HUNTSMAN

Ethylene Carbonate
Propylene Carbonate
Butylene Carbonate
UltraPure™ Ethylene Carbonate
UltraPure™ Propylene Carbonate
Carbonate Blends

JEFFSOL® Alkylene Carbonates

HUNTSMAN

THE HUNTSMAN MISSION

We will operate safe, clean, efficient facilities in an environmentally and socially responsible manner.

We provide a work environment that fosters teamwork, innovation, accountability and open communication.

We will place into society assistance for those who suffer, hope for those who may need inspiration, and education for those who may feel the challenge but do not have the means.

We have an aggressive growth philosophy which reflects the spirit of free enterprise and maximization of long term profits, the best motives for creating mutual benefits for customers, employees, suppliers and the communities in which we are located.

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GLOSSARY of ABBREVIATIONS

BA	Benzyl Alcohol
BC	1, 2-Butylene Carbonate
DB	Diethylene Glycol Butyl Ether
DBA	Diethylene Glycol Butyl Ether Acetate
DBE	Dibasic Ester Mixture
DMSO	Dimethyl Sulfoxide
DPM	Dipropylene Glycol Methyl Ether
EB	Ethylene Glycol Butyl Ether
EC	Ethylene Carbonate
EC-25	EC/PC (25/75 by weight)
EC-50	EC/PC (50/50 by weight)
EC-75	EC/PC (75/25 by weight)
EEP	3-Ethoxy Ethyl Propionate
EGDA	Ethylene Glycol Diacetate
FA	Furfuryl Alcohol
GBL	γ - Butyrolactone
MEK	Methyl Ethyl Ketone
MIAK	Methyl Isoamyl Ketone
NAAC	N-Amyl Acetate
NMP	N-Methyl-2-Pyrrolidone
PB	Propylene Glycol Butyl Ether
PC	Propylene Carbonate
PM	Propylene Glycol Methyl Ether
PMA	Propylene Glycol Methyl Ether Acetate
TEG	Triethylene Glycol

INTRODUCTION

HUNTSMAN

Huntsman Corporation is the world's largest producer of alkylene carbonates. At a production capacity of 65 million pounds per year, Huntsman can produce about 50% of the world's carbonates.

The roots of Huntsman's carbonates experience date back to the 1950's; however, in 1996, the company brought on stream the first "large" scale plant in the world.

Huntsman produces its carbonates in three separate manufacturing facilities on two continents and maintains bulk storage of these materials in various sites around the world.

In addition to JEFFSOL® Ethylene Carbonate (EC), JEFFSOL® Propylene Carbonate (PC) and JEFFSOL® Butylene Carbonate (BC), the group produces a series of UltraPure™ Carbonates and is continuing to invest in specialty carbonates and carbamates.

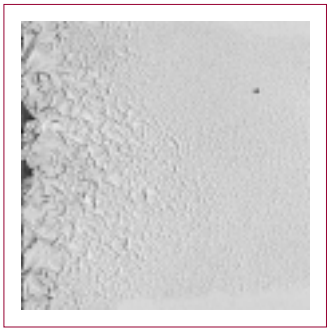
Huntsman is dedicated to developing the latest production technology and specialized derivatives for use in a variety of markets.

The JEFFSOL® Carbonates can be used as "safe" and environmentally friendly solvents replacing harsh products such as methylene chloride, acetone, aromatic solvents, and other highly volatile and hazardous solvents.

Carbonates can also be used as reactive intermediates replacing ethylene and propylene oxides and ethylene and propylene glycols in many reactions.

Where substitution occurs, use of the carbonates may allow for a more selective reaction and minimizes side reactions and contaminants.

In many cases, our technical staff will assist our customers in formulations, carbonate reactions, and development of specialized products.



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JEFFSOL® CARBONATES

The JEFFSOL® Carbonates are cyclic organic esters made from the reaction of ethylene oxide, propylene or butylene oxide with carbon dioxide.

Our core products are JEFFSOL® Ethylene Carbonate, Propylene Carbonate, and Butylene Carbonate (see structures below).

Blends of JEFFSOL® Ethylene Carbonate and Propylene Carbonate are also available.

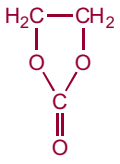
These blends may be used where liquid products are required. (Note JEFFSOL® Ethylene Carbonate is solid at room temperature.)

JEFFSOL® EC-75, EC-50 and EC-25 are blends of JEFFSOL® Ethylene Carbonate and Propylene Carbonate in the ratios of 75/25, 50/50 and 25/75 by weight, respectively.

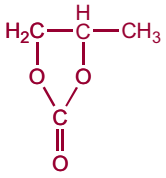
All JEFFSOL® Carbonate products are clear in appearance.

The JEFFSOL® Carbonates have found use in numerous applications that require outstanding solvency combined with high flash points, low evaporation rates, low VOCs, and low toxicity. In addition, these molecules can be used as reactive intermediates.

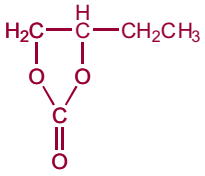
They produce a variety of commercially important chemicals and derivatives through chemistries such as hydroxyalkylation, transesterification, and carbamate formation.



Ethylene Carbonate (EC)



Propylene Carbonate (PC)



Butylene Carbonate (BC)

Table 1 — Typical Analyses of JEFFSOL® Carbonates

	EC	PC	BC	EC-75	EC-50	EC-25
Carbonate (wt.%, GLC)	99.8-99.95	99.8-99.95	99.8-99.95	99.8-99.95	99.8-99.95	99.8-99.95
Glycol Content (wt. %, GLC)	0.005-0.02	0.02-0.10	0.02-0.1	0.03-0.10	0.03-0.10	0.03-0.10
Water (wt. %, Karl Fisher	0.01-0.05	0.01-0.05	0.01-0.10	0.01-0.10	0.01-0.10	0.01-0.10
Ash (wt. %)	0-0.0002	0-0.0002	0.0002	0.0002	0.0002	0.0002
pH (10% aq. solution)	6.7-7.0	6.7-7.0	6.7-7.0	6.7-7.0	6.7-7.0	6.7-7.0
Pt-Cobalt Color	5.0-20.0	5.0-20.0	10-50	5.0-20.0	5.0-20.0	5.0-20.0

