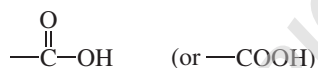


# 1

## ACIDS, CARBOXYLIC

### 1.1 GENERAL DISCUSSION

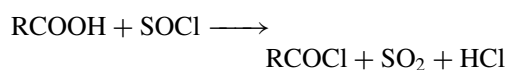
Carboxylic acids are weak organic acids that exhibit the following characteristics of acids: (1) undergo dissociation in aqueous solutions, forming a carboxylate ion  $\text{RCOO}^-$  and  $\text{H}^+$  (proton) or a hydronium ion,  $\text{H}_3\text{O}^+$  (hydronium); (2) transfer protons to bases forming salts; and (3) the water-soluble acids have a sour taste. The carboxylic acids are characterized by carboxyl functional groups,



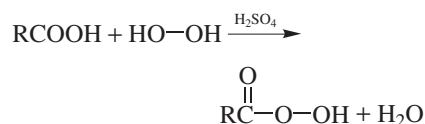
consisting of carbonyl and hydroxyl groups. The general formula for the homologous series of monocarboxylic acids is  $\text{C}_n\text{H}_{2n}\text{O}_2$  or  $\text{R—COOH}$ , where R is an alkyl group. Dicarboxylic acids such as oxalic or succinic acid contain two  $\text{—COOH}$  groups. The acid strength of carboxylic acids is much lower than those of mineral acids.

Carboxylic acids form a large number of derivatives that are very useful. The important general reactions include (1) the formation of esters when these compounds react with alcohols in the presence of an acid catalyst,

(2) reaction with alkalis to form the corresponding metal salts, (3) reduction to primary alcohols, and (4) decomposition to ketones on heating with a catalyst. Carboxylic acids react with sodium azide and sulfuric acid or with hydrazoic acid (Schmidt reaction) in an inert solvent such as chloroform to produce amines. Many aliphatic amines are strong irritants to the skin and respiratory tract (Chapter 8). Reactions with inorganic acid chlorides may produce acyl halides ( $\text{RCOCl}$ ), many of which are strongly corrosive, causing severe burns. With thionyl chloride, the reaction products include the toxic gases sulfur dioxide and hydrogen chloride.



Heat- and shock-sensitive peroxyacids (peracids) are formed when carboxylic acids react with hydrogen peroxide in the presence of methanesulfonic acid or sulfuric acid, or a strong acid cation-exchange resin:



The toxicity of monocarboxylic acids is moderate to low, and decreases with increase in carbon chain length. Some of the lower dicarboxylic acids exhibit moderate to high toxicity. The high-molecular-weight long-chain fatty acids are nontoxic compounds. Low-molecular-weight carboxylic acids are combustible but not flammable liquids. A fire or explosion hazard due to carboxylic acids is uncommon. However, there are cases of formic acid bottles exploding when opened after long storage. As mentioned earlier, among the most hazardous reactions is the formation of peroxyacids with hydrogen peroxide. This reaction occurs with a concentrated solution of hydrogen peroxide and in the presence of an acid catalyst. Reactions with strong oxidizing agents such as perchlorates, permanganates, chromic acid, nitric acid, and ozone may proceed to explosive violence.

### Analysis

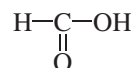
The carboxylic functional group,  $-\text{COOH}$ , can be identified by IR and nuclear magnetic resonance NMR spectra. The characteristic IR absorption of saturated aliphatic acids produces strong bands at  $1725\text{--}1700\text{ cm}^{-1}$  and  $1320\text{--}1211\text{ cm}^{-1}$  due to C–O stretching absorption, and a broad band of O–H stretching absorption over the region  $3500\text{--}2500\text{ cm}^{-1}$  with various submaxima. The C–H stretching absorptions occur at  $2960\text{--}2850\text{ cm}^{-1}$ . Individual carboxylic acids may be analyzed by a GC technique using an FID) or by GC/MS. The acid may be converted to a suitable derivative and the molecular ion may be identified as a further confirmatory test. NIOSH Method 1603 (NIOSH 1984, Suppl. 1989) describes the analysis of acetic acid in air. Between 20 and 300 L of air at a flow rate of  $0.01\text{--}1.0\text{ L/min}$  is passed over coconut shell charcoal. The analyte is desorbed with 1 mL of formic acid, allowed to stand for an hour, and injected into a GC equipped with an FID. Suitable GC columns for this analysis are 0.3% SP-1000 + 0.3%  $\text{H}_3\text{PO}_4$  on Carbopack A, 0.3% Carbowax 20M + 0.1%

