 – Sir Henry Furnese, 1st Baronet, English merchant and politician (d. 1712) June 10 – John March, Massachusetts businessman, colonel (d. 1712) June 11 – Victor Honoré Janssens, Flemish painter (d. 1736) June 22 – Louis VII, Landgrave of Hesse-Darmstadt (d. 1678) July 10 – Luigi Ferdinando Marsili, Italian soldier and naturalist (d. 1730) July 14 – Camillo Rusconi, Italian artist (d. 1728) July 17 – Diogo de Mendonça Corte-Real, Portuguese politician (d. 1736) July 21 – Alexis Littré, French physician and anatomist (d. 1726) July 25 – Archibald Campbell, 1st Duke of Argyll, Scottish privy councillor (d. 1703) July 28 – Roelof Diodati, Dutch Governor of Mauritius (d. 1723) August 1 – Pierre Joseph Garidel, French botanist (d. 1737) August 5 – Claude Audran III, French painter (d. 1734) August 10 – Susanne Maria von Sandrart, German engraver (d. 1716) August 11 – Sir Justinian Isham, 4th Baronet, English baronet and Member of Parliament (d. 1730) August 16 – Jan Frans van Son, Flemish Baroque painter (d. 1704) August 16 – Ralph Thoresby, British historian (d. 1725) August 18 – Jan František Beckovský, Czech historian (d. 1722) August 22 – John Ernest IV, Duke of Saxe-Coburg-Saalfeld (d. 1729) August 28 – Honoré Tournély, French theologian (d. 1729) September 1 – Jacques Bernard, French theologian and publicist (d. 1718) September 16 – John Dennis, English dramatist and critic (d. 1734) September 24 – Sir Robert Anstruther, 1st Baronet, Scottish politician (d. 1737) September 30 – Elisabeth Eleonore of Brunswick-Wolfenbüttel, Duchess consort of Saxe-Meiningen (d. 1729) October 2 – Nicholas Roosevelt (1658–1742), Dutch-American politician (d. 1742) October 5 – Mary of Modena, queen of James II of England (d. 1718) October 11 – Christian Heinrich Postel, German jurist (d. 1705) October 18 – Alexander of Courland, German prince (d. 1686) October 19 – Adolphus Frederick II, Duke of Mecklenburg-Strelitz (d. 1704) October 21 – Henri de Boulainvilliers, French nobleman (d. 1722) October 24 – Marko Gerbec, Carniolan physician, scientist (d. 1718) November 2 – Baptist Noel (MP), English politician (d. 1690) November 4 – Sulkhan-Saba Orbeliani, Georgian prince, writer, monk and author (d. 1725) November 21 – Johann Gottfried Roesner, Prussian burgomaster (d. 1724) November 27 – Tsarevna Catherine Alekseyevna of Russia, daughter of Tsar Alexis of Russia (d. 1718) November 27 – Hercule-Louis Turinetti, marquis of Prié (d. 1726) December 2 – Sir Thomas Roberts, 4th Baronet, English politician (d. 1706) December 10 – Lancelot Blackburne, Archbishop of York (d. 1743) date unknown – Elizabeth Barry, English actress (d. 1713) John Cleveland Witte Corneliszoon de With January 1 – Caspar Sibelius, Dutch Protestant minister (b. 1590) January 2 – Sir William Armine, 2nd Baronet, English politician (b. 1622) January 7 – Theophilus Eaton, English-born Connecticut colonist (b. 1590) January 13 – Edward Sexby, English Puritan soldier (b. 1616) February 19 – Henry Wilmot, 1st Earl of Rochester (b. 1612) March 25 – Herman IV, Landgrave of Hesse-Rotenburg (b. 1607) February 27 – Adolf Frederick I, Duke of Mecklenburg-Schwerin (1592–1628 and again 1631–1658) (b. 1588) March 29 – Bertuccio Valiero, Doge of Venice (b. 1596) April 7 – Juan Eusebio Nieremberg, Spanish mystic (b. 1595) April 19 Kirsten Munk, second wife of Christian IV of Denmark (b. 1598) Robert Rich, 2nd Earl of Warwick, English colonial administrator and admiral (b. 1587) April 24 – Francesco Maria Richini, Italian architect (b. 1584) April 29 – John Cleveland, English poet (b. 1613) May 20 – Bartholomew Holzhauser, German priest, visionary and writer of prophecies (b. 1613) June 18 – Louis Cappel, French Protestant churchman and scholar (b. 1585) June 8 – Sir Henry Slingsby, 1st Baronet, English baronet (b. 1602) June 27 – Ercole Gennari, Italian drawer and painter (b. 1597) July 22 – Frederick, Duke of Schleswig-Holstein-Sønderburg-Norburg (b. 1581) August 5 – Gundakar, Prince of Liechtenstein, court official in Vienna (b. 1580) August 6 – Elizabeth Claypole, daughter of Oliver Cromwell (b. 1629) August 19 – Christine of Hesse-Kassel, Duchess of Saxe-Eisenach and Saxe-Coburg (b. 1578) September 3 – Oliver Cromwell, Lord Protector of England, Scotland, and Ireland (b. 1599) September 17 – Kaspar von Barth, German philologist and writer (b. 1587) September 22 – Georg Philipp Harsdörffer, German poet (b. 1607) October 14 – Francesco I d'Este, Duke of Modena, Italian noble (b. 1610) October 23 – Thomas Pride, Parliamentarian general in the English Civil War November 4 – Antoine Le Maistre, French Jansenist (b. 1608) November 6 – Pierre du Ryer, French dramatist (b. 1606) November 7 – Maeda Toshitsune, Japanese warlord (b. 1594) November 8 – Witte de With, Dutch naval officer (b. 1599) November 26 – Duke Francis Henry of Saxe-Lauenburg (b. 1604) November 29 – Margrave Charles Magnus of Baden-Durlach (b. 1621) December 6 – Baltasar Gracián y Morales, Spanish writer (b. 1601) December 15 – Carlo Emanuele Madruzzo, Italian prince-bishop (b. 1599) December 20 – Jean Jannon, French typefounder (b. 1580) Date unknown: Osoet Pegua, Thai businesswoman (b. 1615) ^ "killing". Oxford Reference. Retrieved December 14, 2021. ^ Brems, Hans (June 1970). "Sweden: From Great Power to Welfare State". Journal of Economic Issues. 4 (2, 3). Association for Evolutionary Economics: 1–16. doi:10.1080/00213624.1970.11502941. JSTOR 4224039. A swift and brilliantly conceived march from Holstein across the frozen Danish waters on Copenhagen, by Karl X Gustav in 1658, finally wrests Bohuslän, Sk'ane, and Blekinge from Denmark-Norway. Denmark no longer controls both sides of Oresund, and Swedish power is at its peak. ^ "Nicolas Coustou | French sculptor | Britannica". www.britannica.com. Retrieved December 14, 2021. Retrieved from " 3One hundred years, from 1501 to 1600 This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "16th century" – news · newspapers · books · scholar · JSTOR (September 2022) (Learn how and when to remove this message) Millennia 2nd millennium Centuries 15th century 16th century 17th century Timelines 15th century 16th century 17th century State leaders 15th century 16th century 17th century Decades 1500s 1510s 1520s 1530s 1540s 1550s 1560s 1570s 1580s 1590s Categories: Births – Deaths Establishments – Disestablishments vte The world map by the Italian Amerigo Vespucci (from whose name the word America is derived) and Belgian Gerardus Mercator shows (besides the classical continents Europe, Africa, and Asia) the Americas as America sive India Nova', New Guinea, and other islands of Southeast Asia, as well as a hypothetical Arctic continent and a yet undetermined Terra Australis.[1]The 16th century begins with the Julian year 1501 (represented by the Roman numerals MDI) and ended with either the Julian or the Gregorian year 1600 (MDC), depending on the reckoning used (the Gregorian calendar introduced a lapse of 10 days in October 1582).[1] The Renaissance in Italy and Europe saw the emergence of important artists, authors and scientists, and led to the foundation of important subjects which include accounting and political science. Copernicus proposed the heliocentric universe, which was met with strong resistance, and Tycho Brahe refuted the theory of celestial spheres through observational measurement of the 1572 appearance of a Milky Way supernova. These events directly challenged the long-held notion of an immutable universe supported by Ptolemy and Aristotle, and led to major revolutions in astronomy and science. Galileo Galilei became a champion of the new sciences, invented the first thermometer and made substantial contributions in the fields of physics and astronomy, becoming a major figure in the Scientific Revolution in Europe. Spain and Portugal colonized large parts of Central and South America, followed by France and England in Northern America and the Lesser Antilles. The Portuguese became the masters of trade between Brazil, the coasts of Africa, and their possessions in the Indies, whereas the Spanish came to dominate the Greater Antilles, Mexico, Peru, and opened trade across the Pacific Ocean, linking the Americas with the Indies. English and French privateers began to practice persistent theft of Spanish and Portuguese treasures. This era of colonialism established mercantilism as the leading school of economic thought, where the economic system was viewed as a zero-sum game in which any gain by one party required a loss by another. The mercantilist doctrine encouraged the many intra-European wars of the period and arguably fueled European expansion and imperialism throughout the world until the 19th century or early 20th century. The Reformation in central and northern Europe gave a major blow to the authority of the papacy and the Catholic Church. In England, the British-Italian Alberico Gentili wrote the first book on public international law and divided secularism from canon law and Catholic theology. European politics became dominated by religious conflicts, with the groundwork for the epochal Thirty Years' War being laid towards the end of the century. In the Middle East, the Ottoman Empire continued to expand, with the sultan taking the title of caliph, while dealing with a resurgent Persia. Iran and Iraq were caught by a major popularity of the Shia sect of Islam under the rule of the Safavid dynasty of warrior-mystics, providing grounds for a Persian independent of the majority-Sunni Muslim world.[2] In the Indian subcontinent, following the defeat of the Delhi Sultanate and Vijayanagara Empire, new powers emerged, the Sur Empire founded by Sher Shah Suri, Deccan sultanates, Rajput states, and the Mughal Empire[3] by Emperor Babur, a direct descendant of Timur and Genghis Khan.[4] His successors Humayun and Akbar, enlarged the empire to include most of South Asia. Japan suffered a severe civil war at this time, known as the Sengoku period, and emerged from it as a unified nation under Toyotomi Hideyoshi. China was ruled by the Ming dynasty, which was becoming increasingly isolationist, coming into conflict with Japan over the control of Korea as well as Japanese pirates. In Africa, Christianity had begun to spread in Central Africa and Southern Africa. Until the Scramble for Africa in the late 19th century, most of Africa was left uncolonized. For timelines of earlier events, see 15th century and Timeline of the Middle Ages. Main article: 1500s Mona Lisa, by Leonardo da Vinci, c. 1503–1506, one of the world's best-known paintings 1501: Michelangelo returns to his native Florence to begin work on the statue David. 1501: Safavid dynasty reunifies Iran and rules over it until 1736. Safavids adopt a Shia branch of Islam.[5] 1501: First Battle of Cannanore between the Third Portuguese Armada and Kingdom of Cochin under João da Nova and Zamorin of Kozhikode's navy marks the beginning of Portuguese conflicts in the Indian Ocean. 1502: First reported African slaves in the New World 1502: The Crimean Khanate sacks Sarai in the Golden Horde, ending its existence. 1503: Spain defeats France at the Battle of Cerignola. Considered to be the first battle in history won by gunpowder small arms. 1503: Leonardo da Vinci begins painting the Mona Lisa and completes it three years later. 1503: Nostradamus is born on either December 14 or December 21. 1504: A period of drought, with famine in all of Spain. 1504: Death of Isabella I of Castile; Joanna of Castile becomes the Queen. 1504: Foundation of the Sultanate of Sennar by Amara Dunqas. in what is modern Sudan 1505: Zhengde Emperor ascends the throne of Ming dynasty. 1505: Martin Luther enters St. Augustine's Monastery at Erfurt, Germany, on 17 July and begins his journey to instigating the Reformation. 1505: Sultan Trenggono builds the first Muslim kingdom in Java, called Demak, in Indonesia. Many other small kingdoms were established in other islands to fight against Portuguese. Each kingdom introduced local language as a way of communication and unity. 1506: Leonardo da Vinci completes the Mona Lisa. 1506: King Afonso I of Kongo wins the battle of Mbanza Kongo, resulting in Catholicism becoming Kongo's state religion.Battle of Cerignola: El Gran Capitan finds the corpse of Louis d'Armagnac, Duke of Nemours 1506: At least two thousand converted Jews are massacred in a Lisbon riot, Portugal. 1506: Christopher Columbus dies in Valladolid, Spain. 1506: Poland is invaded by Tatars from the Crimean Khanate. 1507: The first recorded epidemic of smallpox in the New World on the island of Hispaniola. It devastates the native Taíno population.[6] 1507: Afonso de Albuquerque conquered Hormuz and Muscat, among other bases in the Persian Gulf, taking control of the region at the entrance of the Gulf. 1508: The Christian-Islamic power struggle in Europe and West Asia spills over into the Indian Ocean as Battle of Chaul during the Portuguese-Mamluk War 1508–1512: Michelangelo paints the Sistine Chapel ceiling. 1509: The defeat of joint fleet of the Sultan of Gujarat, the Mamlûk Burji Sultanate of Egypt, and the Zamorin of Calicut with support of the Republic of Venice and the Ottoman Empire in the Battle of Diu marks the beginning of Portuguese dominance of the Spice trade and the Indian Ocean. 1509: The Portuguese king sends Diogo Lopes de Sequeira to find Malacca, the eastern terminus of Asian trade. After initially receiving Sequeira, Sultan Mahmud Shah captures and/or kills several of his men and attempts an assault on the four Portuguese ships, which escape.[7] The Javanese fleet is also destroyed in Malacca. 1509: Krishnadevaraya ascends the throne of Vijayanagara Empire. 1509: The 'great plague' in various parts of Tudor England.[8] 1510: Afonso de Albuquerque of Portugal conquers Goa in India. 1511: Afonso de Albuquerque of Portugal conquers Malacca, the capital of the Sultanate of Malacca in present-day Malaysia. 1512: Copernicus writes Commentariolus, and proclaims the Sun the center of the Solar System. 1512: The southern part (historical core) of the Kingdom of Navarre is invaded by Castile and Aragon. 1512: Qutb Shahi dynasty, founded by Quli Qutb Mulk, rules Golconda Sultanate until 1687. 1512: The first Portuguese exploratory expedition was sent eastward from Malacca (in present-day Malaysia) to search for the 'Spice Islands' (Maluku) led by Francisco Serrão. Serrão is shipwrecked but struggles on to Hitu (northern Ambon) and wins the favour of the local rulers.[9] 1513: Machiavelli writes The Prince, a treatise about political philosophy 1513: The Portuguese mariner Jorge Álvares lands at Macau, China, during the Ming dynasty. 