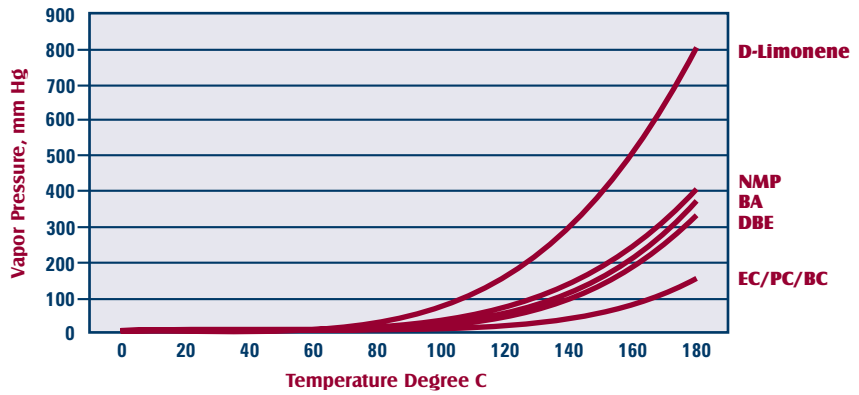
Table 2 — Physical Properties of JEFFSOL® Carbonates

Property	EC	PC	BC	EC-75	EC-50	EC-25
Molecular Wt. (g/mole)	88.06	102.09	116.12	91.19	94.55	98.18
Boiling Point (C°)	248	242	251	246 - 247	244 - 245	243-244
Freezing Point (C°)	—	- 49	< - 45	17	- 10	< - 51
Melting Point (C°)	36.4	—	—	—	—	—
Flash Point (°F, PMCC)	320	275	275	305 - 310	295 - 300	285 - 290
Evaporation Rate (25°C, n-BuAc = 1.00)	< .005	< .005	< .005	< .005	< .005	< .005
Density (g/ml, 25°C)	1.338*	1.200	1.141	1.302	1.266	1.232
Density (g/ml, 40°C)	1.321	1.183	1.127	1.259	1.251	1.217
Molar Volume (ml/g mole, 25°C)	65.8	85.1	101.8	70.6	74.6	80.3
Viscosity (cp, 25°C)	2.56*	2.50	3.15	2.55	2.52	2.52
Viscosity (cp, 40°C)	1.95	1.86	2.24	1.92	1.90	1.88
CAS registry number	96-49-1	108-32-7	4437-85-8	96-49-1 108-32-7	96-49-1 108-32-7	96-49-1 108-32-7

* Supercooled

The vapor pressure graph below clearly illustrates the low volatility advantage of JEFFSOL® EC, PC, and BC compared to traditional solvents.

Vapor Pressure Comparison



HUNTSMAN

APPLICATIONS

JEFFSOL® Carbonates are used in a wide spectrum of applications. The matrix below illustrates some of the more common ones.

Huntsman has a Technical Service staff dedicated to developing new markets, new applications, and improved formulations with JEFFSOL® Carbonates.

Table 3 — JEFFSOL® CARBONATES Applications Matrix

Application	Ethylene Carbonate	Propylene Carbonate	Butylene Carbonate	Carbonate Blends	UltraPure™ Carbonates	Literature Available
"Safe" Solvents		★	★	★		❋
• Electrochemical	★	★	★	★	★	❋
• Ag		★	★	★		❋
• Cosmetics & Personal Care		★	★	★	★	❋
Cleaners / Degreasers		★	★	★		❋
• Industrial & Consumer		★	★	★		❋
Paint Strippers / Removers		★	★	★		❋
Chemical Intermediates	★	★	★	★		❋
Woodbinder Resins	★	★	★	★		❋
Urethane (Reactive Diluent)	★	★	★	★		❋
Foundry Sand Binders	★	★	★	★		❋
Lubricants / Greases		★	★	★		❋
Photochromic		★	★	★		❋
Plasticizer	★	★	★	★		❋
Gas Treating		★	★	★		❋
Epoxy Resins (Reactive Diluent)	★	★	★	★		❋
Water Scavenger	★	★	★	★		❋
Antipilling	★	★	★	★		❋
Textile Dyeing	★	★	★	★		❋
Superabsorbent Polymers	★	★				❋
Tail Solvent (Bake Enamels)		★	★	★		❋

❋ Contact your Huntsman sales representative for more information

The JEFFSOL® Carbonates are excellent polar solvents for many organic and inorganic materials.

Their excellent solvency properties combined with high flash points, high boiling points, low evaporation rates, low VOC, low toxicity, and low odor make them particularly attractive choices for many solvent applications today.

Some of the traditional solvents targeted for replacement in the United States include: methylene chloride, 1,1,1-trichloroethane, perchloroethylene, trichloroethylene, NMP, acetone, MEK, and toluene among others.

The JEFFSOL® Carbonates offer outstanding properties and advantages as substitutes for these targeted solvents as illustrated in Tables 4 and 5.

Table 4 — Volatile Organic Content (ASTM D-2369)

Products	% VOC (110° C)
JEFFSOL® BC	18
JEFFSOL® PC	28
JEFFSOL® EC-50	31
JEFFSOL® EC	34
PM	100
DPM	100
DBE	100
BA	100
NMP	100
D-Limonene	100
Limonene 145	100

SOLVENTS *(continued)*

These advantages make the JEFFSOL® Carbonates extremely beneficial in numerous solvent applications.

Two primary uses are in cleaners/degreasers and paint strippers.

In addition, the UltraPure ™ grades are used in electronic applications because of their high purity and low glycol and water content.

