ResourcesMaterialsPolyurethane: What It Is, History, and How It's MadeWritten by 10 min readTable 1: Physical Properties of PolyurethanePropertyValueCompressive Strength (MPa)Modulus of Elasticity (MPa)Thermal Conductivity (W/m·K)Table 2: Chemical Properties of PolyurethanePropertyDescriptionPolyurethanes are polymers composed of organic units joined by urethane (carbamate) links.Generally resistant to oils, greases, solvents, and various chemicals, but susceptibility varies by type.Varies depending on the formulation and exposure conditions. Some types are resistant to water, others less so.Generally resistant to oxidation, but prolonged exposure to UV light and certain chemicals can cause degradation.Some polyurethanes are flammable, while others can be made flame-retardant through additives or modifications.Can withstand moderate temperatures, but prolonged exposure to high heat can lead to degradation.Reactivity with Other MaterialsCan react with certain materials under specific conditions, such as certain plastics or metals.A photograph of a polyurethane gearDean McClements is a B.Eng Honors graduate in Mechanical Engineering with over two decades of experience in the manufacturing industry. His professional journey includes significant roles at leading companies such as Caterpillar, Autodesk, Collins Aerospace, and Hyster-Yale, where he developed a deep understanding of engineering processes and innovations.Read more articles by Dean McClements Polyurethane (/ˌpɒliˈjʊərəθeɪn, -juːˈrɛθeɪn/;[1] often abbreviated PUR and PU) is a class of polymers composed of organic units joined by carbamate (urethane) links. In contrast to other common polymers such as polyethylene and polystyrene, polyurethane term does not refer to the single type of polymer but a group of polymers. Unlike polyethylene and polystyrene, polyurethanes can be produced from a wide range of starting materials resulting in various polymers within the same group. This chemical variety produces polyurethanes with different chemical structures leading to many different applications. These include rigid and flexible foams, and coatings, adhesives, electrical potting compounds, and fibers such as spandex and polyurethane laminate (PUL). Foams are the largest application accounting for 67% of all polyurethane produced in 2016.[2] Polyurethane synthesis, wherein the urethane groups −NH−(C=O)−O− link the molecular units A kitchen sponge made of polyurethane foam A polyurethane is typically produced by reacting a polymeric isocyanate with a polyol.[3] Since a polyurethane contains two types of monomers, which polymerize one after the other, they are classed as alternating copolymers. Both the isocyanates and polyols used to make a polyurethane contain two or more functional groups per molecule. Global production in 2019 was 25 million metric tonnes,[4] accounting for about 6% of all polymers produced in that year. Otto Bayer in 1952 demonstrating his creation Otto Bayer and his coworkers at IG Farben in Leverkusen, Germany, first made polyurethanes in 1937.[5][6] The new polymers had some advantages over existing plastics that were made by polymerizing olefins or by polycondensation, and were not covered by patents obtained by Wallace Carothers on polyesters.[7] Early work focused on the production of fibers and flexible foams and PUs were applied on a limited scale as aircraft coating during World War II.[7] Polyisocyanates became commercially available in 1952, and production of flexible polyurethane foam began in 1954 by combining toluene diisocyanate (TDI) and polyester polyols. These materials were also used to produce rigid foams, gum rubber, and elastomers. Linear fibers were produced from hexamethylene diisocyanate (HDI) and 1,4-Butanediol (BDO). DuPont introduced polyethers, specifically poly(tetramethylene ether) glycol, in 1956. BASF and Dow Chemical introduced polyalkylene glycols in 1957. Polyether polyols were cheaper, easier to handle and more water-resistant than polyester polyols. Union Carbide and Mobay, a U.S. Monsanto/Bayer joint venture, also began making polyurethane chemicals.[7] In 1960 more than 45,000 metric tons of flexible polyurethane foams were produced. The availability of chlorofluoroalkane blowing agents, inexpensive polyether polyols, and methylene diphenyl diisocyanate (MDI) allowed polyurethane rigid foams to be used as high-performance insulation materials. In 1967, urethane-modified polyisocyanurate rigid foams were introduced, offering even better thermal stability and flammability resistance. During the 1960s, automotive interior safety components, such as instrument and door panels, were produced by back-filling thermoplastic skins with semi-rigid foam. In 1969, Bayer exhibited an all-plastic car in Düsseldorf, Germany. Parts of this car, such as the fascia and body panels, were manufactured using a new process called reaction injection molding (RIM), in which the reactants were mixed and then injected into a mold. The addition of fillers, such as milled glass, mica, and processed mineral fibers, gave rise to reinforced RIM (RRIM), which provided improvements in flexural modulus (stiffness), reduction in coefficient of thermal expansion and better thermal stability. This technology was used to make the first plastic-body automobile in the United States, the Pontiac Fiero, in 1983. Further increases in stiffness were obtained by incorporating pre-placed glass mats into the RIM mold cavity, also known broadly as resin injection molding, or structural RIM. Starting in the early 1980s, water-blown microcellular flexible foams were used to mold gaskets for automotive panels and air-filter seals, replacing PVC polymers. Polyurethane foams are used in many automotive applications including seating, head and arm rests, and headliners. Polyurethane foam (including foam rubber) is sometimes made using small amounts of blowing agents to give less dense foam, better cushioning/energy absorption or thermal insulation. In the early 1990s, because of their impact on ozone depletion, the Montreal Protocol restricted the use of many chlorine-containing blowing agents, such as trichlorofluoromethane (CFC-11). By the late 1990s, blowing agents such as carbon dioxide, pentane, 1,1,1,2-tetrafluoroethane (HFC-134a) and 1,1,1,3,3-pentafluoropropane (HFC-245fa) were widely used in North America and the EU, although chlorinated blowing agents remained in use in many developing countries. Later, HFC-134a was also banned due to high ODP and GWP readings, and HFC-141B was introduced in early 2000s as an alternate blowing agent in developing nations.[8] Polyurethanes are produced by reacting diisocyanates with polyols,[9][10][11][12][13][14] often in the presence of a catalyst, or upon exposure to ultraviolet radiation.[15] Common catalysts include tertiary amines, such as DABCO, DMDEE, or metallic soaps, such as dibutyltin dilaurate. The stoichiometry of the starting materials must be carefully controlled as excess isocyanate can trimerise, leading to the formation of rigid polyisocyanurates. The polymer usually has a highly crosslinked molecular structure, resulting in a thermosetting material which does not melt on heating; although some thermoplastic polyurethanes are also produced. R − N = C = O + H 2 O ⟶ step 1 R 1 − N | H − C O ‖ − O − H ⟶ decomposes step 2 R − NH 2 + CO 2 ( g ) R − N = C = O + R − NH 2 ⟶ step 3 − R − N | H − C O ‖ − N | H − R − {\displaystyle {\begin{array}{l}{\ce {R-N=C=O}+H2O->[{\ce {step}}\ 1]R1-{\overset {\displaystyle O \atop \|}{C}}-O-H->[{\ce {decomposes}}]R-NH2\ + \ CO2(g)}}\\{\ce {R-N=C=O}+R-NH2->[{\ce {step}}\ 3]-R-{\underset {| \atop \displaystyle H}{N}}-{\overset {\displaystyle O \atop \|}{C}}-{\underset {| \atop \displaystyle H}{N}}-R}-}\end{array}}} Carbon dioxide gas and urea links formed by reacting water with isocyanate The most common application of polyurethane is as solid foams, which requires the presence of a gas, or blowing agent, during the polymerization step. This is commonly achieved by adding small amounts of water, which reacts with isocyanates to form CO2 gas and an amine, via an unstable carbamic acid group. The amine produced can also react with isocyanates to form urea groups, and as such the polymer will contain both these and urethane linkers. The urea is not very soluble in the reaction mixture and tends to form separate "hard segment" phases consisting mostly of polyurea. The concentration and organization of these polyurea phases can have a significant impact on the properties of the foam.[16] The type of foam produced can be controlled by regulating the amount of blowing agent and also by the addition of various surfactants which change the rheology of the polymerising mixture. Foams can be either "closed-cell", where most of the original bubbles or cells remain intact, or "open-cell", where the bubbles have broken but the edges of the bubbles are stiff enough to retain their shape, in extreme cases reticulated foams can be formed. Open-cell foams feel soft and allow air to flow through, so they are comfortable when used in seat cushions or mattresses. Closed-cell foams are used as rigid thermal insulation. High-density microcellular foams can be formed without the addition of blowing agents by mechanically frothing the polyol prior to use. These are tough elastomeric materials used in covering car steering wheels or shoe soles. The properties of a polyurethane are greatly influenced by the types of isocyanates and polyols used to make it. Long, flexible segments, contributed by the polyol, give soft, elastic polymer. High amounts of crosslinking give tough or rigid polymers. Long chains and low crosslinking give a polymer that is very stretchy, short chains with many crosslinks produce a hard polymer while long chains and intermediate crosslinking give a polymer useful for making foam. The choices available for the isocyanates and polyols, in addition to other additives and processing conditions allow polyurethanes to have the very wide range of properties that make them such widely used polymers. The main ingredients to make a polyurethane are di- and tri-isocyanates and polyols. Other materials are added to aid processing the polymer or to modify the properties of the polymer. PU foam formulation sometimes have water added too. Isocyanates used to make polyurethane have two or more isocyanate groups on each molecule. The most commonly used isocyanates are the aromatic diisocyanates, toluene diisocyanate (TDI) and methylene diphenyl diisocyanate, (MDI). These aromatic isocyanates are more reactive than aliphatic isocyanates. TDI and MDI are generally less expensive and more reactive than other isocyanates. Industrial grade TDI and MDI are mixtures of isomers and MDI often contains polymeric materials. They are used to make flexible foam (for example slabstock foam for mattresses or molded foams for car seats),[17] rigid foam (for example insulating foam in refrigerators) elastomers (shoe soles, for example), and so on. The isocyanates may be modified by partially reacting them with polyols or introducing some other materials to reduce volatility (and hence toxicity) of the isocyanates, decrease their freezing points to make handling easier or to improve the properties of the final polymers. MDI isomers and polymer MDI isocyanates are used in smaller quantities, most often in coatings and other applications where color and transparency are important since polyurethanes made with aromatic isocyanates tend to darken on exposure to light.[page needed][18] The most important aliphatic and cycloaliphatic isocyanates are 1,6-hexamethylene diisocyanate (HDI), 1-isocyanato-3-isocyanatomethyl-3,5,5-trimethyl-cyclohexane (isophorone diisocyanate, IPDI), and 4,4′-diisocyanato dicyclohexylmethane (H12MDI or hydrogenated MDI). Other more specialized isocyanates include Tetramethylxylylene diisocyanate (TMXDI). Main article: Polyol Polyols are polymers in their own right and have on average two or more hydroxyl groups per molecule. They can be converted to polyether polyols by co-polymerizing ethylene oxide and propylene oxide with a suitable polyol precursor.[19] Polyester polyols are made by the polycondensation of multifunctional carboxylic acids and polyhydroxyl compounds. They can be further classified according to their end use. Higher molecular weight polyols (molecular weights from 2,000 to 10,000) are used to make more flexible polyurethanes while lower molecular weight polyols make more rigid products. Polyols for flexible applications use low functionality initiators such as dipropylene glycol (f = 2), glycerine (f = 3), or a sorbitol/water solution (f = 2.75).[20] Polyols for rigid applications use higher functionality initiators such as sucrose (f = 8), sorbitol (f = 6), toluenediamine (f = 4), and Mannich bases (f = 4). Propylene oxide and/or ethylene oxide is added to the initiators until the desired molecular weight is achieved. The order of addition and the amounts of each oxide affect many polyol properties, such as compatibility, water-solubility, and reactivity. Polyols made with only propylene oxide are terminated with secondary hydroxyl groups and are less reactive than polyols capped with ethylene oxide, which contain primary hydroxyl groups. Incorporating carbon dioxide into the polyol structure is being researched by multiple companies. Graft polyols (also called filled polyols or polymer polyols) contain finely dispersed styrene–acrylonitrile, acrylonitrile, or polyurea (PHD) polymer solids chemically grafted to a high molecular weight polyether backbone. They are used to increase the load-bearing properties of low-density high-resiliency (HR) foam, as well as add toughness to microcellular foams and cast elastomers. Initiators such as ethylenediamine and triethanolamine are used to make low molecular weight rigid foam polyols that have built-in catalytic activity due to the presence of nitrogen atoms in the backbone. A special class of polyether polyols, poly(tetramethylene ether) glycols, which are made by polymerizing tetrahydrofuran, are used in high performance coating, wetting and elastomer applications. Conventional polyester polyols are based on virgin raw materials and are manufactured by the direct polyesterification of high-purity diacids and glycols, such as adipic acid and 1,4-butanediol. Polyester polyols are usually more expensive and more viscous than polyether polyols, but they make polyurethanes with better solvent, abrasion, and cut resistance. Other polyester polyols are based on reclaimed raw materials. They are manufactured by transesterification (glycolysis) of recycled poly(ethyleneterephthalate) (PET) or dimethylterephthalate (DMT) distillation bottoms with glycols such as diethylene glycol. These low molecular weight, aromatic polyester polyols are used in rigid foam, and bring low cost and excellent flammability characteristics to polyisocyanurate (PIR) boardstock and polyurethane spray foam insulation. Specialty polyols include polycarbonate polyols, polycaprolactone polyols, polybutadiene polyols, and polysulfide polyols. The materials are used in elastomer, sealant, and adhesive applications that require superior weatherability, and resistance to chemical and environmental attack. Natural oil polyols derived from castor oil and other vegetable oils are used to make elastomers, flexible bunstock, and flexible molded foam. Co-polymerizing chlorotrifluoroethylene or tetrafluoroethylene with vinyl ethers containing hydroxyalkyl vinyl ether produces fluorinated (FEVE) polyols. Two-component fluorinated polyurethanes prepared by reacting FEVE fluorinated polyols with polyisocyanate have been used to make ambient cure paints and coatings. Since fluorinated polyurethanes contain a high percentage of fluorine–carbon bonds, which are the strongest bonds among all chemical bonds, fluorinated polyurethanes exhibit resistance to UV, acids, alkali, salts, chemicals, solvents, weathering, corrosion, fungi and microbial attack. These have been used for high performance coatings and paints.