Safety Assessment of Polyurethanes as Used in Cosmetics

Status: Final Report
Release Date: October 13, 2017
Panel Meeting Date: September 11-12, 2017

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ABSTRACT

The Cosmetic Ingredient Review (CIR) Expert Panel (Panel) assessed the safety of 66 polyurethane ingredients as used in cosmetics. The functions of these ingredients include artificial nail builders, binders, and surface modifiers. The Panel reviewed available data related to these ingredients and determined that there would be no detectable residual isocyanate or other monomers in these ingredients. The Panel concluded that these polyurethanes are safe in the practices of use and concentration of this safety assessment.

INTRODUCTION

This is a safety assessment of polyurethane ingredients as used in cosmetics. According to the *web-based International Cosmetic Ingredient Dictionary and Handbook* (wINCI *Dictionary*), the functions of these 66 ingredients include artificial nail builders, binders, film formers, hair fixatives, plasticizers, and surface modifiers (Table 1).[1] The ingredients in this group are:

Polyurethane-1	Polyurethane-25	Polyurethane-51
Polyurethane-2	Polyurethane-26	Polyurethane-52
Polyurethane-4	Polyurethane-27	Polyurethane-53
Polyurethane-5	Polyurethane-28	Polyurethane-54
Polyurethane-6	Polyurethane-29	Polyurethane-55
Polyurethane-7	Polyurethane-32	Polyurethane-56
Polyurethane-8	Polyurethane-33	Polyurethane-57
Polyurethane-9	Polyurethane-34	Polyurethane-58
Polyurethane-10	Polyurethane-35	Polyurethane-59
Polyurethane-11	Polyurethane-36	Polyurethane-60
Polyurethane-12	Polyurethane-39	Polyurethane-61
Polyurethane-13	Polyurethane-40	Polyurethane-62
Polyurethane-14	Polyurethane-41	Polyurethane-63
Polyurethane-15	Polyurethane-42	Polyurethane-64
Polyurethane-16	Polyurethane-43	Polyurethane-65
Polyurethane-17	Polyurethane-44	Polyurethane-66
Polyurethane-18	Polyurethane-45	Polyurethane-67
Polyurethane-19	Polyurethane-46	Polyurethane-68
Polyurethane-20	Polyurethane-47	Polyurethane-69
Polyurethane-21	Polyurethane-48	Polyurethane-70
Polyurethane-23	Polyurethane-49	Polyurethane-71
Polyurethane-24	Polyurethane-50	Polyurethane-72

These ingredients are copolymers containing carbamate (i.e., urethane) linkages. Some of these polyurethane ingredients, as defined, are dispersed in water (e.g., Polyurethane-17, -35, -36, -58, -60, -61, -70, -71, and -72).[1] Many of these polyurethanes are reported to be supplied to formulators in an emulsion or solution that may consist of several chemicals, creating complicated mixtures.

Polyurethane-type ingredients with 4 or more monomers, such as the ingredients in this report, are named "Polyurethane-x".[1]

Several precursors and moieties of these polymers have been reviewed by the CIR Panel.[2-26]

Table 2 lists the previously reviewed ingredients and connects them to the relevant polyurethanes in this report. Other chemicals, including cosmetic ingredients which have not been reviewed by the Panel but are precursors or moieties of the polyurethanes in this safety assessment are listed in Table 3. The diisocyanate monomers used in the manufacturing of polyurethanes are listed separately in Table 4. These polyurethane ingredients are copolymers, each of which is synthesized, in part, from isocyanate analogs.[27,28] Exposure to diisocyanates in the work place is one of the leading causes of occupational asthma and related issues; diisocyanates have also been associated with irritant and allergic contact dermatitis, as well as skin and conjunctival irritation. The Panel has reviewed hexamethylene diisocyanate (HDI) polymers, which are polymers (polyurethanes) also derived from isocyanates, and found that 17 of these ingredients are safe in cosmetics in the present practices of use and concentration, and that the available data are insufficient to make a determination that 2 HDI polymers are safe (Table 2; the full reports on these and all ingredients are available on the CIR website: http://www.cir-safety.org/ingredients).[29]

Data on polyurethanes that are not listed in the wINCI *Dictionary* as cosmetic ingredients have been included for potential supporting information (e.g., cosmetic use and inflammatory response).

This safety assessment includes relevant published and unpublished data that are available for each endpoint that is evaluated. Published data are identified by conducting an exhaustive search of the world's literature. A listing of the search engines and websites that are used and the sources that are typically explored, as well as the endpoints that CIR typically

evaluates, is provided on the CIR website (http://www.cir-safety.org/supplementaldoc/preliminary-search-engines-and-websites; http://www.cir-safety.org/supplementaldoc/cir-report-format-outline). Unpublished data are provided by the cosmetics industry, as well as by other interested parties.

CHEMISTRY

Definition and Structure

The structures, definitions, and functions of the polyurethane ingredients in this safety assessment are provided in Table 1. Some of the definitions may give insight into the method of manufacture. Several of these polyurethane ingredients, as defined, are the polymers dispersed in water (e.g., Polyurethane-17, -35, -36, -58, -60, -61, -70, -71, and -72).[1] Other polyurethanes may be supplied as dispersions (in water or other solvents), as indicated in ingredient specifications (e.g. Polyurethane-1, 14, -21, -28, -39 -42, and -69).[30-34]

The polyurethane ingredients in this report are copolymers containing carbamate (i.e., urethane) linkages. Polyurethanes are formed by reacting a polyol (e.g., a glycol) with a diisocyanate or a polyisocyanate. These polyurethane copolymers are a highly heterogeneous group of structures created from diverse diisocyanate, glycol, and carboxylic acid monomers. Representative structure motifs of three different urethane copolymers are depicted in Figure 1.

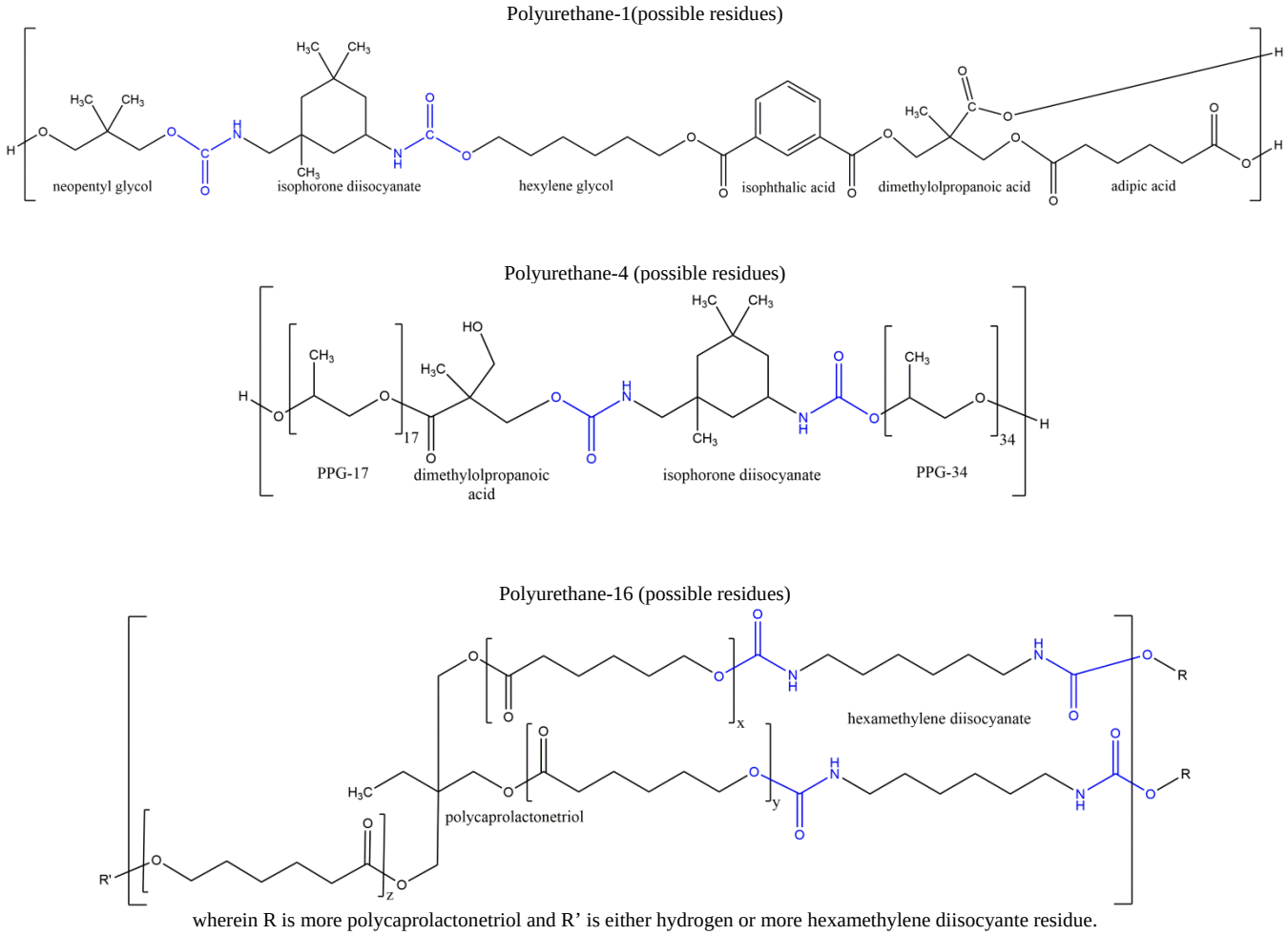


Figure 1. Examples of monomeric linkages in these urethane copolymers

Physical and Chemical Properties

Chemical and physical properties are provided in Table 5.

Some of the polyurethanes are linear polymers, but when multi-functional monomers (e.g., glycerin) are used as reactants, branched or cross-linked structures are probable. The degree of polymerization of these ingredients can be controlled to obtain a product having a desired functionality, such as rheology modifier. Accordingly, the molecular weights and molecular volumes of these ingredients could vary widely, unless otherwise noted in specifications. These polymers, by virtue of their monomers, contain both hydrophilic and hydrophobic groups. The ratio of hydrophilic and hydrophobic groups may vary within one ingredient name. Estimating some of the chemical and physical properties of these ingredients is

challenging in the absence of ingredient-explicit specifications. These ingredients potentially can range from liquid to solid and soluble to insoluble. Aside from the potential presence of a diisocyanate or end-capping agent residue, these ingredients are likely to be similar to unmodified polyurethane-type polymers.

Polyurethane-11

Polyurethane-11 is reported to have a mean molecular weight > 100,000 daltons (Da), with no fractions < 1000 Da.[35]

Polyurethane-14

Based on the monomer composition and general hydrophobic properties of Polyurethane-14, it is not expected to be significantly soluble in water.[33] It is not expected to undergo significant hydrolysis within a pH range of 4 to 9. Polyurethane-14 partitions primarily in the organic phase in octanol-water separation systems.

Polyurethane-21

Polyurethane-21 is stable at a pH range of 7 to 11, but is not stable below pH 7.[32]

Polyurthane-28

Polyurethane-28 is reported to have a mean molecular weight > 30,000 Da with no molecules < 1000 Da.[34] This ingredient is reported to be stable at 5 to 50°C for 3 years under storage conditions.

Polyurethane-35

Based on the high mean molecular weight (> 1000 Da) and predominantly hydrophobic structure, Polyurethane-35 is expected to have low solubility in water.[36] This polymer is stable under normal environmental conditions and will not degrade in cosmetic products at 5% to 15%.

Polyurethane-42

Polyurethane-42 is reported to have a mean molecular weight of > 36,000 with no molecules < 1000 Da.[34] This ingredient is reported to be stable at 5 to 50°C for 3 years under storage conditions.

Polyurethane-60

A supplier reported that Polyurethane-60 is supplied as an aqueous, low viscosity, anionic dispersion polycarbonate-polyurethane.[37] The mean molecular weight of Polyurethane-60 is > 50,000 Da.

Polyurethane-61

A supplier reported that Polyurethane-61 is supplied as an aqueous, low viscosity dispersion of an aliphatic polyester-polyurethane.[38] The mean molecular weight of Polyurethane-61 is > 50,000 Da.

Polyurethane-62

A supplier reported that the particle size of Polyurethane-62 was 50 to 1000 µm and the mean molecular weight is > 70,000 Da.[39] Polyurethane-62 is stable under normal environmental conditions and yields no degradation products under normal conditions of use. Another supplier reports that the average molecular weight of Polyurethane-62 is approximately 100,000 Da.[40]

Polyurethane-69

The average total molecular weight of Polyurethane-69 is > 3400 Da.[34] Low molecular weight fractions (< 1000 Da) were detected at 4%. Polyurethane-69 is stable for 16 weeks at 5, 25, and 50°C in normal storage conditions; there is no formation of high molecular weight crosslinked fractions and no depolymerization is detected.

Method of Manufacture

In general, polyurethanes are formed by reacting a polyol (e.g., a glycol) with a diisocyanate or polyisocyanate. Table 6 cites the methods of manufacture of individual polyurethanes.

Infrared spectroscopy is typically used to make sure the reaction is complete and that no diisocyanates are present.[35]

Impurities/Constituents

Table 7 cites the polyurethanes that are reported to commonly be supplied, in tradename mixtures, as suspensions or solutions. Such suspensions typically include water and cyclopentasiloxane. However, preservatives, such as methylisothiazolinone (MI), and neutralizing agents may also be included in the suspension.[33,34,36-38,41] The non-polyurethane components of these tradename mixtures are not impurities or constituents of the ingredients in this report. Thus, their safety is assessed elsewhere. In 2014, the Panel concluded that MI is safe for use in rinse-off cosmetic products at concentrations up to 100 ppm and safe in leave-on cosmetic products when they are formulated to be non-sensitizing, which may be determined based on a quantitative risk assessment (QRA).[42]

A supplier reports that Polyurethane-36, -60, and -61, which are supplied as dispersions in water, are reported to be

free from other solvents and isocyanate groups; residual isocyanates are expected to react with water in the dispersion and form polyureas.[37,38,41]

Polyurethane-11

Polyurethane-11 is reported to contain no residual isocyanates since free isocyanates react with water.[35]

Polyurethane-28, -42, and -69

Polyurethane-28, -42, and -69 are reported to contain no detectable residual isophorone diisocyanate (IPDI; a monomer used in their synthesis), as determined by high-performance liquid chromatography-mass spectrometry (HPLC-MS; detection limit 5 ppm).[34]

Polyurethane-59

Polyurethane-59 is reported to contain no detectable residual ethylene oxide (detection limit < 1 ppm), dioxane (< 10 ppm), formaldehyde (< 1 ppm), and HDI (< 20 ppm).[43]

Polyurethane-62

Polyurethane-62 is reported to contain no detectable residual unreacted isocyanate (HDI; a monomer used in their synthesis).[40]

Polyurethane-2, -17, -29, -33, -40, -60, and -61

4,4'-Diaminodiphenylmethane (MDA) is classified as a carcinogen and is used in the production of methylene diphenyldiisocyanate (MDI).[44] MDI, or an analog thereof (E.G., saturated methylene diphenyldiisocyanate (SMDI)), is a monomer component of some of the polyurethanes in this safety assessment (e.g., Polyurethane-2, -17, -29, -33, -40, -60, and -61).[1] In a study to determine the safety profile of MDI in consumer products, no residual MDA was detected in the resultant production of MDI.[44] Furthermore, any remaining MDA would be expected to be further reduced when MDI is polymerized in the manufacture of polyurethanes.

USE

Cosmetic

The safety of the cosmetic ingredients addressed in this assessment is evaluated based on data received from the United States (U.S.) Food and Drug Administration (FDA) and the cosmetics industry on the expected use of these ingredients in cosmetics. Use frequencies of individual ingredients in cosmetics are collected from manufacturers and reported by cosmetic product category in FDA's Voluntary Cosmetic Registration Program (VCRP) database. Use concentration data are submitted by the cosmetic industry in response to a survey, conducted by the Personal Care Products Council (Council), of maximum reported use concentrations by product category.

According to VCRP survey data received in 2017, Polyurethane-11 was reported to be used in 315 formulations, with 303 uses reported in leave-on formulations and 12 uses in rinse-off formulations (Table 8).[45] The additional ingredients with reported uses in the VCRP were each reported to have uses in 33 or fewer formulations.

The VCRP has an entry for "polyurethane" with 17 uses in a pattern similar to the polyurethanes in this safety assessment. It is unknown to what extent, if any, "polyurethane" is the same as or similar to, one or more of the polyurethane ingredients in this safety assessment. Since the composition of this ingredient is unknown, this ingredient will not be further addressed in this safety assessment.

The results of the concentration of use survey conducted by the Council in 2016 indicate that Polyurethane-1 has the highest reported maximum concentration of use; it is used at up to 15% in nail products.[46] The highest maximum concentration of use reported for products resulting in leave-on dermal exposure is 7.5% Polyurethane-33 in the category of other skin care preparations.

In some cases, uses were reported to the VCRP, but concentrations of use data were not provided. For example, Polyurethane-7 was reported to be used in 14 cosmetic formulations, but no use concentration data were reported. In other cases, no uses were reported to the VCRP, but concentration of use data were received from industry; for example, Polyurethane-10 had no reported uses in the VCRP, but use concentrations in the categories of mascara; tonics, dressings, and other hair grooming aids; and foundations were provided in the industry survey. Therefore, it should be presumed there is at least one use in every category for which a concentration is reported.

The ingredients not in use according to the VCRP and industry survey are listed in Table 9.

Polyurethane-1, -2, -10, -11, -14, -33, -34, -35, and -40 were reported to be used in products that are applied around the eye; the highest reported concentration of use was 7%, which was for Polyurethane-35 in mascara. Polyurethane-11, -15, and -34 were reported to be used in products that may be ingested and come in contact with mucous membranes; the highest reported concentration of use was 2.9%, which was for Polyurethane-34 in lipsticks.

Several of the polyurethanes are used in cosmetic sprays and could possibly be inhaled. Polyurethane-1, -6, -11, -14, -18, -24, -33, and -34 were reported to be used in spray products; the maximum reported concentration for a spray product was 6% Polyurethane-6 in pump hair sprays. In practice, 95% to 99% of the droplets/particles released from cosmetic sprays have aerodynamic equivalent diameters > 10 µm.[47-50] Therefore, most droplets/particles incidentally inhaled

from cosmetic sprays would be deposited in the nasopharyngeal and bronchial regions and would not be respirable (i.e., they would not enter the lungs) to any appreciable amount.[47,49] Polyurethane-2, -7, -11, and -15 were reported to be used in powders; the highest maximum reported concentration was at up to 3.2% Polyurethane-11. Conservative estimates of inhalation exposures to respirable particles during the use of loose-powder cosmetic products are 400-fold to 1000-fold less than protective regulatory and guidance limits for inert airborne respirable particles in the workplace.[51-53]

In Europe the amount of residual trialkylamines is limited to 2.5% in ready-for-use preparations in the category of leave-on products (which may be residuals in Polyurethane-17 and -21).[54,55] Also, trialkylamines are further limited in that they are not to be used with nitrosating systems, have a maximum secondary amine content of 0.5%, have a maximum nitrosamine content of 50 µg/kg, have a minimum purity of 99%, and must be kept in nitrite-free containers.