Other diversified applications for JEFFSOL® Carbonates include, but are not limited to:

- Circuit Board Cleaners
- Polyurethane Cleanup Solvents
- Carburetor Cleaners
- Polymer/resin Cleanup
- Solvents for Inks and Ink Cleaners
- Solvent for Dye used in Carbonless Paper
- Solvents for Cosmetics (wetting agent for clays)
- Unsaturated Polyester Cleanup Solvent
- All-Purpose Cleaners
- Structural Adhesives Cleanup Solvent
- Polymer Solvent for Reaction Processing
- Solvent for Polyurethane Elastomer Pellets
- Cleaning stereolithography parts (remove resins)

Table 5 — Advantages in Using JEFFSOL® Carbonates

Products	Flash Pt., °F	Boiling Pt., °C	Evap. Rate NBAC-1.0	Overall Toxicity	Odor	Damaging to Atmosphere
JEFFSOL® EC	320	248	<0.005	T	No	No
JEFFSOL® PC	275	242	<0.005	None	No	No
JEFFSOL® BC	275	251	<0.005	None	No	No
Benzyl OH	213	205	0.007	N	Slight	No
DBE	212	225	0.009	none	Yes	No
GBL (γ-butyrolactone)	209	205	0.030	Slight	Slight	No
NMP	187	202	0.030	T	Yes	No
Isophorone	184	214	0.020	AC	Yes	Yes
DMF	136	153	0.200	T, Liver Damage	Yes	No
D-Limonene	119	176	0.253	T	Yes	No
MEK	26	80	4.030	T,N	Yes	No
CH_2Cl_2	None	40	14.50	N, AC	Yes	Yes

AC = Animal Carcinogen **N** = Neurotoxin **T** = Teratogen

Formulators are being challenged to replace traditional solvents in cleaners and degreasers because of volatility and toxicity concerns. The search for both "safe" solvents and high performance in solvent-based, water-based and water-rinseable systems has led to the use of materials such as the JEFFSOL® Carbonates.

In addition to reducing VOC levels (Table 4) and offering outstanding performance, they provide exceptional compatibility and solubility properties to aid in formulating cleaners.

They are effective in reducing the surface tension and so promote cleaning by improving wetting and soil removal.

Tables 6-8 depict typical solubility characteristics of JEFFSOL® Carbonates and their relative solubilities in water.

Table 6 — Solubility Characteristics of JEFFSOL® Carbonates

Property	EC	PC	BC	EC-75	EC-50	EC-25
Hansen Sol Par, total (cal $^{1/2}$ cm $^{-3/2}$)	14.5	13.3	10.1	14.0	13.9	13.5
Hansen Sol Par, dispersive (cal $^{1/2}$ cm $^{-3/2}$)	9.5	9.8	8.3	9.5	9.6	9.7
Hansen Sol Par, polar (cal $^{1/2}$ cm $^{-3/2}$)	10.6	8.8	3.0	10.1	9.8	9.2
Hansen Sol Par, hydrogen bonding (cal $^{1/2}$ cm $^{-3/2}$)	2.5	2.0	4.8	2.3	2.2	2.1
Dipole Moment (Debyes, 40°C)	4.80	4.98	5.28	n.a.	n.a.	n.a.
Surface Tension (dynes/cm, 25°C)	44.0*	40.9	38.1	48.5	45.9	43.2
Surface Tension (dynes/cm, 40°C)	42.2	39.6	37.0	47.0	44.0	41.9

* Supercooled
n.a. = not available

Table 7
Solubility of Water in 100 Grams of JEFFSOL® Carbonates (25°C)

Type JEFFSOL® Carbonate	Amount of Water
JEFFSOL® EC	∞
JEFFSOL® PC	8.3g
JEFFSOL® BC	2.0g
JEFFSOL® EC-75	33.0g
JEFFSOL® EC-50	19.0g
JEFFSOL® EC-25	10.3g

Table 8
Solubility of JEFFSOL® Carbonates in 100 Grams of Water (25°C)

Type JEFFSOL® Carbonate	Amount of JEFFSOL® Carbonate
JEFFSOL® EC	∞
JEFFSOL® PC	25g
JEFFSOL® BC	7g
JEFFSOL® EC-75	>100g
JEFFSOL® EC-50	48g
JEFFSOL® EC-25	33g

Please refer to our other technical documents listed on P. 28 of this brochure that specifically address solubility, miscibility, compatibility, and comparative solvent properties.

Some starting formulations for a variety of cleaners and degreasers are illustrated below.

Tub & Tile Cleaners & Performance Data (Patents Pending)

Ingredients	Ingredient Ratios	Water (dilution)	Average delta G (20° / 60°)
JEFFSOL® PC / PM / ACTIVATOR	5.00 / 5.00 / 0.02	89.98	96.0 / 98.14
JEFFSOL® PC / PM / ACTIVATOR	2.49 / 2.49 / 0.56	89.50	94.3 / 95.2
JEFFSOL® PC / PM / ACTIVATOR	2.48 / 2.48 / 0.91	89.18	96.1 / 95.3
Commercial Clear Cleaner I			83.5 / 86.9
Commercial Clear Cleaner II			82.4 / 88.6

NOTE: Activator may be one of the following compounds: citric acid, maleic acid or maleic anhydride

Hard Surface Cleaners, Floor Cleaners (Concentrates to be diluted with water)

Ingredients	Ingredient Ratios	Water (dilution)
JEFFSOL® PC / PM / SURFONIC®* N-95, N-120 or JL-80X	13 / 6 / 1	80
JEFFSOL® PC / PM / DPM / SURFONIC®* N-95, N-120 or JL-80X	13 / 3 / 1	80

* SURFONIC® is the trade name for Huntsman nonionic surfactants

Degreaser Formulations & Performance Data (Patents Pending)

Formulations	Ingredient Ratios
JEFFSOL® PC/BC$_{70/30}$ / PB / [1]Naphthene	11.66 / 39.73 / 48.60
JEFFSOL® PC/BC$_{70/30}$ / [2]Exxate™ 900 / [1]Naphthene	25.06 / 54.14 / 20.80
JEFFSOL® PC/BC$_{70/30}$ / [2]Exxate™ 900 / [1]Naphthene	39.05 / 44.76 / 16.19
JEFFSOL® PC/PB$_{50/50}$ / PB	44.40 / 55.60

Performance Data – % removal of greases listed here in 1 hour	Chevron Moly EP	Chevron FM EP	Chevron Ultra Duty
JEFFSOL® PC/BC$_{70/30}$ / PB / [1]Naphthene	97.14	96.88	96.88
JEFFSOL® PC/BC$_{70/30}$ / [2]Exxate™ 900 / [1]Naphthene	97.06	96.94	96.43
JEFFSOL® PC/BC$_{70/30}$ / [2]Exxate™ 900 / [1]Naphthene	93.33	100.00	100.00
JEFFSOL® PC/PB$_{50/50}$ / PB	97.14	84.38	96.43

1 Naphthene is a aliphatic solvent produced by Huntsman Europe. *Shell's Cypar*® solvents or ExxonMobil Chemical's Isopar® solvents may be substituted. 2 ExxonMobil Chemical solvent