[21] Phosphorus-containing polyols are available that become chemically bonded to the polyurethane matrix for the use as flame retardants. This covalent linkage prevents migration and leaching of the organophosphorus compound. Interest in sustainable "green" products raised interest in polyols derived from vegetable oils,[22][23][24] fatty acids,[25] lignin, sorbitol,[26] etc. These are mostly contributing to polyol part. There are attempts made to prepare isocyanate part using bio-derived material. However, as far as commercialization is concern, polyol part is more targeted being easy and required in more quantity than isocyanate part. Various oils used in the preparation polyols for polyurethanes include soybean oil, cottonseed oil, neem seed oil, algae oil,[27] and castor oil. Vegetable oils are functionalized in various ways and modified to polyetheramides, polyethers, alkyds, etc. Renewable sources used to prepare polyols may be fatty acids or dimer fatty acids.[29] Some biobased and isocyanate-free polyurethanes exploit the reaction between polyamines and cyclic carbonates to produce polyhydroxyurethanes.[30] Chain extenders (f = 2) and cross linkers (f ≥ 3) are low molecular weight hydroxyl and amine terminated compounds that play an important role in the polymer morphology of polyurethane fibers, elastomers, adhesives, and certain integral skin and microcellular foams. The elastomeric properties of these materials are derived from the phase separation of the hard and soft copolymer segments of the polymer, such that the urethane hard segment domains serve as cross-links between the amorphous polyether (or polyester) soft segment domains. This phase separation occurs because the mainly nonpolar, low melting soft segments are incompatible with the polar, high melting hard segments. The soft segments, which are formed from high molecular weight polyols, are mobile and are normally present in coiled formation, while the hard segments, which are formed from the isocyanate and chain extenders, are stiff and immobile. As the hard segments are covalently coupled to the soft segments, they inhibit plastic flow of the polymer chains, thus creating elastomeric resiliency. Upon mechanical deformation, a portion of the soft segments are stressed by uncoiling, and the hard segments become aligned in the stress direction. This reorientation of the hard segments and consequent powerful hydrogen bonding contributes to high tensile strength, elongation, and tear resistance values.[12][31][32][33][34] The choice of chain extender also determines flexural, heat, and chemical resistance properties. The most important chain extenders are ethylene glycol, 1,4-butanediol (1,4-BDO or BDO), 1,6-hexanediol, cyclohexane dimethanol and hydroquinone bis(2-hydroxyethyl) ether (HQEE). All of these glycols form polyurethanes that phase separate well and form well defined hard segment domains, and are melt processable. They are all suitable for thermoplastic polyurethanes with the exception of ethylene glycol, since its derived bis-phenyl urethane undergoes unfavorable degradation at high hard segment levels.[10] Diethanolamine and triethanolamine are used in flex molded foams to build firmness and add catalytic activity. Diethyltoluenediamine is used extensively in RIM, and in polyurethane and polyurea elastomer formulations. Table of chain extenders and cross linkers[35] Compound type Molecule Mol. mass Density(g/cm3) Melting pt (°C) Boiling pt (°C) Hydroxyl compounds – difunctional molecules Ethylene glycol 62.1 1.110 −13.4 197.4 Diethylene glycol 106.1 1.111 −8.7 245.5 Triethylene glycol 150.2 1.120 −7.2 287.8 Tetraethylene glycol 194.2 1.123 −9.4 325.6 Propylene glycol 76.1 1.032 Supercools 187.4 Dipropylene glycol 134.2 1.022 Supercools 232.2 Tripropylene glycol 192.3 1.110 Supercools 265.1 1,3-Propanediol 76.1 1.060 −28 210 1,3-Butanediol 92.1 1.005 — 207.5 1,4-Butanediol 92.1 1.017 20.1 235 Neopentyl glycol 104.2 — 130 206 1,6-Hexanediol 118.2 1.017 43 250 1,4-Cyclohexanedimethanol — — — — HQEE — — — — Ethanolamine 61.1 1.018 10.3 170 Diethanolamine 105.1 1.097 28 271 Methyldiethanolamine 119.1 1.043 −21 242 Phenyldiethanolamine 181.2 — 58 228 Hydroxyl compounds – trifunctional molecules Glycerol 92.1 1.261 18.0 290 Trimethylolpropane — — — — 1,2,6-Hexanetriol — — — — Triethanolamine 149.2 1.124 21 — Hydroxyl compounds – tetrafunctional molecules Pentaerythritol 136.2 — 260.5 — N,N,N′,N′-Tetrakis(2-hydroxypropyl)ethylenediamine — — — — Amine compounds – difunctional molecules Diethyltoluenediamine 178.3 1.022 — 308 Dimethylthiotoluenediamine 214.0 1.208 — — Main article: catalyst Polyurethane catalysts can be classified into two broad categories, basic and acidic amine. Tertiary amine catalysts function by enhancing the nucleophilicity of the diol component. Alkyl tin carboxylates, oxides and mercaptides oxides function as mild Lewis acids in accelerating the formation of polyurethane. As bases, traditional amine catalysts include triethylenediamine (TEDA, also called DABCO, 1,4-diazabicyclo[2.2.2]octane), dimethylcyclohexylamine (DMCHA), dimethylethanolamine (DMEA), Dimethylaminoethoxyethanol and bis-(2-dimethylaminoethyl)ether, a blowing catalyst also called A-99. A typical Lewis acidic catalyst is dibutyltin dilaurate. The process is highly sensitive to the nature of the catalyst and is also known to be autocatalytic.[36] Another class of catalysts was published in a study in May 2024. In this study, polyurethane synthesis was investigated in the presence of acid catalysts, namely dimethylphosphite (DMHP), methanesulfonic acid (MSA), and trifluoromethanesulfonic acid (TFMSA). The thermodynamic profile was examined and described in detail through computational tools, showing that TFMSA had the best catalytic properties. The study aimed to open the door to a new class of catalysts.[37] Factors affecting catalyst selection include balancing three reactions: urethane (polyol+isocyanate, or gel) formation, the urea (water+isocyanate, or "blow") formation, or the isocyanate trimerization reaction (e.g., using potassium acetate, to form isocyanurate rings). A variety of specialized catalysts have been developed.[38][39][40] Main article: Surfactant Surfactants are used to modify the characteristics of both foam and non-foam polyurethane polymers. They take the form of polydimethylsiloxane-polyoxyalkylene block copolymers, silicone oils, nonylphenol ethoxylates, and other organic compounds. In foams, they are used to emulsify the liquid components, regulate cell size, and stabilize the cell structure to prevent collapse and sub-surface voids.[41] In non-foam applications they are used as air release and antifoaming agents, as wetting agents, and are used to eliminate surface defects such as pin holes, orange peel, and sink marks. Polyurethanes are produced by mixing two or more liquid streams. The polyol stream contains catalysts, surfactants, blowing agents (when making polyurethane foam insulation) and so on. The two components are referred to as a polyurethane system, or simply a system. The isocyanate is commonly referred to in North America as the 'A-side' or just the 'iso'. The blend of polyols and other additives is commonly referred to as the 'B-side' or as the 'poly'.[citation needed] This mixture might also be called a 'resin' or 'resin blend'. In Europe the meanings for 'A-side' and 'B-side' are reversed.[citation needed] Resin blend additives may include chain extenders, cross linkers, surfactants, flame retardants, blowing agents, pigments, and fillers. Polyurethane can be made in a variety of densities and hardnesses by varying the isocyanate, polyol or additives. Fully reacted polyurethane polymer is chemically inert.[42] No exposure limits have been established in the U.S. by OSHA (Occupational Safety and Health Administration) or ACGIH (American Conference of Governmental Industrial Hygienists). It is not regulated by OSHA for carcinogenicity. Open-flame test. Top: untreated polyurethane foam burns vigorously. Bottom: with fire-retardant treatment. Polyurethanes are combustible.[43] Decomposition from fire can produce significant amounts of carbon monoxide and hydrogen cyanide, in addition to nitrogen oxides, isocyanates, and other toxic products.[44] Due to the flammability of the material, it has to be treated with flame retardants (at least in case of furniture), almost all of which are considered harmful.[45][46] California later issued Technical Bulletin 117 2013 which allowed most polyurethane foam to pass flammability tests without the use of flame retardants. Green Science Policy Institute states: "Although the new standard can be met without flame retardants, it does NOT ban their use. Consumers who wish to reduce household exposure to flame retardants can look for a TB117-2013 tag on furniture, and verify with retailers that products do not contain flame retardants."[47] Liquid resin blends and isocyanates may contain hazardous or regulated components. Isocyanates are known skin and respiratory sensitizers. Additionally, amines, glycols, and phosphate present in spray polyurethane foams present risks.[48] Exposure to chemicals that may be emitted during or after application of polyurethane spray foam (such as isocyanates) are harmful to human health and therefore special precautions are required during and after this process.[49] In the United States, additional health and safety information can be found through organizations such as the Polyurethane Manufacturers Association (PMA) and the Center for the Polyurethanes Industry (CPI), as well as from polyurethane system and raw material manufacturers. Regulatory information can be found in the Code of Federal Regulations Title 21 (Food and Drugs) and Title 40 (Protection of the Environment). In Europe, health and safety information is available from ISOPA,[50] the European Diisocyanate and Polyol Producers Association. The methods of manufacturing polyurethane finished goods range from small, hand pour piece-part operations to large, high-volume bunstock and boardstock production lines. Regardless of the end-product, the manufacturing principle is the same: to meter the liquid isocyanate and resin blend at a specified stoichiometric ratio, mix them together until a homogeneous blend is obtained, dispense the reacting liquid into a mold or on to a surface, wait until it cures, then demold the finished part. Although the capital outlay can be high, it is desirable to use a meter-mix or dispense unit for even low-volume production operations that require a steady output of finished parts. Dispense equipment consists of material holding (day) tanks, metering pumps, a mix head, and a control unit. Often, a conditioning or heater–chiller unit is added to control material temperature in order to improve mix efficiency, cure rate, and to reduce process variability. Choice of dispense equipment components depends on shot size, throughput, material characteristics such as viscosity and filler content, and process control. Material day tanks may be single to hundreds of gallons in size and may be supplied directly from drums, IBCs (intermediate bulk containers, such as caged IBC totes), or bulk storage tanks. They may incorporate level sensors, conditioning jackets, and mixers. Pumps can be sized to meter in single grams per second up to hundreds of pounds per minute. They can be rotary, gear, or piston pumps, or can be specially hardened lance pumps to meter liquids containing highly abrasive fillers such as chopped or hammer-milled glass fiber and wollastonite.[citation needed] A high-pressure polyurethane dispense unit, showing control panel, high-pressure pump, integral day tanks, and hydraulic drive unit A high-pressure mix head, showing simple controls (front view) A high-pressure mix head, showing material supply and hydraulic actuator lines (rear view) The pumps can drive low-pressure (10 to 30 bar, 1 to 3 MPa) or high-pressure (125 to 250 bar, 12.5 to 25.0 MPa) dispense systems. Mix heads can be simple static mix tubes, rotary-element mixers, low-pressure dynamic mixers, or high-pressure hydraulically actuated direct impingement mixers. Control units may have basic on/off and dispense/stop switches, and analogue pressure and temperature gauges, or may be computer-controlled with flow meters to electronically calibrate mix ratio, digital temperature and level sensors, and a full suite of statistical process control software. Add-ons to dispense equipment include nucleation or gas injection units, and third or fourth stream capability for adding pigments or metering in supplemental additive packages. A low-pressure mix head with calibration chamber installed, showing material supply and air actuator lines Low-pressure mix head components, including mix chambers, conical mixers, and mounting plates 5-gallon (20-liter) material day tanks for supplying a low-pressure dispense unit Distinct from pour-in-place, bun and boardstock, and coating applications, the production of piece parts requires tooling to contain and form the reacting liquid. The choice of mold-making material is dependent on the expected number of uses to end-of-life (EOL), molding pressure, flexibility, and heat transfer characteristics. RTV silicone is used for tooling that has an EOL in the thousands of parts. It is typically used for molding rigid foam parts, where the ability to stretch and peel the mold around undercuts is needed. The heat transfer characteristic of RTV silicone tooling is poor. High-performance, flexible polyurethane elastomers are also used in this way. Epoxy, metal-filled epoxy, and metal-coated epoxy is used for tooling that has an EOL in the tens of thousands of parts. It is typically used for molding flexible foam cushions and seating, integral skin and microcellular foam padding, and shallow-draft RIM bezels and fascia. The heat transfer characteristic of epoxy tooling is fair; the heat transfer characteristic of metal-filled and metal-coated epoxy is good. Copper tubing can be incorporated into the body of the tool, allowing hot water to circulate and heat the mold surface. Aluminum is used for tooling that has an EOL in the hundreds of thousands of parts. It is typically used for molding microcellular foam gasketing and cast elastomer parts, and is milled or extruded into shape. Mirror-finish stainless steel is used for tooling that imparts a glossy appearance to the finished part. The heat transfer characteristic of metal tooling is excellent. Finally, molded or milled polypropylene is used to create low-volume tooling for molded gasket applications. Instead of many expensive metal molds, low-cost plastic tooling can be formed from a single metal master, which also allows greater design flexibility. The heat transfer characteristic of polypropylene tooling is poor, which must be taken into consideration during the formulation process. Main articles: List of polyurethane applications In 2007, the global consumption of polyurethane raw materials was above 12 million metric tons, and the average annual growth rate was about 5%.[51] Revenues generated with PUR on the global market are expected to rise to approximately US$75 billion by 2022.[52] As they are such an important class of materials, research is constantly taking place and papers published.[53] Polyurethane foam made with an aromatic isocyanate, which has been exposed to UV light. Readily apparent is the discoloration that occurs over time. Wikinews has related news: Polyurethane plastic substitute can biodegrade in seawater, say scientists Polyurethanes, especially those made using aromatic isocyanates, contain chromophores that interact with light. This is of particular interest in the area of polyurethane coatings, where light stability is a critical factor and is the main reason that aliphatic isocyanates are used in making polyurethane coatings. When PU foam, which is made using aromatic isocyanates, is exposed to visible light, it discolors, turning from off-white to yellow to reddish brown. It has been generally accepted that apart from yellowing, visible light has little effect on foam properties.[54][55] This is especially the case if the yellowing happens on the outer portions of a large foam, as the deterioration of properties in the outer portion has little effect on the overall bulk properties of the foam itself. It has been reported that exposure to visible light can affect the variability of some physical property test results.[56] Higher-energy UV radiation promotes chemical reactions in foam, some of which are detrimental to the foam structure.[57] Polyurethanes may degrade due to hydrolysis. This is a common problem with shoes left in a closet, and reacting with moisture in the air.[58] Microbial degradation of polyurethane is believed to be due to the action of esterase, urethanase, hydrolase and protease enzymes.[59] The process is slow as most microbes have difficulty moving beyond the surface of the polymer. Susceptibility to fungi is higher due to their release of extracellular enzymes, which are better able to permeate the polymer matrix. Two species of the Ecuadorian fungus Pestalotiopsis are capable of biodegrading polyurethane in aerobic and anaerobic conditions such as found at the bottom of landfills.[60][61] Degradation of polyurethane items at museums has been reported.[62] Polyester-type polyurethanes are more easily biodegraded by fungus than polyether-type.[63] Botanol, a material with higher plant-based content Passive fire protection Penetrant (mechanical, electrical, or structural) Polyaspartic Polyurethane dispersion Thermoplastic polyurethanes Thermoset polymer matrix