The National Industrial Chemical Notification and Assessment Scheme (NICNAS) of Australia determined that there is negligible concern to public health when Polyurethane-14 is used as a hair fixative agent in hair care products such as pump sprays and hair gel formulations at concentrations up to 6%.[33] NICNAS also determined that Polyurethane-35 and -62 were not considered to pose an unreasonable risk to the health of workers and the public.[36,39]

Polyurethane-11 is reported to be used to coat cosmetic glitter.[35]

Non-Cosmetic

In the U.S., polyurethanes may come in contact with food as direct and indirect food additives, and in single use and repeated use food containers. [21 CFR 174.5; 21 CFR 175.105; 21 CFR 176.170; 21 CFR 177.1210; 21 CFR 177.1390; 21 CFR 177.1395; 21 CRF 177.1680; 21 CFR 177.2600] Polyurethanes used in food packaging adhesives and polyurethane resins may not contain 4,4'-methylenebis (2-chloroanaline; or saturated methylene diphenyldiisocyanate (SMDI)). [21 CFR 189.280]

Polyurethanes may be used in ear, nose and throat medical devices, and in general and plastic surgery devices (e.g., silicone gel-filled breast prosthesis and occlusive wound dressing). [21 CFR 874.3695; 21 CFR 878.3540; 21 CFR 878.4020]

A supplier states that Polyurethane-36, -60, and -61 are not in compliance for use in food contact adhesives according to FDA regulations.[37,38,41]

The FDA stipulates that polyurethane resins that are used in adhesives that may come in contact with food must be produced by one of four methods. 1) Reacting diisocyanates with one or more of the listed polyols or polyesters (this is a large list and is not provided here; an abbreviated list of monomers and precursors are provided in Table 10). 2) Reacting the chloroformate derivatives of one or more of the listed polyols or polyesters with one or more of the polyamines listed in Table 10. 3) Reacting toluene diisocyanate or 4,4'-methylenebis(cyclohexylisocyanate), also called saturated methylene diphenyldiisocyanate (SMDI), with either one or more of the listed polyols or polyesters listed in Table 10 and with either *N*-methyldiethanolamine and dimethyl sulfate or dimethylolpropionic acid and triethylamine, or a fumaric acid-modified polypropylene glycol or fumaric acid-modified tripropylene glycol, triethylamine, and ethylenediamine. 4) Reacting *meta*-tetramethylxylene diisocyanate with one or more of the listed polyols and polyesters (not listed here; Table 10) and with dimethylolpropionic acid and triethylamine, *N*-methyldiethanolamine, 2-dimethylaminoethanol, 2-dimethylamino-2-methyl-1-propanol, and/or 2-amino-2-methyl-1-propanol. [21 CFR 175.105]

Polyurethane-36 is exempt from the Toxic Substances Control Act (TSCA) Inventory listing requirements under the provisions of the TSCA Polymer Exemption.[33] [40 CFR 723.250] The CFR citation is the exemption for polymers, so it is likely that many of the polymers in this report are exempt from TSCA.

Polyurethane foam or porous polyurethane films are used to make wound dressings.[56-58] Polyurethane prostheses are being developed for soft tissue scaffolds of blood vessels and tissues of the cardiovascular system; some of these are impregnated with drugs to control smooth muscle cell proliferation.[59] Polyurethanes are used to coat medical implants, including percutaneous leads, catheters, tubing, and intra-aortic balloons.[60,61] Polyurethane has been used as a coating on breast implants.[62]

Sprayed polyurethane foam is used for roofing material and other protective applications such as truck bed liners.[63]

TOXICOKINETIC STUDIES

Toxicokinetic studies were not found in the published literature and no unpublished data were submitted.

TOXICOLOGICAL STUDIES

Acute Dose Toxicity

Acute dermal toxicological studies were not found in the published literature and no unpublished data were submitted.

Oral

Polyurethane-1

The oral LD_{50} of Polyurethane-1 in rats was reported to be > 2000 mg/kg.[30] The test was conducted in accordance with the Organisation for Economic Co-operation and Development test guideline (OECD TG) 423 (Acute Oral toxicity).

Polyurethane-35

The oral LD_{50} of Polyurethane-35 in rats was reported to be 4890 mg/kg.[36] The test was conducted in accordance with the OECD TG 423. No further details were provided.

Polyurethane-39

The oral LD_{50} for Polyurethane-39 was reported to be > 2000 mg/kg for female Sprague-Dawley rats (n = 6).[31] The test substance was administered by gavage and the rats were observed for 14 days after dosing.

Inhalation

Polyurethane-1

The inhalation no-observed-adverse-effects-concentration (NOAEC) for Polyurethane-1 (tested at 0, 3, 10, 30, and 100 mg/m^3) was 3 mg/m^3 when administered to rats (n = 8) for 6 h/day for 5 days.[30]

Polyurethane-14

Sprague Dawley rats (n = 5/sex) were exposed to Polyurethane-14 (9.6% in 55% ethanol) for 4 h in a whole body inhalation chamber at 110 mg/m^3 Polyurethane-14 and 964,000 mg/m^3 ethanol as a liquid droplet aerosol.[64] The mean aerodynamic diameter of the particles was 1.9 ± 3.21 µm. There were no mortalities during the experiment or during the 14-day observation period. Clear nasal discharge was observed in one male following exposure. No toxicologically significant clinical findings were observed. There were no remarkable body weight changes or observations at necropsy. The LC_{50} of Polyurethane-14 was reported to be > 110 mg/m^3.

Short-Term Toxicity Studies

Short-term dermal and oral toxicity studies were not found in the published literature and no unpublished data were submitted.

Inhalation

Polyurethane-14

Sprague Dawley rats (n = 5/sex) were exposed to Polyurethane-14 (9.6% in 55% ethanol) 6 h/day for 14 days in a whole body inhalation chamber at 10, 30, and 100 mg/m^3 Polyurethane-14 and 964 ppm ethanol as a liquid droplet aerosol.[65] There were no mortalities during the exposure period. At necropsy, pallor was observed in the lungs of one male and one female in the 30 mg/m^3 group; this finding was consistent with histopathologic observations of alveolar histiocytosis and was considered an effect of exposure to the test material. The mean absolute lung weights were increased in both sexes of the 100 mg/m^3 group and the females of the 30 mg/m^3 group; mean relative lung weights were increased in both sexes in the 30 and 100 mg/m^3 groups. The increased lung weights were considered an effect of exposure to the test material and correlated with the increased incidence and severity of alveolar histiocytosis. The diffuse alveolar histiocytosis, observed in the lungs of the rats in the 30 and 100 mg/m^3 groups, increased in severity with increased exposure. Multifocal, minimal alveolar histiocytosis was observed in the lungs of some of the rats in the control and 10 mg/m^3 groups and was not considered to be an effect of exposure to the test material.

Subchronic Toxicity Studies

Subchronic oral and dermal toxicity studies were not found in the published literature and no unpublished data were submitted.

Inhalation

Polyurethane-1

The inhalation NOAEC for Polyurethane-1 (tested at 0, 1, 3, and 10 mg/m^3) was 1 mg/m^3 when administered to rats (n = 20) for 6 h/day for 65 exposures over 90 days.[30] The experiment was conducted in a head/nose apparatus and the recovery period was 3 months.

Polyurethane-14

Sprague Dawley rats (n = 15/sex) were exposed to Polyurethane-14 (9.6% in 54.9% ethanol neutralized with adenosine monophosphate) 6 h/day, 5 days/week, for 90 days (66 doses) in a nose-only inhalation chamber at 1.17 ± 0.3, 5.3 ± 1.1, and 40.6 ± 4.8 mg/m^3 (50, 147, 320 ppm, respectively) Polyurethane-14 and 964 ppm ethanol as a liquid droplet aerosol.[66] The particle aerodynamic diameters were 1.5 ± 2.7, 1.4 ± 2.1, and 1.9 ± 2.2 µm (± geometric standard deviation), which resulted in a respirable percentage of 97.2%, 99.6%, and 98.3%, respectively. After exposure, 5 rats/sex were allowed to recover for 13 weeks.

There were no test material-related deaths or clinical observations. There were no toxicologically significant effects on mean body weights, body weight gains, feed consumption, microscopic organ evaluations (except the lung and lymph nodes), or on hematology or serum chemistry parameters. In the air and ethanol controls and the low dose group, a background syndrome was present, which was described as concurrent mild perivascular inflammatory cell infiltrate and/or

subacute inflammation (mixed cell type) with interstitial pneumonia. This pattern was distinguishable from test-article induced responses. Exposure to Polyurethane-14 in the 5.3 and 40.6 mg/m^3 groups resulted in a low incidence of macroscopic findings, such as white areas in the lungs and enlarged lymph nodes, a dose-dependent increase in lung weights, accumulation of foamy alveolar macrophages, interstitial pneumonia, and acute inflammation (alveolar neutrophils) in the lung. The incidence and severity of the above findings generally decreased in the recovery animals, indicating partial recovery. A few 1.2 mg/m^3 and greater numbers of 5.3 and 40.6 mg/m^3 exposed rats had foamy macrophage accumulations in the mediastinal and/or tracheobronchial lymph nodes. Accumulation of foamy macrophages in the lung or lymph node is considered a normal physiological response necessary to remove particles from the lung, and was not considered to be an adverse health effect. Based on the results of this study, the no observed adverse effect level (NOAEL) was 1.2 mg solids/m^3. The lack of primary parenchymal toxicity and progressive lesions demonstrated that Polyurethane-14 is a polymer of low toxicity.[66]

Chronic Toxicity Studies

Chronic toxicity studies were not found in the published literature and no unpublished data were submitted.

DEVELOPMENTAL AND REPRODUCTIVE TOXICITY (DART) STUDIES

DART studies were not found in the published literature and no unpublished data were submitted.

GENOTOXICITY STUDIES

In Vitro

Genotoxicity studies are summarized in Table 11.

Polyurethane-1 (30%) was not mutagenic in an Ames test when tested at up to 16,000 µg/plate, both with and without metabolic activation.[30] Polyurethane-28 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay conducted in accordance with OECD TG 471 (Bacterial Reverse Mutation Test) using *Salmonella typhimurium* and *Escherichia coli*.[34] Polyurethane-35 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay conducted in accordance with OECD TG 471.[36] Polyurethane-42 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay conducted in accordance with OECD TG 471 using *S. typhimurium* and *E. coli*.[34] In an Ames mutagenicity test of Polyurethane-62 (up to 5000 µg/plate) using *S. typhimurium* and *E. coli*, no cytotoxicity or precipitation was observed with or without metabolic activation and there were no significant increases in the frequency of revertant colonies.[67]

In Vivo

In vivo genotoxicity studies were not found in the published literature and no unpublished data were submitted.

CARCINOGENICITY STUDIES

Carcinogenicity studies were not found in the published literature and no unpublished data were submitted.

OTHER RELEVANT STUDIES

Inflammatory Response

Male Swiss albino mice (n = 6) received a polyurethane nanoparticle solution (0, 2, 5, or 10 mg/kg in saline) by gavage daily for 10 days.[68] The polyurethane tested was manufactured with a natural triol, diisocyanate, and olive oil that were added to a solution of Polysorbate 80 while stirring at room temperature. The polyurethane particles had a diameter of 249 ± 5.7 nm and a polydispersity index (PDI) of 0.3 ± 0.04. All mice survived the study and there were no behavioral changes observed. At necropsy, there were no differences in body weights or organ weights among the groups. There was increased visceral fat accumulation in the mice in all treatment groups compared to controls. The lungs of mice in the 5 and 10 mg/kg/day groups (4 and 6 mice, respectively) showed inflammation, and inflammatory infiltrate was observed in all treatment groups. The kidneys of mice in the 5 and 10 mg/kg/day groups (5 and 6 mice, respectively) showed glomerular necrosis and glomerular atrophy. Histological examination of the adipose tissue did not reveal any alterations in morphology in any group. Oral polyurethane administration induced an increase in alanine aminotransferase (ALT) levels (58 ± 7.7, 69 ± 15, and 78 ± 4.5 IU/L in the 2, 5, and 10 mg/kg groups, respectively, versus control mice 34 ± 3.5 IU/L). Mice in the 5 and 10 mg/kg groups also showed an increase in alkaline phosphatase activities (ALP; 20 ± 4 and 24 ± 2 IU/L, respectively, versus controls, 8.5 ± 1.7 IU/L). Hematological evaluation revealed no changes in any parameter. There was an increase in TNF-α level (approximately 80-fold) in mice in the 10 mg/kg group. The authors concluded that oral administration of polyurethane nanoparticles generates an inflammatory response in mice.

DERMAL IRRITATION AND SENSITIZATION STUDIES

Irritation

In Vitro

Polyurethane-35

In an in vitro dermal corrosion assay conducted in accordance with OECD TG 431 (In Vitro Skin Corrosion: Human Skin Model Test), Polyurethane-35 was not corrosive.[36] No further information was provided.

Polyruethane-62

An EpiSkin assay using the reconstructed human epidermis (RhE) model conducted in accordance with OECD TG 439 (In Vitro Skin Irritation: Reconstructed Human Epidermis Test Method) was conducted on Polyurethane-62 (tested without trideceth-6 solvent; not specified if tested in water or other neutral solvent).[67] Polyrurethane-62-treated cells had a 95% survival rate. Survival greater than 50% is considered negative for dermal irritation. The control had the expected result.

Animal

Polyurethane-1

Polyurethane-1 (30% in water and ethanol; 0.5 mL) was not a dermal irritant in rabbits when exposed for 4 h under semi-occlusion.[30]

Polyurethane-35

In a skin irritation study conducted in accordance with OECD TG 404 (Acute Dermal Irritation/Corrosion), Polyurethane-35 (40% in water) was slightly irritating to the skin of rabbits (n = 3).[36] The author noted that the removal of the patch was not possible without altering the response or the integrity of the epidermis in one rabbit. All irritation effects were reversible within 7 days. The irritant effects were not sufficient to warrant classification as a skin irritant. No further information was provided.

Polyurethane-39

Polyurethane-39 was not irritating to rabbits (n = 2 males, 1 female) when applied under semi-occlusion.[31] The experiment was conducted in accordance with OECD TG 404.

Human

Polyurethane-14

In a cumulative irritation assay, subjects (n = 29) were topically exposed to Polyurethane-14 (9.6% in 55% ethanol; 0.2 mL), 55% ethanol, distilled water, or sodium lauryl sulfate (0.075%) for 21 days.[69] Exposure was under semi-occlusive conditions for days 1 through 9; exposure was changed to semi-open due to irritation observed in the polyurethane and ethanol control groups. Scoring for cumulative irritation was performed every 24 h immediately prior to reapplication or until excessive irritation was noted. Polyurethane-14 produced erythema and papules in three subjects by the fourth application. After changing to semi-open patches, an additional subject was observed with erythema and papules on day 19. Under identical conditions, the ethanol control produced erythema and papules in three subjects by the third application. No to very slight erythema was observed at the majority of sites treated with Polyurethane-14 or ethanol. Sites treated with distilled water elicited a very low response. Distilled water and 0.1% sodium lauryl sulfate produced the expected results. The cumulative scores were 232 (Polyurethane-14 solution), 208 (ethanol solution), 13 (water), and 338 (sodium lauryl sulfate) out of a possible 1575. Under the conditions of the study, both 9.6% Polyurethane-14 and the ethanol control produced mild to moderate irritation in a few subjects, with no differences in the responses to these two test articles.

Polyurethane-21

In a human dermal irritation study (n = 10), Polyurethane-21 was applied twice to scarified skin for 24 h using a chamber device with a 12 mm well.[70] Saline was used as the control. The test substance had an average irritation score of 0.50 (out of 4); the saline control had an average score of 0.55. The irritation potential of Polyurethane-21 was low.

Sensitization

In Vitro

Polyurethane-62

A Direct Peptide Reactivity Assay (DPRA) measuring reactivity (percent depletion) of cysteine and lysine peptides by liquid chromatography with a UV detector (LC-UV) was conducted on Polyrurethane-62 (tested without trideceth-6 solvent; not specified if tested in water or other neutral solvent).[67] This assay was conducting in accordance with the OECD Draft Proposal for Guideline, *In Chemico* Skin Sensitization (Direct Peptide Reactivity Assay). The mean depletion rates were 0.02% for Polyrurethane-62 and 78.04% for the positive control. Depletion less than 6.38% is considered to have no, or minimal, reactivity and is predicted to be negative for dermal sensitization. The control had the expected result.

Animal

Polyurethane-1

Polyurethane-1 (30% in water and ethanol) was not sensitizing to guinea pigs (n = 20; control = 10) in a Buehler assay.[30] The induction was conducted at 10% (approximately 3% Polyurethane-1 in distilled water) and the challenge at 5% (1.5%). The induction and challenge applications were in contact with the skin for 6 h.

Polyurethane-14

A guinea pig maximization test was conducted in accordance with OECD TG 406 (Skin Sensitization) on Polyurethane-14 (23.4% solids in 27% ethanol).[71] The guinea pigs (n = 10/sex; control = 5/sex) were injected with 0.1 mL of a 1% solution of Polyurethane-14 with and without Freund's Complete Adjuvant. After pretreatment with 10% sodium lauryl sulfate, an 8 cm^2-patch of filter paper saturated with the test article was applied topically for 48 h. The challenge was applied to virgin sites. A 4-cm^2 patch of filter paper saturated with the test material was applied topically for 24 h. The application sites were evaluated for erythema 48 and 72 h after application. Moderate to intense redness was observed after the intradermal injection, which was reduced to scabbing for the remainder of the induction period. No erythema was observed after challenge with the test material or the control. Under the described test conditions, the test material did not cause a sensitization reaction in guinea pigs.

Polyurethane-35

In Buehler and maximization tests conducted in accordance with OECD TG 406, Polyurethane-35 showed no evidence of causing sensitization.[36] No further information was provided.

Polyurethane-39

Polyurethane-39 (0, 3%, 10%, and 30% in 70% ethanol in water) was not sensitizing to mice (n = 5) in a local lymph node assay (LLNA).[31]

Human

Human repeated insult patch tests (HRIPT) of polyurethanes are summarized in Table 12.

Mascaras containing Polyurethane-1 (28.5% and 30%) were not sensitizing in HRIPTs.[72,73] Polyurethane-14 (9.61% solids) caused mild erythema in a few subjects but did not demonstrate a hypersensitivity response.[74] Polyurethane-21 (tested at 21% and 35% solids) was not a sensitizer.[75,76]

OCULAR IRRITATION STUDIES

In Vitro

In vitro ocular irritation assays are summarized in Table 13.

A mascara containing Polyurethane-1 (30%) was not predicted to be an ocular irritant in a neutral red release assay (NRR), chorioallantoic membrane of the embryonic hen's egg assay (HET-CAM), and reconstituted human epithelial culture (REC) assays.[77] Considering the 3 assays above, the estimated Draize classification of the test material is a slight irritant with a score of 0 to 15. Another mascara containing Polyurethane-1 (30%) was tested for ocular irritation in a HET-CAM assay (tested at 50%; final concentration 15%), BCOP, and EpiOcular™ assay (tested at 20%; final concentration 6%), and was predicted to not be an ocular irritant.[78-80] In an EpiOcular assay, a product containing Polyurethane-14 (10%) was tested at 20% (final concentration of Polyurethane-14 was 2%); the estimated Draize ocular irritation score of the test material at 100% was predicted to be 0 and Polyurethane-14 was predicted to be a non-irritant.[81] Polyurethane-21 (100%; 35% solids) was predicted to not be an ocular irritant in HET-CAM and BCOP assays.[82,83] Polyurethane-42 was predicted to be a moderate irritant in a HET-CAM assay and a non-irritant in a BCOP assay.[34] Polyurethane-62 was predicted to not be an ocular irritation in an EpiOcular assay.[67]

Animal

Polyurethane-1

Polyurethane-1 (30% in water and ethanol; 0.5 mL) was not an ocular irritant to rabbits.[30] The test was conducted according to OECD TG 405 (Acute Eye Irritation/Corrosion).

Polyurethane-35

In an eye irritation study conducted in accordance with OECD TG 405, two of the rabbits (n = 3) exhibited redness in the conjunctivae in the treated eye of one rabbit 1 h after instillation of Polyurethane-35, and the remaining rabbit exhibited these effects in 1 treated eye 24 h after instillation.[36] All irritation responses were reversible within 48 h and were not sufficient to warrant classification of the polymer as an eye irritant.

Polyurethane-39

Polyurethane-39 (approximately 30% solids) was not irritating when instilled into the eyes of rabbits.[31] The test was

conducted according to OECD TG 405.

Human

A 4-week use study of two mascaras containing Polyurethane-1 (30% and 28.5%) was conducted in subjects (n = 38) that either wore contact lenses or were self-assessed as having sensitive eyes.[84] Trace increases in redness of the palpebral conjunctivae were observed in three subjects during weeks 2 and/or 4; a trace increase in bulbar conjunctival redness was observed in one subject in week 2. There were no reports of subjective irritation. There were no increases in lacrimation or eyelid inflammation. There were no changes in visual acuity or corneal tissue integrity. Both mascaras were found to be non-irritating.

SUMMARY

This is a review of the available scientific literature and unpublished data relevant for assessing the safety of polyurethanes as used in cosmetics. According to the wINCI *Dictionary*, the functions of these 66 ingredients include artificial nail builders, binders, film formers, hair fixatives, plasticizers, and surface modifiers. The polyurethane ingredients in this report are copolymers, which comprise carbamate (i.e., urethane) linkages within the respective polymer backbone.

Several of these polyurethane ingredients, as defined, are the polymers dispersed in water (e.g., Polyurethane-17, -35, -36, -58, -60, -61, -70, -71, and -72). Polyurethane ingredients for which molecular weights were reported were all greater than 1000 Da.