$\text{H}_3\text{PO}_4$  on Carbopack C, and Carbopack B 60/80 mesh + 3% Carbowax 20M + 0.5%  $\text{H}_3\text{PO}_4$ . This method should also be effective for the analysis of  $\text{C}_3\text{--}$  and  $\text{C}_4\text{--}$  carboxylic acids in air.

### 1.2 FORMIC ACID

EPA Designated Toxic Waste, RCRA Waste Number U123; DOT Label: Corrosive Material, UN 1779

Formula  $\text{CH}_2\text{O}_2$ ; MW 46.03; CAS [64-18-6]  
Structure:



the first member of the homologous series of carboxylic acids. The carboxyl group is attached to a hydrogen atom rather than to a carbon atom as in all other carboxylic acids. The acid strength of formic acid is about 10 times greater than that of acetic acid but less than that of strong mineral acids.

Synonyms: methanoic acid; formylic acid

### Uses and Exposure Risk

Formic acid occurs in the stings of ants and bees. It is used in the manufacture of esters and salts, dyeing and finishing of textiles and papers, electroplating, treatment of leather, and coagulating rubber latex, and also as a reducing agent.

### Physical Properties

Colorless liquid with a pungent, penetrating odor; boils at  $100.5^\circ\text{C}$  ( $212.9^\circ\text{F}$ ); freezes at  $9.4^\circ\text{C}$  ( $48.92^\circ\text{F}$ ); density 1.220 at  $20^\circ\text{C}$  ( $68^\circ\text{F}$ ); miscible in water, alcohol, and ether;  $pK_a$  3.74 at  $25^\circ\text{C}$  ( $77^\circ\text{F}$ ).

### Health Hazard

Formic acid is a low to moderately toxic but highly caustic compound. It is corrosive

to the skin, and contact with pure liquid can cause burns on the skin and eyes. It is more toxic than acetic acid. Formic acid is a metabolite of methanol responsible for the latter's toxicity. Thus, the acute acidosis of methanol is due to the *in vivo* formation of formic acid generated by the action of enzymes, alcohol dehydrogenase, and aldehyde dehydrogenase. Ingestion of formic acid can cause death. Long-term exposure to formic acid can cause kidney damage. Green et al. (2003) have found increased excretion of formic acid and the development of kidney toxicity in rats following chronic dosing with trichloroethanol and trichloroethylene. Such induced nephrotoxicity was attributed to excretion and acidosis from formic acid.

Exposure to formic acid vapors may produce irritation of the eyes, skin, and mucous membranes, causing respiratory distress.

LD<sub>50</sub> value, oral (mice): 700 mg/kg

LC<sub>50</sub> value, inhalation (mice): 6200 mg/m<sup>3</sup>/15 minutes

Liesivuori and Savolainen (1991) studied the biochemical mechanisms of toxicity of methanol and formic acid. Formic acid is an inhibitor of the enzyme mitochondrial cytochrome oxidase causing histotoxic hypoxia. It is, however, a weaker inhibitor than cyanide and hydrosulfide anions. The effects of its acidosis are dilation of cerebral vessels, facilitation of the entry of calcium ions into cells, loss of lysosomal latency, and deranged production of ATP, the latter affecting calcium reabsorption in the kidney tubules. Also, urinary acidification from formic acid and its excretion may cause continuous recycling of the acid by the tubular cell Cl<sup>-</sup>/formate exchanger. Such sequence of events probably causes an accumulation of formate in urine. Other than methanol, methyl ethers, esters, and amides also metabolize forming formic acid.

Chan et al. (1995) have reported a case of systemic toxicity developed in a 3-year-old girl burned by formic acid over 35% of

her total body surface area. The metabolic acidosis in this case was profound with the serum formate level reaching at 400 µg/mL, the highest reported in the literature for poisoning by any route. The patient was successfully treated with hemodialysis, IV bicarbonate, and supportive measures.