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Center for the Polyurethanes Industry: information for EH&S issues related to polyurethanes developments Polyurethane synthesis, Polymer Science Learning Center, University of Southern Mississippi Polyurethane Foam Association: Industry information, educational materials and resources related to flexible polyurethane foam PU Europe: European PU insulation industry association (formerly BING): European voice for the national trade associations representing the polyurethane insulation industry ISOPA: European Diisocyanate & Polyol Producers Association: ISOPA represents the manufacturers in Europe of aromatic diisocyanates and polyols Retrieved from " 2 1,4-Butanediol, also called Butane-1,4-diol (other names include 1,4-B, BD, BDO, and 1,4-BD),[5] is a primary alcohol and an organic compound with the formula HOCH2CH2CH2CH2OH. It is a colorless viscous liquid first synthesized in 1890 via acidic hydrolysis of N,N'-dinitro-1,4-butanediamine by Dutch chemist Pieter Johannes Dekkers, who called it "tetramethylene glycol".[6][7] 1,4-Butanediol Names Preferred IUPAC name Butane-1,4-diol Other names Tetramethylene glycol Identifiers CAS Number 110-63-4 Y 3D model (JSmol) Interactive image ChEBI CHEBI:41189 Y ChEMBL ChEMBL171623 Y ChemSpider 13835209 Y DrugBank DB01955 Y ECHA InfoCard 100.003.443 EC Number 203-786-5 PubChem CID 8064 RTECS number EK0525000 UNII 7XOO2LE6G3 Y CompTox Dashboard (EPA) DTXSID2042307 DTXSID2024666, DTXSID2042307 InChI InChI=1S/C4H10O2/c5-3-1-2-4-6/h5-6H,1-4H2 YKey: WERYXYBDKMZEQL-UHFFFAOYSA-N YInChI=1/C4H10O2/c5-3-1-2-4-6/h5-6H,1-4H2 SMILES OCCCCOC(CCO)CO Properties[1][2] Chemical formula C4H10O2 Molar mass 90.122 g·mol−1 Density 1.0171 g/cm3 (20 °C) Melting point 20.1 °C (68.2 °F; 293.2 K) Boiling point 235 °C (455 °F; 508 K) Solubility in water Miscible Solubility in ethanol Soluble Magnetic susceptibility (χ) −61.5·10−6 cm3/mol Refractive index (nD) 1.4460 (20 °C) Hazards[3][4] GHS labelling: Pictograms Signal word Warning Hazard statements H302, H336 Precautionary statements P261, P264, P270, P271, P301+P312, P304+P340, P312, P330, P403+P233, P405, P501 NFPA 704 (fire diamond) 1 1 0 Flash point (open cup) 121 °C (250 °F; 394 K) Autoignitiontemperature 350 °C (662 °F; 623 K) Related compounds Related butanediols 1,2-Butanediol1,3-Butanediol2,3-Butanediolcis-Butene-1,4-diol Related compounds SuccinaldehydeSuccinic acid Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). Y verify (what is YN ?) Infobox references Conversion of butane to butanediol or butyrolactone via oxidation to maleic anhydride followed by hydrogenation over copper chromite.[8] In one industrial chemical synthesis, acetylene reacts with two equivalents of formaldehyde to form butyne-1,4-diol. Hydrogenation of butyne-1,4-diol gives butane-1,4-diol.[9] It is also made on an industrial scale from maleic anhydride in the Davy process, which is first converted to the methyl maleate ester, then hydrogenated. Other routes are from butadiene, allyl acetate and succinic acid. A biological route to BD has been commercialized that uses a genetically modified organism.[10] The biosynthesis proceeds via 4-hydroxybutyrate. Butane-1,4-diol is used industrially as a solvent[additional citation(s) needed] and in the manufacture of some types of plastics, elastic fibers and polyurethanes. In organic chemistry, 1,4-butanediol is used for the synthesis of γ-butyrolactone (GBL). In the presence of phosphoric acid and high temperature, it dehydrates to the important solvent tetrahydrofuran.[11] At about 200 °C in the presence of soluble ruthenium catalysts, the diol undergoes dehydrogenation to form butyrolactone.[12] It is used to synthesize 1,4-butanediol diglycidyl ether which is then used as a reactive diluent for epoxy resins.[13] 1,4-Butanediol is used in the production of polybutylene terephthalate (PBT) plastic.[14] World production of butane-1,4-diol was claimed to be about one million metric tons per year and market price is about US$2,000 (€1,600) per ton in 2005. In 2013, worldwide production was claimed to be billions of pounds (consistent with approximately one million metric tons).[15] Almost half of it is dehydrated to tetrahydrofuran to make fibers such as Spandex.[16] The largest producer is BASF.[17] FDA warning against products containing GHB and its prodrugs, such as butane-1,4-diol. Butane-1,4-diol is also used as a recreational drug known by some users as "Bute",[18] "One Comma Four", "Liquid Fantasy", "One Four Bee" or "One Four B-D-O". Some federal courts in the USA have stated that 1,4-butanediol exerts effects similar to its metabolite, GABA analogue gamma-hydroxybutyrate (GHB), but several other federal courts have ruled that it does not. 1,4-butenediol (CAS 110-64-5) may be incorrectly sold as 1,4-butanediol but should not be confused with it. Butane-1,4-diol is rapidly converted into GHB acid by the enzymes alcohol dehydrogenase and aldehyde dehydrogenase, and differing levels of these enzymes may account for differences in effects and side effects between users.[19] While co-administration of ethanol and GHB already poses serious risks, co-administration of ethanol with 1,4-butanediol will interact considerably and has many other potential risks. This is because the same enzymes that are responsible for metabolizing alcohol also metabolize 1,4-butanediol so there is a strong chance of a dangerous drug interaction.[19][20] Emergency room patients who overdose on both ethanol and 1,4-butanediol often present with symptoms of alcohol intoxication initially and as the ethanol is metabolized the 1,4-butanediol is then able to better compete for the enzyme and a second period of intoxication ensues as the 1,4-butanediol is converted into GHB.[19] Metabolic pathway of butane-1,4-diol, γ-butyrolactone and γ-hydroxybutyric acid (GHB). Butane-1,4-diol seems to have two types of pharmacological actions. The major psychoactive effects of 1,4-butanediol are because it is metabolized into GHB; however there is a study suggesting that 1,4-butanediol may have potential alcohol-like pharmacological effects on its own.[20] The study arrived at this conclusion based on the finding that butane-1,4-diol coadministered with ethanol led to potentiation of some of the behavioral effects of ethanol. However, potentiation of ethanol's effects may simply be caused by competition for the alcohol dehydrogenase and aldehyde dehydrogenase enzymes with co-administered 1,4-butanediol. The shared metabolic rate-limiting steps thus leads to slowed metabolism and clearance for both compounds including ethanol's known toxic metabolite acetaldehyde. Another study found no effect following intracerebroventricular injection of butane-1,4-diol in rats.[21] This contradicts the hypothesis of butane-1,4-diol having inherent alcohol-like pharmacological effects. Like gamma-hydroxybutyric acid, butane-1,4-diol is safe only in small amounts. Adverse effects in higher doses include nausea, vomiting, dizziness, sedation, vertigo, and potentially death if ingested in large amounts. Anxiolytic effects are diminished and side effects increased when used in combination with alcohol. While butane-1,4-diol is not currently scheduled federally in the United States,[22] a number of states have classified 1,4-butanediol as a controlled substance. Individuals have been prosecuted for possession of 1,4-butanediol under the Federal Analog Act as substantially similar to GHB.[23] A federal case in New York in 2002 ruled that 1,4-butanediol could not be considered an analog of GHB under federal law,[24] but that decision was later overturned by the Second Circuit.[25] A jury in Federal District Court in Chicago found that 1,4-butanediol was not an analog of GHB under federal law, which was not disputed on the case's appeal to the Seventh Circuit Court of Appeals, however this finding did not affect the outcome of the case.[26] In the United Kingdom, 1,4-butanediol was scheduled in December 2009 (along with another GHB precursor, gamma-butyrolactone) as a Class C controlled substance. In Germany, the drug is not explicitly illegal, but might also be treated as illegal if used as a drug. It is controlled as a Schedule VI precursor in Canada. See also: Bindeez A toy called "Bindeez" ("Aqua Dots" in North America) was recalled by the distributor in November 2007 because of the presence of butane-1,4-diol. The toy consists of small beads that stick to each other by sprinkling water. Butane-1,4-diol was detected by GC-MS.[27] The production plant seems to have intended to cut costs by replacing less toxic pentane-1,5-diol with butane-1,4-diol. ChemNet China listed the price of butane-1,4-diol at between about US$1,350–2,800 per metric ton, while the price for 1,5-pentanediol is about US$9,700 per metric ton.[28] In August 2021, several people fell severely ill after consuming drinks at building L2.01 at the Lichtwiese Campus of Darmstadt Technical University, Germany. Seven showed severe symptoms, two were transported to a hospital in Frankfurt am Main, and a 30-year-old person was, for a time, in a critical state. Butane-1,4-diol had been detected in milk packages, as well as in water filters. At the location, detectives also found bromophenols and dicyclohexylamine.[29] A variety of 1,4-butanediol derivatives are GHB-like drugs or GHB receptor agonists. These include GHB itself, γ-butyrolactone (GBL), aceburic acid, ethyl acetoxy butanoate (EAB), Γ-crotonolactone, γ-hydroxybutyraldehyde, γ-hydroxyvaleric acid (GHV), γ-valerolactone, γ-hydroxycrotonic acid (GHC or T-HCA), and 4-hydroxy-4-methylpentanoic acid (UMB68), among others. An analogue that is not a 1,4-butanediol derivative but is related and still shows affinity for the GHB receptor is 3-chloropropanoic acid (UMB66). 1,3-Butanediol 1,4-Butanediol diglycidyl ether 2-Methyl-2-propyl-1,3-propanediol 4-Amino-1-butanol ^ Weast, Robert C., ed. (1981), CRC Handbook of Chemistry and Physics (62nd ed.), Boca Raton, Florida: CRC Press, p. 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Turcotte, 405 F.3d 515 (7th Cir. 2005) "With specific regard to 1,4 Butanediol, the jury has returned a special verdict which states that 1,4-Butanediol is not a Schedule I Narcotic Drug Controlled Substance analogue, because 1,4-Butanediol's chemical structure is not significantly similar to the chemical structure of GHB. ^ Wang, Linda (9 November 2007), "Industrial Chemical Sullies Popular Children's Toy", Chemical & Engineering News, retrieved 11 August 2009 ^ "US mother says her son began to stumble and vomit after eating Chinese-made toy, now recalled", Boston Herald, Associated Press, 8 November 2007 ^ "Ermittler finden nach Vergiftungen an TU Darmstadt offenbar K.-o.-Tropfen in Küche", Stern, 27 August 2021, retrieved 1 September 2021{{cite web}}: CS1 maint: overridden setting (link) International Chemical Safety Card 1104 SIDS Initial Assessment Report for 1,4-Butanediol from the Organisation for Economic Co-operation and Development (OECD) Record in the Household Products Database of NLM Retrieved from " 3 1,2-Butanediol is the organic compound with the formula HOCH2(HO)CHCH2CH3. It is classified as a vic-diol (glycol). It is chiral, although typically it is encountered as the racemic mixture. It is a colorless liquid. 1,2-Butanediol Molecular formula of 1,2-Butanediol Names Preferred IUPAC name Butane-1,2-diol Other names 1,2-Dihydroxybutaneα-Butylene glycol Identifiers CAS Number 584-03-2 Y40348-66-1 (R) N73522-17-5 (S) N 3D model (JSmol) Interactive imageInteractive image ChEBI CHEBI:52682 Y ChemSpider 10948 Y ECHA InfoCard 100.008.663 EC Number 209-527-2 PubChem CID 11429 RTECS number EK0380000 UNII RUN0H01QEU Y CompTox Dashboard (EPA) DTXSID6040375 InChI InChI=1S/C4H10O2/c1-2-4(6)3-5/h4-6H,2-3H2,1H3 YKey: BMRWNKZVCUKKSR-UHFFFAOYSA-N YInChI=1/C4H10O2/c1-2-4(6)3-5/h4-6H,2-3H2,1H3Key: BMRWNKZVCUKKSR-UHFFFAOYAV SMILES OCC(O)CCCCC(CO)O Properties[1] Chemical formula C4H10O2 Molar mass 90.121 g/mol Density 1.0023 g/cm3 (20 °C) Melting point −50 °C (−58 °F; 223 K)[note 1] Boiling point 195 to 196.9 °C (383.0 to 386.4 °F; 468.1 to 470.0 K) (96.5 °C at 10 mmHg) Solubility in water miscible Solubility soluble in ethanol, acetone; sparingly soluble in esters and ethers; insoluble in hydrocarbons Refractive index (nD) 1.4378 (20 °C) Viscosity 7.3 mPa·s (20 °C) Thermochemistry Std enthalpy offormation (ΔfH298) −532.8 kJ/mol [2] Std enthalpy ofcombustion (ΔcH298) −2479 kJ/mol Hazards[3] Flash point 90 °C (194 °F; 363 K) Safety data sheet (SDS) ICSC 0395 Related compounds Related butanediols 1,3-Butanediol1,4-Butanediol2,3-Butanediol Related compounds Ethylene glycolPropylene glycol2-Hydroxybutyraldehyde2-Hydroxybutyric acidα-Ketobutyric acid Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). N verify (what is YN ?) Infobox references This diol was first described by Charles-Adolphe Wurtz in 1859.[4] It is produced industrially by hydration of 1,2-epoxybutane.[5][6] This process requires a ten- to twenty-fold excess of water to suppress the formation of polyethers. Depending on the amount of excess water, the selectivity varies from 70 to 92%.[7] Sulfuric acid or strongly acidic ion exchange resins may be used as catalysts, which allows the reaction to occur under 160 °C and at slightly above atmospheric pressure. 1,2-Butanediol is a byproduct of the production of 1,4-butanediol from butadiene.[8] It is also a byproduct of the catalytic hydrocracking of starches and sugars such as sorbitol to ethylene glycol and propylene glycol.[9] It can also be obtained from the dihydroxylation of but-1-ene by OsO4. It has been patented for the production of polyester resins and plasticizers.[6][8] It is a potential feedstock for the industrial production of α-ketobutyric acid, a precursor to some amino acids.[10] The LD50 (rats, oral) is 16g/kg.