1513: Henry VIII defeats the French at the Battle of the Spurs. 1513: The Battle of Flodden Field in which invading Scots are defeated by Henry VIII's forces. 1513: Sultan Selim I (The Grim") orders the massacre of Shia Muslims in Anatolia (present-day Turkey). 1513: Vasco Núñez de Balboa, in service of Spain arrives at the Pacific Ocean (which he called Mar del Sur) across the Isthmus of Panama. He was the first European to do so. 1514: The Battle of Orsha halts Muscovy's expansion into Eastern Europe. 1514: Dózsa rebellion (peasant revolt) in Hungary.Martin Luther initiated the Reformation with his Ninety-five Theses in 1517. 1514: The Battle of Chaldiran, the Ottoman Empire gains decisive victory against Safavid dynasty. 1515: Ascension of Francis I of France as King of France following the death of Louis XII. 1515: The Ottoman Empire wrests Eastern Anatolia from the Safavids after the Battle of Chaldiran. 1516: The Ottomans conquer the last beyliks of Anatolia, the Dulkadirs and the Ramadanids. 1516–1517: The Ottomans defeat the Mamluks and gain control of Egypt, Arabia, and the Levant. 1517: The Sweating sickness epidemic in Tudor England.[10] 1517: The Reformation begins when Martin Luther posts his Ninety-five Theses in Saxony. 1518: The Treaty of London was a non-aggression pact between the major European nations. The signatories were Burgundy, France, England, the Holy Roman Empire, the Netherlands, the Papal States and Spain, all of whom agreed not to attack one another and to come to the aid of any that were under attack. 1518: Mir Chakar Khan Rind leaves Baluchistan and settles in Punjab. 1518: Leo Africanus, also known as al-Hasan ibn Muhammad al-Wazzan al-Fasi, an Andalusian Berber diplomat who is best known for his book Descrittione dell'Africa (Description of Africa), is captured by Spanish pirates; he is taken to Rome and presented to Pope Leo X. 1518: The dancing plague of 1518 begins in Strasbourg, lasting for about one month. 1519: Leonardo da Vinci dies of natural causes on May 2.Europe at the time of the accession of Charles V in 1519 1519: Wang Yangming, the Chinese philosopher and governor of Jiangxi province, describes his intent to use the firepower of the fo-lang-ji, a breech-loading Portuguese culverin, in order to suppress the rebellion of Prince Zhu Chenhao. 1519: Barbary pirates led by Hayreddin Barbarossa, a Turk appointed to ruling position in Algiers by the Ottoman Empire, raid Provence and Toulon in southern France. 1519: Death of Emperor Maximilian; Charles I of Austria, Spain, and the Low Countries becomes Emperor of Holy Roman Emperor as Charles V, Holy Roman Emperor (ruled until 1556). 1519–1522: Spanish expedition commanded by Magellan and Elcano are the first to Circumnavigate the Earth. 1519–1521: Hernán Cortés leads the Spanish conquest of the Aztec Empire. Main article: 1520s Ferdinand Magellan led the first expedition that circumnavigated the globe in 1519–1522. 1520–1566: The reign of Suleiman the Magnificent marks the zenith of the Ottoman Empire. 1520: The first European diplomatic mission to Ethiopia, sent by the Portuguese, arrives at Massawa 9 April, and reaches the imperial encampment of Emperor Dawit II in Shewa 9 October. 1520: Vijayanagara Empire forces under Krishnadevaraya defeat the Adil Shahi under at the Battle of Raichur 1520: Sultan Ali Mughayat Shah of Aceh begins an expansionist campaign capturing Daya on the west Sumatran coast (in present-day Indonesia), and the pepper and gold producing lands on the east coast. 1520: The Portuguese establish a trading post in the village of Lamakera on the eastern side of Solor (in present-day Indonesia) as a transit harbour between Maluku and Malacca. 1521: Belgrade (in present-day Serbia) is captured by the Ottoman Empire. 1521: After building fortifications at Tuen Mun, the Portuguese attempt to invade Ming dynasty China, but are expelled by Chinese naval forces. 1521: Philippines encountered by Ferdinand Magellan. He was later killed in the Battle of Mactan in central Philippines in the same year. 1521: Jiajing Emperor ascended the throne of Ming dynasty, China. 1521: November, Ferdinand Magellan's expedition reaches Maluku (in present-day Indonesia) and after trade with Ternate returns to Europe with a load of cloves. 1521: Pati Unus leads the invasion of Malacca (in present-day Malaysia) against the Portuguese occupation. Pati Unus was killed in this battle, and was succeeded by his brother, sultan Trenggana. 1522: Rhodes falls to the Ottomans of Suleiman the Magnificent.[11]Sack of Rome of 1527 by Charles V's forces (painting by Johannes Lingelbach) 1522: The Portuguese ally themselves with the rulers of Ternate (in present-day Indonesia) and begin construction of a fort.[9] 1522: August, Luso-Sundanese Treaty signed between Portugal and Sunda Kingdom granted Portuguese permit to build fortress in Sunda Kelapa. 1523: Sweden gains independence from the Kalmar Union. 1523: The Cacao bean is introduced to Spain by Hernán Cortés 1524–1525: German Peasants' War in the Holy Roman Empire. 1524: Giovanni da Verrazzano is the first European to explore the Atlantic coast of North America between South Carolina and Newfoundland. 1524: Ismail I, the founder of Safavid dynasty, dies and Tahmasp I becomes king.Gun-wielding Ottoman Janissaries and defending Knights of Saint John at the siege of Rhodes in 1522, from an Ottoman manuscript 1525: Timurid Empire forces under Babur defeat the Lodi dynasty at the First Battle of Panipat, end of the Delhi Sultanate. 1525: German and Spanish forces defeat France at the Battle of Pavia, Francis I of France is captured. 1526: The Ottomans defeat the Kingdom of Hungary at the Battle of Mohács. 1526: Mughal Empire, founded by Babur. 1527: Sack of Rome by Pope Clement VII escaping and the Swiss Guards defending the Vatican being killed. 1527: The sack of the city of Rome considered the end of the Italian Renaissance. 1527: Protestant Reformation begins in Sweden. 1527: The last ruler of Majapahit falls from power. This state (located in present-day Indonesia) was finally extinguished at the hands of the Demak. A large number of courtiers, artisans, priests, and members of the royalty moved east to the island of Bali; however, the power and the seat of government transferred to Demak under the leadership of Pangeran, later Sultan Fatah. 1527: June 22, The Javanese Prince Fatahillah of the Cirebon Sultanate successfully defeated the Portuguese armed forces at the site of the Sunda Kelapa Harbor. The city was then renamed Jayakarta, meaning "a glorious victory." This eventful day came to be acknowledged as Jakarta's Founding Anniversary. 1527: Mughal Empire forces defeat the Rajput led by Rana Sanga of Mewar at the Battle of Khanwa 1529: The Austrians defeat the Ottoman Empire at the siege of Vienna. 1529: Treaty of Zaragoza defined the antimeridian of Tordesillas attributing the Moluccas to Portugal and Philippines to Spain. 1529: Imam Ahmad Gurey defeats the Ethiopian Emperor Dawit II in the Battle of Shimbra Kure, the opening clash of the Ethiopian–Adal War. Main article: 1530s Spanish conquistadors with their Tlaxcallan allies fighting against the Otomies of Metztitlan in present-day Mexico, a 16th-century codex 1531–1532: The Church of England breaks away from the Catholic Church and recognizes King Henry VIII as the head of the Church. 1531: The Inca Civil War is fought between the two brothers, Atahualpa and Huáscar. 1532: Francisco Pizarro leads the Spanish conquest of the Inca Empire. 1532: Foundation of São Vicente, the first permanent Portuguese settlement in the Americas. 1533: Anne Boleyn becomes Queen of England. 1533: Elizabeth Tudor is born. 1534: Jacques Cartier claims Canada for France. 1534: Ottomans capture Baghdad from the Safavids. 1534: Affair of the Placards, where King Francis I becomes more active in repression of French Protestants. 1535: The Münster Rebellion, an attempt of radical, millennialist, Anabaptists to establish a theocracy, ends in bloodshed. 1535: The Portuguese in Ternate depose Sultan Tabariji (or Tabarija) and send him to Portuguese Goa where he converts to Christianity and bequeaths his Portuguese godfather Jordao de Freitas the island of Ambon.[12] Hairun becomes the next sultan. 1536: Catherine of Aragon dies in Kimbolton Castle, in England.Territorial expansion of the Ottoman Empire under Suleiman (in red and orange) 1536: In England, Anne Boleyn is beheaded for adultery and treason. 1536: Establishment of the Inquisition in Portugal. 1536: Foundation of Buenos Aires (in present-day Argentina) by Pedro de Mendoza. 1537: The Portuguese establish Recife in Pernambuco, north-east of Brazil. 1537: William Tyndale's partial translation of the Bible into English is published, which would eventually be incorporated into the King James Bible. 1538: Gonzalo Jiménez de Quesada founds Bogotá. 1538: Spanish-Venetian fleet is defeated by the Ottoman Turks at the Battle of Preveza. 1539: Hernando de Soto explores inland North America. 1539: Nicolaus Copernicus 1540: The Society of Jesus, or the Jesuits, is founded by Ignatius of Loyola and six companions with the approval of Pope Paul III. 1540: Sher Shah Suri founds the Sur dynasty in South Asia, an ethnic Pashtun (Pathan) of the house of Sur, who supplanted the Mughal dynasty as rulers of North India during the reign of the relatively ineffectual second Mughal emperor Humayun. Sher Shah Suri decisively defeats Humayun in the Battle of Bilgram (May 17, 1540). 1541: Pedro de Valdivia founds Santiago in Chile. 1541: An Algerian military campaign by Charles V of Spain (Habsburg) is unsuccessful. 1541: Amazon River is encountered and explored by Francisco de Orellana. 1541: Capture of Buda and the absorption of the major part of Hungary by the Ottoman Empire. 1541: Sahib I Giray of Crimea invades Russia. 1542: The Italian War of 1542–1546 War resumes between Francis I of France and Emperor Charles V. This time Henry VIII is allied with the Emperor, while James V of Scotland and Sultan Suleiman I are allied with the French. 1542: Akbar The Great is born in the Rajput Umarkot Fort 1542: Spanish explorer Ruy López de Villalobos named the island of Samar and Leyte Las Islas Filipinas honoring Philip II of Spain and became the official name of the archipelago. 1543: Ethiopian/Portuguese troops defeat the Adal army led by Imam Ahmad Gurey at the Battle of Wayna Daga; Imam Ahmad Gurey is killed at this battle. 1543: Copernicus publishes his theory that the Earth and the other planets revolve around the Sun. 1543: The Nanban trade period begins after Portuguese traders make contact with Japan. 1544: The French defeat an Imperial–Spanish army at the Battle of Ceresole. Scenes of everyday life in Ming China, by Qiu Ying 1544: Battle of the Shirts in Scotland. The Frasers and Macdonalds of Clan Ranald fight over a disputed chiefship; reportedly, 5 Frasers and 8 Macdonalds survive. 1545: Songhai forces sack the Malian capital of Niani 1545: The Council of Trent meets for the first time in Trent (in northern Italy). 1546: Michelangelo Buonarroti is made chief architect of St. Peter's Basilica. 1546: Francis Xavier works among the peoples of Ambon, Ternate and Morotai (Moro) laying the foundations for a permanent mission. (to 1547) 1547: Henry VIII dies in the Palace of Whitehall on 28 January at the age of 55. 1547: Francis I dies in the Château de Rambouillet on 31 March at the age of 52. 1547: Edward VI becomes King of England and Ireland on 28 January and is crowned on 20 February at the age of 9. 1547: Emperor Charles V decisively dismantles the Schmalkaldic League at the Battle of Mühlberg. 1547: Grand Prince Ivan the Terrible is crowned tsar of (All) Russia, thenceforth becoming the first Russian tsar. 1548: Battle of Uedahara: Firearms are used for the first time on the battlefield in Japan, and Takeda Shingen is defeated by Murakami Yoshikiyo. 1548: Askia Daoud, who reigned from 1548 to 1583, establishes public libraries in Timbuktu (in present-day Mali). 1548: The Ming dynasty government of China issues a decree banning all foreign trade and closes down all seaports along the coast; these Hai jin laws came during the Wokou wars with Japanese pirates. 1549: Tomé de Sousa establishes Salvador in Bahia, north-east of Brazil. 1549: Arya Penangsang with the support of his teacher, Sunan Kudus, avenges the death of Raden Kikin by sending an envoy named Rangkud to kill Sunan Prawoto by Keris Kyai Satan Kober (in present-day Indonesia). Main article: 1550s The Islamic gunpowder empires: Mughal Army artillerymen during the reign of Jalaluddin Akbar 1550: The architect Mimar Sinan builds the Süleymaniye Mosque in Istanbul. 1550: Mongols led by Altan Khan invade China and besiege Beijing. 1550–1551: Valladolid debate concerning the human rights of the Indigenous people of the Americas. 1551: Fifth outbreak of sweating sickness in England. John Caius of Shrewsbury writes the first full contemporary account of the symptoms of the disease. 1551: North African pirates enslave the entire population of the Maltese island Gozo, between 5,000 and 6,000, sending them to Libya. 1552: Russia conquers the Khanate of Kazan in central Asia. 1552: Jesuit China Mission, Francis Xavier dies. 1553: Mary Tudor becomes the first queen regnant of England and restores the Church of England under Papal authority. 1553: The Portuguese found a settlement at Macau. 1554: Missionaries José de Anchieta and Manuel da Nóbrega establishes São Paulo, southeast Brazil. 1554: Princess Elizabeth is imprisoned in the Tower of London upon the orders of Mary I for suspicion of being involved in the Wyatt rebellion. 1555: The Muscovy Company is the first major English joint stock trading company. 1556: Publication in Venice of Delle Navigationi et Viaggi (terzo volume) by Giovanni Battista Ramusio, secretary of Council of Ten, with plan La Terra de Hochelaga, an illustration of the Hochelaga.[13] 1556: The Shaanxi earthquake in China is history's deadliest known earthquake during the Ming dynasty. 1556: Georgius Agricola, the "Father of Mineralogy", publishes his De re metallica. 1556: Akbar defeats Hemu at the second battle of Panipat. 1556: Russia conquers the Astrakhan Khanate. 1556–1605: During his reign, Akbar expands the Mughal Empire in a series of conquests (in the Indian subcontinent).Political map of the world in 1556 1556: Mir Chakar Khan Rind captures Delhi with Humayun. 1556: Pomponio Algerio, radical theologian, is executed by boiling in oil as part of the Roman Inquisition. 1557: Habsburg Spain declares bankruptcy. Philip II of Spain had to declare four state bankruptcies in 1557, 1560, 1575 and 1596. 