Polymer / Resin Cleaners*

Ingredients	Ingredient Ratios
JEFFSOL® PC / NMP / PM	33.3 / 33.3 / 33.3
JEFFSOL® PC / NMP / DPM	33.3 / 33.3 / 33.3
JEFFSOL® PC / NMP / PMA	33.3 / 33.3 / 33.3
JEFFSOL® PC / NMP / DBE	33.3 / 33.3 / 33.3
JEFFSOL® PC / NMP / DBE / BA	25 / 25 / 25 / 25
JEFFSOL® PC / PM	50 / 50
JEFFSOL® PC / NMP	50 / 50

* U.S. Patent #6,187,108

CLEANERS / DEGREASERS *(continued)*

Fiberglass Resin Cleaners*

Ingredients	Ingredient Ratios
JEFFSOL® PC	100
JEFFSOL® PC / PM	50 / 50
JEFFSOL® PC / NMP	50 / 50
JEFFSOL® PC / EEP	50 / 50
JEFFSOL® PC / DBE	50 / 50
JEFFSOL® PC / DPM	70 / 30
JEFFSOL® PC / DBA	70 / 30
JEFFSOL® PC / DB	70 / 30

Unsaturated Polyester Resin Cleaners*

Ingredients	Ingredient Ratios
JEFFSOL® EC-50 / PM	50 / 50
JEFFSOL® EC-50 / DBE / DB	40 / 40 / 20
JEFFSOL® EC-50 / DBE / DPM	40 / 40 / 20
JEFFSOL® EC-50 / PM	75 / 25
JEFFSOL® EC-50 / EB	75 / 25
JEFFSOL® PC / Acetone	95 / 5

Polyurethane Resin Cleaners*

Ingredients	Ingredient Ratios
JEFFSOL® PC / BA / DBE	40 / 20 / 40
JEFFSOL® EC-50 / PM	50 / 50
JEFFSOL® PC / PM	50 / 50
JEFFSOL® PC / NMP / BA / DBE	25 / 25 / 25 / 25
JEFFSOL® PC / NMP / DPM / MIAK / DBE	15 / 15 / 15 / 15 / 40
JEFFSOL® PC / NMP	50 / 50
JEFFSOL® EC-50 / NMP	50 / 50
JEFFSOL® PC / BA	50 / 50
JEFFSOL® PC / NMP / DBE	25 / 50 / 25
JEFFSOL® PC / NMP / DPM / BA / PM / DBE	20 / 20 / 10 / 20 / 10 / 20
JEFFSOL® PC / NMP / DPM / BA / MIAK / DBE	25 / 15 / 15 / 15 / 15 / 15
JEFFSOL® PC / NMP / BA / MIAK / PM / DBE	25 / 15 / 15 / 15 / 15 / 15
JEFFSOL® PC / NMP / DPM / BA / MIAK / PM / DBE	20 / 20 / 10 / 10 / 15 / 15 / 10

Typical Carburetor Cleaners

Ingredients	Ingredient Ratios
JEFFSOL® PC / Ethyl Acetate / Toluene or Xylene / PM / Butyl Acetate	29 / 24 / 24 / 12 / 11

* U.S. Patent #6,187,108

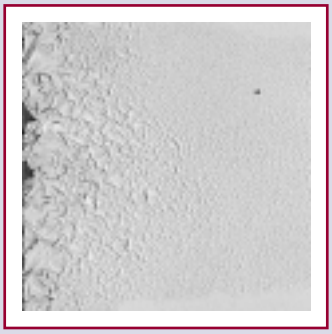
PAINT STRIPPERS / REMOVERS

JEFFSOL® Carbonates can replace the traditional methylene chloride in paint remover formulations.

They offer advantages over methylene chloride and other major solvents targeted for replacement such as 1,1,1-trichloroethane, perchloroethylene, trichloroethylene, NMP, acetone, and MEK among others.

The JEFFSOL® Carbonates advantages include:

- High solvency
- High boiling points
- High flash points
- Low toxicity
- Low evaporation rates
- Low odor
- Not damaging to the atmosphere
- Readily biodegradable
- Reasonable cost



Some starting paint remover formulations based on JEFFSOL® PC and EC-50 are illustrated below.

These formulations are covered under U.S. Patent # 6,159,915

Paint Remover Formulations & Performance Data

Formulations	Ingredient Ratios
JEFFSOL® PC / DBE / EEP	19.5 / 40.5 / 40
JEFFSOL® EC-50 / DBE / EEP	19.5 / 40.5 / 40
JEFFSOL® PC / DBE / EEP / DMSO	19.5 / 34.5 / 23.5 / 22.5
JEFFSOL® PC / DBE / EEP / DMSO / DPM / MIAK	19.5 / 20.5 / 20 / 20.5 / 10.5 / 9
JEFFSOL® PC / DBE / EEP	19.5 / 40 / 40.5

Performance Data – Blister time in minutes	Latex/Enamel Wood	Acrylic/Enamel Metal	Latex/Enamel Metal
JEFFSOL® PC / DBE / EEP	1.75	1.53	2.47
JEFFSOL® EC-50 / DBE / EEP	0.87	2.77	5.77
JEFFSOL® PC / DBE / EEP / DMSO	2.22	4.90	3.05
JEFFSOL® PC / DBE / EEP / DMSO / DPM / MIAK	2.67	5.52	4.83
JEFFSOL® PC / DBE / EEP	1.67	5.97	4.52
Commercial Paint Stripper (cont'g toluene & methylene chloride)	0.98	1.32	4.22
Commercial "Safe" Paint Stripper (cont'g DBE)	> 1 hour →		

PAINT STRIPPERS / REMOVERS *(continued)*

Huntsman Corporation is continually offering new products and technologies for paint stripping applications.

Examples include the formulations above as well as and the unique JEFFSTRIP ™ FST component for paint strippers. This new technology is based upon Huntsman's JEFFSOL® Carbonate product line.

It enables customers to formulate "environmentally safe" products, which rival the performance of acetone and methylene chloride based paint strippers.

Table 9 illustrates results comparing the performance of a JEFFSTRIP™ FST based formulation to nine commercially available paint strippers. The paint strippers were evaluated for paint removal from standard military/commercial airlines-type panels coated with five different types of paint.