[5] ^ The value of −50 °C for the melting point is taken from Ullmann's Encyclopedia of Industrial Chemistry and used by the Hazardous Substances Data Bank and the OECD Screening Information Dataset. Other reported values of the melting point range from −114 °C to −30 °C. ^ Weast, Robert C., ed. (1981). CRC Handbook of Chemistry and Physics (62nd ed.). Boca Raton, Florida: CRC Press. p. C-190. ISBN 0-8493-0462-8.. ^ Moureu, H.; Dode, M. (1937), "Chaleurs de formation de l'oxyde d'ethylene, de l'ethanediol et de quelques homologues", Bull. Soc. Chim. Fr., 4: 637–47. ^ 1,2-Butanediol, International Chemical Safety Card 0395, Geneva: International Programme on Chemical Safety, March 1996. ^ Wurtz, A. (1859), "Mémoire sur les glycols ou alcools diatomique" [Dissertation on glycols, or diatomic alcohols], Ann. Chim. Phys., 55: 400. ^ a b "Butanediols, Butenediol, and Butynediol". Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH. 2005. doi:10.1002/14356007.a04_455. ISBN 978-3-527-30673-2. ^ a b 1,2-Butanediol (PDF), SIDS Initial Assessment Report, Geneva: United Nations Environment Programme, February 1995. ^ Gräfje, Heinz; Körnig, Wolfgang; Weitz, Hans-Martin; Reiß, Wolfgang; Steffan, Guido; Diehl, Herbert; Bosche, Horst; Schneider, Kurt; Kieczka, Heinz (2019-07-23), "Butanediols, Butenediol, and Butynediol", Ullmann's Encyclopedia of Industrial Chemistry, Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, pp. 1–12, doi:10.1002/14356007.a04_455.pub2, ISBN 978-3-527-30673-2, retrieved 2022-02-18 ^ a b US 4596886, Hasegawa, Ryuichi & Hayashi, Kohji, "Polyester containing impure 1,2-butanediol", published 1986-06-24, assigned to Mitsubishi Monsanto Chemical Company . ^ US 4966658, Berg, Lloyd, "Recovery of ethylene glycol from butanediol isomers by azeotropic distillation", published 1990-10-30 . ^ US 5423955, Berg, Lloyd, "Separation of propylene glycol from 1,2-butanediol by azeotropic distillation", published 1995-06-13 . ^ US 5155263, Imanari, Makoto; Iwane, Hiroshi & Suzuki, Masashi et al., "Process for preparing α-ketobutyric acid", published 1992-10-13, assigned to Mitsubishi Petrochemical Co., Ltd. . International Chemical Safety Card 03 SIDS Initial Assessment Report for 1,2-Butanediol from the Organisation for Economic Co-operation and Development (OECD) Retrieved from " 4 1,3-Butanediol is an organic compound with the formula CH3CH(OH)CH2CH2OH, not to be confused with 1,4 Butanediol. With two alcohol functional groups, the molecule is classified as a diol. The compound without the R (or D) designation is racemic, which is what has been used in most studies before 2023. The compound is a colorless, bittersweet, water-soluble liquid. It is one of four common structural isomers of butanediol.[1][2][3] It is used in grape flavoring,[4] and as a precursor to some antibiotics.[5] 1,3-Butanediol Skeletal formula of 1,3-butanediol Ball and stick model of 1,3-butanediol (S) Spacefill model of 1,3-butanediol (S) Names Preferred IUPAC name Butane-1,3-diol Other names 1,3-butylene glycol, butane-1,3-diol, or 1,3-dihydroxybutane Identifiers CAS Number 107-88-0 Y6290-03-5 (R) Y24621-61-2 (S) Y 3D model (JSmol) Interactive image Beilstein Reference 1731276 1718944 (R) 1718943 (S) ChEBI CHEBI:52683 N ChEMBL ChEMBL1231503 N ChemSpider 7608 Y553103 (R) Y394191 (S) Y DrugBank DB02202 N ECHA InfoCard 100.003.209 EC Number 203-529-7 E number E1502 (additional chemicals) Gmelin Reference 2409 2493173 (R) 1994384 (S) KEGG D10695 N MeSH 1,3-Butylene+glycol PubChem CID 7896637497 (R)446973 (S) RTECS number EK0440000 UNII 3XUS85K0RA Y CompTox Dashboard (EPA) DTXSID8026773 InChI InChI=1S/C4H10O2/c1-4(6)2-3-5/h4-6H,2-3H2,1H3 NKey: PUPZLCDOIYMWBV-UHFFFAOYSA-N N SMILES CC(O)CCO Properties Chemical formula C4H10O2 Molar mass 90.122 g·mol−1 Appearance Colourless liquid Density 1.0053 g cm−3 Melting point −50 °C (−58 °F; 223 K) Boiling point 204 to 210 °C; 399 to 410 °F; 477 to 483 K Solubility in water 1 kg dm−3 log P −0.74 Vapor pressure 8 Pa (at 20 °C) Refractive index (nD) 1.44 Thermochemistry Std molarentropy (S298) 227.2 J K−1 mol−1 Std enthalpy offormation (ΔfH298) −501 kJ mol−1 Std enthalpy ofcombustion (ΔcH298) −2.5022 MJ mol−1 Hazards GHS labelling: Pictograms Signal word Warning Hazard statements H319, H413 Precautionary statements P305+P351+P338 NFPA 704 (fire diamond) 1 1 0 Flash point 108 °C (226 °F; 381 K) Autoignitiontemperature 394 °C (741 °F; 667 K) Related compounds Related butanediol 1,2-Butanediol 1,4-Butanediol 2,3-Butanediol Related compounds 2-Methylpentane Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). N verify (what is YN ?) Infobox references Hydrogenation of 3-hydroxybutanal gives 1,3-butanediol:[6] CH3CH(OH)CH2CHO + H2 → CH3CH(OH)CH2CH2OH Dehydration of 1,3-butanediol gives 1,3-butadiene: CH3CH(OH)CH2CH2OH → CH2=CH-CH=CH2 + 2 H2O 1,3-Butanediol has sedative, hypotensive and hypoglycaemic action comparable to ethanol, with the (R), also known as (D), enantiomer being more active.[7][8] Fatty acid esters of 1,3-butanediol such as the acetoacetate, lactate or hexanoate have been researched for inducing ketogenesis.[9][10][11][12][13][14][15] Recent research highlights the stereospecific metabolism of (R)-1,3-butanediol, emphasizing its efficient conversion to β-hydroxybutyrate via alcohol dehydrogenase. This process involves zinc coordination and maintains cellular redox balance. Notably, (R)-1,3-butanediol induces mild euphoric effects through ketone body signaling pathways, distinct from the GABAergic mechanisms associated with ethanol.[16] 1,3-Butanediol has been detected in green bell peppers, orange bell peppers, pepper (Capsicum annuum), red bell peppers, and yellow bell peppers.[17] 1,3 Butanediol, | quote = Also referred to as 1,3-Butylene glycol, maintains FDA GRAS status as a flavor molecule.[18] The metabolism of (R)-1,3-butanediol is compartmentalized within hepatic cells, occurring in both cytosolic and mitochondrial domains. Enzymatic studies have quantified the distribution of alcohol dehydrogenase isoforms involved in its conversion to β-hydroxybutyrate, underscoring the molecule's potential in therapeutic ketone body production.[16] ^ Gräfje H, Körnig W, Weitz HM, Reiß W, Steffan G, Diehl, et al. (2000). "Butanediols, Butenediol, and Butynediol". Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH. doi:10.1002/14356007.a04_455. 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Retrieved from " 5 2,3-Butanediol is the organic compound with the formula (CH3CHOH)2. It is classified as a vic-diol (glycol). It exists as three stereoisomers, a chiral pair and the meso isomer. All are colorless liquids. Applications include precursors to various plastics and pesticides. 2,3-Butanediol 2,3-butanediol Names Preferred IUPAC name Butane-2,3-diol Other names 2,3-Butylene glycolPseudobutylene glycol2,3-DihydroxybutaneButan-2,3-diolDiethanol[citation needed] & Bis-ethanol Identifiers CAS Number 513-85-9 Y19132-06-0 (2S,3S)-(+) Y24347-58-8 (2R,3R)-(−) Y5341-95-7 (2R,3S) Y 3D model (JSmol) Interactive image ChEBI CHEBI:62064 N ChEMBL ChEMBL2312529 ChemSpider 257 Y ECHA InfoCard 100.007.431 EC Number 208-173-6 PubChem CID 262 UNII 45427ZB5IJ Y7E9UXG71S1 (2S,3S)-(+) YOR02B2286A (2R,3R)-(−) YF5IA8X9O8M (2R,3S) Y CompTox Dashboard (EPA) DTXSID8041321 InChI InChI=1S/C4H10O2/c1-3(5)4(2)6/h3-6H,1-2H3Key: OWBTYPJTUOEWEK-UHFFFAOYSA-N SMILES CC(C(C)O)O Properties Chemical formula C4H10O2 Molar mass 90.122 g·mol−1 Appearance Colorless liquid Odor odorless Density 0.987 g/mL Melting point 19 °C (66 °F; 292 K) Boiling point 177 °C (351 °F; 450 K) Solubility in water Miscible Solubility in other solvents Soluble in alcohol, ketones, ether log P −0.92 Vapor pressure 0.23 hPa (20 °C) Acidity (pKa) 14.9 Refractive index (nD) 1.4366 Thermochemistry Heat capacity (C) 213.0 J/K mol Std enthalpy offormation (ΔfH298) −544.8 kJ/mol Hazards NFPA 704 (fire diamond) 1 1 0 Flash point 85 °C (185 °F; 358 K) Autoignitiontemperature 402 °C (756 °F; 675 K) Lethal dose or concentration (LD, LC): LD50 (median dose) 5462 mg/kg (rat, oral) Related compounds Related butanediols 1,4-Butanediol1,3-Butanediol2,3-Butanediol Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). N verify (what is YN ?) Infobox references Of the three stereoisomers, two are enantiomers (levo- and dextro-2,3-butanediol) and one is a meso compound.[1][2] The enantiomeric pair have (2R, 3R) and (2S, 3S) configurations at carbons 2 and 3, while the meso compound has configuration (2R, 3S) or, equivalently, (2S, 3R). 2,3-Butanediol is prepared by hydrolysis of 2,3-epoxybutane:[3] (CH3CH)2O + H2O → CH3(CHOH)2CH3 The isomer distribution depends on the stereochemistry of the epoxide. The meso isomer is used to combine with naphthalene-1,5-diisocyanate. The resulting polyurethane is called "Vulkollan".[3] The (2R,3R)-stereoisomer of 2,3-butanediol is produced by a variety of microorganisms in a process known as butanediol fermentation.[4] It is found naturally in cocoa butter, in the roots of Ruta graveolens, sweet corn, and in rotten mussels. It is used in the resolution of carbonyl compounds in gas chromatography.[5] During World War II research was done towards producing 1,3-butadiene, the monomer of the polybutadiene used in a leading type of synthetic rubber.[6] It can be derived from the fermentation of sugarcane molasses.[7] Fermentative production of 2,3-butanediol from carbohydrates involves a network of biochemical reactions that can be manipulated to maximize production.[8] 2,3-Butanediol has been proposed as a rocket fuel that could be created on Mars by means of cyanobacteria and E. coli, shipped from Earth, working on resources available at the surface of Mars.[9] 2,3-Butanediol is detected in peppers, grape wine, anatidaes. 2,3-Butanediol undergo dehydration to form butanone (methyl ethyl ketone):[10] (CH3CHOH)2 → CH3C(O)CH2CH3 + H2O It can also undergo deoxydehydration to form butene:[11] (CH3CHOH)2 + 2 H2 → C4H8 + 2 H2O ^ Boutron P (1992). 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ChemCatChem. 8 (7): 1346–1353. doi:10.1002/cctc.201501399. ISSN 1867-3880. S2CID 102153512. ^ Kwok, Kelvin Mingyao; Choong, Catherine Kai Shin; Ong, Daniel Soo Wei; Ng, Joy Chun Qi; Gwie, Chuandayani Gunawan; Chen, Luwei; Borgna, Armando (2017-06-07). "Hydrogen-Free Gas-Phase Deoxydehydration of 2,3-Butanediol to Butene on Silica-Supported Vanadium Catalysts". ChemCatChem. 9 (13): 2443–2447. doi:10.1002/cctc.201700301. ISSN 1867-3880. S2CID 99415384. Retrieved from " 6The editor will now load If you still see this message after a few seconds, please reload the page. Retrieved from " 1kg of PU systems creates 3,5kg of CO2 in production, but reduces 350kg of emissions over a 50-year lifetime. 1.6cm-thick polyurethane insulation has the same insulation efficiency as a 1.34m-thick concrete wall! Since 2003, all polyurethane foams have been HCFC-free in the EU. The polyurethane industry employs over 360.000 people in the EU. The first polyurethane surfboard was made and used in the 1950s. Thanks to the introduction of polyurethanes into refrigerators, models designated A++ today are 60% more efficient than refrigerators 15 years ago. In 1973, roller skates were improved and popularised by the introduction of thermoplastic polyurethane (TPU) wheels and, later, TPU boots. Today they are known as Rollerblades. The amount of energy used to produce enough polyurethane insulation for one house is subsequently saved in the space of just one year thanks to the insulation provided. Polyurethane is often referred to as PU or PUR. Since 1995, all polyurethane foams have been CFC-free in the EU. Since 2003, they have been HCFC free as well That renewable raw materials can be used to produce polyols for several applications such as mattresses More and more dams and dykes are protected against storms with a PU-based solution Without some kind of finish to protect it from the elements, wood can become as dry and lifeless as day-old toast. Coating wood cabinetry, furniture, or trim with a clear finish gives it richness and depth while protecting it from knocks, scrapes, and the weather.One of the best clear coat finishes is polyurethane. Polyurethane creates a protective, durable finish ideal for a variety of applications, from furniture to floors. In this guide, we'll walk through how to best use polyurethane to give new life to the wood in your home.Polyurethane is a synthetic resin used to protect and enhance the appearance of wood surfaces. It works by forming a hard, protective coating on the wood surface. This coating can range from a clear finish, which preserves the natural look of the wood, to a tinted finish that adds color and depth. The resulting surface is not only aesthetically pleasing but also resistant to scratches, stains, and moisture.Polyurethane comes in two primary varieties, with hybrids between the two also available. Oil-based polyurethane is a popular choice for its durability and rich finish. It penetrates the wood deeply, enhancing the natural grain and creating a warm, amber hue over time. It's known for its toughness and resistance to wear, making it ideal for high-traffic areas like floors.However, oil-based polyurethane has a longer drying time and emits strong fumes. Proper ventilation and protective gear are essential when working with this type of polyurethane.Water-based polyurethane is favored for its minimal odor and quick drying time. It typically goes on clear and stays clear, making it a good choice for light-colored woods or projects where maintaining the original color is essential. It is also easier to clean up with soap and water.While water-based polyurethane is not as durable as oil-based polyurethane, technological advancements have significantly improved its performance. It is now a viable option for most interior applications, including furniture and cabinets.Water-based oil-modified polyurethane combines the best of both worlds: the durability of oil-based and the quick drying time of water-based polyurethane. It provides a clear finish with a slight amber tint, adding warmth to the wood while maintaining a natural look.This type is more environmentally friendly than traditional oil-based polyurethane due to its lower VOC content. It is an excellent option for those looking for a balance between performance and environmental impact.Selecting the right polyurethane for your project involves considering the specific requirements of your application. Here's how to make the right decision.For interior projects, both oil-based and water-based polyurethanes are suitable. However, for exterior applications, you should choose a polyurethane that offers UV protection and is formulated to withstand the elements. Oil-based polyurethanes are typically more durable for exterior use, but some water-based formulas are designed for outdoor applications.Polyurethane finishes come in various gloss levels: high-gloss, semi-gloss, satin, and matte. The choice of gloss level affects both the appearance and the practicality of the finish.High-gloss: High-gloss finishes are very shiny and reflective. They enhance the wood's grain and color but show scratches and imperfections more readily.Semi-gloss: Semi-gloss finishes have a slightly less reflective surface, offering a good balance between shine and practicality. They are commonly used for furniture and cabinetry.Satin: Satin finishes have a soft sheen that provides a more muted look. They hide imperfections better than glossier finishes and are versatile for various applications, including floors and furniture.Matte: Matte finishes offer the least amount of shine and provide a natural, understated look. They are ideal for projects where a subtle, rustic appearance is desired.Applying polyurethane correctly is vital to achieving a smooth, professional finish. In most cases, you'll either brush on the material, wipe it on like you would a stain, or spray it on.Brushing on polyurethane is the most traditional application method. It requires a high-quality brush designed for use with polyurethane to avoid brush marks and ensure even coverage.Using a brush gives you excellent control over the process and provides a thick, protective coat. However, you risk leaving brush marks if not applied correctly, and there's