The ingredients in this report are copolymers, each of which is synthesized, in part, from isocyanate analogs. Exposure to diisocyanates (monomers of the polymers in this report) in the work place is one of the leading causes of occupational asthma.

Polyurethane-36 and -60 are reported to be free of solvents and isocyanate groups; residual isocyanates are expected to react with water in trademark mixture dispersions and form carbonic acids. As supplied, a tradename mixture of Polyurethane-36 contains approximately 1.0% to 1.5% phenoxyethanol as a preservative and approximately 1.0% to 1.5% trimethylamine as a neutralizing agent. In tradename mixtures thereof, Polyurethane-60 and -61 contain approximately 0.0075% MI and 0.0075% benzisothiazolinone as preservatives, and approximately 1.3% and 1.5% by weight, respectively, dimethylethanolamine as a neutralizing agent. However, these non-polyurethane ingredients are components of the certain tradename mixtures, not components of the ingredients under review in this report. Accordingly, their safety is evaluated elsewhere. Polyurethane-62 is reported to contain no detectable residual unreacted isocyanate monomer (HDI).

According to VCRP survey data received in 2017, Polyurethane-11 was reported to be used in 315 formulations, including 303 in leave-on formulations and 12 in rinse-off formulations. The other ingredients that had reported uses were reported to be used in 33 or fewer formulations. The results of the concentration of use survey conducted by the Council in 2016 indicate that Polyurethane-1 has the highest reported maximum concentration of use; it is used at up to 15% in nail products. The highest maximum concentration of use reported for products resulting in leave-on dermal exposure is 7.5% Polyurethane-33 in the category of other skin care preparations.

The oral LD_{50} of Polyurethane-1 in rats was reported to be > 2000 mg/kg. The oral LD_{50} of Polyurethane-35 in rats was reported to be 4890 mg/kg. The oral LD_{50} for Polyurethane-39 was reported to be > 2000 mg/kg for rats.

The inhalation NOAEC for Polyurethane-1 was 3 mg/m^3 when administered to rats for 6 h/day for 5 days. The inhalation LC_{50} of Polyurethane-14 for rats for 4 h was 110 mg/m^3 in a whole body chamber.

The oral administration of polyurethane particles at 5 and 10 mg/kg/day for 10 days generated inflammation in mice. The polyurethane particles had a diameter of 249 ± 5.7 nm and a PDI of 0.3 ± 0.04. There was increased visceral fat accumulation in the treated mice in all groups (2, 5, 10 mg/kg/d) compared to controls. The lungs of mice in the 5 and 10 mg/kg/day groups showed inflammation, and inflammatory infiltrate was observed in all treatment groups.

Polyurethane-14 caused alveolar histiocytosis in rats exposed for 6 h/day for 14 days in a whole body inhalation chamber at 30 and 100 mg/m^3 in a dose-dependent manner. Multifocal, minimal alveolar histiocytosis was observed in the lungs of some of the rats in the control and 10 mg/m^3 groups and was not considered to be an effect of exposure to Polyurethane-14.

Polyurethane-1 (30%) was not mutagenic in an Ames test; Polyurethane-1 was tested up to 16,000 µg/plate in both SPT and PIT assays, both with and without metabolic activation. Polyurethane-28 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay conducted in accordance with OECD TG 471 using *S. typhimurium* and *E. coli*. Polyurethane-35 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay. Polyurethane-42 (concentration not specified) was not mutagenic in a bacterial reverse mutation assay using *S. typhimurium* and *E. coli*. In an Ames mutagenicity test of Polyurethane-62 (up to 5000 µg/plate) using *S. typhimurium* and *E. coli*, no cytotoxicity or precipitation was observed with or without metabolic activation and there were no significant increases in the frequency of revertant colonies.

Polyurethane-35 and -62 were not corrosive to human skin cells in in vitro dermal corrosion assays.

Polyurethane-1 at 30% was not a dermal irritant in rabbits when exposed for 4 h under semi-occlusion. Polyurethane-39 was not irritating to rabbits when applied under semi-occlusion.

In a skin irritation study, Polyurethane-35 (40% in water) had a slight irritating effect to the skin of rabbits. All irritation effects were reversible within 7 days.

Polyurethane-62 was predicted to be non-sensitizing in a DPRA.

Polyurethane-1 was not sensitizing to guinea pigs in a Buehler assay. The induction was conducted at approximately 3% and the challenge at approximately 1.5%. In a guinea pig maximization test, Polyurethane-14 (23.4% solids) was not sensitizing. In Buehler and maximization tests, Polyurethane-35 (concentration not specified) showed no evidence of sensitization. Polyurethane-39 (up to 30%) was not sensitizing to mice in an LLNA.

In a cumulative irritation test, Polyurethane-14 (9.6% in 55% alcohol) was mildly to moderately irritating to human subjects and had similar results as ethanol (55%). In a human dermal irritation study, Polyurethane-21 had an average irritation score of 0.50 (out of 4); the saline control had an average score of 0.55. The irritation potential of Polyurethane-21 was low.

Mascaras containing 28.5% and 30% Polyurethane-1 did not demonstrate a potential for eliciting dermal irritation or sensitization in HRIPTs.

In an HRIPT of Polyurethane-21 (21% solids), no adverse reactions of any kind were observed during the course of the study. The study authors concluded that Polyurethane-21, as tested, was considered a non-primary irritant and a non-primary sensitizer. In an HRIPT of Polyurethane-21 (35% solids), no adverse reactions of any kind were observed during the course of the study. The study authors concluded that Polyurethane-21, as supplied, was considered a non-primary irritant and a non-primary sensitizer. In an HRIPT, Polyurethane-14 (10%) was not sensitizing and there were no adverse reactions observed at any time during the study. In another HRIPT, Polyurethane-14 (9.61% solids) was not sensitizing.

In in vitro tests of a mascara containing Polyurethane-1 at 30%, the test material was rated slightly cytotoxic in a NRR assay, HET-CAM assay, and a REC assay; when considering these three assays together, the authors concluded that the results might be equivalent to a Draize score of 0-15 (slightly irritating). Based on in vitro tests of another mascara containing Polyurethane-1 at 30%, the test substance was predicted to have practically no ocular irritation potential (HET-CAM assay and a BCOP assay). In EpiOcular assays, a product containing Polyurethane-14 (10%) and Polyurethane-62 were predicted to not be ocular irritants. Polyurethane-21 (100%; 35% solids) was predicted to not be an ocular irritant in HET-CAM and BCOP assays. Polyurethane-42 was found to be a “moderately irritant” in a HET-CAM assay and a non-irritant in a BCOP assay.

Polyurethane-1 at 30% was not an ocular irritant to rabbits. In an eye irritation study conducted with rabbits, the irritant effects were not sufficient to warrant classification of Poluyrethane-35 as an eye irritant. Polyurethane-39 (approximately 30% solids) was not irritating when instilled into the eyes of rabbits.

In a 4-week use study with human subjects of two mascaras containing Polyurethane-1 (30% and 28.5%), the mascaras were found to be non-irritating.

DISCUSSION

The CIR Panel examined the available data, which included method of manufacture and impurity data; acute and repeated-dose oral and inhalation toxicity; genotoxicity; dermal and ocular irritation data; and sensitization data. These ingredients are mixtures of very large polymeric molecules. The assays for ocular and dermal irritation showed that there were no concerns that these ingredients would be irritating under the conditions of use. There is limited toxicity data for only 7 of these ingredients; the Panel relied heavily on the fact that these molecules are large and will not penetrate the epidermis, making systemic toxicity studies unnecessary.

Many of these polyurethanes are reported to be supplied, in tradename mixtures, as emulsions or in solutions with multiple non-polyurethane ingredients that may include sensitizers such as the preservative MI (e.g., as reported in some tradename mixtures containing Polyurethane-60 and -61), even though these preservatives may not be disclosed in the information provided by suppliers. Cosmetics manufacturers and formulators are advised to be aware of the presence of potentially sensitizing constituents in these ingredients, as supplied, and to avoid reaching levels of potential sensitizers that may be hazardous to consumers, especially when combining these ingredients with other ingredients that may contain sensitizers. The Panel recommended that a QRA be used to determine the levels needed to minimize sensitization in consumers.

The Panel noted that these polyurethanes contain monomers that could be of concern if there was significant residual monomer present. For example, inhalation of the HDI monomer can cause occupational asthma, hypersensitivity pneumonitis, rhinitis, and accelerated lung deterioration. The Panel noted that these polyurethane ingredients are heterogeneous in their structures and monomeric components. However, these ingredients are all large molecules and will not be readily absorbed through the skin. These polymers are expected to be stable and any residual monomers would be either washed away in manufacturing or, because the monomers are reactive, consumed in reaction with solution or formulations. The Panel was comfortable that there would not be any significant residual HDI (or other isocyanate analogs such as isophorone diisocyanate, saturated methylene diphenyldiisocyanate, 1-isocyanato-1-methylethylbenzene, or hexamethylene diisocyanate) or other monomers in these ingredients, as supplied for formulation. However, producers and formulators should continue to use current good manufacturing practices (cGMP) and avoid creating conditions where monomers could be released into solution or formulation.

The Panel noted that Europe restricts the amount of residual amines, which may be present as residuals from the manufacturing process in Polyurethane-17 and -21, to 2.5% in ready-for-use leave-on preparations. These amines are used in low concentrations. However, residual low-molecular-weight amines should be minimized in polyurethane ingredients to reduce risk of nitrosating reactions and should not be used in cosmetic products in which *N*-nitroso compounds can be formed.

Because these polyurethanes are commonly only supplied as tradename mixture emulsions or solutions (at 20% to 66%), there has been some confusion about the concentration of the polyurethanes in the safety data (e.g., was the concentration stated of the emulsion or the polyurethane in the emulsion). It was necessary to discern how the concentration of the polyurethane in each test was presented.

The Panel recognizes that there are data gaps regarding use and concentration of these ingredients. However, the overall information available on the types of products in which these ingredients are used and at the concentrations provided, indicate a pattern of use which was considered by the Panel in assessing safety.

The Panel discussed the issue of incidental inhalation exposure from body and hand products, and hair sprays. The limited data available from inhalation studies, including acute and short-term exposure data, suggest little potential for respiratory effects at relevant doses. The mean aerodynamic diameter of the tested particles of Polyurethane-14 was 1.9 ± 3.21 µm. The Panel believes that the sizes of a substantial majority of the particles of these ingredients, as manufactured, are larger than the respirable range and/or aggregate and agglomerate to form much larger particles in formulation. Thus, the adverse effects reported using high doses of respirable particles in the inhalation studies do not indicate risks posed by use in cosmetics. These ingredients are reportedly used at concentrations up to 6% in cosmetic products that may be sprayed and up to 3.2% in loose powder products that may become airborne. The Panel noted that droplets/particles from cosmetic products would not be respirable to any appreciable amount. Coupled with the small actual exposure in the breathing zone and the concentrations at which the ingredients are used, the available information indicates that incidental inhalation would not be a significant route of exposure that might lead to local respiratory or systemic effects. The Panel considered other data available to characterize the potential for polyurethanes to cause systemic toxicity, irritation, sensitization, and genotoxicity and noted the lack of systemic toxicity in acute oral exposure studies, little or no irritation or sensitization in multiple tests of dermal and ocular exposure, the absence of genotoxicity in multiple Ames tests, and the lack of irritation or sensitization in tests of dermal exposure. In addition, these ingredients are large macromolecules, are reported or predicted to be insoluble in water, and chemically inert under physiological conditions or conditions of use, which supports the view that they are unlikely to be absorbed or cause local effects in the respiratory tract. A detailed discussion and summary of the Panel's approach to evaluating incidental inhalation exposures to ingredients in cosmetic products is available at http://www.cir-safety.org/cir-findings.

CONCLUSION

The CIR Expert Panel concluded that the following ingredients are safe as used in cosmetics in the present practices of use and concentration described in this safety assessment:

Polyurethane-1	Polyurethane-19*	Polyurethane-41*	Polyurethane-58*
Polyurethane-2	Polyurethane-20*	Polyurethane-42*	Polyurethane-59*
Polyurethane-4*	Polyurethane-21*	Polyurethane-43*	Polyurethane-60*
Polyurethane-5*	Polyurethane-23*	Polyurethane-44*	Polyurethane-61*
Polyurethane-6	Polyurethane-24	Polyurethane-45*	Polyurethane-62*
Polyurethane-7	Polyurethane-25*	Polyurethane-46	Polyurethane-63*
Polyurethane-8	Polyurethane-26*	Polyurethane-47*	Polyurethane-64*
Polyurethane-9	Polyurethane-27*	Polyurethane-48*	Polyurethane-65*
Polyurethane-10	Polyurethane-28*	Polyurethane-49*	Polyurethane-66*
Polyurethane-11	Polyurethane-29*	Polyurethane-50*	Polyurethane-67*
Polyurethane-12*	Polyurethane-32*	Polyurethane-51*	Polyurethane-68*
Polyurethane-13*	Polyurethane-33	Polyurethane-52*	Polyurethane-69*
Polyurethane-14	Polyurethane-34	Polyurethane-53*	Polyurethane-70*
Polyurethane-15	Polyurethane-35	Polyurethane-54*	Polyurethane-71*
Polyurethane-16	Polyurethane-36*	Polyurethane-55*	Polyurethane-72*
Polyurethane-17*	Polyurethane-39	Polyurethane-56*	
Polyurethane-18	Polyurethane-40	Polyurethane-57*	

* Not reported to be in current use. Were ingredients in this group not in current use to be used in the future, the expectation is that they would be used in product categories and at concentrations comparable to others in this group.

TABLES

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

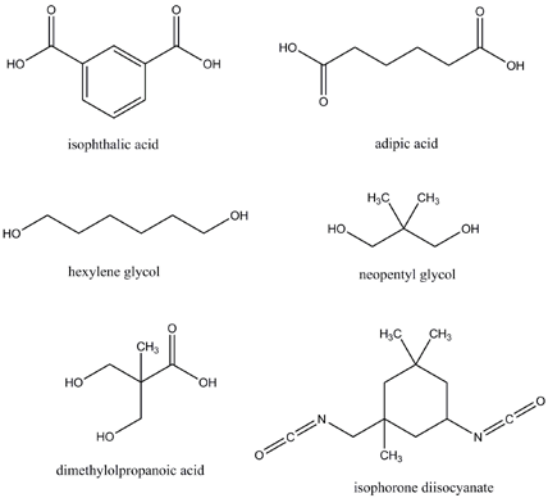
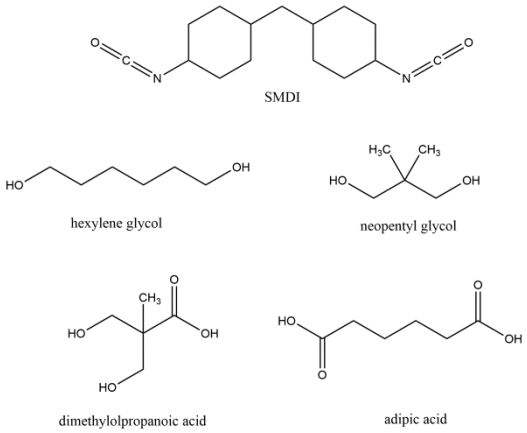
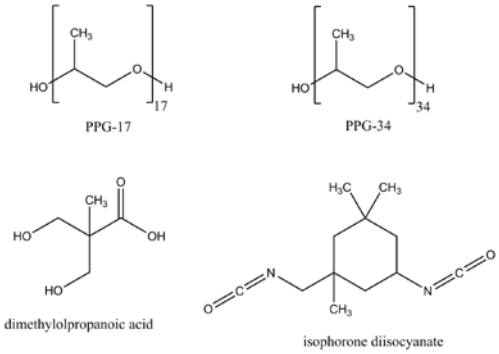
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-1	Polyurethane-1 is a copolymer of isophthalic acid, adipic acid, hexylene glycol, neopentyl glycol, dimethylolpropanoic acid [DMPA], and isophorone diisocyanate monomers. [Monomers:]  	Binder; film former; hair fixative
Polyurethane-2	Polyurethane-2 is a copolymer of hexylene glycol, neopentyl glycol, adipic acid, saturated methylene diphenyldiisocyanate (SMDI), and dimethylolpropanoic acid monomers. [Monomers:]  	Film former
Polyurethane-4	Polyurethane-4 is a copolymer of PPG-17, PPG-34, isophorone diisocyanate and dimethylolpropanoic acid [DMPA] monomers. [Monomers:]  	Film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

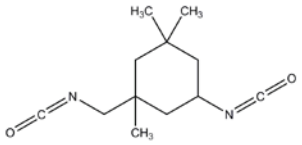
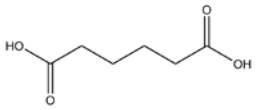
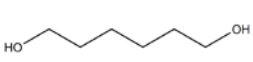
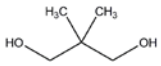
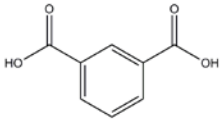
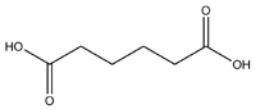
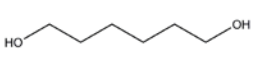
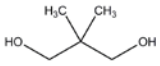
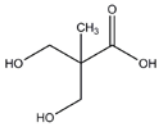
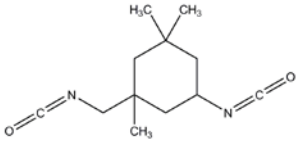
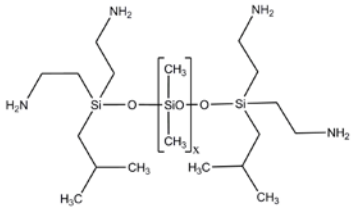
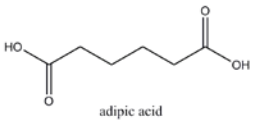
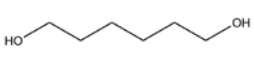
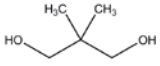
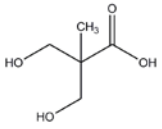
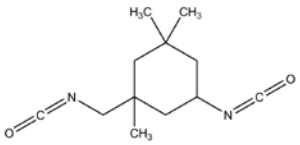
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-5	Polyurethane-5 is a copolymer of hexylene glycol, neopentyl glycol, adipic acid and isophorone diisocyanate monomers. [Monomers:]  isophorone diisocyanate  adipic acid  hexylene glycol  neopentyl glycol	Film former
Polyurethane-6	Polyurethane-6 is a copolymer of isophthalic acid, adipic acid, hexylene glycol, neopentyl glycol, dimethylolpropanoic acid [DMPA], isophorone diisocyanate and bis-ethylaminoisobutyl-dimethicone monomers. [Monomers:]  isophthalic acid  adipic acid  hexylene glycol  neopentyl glycol  dimethylolpropanoic acid  isophorone diisocyanate  bis-ethylaminoisobutyl-dimethicone	Binder; film former; hair fixative
Polyurethane-7	Polyurethane-7 is a copolymer of hexylene glycol, neopentyl glycol, adipic acid, isophorone diisocyanate and dimethylolpropanoic acid [DMPA] monomers. [Monomers:]  adipic acid  hexylene glycol  neopentyl glycol  dimethylolpropanoic acid  isophorone diisocyanate	Film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