The results shown in Table 9 are for the removal of Mil-R-8129D, Polysulfide Seal. The results show the safe JEFFSTRIP™ FST formulation performs as well as the best commercially available formulations, and much better than other "safe" products.

This technology is covered under U.S. Patent # 6,040,284, # 6,162,776 and #6,169,061.

Table 9 — Paint Removal Evaluations on Airline Panels

Product	Base Components	Blister Time*/min.
Commercial Paint Stripper A	Methylene chloride, methanol, ethanol	10
Commercial Paint Stripper B	Methylene chloride, toluene, acetone, methanol, nonylphenoxypolyethoxyethanol	21
JEFFSTRIP™ FST Formulation	**JEFFSTRIP™ FST + co-solvent**	**26**
Commercial Paint Stripper C	Acetone, xylene, methanol	35
Commercial Paint Stripper D	Methylene chloride, toluene, acetone	42
Industrial Acid Paint Stripper E	Acid	91
Commercial Paint Stripper F	Dibasic Ester (DBE)	120
Industrial Alkaline Paint Stripper G	Alkali	174
Commercial Paint Stripper H	N-methyl-2-pyrrolidinone (NMP), dibasic ester, limonene	1320
Commercial Paint Stripper I	Toluene, acetone, hexane, isopropanol, EEP, n-butyl acetate	No Blister

* Blister times will vary depending on laboratory conditions

In addition, Table 10 illustrates results comparing the performance of JEFFSTRIP™ FST based formulations to four commercially available paint strippers for removal of household paints and coatings.

The results shown in Table 10 are for the removal of latex from wood.

The results indicate that the safe JEFFSTRIP™ FST formulations outperform other "safe" type paint strippers and approach or exceed the performance of conventional volatile, hazardous type paint strippers.

Table 10 — Paint Removal Evaluations on Household Panels

Product	Base Components	Blister Time*/min.
JEFFSTRIP™ FST Formulation A B C	**JEFFSTRIP™ FST + co-solvent**	**1.97 1.75 0.77**
Commercial Paint Stripper A	Methylene chloride, toluene, acetone	1.18
Commercial Paint Stripper B	Formulated with **JEFFSTRIP™ FST** technology	1.45
Commercial Paint Stripper C	Acetone, xylene, methanol	2.33
Commercial Paint Stripper D	Dibasic Ester (DBE)	No Blister

* Blister times will vary depending on laboratory conditions

ELECTROCHEMICAL APPLICATIONS

JEFFSOL® Carbonates can be used similarly to N-methylpyrrolidone (NMP) in electronic cleaning applications.

In addition, propylene carbonate is the solvent of choice to be used with supercritical carbon dioxide to clean away photoresists temporarily applied to silicon wafers during the semiconductor manufacturing process.

Propylene carbonate is not only a benign solvent, but it offers significant reduction in the generation of waste compared to the use of traditional harsh solvent systems.

Work in this area has been pioneered by the Los Alamos National Laboratory (Chemical & Engineering News, June 14, 1999, p. 11).

It has also been shown that alkylene carbonates can be used as insulators in high voltage applications, such as capacitors and transformers.

Huntsman's UltraPure™ product line of alkylene carbonates has found uses as electrolyte solvents for lithium (Li) batteries and in photochromic applications.

Many of the electrochemical properties of JEFFSOL® Carbonates are listed in Table 11.

Table 11 — Electrochemical Characteristics of JEFFSOL® Carbonates

Property	EC	PC	BC	EC-75	EC-50	EC-25
Dielectric Constant (esu, 20°C)	90.0 (40°C)	64.0	57.7	83.5	78.3	70.8
Specific Cond. ($\Omega^{-1}cm^{-1}$)	$9x10^{-9}$	$9.5x10^{-8}$	$2x10^{-6}$	$6.5x10^{-8}$	$4x10^{-8}$	$2.5x10^{-8}$
Dipole Moment (Debyes, 40°C)	4.80	4.98	5.28	n.a.	n.a.	n.a.