a longer drying time between coats.Wipe-on polyurethane is applied using a cloth, creating a thin, even layer. It is suitable for smaller projects or surfaces with intricate details. This method is easier to apply evenly, reducing the risk of drips and brush marks. It also dries faster between coats. But wiping on polyurethane requires more coats to build up a protective layer and may not provide as durable a finish as brush-on methods.Spray-on polyurethane offers a smooth, even finish with minimal effort. It's ideal for large surfaces or projects requiring a flawless appearance. The big advantage is its quick and even application with no risk of brushmarks and few drips. However, you'll need the right spray equipment and proper ventilation, and there's the potential for overspray and waste.Achieving the best results with polyurethane involves careful preparation, application, and curing. Follow these instructions for a successful project.Start by sanding the wood surface with progressively finer grits of sandpaper, finishing with 220 grit. This creates a smooth, even surface for the polyurethane to adhere to.Next, clean the surface thoroughly to remove all dust and debris. Tack cloths or a vacuum with a brush attachment are effective tools for this task. Ensuring the surface is clean will prevent imperfections in the final finish.Stir the polyurethane gently to avoid creating bubbles. Pour a small amount into a separate container to prevent contamination of the main can.If using the brush-on method:Dip the brush into the polyurethane, blot excess on the side of the container.Apply in long, even strokes, following the grain of the wood.Overlap brush strokes slightly to ensure even coverage.Allow the first coat to dry completely, following the manufacturer's instructions.For the wipe-on method:Soak a clean cloth in polyurethane and wring out excess.Wipe onto the wood surface with long, even strokes, following the grain.Apply additional coats as needed, allowing each to dry completely.Finally, for the spray-on method:Ensure the spray gun is clean and properly adjusted.Apply light, even coats, moving the spray gun steadily across the surface.Allow each coat to dry before applying the next.Proper curing is essential for a durable finish. Allow the final coat of polyurethane to cure for at least 24 hours before handling. For floors or surfaces that will experience heavy traffic, curing time might extend to several days or more.Maintaining a polyurethane finish involves regular cleaning and occasional reapplication to keep it looking its best.For routine cleaning, use a damp cloth to wipe away dust and dirt. Avoid using harsh chemicals or abrasive cleaners that can damage the polyurethane finish. Mild soap and water are usually sufficient for removing more stubborn stains.Over time, high-traffic areas may show signs of wear and require reapplication of polyurethane. Lightly sand the worn areas with fine-grit sandpaper to create a smooth surface for the new coat to adhere to. Clean the area thoroughly and apply a thin coat of polyurethane, following the same application techniques as initially used.Different household projects require specific considerations to achieve the best results with polyurethane. Here is some tailored advice for floors, furniture, and outdoor projects.Floors endure a lot of wear and tear, so choosing a durable polyurethane is essential. Oil-based polyurethanes are usually more resilient for flooring applications. Apply at least three coats for optimal protection, allowing each coat to dry thoroughly before the next.For furniture projects, consider the type of wood, the desired appearance, and the amount of use the piece will get. Satin or semi-gloss finishes are often preferred for furniture due to their balanced sheen and scratch resistance.Outdoor projects require polyurethane with UV protection. Water-based oil-modified polyurethanes are an excellent choice for outdoor applications as they provide good durability while being less harmful to the environment.Safety is paramount when working with polyurethane due to its chemical components. Here are some key safety tips you should follow when working with the material: Always work in a well-ventilated area to minimize inhalation of fumes. If working indoors, open windows and doors to allow for air circulation. Using fans can also help to disperse fumes more effectively.Wear protective gear such as gloves, goggles, and a mask to protect your skin and eyes from splashes and to prevent inhalation of harmful vapors. For oil-based polyurethane, a respirator mask is recommended to filter out VOCs.Clean brushes and other equipment used with oil-based polyurethane with mineral spirits or turpentine. For water-based polyurethane, soap and water are sufficient. Dispose of used rags and brushes safely, as some materials may be flammable.Even with careful application, issues may arise when working with polyurethane. Here are solutions to common problems.Bubbles can form if the polyurethane is shaken or stirred too vigorously or if applied too quickly. To avoid bubbles, stir the polyurethane gently and apply it slowly. If bubbles appear, gently brush them out while the finish is still wet.Brush marks are a common issue, especially with thicker coats. Using a high-quality brush and applying thin coats can help minimize brush marks. Lightly sanding between coats can smooth out any imperfections.If too much polyurethane is applied at once, drips and runs can occur. Apply thinner coats and check the surface regularly to catch and smooth out any drips before they dry.Polyurethane is not the only finish available, and understanding how it compares to other options can help you make an informed choice.Lacquer dries quickly and provides a hard, durable finish but is more brittle and prone to chipping. Polyurethane is more flexible and durable, making it a better choice for surfaces that will see heavy use.Shellac offers a beautiful, warm finish but is not as durable as polyurethane. It is more susceptible to water and heat damage, making polyurethane the preferred option for high-traffic or moisture-prone areas.Varnish is similar to polyurethane but generally has a higher oil content, making it more flexible. It is often used for outdoor projects due to its UV resistance. However, polyurethane tends to be harder and more durable, making it suitable for indoor applications.Polyurethane is a versatile and durable finish that offers excellent protection and aesthetic benefits for a wide range of projects. Whether you are refinishing a floor, protecting a piece of furniture, or tackling an outdoor project, understanding the types of polyurethane, their applications, and best practices for use will help you achieve professional results. Polyurethane is a versatile synthetic thermoset polymer. Commonly abbreviated as PUR and PU, it is known for its wide application in various industries and offers excellent properties such as strength, durability, flexibility, and thermal stability.The main ingredients used in the production of polyuritane are polyols and diisocyanates, which react to form a cross-linked structure. Able to be customized into different forms and offering numerous benefits from flexible foams to hard coatings, polyurethane's adaptability makes it a popular choice for a variety of uses.What is the origin of polyurethane?Polyurethane originated from scientific research and development conducted by Otto Bayer and his team at IG Farben in Germany in the late 1930s. During this time, they were exploring the synthesis of new polymers and discovered the reaction between polyols and diisocyanates to create polyurethanes.IG Farben, a large chemical company at the time, recognized the potential of polyurythane and began commercial production of the material in the 1950s. The versatility, durability, and wide range of properties exhibited by polyurethane have quickly made it popular across a variety of industries. Since its discovery, polyurethane formulations and applications have continued to advance and improve. Today, it has become a widely used material.What is polyurethane made of?Polyurethane is a polyurethane material that combines polyols and diisocyanates through a chemical reaction, and its properties can be tailored by adjusting the composition and formulation of these components. Polyols contain multiple hydroxyl (OH) groups, while diisocyanates contain two isocyanate (NCO) functional groups.In the production of polyurythane, these two components react together in a process called polyurethane polymerization. The reaction between polyols and diisocyanates forms polymer chains with repeating urethane bonds, thus forming polyeurethene.The specific types of polyols and diisocyanates used and their ratios and other additives can be varied to produce different forms of polyurethane with different properties. For example, flexible foams can be produced using flexible polyols, while rigid foams require different polyols and diisocyanates.In addition to polyols and diisocyanates, various additives such as catalysts, blowing agents, flame retardants, and fillers can be incorporated into polyeurethene formulations to achieve desired properties such as foam expansion, flame retardancy, or enhanced mechanical properties.What are the properties of polyurethane?Polyurethane has a range of physical and chemical properties, the following are the specific physical and chemical properties of polyuritane:Physical properties:Density diversity: Polyurethane can have different densities depending on its formulation, which means it does not have a fixed density and different types of polyurethane material parts can be produced based on this characteristic. Variety of Hardnesses: Polyurthane can be formulated in a variety of hardnesses, from soft and pliable materials to rigid and hard materials. Elasticity: Polyurethane elastomer has high elasticity and exhibits excellent resilience, allowing it to return to its original shape after deformation. Thermal Stability: Polyurethane has good thermal stability and can maintain its properties over a wide temperature range. Abrasion Resistance: Polyurthane is highly abrasion resistant, making it suitable for applications requiring durability. Impact Resistance: Polyurethane has good impact resistance, absorbing and dissipating energy upon impact. Tear Strength: Polyutethane has high tear strength, making it tear-resistant and durable. Flexibility: Polyurethanes can be designed with various levels of flexibility, from flexible foams to elastomers with varying hardnesses.Chemical Properties:Chemical resistance: Polyutethane is resistant to a wide range of chemicals, including oils, solvents, acids, and alkalis. Water Resistance: Polyurethane is formulated to have good water resistance and moisture absorption. UV Resistance: Certain polyeurethane formulations have good resistance to ultraviolet (UV) radiation, preventing degradation and fading when exposed to sunlight. Flame retardancy: Polyurethane can be modified to make it flame retardant, reducing its flammability and limiting the spread of flames. Compatibility: Polyeurethane is compatible with a wide range of materials and can effectively bond and adhere to a variety of substrates. Biocompatibility: Some polyurethane formulations are biocompatible, making them suitable for medical and healthcare applications.What Are the Mechanical Properties of Polyurethane?The table below lists some mechanical properties of polyurethane:Polyurethane Mechanical Properties TablePropertyValueUnitTensile Strength20-50MPaYield Strength10-40MPaModulus of Elasticity0.5-10GPaPoisson's Ratio0.3-0.5-Shear Modulus0.2-1GPaHardness (Shore A)40-90-Hardness (Shore D)30-70-Fatigue Strength 10-30MPaFracture Toughness0.5-2MPa·m^0.5Density0.9-1.3g/cm^3Melting PointN/A °CThermal Conductivity0.01-0.3 W/(m·K)Electrical Conductivity1e-15-1e-12S/mWhat are the uses of polyurethane?Polyurethane is widely used in a variety of industries and applications due to its versatility and desirable properties. Some common uses of polyeurthane include:Foam Products: Polyurethane foam is widely used in upholstery, mattresses, cushions, and pillows because of its comfort, support, and resilience. It is also used in car seats, insulation panels, packaging materials, and soundproofing materials.Thermal insulation: Polyurethane rigid foam is an excellent thermal insulation material. It is used in the construction of insulated walls, roofs, and floors, as well as in refrigeration and cold storage applications.Coatings and Sealers: Polyurethane coatings provide a protective finish on a variety of surfaces, including wood, metal, concrete, and floors. Polyeurthane sealants are used to seal joints and gaps in the construction, automotive, and manufacturing industries.Adhesives: Polyurethane adhesives have strong bonding capabilities and are used in a wide range of applications, including automotive assembly, woodworking, footwear, and packaging.Elastomers: Polyurethane elastomers, also known as Polyeurthane elastomers, are used in the production of gaskets, seals, O-rings, rollers, wheels, and industrial parts. They offer excellent flexibility, abrasion resistance, and durability.Automotive: Polyurethanes are used in the automotive industry for a variety of components such as foam seats, interior trim, bumpers, gaskets, suspension bushings, and tires.Footwear: Polyurathane is used in footwear manufacturing for outsoles, midsoles, insoles, and cushioning. It provides comfort, shock absorption, and durability.Sports and Recreation: Polyurethanes are used in sports and recreation equipment, including ski boots, protective gear, inflatable rafts, and sports liners.Electrical and electronic applications: Polyurethanes are used in electrical insulation materials, cable jacketing, potting compounds, and encapsulation of electrical and electronic components.Industrial Applications: Polyurathane are used in a variety of industrial applications such as rollers, conveyor belts, gaskets, seals, sound insulation, and vibration-damping components.What types of polyurethane are there?There are many types of polyurethane, the main types of polyurethane include:Flexible polyurethane foam: This type of polyurathine is commonly used in upholstery and other comfort applications. It has excellent flexibility, softness, and cushioning properties.Rigid polyurethane foam: Rigid polyurathine foam is used for thermal insulation in construction, refrigeration, and other applications. It has excellent insulation properties, structural strength, and low density.Polyurethane Elastomers: Polyurethane elastomers, also known as polyurethanium elastomers, are highly elastic materials used in applications requiring flexibility, resilience, and abrasion resistance.Polyurethane Coatings: Polyurethane coatings are used as protective topcoats on a variety of surfaces, including wood, metal, and concrete. They offer excellent resistance to abrasion, chemicals, UV radiation, and weathering.Polyurethane Adhesives and Sealants: Polyurethane adhesives have strong bonding capabilities and are used in a variety of industries, including automotive, construction, and manufacturing. polyurethanium sealants are used to seal joints and gaps, providing air and water tightness.Self-skinning polyurethane foam: Self-skinning foam is a flexible polyurethane foam with a dense outer skin layer that provides durability, abrasion resistance, and a smooth surface.Microcellular polyurethane foam: Microcellular foam has a fine cell structure that provides enhanced mechanical properties such as improved resistance to compression set and higher load-bearing capacity.Water-based polyurethane: The water-based polyurethene formula uses water as the solvent instead of traditional organic solvents, making it more environmentally friendly. They are used in coatings, adhesives, and sealants.What processing techniques are suitable for