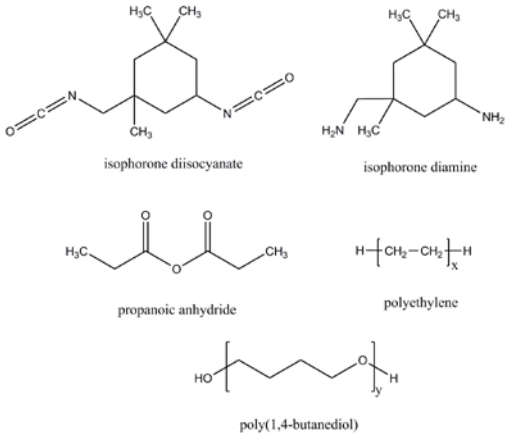
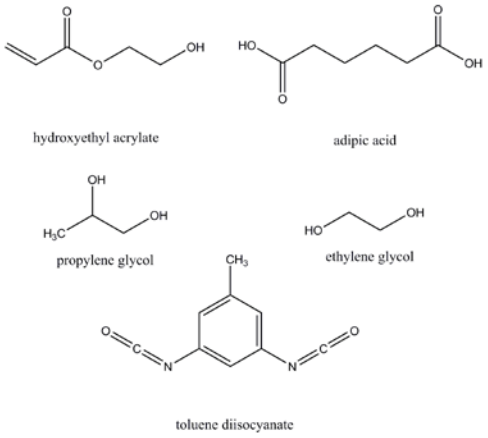
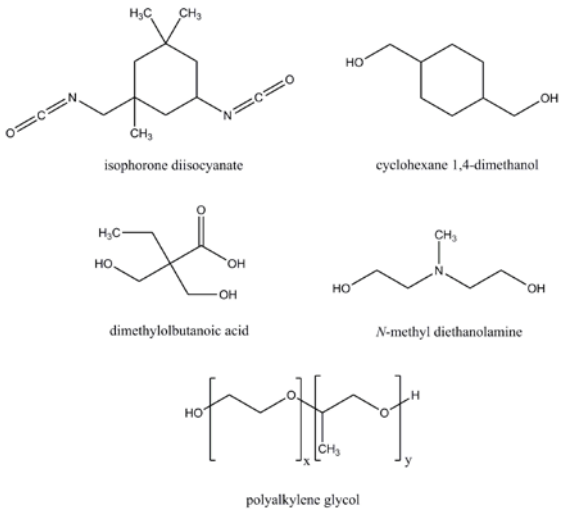
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-8	Polyurethane-8 is a copolymer of polyethylene, poly(1,4-butanediol), propanoic anhydride, isophorone diisocyanate, and isophorone diamine. [Monomers:]  isophorone diisocyanate isophorone diamine propanoic anhydride polyethylene poly(1,4-butanediol)	Binder; film former; plasticizer
Polyurethane-9 69011-31-0	Polyurethane-9 is the copolymer of adipic acid, toluene diisocyanate, propylene glycol, ethylene glycol and hydroxyethyl acrylate monomers. [Monomers:]  hydroxyethyl acrylate adipic acid propylene glycol ethylene glycol toluene diisocyanate	Artificial nail builder
Polyurethane-10	Polyurethane-10 is a copolymer of isophorone diisocyanate, cyclohexanedimethanol, dimethylolbutanoic acid, polyalkylene glycol and *N*-methyl diethanolamine monomers. [Monomers:]  isophorone diisocyanate cyclohexane 1,4-dimethanol dimethylolbutanoic acid *N*-methyl diethanolamine polyalkylene glycol	Film former; hair fixative

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

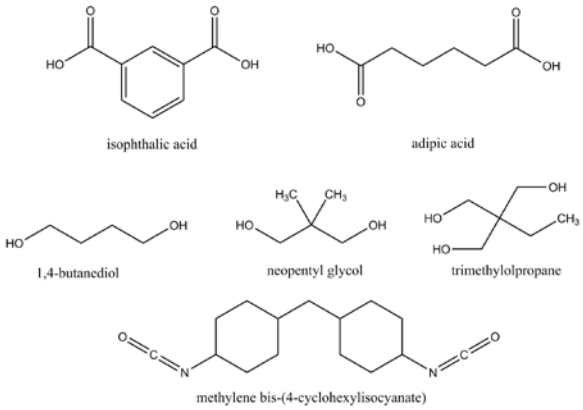
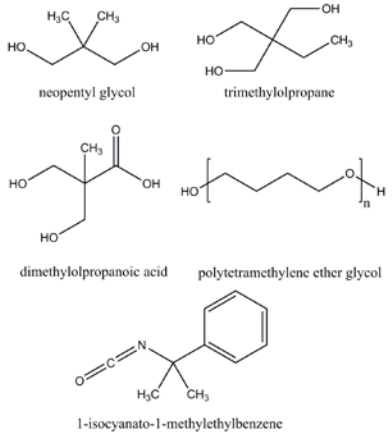
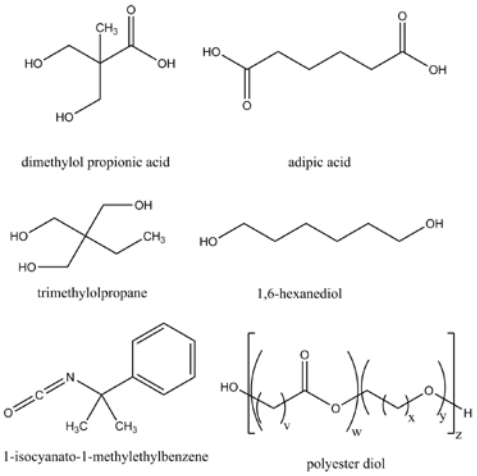
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-11 68258-82-2	Polyurethane-11 is a copolymer of adipic acid, 1,4-butanediol, isophthalic acid, methylene bis-(4-cyclohexylisocyanate) [SMDI], neopentyl glycol and trimethylolpropane monomers. [Monomers:]  isophthalic acid; adipic acid; 1,4-butanediol; neopentyl glycol; trimethylolpropane; methylene bis-(4-cyclohexylisocyanate)	Film former
Polyurethane-12	Polyurethane-12 is a copolymer of trimethylolpropane, neopentyl glycol, dimethylolpropanoic acid [DMPA], polytetramethylene ether glycol and isocyanato methylethylbenzene monomers. [Monomers:]  neopentyl glycol; trimethylolpropane; dimethylolpropanoic acid; polytetramethylene ether glycol; 1-isocyanato-1-methylethylbenzene	Binder; film former
Polyurethane-13	Polyurethane-13 is a copolymer of trimethylolpropane, dimethylol propionic acid [DMPA], hexanediol, adipic acid, polyester diol, and isocyanato methylethylbenzene monomers. [Monomers:]  dimethylol propionic acid; adipic acid; trimethylolpropane; 1,6-hexanediol; 1-isocyanato-1-methylethylbenzene; polyester diol	Binder; film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

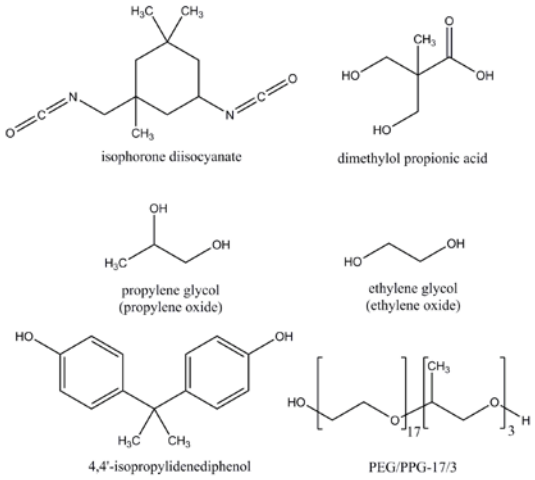
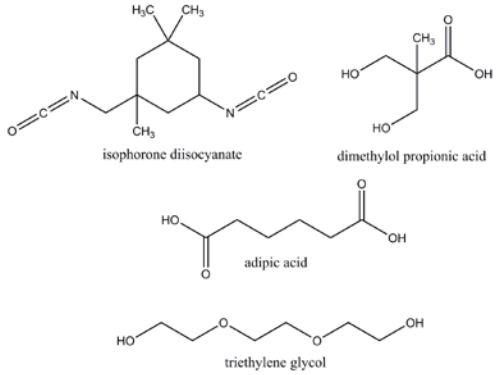
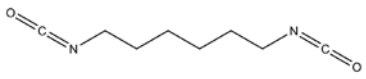
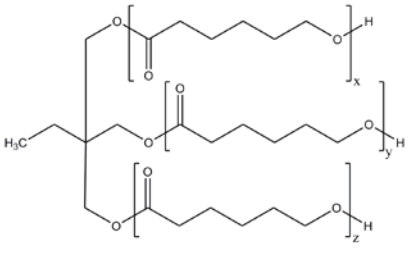
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-14	Polyurethane-14 is a copolymer of isophorone diisocyanate, dimethylol propionic acid [DMPA], and 4,4'-isopropylidenediphenol reacted with propylene oxide, ethylene oxide and PEG/PPG-17/3. [Monomers:]  isophorone diisocyanate dimethylol propionic acid propylene glycol (propylene oxide) ethylene glycol (ethylene oxide) 4,4'-isopropylidenediphenol PEG/PPG-17/3	Film former; hair conditioning agent
Polyurethane-15	Polyurethane-15 is a copolymer of isophorone diisocyanate, adipic acid, triethylene glycol, and dimethylolpropanoic acid. [Monomers:]  isophorone diisocyanate dimethylol propionic acid adipic acid triethylene glycol	Film former
Polyurethane-16	Polyurethane-16 is a cross-linked condensation polymer formed from the addition polymerization of 2 [stoichiometric equivalents] of hexamethylene diisocyanate with 1 [stoichiometric equivalent] of polycaprolactonetriol terminated with 3 hydroxyl groups. [Monomers:]  hexamethylene diisocyanate  polycaprolactonetriol	Anticaking agent; emulsion stabilizer; film former; slip modifier; surface modifier

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

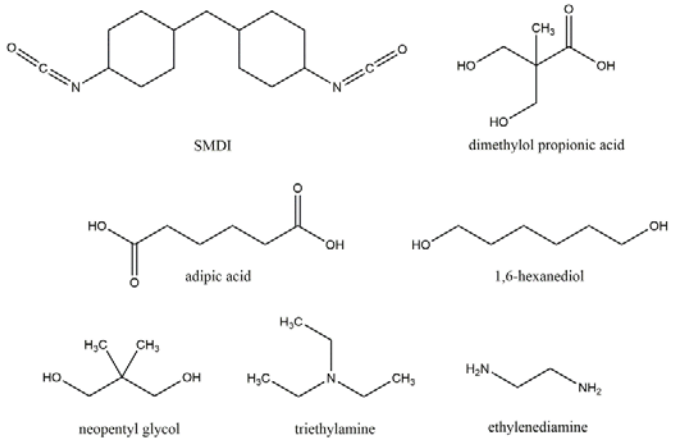
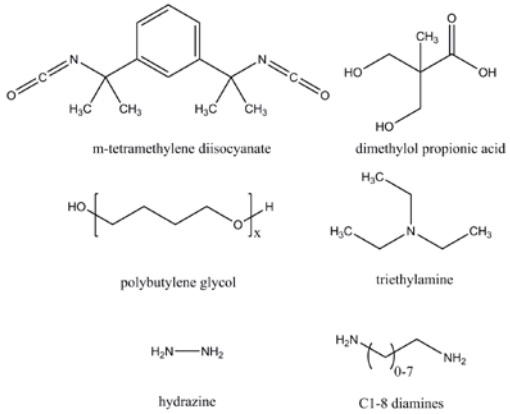
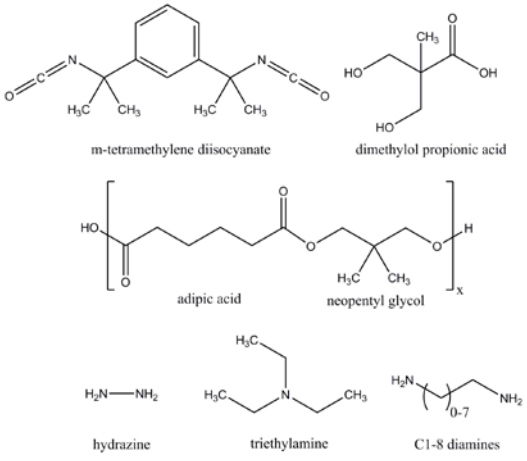
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-17 347175-78-4	Polyurethane-17 is a complex polymer made by neutralizing hexylene glycol/neopentyl glycol/adipic acid/SMDI/DMPA copolymer with triethylamine in the presence of water. Further chain extension is achieved by reacting the polymer with ethylenediamine. [Monomers/reactants:]  SMDI; dimethylol propionic acid; adipic acid; 1,6-hexanediol; neopentyl glycol; triethylamine; ethylenediamine	Film former
Polyurethane-18	Polyurethane-18 is a complex polymer formed by the reaction of *m*-tetramethylene diisocyanate, polybutylene glycol and dimethylol propionic acid [DMPA]. The pre-polymer is neutralized with triethylamine and condensed with a combination of hydrazine and C1-8 diamines to achieve chain extension. [Monomers/reactants:]  m-tetramethylene diisocyanate; dimethylol propionic acid; polybutylene glycol; triethylamine; hydrazine; C1-8 diamines	Binder; hair fixative
Polyurethane-19	Polyurethane-19 is a complex polymer formed by the reaction of *m*-tetramethylene diisocyanate, neopentyl glycol, trimethylol propane, dimethylol propionic acid [DMPA] and a polyester formed by condensing neopentyl glycol and adipic acid. The pre-polymer is neutralized with triethylamine and condensed with a combination of hydrazine and C1-8 diamines to achieve chain extension. [Monomers/reactants:]  m-tetramethylene diisocyanate; dimethylol propionic acid; adipic acid; neopentyl glycol; hydrazine; triethylamine; C1-8 diamines	Binder; hair fixative

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

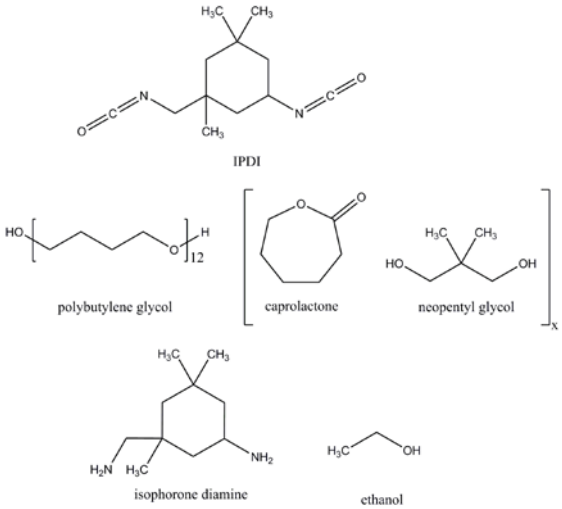
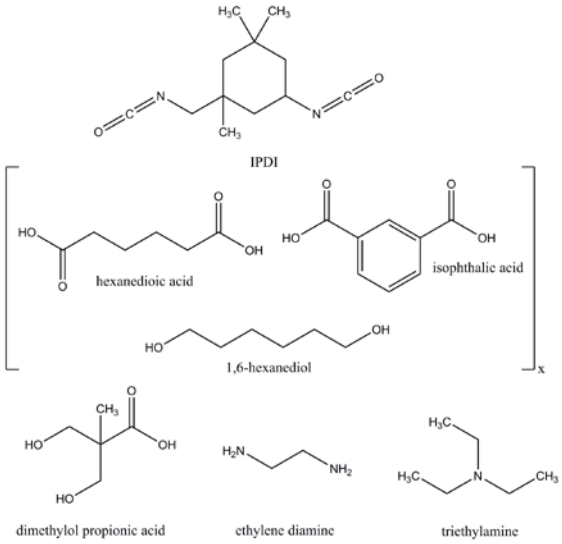
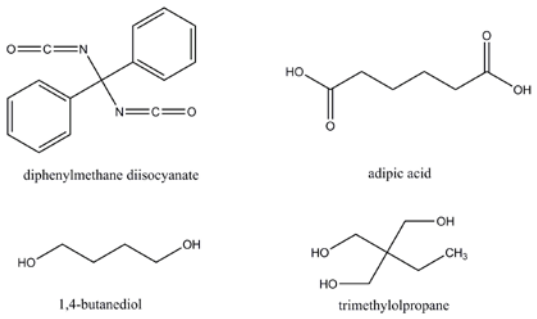
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-20	Polyurethane-20 is a complex polymer formed by the reaction of isophorone diisocyanate (IPDI), and two polyols: The first polyol is polybutylene glycol containing approximately 12 butylene glycol units. The second polyol is formed by the reaction of approximately 10 [stoichiometric equivalents] of caprolactone [with 1 stoichiometric equivalent of] neopentyl glycol. The urethane polymer is then reacted with isophorone diamine to build molecular weight and the resulting polymer is capped with ethanol to eliminate residual isocyanate groups. [Monomers/reactants:]  IPDI polybutylene glycol caprolactone neopentyl glycol isophorone diamine ethanol	Binder; film former; plasticizer
Polyurethane-21	Polyurethane-21 is a urethane copolymer prepared by reacting isophorone diisocyanate (IPDI) with dimethylol propionic acid (DMPA), a polyester of hexanedioic acid, isophthalic acid and 1,6-hexanediol, and ethylene diamine, neutralized with triethylamine. [Monomers/reactants:]  IPDI hexanedioic acid isophthalic acid 1,6-hexanediol dimethylol propionic acid ethylene diamine triethylamine	Film former
Polyurethane-23	Polyurethane-23 is a copolymer of adipic acid, 1,4 butanediol, diphenylmethane diisocyanate, and trimethylolpropane. [Monomers:]  diphenylmethane diisocyanate adipic acid 1,4-butanediol trimethylolpropane	Film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

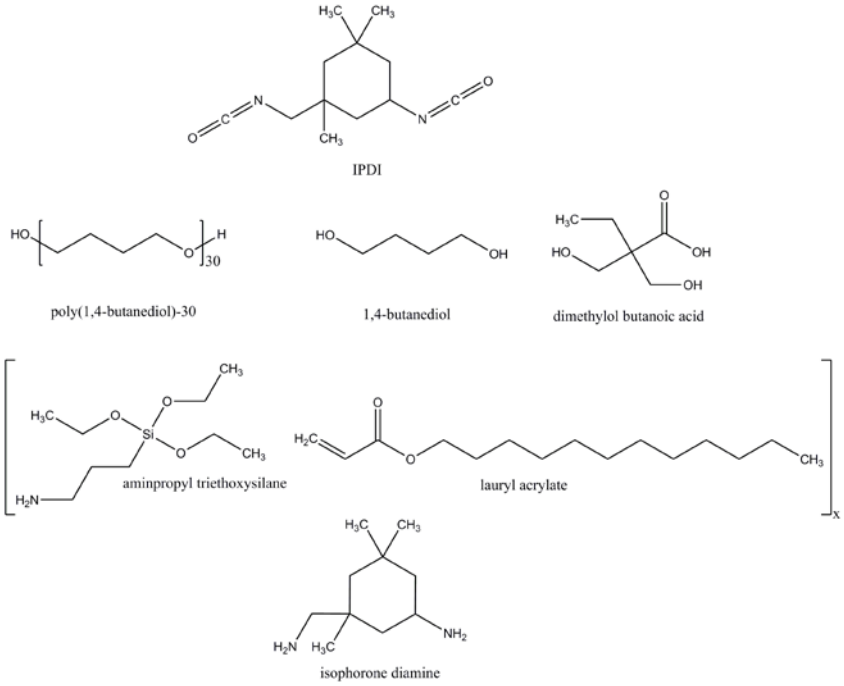
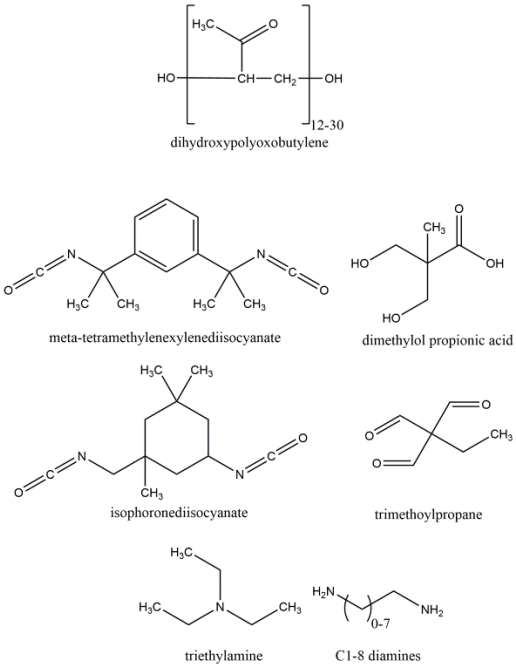
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-24	Polyurethane-24 is a complex polymer prepared via the following multi-step synthesis. First, isophorone diisocyanate (IPDI) is reacted with three different polyols: poly(1,4-butanediol)-30, 1,4-butanediol, and dimethylol butanoic acid. This pre-polymer is then reacted with a reagent formed by the reaction between aminpropyl triethoxysilane and lauryl acrylate. The resulting polymer is subsequently chain extended by reaction with isophorone diamine in aqueous solution to produce Polyurethane-24. [Monomers/reactants:] 	Hair conditioning agent; hair fixative
Polyurethane-25	Polyurethane-25 is a complex polymer formed by the reaction of dihydroxypolyoxobutylene (degree of polymerization 12-30), dimethylol propionic acid [DMPA], meta-tetramethylenexylenediisocyanate, isophoronediisocyanate and trimethoylpropane. The prepolymer is neutralized with triethylamine and chain extended with C1-8 alkyl diamine. [Monomers/reactants:] 	Binder; hair-waving/ straightening agent; skin-conditioning agent-occlusive