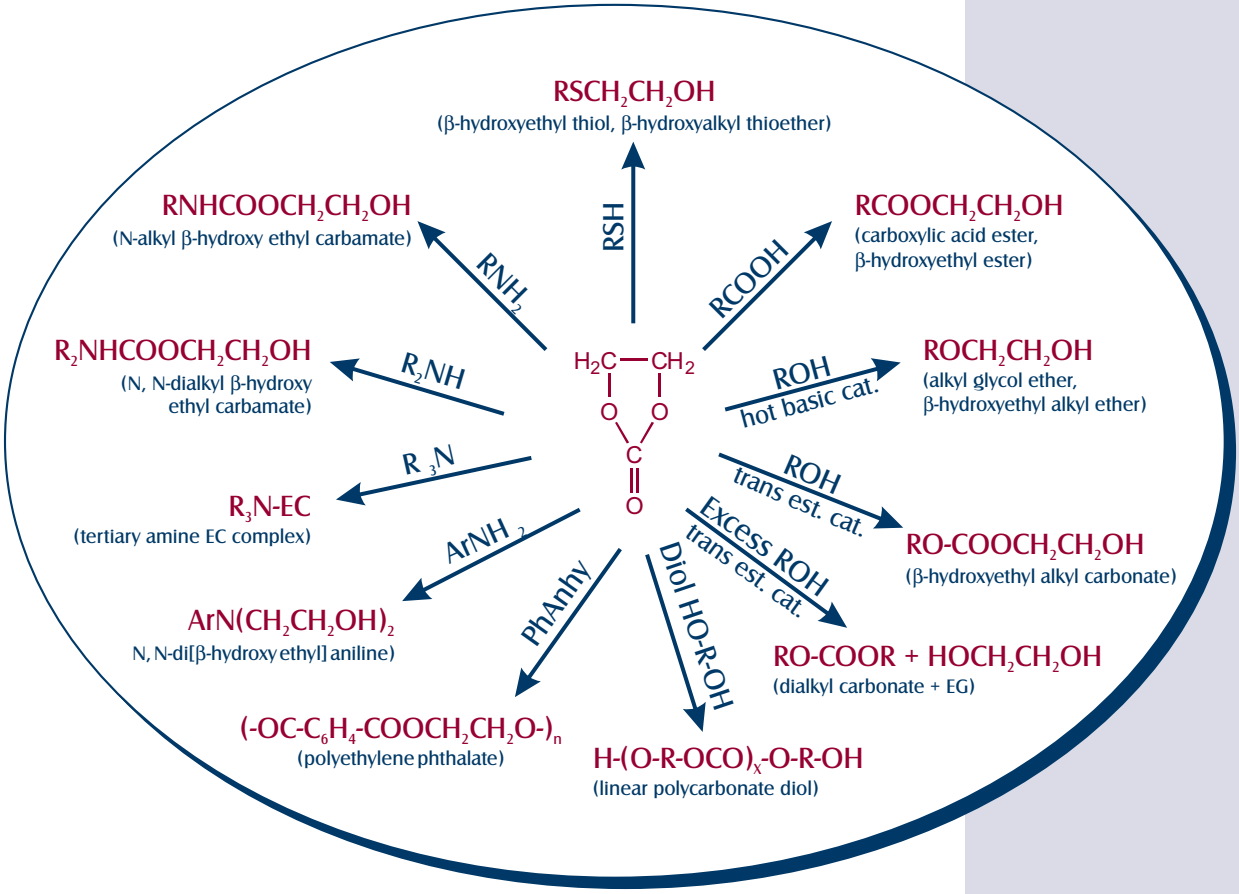
n.a. = not available

JEFFSOL® Carbonates can be used as reactive intermediates.

They produce a variety of commercially important derivatives through chemistries such as carbamate formation, hydroxyalkylation, transesterification, and others.

The resulting materials are used as such or further reacted to produce numerous valuable chemicals.

This unique versatility is illustrated below.



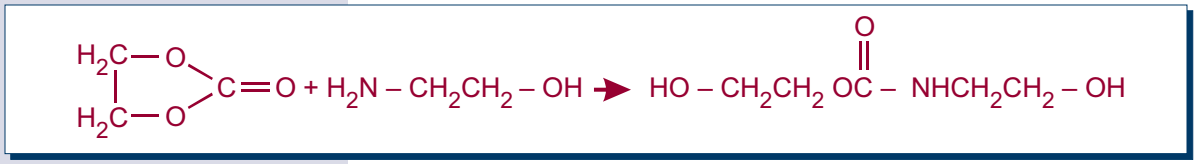
Carbamates

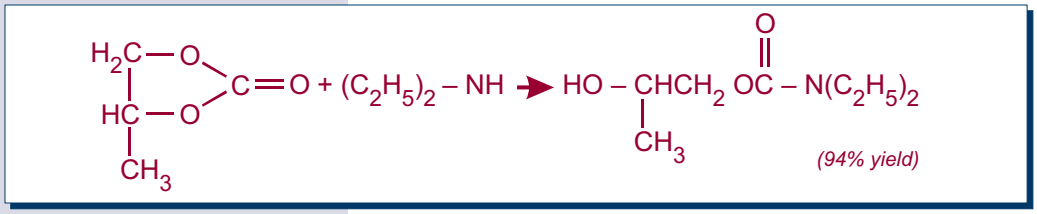
JEFFSOL®EC and PC react at low temperatures with most primary and secondary aliphatic amines to yield carbamates.

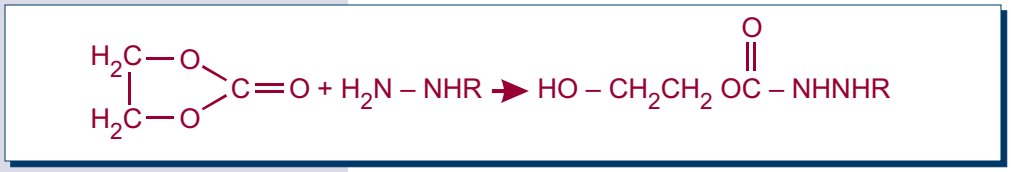
The reaction product of an aliphatic amine and JEFFSOL® EC is a hydroxyethyl carbamate.

The reaction product of an aliphatic amine and JEFFSOL® PC is a hydroxypropyl carbamate.

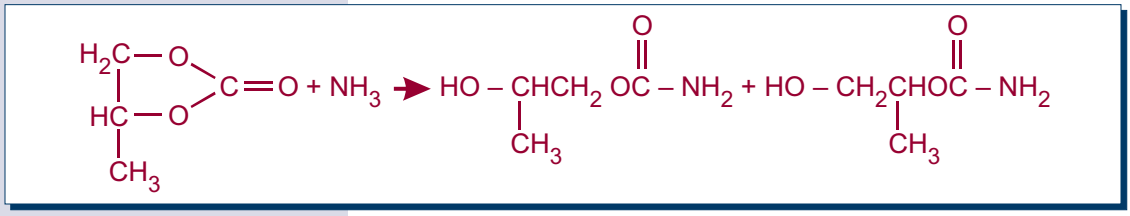
Reactions of several aliphatic amines with JEFFSOL® EC and PC are shown below.



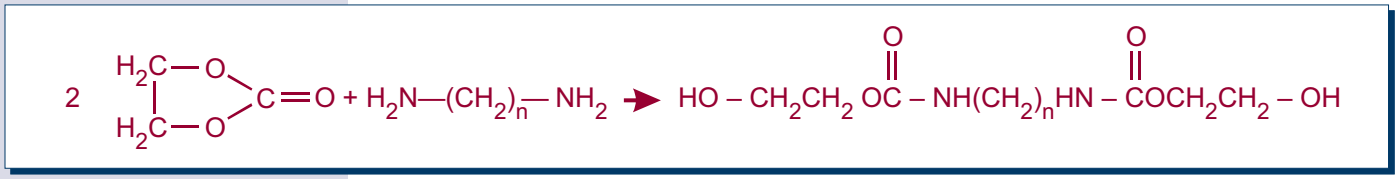




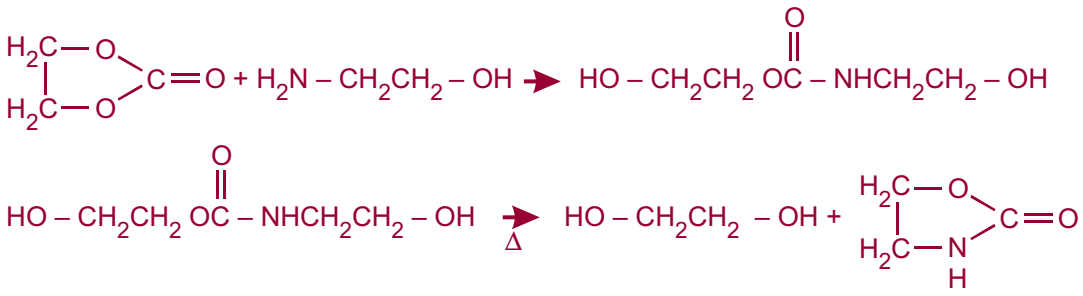
Anhydrous ammonia, under pressure or in methanol or water solution, reacts with JEFFSOL® EC and PC to yield carbamates.