1557: The Portuguese settle in Macau (on the western side of the Pearl River Delta across from present-day Hong Kong). 1557: The Ottomans capture Massawa, all but isolating Ethiopia from the rest of the world. 1558: Elizabeth Tudor becomes Queen Elizabeth I at age 25. 1558–1603: The Elizabethan era is considered the height of the English Renaissance. 1558–1583: Livonian War between Poland, Grand Principality of Lithuania, Sweden, Denmark and Russia. 1558: After 200 years, the Kingdom of England loses Calais to France. 1559: With the Peace of Cateau Cambrésis, the Italian Wars conclude. 1559: Sultan Hairun of Ternate (in present-day Indonesia) protests the Portuguese's Christianisation activities in his lands. Hostilities between Ternate and the Portuguese. Main article: 1560s The Mughal Emperor Akbar shoots the Rajput warrior Jaimal during the Siege of Chittorgarh in 1567 1560: Ottoman navy defeats the Spanish fleet at the Battle of Djerba. 1560: Elizabeth Bathory is born in Nyírbátor, Hungary. 1560: By winning the Battle of Okehazama, Oda Nobunaga becomes one of the pre-eminent warlords of Japan. 1560: Jeanne d'Albret declares Calvinism the official religion of Navarre. 1561: Lazarus Church, Macau 1561: Sir Francis Bacon is born in London. 1561: Tenth battle of Kawanakajima between the Uesugi and Takeda at Hachimanbara takes place. 1561: Guido de Bres draws up the Belgic Confession of Protestant faith. 1562: Mughal emperor Akbar reconciles the Muslim and Hindu factions by marrying into the powerful Rajput Hindu caste. 1562–1598: French Wars of Religion between Catholics and Huguenots. 1562: Massacre of Wassy and Battle of Dreux in the French Wars of Religion. 1562: Portuguese Dominican priests build a palm-trunk fortress which Javanese Muslims burned down the following year. The fort was rebuilt from more durable materials and the Dominicans commenced the Christianisation of the local population.[12] 1563: Plague outbreak claimed 80,000 people in Elizabethan England. In London alone, over 20,000 people died of the disease. 1564: Galileo Galilei born on February 15 1564: William Shakespeare baptized 26 April 1565: Deccan sultanates defeat the Vijayanagara Empire at the Battle of Talikota. 1565: Mir Chakar Khan Rind dies at aged 97. 1565: Estácio de Sá establishes Rio de Janeiro in Brazil. 1565: The Hospitallers, a Crusading Order, defeat the Ottoman Empire at the siege of Malta (1565). 1565: Miguel López de Legazpi establishes in Cebu the first Spanish settlement in the Philippines starting a period of Spanish colonization that would last over three hundred years. 1565: Spanish navigator Andres de Urdaneta discovers the maritime route from Asia to the Americas across the Pacific Ocean, also known as the tornaviaje. 1565: Royal Exchange is founded by Thomas Gresham. 1566: Suleiman the Magnificent, ruler of the Ottoman Empire, dies on September 7, during the battle of Szigetvar.Siege of Valenciennes during the Dutch War of Independence in 1567 1566–1648: Eighty Years' War between Spain and the Netherlands. 1566: Da le Balle Contrade d'Oriente, composed by Cipriano de Rore. 1567: After 45 years' reign, Jiajing Emperor died in the Forbidden City, Longqing Emperor ascended the throne of Ming dynasty. 1567: Mary, Queen of Scots, is imprisoned by Elizabeth I. 1568: The Transylvanian Diet, under the patronage of the prince John Sigismund Zápolya, the former king of Hungary, inspired by the teachings of Ferenc Dávid, the founder of the Unitarian Church of Transylvania, promulgates the Edict of Torda, the first law of freedom of religion and of conscience in the World. 1568–1571: Morisco Revolt in Spain. 1568–1600: The Azuchi-Momoyama period in Japan. 1568: Hadiwijaya sent his adopted son and son in-law Sutawijaya, who would later become the first ruler of the Mataram dynasty of Indonesia, to kill Arya Penangsang. 1569: Rising of the North in England. 1569: Mercator 1569 world map published by Gerardus Mercator. 1569: The Polish–Lithuanian Commonwealth is created with the Union of Lublin which lasts until 1795. 1569: Peace treaty signed by Sultan Hairun of Ternate and Governor Lopez De Mesquita of Portugal. Main article: 1570s The Battle of Lepanto 1570: Ivan the Terrible, tsar of Russia, orders the massacre of inhabitants of Novgorod. 1570: Pope Pius V issues Regnans in Excelsis, a papal bull excommunicating all who obeyed Elizabeth I and calling on all Catholics to rebel against her. 1570: Sultan Hairun of Ternate (in present-day Indonesia) is killed by the Portuguese.[12] Babullah becomes the next Sultan. 1570: 20,000 inhabitants of Nicosia in Cyprus were massacred and every church, public building, and palace was looted. Cyprus fell to the Ottoman Turks the following year. 1571: Pope Pius V completes the Holy League as a united front against the Ottoman Turks, responding to the fall of Cyprus to the Ottomans. 1571: The Spanish-led Holy League navy destroys the Ottoman Empire navy at the Battle of Lepanto. 1571: Crimean Tatars attack and sack Moscow, burning everything but the Kremlin. 1571: American Indians kill Spanish missionaries in what would later be Jamestown, Virginia. 1571: Spanish conquistador Miguel López de Legazpi establishes Manila, Philippines as the capital of the Spanish East Indies. 1572: Brielle is taken from Habsburg Spain by Protestant Watergeuzen in the Capture of Brielle, in the Eighty Years' War. 1572: Spanish conquistadores apprehend the last Inca leader Tupak Amaru at Vilcabamba, Peru, and execute him in Cuzco. 1572: Jeanne d'Albret dies aged 43 and is succeeded by Henry of Navarre. 1572: Catherine de' Medici instigates the St. Bartholomew's Day massacre which takes the lives of Protestant leader Gaspard de Coligny and thousands of Huguenots. The violence spreads from Paris to other cities and the countryside. 1572: First edition of the epic The Lusiads of Luís Vaz de Camões, three years after the author returned from the East.[14] 1572: The 9 years old Taizi, Zhu Yijun ascended the throne of Ming dynasty, known as Wanli Emperor. 1573: After heavy losses on both sides the siege of Haarlem ends in a Spanish victory.St. Bartholomew's Day massacre of French Protestants 1574: in the Eighty Years' War the capital of Zeeland, Middelburg declares for the Protestants. 1574: After a siege of 4 months the siege of Leiden ends in a comprehensive Dutch rebel victory. 1575: Oda Nobunaga finally captures Nagashima fortress. 1575: Following a five-year war, the Ternateans under Sultan Babullah defeated the Portuguese. 1576: Tahmasp I, Safavid shah, dies. 1576: The Battle of Haldighati is fought between the ruler of Mewar, Maharana Pratap and the Mughal Empire's forces under Emperor Akbar led by Raja Man Singh. 1576: Sack of Antwerp by badly paid Spanish soldiers. 1577–1580: Francis Drake circles the world. 1577: Ki Ageng Pemanahan built his palace in Pasargede or Kotagede. 1578: King Sebastian of Portugal is killed at the Battle of Alcazarquivir. 1578: The Portuguese establish a fort on Tidore but the main centre for Portuguese activities in Maluku becomes Ambon.[12] 1578: Sonam Gyatso is conferred the title of Dalai Lama by Tumed Mongol ruler, Altan Khan. Recognised as the reincarnation of two previous Lamas, Sonam Gyatso becomes the third Dalai Lama in the lineage.[15] 1578: Governor-General Francisco de Sande officially declared war against Brunei in 1578, starting the Castilian War of 1578. 1579: The Union of Utrecht unifies the northern Netherlands, a foundation for the later Dutch Republic. 1579: The Union of Arras unifies the southern Netherlands, a foundation for the later states of the Spanish Netherlands, the Austrian Netherlands and Belgium.The Irish Gaelic chieftain's feast, from The Image of Ireland 1579: The British navigator Sir Francis Drake passes through Maluku and transit in Ternate on his circumnavigation of the world. The Portuguese establish a fort on Tidore but the main centre for Portuguese activities in Maluku becomes Ambon.[16] Main article: 1580s The fall of Spanish Armada 1580: Drake's royal reception after his attacks on Spanish possessions influences Philip II of Spain to build up the Spanish Armada. English ships in Spanish harbours are impounded. 1580: Spain unifies with Portugal under Philip II. The struggle for the throne of Portugal ends the Portuguese Empire. The Spanish and Portuguese crowns are united for 60 years, i.e. until 1640. 1580–1587: Nagasaki comes under control of the Jesuits. 1581: Dutch Act of Abjuration, declaring abjuring allegiance to Philip II of Spain. 1581: Bayinnaung dies at the age of 65. 1582: Oda Nobunaga commits seppuku during the Honnō-ji Incident coup by his general, Akechi Mitsuhide. 1582: Pope Gregory XIII issues the Gregorian calendar. The last day of the Julian calendar was Thursday, 4 October 1582 and this was followed by the first day of the Gregorian calendar, Friday, 15 October 1582 1582: Yermak Timofeyevich conquers the Siberia Khanate on behalf of the Stroganovs. 1583: Denmark builds the world's first theme park, Bakken. 1583: Death of Sultan Babullah of Ternate. 1584–1585: After the siege of Antwerp, many of its merchants flee to Amsterdam. According to Luc-Normand Tellier, "At its peak, between 1510 and 1557, Antwerp concentrated about 40% of the world trade...It is estimated that the port of Antwerp was earning the Spanish crown seven times more revenues than the Americas."[17] 1584: Ki Ageng Pemanahan died. Sultan Pajang raised Sutawijaya, son of Ki Ageng Pemanahan as the new ruler in Mataram, titled "Loring Ngabehi Market" (because of his home in the north of the market). 1585: Akbar annexes Kashmir and adds it to the Kabul SubahPortuguese fusta in India from a book by Jan Huygen van Linschoten 1585: Colony at Roanoke founded in North America. 1585–1604: The Anglo-Spanish War is fought on both sides of the Atlantic. 1587: Mary, Queen of Scots is executed by Elizabeth I. 1587: The reign of Abbas I marks the zenith of the Safavid dynasty. 1587: Troops that would invade Pajang Mataram Sultanate storm ravaged the eruption of Mount Merapi. Sutawijaya and his men survived. 1588: Mataram into the kingdom with Sutawijaya as Sultan, titled "Senapati Ingalaga Sayidin Panatagama" means the warlord and cleric Manager Religious Life. 1588: England repulses the Spanish Armada. 1589: Spain repulses the English Armada. 1589: Catherine de' Medici dies at aged 69. Main articles: 1590s and 1600s Abu'l-Fazl ibn Mubarak presenting Akbarnama to Mughal Azam Akbar, Mughal miniature 1590: Siege of Odawara: the Go-Hojo clan surrender to Toyotomi Hideyoshi, and Japan is unified. 1591: Gazi Giray leads a huge Tatar expedition against Moscow. 1591: In Mali, Moroccan forces of the Sultan Ahmad al-Mansur led by Judar Pasha defeat the Songhai Empire at the Battle of Tondibi. 1592–1593: John Stow reports 10,675 plague deaths in London, a city of approximately 200,000 people. 1592–1598: Korea, with the help of Ming dynasty China, repels two Japanese invasions. 1593–1606: The Long War between the Habsburg monarchy and the Ottoman Turks. 1594: St. Paul's College, Macau, founded by Alessandro Valignano. 1595: First Dutch expedition to Indonesia sets sail for the East Indies with two hundred and forty-nine men and sixty-four cannons led by Cornelis de Houtman.[18] 1596: Birth of René Descartes. 1596: June, de Houtman's expedition reaches Banten the main pepper port of West Java where they clash with both the Portuguese and Indonesians. It then sails east along the north coast of Java losing twelve crew to a Javanese attack at Sidayu and killing a local ruler in Madura.[18] 1597: Romeo and Juliet is published. 1597: Cornelis de Houtman's expedition returns to the Netherlands with enough spices to make a considerable profit.[18] 1598: The Edict of Nantes ends the French Wars of Religion. 1598: Abbas I moves Safavids capital from Qazvin to Isfahan in 1598. 1598–1613: Russia descends into anarchy during the Time of Troubles. 1598: The Portuguese require an armada of 90 ships to put down a Solorese uprising.[12] (to 1599) 1598: More Dutch fleets leave for Indonesia and most are profitable.[18]Edo period screen depicting the Battle of Sekigahara 1598: The province of Santa Fe de Nuevo México is established in Northern New Spain. The region would later become a territory of Mexico, the New Mexico Territory in the United States, and the US State of New Mexico. 1598: Death of Toyotomi Hideyoshi, known as the unifier of Japan. 1599: The Mali Empire is defeated at the Battle of Jenné. 1599: The van Neck expedition returns to Europe. The expedition makes a 400 per cent profit.[18] (to 1600) 1599: March, Leaving Europe the previous year, a fleet of eight ships under Jacob van Neck was the first Dutch fleet to reach the 'Spice Islands' of Maluku.[18] 1600: Giordano Bruno is burned at the stake for heresy in Rome.Siege of Fiľakovo castle during the Long Turkish War 1600: Battle of Sekigahara in Japan. End of the Warring States period and beginning of the Edo period. 1600: The Portuguese win a major naval battle in the bay of Ambon.[19] Later in the year, the Dutch join forces with the local Hituese in an anti-Portuguese alliance, in return for which the Dutch would have the sole right to purchase spices from Hitu.[19] 1600: Elizabeth I grants a charter to the British East India Company beginning the English advance in Asia. 1600: Michael the Brave unifies the three principalities: Wallachia, Moldavia and Transylvania after the Battle of Șelimbăr from 1599. For later events, see Timeline of the 17th century. Polybius' The Histories translated into Italian, English, German and French.[20] Mississippian culture disappears. Medallion rug, variant Star Ushak style, Anatolia (modern Turkey), is made. It is now kept at the Saint Louis Art Museum. Hernan Cortes (1485–1547) Henry VIII, (1491–1547) King of England and Ireland Don Fernando Álvarez de Toledo (1507–1582) Suleiman the Magnificent, Sultan of the Ottoman Empire (1520–1566) Ivan IV the Terrible (1530–1584) Oda Nobunaga (1534–1582) Sir Francis Drake (c. 1540 – 1596) Alberico Gentili, (1552–1608) the Father of international law Philip II of Spain, King of Spain (1556–1598) Akbar the Great, Mughal emperor (1556–1605) Related article: List of 16th century inventions. The Columbian Exchange introduces many plants, animals and diseases to the Old and New Worlds. Introduction of the spinning wheel revolutionizes textile production in Europe. The letter J is introduced into the English alphabet. 