PU products?At Ruitai, polyurethane (PU) products can be manufactured using a variety of processing techniques. The choice of our processing method depends on the specific PU formulation, desired product properties, and production requirements. Some of our common PU product processing technologies include:Casting: Casting involves pouring a liquid PU mixture into a mold and allowing it to solidify. This method is commonly used to produce polyurethene elastomers, coatings, and certain types of flexible foams.Injection Molding: Injection molding is a widely used process for manufacturing polyurethane products with complex shapes and precise dimensions. It involves injecting molten PU material into a mold under high pressure. Injection molding is commonly used to produce rigid PU foam parts, automotive components, and industrial components.Extrusion: PU materials can be processed by extrusion, which involves forcing molten PU through a die to form a continuous profile with a consistent cross-section. Extrusion is used to manufacture PU tubes, rods, gaskets, seals, and profiles.Spray Foam: Spray foam technology involves spraying a two-component PU blend (polyol and isocyanate) using specialized equipment. The mixture reacts quickly and expands, forming a foam that adheres to the sprayed surface. Spray foam is commonly used in insulation, construction, and sealing applications.Pour-in-place: The pour-in-place method involves pouring a liquid PU mixture directly into a surface or cavity, allowing it to expand and cure in place. This technology is commonly used to create custom foam molds, liners, and flexible foam products.Lamination: PU materials can be laminated to various substrates to form composite structures. The process involves bonding a PU film, sheet, or coating to a surface such as fabric, metal, or plastic. Lamination is used in applications such as automotive interiors, footwear, and upholstery.Reaction Injection Molding (RIM): RIM is a process in which liquid PU ingredients are mixed in a mixing chamber and the mixture is injected into a mold. The mixture reacts and solidifies, forming the desired shape. RIM is often used to produce large, complex PU parts with high strength and impact resistance, such as automotive bumpers and panels.These are some of the common processing techniques used to manufacture PU products. Each method offers unique advantages and is suitable for different types of polyurithane formulations and applications. If you need to produce some polyurethane parts, our online polyurethane overmolding service is your best choice.What are the advantages and disadvantages of polyurethane?Polyurethane (PU) is a versatile material with several advantages and disadvantages. Here are some of the key advantages and disadvantages of polyurithane:Advantages of Polyurethane:Versatility: Polyurethane can be formulated into various forms, including foams, elastomers, coatings, adhesives, and sealants. This versatility allows for a wide range of applications across different industries.Durability: Polyurethane is known for its durability and resistance to wear, tear, and abrasion. It can withstand harsh environments and heavy use, making it suitable for demanding applications.Flexibility: Polyurtheane can be tailored to exhibit a wide range of hardness and flexibility, from soft and flexible foams to rigid and stiff materials. This flexibility allows for customization to meet specific application requirements.Excellent Load-Bearing Capacity: Polyurethane exhibits high load-bearing capacity, making it suitable for applications that require weight-bearing support or impact resistance. It is commonly used in automotive components, industrial parts, and elastomeric materials.Thermal Insulation: Polyurethane foam, especially rigid foam, offers excellent thermal insulation properties. It is widely used in construction for insulation panels and in refrigeration equipment to maintain temperature control.Chemical Resistance: Polyurethane is resistant to many chemicals, oils, and solvents. This property makes it suitable for applications where exposure to such substances is expected, such as gaskets, seals, and coating applications.Bonding Strength: Polyurethane adhesives exhibit strong bonding capabilities, providing reliable adhesion for various substrates. They are commonly used in applications such as automotive assembly, woodworking, and construction.Disadvantages of Polyurethane:Environmental Impact: The production and disposal of polyurethane can have environmental impacts. Some polyurethane formulations may contain hazardous chemicals, and traditional polyurethane foam is not easily biodegradable.Cost: Polyurethane materials can be relatively expensive compared to some other materials. The cost of raw materials and processing equipment can contribute to higher production costs.Sensitivity to UV Radiation: Polyurethane materials, especially in their raw form, can be sensitive to prolonged exposure to ultraviolet (UV) radiation, which can cause degradation and discoloration. UV stabilizers or protective coatings are often used to mitigate this issue.Processing Complexity: Processing polyurethane can be more complex compared to some other materials. It may require precise control of mixing ratios, temperature, and curing conditions, which can add complexity to manufacturing processes.Recycling Challenges: While polyurethane can be recycled, it can present challenges due to the variety of formulations and the difficulty in separating different types of polyurethane products.GeneralizeThis article introduces polyurethane, explains its definition, and discusses its properties and applications. In addition to this, we've picked out some frequently asked questions to answer, so if you'd like to find out more about polyurethanes, get in touch with our team.Through the introduction and description of polyurethane, we hope you have gained a deeper understanding of this fascinating material.Ruitai is a prototype parts manufacturer offering a wide range of manufacturing services for all your prototyping and production needs. You can contact us anytime for a free quote.DisclaimerThe content provided in this article is for reference only, and Ruitai Mould makes no representations or warranties, express or implied, as to the completeness, accuracy, or validity of the information. An action figure is a doll-like toy designed to resemble characters from movies or literature. The figures can be articulated to hold a variety of poses and may come equipped with accessories, such as clothing, tools, weapons, and vehicles. Air Freshener An air freshener is a product designed to mask or remove unpleasant room odors. These products typically deliver fragrance and other counteractants into the air. Angioplasty Balloon An angioplasty balloon is a medical device that is inserted into a clogged artery and inflated to clear blockage and allow blood to flow. The full medical name for the angioplasty procedure is percutaneous transluminal coronary angioplasty. Artificial Heart A natural heart has two pumps, each with two chambers. The right atrium pumps oxygen-depleted blood from the body into the right ventricle, which pumps it to the lungs. Artificial Heart Valve A heart valve acts as a check valve, opening and closing to control blood flow. This cycle occurs about 40 million times per year for each of the four valves in the human heart. Baby Carrier Family members have carried babies in a variety of carriers since the beginning of human civilization. Baby carriers keep the baby close and provide the infant with comfort and security while allowing the carrier some freedom to work and care for other members of the family. Baby Wipes Baby wipes are disposable cloths used to cleanse the sensitive skin of infants. These cloths are made from non-woven fabrics similar to those used in dryer sheets and are saturated with a solution of gentle cleansing ingredients. Backhoe The backhoe is one of the most commonly seen pieces of construction equipment due to its adaptability. Its cousin, the front-end loader, is also a popular piece of equipment that has a broad bucket like the one on the front of the backhoe for hauling soil, debris, and materials, and lifting them up into trucks. Bagpipes The bagpipe is a wind instrument with a number of pipes and a bag. The melody pipe, or chanter, has eight finger holes that are played to produce the tune. Baking Powder Baking powder is a solid mixture that is used as a chemical leavening agent in baked goods. It can be composed of a number of materials, but most commonly contains baking soda (sodium bicarbonate, NaHCO3), cream of tartar (potassium bitartrate, C4H5KO6), and cornstarch. Basketball Basketball was a new game to many who saw a man claim to be playing the only sport that is an American invention. From high school to the professional level, basketball attracts a large following for live games as well as television coverage of events like the National Collegiate Athletic Association (NCAA) annual tournament and the National Basketball Association (NBA) and Women's National Basketball Association (WNBA) playoffs. Boomerang A boomerang is an aerodynamically shaped object designed to fly efficiently through the air when thrown by hand. The term usually refers to an object made to follow a circular flight path that returns it to the thrower. Boxing Gloves Fist fighting has existed as a form of entertainment since the early days of human civilization. Some form of the sport appeared as long as 6,000 years ago in present-day Ethiopia. Brass Brass is a metal composed primarily of copper and zinc. Copper is the main component, and brass is usually classified as a copper alloy. Breath Mint Aromatic herbs have been used throughout history in a number of ways; fragrant soaps, pomanders, bath-water fresheners, potpourri, sachets, incense, scented candles, and natural herbs to sweeten sour breath are common in many cultures and eras, and the mint family has an especially excellent reputation for keeping pests away from people and other plants. Broom Brooms have been used for centuries to sweep up dirt, in and around the home and workplace. They may be made from a variety of materials, both man-made and natural. Canal and Lock A canal is a man-made waterway. Canals are built for a variety of uses including irrigation, land drainage, urban water supply, hydroelectric power generation, and transportation of cargo and people. Candy Corn Candy corn are the small pieces of triangular candy made primarily from corn syrup, honey and sugar (it is usually fat-free) and is traditionally colored in a specific pattern of three stripes. It is recognized by the white tip, orange in the center, and yellow at the widest end. Caramel Caramel is often eaten as a little brown, sweet, buttery nuggets wrapped in cello-phane, but it is also delicious in candy bars and on top of fresh popcorn. The best caramels are sweet and just a bit chewy. Cherries Cherries may be either deliciously sweet and deep brown-red, or quite tart and bright red. The two most common are the sweet cherry, Prunus avium L., and the sour (often referred to by growers as the pie or tart) cherry Prunus cerasus L.. Chess Chess is a classic two person board game. It is played with specially designed pieces on a square board made up of 64 alternating light and dark squares arranged in eight rows and columns. Clothes Iron A clothes iron is a household appliance used to press the wrinkles out of fabrics. When the iron is turned on, the consumer moves it over an item of clothing on an ironing board. Cognac Cognac, a type of brandy, is considered to be one of the finest, if not the finest, of the spirits. It is made from white grapes grown in the Charente region of France, and is named after the town of Cognac in the French region of Charente. Coconut What is commonly called a coconut, as found in grocery stores, is actually only the single seed of a fruit of the coconut palm tree (Cocos nucifera). Before being shipped to market, the seed is stripped of an external leathery skin and a 2-3 in (5-8 cm) thick intermediate layer of fibrous pulp. Comic Book A comic book portrays a story through a series of sequential illustrations that incorporate short bits of text containing dialogue, sounds, or narratives. The story may be humorous, or it may present a world of adventure, mystery, or fantasy. Corkscrew Uncorking a bottle of wine presents a challenge. There is no way to grip the cork, which is completely recessed in the bottle's neck. Cotton Cotton is a shrubby plant that is a member of the Mallow family. Its name refers to the cream-colored fluffy fibers surrounding small cottonseeds called a boll. Cuckoo Clock The cuckoo clock is a favorite souvenir of travelers in Germany, Austria, and Switzerland, and particularly the Black Forest region of Germany. The clock is prized for its features. Dishwasher Washing dishes is not the most rewarding task. Cooking can be creative, but cleaning up afterward seems like a waste of time and leaves the person washing complaining about "dishpan hands." The development of the dishwasher has helped relieve some of the monotony, as well as the grease and grime. DNA Synthesis Deoxyribonucleic acid (DNA) synthesis is a process by which copies of nucleic acid strands are made. In nature, DNA synthesis takes place in cells by a mechanism known as DNA replication. Draw Bridge A bridge over a navigable waterway must allow boats and ships to cross its path, usually by being tall enough to allow them to pass underneath. Sometimes it is impractical to build a bridge high enough; for example, it may rise too steeply or block the view of an important landmark. Duct Tape Duct tape is a cloth tape coated with a poly-ethylene resin on one side and very sticky rubber-based adhesive on the other. Unlike other tapes, the fabric backing gives duct tape strength yet allows it to be easily torn. Electric Blanket An electric blanket is a bed covering with a built-in heating element so it can be used to warm a bed. Electric blankets became much more popular than the heated pads that preceded them. Electronic Ink Electronic ink is a special type of ink that can display different colors when exposed to an electric field. It is made through a two step process that involves creating two-toned charged particles and encapsulating them in a transparent polymeric shell. Evaporated and Condensed Milk Evaporated and condensed milk are two types of concentrated milk in which the water is one-half or less of its original bulk by evaporation under high pressures and temperatures, without the addition of sugar, and usually contains a specified amount of milk fat and solids. Faucet A faucet is a device for delivering water from a plumbing system. It can consist of the following components: spout, handle(s), lift rod, cartridge, aerator, mixing chamber, and water inlets. Ferris Wheel A ferris wheel is an amusement park ride consisting of a large vertical wheel with places for people to sit or stand spaced evenly around the outer circumference. In operation, the ferris wheel revolves about a horizontal axis, and the riders are alternately lifted and then lowered as they go round. Flashlight A flashlight is a portable, battery-operated device used for illumination. A typical unit consists of a bulb (or LED) and a reflector mounted in a case; in many ways, it is a small portable version of a searchlight. Footbag Footbags are small bags filled with pellets, and also known as Hacky Sacks—the brand name for certain footbags—they are a little bigger than a golf ball, a few inches in diameter and an ounce or so in weight. Geodesic Dome A geodesic sphere is an arrangement of polygons that approximates a true sphere. A geodesic dome is a portion of a geodesic sphere. Gyroscope The gyroscope is a familiar toy that is deceptively simple in appearance and introduces children to several mechanical principles, although