In a study on the poisoning effect of methanol and its toxic metabolite formic acid on the retinal photoreceptors and the retinal pigment epithelial cells Treichel et al. (2004) found that the cytotoxic effects were greater in the retinal photoreceptors although both the cell types accumulated similar levels of formate when their cultured cell lines were exposed to formic acid *in vitro*. Formic acid treatment in both cell types produced decreases in glutathione and glutathione peroxidase.

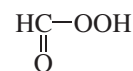
#### Exposure Limits

TLV-TWA 5 ppm (~9 mg/m<sup>3</sup>) (ACGIH, MSHA, OSHA, and NIOSH); IDLH 100 ppm (180 mg/m<sup>3</sup>) (NIOSH).

#### Fire and Explosion Hazard

Combustible liquid; flash point (open cup) 69°C (156°F), flash point of 90% solution 50°C (122°F); vapor pressure 23–33 torr at 20°C (68°F); autoignition temperature 601°C (1114°F) for anhydrous liquid and 456°C (852°F) for 90% solution. Formic acid vapors form explosive mixtures with air within the range 18–57% by volume in air.

When mixed with a concentrated solution of hydrogen peroxide, formic acid can form peroxyformic acid,



which is highly sensitive to shock and heat and can explode. The reaction is catalyzed by a mineral acid catalyst. Its reaction with other strong oxidizers can be violent. Explosions arising from reaction of formic acid with furfuryl alcohol and thallium nitrate trihydrate

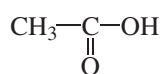
in the presence of vanillin have been documented (NFPA 1986). Formic acid decomposes to carbon monoxide and water upon heating or when mixed with concentrated sulfuric acid. Robertson (1989) reported an explosion in which a stores clerk lost an eye when he lifted a 1-L bottle of 98–100% formic acid off the shelf. Slow decomposition to carbon monoxide and water on prolonged storage produced sufficient gas pressure, which probably ruptured the sealed glass container.

### 1.3 ACETIC ACID

DOT Label: Corrosive Material, UN 2789 (glacial, more than 80% acid by weight) and UN 2789 (between 25 and 80% acid by weight)

Formula  $C_2H_4O_2$ ; MW 60.06; CAS [64-19-7]

Structure:



Synonyms: glacial acetic acid; ethanoic acid; methanecarboxylic acid; vinegar acid

#### Uses and Exposure Risk

Acetic acid occurs in vinegar. It is produced in the destructive distillation of wood. It finds extensive application in the chemical industry. It is used in the manufacture of cellulose acetate, acetate rayon, and various acetate and acetyl compounds; as a solvent for gums, oils, and resins; as a food preservative in printing and dyeing; and in organic synthesis.

#### Physical Properties

Colorless liquid with a pungent odor of vinegar; boils at 118°C (244.4°F); solidifies at 16.7°C (62.06°F); density of the liquid 1.049 at 25°C (77°F); miscible with water and most

organic solvents, insoluble in carbon disulfide; weakly acid,  $pK_a$  4.74, pH of 1.0 M, 0.1 M, and 0.01 M aqueous solutions: 2.4, 2.9, and 3.4, respectively.

#### Health Hazard

Glacial acetic acid is a highly corrosive liquid. Contact with the eyes can produce mild to moderate irritation in humans. Contact with the skin may produce burns. Ingestion of this acid may cause corrosion of the mouth and gastrointestinal tract. The acute toxic effects are vomiting, diarrhea, ulceration, or bleeding from intestines and circulatory collapse. Death may occur from a high dose (20–30 mL), and toxic effects in humans may be felt from ingestion of 0.1–0.2 mL. An oral  $LD_{50}$  value in rats is 3530 mg/kg (Smyth 1956).

Glacial acetic acid is toxic to humans and animals by inhalation and skin contact. In humans, exposure to 1000 ppm for a few minutes may cause eye and respiratory tract irritation. Rabbits died from 4-hour exposure to a concentration of 16,000 ppm in air.