1500: First portable watch is created by Peter Henlein of Germany.The Iberian Union in 1598, under Philip II, King of Spain and Portugal 1513: Juan Ponce de León sights Florida and Vasco Núñez de Balboa sights the eastern edge of the Pacific Ocean. 1519–1522: Ferdinand Magellan and Juan Sebastián Elcano lead the first circumnavigation of the world. 1519–1540: In America, Hernando de Soto expeditions map the Gulf of Mexico coastline and bays. 1525: Modern square root symbol (√) 1540: Francisco Vásquez de Coronado sights the Grand Canyon. 1541–42: Francisco de Orellana sails the length of the Amazon River. 1542–43: Firearms are introduced into Japan by the Portuguese. 1543: Copernicus publishes his theory that the Earth and the other planets revolve around the Sun 1545: Theory of complex numbers is first developed by Gerolamo Cardano of Italy. 1558: Camera obscura is first used in Europe by Giambattista della Porta of Italy. 1559–1562: Spanish settlements in Alabama/Florida and Georgia confirm dangers of hurricanes and local native warring tribes. 1565: Spanish settlers outside New Spain (Mexico) colonize Florida's coastline at St. Augustine. 1565: Invention of the graphite pencil (in a wooden holder) by Conrad Gesner. Modernized in 1812. 1568: Gerardus Mercator creates the first Mercator projection map. 1572: Supernova SN 1572 is observed by Tycho Brahe in the Milky Way. 1582: Gregorian calendar is introduced in Europe by Pope Gregory XIII and adopted by Catholic countries. c. 1583: Galileo Galilei of Pisa, Italy identifies the constant swing of a pendulum, leading to development of reliable timekeepers. 1585: earliest known reference to the 'sailing carriage' in China. 1589: William Lee invents the stocking frame. 1591: First flush toilet is introduced by Sir John Harrington of England, the design published under the title 'The Metamorphosis of Ajax'. 1593: Galileo Galilei invents a thermometer. 1596: William Barents discovers Spitsbergen. 1597: Opera in Florence by Jacopo Peri. Entertainment in the 16th century ^ a b Modern reference works on the period tend to follow the introduction of the Gregorian calendar for the sake of clarity; thus NASA's lunar eclipse catalogue states "The Gregorian calendar is used for all dates from 1582 Oct 15 onwards. Before that date, the Julian calendar is used." For dates after 15 October 1582, care must be taken to avoid confusion of the two styles. ^ de Vries, Jan (14 September 2009). "The limits of globalization in the early modern world". The Economic History Review. 63 (3): 710–733. CiteSeerX 10.1.1.186.2862. doi:10.1111/j.1468-0289.2009.00497.x. JSTOR 40929823. S2CID 219969360. SSRN 1635517. ^ Singh, Sarina; Lindsay Brown; Paul Clammer; Rodney Cocks; John Mock (2008). Pakistan & the Karakoram Highway. Vol. 7, illustrated. Lonely Planet. p. 137. ISBN 978-1-74104-542-0. Retrieved 23 August 2010. ^ Babur (2006). Babur Nama. Penguin Books. p. vii. 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An Encyclopedia of World History (5th ed. 1973); highly detailed outline of events online free Media related to 16th century at Wikimedia Commons Timelines of 16th century events, science, culture and persons Retrieved from " 4 The following pages link to 16th century External tools (link count transclusion count sorted list) · See help page for transcluding these entries Showing 50 items. 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These smaller samples are known as fractions.Fractional distillation has been used for hundreds of years to purify and separate various liquids. However, its biggest use today is in petroleum refineries and petrochemical plants. The easiest way to understand fractional distillation is by looking at how it is used within these industries to refine a substance known as crude oil.Four hundred million years ago, the world was a different place. This was a time before the dinosaurs and before the glaciers of the ice ages took over the planet. Spiders had only been crawling about for 80 million or so years, the first four-legged tetrapods had just made it onto land, and green plants hadn't yet evolved into forests. The majority of the Earth was covered in oceans full of crustaceans, fish, and various types of vegetation like phytoplankton - microscopic green algae. When these organisms died, their remains fell to the ocean floors and were gradually covered in layers of silt and sand. As the layers grew higher over hundreds of thousands of years, the conditions intensified. Eventually, the heat and pressure pushing down upon the remains were so great that the dead organic matter started turning into a substance of great importance to humans today - crude oil. Crude oil is a complex mixture of hydrocarbons and other organic impurities. Fig. 1 - A representation of the formation of crude oilWhen crude oil is mined, it is a thick, black liquid full of hydrocarbons (such as alkanes), impurities, and contaminants. It isn't very useful to us in its original state The hydrocarbons all have different lengths and properties, which makes them hard to use when they are muddled together in such a way. However, if we distil crude oil using fractional distillation, we can obtain different fractions of hydrocarbons that all have similar sizes and properties. These are much more useful to us than the raw mixture.Let's now look at the process of fractional distillation. Here's how it is carried out:Fractional distillation of crude oil takes place in a fractionating column. This is a huge chamber, typically eight meters wide and forty meters high. For context, that's slightly taller than the statue of Christ the Redeemer in Rio de Janeiro, and only just shorter than the distance between the top of the Titanic's tallest funnels and the water!Crude oil enters at the bottom of the fractionating column. It is heated to high temperatures and so it evaporates.The evaporated vapours rise up the fractionating column. The column has a temperature gradient - the bottom of the column is warmer than the top. This means that as the vapours rise, they gradually cool down. When the temperature of the column gets cool enough, the vapours condense. They are then collected in trays and piped off for further refinement.The most important feature of a fractionating column is its temperature gradient. It means that hydrocarbons with different boiling points condense at different heights. This all depends on their size:Heavier, longer-chain hydrocarbons have higher boiling points. They condense at relatively high temperatures, and so their fractions are collected lower down in the column.Lighter, shorter-chain hydrocarbons have lower boiling points. They condense at relatively low temperatures, and so are collected higher up in the column.Fig. 2 - A diagram showing the process of fractional distillation. The fractions produced are named.So, we've learned that fractional distillation's primary function is to separate crude oil, which by itself doesn't have many uses, into different fractions. Hydrocarbons within a fraction all share similar boiling points thanks to their similar sizes. A hydrocarbon's size dictates many of its other properties, too, and so molecules in the same fraction also have multiple other properties in common. This gives different fractions different uses - they have a whole range of applications and are much more valuable. By separating crude oil, we've managed to make a relatively worthless substance infinitely more useful! For example:The largest hydrocarbons, with chain lengths of 70 or longer, form bitumen. This is a thick, tar-like substance used for road surfaces and roofing. Other long-chain hydrocarbons are good fuels for ships and power stations.Medium-length hydrocarbons make up fuel for vehicles. For example, butane is useful as a component of petrol because of its low boiling point, meaning we can burn it in internal combustion engines. These hydrocarbons also form diesel. The shortest-chain hydrocarbons, which are gases at room temperature, are used as fuel for camping stoves. You might also use bottled gas to heat your home. But crude oil fractions have many uses beyond construction and fuel. For example:Naphtha is a fraction containing hydrocarbons with about five or six carbon atoms. When we crack naphtha, we end up with alkenes which are then used to make plastics, detergents, and alcohols. In fact, hydrocarbons make great chemical feedstocks - they're easily transformed industrially into other types of molecules. In addition, many of your clothes are based on hydrocarbons. Hydrocarbons are also found in various paints, solvents, and lubricants. Even the coolant in your refrigerator is derived from a particular short-chain hydrocarbon! Just take a look around you: You are bound to find a huge range of products that, one way or another, originate from crude oil.Crude oil is our main source of organic chemicals and an extremely useful fossil fuel when mined, purified, and refined. It is a substance that powers our vehicles, keeps our electronics ticking over, can be turned into clothes and packaging, and is just lying there under the ocean floors, waiting to be used. In fact, you could argue that it plays an essential role in almost all areas of our lives. If so, then why are some people so against using it? Let's now consider the disadvantages of extracting and distilling crude oil. These include:Its renewability.The greenhouse gases associated with its use.Its various impurities.Because crude oil forms so slowly, it is a non-renewable resource. A renewable resource is one that is replenished naturally at the rate that we use it. Non-renewable resources are therefore resources that we use faster than the rate they are replenished at.Unless we stop extracting crude oil so quickly, we will soon run out. Our crude oil resources are finite. By relying heavily on crude oil for such a plethora of products, we disadvantage future generations. When our oil reserves run out, they will quickly have to find alternative ways to produce items such as fuel, plastics, and chemical feedstocks, that have become such a fundamental part of everyday life.As you now know, crude oil is made up of hydrocarbons of all different lengths and sizes. We burn lots of these hydrocarbons as fuels for cars, boats, and planes. Whilst they are great sources of energy, hydrocarbons release carbon dioxide (CO_2) and water vapour (H_2O) when burnt. This is a serious problem because carbon dioxide and water vapour are both greenhouse gases.A greenhouse gas is a gas that absorbs radiation from the sun reflected off the Earth, instead of letting it escape back into outer space.Greenhouse gases trap heat in the atmosphere and warm the planet, contributing to something called the greenhouse effect.The greenhouse effect is a term used to describe how greenhouse gases in the atmosphere absorb radiation from the Earth, which traps heat and warms the Earth up. It works in much the same way as a greenhouse used for growing plants, hence the name.By burning crude oil fractions, humans are contributing to the steady increase in global temperature that is melting glaciers, causing crop failure, and intensifying freak weather events like floods and droughts.Fig. 3 - The greenhouse effect. Greenhouse gases trap heat from the sun, thereby warming the EarthSee Combustion for more information about burning hydrocarbons and its negative effects. Crude oil is an organic mixture that can contain many impurities, such as sulphur. These impurities come from the bodies of the deep-sea creatures that break down to form crude oil, as explored above. When we burn crude oil as a fuel, we release the impurities back into the environment.Sulphur, for example, burns to form sulphur dioxide. You may know that this gas causes breathing difficulties, skin irritation, and corrosive acid rain. Sounds fun, right?For all the reasons explored above, extracting and distilling crude oil remains a controversial topic and many parties are actively protesting against it. But it isn't all bad news. Alternatives to crude oil are becoming ever cheaper and more accessible. You may have drunk coffee from a fully compostable cup, worn clothes made from natural linen, cotton, or even hemp, or perhaps powered your phone with solar energy. The UK government recently announced plans to phase out all sales of new petrol and diesel cars by 2030. Although this may seem like an unachievable goal right now, it is a great step in the right direction towards a greener, more sustainable future.Fractional distillation is a process that involves separating a mixture into smaller samples with similar boiling points, known as fractions. It is primarily used for separating crude oil.Crude oil is a mixture of hydrocarbons formed from plant and animal matter that has been compressed under high temperatures and pressures over millions of years.Fractional distillation uses a temperature gradient to separate crude oil into more useful fractions of hydrocarbons (primarily alkanes) with similar sizes, boiling points, and properties.Heavier, longer-chain hydrocarbons have a higher boiling point. They condense at relatively high temperatures and so are collected as one fraction lower down in the column.Lighter, shorter-chain hydrocarbons have a lower boiling point. They condense at relatively low temperatures and so continue rising towards the top of the column. They are only collected when the temperature in the column drops below their boiling point, making it cool enough for them to condense.Crude oil fractions have various uses depending on their properties. They are used as fuels, construction materials, and chemical feedstock.Burning crude oil fractions as fuel has negative impacts on the environment, but crude oil is widely regarded as an important part of modern life. What is fractional distillation? Fractional distillation is the process of separating a mixture into fractions according to their boiling points. How does fractional distillation work? Fractional distillation works by heating a mixture so it evaporates. The vapours rise up a fractionating column with a temperature gradient, so similar length hydrocarbons condense and are collected at different points. Heavier, longer chain hydrocarbons will condense lower down in the column due to their higher boiling points, whilst lighter hydrocarbons continue rising up. What does fractional distillation separate? Fractional distillation is mostly used to separate crude oil, a mixture of hydrocarbons, into fractions of alkanes with similar chain lengths. Why is fractional distillation important? Fractional distillation is important because it is used as a useful separation technique, used separating mixtures into fractions with similar boiling points. Save Article At StudySmarter, we have created a learning platform that serves millions of students. Meet the people who work hard to deliver fact based content as well as making sure it is verified. Content Creation Process: Lily Hulatt is a Digital Content Specialist with over three years of experience in content strategy and curriculum design. She gained her PhD in English Literature from Durham University in 2022, taught in Durham University's English Studies Department, and has contributed to a number of publications. Lily specialises in English Literature, English Language, History, and Philosophy. 