they may not realize it. Something like a complex top made of precisely machined metal, the gyroscope is a spinning wheel that may be set within two or more circular frames, each oriented along a different line or axis. Halogen Lamp A halogen lamp is a type of incandescent lamp. The conventional incandescent lamp contains a tungsten filament sealed within a glass envelope that is either evacuated or filled with an inert gas or a mixture of these gases (typically nitrogen, argon and krypton). Hard Hat An industrial hard hat is a helmet worn to protect the head of a worker from falls or from impacts by sharp or blunt objects. Typical users include construction laborers, repairmen, and warehouse workers. Harpsichord The harpsichord is the distinguished, classical ancestor of the piano. Its shape, derived from the lyre, is like that of a grand piano. Hockey Puck Hockey pucks are black, disk-shaped objects made of vulcanized rubber. Regulation National Hockey League (NHL) pucks are black, 3 in (7.6 cm) in diameter, 1 in (2.54 cm) thick, and weighing 5.5-6 oz (154-168 g). Horseshoe Horseshoes protect a horse's hooves from wear and tear and are also used to improve a horse's gait, to help with the stance (how the horse stands), and to control interference problems (when hooves or legs collide with each other). Hula Hoop The late 1950s saw one of biggest fads documented by sociologists, the Hula Hoop. Like many fads, the hoop is deceptively simple. Ice Cream Cone Today, the ice cream cone is a standard in any ice cream store or parlor. This tasty treat is known as a way to cool down in the summer and makes an edible container for a cold snack. Indigo Indigo, or indigotin, is a dyestuff originally extracted from the varieties of the indigo and woad plants. Indigo was known throughout the ancient world for its ability to color fabrics a deep blue. Industrial Hemp Hemp is a distinct variety of the plant species Cannabis sativa L. that can grow to a height anywhere from 4-15 ft (1.2-4.5 m) and up to 0.75 in (2 cm) in diameter. Jawbreaker The jawbreaker is a type of hard, round candy that is usually quite large and is extremely difficult to bite down on that it must be sucked. Jawbreakers range from the size of a hazel nut to about the size of a golf ball. They can be made in many flavors and colors. Kaleidoscope The kaleidoscope makes magic with light and mirrors. It may be considered a child's toy (a toy for all ages), but it is also a simple optical device with technical applications for designers and pattern-makers. Litmus Paper Litmus paper is the most recognized member of chemical indicators. Like most pH paper, litmus changes color when exposed to an acidic or basic solution. Lollipop Lollipops, or suckers as some call them, are essentially hard candies with a short stick of some sort. The tightly wrapped white paper stick serves as a handle, and the hard candy lollipop is either sucked or bitten apart until consumed. Matryoshka Doll The matryoshka doll is a symbol of Russia and its culture. It is truly a doll—a child's plaything—but it began its history just over 100 years ago as a highly collectible art form. Mayonnaise Mayonnaise is a cold, emulsified sauce used as a sauce or as a condiment. It may be blending egg yolks and oil, then flavored with varying combinations of vinegar, mustard, herbs and spices. Mouthwash Mouthwash is a liquid oral product designed to freshen the breath. Certain varieties may also kill bacteria and whiten teeth. Natural Gas Natural gas is a mixture of combustible gases formed underground by the decomposition of organic materials in plants and animal. It is usually found near petroleum underground, and is pumped from wells. Needle-free Injection System Needle-free injection systems are novel ways to introduce various medicines into patients without piercing the skin with a conventional needle. They can take the form of power sprays, edible products, inhalers, and skin patches. Paintball Paintball is a game developed in the 1980s that soon became popular worldwide. Players shoot pellets of paint from airguns at opposing players in a strategic game similar to the children's classic Capture the Flag. Patent Leather Patent leather is leather that has been finished with chemicals that give it a shiny, reflective surface. It is usually black, and has long been popular for dress and dancing shoes. Pillow Americans usually have two or three pillows on their bed. Today, pillows are stuffed primarily with materials such as polyester (a synthetic), feathers, down, or a combination of the latter two. Pinball Pinball is a popular coin-operated game frequently found in amusement arcades. Players shoot metal balls through complicated paths and into targets on a playing field under glass. Polyurethane Polyurethanes are linear polymers that have a molecular backbone containing carbamate groups (-NHCO2). Pool Table In pool (the common American term for pocket billiards), a ball is struck with the end of a long, slender stick (cue), causing it to roll into other balls and knock them into holes (pockets) around the edges of the playing table. A short wall (rail) around the perimeter of the table keeps the balls on the playing surface. Popsicle The sound of an ice cream truck is a delight to the ears of children and adults alike on a hot summer day. That truck carries delicious concoctions that the industry calls "frozen novelties." And it is guaranteed to carry a variety of frozen pops—ices, sherbets, pops in push tubes, and pops on sticks—in fruit flavors and colorful shapes that appeal to kids. Raincoat Raincoats are jackets made of fabric that is specially treated to repel water. In 1836, Charles Macintosh invented a method for combining rubber with fabric, which was used in the first modern raincoats. Roller Coaster A roller coaster is an amusement park ride where passengers sit in a series of wheeled cars that are linked together. The cars move along a pair of rails supported by a wood or steel structure. Rubber Cement Rubber cement is a solution of unvulcanized (gum) rubber in a solvent, and is used as an adhesive. Ideally, it is meant to join two pieces of rubber together, which involves a chemical cohesion process. Sailboat For people who like to sail, there are many options. The water sailboat is a means of skimming over its surface. Even when the water is frozen, iceboats (sailboats with runners or blades on the hull) can glide across the ice. Salad Dressing Salad dressing is a type of sauce used to bind and flavor greens and/or vegetables. Saxophone A saxophone is a single reed, woodwind instrument first developed in the mid-1800s by Adolphe Sax. It is comprised of a mouthpiece, conical metal tube, and finger keys. Seedless Fruits and Vegetables The fruits that are grown, sold, and eaten are essentially the ripened ovary of a plant. In the wild, fruit-bearing plants spread their seeds either by dropping their ripe fruits to the ground or by being eaten by animals, who then excrete the seeds. Semiconductor Laser A laser, which is an acronym for Light Amplification by Stimulated Emission of Radiation, is a device that converts energy into light. Electrical or optical energy is used to excite atoms or molecules, which then emit light. Shoelace It is understood how important shoes are for protecting feet from hazards and weather, and shoe designers are constantly trying to maximize protection and comfort for the shoe's wearer. The shoelace is one way to ensure the proper fit, and a simple pair of laces, costing less than two dollars, can make all the difference in the world to the look and fit of a shoe. Shortbread Shortbread is a traditional Scottish baked good with a relatively simple recipe that consists of three basic ingredients (flour, butter, and sugar). Like most baked goods, it is produced in the steps consisting of ingredient mixing, product forming, and baking. Silicon Second only to oxygen, silicon is the most abundant element in Earth's crust. It is found in rocks, sand, clays and soils, combined with either oxygen as silicon dioxide, or with oxygen and other elements as silicates. Skateboard A skateboard is a small piece of wood in the shape of a surfboard with four wheels attached to it. A single person rides the skateboard, guiding the movement with his feet. Skyscraper There is no precise definition of how many stories or what height makes a building a skyscraper. "I don't think it is how many floors you have. Slime Slime is a unique play material composed of a cross-linked polymer. It is classified as a liquid and is typically made by combining polyvinyl alcohol solutions with borate ions in a large mixing container. Snowshoe Snowshoes allow people to walk across the top of deep snow. They distribute weight so that the walker does not sink into soft drifts, and enable people to roam through landscapes that are usually impassable with only ordinary footwear. Sodium Chlorite Sodium chlorite is a compound used for water disinfection and purification. It is produced in large quantities as flakes or a solution from chlorine dioxide and sodium hydroxide. Solid State Laser A laser, which is an acronym for Light Amplification by Stimulated Emission of Radiation, is a device that converts electrical or optical energy into light. Electrical or optical energy is used to excite atoms or molecules, which then emit light. Spam Spam is a brand name for a canned meat product made from ham, pork, salt, flavorings, and preservatives that are mixed and cooked under vacuum pressure. There are other brands of similar canned pork meat products, but Spam—made by Hormel Foods Corporation—is the original and the best-selling of the brands. Springs A spring is a device that changes its shape in response to an external force, returning to its original shape when the force is removed. The energy expended in deforming the spring is stored in it and can be recovered when the spring returns to its original shape. Steel Wool Steel wool is the name given to fine metal wire that are bundled together to form a cluster of abrasive, sharp-edged metal fibers that may be pressed together in a sheet, folded, and turned into pads that are easily held in the hand. Storm Shelter More than half of the United States lie in a broad strip between the Appalachian and Rocky Mountains that is commonly called Tornado Alley. It has more tornado activity than any other area of the world. Teeth Whitener Teeth whiteners are products designed to enhance the appearance of teeth by removing stains and improving brightness. Those whiteners typically contain bleaching agents, such as hydrogen peroxide or other peroxygen-type chemicals, that remove organic residue and oxidize stains on the surface of the teeth. Thompson Submachine Gun A machine gun is a weapon that fires a continuous stream of bullets as long as the trigger is held down. Many inventors worked to come up with such a gun, and early models are the well-known Gatling gun, used prominently in the American Civil War, and Hiram Maxim's fully automatic weapon, patented in 1883. Toilet Paper Most of us can't imagine living without toilet paper. The average American uses over 100 single rolls—about 21,000 sheets—each year. Toy Model Kit Scale models or model kits are produced by the millions and give hours of pleasure to hobbyists. They're sold in specialized hobby and craft stores as well as toy, department, and drug stores—even supermarkets may carry them. Trophy Trophies are a category of awards given primarily for academic, work, and sport contests or events. They are physical objects that one person or group has bested another in some contest. Tunnel A tunnel is an underground or underwater passage that is primarily horizontal. Relatively small-diameter ones carry utility lines or function as pipelines. Ukulele The ukulele is a stringed instrument that originated in Portugal in the second century B.C. With a small, guitar-shaped body that is fitted with four strings, it is considered a member of the chordophone family. Vacuum Cleaner The vacuum cleaner is the appliance that frightens the cat, is chased by the dog, and, perhaps, gives a home the most immediate appearance of being clean. Imagining a home without a vacuum cleaner is next to impossible; yet, like many time and effort-saving devices, its widespread use is less than a century old. Vermiculite The term vermiculite applies to a group of minerals characterized by their ability to expand into long, worm-like threads when heated. This expansion process is called exfoliation. Water Gun Pump-action water guns are a relatively recent addition to the water gun arsenal. Plastic squirt guns have long been a staple summer-time toy of American children. Wood Stain Wood pieces are often decorated to add color and appeal. Wood products are often imparted with a wood-tone stain to enhance the natural grain or add depth or tone to the wood.

Wrapping Paper There are many kinds of wrapping papers manufactured specifically for the types of products they are intended to wrap. For example, wrapping paper is made for bread for sanitary and aesthetic purposes. Xylophone The xylophone is a component of the percussion section of an orchestra and many instrumental groups. Its unique sound, relative rarity, and appearance make it fascinating to the listener. Polyurethanes are linear polymers that have a molecular backbone containing carbamate groups ($-NHCO_2$). These groups, called urethane, are produced through a chemical reaction between a diisocyanate and a polyol. First developed in late 1930s, polyurethanes are some of the most versatile polymers. They are used in building insulation, surface coatings, adhesives, solid plastics, and athletic apparel. Background Polyurethanes, also known as polycarbamates, belong to a larger class of compounds called polymers. Polymers are macromolecules made up of smaller, repeating units known as monomers. Generally, they consist of a primary long-chain backbone molecule with attached side groups. Polyurethanes are characterized by carbamate groups ($-NHCO_2$) in their molecular backbone. Synthetic polymers, like polyurethane, are produced by reacting monomers in a reaction vessel. In order to produce polyurethane, a step—also known as condensation—reaction is performed. In this type of chemical reaction, the monomers that are present contain reacting end groups. Specifically, a diisocyanate (OCN-R-NCO) is reacted with a diol (HO-R-OH). The first step of this reaction results in the chemical linking of the two molecules leaving a reactive alcohol (OH) on one side and a reactive isocyanate (NCO) on the other. These groups react further with other monomers to form a larger, longer molecule. This is a rapid process which yields high molecular weight materials even at room temperature. Polyurethanes that have important commercial uses typically contain other functional groups in the molecule including esters, ethers, amides, or urea groups. History Polyurethane chemistry was first studied by the German chemist, Friedrich Bayer in 1937. He produced early prototypes by reacting toluene diisocyanate reacted with dihydric alcohols. From this work one of the first crystalline polyurethane fibers, Perlon U, was developed. The development of elastic polyurethanes began as a program to find a replacement for rubber during the days of World War II. In 1940, the first polyurethane elastomers were produced. These compounds gave millable gums that could be used as an adequate alternative to rubber. When scientists found that polyurethanes could be made into fine threads, they were combined with nylon to make more lightweight, stretchable garments. In 1953, the first commercial production of a flexible polyurethane foam was begun in the United States. This material was useful for foam insulation. In 1956, more flexible, less expensive foams were introduced. During the late 1950s, moldable polyurethanes were produced. Over the years, improved