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

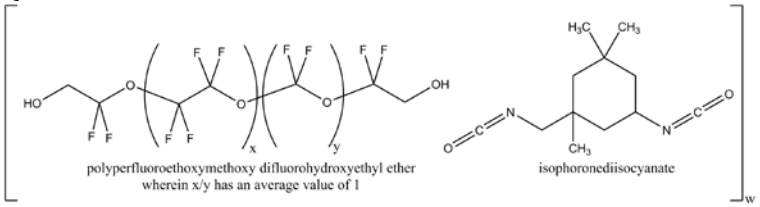
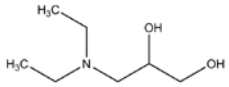
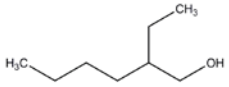
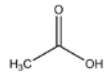
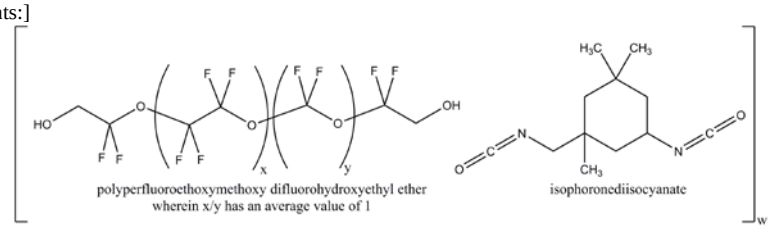
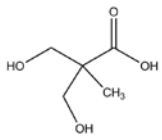
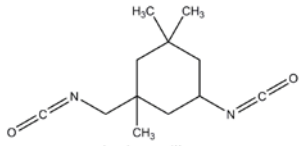
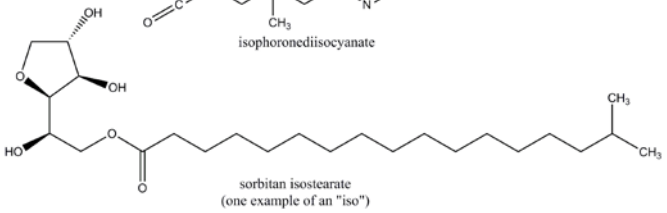
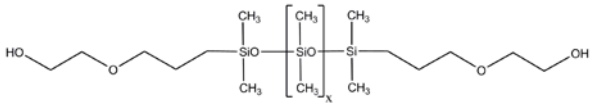
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-26 328389-90-8	Polyurethane-26 is a complex polymer that is formed by the reaction of polyperfluoroethoxymethoxy difluorohydroxyethyl ether and isophorone diisocyanate (IPDI) to form a prepolymer. The prepolymer is further reacted with 3-diethylamino-1,2-propanediol followed by the capping of any residual isocyanate groups with 2-ethyl-1-hexanol. The resulting polymer is neutralized with acetic acid. [Monomers/reactants:]  polyperfluoroethoxymethoxy difluorohydroxyethyl ether wherein x/y has an average value of 1 isophoronediisocyanate  3-diethylamino-1,2-propanediol  2-ethyl-1-hexanol  acetic acid	Film former; hair conditioning agent; skin protectant
Polyurethane-27 328389-91-9	Polyurethane-27 is a complex polymer that is formed by the reaction of polyperfluoroethoxymethoxy difluorohydroxyethyl ether and isophorone diisocyanate (IPDI) to form a prepolymer. The prepolymer is further reacted with the triethylamine salt of 3-hydroxy-2-(hydroxymethyl)-2-methyl-1-propionic acid [DMPA]. [Monomers/reactants:]  polyperfluoroethoxymethoxy difluorohydroxyethyl ether wherein x/y has an average value of 1 isophoronediisocyanate  3-hydroxy-2-(hydroxymethyl)-2-methyl-1-propionic acid	Film former; hair conditioning agent; skin protectant
Polyurethane-28	Polyurethane-28 is a complex polymer formed by the reaction of bis-hydroxyethoxypropyl dimethicone with isophorone diisocyanate (IPDI) and sorbitan isostearate. [Monomers/reactants:]  isophoronediisocyanate  sorbitan isostearate (one example of an "iso")  bis-hydroxyethoxypropyl dimethicone	Surfactant-emulsifying agent

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

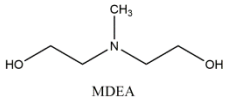
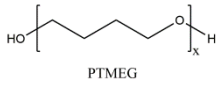
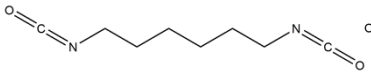
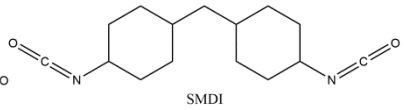
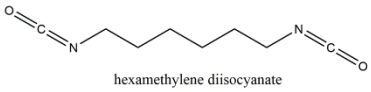
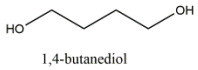
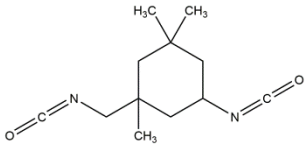
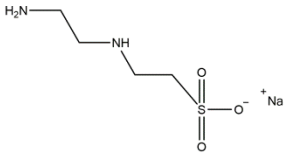
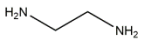
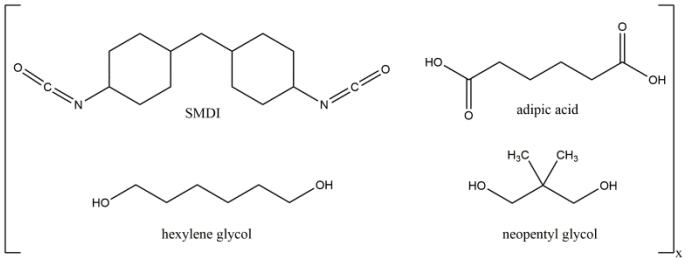
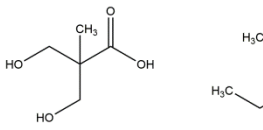
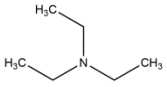
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-29	Polyurethane-29 is a copolymer of methyl diethanolamine (MDEA), polytetramethylene ether glycol (PTMEG), hexamethylene diisocyanate (HDI), and saturated methylene diphenyldiisocyanate (SMDI). [Monomers:]  MDEA  PTMEG  HDI  SMDI	Emulsion stabilizer; film former; hair conditioning agents; hair fixative
Polyurethane-32	Polyurethane-32 is a copolymer of 1,4-butanediol, ethylenediamine, hexamethylene diisocyanate, isophorone diisocyanate, and sodium *N*-(2-aminoethyl)-3-aminoethane sulfonate monomers. [Monomers:]  hexamethylene diisocyanate  1,4-butanediol  isophorone diisocyanate  sodium *N*-(2-aminoethyl)-3-aminoethane sulfonate  ethylenediamine	Binder
Polyurethane-33	Polyurethane-33 is a complex polymer formed by reacting dimethylolpropionic acid [DMPA] and a polyester composed of adipic acid, hexylene glycol, neopentyl glycol with methylene dicyclohexyldiisocyanate (SMDI) to form a prepolymer. The prepolymer is neutralized with triethylamine and then chain-extended with hydrazine. [Monomers/reactants:]  SMDI adipic acid hexylene glycol neopentyl glycol  dimethylol propionic acid  triethylamine hydrazine	Binder

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

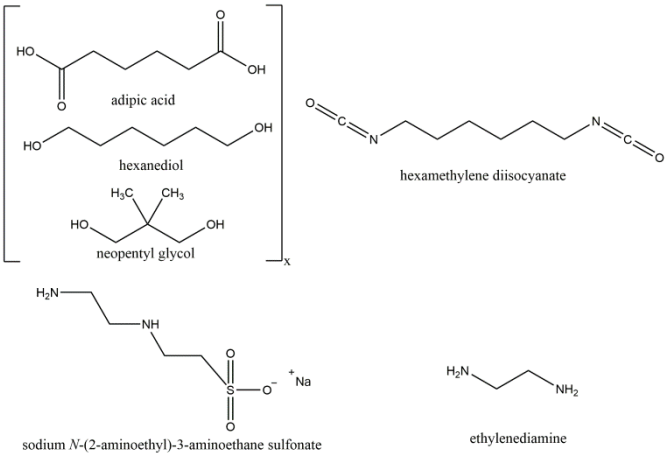
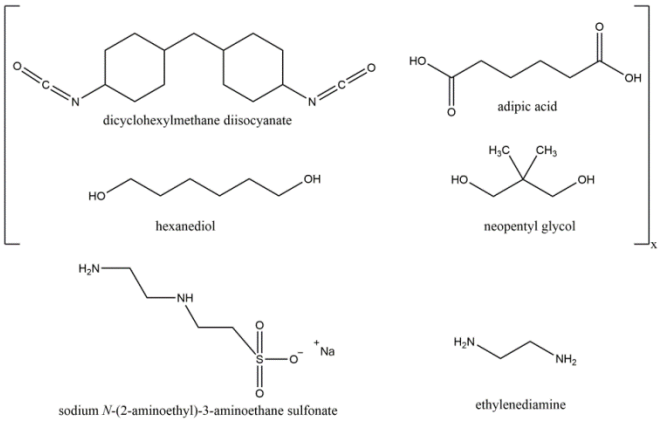
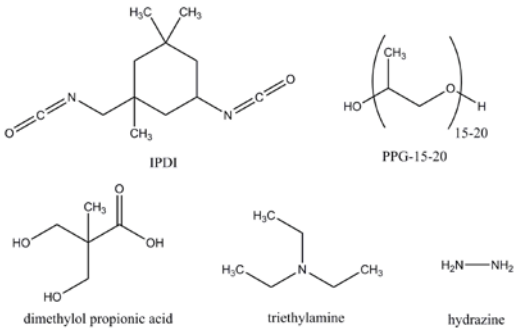
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-34	Polyurethane-34 is a complex polymer that is formed in a multi-step reaction. A copolymer of hexanediol, neopentyl glycol, and adipic acid is reacted with hexamethylene diisocyanate. The resulting polymer is further reacted with *N*-(2-aminoethyl)-3-aminoethanesulfonic acid and ethylenediamine. [Monomers:]  	Binder
Polyurethane-35	Polyurethane-35 is a complex urethane polymer that is made by reacting a polyester pre-polymer consisting of adipic acid, hexanediol, and neopentyl glycol with dicyclohexylmethane diisocyanate [SMDI]. The resulting urethane polymer is further reacted with sodium *N*-(2-aminoethyl)-3-aminoethanesulfonate and ethylenediamine and then dispersed into water. [Monomers:]  	Binder
Polyurethane-36	Polyurethane-36 is a copolymer of isophorone diisocyanate (IPDI), PPG-15-20, and dimethylol propionic acid [DMPA], neutralized in the presence of water with triethylamine. Further chain extension is achieved by reacting the polymer with hydrazine. [Monomers/reactants:]  	Film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

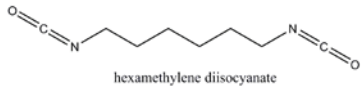
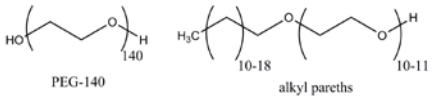
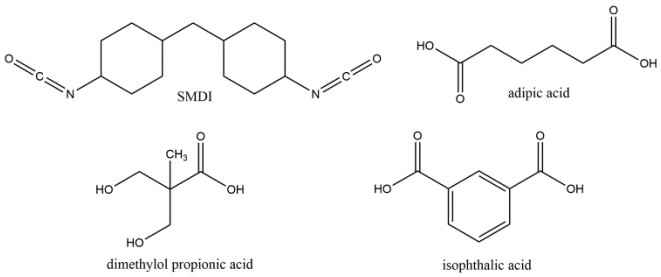
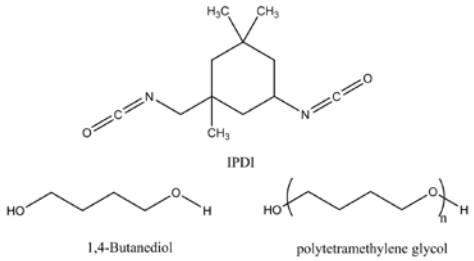
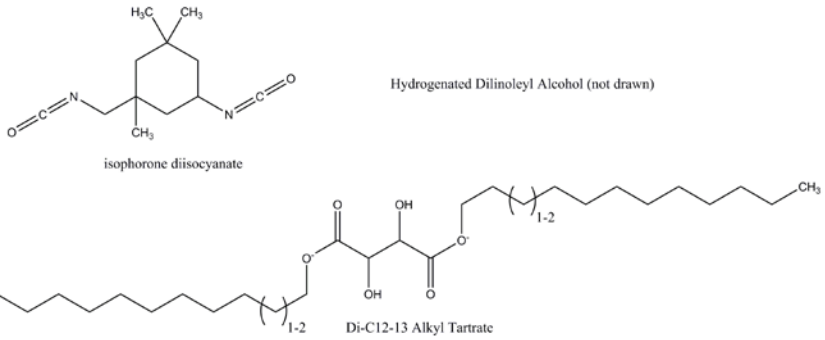
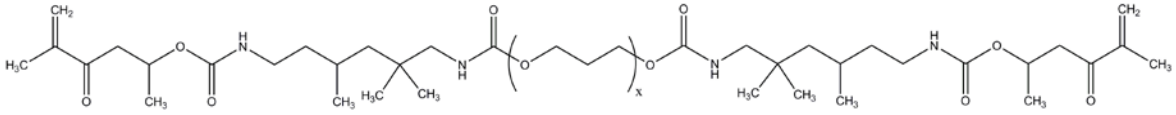
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-39	Polyurethane-39 is a copolymer of PEG-140 and hexamethylene diisocyanate end-capped with C12-14 Pareth-10, C16-18 Pareth-11, and C18-20 Pareth-11. [Monomers:]  hexamethylene diisocyanate  PEG-140 alkyl pareths	Hair conditioner
Polyurethane-40	Polyurethane-40 is a copolymer of Adipic Acid, dimethylolpropanoic acid (DMPA), isophthalic acid and saturated methylene diphenyldiisocyanate (SMDI) monomers. [Monomers:]  SMDI adipic acid dimethylol propionic acid isophthalic acid	Film former; surface modifier
Polyurethane-41	Polyurethane-41 is a copolymer of 1,4-Butanediol, polytetramethylene glycol and isophorone diisocyanate (IPDI) monomers. [Monomers:]  IPDI 1,4-Butanediol polytetramethylene glycol	Film former; hair conditioning agent; skin protectant
Polyurethane-42 1184186-26-2	Polyurethane-42 is a copolymer of di-C12-13 alkyl tartrate, hydrogenated dilinoleyl alcohol and isophorone diisocyanate. [Monomers:]  Hydrogenated Dilinoleyl Alcohol (not drawn) isophorone diisocyanate Di-C12-13 Alkyl Tartrate	Film former
Polyurethane-43	Polyurethane-43 is the polymer that conforms generally to the formula: 	Film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

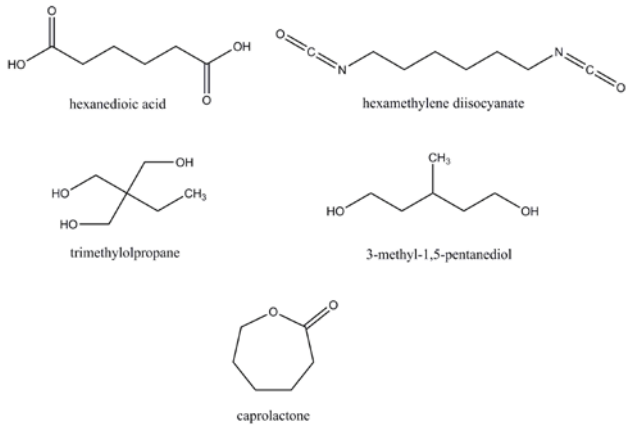
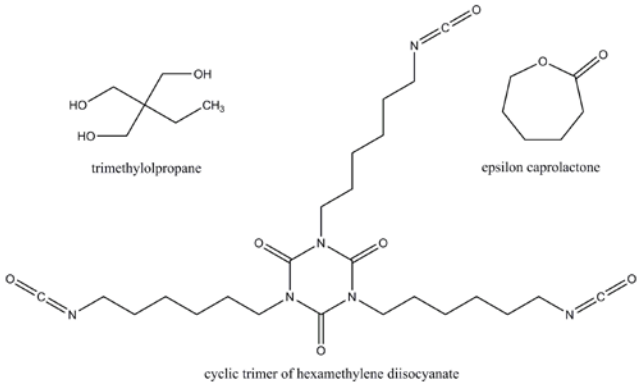
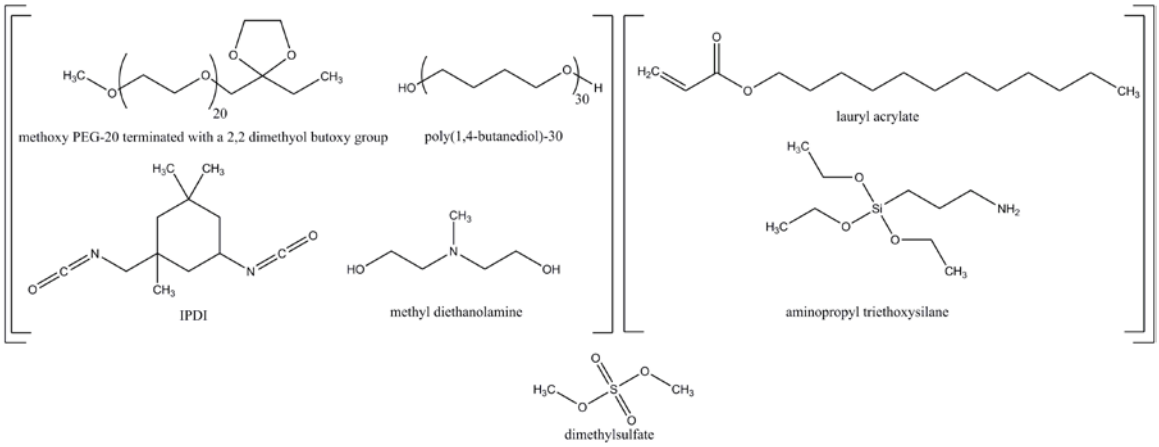
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-44	Polyurethane-44 is a copolymer of hexanedioic acid, hexamethylene diisocyanate (HDI), trimethylolpropane, 3-methyl-1,5-pentanediol (MPD), and caprolactone monomers. [Monomers:]  	Anticaking agent; bulking agent
Polyurethane-45	Polyurethane-45 is a polymer made by the reaction of epsilon caprolactone and trimethylolpropane with the cyclic trimer of hexamethylene diisocyanate. [Monomers:]  	Film former
Polyurethane-46	Polyurethane-46 is a complex urethane-based polymer. Initially, a pre-polymer is made by the reaction of isophorone diisocyanate (IPDI) with three different polyols. The polyols are poly(1,4-butanediol)-30, methoxy PEG-20 terminated with a 2,2 dimethyol butoxy group, and methyl diethanolamine. The pre-polymer is capped with the product formed by the reaction of lauryl acrylate and aminopropyl triethoxysilane (via Michael addition), and finally the amine groups from the methyl diethanolamine are quaternized with dimethylsulfate. [Monomers/reactants:]  	Hair conditioning agent