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Excelling in this area requires an understanding of the basic principles that underpin it and the specific definitions used in its context. The fundamental tenet of 6+4 cycloaddition revolves around the reaction of a conjugated diene and a dienophile to form a six-membered ring. This reaction type is a subset of the broader cycloaddition category in organic chemistry that includes the well-known Diels–Alder reaction. Cycloaddition reactions, including 6+4 cycloaddition, are examples of pericyclic reactions, which occur in a single, seamless, and concertedly reorganising step with no intermediates. Two or more unsaturated molecules combine, with the formation of a cyclic adduct. \[\text{Diene} + \text{Dienophile} \rightarrow \text{Cyclic Adduct} \] The 6+4 cycloaddition is unique amongst the cycloaddition reactions. The name reflects the number of the electrons in the reaction participating in the reaction simultaneously in a cyclic manner with no distinct intermediates. The reaction involves six π electrons from one reactant and four π electrons from another. In this case, six from the triene and four from the polarised dienophile. An integral part of this definition is the understanding of the π electron system. The π electron system consists of electrons occupying pi bonds, allowing the electrons to move more freely across the atoms. The conception of the 6+4 cycloaddition dates back to an era when attempts were made to expand the scope of Diels–Alder reactions. The 4+2 cycloaddition was already established, but chemists pushed boundaries to explore if π systems of dienes and dienophiles with higher than '4+2' were possible. When these efforts culminated in the 6+4 cycloaddition, it was initially met with scepticism, primarily since it broke away from the established Woodward–Hoffmann rules for pericyclic reactions. However, advanced modelling and experimentation validated this rule-breaking scenario, attributing it to quantum mechanical tunnelling. 6+4 cycloaddition has unique characteristics that set it apart from its counterparts. Here are some key distinguishing features: It operates outside the Woodward-Hoffmann rules. It forms ten-membered rings rather than six. A typical 6+4 cycloaddition due to the larger electron system. These features have opened up new avenues of exploration in organic chemistry, providing unique strategies to manipulate the synthesis of compounds. Consequently, it has provided a tool for synthesising complex, polycyclic structures in organic chemistry. Such applications demonstrate the vast potential of this reaction in advancing the field. The intriguing aspect of 6+4 cycloaddition is its distinctive mechanism. Just like the rhythm of a grand symphony, every constituent component in the reaction mechanism gracefully moves in synchrony to come together in a fascinating display of molecular choreography. The mechanism of the 6+4 cycloaddition is complex and layered, making it both captivating and challenging. While the process has been probed through quantum mechanics and advanced spectroscopic techniques, the overall mechanism can be delineated in a simplified manner. The diene activation is the starting point of the 6+4 cycloaddition reaction. It is characteristically a diene – a molecule with two double bonds – that brings six Π electrons to the reaction. Upon activation, the diene character becomes more explicit, aiding the subsequent alignment for cycloaddition. Second, the activated diene combines with a dienophile – a compound that readily reacts with a diene. In the context of a 6+4 cycloaddition, the dienophile provides four Π electrons. The final step is where the cycloaddition happens. Here, the aligned diene and dienophile join to form a new ten-membered ring. The diene and dienophile act in concert during the formation of a ring, a typical feature of pericyclic reactions. Let's take a microscopic look into the individual steps of the 6+4 cycloaddition. This mechanism involves redistribution of the pi electrons among the reacting components, guided by precise molecular alignments. Here's a breakdown of the stages: Stage 1: Activation of the diene for the cycloaddition. Stage 2: Approach and alignment of the polarised dienophile towards the pre-aligned diene system. Stage 3: Formation of the ten-membered ring following the 6+4 cycloaddition. The chemical equation for this reaction can be represented as follows: \[\text{Diene} + \text{Dienophile} \rightarrow \text{Ten-membered cyclic adduct} \] In each of these steps, electrons transition in a concerted process, with no break in their movement. This fluid transfer of electrons is one of the hallmarks of pericyclic reactions, making such processes fascinating to study and observe. Pericyclic reactions, such as the 6+4 cycloaddition, just like many chemical reactions, could benefit significantly from catalysis. A catalyst can help lower the activation energy barrier, speed up the reaction and influence the reaction pathway. A catalyst is a substance that can increase the rate of a chemical reaction without being consumed in the process. In the context of 6+4 cycloaddition, studies have shown that certain Lewis acids can be effective catalysts. These Lewis acids are capable of activating the dienophile, enhancing its reactivity towards the diene. Lewis acids and catalysts in general are not mere spectators of the reaction; they take active roles in facilitating the reaction. Lewis acids, in this context, can forge a bond with the electron-rich dienophile, thus increasing its reactivity and driving the reaction forward. To summarise, in the vast and colourful world of organic chemistry, the 6+4 cycloaddition stands out due to its unique soprano of molecular interaction, its defiance of established rules and its immense potential for applications in organic synthesis. In order to gain a thorough understanding of the 6+4 cycloaddition reaction, it can be of great advantage to focus on actual examples where this reaction type has been successfully used. Practical instances allow you to observe how the fundamental aspects of the 6+4 cycloaddition are applied in real-world scenarios. Through experimentation and research, there are several widely acknowledged examples of 6+4 cycloadditions. Each instance provides a unique perspective on the reaction's potential, highlighting how variations in reactants can lead to diverse product outcomes. A well-documented instance of 6+4 cycloaddition involves the reaction of two specific organic compounds – tropone and 1,3-Butadiene. The tropone serves as the diene (providing six π electrons), and the 1,3-butadiene acts as the diene (supplying six π electrons). The chemical equation: \[\text{Tropone} + \text{1,3-Butadiene} \rightarrow \text{[6+4] Cycloadduct} \] Crucially, the success of this reaction hinges on particular reaction conditions. While the reaction takes place at room temperature, the yield increases significantly with an elevation in temperature, demonstrating the importance of thermodynamics in organic reactions. Another compelling example involves the reaction between cyclopentadiene and benzene. Here, the cyclopentadiene acts as the dienophile and the benzyne as the diene. Unlike the previous example, this reaction requires a catalyst (Rh(PPh3)4) to proceed effectively. These case studies not only illuminate the practical implications of the 6+4 cycloaddition reaction but also offer valuable insights into the intricacies that govern the process. The factors impacting the yield and efficiency of the reaction often turn out to be critical. Variables such as temperature, the presence of a catalyst, and the structure of reactants play a critical role. Understanding and optimizing the reactants' properties and tailoring the reaction conditions to maximise the cycloaddition process' efficiency. In synthetic organic chemistry, the 6+4 cycloaddition reaction plays a central role in the construction of ten-membered ring systems and other intricate molecules. One striking example is the synthesis of Subincanadine E, a bioactive alkaloid that has been synthesised using 6+4 cycloaddition as a key step. The complexity of the Subincanadine E molecule, with its ten-membered ring and attached functional groups, demonstrates the reaction's potential in crafting complicated, bioactive molecules. The synthetic route to Subincanadine E involves the 6+4 cycloaddition between a specifically designed diene and dienophile. The result is a ten-membered ring with proper functional group positioning for further manipulations. This highlights the contribution of 6+4 cycloaddition in facilitating the synthesis of complex organic molecules. In addition to this, the reaction is employed in the catalytic transformation of biomass-derived materials. In this context, 6+4 cycloaddition serves as a critical weapon in the synthetic chemist's arsenal, allowing for the conversion of simple, renewable molecules from abundantly available resources. In conclusion, practical application of 6+4 cycloaddition, whether in classic examples or in cutting-edge adaptations, underlines the reaction's value within the realm of synthetic organic chemistry. Through intellectual curiosity and persistent exploration, the boundaries of so-called 'conventional' chemistry are continually expanded, and the applications of fascinating concepts like 6+4 cycloaddition will only grow. While the principles of the 6+4 cycloaddition are captivating, they are not arbitrary. Indeed, like all other types of chemical reactions, they unfold according to some governing principles. These principles provide a guideline for understanding and predicting the likely outcomes of 6+4 cycloaddition reactions. The 6+4 cycloaddition is categorised as a pericyclic reaction, which means it involves a redistribution of bonding electrons in a cyclic transition state leading to stereospecific products. This type of reaction is guided by the following fundamentals: The Conservation of Orbital Symmetry (also known as the Woodward-Hoffmann rules) controls the stereochemical outcome of pericyclic reactions. Energy levels of reactant molecular orbitals and product molecular orbitals need to match for the reaction to proceed. The FMO theory (Frontier Molecular Orbital Theory) is another vital principle. It posits that reactions occur as a result of interaction between highest occupied molecular orbital (HOMO) of one reactant and the lowest unoccupied molecular orbital (LUMO) of the other reactant. A closer look reveals some fascinating aspects of these principles when applied to 6+4 cycloaddition. \[\text{Diene} + \text{Dienophile} \rightarrow \text{[6+4] Cycloaddition} \] In the equation above, the diene, donating six π electrons to the cyclic transition state, serves as the nucleophile or electron-rich entity. Meanwhile, the dienophile, contributing four π electrons, is playing the role of the electrophile or electron-deficient entity. According to the FMO theory, the HOMO of the diene (nucleophile) interacts with the LUMO of the dienophile (electrophile) to facilitate the 6+4 cycloaddition. Importantly, control of Orbital symmetry is central to the reaction's success. In line with the Woodward-Hoffmann rules, the reaction's pathways are determined by the need to maintain orbital symmetry. These principles collectively govern the reactivity, orientation, and stereochemical outcomes of the 6+4 cycloaddition. In chemistry, exceptions are as constant as the rules themselves. The principles governing the 6+4 cycloaddition, while generally reliable, are sometimes challenged by unusual reactions exhibiting unexpected outcomes. It is these exceptions that refine our understanding and bring excitement into the world of cycloadditions. Some reactions might exhibit a surprising lack of sensitivity to stereochemical control, producing mixtures of possible stereoisomeric products. Similarly, while FMO theory generally predicts the interaction between the HOMO of one reactant and the LUMO of another, there can be exceptions. Occasionally, higher-lying occupied molecular orbitals or lower-lying unoccupied molecular orbitals might come into play, eschewing the typical HOMO-LUMO interaction. Another area where exceptions can glimmer is in the reaction conditions. 6+4 cycloadditions are typically thermal reactions yet, in some cases, the use of light (photochemical conditions) can facilitate cycloaddition reactions albeit with different regioselectivity and stereoselectivity. These are downright exceptions to the common trend and add to the complexity of the 6+4 cycloaddition. Consequently, the 6+4 cycloaddition, like any other chemical concept, is sophisticated and layered, more of a musical composition than a rigid set of instructions. It is the intermingling of principles with their exceptions that makes the 6+4 cycloaddition and indeed, the wider dimension of organic chemistry, a true symphony of its own. The discovery and further exploration of the 6+4 cycloaddition in the late 20th century broadened the horizons of pericyclic reactions, providing synthetic chemists with a potent tool to construct ten-membered ring systems. It invigorated ongoing research in synthesising complex molecules, and has since then significantly influenced the efficiency and selectivity of chemical synthesis in the field of organic chemistry. 