polyurethane polymers have been developed including Spandex fibers, polyurethane coatings, and thermoplastic elastomers. Raw Materials A variety of raw materials are used to produce polyurethanes. These include monomers, prepolymers, stabilizers which protect the integrity of the polymer, and colorants. Isocyanates One of the key reactive materials required to produce polyurethanes are diisocyanates. These compounds are characterized by a (NCO) group, which are highly reactive alcohols. The most widely used isocyanates employed in polyurethane production are toluene diisocyanate (TDI) and polymeric isocyanate (PMDI). TDI is produced by chemically adding nitrogen groups on toluene, reacting these with hydrogen to produce a diamine, and separating the undesired isomers. PMDI is derived by a phosgenation reaction of aniline-formaldehyde polyamines. In addition to these isocyanates, higher end materials are also available. These include materials like 1,5-naphthalene diisocyanate and bitolylene diisocyanate. These more expensive materials can provide higher melting, harder segments in polyurethane elastomers. Polyols The other reacting species required to produce polyurethanes are compounds that contain multiple alcohol groups (OH), called polyols. Materials often used for this purpose are polyether polyols, which are polymers formed from cyclic ethers. They are typically produced through an alkylene oxide polymerization process. They are high molecular weight polymers that have a wide range of viscosity. Various polyether polyols that are used include polyethylene glycol, polypropylene glycol, and polytetramethylene glycol. These materials are generally utilized when the desired polyurethane is going to be used to make flexible foams or thermoset elastomers. Polyester polyols may also be used as a reacting species in the production of polyurethanes. They can be obtained as a byproduct of terephthalic acid production. They are typically based on saturated aromatic carboxylic acids and diols. Branched polyester polyols are used for polyurethane foams and coatings. Polyester polyols were the most used reacting species for the production of polyurethanes. However, polyether polyols became significantly less expense and have supplanted polyester polyols. Additives Some polyurethane materials can be vulnerable to damage from heat, light, atmospheric contaminants, and chlorine. For this reason, stabilizers are added to protect the polymer. One type of stabilizer that protects against light degradation is a UV screener called hydroxybenzotriazole. To protect against oxidation reactions, antioxidants are used. Various antioxidants are available such as monomeric and polymeric hindered phenols. Compounds which inhibit discoloration caused by atmospheric pollutants may also be added. These are typically materials with tertiary amine functionality that can interact with the oxides of nitrogen in air pollution. For certain applications, antimildew additives are added to the polyurethane product. After the polymers are formed and removed from the reaction vessels, they are naturally white. Therefore, colorants may be added to change their aesthetic appearance. Common covalent compounds for polyurethane fibers are dispersed and acid dyes. Design Polyurethanes can be produced in four different forms including elastomers, coatings, flexible foams, and cross-linked foams. Elastomers are materials that can be stretched but will eventually return to their original shape. They are useful in applications that require strength, flexibility, abrasion resistance, and shock absorbing qualities. Thermoplastic polyurethane elastomers can be molded and shaped into different parts. This makes them useful as base materials for automobile parts, ski boots, roller skate wheels, cable jackets, and other mechanical goods. When these elastomers are spun into fibers they produce a flexible material called spandex. Spandex is used to make sock tops, bras, support hose, swimsuits, and other athletic apparel. Polyurethane coatings show a resistance to solvent degradation and have good impact resistance. These coatings are used on surfaces that require abrasion resistance, flexibility, fast curing, adhesion, and chemical resistance such as bowling alleys and dance floors. Water based polyurethane coatings are used for painting aircraft, automobiles, and other industrial equipment. Flexible foams are the largest market for polyurethanes. These materials have high impact strength and are used for making most furniture cushioning. They also provide the material for mattresses and seat cushions in higher priced furniture. Semiflexible A diagram depicting the manufacturing processes used to create rigid polyurethane foam insulation. polyurethane foams are used to make car dashboard and door liners. Other uses include carpet underlay, packaging, sponges, squeegees, and interior padding. Rigid, or cross-linked, polyurethane foams are used to produce insulation in the form of boards or laminate. Laminates are used extensively in the commercial roofing industry. Buildings are often sprayed with a polyurethane foam. The Manufacturing Process While polyurethane polymers are used for a vast array of applications, their production method can be broken into three distinct phases. First, the bulk polymer product is made. Next, the polymer is exposed to various processing steps. Finally, the polymer is transformed into its final product and shipped. This production process can be illustrated by looking at the continuous production of polyurethane foams. Polymer reactions 1 At the start of polyurethane foam production, the reacting raw materials are held as liquids in large, stainless steel tanks. These tanks are equipped with agitators to keep the materials fluid. A metering device is attached to the tanks so that the appropriate amount of reactive material can be pumped out. A typical ratio of polyol to diisocyanate is 1:2. Since the ratio of the component materials produces polymers with varying characteristics, it is strictly controlled. 2 The reacting materials are passed through a heat exchanger as they are pumped into pipes. The exchanger adjusts the temperature to the reactive level. Inside the pipes, the polymerization reaction occurs. By the time the polymerizing liquid gets to the end of the pipe, the polyurethane is already formed. On one end of the pipe is a dispensing head for the polymer. Processing 3 The dispensing head is hooked up to the processing line. For the production of rigid polyurethane foam insulation, a roll of baking paper is spooled at the start of the processing line. This paper is moved along a conveyor and brought under the dispensing head. 4 As the paper passes under, polyurethane is blown onto it. As the polymer is dispensed, it is mixed with carbon dioxide which causes it to expand. It continues to rise as it moves along the conveyor. (The sheet of polyurethane is known as a bun because it "rises" like dough.) 5 After the expansion reaction begins, a second top layer of paper is rolled on. Additionally, side papers may also be rolled into the process. Each layer of paper contains the polyurethane foam giving it shape. The rigid foam is passed through a series of panels that control the width and height of the foam bun. As they travel through this section of the production line, they are typically dried. 6 At the end of the production line, the foam insulation is cut with an automatic saw to the desired length. The foam bun is then conveyored to the final processing steps that include packaging, stacking, and shipping. Quality Control To ensure the quality of the polyurethane material, producers monitor the product during all phases of production. These inspections begin with an evaluation of the incoming raw materials by quality control chemists. They test various chemical and physical characteristics using established methods. Some of characteristics that are tested include the pH, specific gravity, and viscosity or thickness. Additionally, appearance, color, and odor may also be examined. Manufacturers have found that only by strictly controlling the quality at the start of production can they ensure that a consistent finished product will be achieved. After production, the polyurethane product is tested. Polyurethane coating products are evaluated in the same way the initial raw materials are checked. Also, characteristics like dry time, film thickness, and hardness are tested. Polyurethane fibers are tested for things such as elasticity, resilience, and absorbency. Polyurethane foams are checked to ensure they have the proper density, resistance, and flexibility. The Future The quality of polyurethanes has steadily improved since they were first developed. Research in a variety of areas should continue to help make superior materials. For example, scientists have found that by changing the starting prepolymers they can develop polyurethane fibers which have even better stretching characteristics. Other characteristics can be modified by incorporating different fillers, using better catalysts, and modifying the prepolymer ratios. In addition to the polymers themselves, the future will likely bring improvements in the production process resulting in faster, less expensive, and more environmentally friendly polyurethanes. A recent trend in polyurethane production is the replacement of toluene diisocyanates with less-volatile polymeric isocyanates. Also, manufacturers have tried to eliminate chlorinated fluorocarbon blowing agents which are often used in the production of polyurethane foams. Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley & Sons, 1997. Oertel, G. Polyurethane Handbook. Second ed. Munich: Carl Hanser Publishers, 1993. Seymour, Raymond, and Charles Carraher. Polymer Chemistry. New York: Marcel Dekker,1992. Ulrich, H. The Chemistry and Technology of Isocyanates. New York: John Wiley & Sons, 1996. Polyurethane, often abbreviated to PU or PUR, is an organic polymer that features many organic units linked via urethane molecules. Most polyurethanes do not melt upon heating and can, therefore, be classified as thermosetting polymers. However, it can be noted that some specific types of polyurethanes exhibit thermoplastic properties and can be melted and remoulded via the application of heat. Traditional methods of preparing polyurethanes involve chemical reactions between polyols and di- or tri-isocyanates. Polyurethanes can be regarded as alternating copolymers since they feature two kinds of monomers that undergo polymerization one after the other. It can also be noted that both the polyols and the isocyanates that are used as monomers for the production of polyurethanes usually contain at least 2 functional groups in every molecule. Preparation of Polyurethane Polyurethanes, along with phenolics, epoxies, and unsaturated polyesters, can be classified as reaction polymers. They can be prepared via the chemical reactions between diisocyanates (that contain at least two isocyanate groups per molecule) and polyols (that contain at least two hydroxyl groups per molecule). These reactions usually require the presence of a catalyst or some ultraviolet light in order to overcome the activation energy barrier. Polyols, by themselves, can also be considered polymers. For example, polyether polyols can be prepared by subjecting propylene oxide and ethylene oxide to copolymerization along with an appropriate polyol precursor. It can also be noted that the preparation of polyester polyols is quite similar to that of polyether polyols. However, for the production of polyurethanes, the chain length of the polyol and the functionality of the polyol must be controlled. These factors are known to contribute to the properties of the final polyurethane products. For example, the polyols whose molecular weights lie in the hundreds yield rigid polyurethanes whereas the polyols whose molecular weights lie in the thousands yield relatively flexible polyurethanes. Thus, the chain length of the polyol used can be considered a factor that contributes to the flexibility of the polyurethane product. Properties of Polyurethane The properties of polyurethanes are highly dependent on the manner in which they are produced. For example, if the polyol chain (which is used as a raw material for the preparation of the polyurethane) is long and flexible, the final product will be soft and elastic. On the other hand, if the extent of cross-linking is very high, the final polyurethane product will be tough and rigid. The cross-linked structure of polyurethanes generally consists of three-dimensional networks which attribute very high molecular weights to the polymer. This structure also accounts for the thermosetting nature of the polymer, since polyurethane typically does not soften or melt when exposed to heat. Advantages of Polyurethanes Polyurethanes have the ability to be made into foams (which is one of their most desirable properties). This is done by facilitating the production of a gas (usually carbon dioxide) during the urethane polymerization process. Another advantage of polyurethane is that high-density microcellular foams of the polymer can be produced without any blowing agents. Applications of Polyurethane Some important applications of polyurethane are listed below. The primary application of polyurethane is in the production of foams. These foams are used in a variety of materials such as upholstery fabrics, domestic furniture, and refrigerator sheets. Polyurethane is also used in some garments. Polyurethane mouldings are also used in columns and door frames. In fact, it is not uncommon for such mouldings to be employed in window headers and balusters. The low-density foams of polyurethane which exhibit flexibility are widely used in mattresses and other forms of bedding. They are also used in automobile seats and upholstery. Flexible polyurethane is also used in the manufacture of partially elastic straps and bands. The low-density elastomers of polyurethane are widely used in the footwear industry. Another notable application of polyurethane is in the manufacture of bathroom and kitchen sponges. It is also used in seat cushions and couches. Thermoplastic polyurethane, often abbreviated TPU, is a class of polyurethane which are made up of thermoplastic elastomers. Their structures usually feature linearly segmented block copolymers that are made up of soft and hard segments. The desirable properties of thermoplastic polyurethanes include elasticity, resistance to oil, resistance to grease, transparency, and resistance to abrasion. TPUs are widely used in power tools, medical devices, sporting goods, footwear, caster wheels, and inflatable rafts. Another notable application of thermoplastic polyurethane is in cable and wire jacketing. Flexible polyurethane foam is widely used as padding in a wide range of consumer and industrial items including bedding, underlay carpets, vehicle interiors, chairs, and packaging. This type of polyurethane foam can be produced in virtually any shape and firmness. It is known to be lightweight, comfortable, and durable. Rigid polyurethane foams are used in highly energy-efficient and flexible insulations. These foams are known to significantly reduce energy costs in residential and commercial properties. Polyurethanes are prepared by reacting polyols (alcohols with more than two reactive hydroxyl groups in each molecule) with diisocyanates or polymeric isocyanates. Suitable catalysts and additives are used wherever necessary. Since a variety of diisocyanates and a wide range of polyols can be used for the production of polyurethane, a wide spectrum of polyurethane materials can be produced to meet the requirements for specific applications. It can also be noted that polyurethanes can exist in a variety of forms including rigid foams, flexible foams, speciality adhesives, chemical-resistant coatings, sealants, and elastomers. 