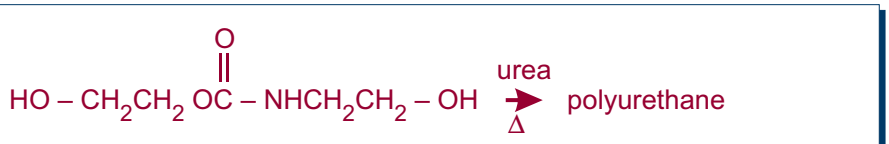
The reaction of diamines with JEFFSOL® EC and PC yields bis-carbamates.



2-Oxazolidinones can be prepared by reacting β-hydroxy alkanolamine with JEFFSOL® EC or PC to form the carbamate, followed by heating the carbamate in the absence of a catalyst at 85 to 190°C for two hours. The corresponding glycol is the coproduct of the reaction.



Bis-hydroxy carbamates may be reacted with urea to form polyurethanes.

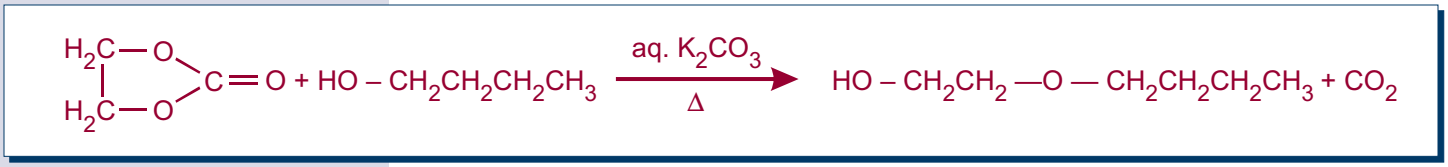


Alkoxylation

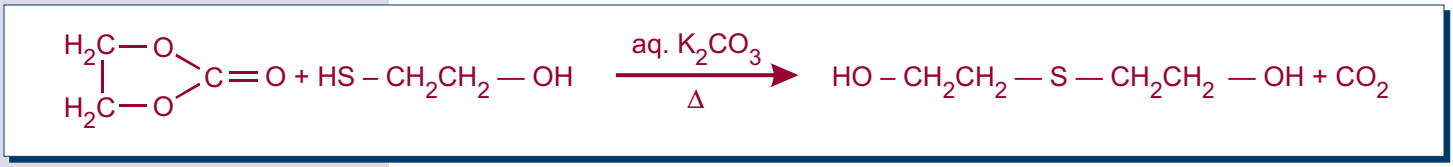
JEFFSOL® EC and PC react with many compounds which contain an active hydrogen to give the corresponding hydroxyethyl and hydroxypropyl derivatives.

These reactions are run at 100 to 200°C, employing a basic catalyst such as potassium carbonate at a 0.5 wt.% level. The reaction of JEFFSOL® EC and PC with various active hydrogen-containing compounds is shown below.