6+4 cycloaddition serves as a cornerstone in pericyclic reactions, a prominent section of the organic chemistry syllabus due to its applications in various domains. * Synthesis of organic compounds: 6+4 cycloaddition has played a significant part in facilitating complex organic synthesis, particularly of bioactive molecules. Its usefulness extends to both academic and industry. For example, it's a key step in synthesising Subincanadine E, a bioactive alkaloid. * In the pharmaceutical sector, the reaction aids in developing active pharmaceutical ingredients (APIs) by allowing for the creation of structurally diverse and complex organic molecules. * In agrochemical development, structurally unique agrochemical agents can be synthesised. * Synthetic strategies in material science also harness 6+4 cycloaddition to create innovative materials with unique properties. The understanding and practice of 6+4 cycloaddition reaction also aids in: * Improving student's perception of pericyclic reactions * Enabling researchers to explore new methodologies in chemical synthesis * Offering the possibility to design novel reaction pathways All these applications contribute to prolific research and ongoing developments in organic chemistry and related fields. Prior to the recognition of 6+4 cycloaddition, traditional cycloaddition reactions (such as the Diels-Alder reaction) primarily focused on six-electron processes. The identification of the 6+4 cycloaddition constituted a paradigm shift, transforming the conceptual landscape by introducing a ten-electron process. This altered the definition of cycloaddition and led to the development of a new domain of pericyclic reactions. In essence, the 6+4 cycloaddition widened the range of what was possible within the framework of cycloaddition reactions, and prompted further exploration and discovery of other types of cycloadditions with varying electron counts. Moreover, the 6+4 cycloaddition has significantly influenced the design of synthetic strategies in organic chemistry. The ability to construct medium-sized rings, particularly ten-membered rings commonly found in bioactive natural products, boosted the reaction's popularity amongst synthetic chemists. It provided a precise, efficient and stereospecific method to achieve complex syntheses. This influence extends beyond just the synthesis of predefined molecules; it fuels curiosity and exploration, leading chemists to craft new molecules that might eventually prove to be of significant utility for mankind. However, the role of the 6+4 cycloaddition extends beyond immediate applications. It also serves as a didactical bridge in the study of pericyclic reactions. The reaction's principles enlighten students about fundamental concepts like the Woodward-Hoffmann rules, frontier molecular orbital theory, conservation of orbital symmetry, stereochemistry, regioselectivity, and catalysis. In sum, the discovery and application of 6+4 cycloaddition has proved to be a great impetus to the ever-evolving field of organic chemistry, providing substantial contributions that resonate with both the practical and theoretical aspects of the science. 6+4 cycloaddition is unique due to its operation outside the Woodward–Hoffmann rules and leveraging quantum mechanical tunnelling. The mechanism of 6+4 cycloaddition consists of stages: reactant activation, diene-dienophile combination, and cycloaddition. Catalysts can lower the activation energy barrier and speed up the 6+4 cycloaddition process. Practical examples of the 6+4 cycloaddition include reactions involving tropone and 1,3-butadiene or cyclopentadiene and benzyne. 6+4 cycloaddition principles include Conservation of Orbital Symmetry and Frontier Molecular Orbital (FMO) Theory, however, exceptions occur which challenge these principles. What is 6 + 4 cycloaddition? Please write in UK English. A 6 + 4 cycloaddition is a chemical reaction between two compounds, one with six π electrons and the other with four π electrons, to form a ten-membered ring. This reaction follows the principles of the Woodward-Hoffmann rules. What is a 6 + 4 cycloaddition reaction? Write in UK English. A 6 + 4 cycloaddition reaction is a type of pericyclic reaction in chemistry wherein a six-atom component and a four-atom component react together to form a ten-membered ring. It's part of the broader class of cycloaddition reactions that create cyclic compounds. What is an example of 6 + 4 cycloaddition? Write in UK English. The process of creating Tetracycline is a classic example of a 6+4 cycloaddition. In this reaction, a six-atom component combines with a four-atom compound to form a new cycloaddition product. What is the 4-cycloaddition reaction? Write in UK English. The 4 cycloaddition reaction, often called [4+2] cycloaddition, is a chemical reaction where a conjugated diene and a dienophile undergo a cycloaddition process to form a six-membered cyclic compound. The most common example is the Diels-Alder reaction. What is the difference between 6 + 4 Cycloaddition and Diels-Alder? Express your answer in UK English. 6 + 4 cycloaddition and Diels-Alder reactions both orchestrate the formation of cyclic compounds. However, the former creates a ten-membered ring, involving a six-atom component and a four-atom component, whilst the latter— a Diels-Alder reaction— yields a six-membered ring, combining a conjugated diene and a dienophile. Save Article Test your knowledge with multiple choice flashcards That was a fantastic start! You can do better! Sign up to create your own flashcards Access over 700 million learning materials Study more efficiently with flashcards Get better grades with AI Sign up for free Already have an account? Log in Good job! 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Graduated in Electrical Engineering at the University of São Paulo, he is currently pursuing an MSc in Computer Engineering at the University of Campinas, specializing in machine learning topics. Gabriel has a strong background in software engineering and has worked on projects involving computer vision, embedded AI, and LLM applications. Get to know Gabriel Discover learning materials with the free StudySmarter app Sign up for free StudySmarter is a globally recognized educational technology company, offering a holistic learning platform designed for students of all ages and educational levels. Our platform provides learning support for a wide range of subjects, including STEM, Social Sciences, and Languages and also helps students to successfully master various tests and exams worldwide, such as GCSE, A Level, SAT, ACT, Abitur, and more. We offer an extensive library of learning materials, including interactive flashcards, comprehensive textbook solutions, and detailed explanations. The cutting-edge technology and tools we provide help students create their own learning materials. StudySmarter's content is not only expert-verified but also regularly updated to ensure accuracy and relevance. Learn more Page 3 Fact Checked Content Last Updated: 21.10.2023 9 min reading time Content creation process designed by Content cross-checked by Content quality checked by In your quest to understand organic chemistry, 8+2 cycloaddition might just become your best friend. An adduct-forming reaction, 8 + 2 cycloaddition, is an integral part of many synthesis pathways and aids in creating complex cyclic structures. An 8+2 cycloaddition is a form of cycloaddition chemical reaction where a compound having an system of eight π electrons reacts with a compound containing two π electrons to create a cyclic product. A fascinating attribute of this reaction is that it falls under the domain of pericyclic reactions where the reaction proceeds in a single step without any intermediates. This characteristic classifies the 8 + 2 cycloaddition as a [4+2] cycloaddition reaction, which involves the concerted movement of two π bonds and two σ bonds. This chemical process can be seen in the formation of 10-membered ring systems as during such a reaction, a 1,3,5,7-octatetraene reacts with ethene to form a 10-membered ring in an endothermic process. To comprehend the mechanism of this fascinating reaction, it's important to break it down to its core components. Note that the 8 + 2 cycloaddition reaction comprises two major components - A cyclooctatetraene system (with eight π electrons) An alkene (with two π electrons) The reaction typically occurs in an endothermic fashion i.e., it absorbs heat from its surroundings to drive the reaction forward. In this reaction, an eight electron element and a two electron element combine to create a larger cyclic structure. The 8 + 2 cycloaddition reaction is a fine example of molecular orbital theory in action, where it incorporates concepts like HOMO (highest occupied molecular orbital) and LUMO (lowest unoccupied molecular orbital) to define its reaction mechanism. Identifying the molecular mechanisms in an 8 + 2 cycloaddition requires a keen sense of molecular interactions. You'll need to pay particular attention to the movement of σ and π bonds since they play a huge role in shaping the final cyclic structure. Firstly, the 1,3,5,7-octatetraene, and ethene mix, creating a perfect reaction ground for the 8+2 cycloaddition. As the reaction proceeds, the two ends of the 1,3,5,7-octatetraene undergo bonding with the alkene's two carbon atoms. This results in the formation of a 10-membered ring structure with the transfer of the four π electrons from the 1,3,5,7-octatetraene system to fill the π* (low energy) antibonding orbital of ethene, forming a conjugated cyclic system. The reaction's key lies in the orbital symmetry allowed by the concerted movement of the π and σ bonds, resulting in a cycloaddition product that beautifully displays the elegance of pericyclic reactions in organic chemistry. The reaction mechanism of 8+2 cycloaddition, often illustrated through the concept of molecular orbitals, is central to the comprehension of organic reactions involving octatetraene systems and alkenes. At first glance, the reaction mechanism of 8+2 cycloaddition might seem slightly enigmatic. However, by diving deeper into the world of pericyclic reactions, understanding how π electron systems come together to form more intricate structures becomes more straightforward. Here's a simple way to think of it: A 1,3,5,7-octatetraene molecule joins forces with an alkene. The steric strain caused by the flat conformation of the octatetraene system incentivises the reaction. The cycloaddition takes place as the component previously carrying eight π electrons reacts with the compound bearing two π electrons. The end result is a ten-membered ring. Seeing it in action: Starting with an octatetraene, you can envision the molecule bending around to permit the ends to react with an alkene in a snug fit, leading to a new cycloaddition product. The actual 8+2 cycloaddition process unravels in a series of fascinating steps that beautifully capture the subtlety of pericyclic reactions. Here is a step-by-step breakdown: Step Process Step 1 The 1,3,5,7-octatetraene combines with the alkene. Step 2 The two reactants merge whilst creating a bond between the ends of the octatetraene system and the alkene's carbon atoms. Step 3 Four π electrons are transferred from the 1,3,5,7-octatetraene system to engage the low energy π* antibonding orbital of the alkene. Step 4 A conjugated cyclic system forms. Several factors come into play to dictate the direction the 8+2 cycloaddition runs. In particular, three significant elements contribute to the success of the reaction: Molecular orbital interactions: The HOMO-LUMO interaction - the interaction between the Highest Occupied Molecular Orbital (HOMO) of the octatetraene and the Lowest Unoccupied Molecular Orbital (LUMO) of the alkene - is crucial to this reaction. Steric strain: The relief of steric strain acts as a driving force in the reaction. The octatetraene's flat conformation becomes less strained in the final structure, driving the reaction forward. Temperature: As an endothermic reaction, heat is absorbed from the surroundings and plays an integral role in driving the reaction. High temperatures aid in populating the more reactive conformations which can participate in the reaction. Furthermore, the reactivity can also be enhanced through the presence of light which promotes the reactants to a higher-energy state fit for reaction. Though seemingly complex, the 8+2 cycloaddition is a fantastic example demonstrating the synergy of theoretical and practical organic chemistry. It reminds you that underlying the seemingly infinite diversity of organic compounds and reactions is a set of unifying principles. Whilst the theory of 8+2 cycloaddition undoubtedly provides you a robust base, translating these concepts into practical examples aids your comprehension greatly. Organic chemistry is not merely about understanding standalone reactions but also about seeing how these reactions interact and materialise in various contexts. When it comes to identifying an 8+2 cycloaddition example in real life, it's all about breaking down the reaction to its bare bones. You need to pinpoint the presence of a 1,3,5,7-octatetraene system and an alkene as the primary players in the reaction. 1,3,5,7-octatetraene refers to a hydrocarbon with the formula C_8H_8 which incorporates a system of eight π electrons. In the life sciences, 8+2 cycloaddition particularly plays a crucial role. Myriad biological and pharmaceutical compounds boast structures formed from cycloaddition reactions, including the 8+2 variant. Many natural products undergo biosynthesis involving cycloaddition due to their unique and beneficial properties. Did you know, for instance, that the polycyclic structure of several antiviral and anticancer compounds, which are used in active pharmaceutical ingredients (APIs), can be rationalised using 8+2 cycloaddition? Now, let's delve deeper by taking a look at a specific example of the 8+2 cycloaddition. Consider an octatetraene system in the presence of ethene. At a glance, it's evident that you have your actors ready - an eight π electron system (octatetraene) and a two π electron component (ethene). The reaction unfolds as follows: The molecular interactions between octatetraene and ethene kick-start the reaction. The ends of the octatetraene bend towards the alkene to form new bonds with the alkene's carbons - remember, this is the crucial step triggering the cycloaddition. Four π electrons from the octatetraene transfer to the alkene's low energy π* antibonding orbital. A cyclic system forms, completing the 8+2 cycloaddition. The product of this reaction is a larger 10-membered ring which encapsulates the transfer and new formation of bonds that define cycloaddition reactions. Analyse the final structure to clearly identify the circular arrangement of atoms and bonds that have resulted from the 8+2 cycloaddition. In real-life situations, the conditions under which an 8+2 cycloaddition takes place can greatly impact the outcome of the reaction. Factors such as temperature, pressure, light exposure, and the presence of catalysts can alter the course of the reaction. Firstly, as 8+2 cycloaddition is an endothermic reaction, increases in temperature can potentially improve the reaction efficiency by supplying additional heat energy to the reaction. Furthermore, interestingly, light exposure can also aid reactivity by promoting the reactants to a higher-energy state more suited for reaction - this is a concept known as photochemical activation. The presence of catalysts can also play a critical role. Should a catalyst be present, it can lower the reaction's activation energy and provide an alternative reaction pathway, allowing the reaction to proceed more rapidly and efficiently. However, it's crucial to remember that the fundamentals of pericyclic reactions and concerted bond movement remain a mainstay. No matter how the conditions vary, the fundamental principles of the 8+2 cycloaddition hold true. As always, it boils down to the dance of electrons, bonds forming and breaking as you join the graceful waltz of organic chemistry. 