#### Exposure Limits

TLV-TWA 10 ppm ( $\sim 25 \text{ mg/m}^3$ ) (ACGIH, OSHA, and MSHA); TLV-STEL 15 ppm ( $37.5 \text{ mg/m}^3$ ) (ACGIH).

#### Fire and Explosion Hazard

Combustible liquid; flash point (closed cup) 39°C (103°F); vapor pressure 11 torr at 20°C (68°F); autoignition temperature 463°C (867°F) (NFPA 1986), 426°C (800°F) (Meyer 1989). The vapor of acetic acid forms explosive mixtures with air; the LEL and UEL values are 4% and 16% by volume of air, respectively. Fire-extinguishing agent: water spray, dry chemical,  $CO_2$ , or “alcohol” foam; use water to keep the fire-exposed containers cool and to flush and dilute the spill.

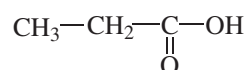
Acetic acid may react explosively with the fluorides of chlorine and bromine: chlorine trifluoride and bromine pentafluoride

(Mellor 1946, Suppl. 1971). Explosions can result when acetic acid is mixed with strong oxidizing agents such as perchlorates, permanganates, chromium trioxide, nitric acid, ozone, and hydrogen peroxide and warmed. When warmed with ammonium nitrate, the mixture may ignite (NFPA 1986). Acetic acid may react violently with phosphorus isocyanate (Mellor 1946, Suppl. 1971). It may react violently and vigorously with potassium hydroxide and sodium hydroxide, respectively.

#### 1.4 PROPIONIC ACID

DOT Label: Corrosive Material, UN 1848  
Formula  $C_3H_6O_2$ ; MW 74.09; CAS [79-09-4]

Structure:



Synonyms: propanoic acid; ethylformic acid; ethanecarboxylic acid; carboxyethane

#### Uses and Exposure Risk

Propionic acid is used in the production of propionates used as mold inhibitors and preservatives for grains and wood chips, in the manufacture of fruit flavors and perfume bases, and as an esterifying agent.

#### Physical Properties

Colorless oily liquid with pungent odor; boils at  $141^\circ C$  ( $285.8^\circ F$ ); melts at  $-21^\circ C$  ( $-5.8^\circ F$ ); density 0.993 at  $20^\circ C$  ( $68^\circ F$ ); soluble in water and most organic acids.

#### Health Hazard

Propionic acid is a toxic and corrosive liquid. Contact with the eyes can result in eye injury. Skin contact may cause burns. Acute exposures to its vapors can cause eye redness, mild to moderate skin burns,

and mild coughing (ACGIH 1986). Ingestion of high amounts of this acid may produce corrosion of the mouth and gastrointestinal tract in humans. Other symptoms include vomiting, diarrhea, ulceration, and convulsions. Oral  $LD_{50}$  value in rats is about 3500–4300 mg/kg. The  $LD_{50}$  value by skin absorption in rabbits is 500 mg/kg.

#### Exposure Limit

TLV-TWA 10 ppm ( $\sim 30$  mg/m<sup>3</sup>) (ACGIH).

#### Fire and Explosion Hazard

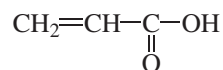
Combustible liquid; flash point (closed cup)  $54.5^\circ C$  ( $130^\circ F$ ), (open cup)  $58^\circ C$  ( $136^\circ F$ ); autoignition temperature  $465^\circ C$  ( $870^\circ F$ ); vapor forms explosive mixtures in air within the range 2.9–12.1% by volume in air. Reactions with strong oxidizers can become violent, especially at elevated temperatures.

#### 1.5 ACRYLIC ACID

EPA Designated Toxic Waste, RCRA Waste Number U008; DOT Label: Corrosive Material, UN 2218

Formula  $C_3H_4O_2$ ; MW 72.07; CAS [79-10-7]

Structure:



an unsaturated monocarboxylic acid containing a vinyl group

Synonyms: glacial acrylic acid; propenoic acid; acroleic acid; ethylenecarboxylic acid; vinylformic acid

#### Uses and Exposure Risk

Acrylic acid is produced by oxidation of acrolein or hydrolysis of acrylonitrile. It is used in the manufacture of plastics; in paints, polishes, and adhesives; and as coatings for leather.

