Distillation

Distillation is a physical process used to separate different substances in a mixture. The distillation process takes advantage of differences in the property of volatility or boiling point. Volatility refers to how easily a substance evaporates – the higher the volatility of a substance, the fast it evaporates. A highly volatile material has a low boiling point. A substance with low volatility has a high boiling point. The quantitative measure of volatility is vapor pressure.

In any mixture, the gases above the mixture have more of the substance that evaporates easily (more volatile substance). In other words if you have 50/50 mixture of two different liquids in a mixture and analyze the gases above the mixture of liquids, you would find that the gases from the more volatile liquid would be more than 50% and the gases from the less volatile liquid would constitute less than 50%. If you would collect the gases above the mixture and condense them (turn them back to liquid), the condensed liquid would no longer be a 50/50 mixture. The condensed liquid would be "enriched" with the more volatile liquid. Enriched means the condensed liquid would contain more than 50% of the more volatile liquid and less than 50% of the less volatile liquid. This is the exact process that occurs in a distillation. In a distillation, the original mixture is heated so the liquids evaporate and the separation occurs more quickly.

For example distillation can separate pure water from a solution that contains table salt (NaCl) and water. The "normal" boiling point of is $100^{o}C$ and the boiling point for NaCl is $1413^{o}C$. Water has a lower boiling point, is more volatile, and evaporates more easily than NaCl. In a distillation of salt water, you would heat the mixture until the water boils. The water is turning into a gas but the NaCl is not turning into a gas to any measurable extent. The water gas leaves the original container and is then condensed back into liquid water. Since the NaCl never turned into a gas, it stays in the original container. The condensed liquid is pure water. This process is one method used to desalinate water. Boiling salt water is very energy intensive so distillation is an expensive way to desalinate salt water. Primarily oil rich countries which have a shortage of fresh water use it.

You can also separate a mixture of ethanol and water using distillation. Ethanol is more volatile than water, so it evaporates faster. The condensed liquid after a distillation of a mixture of ethanol and water is enriched in ethanol. The boiling point of ethanol is $78\ ^{o}C$ and the boiling point of water is $100\ ^{o}C$. Because these boiling points are so close, it takes a number of distillations to achieve maximum separation. Due to the fundamental nature of ethanol and water, 100% separation is not possible by distillation. The maximum separation of ethanol and water by distillation is about 95% ethanol and 5% water solution.

Distillation of Crude Oil

Upon delivery to a refinery, crude oil which is primarily a mixture of organic compounds is distilled. The major component of crude oil is alkanes. The boiling point and volatility of alkanes is a function of the number of carbons in the alkane - the more carbons give a high boiling point and a lower volatility. The fewer the number of carbons leads to higher volatility and lower boiling point. As a result, C1 to C4 alkanes (referred to as gases) distill out first, then come C4 to C10 (naphtha or gasoline), then C10 to C16 (kerosene), next are C16 to C22 (diesel and heating oil), followed by C22 to C30 (lubricating oils) and finally alkanes with more than 25 carbons (asphalt).

To get best separation, a mixture needs to be performed a number of times. By using a technique called fractional distillation, many distillations can occur at the same time and place. In a refinery, this occurs in a fractionating tower. This is the tall tower that you see at refineries. In a fractionating tower, the temperature at the top is lower than the temperature at the bottom. As a result, the gasoline fraction comes out at the top of the tower, a little lower comes the gasoline, then lower still is the kerosene, then lower is the diesel fuel, then lower is th lubricating oil, and finally at the bottom is the asphalts. Please refer to the diagram in your text.