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

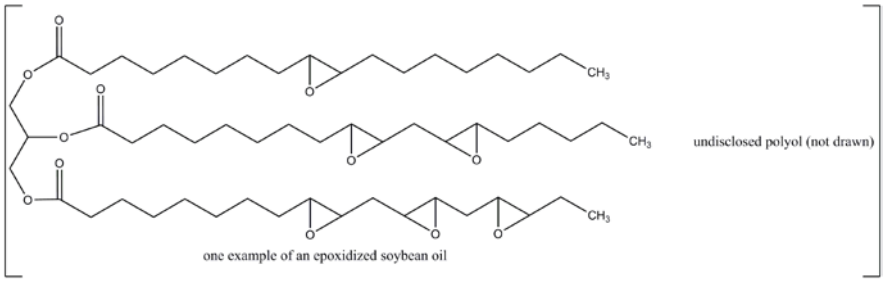
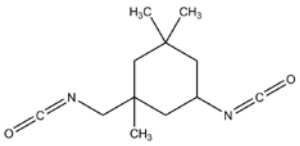
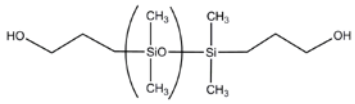
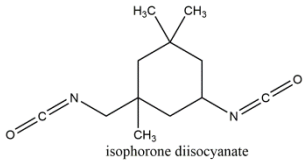
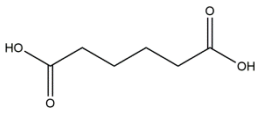
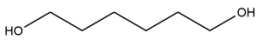
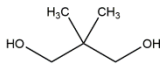
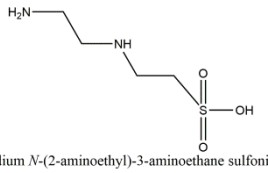
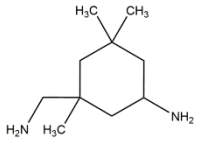
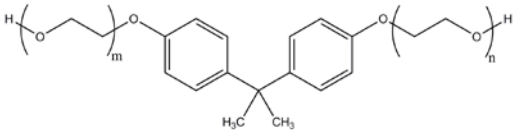
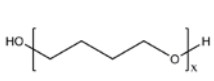
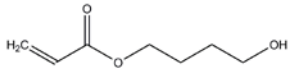
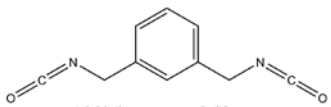
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-47	Polyurethane-47 is a copolymer made by reacting a polyester polyol with isophorone diisocyanate (IPDI) and then bis-hydroxypropyl dimethicone. The polyester polyol is made by reacting epoxidized soybean oil with a polyol. [Soybean oil consists essentially of triglycerides of oleic, linoleic, linolenic and saturated acids. Monomers:]  undisclosed polyol (not drawn) one example of an epoxidized soybean oil  IPDI  bis-hydroxypropyl dimethicone	Binder; film former; hair fixative; skin-conditioning agent-occlusive
Polyurethane-48	Polyurethane-48 is a copolymer of hexanediol, neopentyl glycol, adipic acid, isophorone diisocyanate, isophorone diamine and sodium *N*-(2-aminoethyl)-3-aminoethanesulfonic acid monomers. [Monomers:]  isophorone diisocyanate  adipic acid  hexanediol  neopentyl glycol  sodium *N*-(2-aminoethyl)-3-aminoethane sulfonic acid  isophorone diamine	Film former
Polyurethane-49	Polyurethane-49 is a copolymer of poly(1,4-butanediol), 1,3-bis(isocyanatomethyl)benzene, ethoxylated 4,4'-isopropylidenediphenol and 4-hydroxybutyl acrylate. [Monomers:]  ethoxylated 4,4'-isopropylidenediphenol  poly(1,4-butanediol)  4-hydroxybutyl acrylate  1,3-bis(isocyanatomethyl)benzene	Artificial nail builder

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

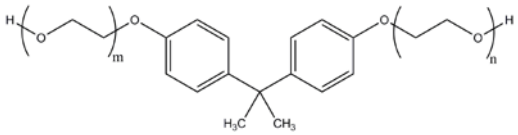
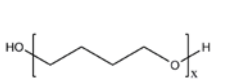
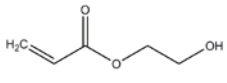
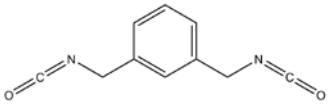
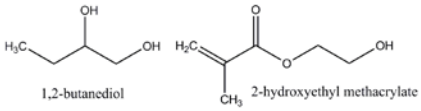
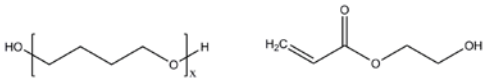
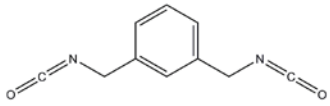
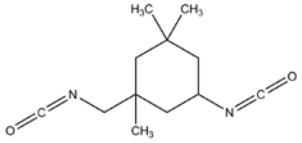
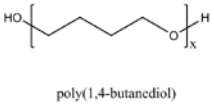
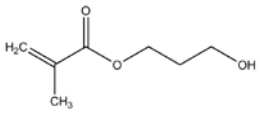
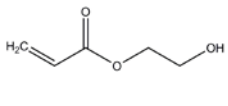
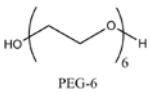
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-50	Polyurethane-50 is a copolymer of poly(1,4-butanediol), 1,3-bis(isocyanatomethyl)benzene, ethoxylated 4,4'-isopropylidenediphenol and 2-hydroxyethyl acrylate. [Monomers:]  ethoxylated 4,4'-isopropylidenediphenol  poly(1,4-butanediol)  2-hydroxyethyl acrylate  1,3-bis(isocyanatomethyl)benzene	Artificial nail builder
Polyurethane-51	Polyurethane-51 is a copolymer made by reacting 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate (HEMA), 1,2-Butanediol, poly(1,4-butanediol) and 1,3-bis(isocyanatomethyl)cyclohexane. [Monomers:]  1,2-butanediol 2-hydroxyethyl methacrylate  poly(1,4-butanediol) 2-hydroxyethyl acrylate  1,3-bis(isocyanatomethyl)benzene	Artificial nail builder
Polyurethane-52	Polyurethane-52 is a copolymer of poly(1,4-butanediol), isophorone diisocyanate, PEG-6, 2-hydroxyethyl acrylate and hydroxypropyl methacrylate. [Monomers:]  isophorone diisocyanate  poly(1,4-butanediol)  hydroxypropyl methacrylate  2-hydroxyethyl acrylate  PEG-6	Artificial nail builder

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

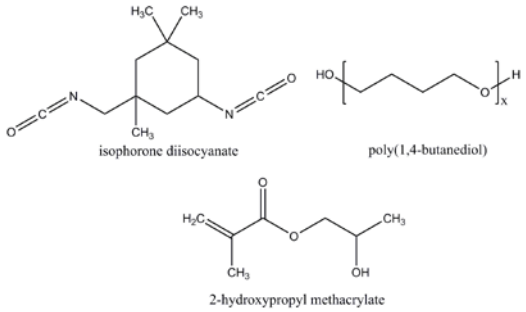
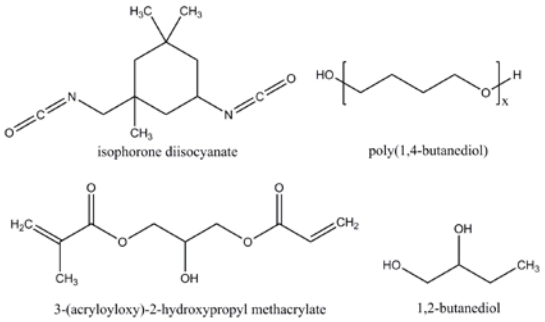
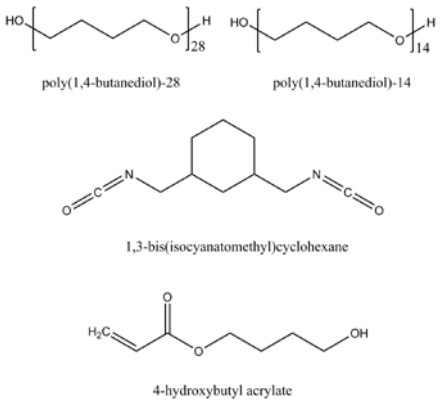
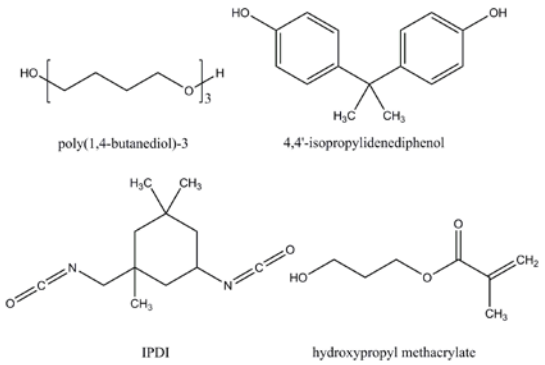
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-53	Polyurethane-53 is a copolymer of poly(1,4-butanediol), isophorone diisocyanate, and 2-hydroxypropyl acrylate. [Monomers:]  isophorone diisocyanate poly(1,4-butanediol) 2-hydroxypropyl methacrylate	Artificial nail builder
Polyurethane-54	Polyurethane-54 is a copolymer of poly(1,4-butanediol)-4, 1,2-butanediol, 3-(acryloyloxy)-2-hydroxypropyl methacrylate, and isophorone diisocyanate. [Monomers:]  isophorone diisocyanate poly(1,4-butanediol) 3-(acryloyloxy)-2-hydroxypropyl methacrylate 1,2-butanediol	Artificial nail builder
Polyurethane-55	Polyurethane-55 is the polymer formed by the reaction of poly(1,4-butanediol)-28, poly(1,4-butanediol)-14, and 1,3-bis(isocyanatomethy[l])cyclohexane. The polymer is capped with 4-hydroxybutyl acrylate. [Monomers:]  poly(1,4-butanediol)-28 poly(1,4-butanediol)-14 1,3-bis(isocyanatomethyl)cyclohexane 4-hydroxybutyl acrylate	Artificial nail builder
Polyurethane-56 1342288-58-7	Polyurethane-56 is a copolymer of 4,4'-isopropylidenediphenol, poly(1,4-butanediol)-3, hydroxypropyl methacrylate, and isophoronediisocyanate (IPDI). [Monomers:]  poly(1,4-butanediol)-3 4,4'-isopropylidenediphenol IPDI hydroxypropyl methacrylate	Binder

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

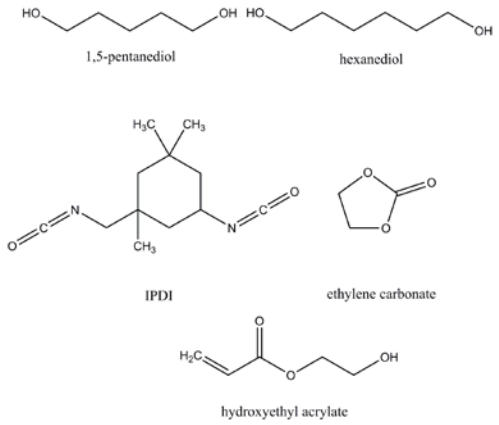
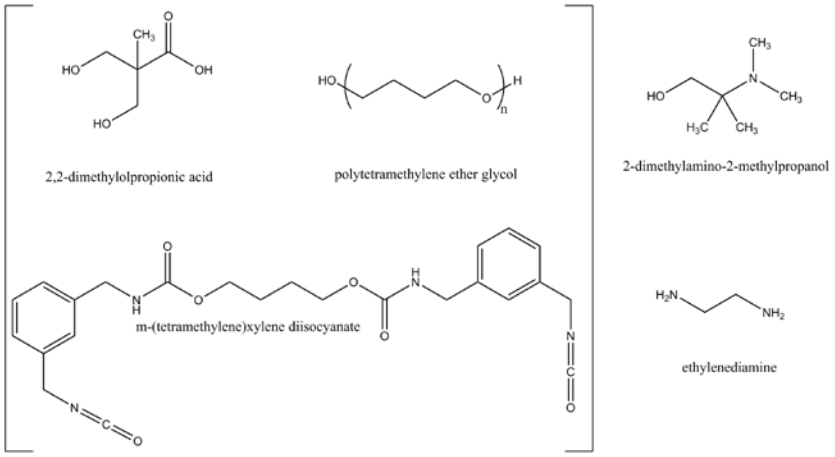
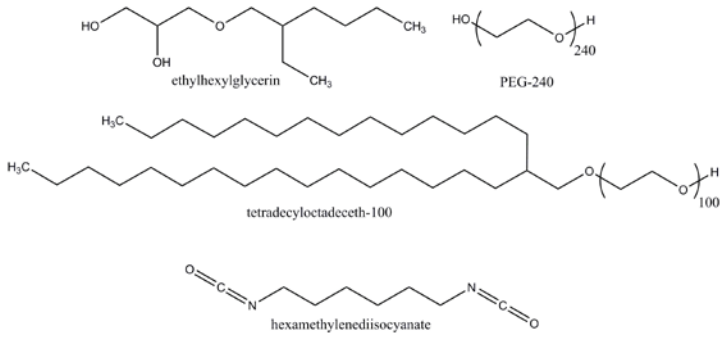
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-57 930592-39-5	Polyurethane-57 is a copolymer of ethylene carbonate, hexanediol, isophorone diisocyanate (IPDI), 1,5-pentanediol, and hydroxyethyl acrylate. [Monomers:]  	Binder
Polyurethane-58	Polyurethane-58 is a complex polymer made by reacting polytetramethylene ether glycol, 2,2-dimethylolpropionic acid, and *meta*-tetramethylenexylenediisocyanate to form a prepolymer. The prepolymer is dispersed in water with 2-dimethylamino-2-methylpropanol as neutralizer and chain-extended with ethylenediamine. [Monomers/reactants:]  	Film former; hair fixative; plasticizer; skin protectant; skin-conditioning agent-occlusive
Polyurethane-59	Polyurethane-59 is a copolymer of ethylhexylglycerin, PEG-240, tetradecyloctadeceth-100, and hexamethylenediisocyanate. [Monomers:]  	Dispersing agent-nonsurfactant; emulsion stabilizer; viscosity increasing agent-aqueous

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

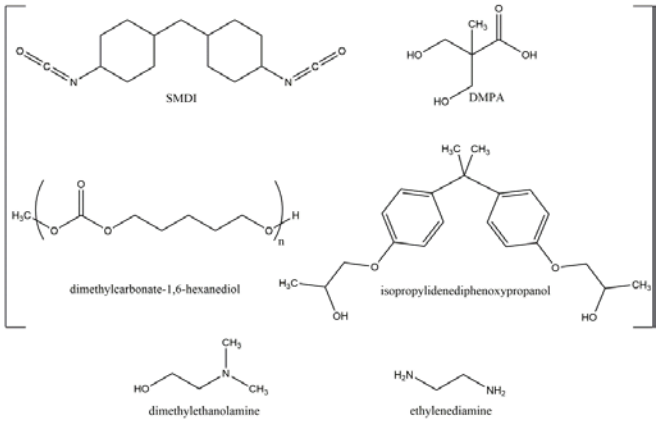
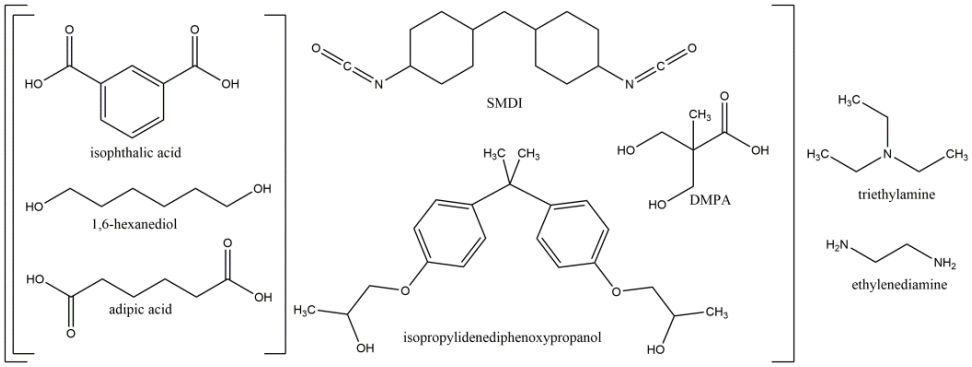
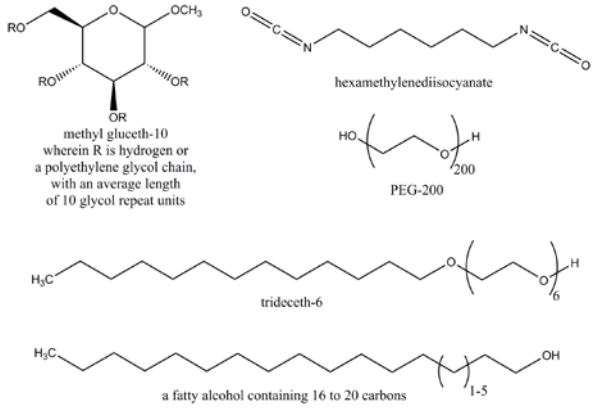
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-60	Polyurethane-60 is the complex polymer made by first reacting saturated methylene diphenyl diisocyanate (SMDI), dimethylolpropionic acid (DMPA), bisphenol a bis-(2-hydroxypropyl) ether, and dimethylcarbonate-1,6-hexanediol to form a prepolymer, followed by dispersion in water with dimethylethanolamine and subsequent chain extension with ethylenediamine. [Monomers/reactants:]  	Nail conditioning agent
Polyurethane-61	Polyurethane-61 is the complex polymer made by first reacting saturated methylene diphenyl diisocyanate (SMDI), dimethylolpropionic acid (DMPA), bisphenol a bis-(2-hydroxypropyl) ether, and the polyester polyol derived from isophthalic acid/1,6-hexanediol/adipic acid to form a prepolymer, followed by dispersion in water with triethylamine and subsequent chain extension with ethylenediamine. [Monomers:]  	Nail conditioning agent
Polyurethane-62	Polyurethane-62 is a copolymer of hexamethylene diisocyanate, PEG-200, methyl gluceth-10 and trideceth-6 monomers, end-capped with a fatty alcohol containing 16 to 20 carbons. [Monomers:]  	Binder; viscosity increasing agent-aqueous

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

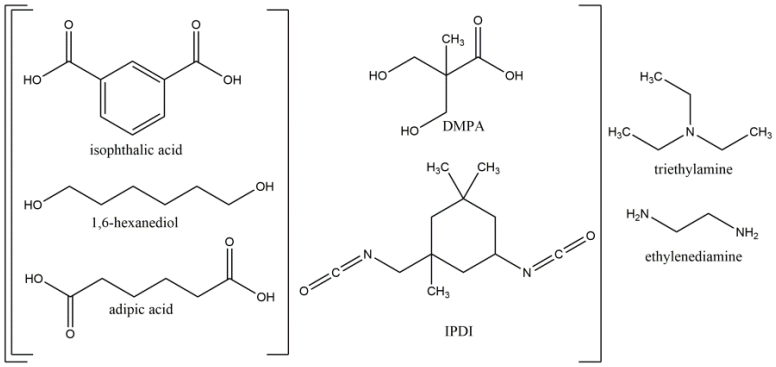
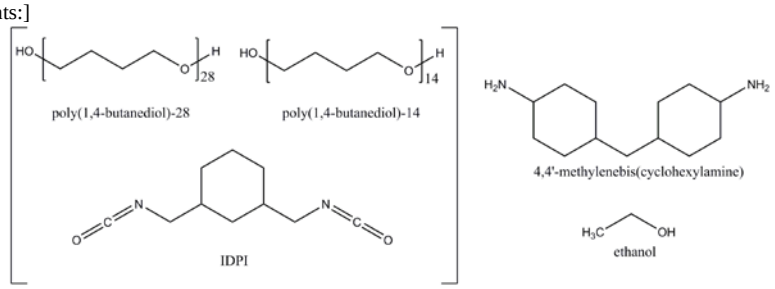
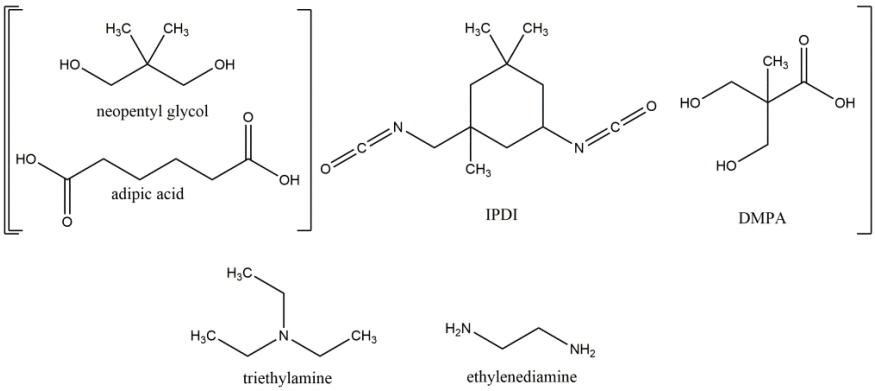
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-63	Polyurethane-63 is a complex polymer formed by first reacting dimethylolpropionic acid (DMPA) and isophorone diisocyanate (IPDI) with a polyester diol made with adipic acid, isophthalic acid, and hexanediol. The resulting prepolymer is then neutralized with triethylamine and finally, chain-extended with ethylenediamine. [Monomers/reactants:]  	Film former
Polyurethane-64	Polyurethane-64 is a urethane copolymer formed by a multi-step reaction. First, isophorone diisocyanate (IDPI) is reacted with a mixture of polytetrahydrofurans (PTHFs), also known as polybutylene glycols or polytetramethylene glycols. One of the PTHFs contains an average of 14 mols and the other an average of 28 mols of butylene glycol. The resulting polyurethane is reacted with 4,4'-methylenebis(cyclohexylamine) and finally the residual isocyanate groups are reacted with ethanol. [Monomers/reactants:]  	Film former
Polyurethane-65	Polyurethane-65 is a complex urethane copolymer made by reacting isophorone diisocyanate (IPDI) with a combination of dimethylolpropionic acid (DMPA) and a copolymer composed of neopentyl glycol and adipic acid. The resulting polymer is chain extended with ethylene diamine and neutralized with trimethylamine. [Monomers:]  	Artificial nail builders