**Physical Properties**

Colorless liquid with an acrid odor; corrosive; boils at 141°C (285.8°F); solidifies at 14°C (57.2°F); polymerizes when exposed to air; density 1.052; miscible with water, alcohol, ether, and other organic solvents.

**Health Hazard**

Acrylic acid is a corrosive liquid that can cause skin burns. Spill into the eyes can damage vision. The vapors are an irritant to the eyes. The inhalation hazard is of low order. An exposure to 4000 ppm for 4 hours was lethal to rats. The oral LD<sub>50</sub> values reported in the literature show wide variation. The dermal LD<sub>50</sub> value in rabbits is 280 mg/kg.

**Exposure Limit**

TLV-TWA 10 ppm (30 mg/m<sup>3</sup>) (ACGIH).

**Fire and Explosion Hazard**

Combustible liquid; flash point (closed cup) 54°C (130°F), (open cup) 68°C (155°F); vapor pressure 31 torr at 25°C (77°F); vapor density 2.5 (air = 1); autoignition temperature 360°C (680°F). Vapors of acrylic acid form explosive mixtures with air within the range 2.9–8.0% by volume in air. Fire-extinguishing agent: water spray, "alcohol" foam, dry chemical, or CO<sub>2</sub>; use a water spray to flush and dilute the spill and to disperse the vapors.

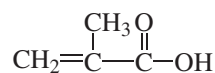
Acrylic acid may readily polymerize at ambient temperature. Polymerization may be inhibited with 200 ppm of hydroquinone monomethyl ether (Aldrich 2006). In the presence of a catalyst or at an elevated temperature, the polymerization rate may accelerate, causing an explosion. The reactions of acrylic acid with amines, imines, and oleum are exothermic but not violent. Acrylic acid should be stored below its melting point with a trace quantity of polymerization inhibitor. Its reactions with strong oxidizing substances can be violent.

**1.6 METHACRYLIC ACID**

DOT Label: Corrosive Material, UN 2531

Formula C<sub>4</sub>H<sub>6</sub>O<sub>2</sub>; MW 86.10; CAS [79-41-4]

Structure:



Synonyms: 2-methylacrylic acid; 2-methyl propenoic acid

**Uses and Exposure Risk**

Methacrylic acid is used in the manufacture of methacrylate resins and plastics.

**Physical Properties**

Colorless liquid with an acrid and repulsive odor; boils at 163°C (325.4°F); solidifies at 16°C (60.8°F); density 1.015 at 20°C (68°F); soluble in water and most organic solvents; polymerizes readily.

**Health Hazard**

Methacrylic acid is a highly corrosive liquid. Contact with eyes can result in blindness. Skin contact may produce burns. No inhalation toxicity was observed in rats. Exposure to its vapors may produce skin and eye irritation, which can be mild to moderate. A dermal LD<sub>50</sub> value in rabbits is 500 mg/kg.

**Exposure Limit**

TLV-TWA 20 ppm (~70 mg/m<sup>3</sup>) (ACGIH).

**Fire and Explosion Hazard**

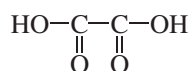
Combustible liquid; flash point (open cup) 76°C (170°F); vapor pressure <0.1 torr at 20°C (68°F). Fire-extinguishing agent: water spray, "alcohol" foam, dry chemical, or CO<sub>2</sub>; use a water spray to dilute and flush the spill and to disperse the vapors.

Methacrylic acid polymerizes readily. The reaction is exothermic. The rate of reaction accelerates on heating, which may result in violent rupture of closed containers. The polymerization may be inhibited with a trace quantity of hydroquinone and hydroquinone monomethyl ether (Aldrich 2006). The acid may be stored safely below its melting point.

## 1.7 OXALIC ACID

Formula  $C_2H_2O_4$ ; MW 90.04; CAS [144-62-7]; Oxalic acid dihydrate,  $C_2H_2O_2 \cdot 2H_2O$ , CAS [6153-56-6]

Structure:



a dicarboxylic acid

Synonyms: ethanedionic acid; ethanedioic acid

### Uses and Exposure Risk

Oxalic acid occurs in the cell sap of *Oxalis* and *Rumex* species of plants as the potassium and calcium salt. It is the metabolic product of many molds (Merck 1989). There are a large number of applications of this compound, including indigo dyeing; calico printing; removal of paint, rust, and ink stains; metal polishing; bleaching leather; in pesticide compositions and manufacture of oxalates. It is also used as an analytical reagent and as a reducing agent in organic synthesis.