8+2 cycloaddition is a type of cycloaddition chemical reaction, it involves a compound with a system of eight π electrons and a compound carrying two π electrons that react to form a larger cyclic structure. The 8+2 cycloaddition belongs to the class of pericyclic reactions, characterized by the reaction proceeding in a single step with no intermediates, involving the concerted movement of two π bonds and two σ bonds. An example of 8+2 cycloaddition is the formation of 10-membered ring systems - a 1,3,5,7-octatetraene reacts with ethene to form a 10-membered ring in an endothermic process. The two vital components of an 8 + 2 cycloaddition are a cyclooctatetraene system (with eight π electrons) and an alkene (with two π electrons). An 8 + 2 cycloaddition reaction uses concepts such as HOMO (highest occupied molecular orbital) and LUMO (lowest unoccupied molecular orbital) in its reaction mechanism. Molecular orbital interactions, relief of steric strain, and temperature are key factors influencing this reaction type. What is 8 + 2 cycloaddition? 8 + 2 Cycloaddition is a chemical reaction where a compound with eight pi electrons reacts with a compound with two pi electrons to produce a ten-membered ring. This type of reaction falls under the pericyclic class of reactions. What is an example of 8 + 2 cycloaddition? Write in UK English. An example of 8 + 2 cycloaddition is the reaction between cyclotetraene and alkenes. This converges to form decalins. This reaction is considered rare but demonstrates the 8 + 2 cycloaddition process. What is the rule for 8+2 cycloaddition? Please write in UK English. The rule for 8+2 cycloaddition, a subtype of pericyclic reactions, states that eight pi electrons from one molecule combine with two pi electrons from another molecule. This results in the formation of a cyclic compound having ten pi electrons, following the conservation of orbital symmetry. What is the equation for an 8 + 2 cycloaddition reaction? Please write in UK English. The equation for 8 + 2 cycloaddition reaction isn't a simple formula. It refers to the reaction of a 4π-electron system (like a diene) with a 6π-electron system (like a triene) to form a 10-membered ring. This fall under pericyclic reactions category. Why is 8+2 cycloaddition important? 8+2 cycloaddition is important in chemistry because it enables the synthesis of complex cyclooctene structures, including many naturally occurring substances and organic materials. It offers great control over the stereochemistry, leading to highly stereoselective products, a crucial aspect in drug design and manufacturing. Save Article Test your knowledge with multiple choice flashcards That was a fantastic start! You can do better! Sign up to create your own flashcards Access over 700 million learning materials Study more efficiently with flashcards Get better grades with AI Sign up for free Already have an account? Log in Good job! Keep learning, you are doing great. Don't give up! Next Open in our app At StudySmarter, we have created a learning platform that serves millions of students. Meet the people who work hard to deliver fact based content as well as making sure it is verified. Content Creation Process: Lily Hulatt is a Digital Content Specialist with over three years of experience in content strategy and curriculum design. 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Learn more Page 4 Fact Checked Content Last Updated: 21.10.2023 12 min reading time Content creation process designed by Content cross-checked by Content quality checked by Delving into the fascinating world of organic chemistry, you'll notice a common structure—the 5 membered ring. These rings play a crucial role in the composition of a variety of chemical compounds, underlying the fundamental properties of many substances required in pharmaceuticals and materials science. A 5 membered ring refers to a cyclic structure present in an organic molecule that consists of five atoms. These atoms, usually carbon, are connected by covalent bonds to form a ring-like structure. This particular structure is not just restricted to carbon atoms. Nitrogen, oxygen, and sulphur atoms can also be part of these ring structures, leading to a rich variety of molecules including alcohols, amines, and ethers, among others. A common example of a 5 membered ring molecule is 'Pentane'. In pentane, the five carbon atoms are connected in a chain with hydrogen atoms filling the remaining bonding slots.$$\text{CH}_3\text{(CH}_2\text{)}_3\text{CH}_3$$ Though it's not a cyclic molecule, it showcases the base structure. Stability: A 5 membered ring is relatively stable due to its bond angles that provide minimal strain. However, this doesn't mean it's completely strain-free. A small degree of torsional strain (Pitzer strain) and angle strain still exist. Reactivity: These rings are pivotal in many organic reactions because of their intermediate stability. Some reactions uniquely occur in 5 membered rings. Variety: As mentioned earlier, 5 membered rings can accommodate various atoms leading to rich structural diversity. Compound Structure Furan $\text{C}_4\text{H}_4\text{O}$ Pyrolle $\text{C}_4\text{H}_5\text{N}$ Thiophene $\text{C}_4\text{H}_4\text{S}$ Did you know that some naturally occurring compounds, including nucleobases of DNA and RNA, such as adenine and guanine, also exhibit a 5 membered ring structure? These ring structures are combined into fused rings to give purine structure in these nucleobases. Understanding the traits and implications of these 5 membered rings is essential for unraveling the vast labyrinth of organic chemistry. As you delve deeper into this fascinating subject, remember that these small structures build the foundation for understanding the complex world of molecules that shape our lives. The concept of a 5 membered ring structure, as discussed, is not restricted to solely carbon atoms. A multitude of other elements can be embedded within its structure, providing a level of variation that significantly enriches organic chemistry. From carbon to nitrogen, oxygen, and sulphur, each atom contributes unique properties and reactivities which broaden the spectrum of possible chemical reactions. A 5 membered ring solely consisting of carbon atoms exhibits unique characteristics. This structure, famously found in cyclopentane, displays considerable stability even though it's not as calm as an exactly planar structure. This deviation is due to the 'puckering' effect. The carbon atoms in a 5 membered ring form an amazing 108 degrees bond angle, which is reasonably close to the 109.5 degrees ideal bond angle in tetrahedral carbon compounds. Here are some other features: Each carbon atom is sp3 hybridised. The compound can exist in different conformations, enhancing its versatility. There are certain ring-flipping behaviours which minimise the potential energy. Furthermore, the simplicity and prevalence of carbon atoms make it a fundamental element in organic chemistry, presenting opportunities to study conformational analysis, substitution reactions, and more. A 5 membered ring can also incorporate nitrogen, one of the most crucial elements in biochemistry. Pyrrole is an ideal example of a 5 membered nitrogen ring, with four carbon atoms and one nitrogen atom. There are unique characteristics that stem from the presence of the nitrogen atom in the ring: Nitrogen in pyrrole contributes two electrons to the π-system, forming a 6 π-electron system that results in a stable aromatic compound. Due to this, the nitrogen-carbon bond is characteristically short, indicating a partial double bond. The H attached to nitrogen is considerably acidic. Such characteristics add up to the rich chemistry of nitrogen-containing 5 membered rings, which constitute significant portions of drugs and pharmaceutical compounds. The versatility of a 5 membered ring extends to structures that can house oxygen atoms, as with the compound furan. In furan, four carbon atoms and one oxygen atom form the ring. Furan's structure gives it unique chemical properties: Oxygen's two lone pair electrons participate in delocalisation, making furan aromatic. Bonds involving oxygen are shorter, indicating partial double bond character. Furan displays electrophilic aromatic substitution. This unique chemistry makes furan and other oxygen-containing 5 membered rings essential in numerous chemical syntheses and reactions. A ring incorporating both nitrogen and sulphur provides another variant of the 5 membered ring structure. Such a structure is found in the compound thiazole. The 5 membered ring in thiazole consists of three carbon atoms, one nitrogen atom, and one sulphur atom. The chemistry of 5 membered ring structures with nitrogen is intriguing: Like the other examples, thiazole is aromatic due to its conjugated π-system. The sulphur atom contributes to the π-system. Due to the presence of both nitrogen and sulphur, thiazole exhibits unique reactivity and stability. Understanding the diverse forms a 5 membered ring structure can take, and the various physical and chemical properties they exhibit, is crucial in navigating the complex world of organic chemistry. Each combination of atoms essentially constructs a piece of the puzzle that constitutes the whole picture of biochemical processes, drug synthesis, and materials science. The realm of organic chemistry is filled with numerous theoretical descriptors, but it is through application and observation in real-life examples that truly brings this branch of science to life. The 5 membered ring structure, intrinsic to many biochemical processes and essential chemical compounds, is no exception to this. Now, let's take a moment to examine such practical examples where we can see the presence of this notable and critical structure. In biochemistry, perhaps one of the most notable applications of the 5 membered ring structure extends to the structure of nucleic acids, DNA and RNA. Here, it constitutes a fundamental structural feature of the nucleobases, adenine and guanine. Adenine ($\text{C}_5\text{H}_5\text{N}_5$) and guanine ($\text{C}_5\text{H}_5\text{N}_5\text{O}$) are purine nucleobases, which are essentially heterocyclic aromatic organic compounds composed of a pyrimidine ring fused to an imidazole ring. The latter ring is the primary 5 membered ring structure where, in the case of adenine, consists of three carbon atoms and two nitrogen atoms, while guanine having an additional oxygen atom connected to the carbon. Another real-world example is the role of 5 membered ring structures in drug chemistry. A commonly known group of drugs, 'Benzodiazepines,' used to treat conditions like anxiety, insomnia, agitation, seizures, muscle spasms and alcohol withdrawal, are characterised by a fusion of a benzene ring and a diazepine ring, where the latter is a seven-membered ring with two nitrogen constituents. However, a 5 membered ring embedded with nitrogen and sulphur atoms, a part of thiazole ring, is present in the structure. A classic example is Diazepam, commonly known as Valium. The structure of diazepam ($\text{C}_{16}\text{H}_{13}\text{Cl}\text{N}_2\text{O}$). In the case of Diazepam, a 7 membered diazepine ring is fused to a benzene ring along with a pendant 5 membered ring incorporating nitrogen and sulphur atoms, creating a thiazole ring. Thus, even in medicinal chemistry, the role of the 5 membered ring is pivotal. Apart from biochemistry and medicinal applications, the 5 membered ring structure finds its importance in the industrial production of various chemical substances. For instance, it is found in the production of Sulfur Vulcanization used in the making of rubber, through a process called 'cyclisation'. The 5 membered ring structure in organic chemistry clearly transcends theoretical confines, showcasing its importance through dynamic and diverse real-world applications. From biological mechanisms intrinsic to life to forging the path to the creation of crucial medicinal drugs and industrial processes, these structures demonstrate their pervasive influence in the intricate workings of the world of science. Anatomy of any chemical structure is not just about identifying what elements make up the compound, but also discerning how these elements are organised - their conformation. Without understanding the shape and layout of molecules, generating accurate predictions about their chemical properties and reactivities would be all but impossible. Hence, let us delve into the conformation of the 5 membered ring – one of the pivotal structures ubiquitous in organic chemistry. A 5 membered ring, for instance in cyclopentane, is not a flat structure as could be construed from its planar skeletal structure. Instead, it encompasses a certain degree of 'puckering'. This specific shape helps reduce the eclipsing interactions and results in an overall reduction of the ring strain. Puckering: This is a phenomenon where the planar structure of the ring deviates to form a bent or twisted conformation. In the case of the 5 membered ring, the 'envelope' and the 'twist' conformations are commonly observed. An envelope conformation means that four of the carbons lie in the same plane, and one is out of the plane, giving the appearance of an envelope-like figure. While in the twisted conformation, all five carbon atoms are out of plane providing a twisted appearance to the ring. One key contributor to the shape of the 5 membered ring is the bond angle. Early chemists deduced that the bond angle in the sp3 hybridised carbon atom is 109.5 degrees. However, the bond angle in a planar 5 membered ring is 108 degrees. This slight divergence from the ideal bond angle results in angle strain. Although small, this