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

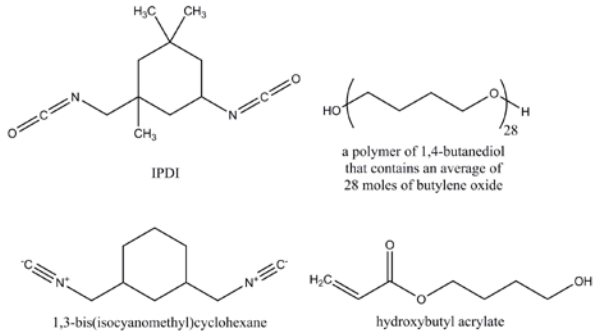
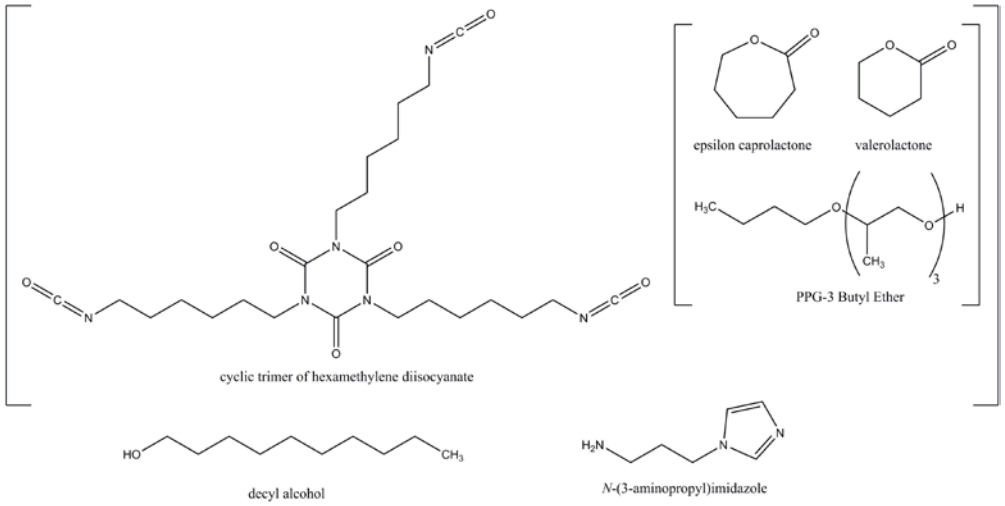
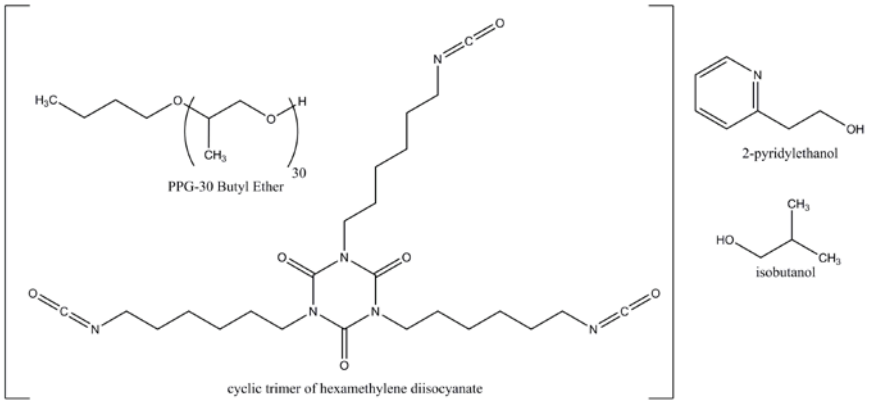
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-66	Polyurethane-66 is a urethane polymer formed by reacting a polymer of 1,4-butanediol that contains an average of 28 moles of butylene oxide with a combination of isophorone diisocyanate (IPDI) and 1,3-bis(isocyanomethyl)cyclohexane. The polymer is end-blocked with hydroxybutyl acrylate. [Monomers:]  	Binder
Polyurethane-67 1334242-38-4	Polyurethane-67 is a complex polymer made by reacting the trimer of hexamethylene diisocyanate (HDI isocyanurate trimer) with a copolymer that is made by reacting PPG-3 Butyl Ether with a mixture of epsilon-caprolactone and valerolactone. Some of the remaining isocyanate groups from the first reaction are reacted with decyl alcohol and in a third step, the remaining isocyanate groups are reacted with *N*-(3-aminopropyl)imidazole. [Monomers:]  	Surface modifier
Polyurethane-68 157420-46-7	Polyurethane-68 is a complex polymer that is made by reacting the trimer of hexamethylene diisocyanate (HDI isocyanurate trimer) with PPG-30 butyl ether. Some of the remaining isocyanate groups from the first reaction are reacted with 2-pyridylethanol and in a third step, the remaining isocyanate groups are reacted with 1-isobutanol. [Monomers:]  	Surface modifier

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

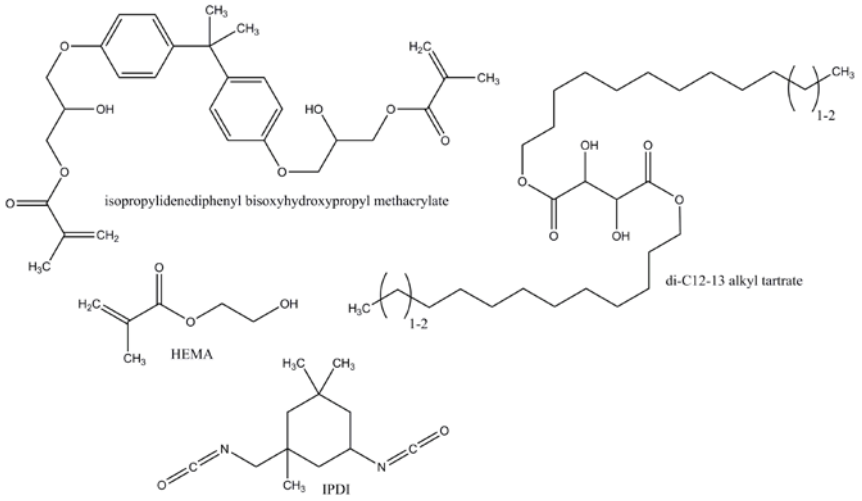
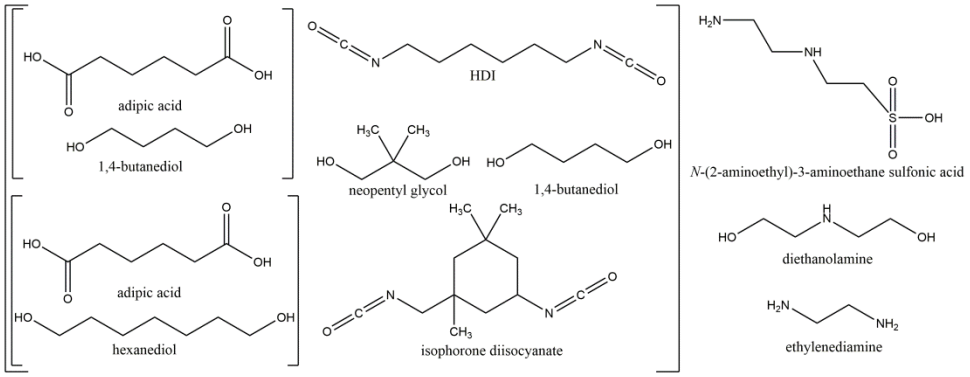
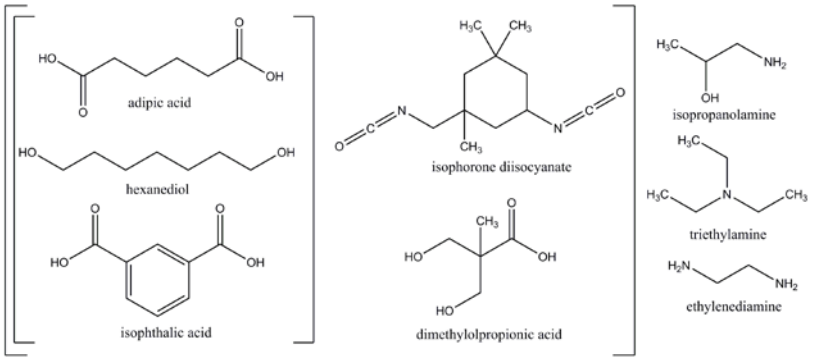
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-69 1668562-30-8	Polyurethane-69 is a copolymer of isopropylidenediphenyl bisoxyhydroxypropyl methacrylate, isophorone diisocyanate (IPDI), and di-C12-13 alkyl tartrate, end-capped with hydroxyethyl methacrylate (HEMA). [Monomers:]  	Skin-conditioning agent-miscellaneous
Polyurethane-70	Polyurethane-70 is a complex polymer that is formed by a multi-step synthesis. First, a mixture of polyester diols (a copolymer of adipic acid and 1,4-butanediol; and a copolymer of adipic acid and hexanediol; and neopentyl glycol and 1,4-butanediol are reacted with isophorone diisocyanate and hexamethylene diisocyanate (HDI). The resulting urethane polymer is reacted with the sodium salt of N-(2-aminoethyl)-3-aminoethanesulfonic acid, ethylene diamine, and diethanolamine. The final polymer is dispersed in water. [Monomers/reactants:]  	Film former
Polyurethane-71	Polyurethane-71 is a complex polymer that is formed by a multi-step synthesis. First, a polyester diol made by condensing hexanediol, adipic acid, and isophthalic acid is reacted with isophorone diisocyanate and dimethylolpropionic acid [DMPA]. The resulting pre-polymer is neutralized with triethylamine. The neutralized polymer is dispersed in water with isopropanolamine and ethylene diamine. [Monomers/reactants:]  	Binder; film former

Table 1. Definitions, idealized monomer structures, and functions of the ingredients in this safety assessment.[1, CIR Staff]

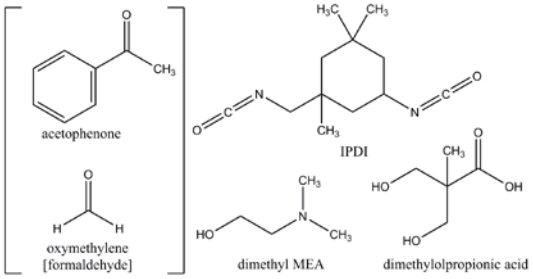
Ingredient CAS No.	Definition & Monomer Structures	Function(s)
Polyurethane-72 502761-95-7	Polyurethane-72 is a urethane polymer made by reacting hydrogenated acetophenone/oxymethylene copolymer with isophorone diisocyanate (IPDI), dimethylolpropanoic acid, and dimethyl MEA. The resulting polymer is dispersed in water. [Monomers/reactants:] 	Binder; film former; nail conditioning agent

Table 2. Previous reports on precursors, monomers, moieties, and related ingredients of polyurethanes in this safety assessment.

Moiety	Conclusion; year	Relevant to	Reference
Acetic Acid	Safe as used; 2012	Polyurethane-26	[22]
Adipic Acid; Hexanedioic Acid	Safe as used; 2012	Polyurethane-1, -2, -5, -6, -7, -9, -11, -13, -15, -17, -19, -21, -23, -33, -34, -35, -40, -48, -61, -63, -65, -70, -71	[6]
Alkyl PEG Ethers	Safe when formulated to be non-irritating; 2012	Polyurethane-39, -62	[23]
Butylene Glycol, Hexylene Glycol	Safe as used; 1985, 2006	Polyurethane-1, -2, -5, -6, -7, -17, -33	[3,5]
1,4-Butanediol; 1,5-Pentadiol; Hexanediol	1,4-Butanediol-Insufficient Data; 1,5-Pentadiol and Hexanediol-safe as used; 2017	Polyurethane-8, -11, -13, -21, -23, -24, -32, -34, -35, -41, -46, -48, -49, -50, -51, -52, -53, -55, -56, -57, -60, -61, -63, -66, -70, -71	[2]
1,2-Butanediol	Safe as used; 2012	Polyurethane-51, -54	[10]
Diethanolamine	Safe when formulated to be non-irritating; 2011	Polyurethane-10, -29, -46, -70	[15]
Ethylhexylglycerin	Safe as used; 2013	Polyurethane-59	[12]
Glycine Soja (Soybean) Oil	Safe as used; 2011	Polyurethane-47	[24]
HDI Polymers	17 are safe as used, 2 insufficient data; 2016	All	[29]
Bis-Hydroxyethoxypropyl Dimethicone	Safe as used; 2014	Polyurethane-28	[7,8]
Hydroxyethyl Acrylate/Sodium Acryloyldimethyl Taurate Copolymer	Safe as used; 2016	Polyurethane-9	[21]
Hydroxypropyl Methacrylate; Isopropylidenediphenyl Bisoxyhydroxypropyl Methacrylate; HEMA (Hydroxyethyl Methacrylate)	Safe in nail enhancement products when skin contact is avoided	Polyurethane-51, -52, -54, -56, -69	[11]
Isopropanolamine	Safe as used if not used in products containing *N*-nitrosating agents;1987, 2006	Polyurethane-71	[3,16]
Isostearic Acid (Sorbitan Isostearate)	Safe as used; 2014	Polyurethane-28	[9]
Methyl Gluceth-10	Safe as used; 2013	Polyurethane-62	[25]
PEGs; Triethylene Glycol	Triethylene Glycol and PEGs ≥4 are safe as used, 2010	Polyurethane-14, -39, -46, -52, -59, -62	[13]
Polyethylene	Safe as used; 2007, 2015	Polyurethane-8	[19]
PPG-3 Butyl Ether; PPG-30 Butyl Ether	Safe when formulated to avoid irritation; 2001 Insufficient Data Announcement; 2016	Polyurethane-67, -68	[17,26]
Propylene Glycol; PPGs	Propylene Glycol and PPGs ≥3 are safe when formulated to be non-irritating, 2012	Polyurethane-4, -9, -14, -36, -67, -68	[18]

Table 3. Precursors, monomers, moieties, and related ingredients of polyurethanes in this safety assessment that are either cosmetic ingredients that have not been reviewed or chemicals that are not cosmetic ingredients.[1]

Acetophenone*	*N*-(3-Aminopropyl)imidazole	Aminpropyl triethoxysilane
bis-Ethylaminoisobutyl-dimethicone monomers	Bisphenol A bis-(2-hydroxypropyl) ether	Butylene oxide
Caprolactone*	Cyclohexanedimethanol*	Decyl Alcohol*
Di-C12-13 Alkyl Tartrate*	3-Diethylamino-1,2-propanediol	Dihydroxypolyoxobutylene
Dilinoleyl Alcohol*	2-Dimethylamino-2-methylpropanol	Dimethylcarbonate-1,6-hexanediol
Dimethyl MEA*	Dimethylolbutanoic acid	Dimethylolpropanoic acid
Dimethylolpropionic acid (DMPA)	Dimethylsulfate	Ethoxylated 4,4'-isopropylidenediphenol
2-Ethyl-1-hexanol	Ethylene Carbonate*	Ethylene diamine
Ethylene glycol*	Ethylene oxide	Hydrazine
4-Hydroxybutyl acrylate	3-Hydroxy-2-(hydroxymethyl)-2-methyl-1-propionic acid	Hydroxypropyl dimethicone*
Hydroxybutyl acrylate	Hydroxyethyl acrylate	1-Isobutanol
Isophthalic acid	Isophorone diamine	4,4'-Isopropylidenediphenol*
Lauryl Acrylate*	4,4'-Methylenebis(cyclohexylamine); saturated methylene diphenyldiisocyanate (SMDI)	*N*-(2-Aminoethyl)-3-aminoethanesulfonic acid
Neopentyl glycol*	Oxymethylene	Poly(1,4)-butanediol
Polyalkylene glycol	Polybutylene glycol	Polycaprolactonetriol
Polyester diol	Polyperfluoroethoxymethoxy Difluorohydroxyethyl Ether*	Polytetrahydrofurans (PTHFs)
Polytetramethylene ether glycol	Polytetramethylene glycol	Propanoic anhydride
Propylene oxide	2-Pyridylethanol	Sodium *N*-(2-aminoethyl)-3-aminoethane sulfonate
Tetradecyloctadeceth	Trimethylamine*	Trimethylolpropane*
Valerolactone*		

*Cosmetic ingredient or closely related to a cosmetic ingredient listed in the wINCI that has not been reviewed. These are largely highly reactive molecules and not likely to be a significant component in final formulation and not likely to be released following polymerization and formulated in a cosmetic product.

Table 4. Diisocyanates used in manufacturing polyurethanes in this safety assessment.[1]

bis(Isocyanatomethyl)benzene	1,3-bis(Isocyanatomethyl)cyclohexane
Diphenylmethane diisocyanate	Cyclic trimer of hexamethylene diisocyanate
Hexamethylenediisocyanate	Isocyanato methylethylbenzene
Isophorone diisocyanate (IPDI)	Methylene bis-(4-cyclohexylisocyanate) (HMDI)
m-Tetramethylene diisocyanate*	meta-Tetramethylenexylenediisocyanate*
Saturated methylene diphenyldiisocyanate (SMDI)	Toluene diisocyanate

* These two ingredients have the same structure.

Table 5. Chemical and physical properties of polyurethanes.

Property	Value	Reference
Polyurethane-11		
Molecular Weight g/mol	> 1000,000	[35]
Polyurethane-14		
Molecular Weight g/mol	> 1000 20,000-35,000	[33] [64,65]
Water Solubility g/L	Miscible	[33]
Polyurethane-21[a]		
Viscosity kg/(s m) @ 25°C	0.160	[32]
Water Solubility	Miscible	[32]
Other solubility		
Propylene glycol	Insoluble	[32]
Ethanol	Insoluble	[32]
Dimethicone	Insoluble	[32]
Polyurethane-28		
Molecular Weight g/mol	> 30,000	[34]
Polyurethane-35		
Molecular Weight g/mol	> 1000	[36]
Disassociation constants (pKa, pKb) @°C		
pKa	0.5-4.5 est.	[36]
Polyurethane-36[b]		
Physical Form	Liquid	[41]
Color	Whitish	[41]
Molecular Weight g/mol	> 50,000	[41]
Density @ 20°C	~ 1.04	[41]
Viscosity kg/(s m)	0.02-0.20	[41]
Vapor pressure mmHg @ 20°C	17.25	[41]
Melting Point °C	~ 0	[41]
Boiling Point °C	100	[41]
Water Solubility	Completely miscible	[41]
Polyurethene-42		
Molecular Weight g/mol	> 36,000	[34]
Polyurethane-59		
Molecular Weight g/mol	25,631	[43]
Polyurethane-60[c]		
Physical Form	Liquid	[37]
Color	Light yellow	[37]
Molecular Weight g/mol	> 50,000	[37]
Density @ 20°C	~1.06	[37]
Viscosity kg/(s m)	0.05-0.5	[37]
Vapor pressure mmHg @ 20°C	17.25	[37]
Melting Point °C	~ 0	[37]
Boiling Point °C	100	[37]
Water Solubility	Completely miscible	[37]
Polyurethane-61[d]		
Physical Form	Liquid	[38]
Color	Light yellow	[38]
Molecular Weight g/mol	> 50,000	[38]
Density/Specific Gravity @ 20°C	~ 1.05	[38]
Viscosity kg/(s m)	0.02-0.5	[38]
Vapor pressure mmHg @ 20°C	17.25	[38]
Melting Point °C	~ 0	[38]
Boiling Point °C	100	[38]
Water Solubility	Completely miscible	[38]

Table 5. Chemical and physical properties of polyurethanes.