Addition of oxalic acid to chromic acid for the anodizing of Al alloy has been reported to modify the morphology and improve the corrosion performance of anodic films (Moutarlier et al. 2004). Also, it is a very effective additive for the ozone treatment of cellulose. It prevents the degradation of cellulose from ozone bleaching.

### Physical Properties

White powder (anhydrous) or colorless crystals (dihydrate); odorless; hygroscopic; the anhydrous acid melts at  $189.5^\circ\text{C}$  ( $373.1^\circ\text{F}$ ) (decomposes) and the dihydrate melts at  $102^\circ\text{C}$  ( $215.6^\circ\text{F}$ ); sublimes at  $157^\circ\text{C}$  ( $314.6^\circ\text{F}$ ); soluble in water, alcohol, and glycerol, insoluble in benzene, chloroform, and petroleum ether.

### Health Hazard

Oxalic acid is a strong poison. The toxic symptoms from ingestion include vomiting, diarrhea, and severe gastrointestinal disorder, renal damage, shock, convulsions, and coma. Death may result from cardiovascular collapse. The toxicity arises as oxalic acid reacts with calcium in the tissues to form calcium oxalate, thereby upsetting the calcium/potassium ratio (ACGIH 1986). Deposition of oxalates in the kidney tubules may result in kidney damage (Hodgson et al. 1988).

Oxalic acid may be absorbed into the body through skin contact. It is corrosive to the skin and eyes, producing burns. Dilute solutions of 10% strength may be a mild irritant to human skin. However, the inhalation toxicity is low because of its low vapor pressure. Airborne dusts can produce eyeburn and irritation of the respiratory tract.

LD<sub>50</sub> value, oral (rats): 375 mg/kg

### Exposure Limits

TLV-TWA for anhydrous acid  $1 \text{ mg/m}^3$  (ACGIH, MSHA, and OSHA); TLV-STEL  $2 \text{ mg/m}^3$  (ACGIH).

### Hazardous Reaction Products

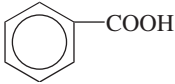
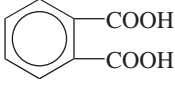
At high temperatures oxalic acid decomposes, producing toxic carbon monoxide, and formic acid. Mixing with warm sulfuric acid may produce the same products:  $\text{CO}_2$ ,  $\text{CO}$ , and formic acid. It reacts with many silver compounds, forming explosive silver oxalate

TABLE 1.1 Toxicity and Flammability of Miscellaneous Carboxylic Acids

Compound/Synonyms/ CAS No.	Formula/MW/ Structure	Toxicity	Flammability
<i>n</i> -Butyric acid (butanoic acid, 1-propanecarboxylic acid, propylformic acid, ethylacetic acid) [107-92-6]	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> 88.12 CH <sub>3</sub> -CH <sub>2</sub> -CH <sub>2</sub> -COOH	Corrosive liquid; contact with eyes can damage vision; irritant to skin; low toxicity; ingestion of high doses may cause vomiting, diarrhea, gastrointestinal problems, ulcerations, and convulsions; LD <sub>50</sub> oral (rats): 2,940 mg/kg; the LD <sub>50</sub> values show wide variations from species to species; DOT Label: Corrosive Material, UN 2820	Combustible liquid; flash point (closed cup) 72°C (161°F) (open cup) 76°C (170°F); auto-ignition temperature 443°C (830°F); vapors form explosive mixtures with air within the range 2–10% by volume in air; reactions with strong oxidizers can be violent
Valeric acid ( <i>n</i> -pentanoic acid, butanecarboxylic acid, propylacetic acid) [109-52-4]	C <sub>5</sub> H <sub>10</sub> O <sub>2</sub> 102.15 CH <sub>3</sub> -CH <sub>2</sub> -CH <sub>2</sub> -CH <sub>2</sub> -COOH	Corrosive liquid; irritant to eyes and skin; low toxicity; toxic effects similar but less than those of propionic acid; LD <sub>50</sub> oral (mice): 600 mg/kg; LC <sub>50</sub> inhalation (mice): 4,100 mg/m <sup>3</sup> /2 hr; DOT Label: Corrosive Material, NA 1760	Combustible liquid; flash point (closed cup) 88°C (192°F), (open cup) 96°C (205°F); auto-ignition temperature 400°C (752°F); may react violently with strong oxidizing compounds
Malonic acid (propanedioic acid, ethanedicarboxylic acid, carboxyacetic acid, dicarboxyethane) [141-82-2]	C <sub>3</sub> H <sub>4</sub> O <sub>4</sub> 104.07 HOOC-CH <sub>2</sub> -COOH	Skin and eye irritant; toxicity of this compound is very low; LD <sub>50</sub> oral (mice): 4,000 mg/kg	Noncombustible liquid
Succinic acid (ethanedicarboxylic acid) [110-15-6]	C <sub>4</sub> H <sub>6</sub> O <sub>4</sub> 118.10 HOOC-CH <sub>2</sub> -CH <sub>2</sub> -COOH	Irritant to eyes, application of about 1 mg in rabbit eyes caused severe irritation; no toxicity is reported	Noncombustible solid