can give rise to substantial destabilisation in the molecule if left unchecked. Consequently, to alleviate this stress, the ring adopts non-planar, puckered conformations. Bond Type Bond Angle Sp3 Hybridised Carbon 109.5° Planar Five-Membered Ring 108° The 5 membered ring then maintains an equilibrium between two prominent conformations - the 'envelope' and the 'twist'. In the envelope conformation, there are four carbons in the plane and one atom out of the plane, showing the figure of an envelope. Conversely, the twist conformation has all carbon atoms out of the plane, resulting in a twist-like structure. The transition between these conformations is referred to as pseudorotation. Such conformers showcase the flexibility of the 5 membered ring structure. The process of interconversion between these conformations is called 'pseudorotation'. Pseudorotation, which shares likenesses to the movement of an umbrella opening and closing, is the shifting of atoms in a ring from one conformation to another. This motion allows for the uniform distribution of the strain over different ring atoms, thus helping the structure achieve the overall minimum energy configuration. Finally, dear readers, the key takeaway here is the understanding that a five-member ring is not a flat, two-dimensional shape. The non-planar, three-dimensional structure of ring compounds is a critical aspect of studying organic chemistry. It's also a crucial element to be considered while studying organic reactions, reaction mechanisms, and synthesis of organic compounds. A 5 membered ring refers to a cyclic structure present in an organic molecule that consists of five atoms. These atoms, usually carbon, are connected by covalent bonds to form a ring-like structure. A 5 membered ring can accommodate atoms of Carbon, Nitrogen, Oxygen, and Sulphur leading to the formation of a wide variety of molecules. Characteristics of a standard 5 membered ring include stability, reactivity, and variety. While it is relatively stable, it also has some degree of torsional and angle strain due to its bond angles. Embedding different elements in a 5 membered ring can lead to unique chemistries. For instance, a 5 membered nitrogen ring like Pyrrole offers stable aromatic compounds while a 5 membered oxygen ring like Furan displays electrophilic aromatic substitution. The conformation of a 5 membered ring is crucial for its functionality. It is not planar, instead exhibiting a degree of 'puckering' in configurations such as the 'envelope' and the 'twist' conformations. The transition between these conformations is known as pseudorotation, allowing for strain distribution and overall energy minimization. What is a 5-membered ring? A 5-membered ring is a common structural feature in organic chemistry that comprises five atoms connected in a cyclic manner. These atoms can be all carbon (as in cyclopentane) or can include other elements like nitrogen, oxygen or sulfur (as in pyrrole, furan, or thiophene). How can one create a fused 6 and 5-membered ring structure? Please write in UK English. To make a fused 6 and 5 membered ring structure in chemistry, Diels-Alder reaction is commonly used. It involves a cycloaddition process of a conjugated diene (4 carbon atoms) and a dienophile (2 carbon atoms) to produce a six-membered ring. Then, a five-membered ring can be attached using various cyclisation reactions. Is the 5-membered ring aromatic with nitrogen? A 5-membered ring can be aromatic if it contains nitrogen, such as in the case of pyrrole. However, not all 5-membered rings with nitrogen are aromatic. The aromaticity depends on the fulfilment of Hückel's rule, which requires a planar ring with 4n+2 π electrons. Which five-membered ring is the most aromatic? The most aromatic 5-membered ring in chemistry is the Pyrrole ring. It's highly aromatic due to the presence of a nitrogen atom that contributes two electrons to the π system, thus satisfying Hückel's rule. Which is more stable, a 5-membered ring or a 6-membered ring? A 6-membered ring is more stable than a 5-membered ring. This is due to the lower angle strain and torsional strain in 6-membered rings, specifically cyclohexane, which adopts a chair conformation. Save Article Test your knowledge with multiple choice flashcards That was a fantastic start! You can do better! Sign up to create your own flashcards Access over 700 million learning materials Study more efficiently with flashcards Get better grades with AI Sign up for free Already have an account? 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The cutting-edge technology and tools we provide help students create their own learning materials. StudySmarter's content is not only expert-verified but also regularly updated to ensure accuracy and relevance. Learn more Fractional distillation separates mixture parts based on different boiling points for purifying chemicals.Fractional distillation helps produce gasoline and chemicals from crude oil by separating hydrocarbon fractions.Simple distillation works for big boiling point differences, but fractional distillation works for close differences. Fractional distillation is a process by which components in a chemical mixture are separated into different parts (called fractions) according to their different boiling points. Fractional distillation is used to purify chemicals and to separate mixtures to obtain their components. The technique is used in labs and in industry, where the process has vast commercial significance. The chemical and petroleum industry rely on fractional distillation. Vapors from a boiling solution are passed along a tall column, called a fractionating column. The column is packed with plastic or glass beads to improve the separation by providing more surface area for condensation and evaporation. The temperature of the column gradually decreases along its length. Components with a higher boiling point condense on the column and return to the solution; components with a lower boiling point (more volatile) pass through the column and are collected near the top. Theoretically, having more beads or plates improves the separation, but adding plates also increases the time and energy required to complete a distillation. Gasoline and many other chemicals are produced from crude oil using fractional distillation. Crude oil is heated until it evaporates. Different fractions condense at certain temperature ranges. The chemicals in a certain fraction are hydrocarbons with comparable numbers of carbon atoms. From hot to cold (largest hydrocarbons to smallest), the fractions might be residue (used to make bitumen), fuel oil, diesel, kerosene, naphtha, gasoline, and refinery gas. Fractional distillation cannot completely separate the components of a mixture of ethanol and water despite the different boiling points of the two chemicals. Water boils at 100 degrees Celcius while ethanol boils at 78.4 degrees Celcius. If an alcohol-water mixture is boiled, the ethanol will concentrate in the vapor, but only up to a point, because alcohol and water form an azeotrope. Once the mixture reaches the point where it consists of 96% ethanol and 4% water, the mixture is more volatile (boils at 78.2 degrees Celcius) than the ethanol. Fractional distillation differs from simple distillation because the fractionating column naturally separates compounds based on their boiling points. It's possible to isolate chemicals using simple distillation, but it requires careful control of the temperature because only one "fraction" can be isolated at a time. How do you know whether to use simple distillation or fractional distillation to separate a mixture? Simple distillation is faster, simpler, and uses less energy, but it's really only useful when there is a large difference between the boiling points of the desired fractions (more than 70 degrees Celcius). If there is only a small temperature difference between the fractions, fractional distillation is your best bet. Here's a breakdown of the differences between simple and fractional distillation: Simple Distillation Fractional Distillation Uses Separating relatively pure liquids that have large boiling point differences. Also separating liquids from solid impurities. Isolating components of complex mixtures with small boiling point differences. Advantages FasterRequires less energy inputSimpler, less expensive equipment Better separation of liquidsBetter at purifying liquids containing many different components Disadvantages Only useful for relatively pure liquidsRequires a large boiling point difference between componentsDoesn't separate fractions as cleanly SlowerRequires more energyMore complicated and expensive setup Fractional distillation is a type of distillation which involves the separation of miscible liquids. The process involves repeated distillations and condensations and the mixture is usually separated into component parts. The separation happens when the mixture is heated at a certain temperature where fractions of the mixture start to vaporize. Table of Contents Principle of Fractional Distillation Normally, the vapour composition of any liquid mixture does not remain equal to the liquid composition. When the mixture is heated, the liquid with the lower boiling point boils and converts to vapours. The more volatile component remains in a vapour state longer than the liquid component. Repeated distillations and condensations are used in the process, and the mixture is usually separated into component parts. The more volatile components increase in a vapour state after heating, and when this vapour is liquefied, the more volatile components increase in a liquid state. Distillation refers to the process of vaporisation followed by condensation (liquefaction). When this distillation process is repeated, a more volatile component will remain in a pure state in the liquid state. By using the fractional distillation method, components of the liquid-liquid mixture can be separated as a pure substance. The basic principle of this type of distillation is that different liquids boil and evaporate at different temperatures. So when the mixture is heated, the substance with lower boiling point starts to boil first and convert into vapours. Fractional Distillation Procedure Few fractional distillation apparatuses are required for the process. It includes distilling flask, condenser, receiver, fractionating column, thermometer and heat source. After setting up the apparatus, a mixture of two miscible liquids A and B is taken where A has more volatility than substance B. The solution is added into the distilling flask while the fractionating column is connected at the tip of the flask. Heat is applied which increases the temperature slowly. The mixture then starts to boil and vapours start rising in the flask. The vapours are from the volatile component A. The vapours then start moving through the fractionating column into the condenser where it is cooled down to form a liquid which is collected in the receiver. Throughout the process, vaporization and condensation take place repeatedly until the two mixtures are separated completely. Industrial Distillation Fractional distillation is one of the popular separation techniques used in several industries. While the principle behind the process remains the same, the distillation is carried out on a larger scale. Usually, huge vertical cylindrical columns are known as "distillation columns" or "distillation or fractionation towers" are used. These industrial towers use reflux which ensures complete separation of the mixtures. Fractional Distillation of Crude Oil A common example of fractional distillation in industries is the separation of various components of crude oil. Crude oil normally contains substances such as paraffin wax, gasoline, diesel, naphtha, lubricating oil and kerosene. The distillation process helps in separating these components effectively. Crude oil is added to the chamber and is heated with high-pressure steam. The mixture starts boiling and vapour is formed. At this point, various substances enter into the vapour phase. The vapour rises up in the fractional distillation column which consists of several plates. The plates have holes that allow the vapour to pass through them. The temperature is usually kept low at the top of the fractionating column. Here, components with the highest boiling point will condense in the lower part of the column while substances with a low boiling point will condense at the top. The condensed vapours or liquid fractions are then removed from the sides of the column. The collected liquid fractions can further be passed through condensers to cool them even more. Recommended Videos Types of Distillation Applications of Fractional Distillation Fractional distillation is used for the purification of water as well as for separating ethanol and water. Fractional distillation is used in several industries like oil refineries and chemical plants mainly for purification and separation of many organic compounds. Fractional distillation is also used for the separation of (liquefied) air. Components like liquid nitrogen and oxygen as well as concentrated argon are obtained. Distillation is used in the production of high-purity silicon from chlorosilanes. The silicon is widely used in semiconductors. Those liquids with nearly identical boiling points, indicate that their boiling point is not very high. In this method, such liquids are used. The conditions for fractional distillation are- The liquids must be miscible with each other. The difference between the boiling points of the two liquids must be less than 25 degrees Celsius. The steps of the process are: Evaporation Condensation Collection Simple distillation is used to separate substances in mixtures with widely disparate boiling points, whereas fractional distillation is used for mixtures containing chemicals with similar boiling points. Different liquids boil and evaporate at different temperatures, which is the basic principle of this type of distillation. As a result, when the mixture is heated, the substance with the lower boiling point begins to boil first, converting to vapours. To learn more about fractional distillation, download BYJU'S – The Learning App. Put your understanding of this concept to test by answering a few MCQs. Click 'Start Quiz' to begin! Select the correct answer and click on the "Finish" buttonCheck your score and answers at the end of the quiz Visit BYJU'S for all Chemistry related queries and study materials 0 out of 0 arewrong 0 out of 0 are correct 0 out of 0 are Unattempted View Quiz Answers and Analysis