Property	Value	Reference
Polyurethane-62		
Physical Form	Powder	39
Color	White to off white	39
Molecular Weight g/mol	> 70,000 ~ 100,000	39 40
Density kg/m^3 @ 23^{o}C	1500	39
Water Solubility	Dispersible	39

est.=estimated

[a] Polyurethane-21 at 35% in an aqueous dispersion.

[b] Polyurethane-36 in an aqueous dispersion with approximately 1.0%-1.5% phenoxyethanol and triethylamine.

[c] Polyurethane-60 in an aqueous dispersion with approximately 0.0075% methylisothiazolinone (MI) and benzisothiazolinone and 1.5% triethylamine.

[d] Polyurethane-61 in an aqueous dispersion with approximately 0.0075% MI and benzisothiazolinone and 1.5% triethylamine.

Table 6. Methods of manufacture for polyurethanes.

Ingredient	Method of manufacture/monomers	Termination	Notes	Reference
Polyurethane-28	Condensation of an isocyanate component and molecules containing hydroxyl groups (sorbitan isostearate)	Addition of ethyl alcohol		34
Polyurethane-42	Condensation of an isocyanate component and molecules containing hydroxyl groups (di-C12-13 alkyl tartrate and hydrogenated dilinoleyl alcohol)	Addition of ethyl alcohol		34
Polyurethane-62	A proprietary anhydrous reaction		The resulting solid is then ground to the desired particle size.	40
Polyurethane-69	Condensation of an isocyanate component with di tetrabromobisphenol A diglycidyl ether isopropylidenediphenyl bisoxyhydroxypropyl methacrylate.	2 -H added to react with terminal isocyanate groups. The reaction is carried on until free isocyanate groups are not detected.		34

Table 7. Polyurethanes that are reported to be supplied in tradename mixtures as dispersions or solutions.

Ingredient	Percentage Solids	Solvent/medium	Reference
Polyurethane-1	30%	Water ~60%, ethanol (denatured) ~ 10%	30
Polyurethane-14	20%	Water	33
Polyruethane-21	35%	Water	32
Polyruethane-28	25%	Cyclopentasiloxane	34
Polyurethane-35	40%	Water	36
Polyurethane-36	39.0% - 41.0%	Water, approximately 1.0% - 1.5% (by weight) phenoxyethanol as a preservative and approximately 1.0% - 1.5% triethylamine as a neutralizing agent	41
Polyurethane-39	~ 20%	Water, ~ 1.2% preservative mixture of phenoxyethanol, phenylpropanol, 1,3-propane diol, caprylyl glycol, and α-tocopherol	31
Polyurethane-42	47.50%	Isododecane and ethanol	34
Polyurethane-60	37.0% - 39.0%	Water, approximately 0.0075% MI and benzisothiazolinone as preservatives, and approximately 1.3% (by weight) dimethylethanolamine as a neutralizing agent	37
Polyurethane-61	38.0% - 40.0%	Water, approximately 0.0075% MI and 75 ppm benzisothiazolinone as preservatives, and approximately 1.3% and 1.5% by weight, respectively, dimethylethanolamine as a neutralizing agent	38
Polyurethane-69	66%	Butyl acetate and ethanol	34

Table 8. Frequency of use according to duration and exposure of polyurethanes.[45,46]

Use type	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)
	Polyurethane-1		**Polyurethane-2**		**Polyurethane-6**		**Polyurethane-7**	
Total/range	**19**	**0.15-15**	**13**	**0.63-9**	**16**	**3-6**	**14**	**NR**
Duration of use[a]								
Leave-on	17	0.5-15	12	0.63-9	13	3-6	14	NR
Rinse-off	2	0.15	1	NR	3	NR	NR	NR
Diluted for (bath) use	NR	NR	NR	NR	NR	NR	NR	NR
Exposure type								
Eye area	10	0.9-4.6	8	NR	NR	NR	NR	NR
Incidental ingestion	NR	NR	NR	NR	NR	NR	NR	NR
Incidental Inhalation-sprays	4;2[b]	0.5-5	1[b]; 3[c]	NR	8	3-6	NR	NR
Incidental inhalation-powders	NR	NR	3[c]	0.63; 1.1[c]	NR	NR	6	NR
Dermal contact	2	2.3	7	0.63-1.1	NR	NR	14	NR
Deodorant (underarm)	NR	NR	NR	NR	NR	NR	NR	NR
Hair-noncoloring	9	0.5-5	NR	NR	16	3-6	NR	NR
Hair-coloring	NR	0.15	NR	NR	NR	NR	NR	NR
Nail	NR	15	NR	9	NR	NR	NR	NR
Mucous Membrane	NR	NR	NR	NR	NR	NR	NR	NR
Baby	NR	NR	NR	NR	NR	NR	NR	NR

	Polyurethane-8		**Polyurethane-9**		**Polyurethane-10**		**Polyurethane-11**	
Total/range	**1**	**NR**	**1**	**NR**	**NR**	**0.098-3**	**315**	**0.0015-5.2**
Duration of use								
Leave-on	1	NR	1	NR	NR	0.098-3	303	0.0072-5.2
Rinse-off	NR	NR	NR	NR	NR	NR	12	0.016
Diluted for (bath) use	NR	NR	NR	NR	NR	NR	NR	0.0015
Exposure type								
Eye area	NR	NR	NR	NR	NR	0.098	195	0.051-1.5
Incidental ingestion	NR	NR	NR	NR	NR	NR	2	0.058
Incidental Inhalation-sprays	NR	NR	NR	NR	NR	3[c]	2; 1[b]; 2[c]	0.0072-0.086
Incidental inhalation-powders	NR	NR	NR	NR	NR	NR	2; 2[c]	3-3.2; 0.024[c]
Dermal contact	1	NR	1	NR	NR	2	235	0.0015-3.2
Deodorant (underarm)	NR	NR	NR	NR	NR	NR	NR	NR
Hair-noncoloring	NR	NR	NR	NR	NR	3	NR	NR
Hair-coloring	NR	NR	NR	NR	NR	NR	NR	0.086
Nail	NR	NR	NR	NR	NR	NR	78	0.06-5.2
Mucous Membrane	NR	NR	NR	NR	NR	NR	14	0.0015-0.058
Baby	NR	NR	NR	NR	NR	NR	NR	NR

Table 8. Frequency of use according to duration and exposure of polyurethanes.[45,46]

Use type	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)
	Polyurethane-14		**Polyurethane-15**		**Polyurethane-16**		**Polyurethane-18**	
Total/range	**33**	**0.18-2.8**	**2**	**0.01-0.2**	**1**	**0.98**	**11**	**0.8**
Duration of use								
Leave-on	31	0.28	2	0.01-0.2	1	0.98	11	0.8
Rinse-off	2	0.18	NR	NR	NR	NR	NR	NR
Diluted for (bath) use	NR	NR	NR	NR	NR	NR	NR	NR
Exposure type								
Eye area	NR	0.62	NR	NR	NR	NR	NR	NR
Incidental ingestion	NR	NR	NR	0.036	NR	NR	NR	NR
Incidental Inhalation-sprays	10; 15[b]	0.6-2.4; 0.6-2.8[c]	NR	NR	NR	NR	3; 7[b]	NR
Incidental inhalation-powders	NR	NR	1	0.2	NR	NR	NR	NR
Dermal contact	2	0.62-1.5	2	0.01-0.2	1	0.98	1	NR
Deodorant (underarm)	NR	NR	NR	NR	NR	NR	NR	NR
Hair-noncoloring	31	0.18-2.8	NR	NR	NR	NR	10	0.8
Hair-coloring	NR	0.63	NR	NR	NR	NR	NR	NR
Nail	NR	NR	NR	NR	NR	NR	NR	NR
Mucous Membrane	NR	NR	NR	0.036	NR	NR	NR	NR
Baby	NR	NR	NR	NR	NR	NR	NR	NR

	Polyurethane-24		**Polyurethane-33**		**Polyurethane-34**		**Polyurethane-35**	
Total/range	**NR**	**0.0018-2**	**27**	**0.04-7.5**	**9**	**0.36-3.2**	**18**	**0.84-7**
Duration of use								
Leave-on	NR	0.0018-2	27	0.04-7.5	8	0.36-3.2	18	0.84-7
Rinse-off	NR	NR	NR	NR	1	NR	NR	NR
Diluted for (bath) use	NR	NR	NR	NR	NR	NR	NR	NR
Exposure type								
Eye area	NR	NR	2	0.5-1.8	8	3.2	17	2-7
Incidental ingestion	NR	NR	NR	NR	NR	2.9	NR	NR
Incidental Inhalation-sprays	NR	0.0018	NR	0.04	NR	0.36-0.75; 0.5[c]	NR	NR
Incidental inhalation-powders	NR	NR	NR	NR	NR	NR	NR	0.84[d]
Dermal contact	NR	NR	1	0.5-7.5	1	NR	4	0.84-2.9
Deodorant (underarm)	NR	NR	NR	NR	NR	NR	NR	NR
Hair-noncoloring	NR	0.0018-2	NR	0.04	NR	0.36-0.75	NR	NR
Hair-coloring	NR	NR	NR	NR	NR	NR	NR	NR
Nail	NR	NR	25	0.3-7.5	NR	NR	1	NR
Mucous Membrane	NR	NR	NR	NR	NR	2.9	NR	NR
Baby	NR	NR	NR	NR	NR	NR	NR	NR

Table 8. Frequency of use according to duration and exposure of polyurethanes.[45,46]

Use type	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)	Uses	Maximum Concentration (%)
	Polyurethane-39		Polyurethane-40		Polyurethane-46			
Total/range	**8**	**NR**	**9**	**NR**	**NR**	**0.2**		
Duration of use								
Leave-on	5	NR	9	NR	NR	NR		
Rinse-off	3	NR	NR	NR	NR	0.2		
Diluted for (bath) use	NR	NR	NR	NR	NR	NR		
Exposure type								
Eye area	NR	NR	3	NR	NR	NR		
Incidental ingestion	NR	NR	NR	NR	NR	NR		
Incidental Inhalation-sprays	3[b]	NR	2[b]	NR	NR	NR		
Incidental inhalation-powders	NR	NR	1	NR	NR	NR		
Dermal contact	1	NR	9	NR	NR	NR		
Deodorant (underarm)	NR	NR	NR	NR	NR	NR		
Hair-noncoloring	7	NR	NR	NR	NR	0.2		
Hair-coloring	NR	NR	NR	NR	NR	NR		
Nail	NR	NR	NR	NR	NR	NR		
Mucous Membrane	NR	NR	NR	NR	NR	NR		
Baby	NR	NR	NR	NR	NR	NR		

NR = Not Reported; Totals = Rinse-off + Leave-on + Diluted for Bath Product Uses.

[a] Because each ingredient may be used in cosmetics with multiple exposure types, the sum of all exposure types may not equal the sum of total uses.

[b] It is possible these products may be sprays, but it is not specified whether the reported uses are sprays.

[c] Not specified whether a powder or a spray, so this information is captured for both categories of incidental inhalation.

[d] It is possible these products may be powders, but it is not specified whether the reported uses are powders.

Table 9. Polyurethanes that have no reported uses in the VCRP or from an industry survey.[45,46]

Polyurethane-4	Polyurethane-5	Polyurethane-12
Polyurethane-13	Polyurethane-17	Polyurethane-19
Polyurethane-20	Polyurethane-21	Polyurethane-23
Polyurethane-25	Polyurethane-26	Polyurethane-27
Polyurethane-28	Polyurethane-29	Polyurethane-32
Polyurethane-36	Polyurethane-41	Polyurethane-42
Polyurethane-43	Polyurethane-44	Polyurethane-45
Polyurethane-47	Polyurethane-48	Polyurethane-49
Polyurethane-50	Polyurethane-51	Polyurethane-52
Polyurethane-53	Polyurethane-54	Polyurethane-55
Polyurethane-56	Polyurethane-57	Polyurethane-58
Polyurethane-59	Polyurethane-60	Polyurethane-61
Polyurethane-62	Polyurethane-63	Polyurethane-64
Polyurethane-65	Polyurethane-66	Polyurethane-67
Polyurethane-68	Polyurethane-69	Polyurethane-70
Polyurethane-71	Polyurethane-72	

Table 10. Precursors and monomers of the polyurethanes in this safety assessment that may be used in polyurethane resins that are used in adhesives that may come in contact with food in accordance with the FDA. [21CFR175.105]

1,4-Butanediol	1,4-Butanediol modified with adipic acid
1,4-Cyclohexanedimethanol [part of a polyester resin]	1,6-Hexanediol (CAS Reg. No. 629-11-8) [part of a polyester resin]
2-Hydroxypropyl methacrylate	4,4'-Isopropylidenediphenol
Dehydroacetic acid	Diethanolamine
Diethylene glycol adipic acid copolymer	Diethylene glycol copolymer of adipic acid and phthalic anhydride
Dipropylene glycol copolymer of adipic acid and phthalic anhydride	Ethylene glycol
Ethylenediamine	Ethylenediaminetetra-acetic acid, calcium, ferric, potassium, or sodium salts, single or mixed
Fats and oils derived from animal or vegetable sources, and the hydrogenated, sulfated, or sulfonated forms of such fats and oils	Hydroxyacetic acid
Isobutyl alcohol (isobutanol)	Isophthalic acid
Isopropanolamine (mono-, di-, tri-)	Monochloracetic acid
Octylphenoxypolyethoxy-polypropoxyethanol (13 moles of ethylene oxide and propylene oxide)	Polybutylene glycol (molecular weight 1,000)
Polyester of adipic acid, phthalic acid, and propylene glycol, terminated with butyl alcohol	Polyethylene glycol (molecular weight 200-6,000)
Polyethyleneadipate modified with ethanolamine with the molar ratio of the amine to the adipic acid less than 0.1 to 1	Propylene Glycol and *p,p'*-isopropylidenediphenol diether
Tetramethyl decynediol plus 1-30 moles of ethylene oxide	Toluene
Tridecyl alcohol	Triethylene Glycol

Table 11. Genotoxicity studies of polyurethanes.

Ingredient	Concentration/dose	Method	Results	Reference
Polyurethane-1	0 and 64-16,000 µg/plate of 30% Polyurethane-1 in water and ethanol	Ames test, SPT and PIT. *Salmonella typhimurium* (TA98, TA100, TA1535, and TA1537) and *Escherichia coli* (WP2 uvrA).	Not mutagenic	[30]
Polyurethane-21	100%; 35% solids	Ames test using *S. typhimurium* (strains TA97a, TA98, TA100, TA102, and TA1535)	Not a potential mutagen with and without metabolic activation	[85]
Polyurethane-28	Not specified	OECD TG 471 (Bacterial Reverse Mutation Test)	Not mutagenic	[34]
Polyurethane-35	Not specified	OECD TG 471 (Bacterial Reverse Mutation Test)	Not mutagenic	[36]
Polyurethane-42	Not specified	OECD TG 471 (Bacterial Reverse Mutation Test) using *S. typhimurium* and *E. coli*	Not mutagenic	[34]
Polyurethane-59	0, 312.5, 625, 1250, 2500, and 5000 µg/plate	Ames test, SPT and PIT, using *S. typhimurium* (TA98, TA100, TA1535, and TA1537) and *E. coli* (WP2 uvrA)	Not mutagenic	[31]
Polyurethane-62	Up to 5000 µg/plate (tested without trideceth-6 solvent; not specified if tested in water or other neutral solvent)	Ames test using *S. typhimurium* (strains TA98, TA100, TA1535, and TA1537) and *E. coli* (WPluvrA)	No cytotoxicity or precipitation was observed with or without metabolic activation. There were no significant increases in the frequency of revertant colonies.	[67]

PIT- pre-incubation test
SPT- standard plate test

Table 12. Human sensitization assays of polyurethanes.

Ingredient/test article	Concentration/Dose	Procedure	Results	Reference
Polyurethane-1	30% in a mascara	HRIPT (n=103)	Did not demonstrate a potential for eliciting dermal irritation or sensitization.	[73]
Polyurethane-1	28.5% in a mascara	HRIPT (n=103)	Did not demonstrate a potential for eliciting dermal irritation or sensitization	[72]
Polyurethane-14	9.61% solids in 54.9% ethanol. Control was 55% ethanol.	HRIPT (n=104). Semi-occlusion to upper arms of subjects 3 times per week for 3 weeks. Challenge was administered at same concentration. Test material was applied to the patch pad 15-30 min before application to the subjects.	Mild erythema was observed in both treatment and control groups in a few subjects at various evaluation periods during induction. No reaction was observed in any subject during challenge phase. Test material did not yield evidence of delayed contact hypersensitivity response in human subjects.	[74]
Polyurethane-21	60% in corn oil; 21% solids; 0.2 mL/0.2 g	HRIPT (n=50). Applied under occlusion	No adverse reactions of any kind were observed during the course of the study. Considered a non-primary irritant and a non-primary sensitizer.	[75]
Polyurethane-21	35% solids; 0.2 mL	HRIPT (n=100). Applied under occlusion	No adverse reactions of any kind were observed during the course of the study. Considered a non-primary irritant and a non-primary sensitizer.	[76]

Table 13. In vitro ocular assays of polyurethanes.

Ingredient	Concentration	Method	Results	Reference
Polyurethane-1	30% in a mascara tested at 0, 5%, 15%, 25%, 35%, and 50%; effective concentrations: 0.015%, 0.045%, 0.075%, 0.105%, and 0.15% Polyurethane-1	NRR using rabbit cornea fibroblasts	NR_{50} >50%; equivalent to a Draize score of 0-15 (slight irritant)	[77]
Polyurethane-1	30% in a mascara	HET-CAM	Mean scores: Hyperhemia - 3.5; hemorrhage-5.0; coagulation-0; overall-8.5. Equivalent to a Draize score of 15.1-30 (moderate irritant)	[77]
Polyurethane-1	30% in a mascara	REC	Cumulative SMCI-0.71. Slightly cytotoxic; equivalent to a Draize score of 0-15 (slight irritant)	[77]
Polyurethane-1			Considering the 3 assays above (NRR, HET-CAM, and REC), the estimated Draize classification of the test material might be a slight irritant with an estimated Draize score of 0-15.	[77]
Polyurethane-1	30% in a mascara tested at 50%; effective concentration-15%	HET-CAM	Mean cumulative score-1.25; predicted to be practically no irritation potential at 100%.	[80]
Polyurethane-1	30% in a mascara	BCOP	Mean score-1.0; minimally irritating. Estimated Draize score approaching 0 (non-irritant).	[79]
Polyurethane-1	30% in a mascara; tested at 20%; effective concentration-6%	EpiOcular™	Viability at 20 min-105%; 1 h-102%; 4 h-92%. ET_{50} >256 min. Estimated Draize score approaching 0 (non-irritant).	[78]
Polyurethane-14	10%, tested at 20%, final concentration 2%	EpiOcular™	ET_{50} was > 256 min. Estimated Draize ocular irritation score of the test material at 100% was 0 and Polyurethane-14 can be predicted to be a non-irritant.	[81]
Polyurethane-21	100% with 35% solids	HET-CAM	Mean cumulative score-0.50, predicted not to have ocular irritation potential	[83]
Polyurethane-21	100% with 35% solids	BCOP	Average score of 1.7. Predicted to be a non-irritant and expected to elicit a Draize score approaching 0.	[82]
Polyurethane-42	100% with 35% solids	HET-CAM	Moderate irritant	[34]
Polyurethane-42	100% with 35% solids	BCOP	Non-irritant	[34]
Polyurethane-62	Tested without trideceth-6 solvent; not specified if tested in water or other neutral solvent	EpiOcular™ assay using the reconstructed human cell epithelial (RhCE) model (conducted in accordance with OECD Draft Guideline titled Reconstructed Human Cornea-Like Epithelium (RhCE) Test Method for Identifying Chemicals Not Requiring Classification and Labelling for Eye Irritation or Serious Eye Damage)	Treated cells had 63% survival. Survival >60% is considered negative for ocular irritation. The control had expected result.	[67]

BCOP = bovine corneal opacity and permeability assay; ET_{50} = The estimated time at which the percent viability would be 50%; HET-CAM = chorioallantoic membrane of the embryonic hen's egg assay; NR_{50} = The amount of test substance that will cause a 50% decrease in neutral red uptake measured by optical density; NRR = Neutral red release assay; REC = Reconstituted human epithelial culture assay; SMCI = Simplified mean cytotoxicity index

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