TABLE 1.1 (Continued)

Compound/Synonyms/ CAS No.	Formula/MW/ Structure	Toxicity	Flammability
Adipic acid (1,6-hexanedioic acid, 1,4-butanedicarboxylic acid) [124-04-9]	$C_6H_{10}O_4$ 146.16 $CH_2-CH_2-COOH$   $CH_2-CH_2-COOH$	Mild eye irritant, irritation due to 20 mg over 24 hr was moderate in rabbit eyes; toxicity from oral intake was low in mice; $LD_{50}$ oral (mice): 1,900 mg/kg	Noncombustible solid; auto-ignition temperature 420°C (788°F)
Benzoic acid (benzenemethanoic acid, benzeneformic acid, benzencarboxylic acid, phenylcarboxylic acid, carboxybenzene) [65-85-0]	$C_7H_6O_2$ 122.13 	Mild irritant to skin and eye; low to very low toxicity in animals; toxic symptoms include somnolence, respiratory depression, and gastrointestinal disorder; $LD_{50}$ oral (mice): 2,000–2,500 mg/kg; tested negative in histidine reversion — Ames test for mutagenicity	Noncombustible solid; auto-ignition temperature 570°C (1058°F)
Phthalic acid (1,2-benzenedicarboxylic acid, <i>o</i> -dicarboxybenzene) [88-99-3]	$C_8H_6O_4$ 166.14 	Acute oral toxicity in rats was found to be very low, $LD_{50}$ value is 7,900 mg/kg; high intraperitoneal doses caused change in motor activity, muscle contraction, and cyanosis (NIOSH 1986), $LD_{50}$ intraperitoneal (mice): 550 mg/kg	Noncombustible solid; nitration with a mixture of fuming nitric acid and sulfuric acid produces explosive products, which include phthaloyl nitrate, nitrite, or their nitro derivatives (NFPA 1986)

(NFPA 1986). An explosion occurred when water was added to an oxalic acid/sodium chlorite mixture in a stainless steel beaker. There was also evolution of highly toxic chlorine dioxide gas (MCA 1962). Oxalic acid reacts violently with strong oxidizing substances.

## 1.8 MISCELLANEOUS CARBOXYLIC ACIDS

Among the monocarboxylic acids, compounds containing six carbon atoms or more are almost nontoxic, with mild or no irritant action. Similarly, the dicarboxylic acids

become less toxic with an increase in alkyl chain length. However, the decrease in toxicity is very sharp immediately after oxalic acid. Aromatic acids are of low toxicity. One or two carboxyl groups attached to the benzene ring do not impart any significant toxic characteristics to the molecule.

The series of acids starting with valeric acid are noncombustible compounds. Simple aromatic acids such as benzoic and phthalic acids are noncombustible solids. As with most other classes of organic compounds, the reactions of carboxylic acids may become violent with strong oxidizing compounds. Table 1.1 presents toxicity and flammability data for a few carboxylic acids in the low-molecular-weight range.

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