Chemistry 101

Chemical companies rely on vertical integration to optimize their operational efficiencies. This means that chemical bonds are maximized to gain the most economic benefit. The method and strategy companies choose to optimize these bonds is critical to the growth and profitability of their business. The following is an outline of how polyvinyl chloride, polypropylene and polyethylene are manufactured:

Polyvinyl Chloride (PVC)

PVC resins are some of the most versatile resins in everything from flexible meat wraps, to medical gloves, to luxury vinyl tiles, to window profiles, to vinyl siding, and to rigid pipes.

- Base Feedstock: The base feedstock is brine, a solution of salt (NaCl) and water (H_2O) in which the salt composition is greater than 5%. Natural brines occur underground, in salt lakes or as seawater.
- Step 1: Brine is piped to a membrane electrolysis plant where it passes through high volts of electricity. This process generates the chlorine and sodium ions. The sodium ions attract oxygen-hydrogen (-OH) group from water to form caustic soda (NaOH). It is a chemical base used to produce many products such as paper, aluminum, and soaps. Caustic soda is typically sold via barges and trucks.
- Step 2: The chlorine generated is piped to an ethylene dichloride plant where it reacts with ethylene (C_2H_4) in the presence of a catalyst. The ethylene double carbon bond is broken and replaced by two chlorine ions. The resulting compound is ethylene dichloride ($C_2H_4Cl_2$), commonly referred to as EDC.
- Step 3: EDC is the precursor to vinyl chloride monomer, referred to as VCM. VCM (C_2H_3Cl) is produced by removing one chlorine ion from the EDC and resulting in new carbon double bond.
- Step 4: VCM is piped to a PVC plant where the double carbon bond is broken forming a chain of repeating VCM units $[C_2H_3Cl]_n$ called PVC. This final process is referred to as the polymerization process.

Polypropylene (PP)

Polypropylene is a favorite of engineers for its balance of properties. It can make everything from simple disposable cutlery to highly complex automotive interior trim.

- Base Feedstock: The base feedstock can be either natural gas or crude oil. Historically, propylene (C_3H_6) monomer yield from the distillation and fractionation of crude oil has been much higher.
- Step 1: Crude oil processed in a refinery complex produces various products. To produce polypropylene, the essential monomer needed is propylene. Propylene can be obtained from several different streams: the naphtha stream, the fractionation stream or the on-purpose stream.
    - Naphtha Stream: Naphtha is a complex mixture of hydrocarbons containing between 5 and 10 carbon atoms, such as: pentane (C_5H_{12}), hexane (C_6H_{14}), heptane (C_7H_{16}), and octane (C_8H_{18}). Naphtha is obtained from the distillation of crude oil. Distillation entails heating up crude oil in a distillation column and taking off the various hydrocarbons at different boiling points. Naphtha is typically taken off between 185 – 350°F and is mainly used as a feed for olefin plants (aka. ethylene plants or steam crackers). Due to the greater number of carbon atoms in the naphtha compounds, the propylene yield from an olefins plants is greater than with lighter hydrocarbons containing less than 5 carbon atoms.

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- Fractionation Stream: After the distillation of crude oil, gas oils are gathered and sent to a fluid catalytic cracking unit (FCC). FCC units are extremely versatile operating units that use a catalyst to take heavier hydrocarbons and convert them into smaller ones, such as refinery grade propylene (RPG). RPG can be used to make either high octane transportation fuels via an alkylation plant or polymer grade propylene (PGP) via a splitter plant for the chemicals and plastics industry. Today, with most olefin plants running on lighter feeds, the fractionation stream is the main source of propylene for the production of polypropylene. The method in which refiners operate their FCC units has a huge impact on the supply and price of propylene. When higher octane fuels are in demand, refiners push more RPG to alkylation, reducing the supply of PGP and in turn impacting its price and availability.
- On-purpose Stream: The newest stream gaining popularity is the on-purpose propylene stream. It takes propane (C_3H_8) and removes two hydrogen ions to produce propylene (C_3H_6). One of the leading technologies in this area is Propane Dehydrogenation, or PDH.

- Step 2: Propylene is fed into a polypropylene plant, which produces various types of polypropylenes: homopolymers, copolymers or random copolymers. This is achieved by breaking the double carbon bond in propylene and forming a chain of $[C_3H_6]_n$ repeating units in presence of a polymerization catalyst.

Polyethylene (PE)

Polyethylene is chemically the simplest of the three polymer types. It is formed by the polymerization of ethylene (C_2H_4). Polyethylene is the largest volume resin produced globally. It is used to make diverse products ranging from grocery bags, to pressurized water pipes and large industrial containers.

- Base Feedstock: Polyethylene can be derived from either crude oil or natural gas. In the United States, the shale gas boom has pushed most olefin producers to use natural gas liquids (NGLs), which are derived from natural gas production.
- Step 1: NGLs consist of ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). Olefin producers switch between these NGL feeds to run their plants in the most economic manner. For the production of ethylene (C_2H_4), the ethane feed provides the most ethylene yield.
- Step 2: Ethylene is fed into the various polyethylene plants to produce high density, linear low density or low density polyethylene. This is achieved by breaking the double carbon bond in ethylene and adding a high alpha olefin as a comonomer to form a chain of $[C_2H_4]_n$ repeating units in presence of a polymerization catalyst.

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