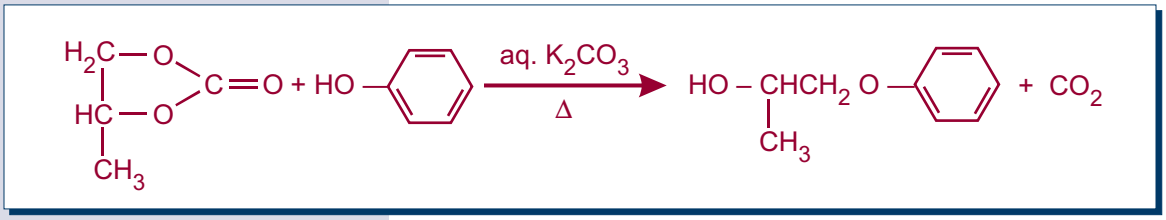
With alcohols



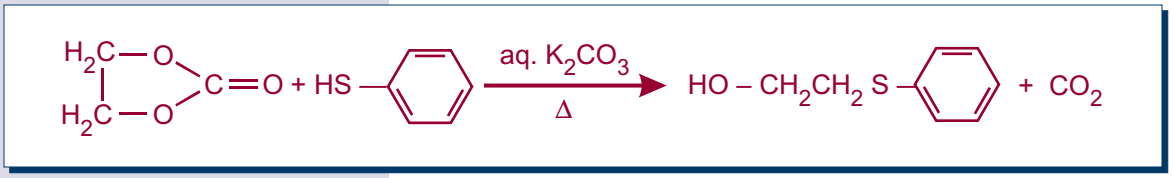
With mercaptans



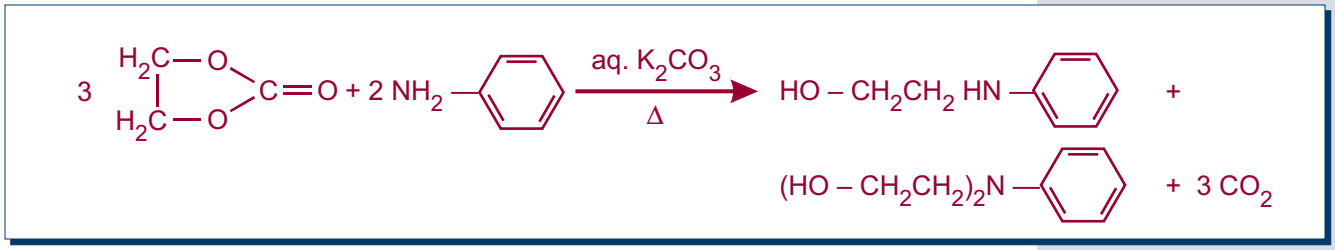
With phenols



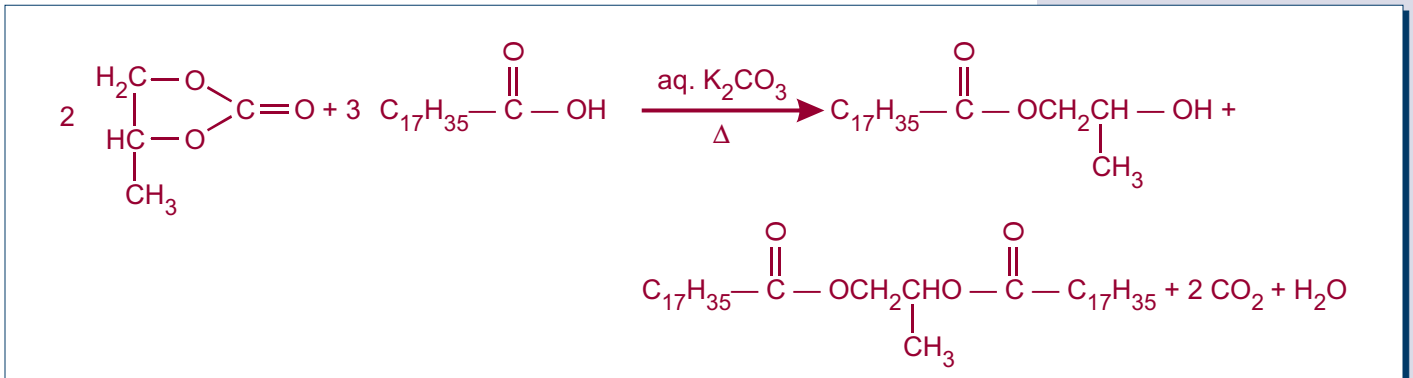
With thiophenols



With amines



With carboxylic acids



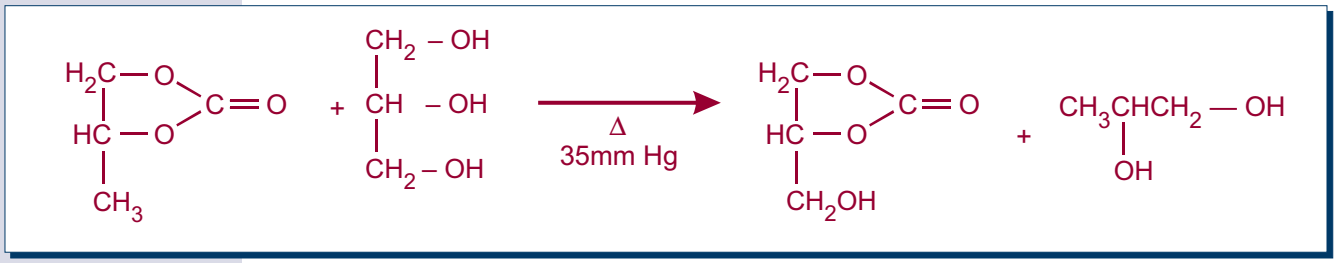
Many materials which are difficult to hydroxyalkylate with ethylene oxide or propylene oxide can be hydroxyalkylated with JEFFSOL® EC and PC.

Among these materials are starches, disaccharides, natural amino acids, pentaerythritol, commercial pectin, and imidazoles.

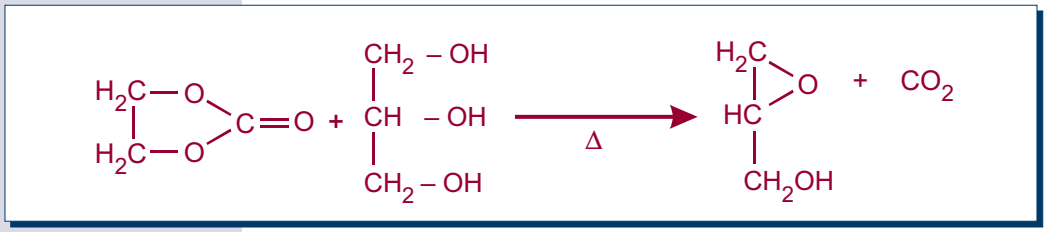
Transesterification

JEFFSOL® PC undergoes an ester interchange reaction with glycerine in the presence of catalysts at 100 to 150°C and about 35 mm Hg pressure to give good yields of glycerine carbonate.

Propylene glycol may by removed continuously from the reaction mixture by distillation.



JEFFSOL® EC reacts with glycerine to give glycidol. This reaction probably proceeds through the cyclic carbonate ester of glycerine.



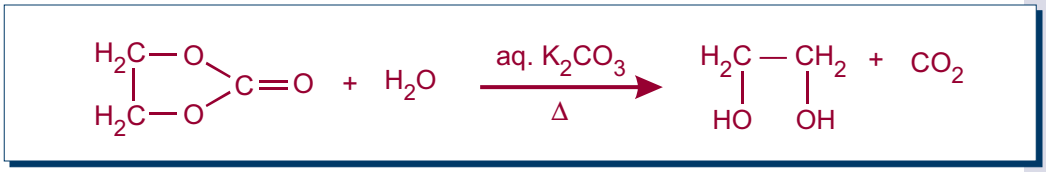
JEFFSOL® EC and PC may be used in the ester interchange reaction to prepare a number of different polyesters.

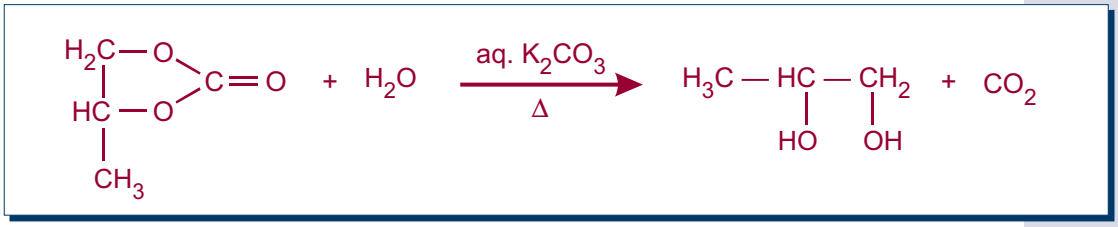
Polycarbonate Formation

Linear polycarbonates may be formed by reacting JEFFSOL® EC with aliphatic, cycloaliphatic, or araliphatic dihydroxy compounds such as 1,4-cyclohexanedimethanol, 1,4-butanediol, or diethylene glycol.

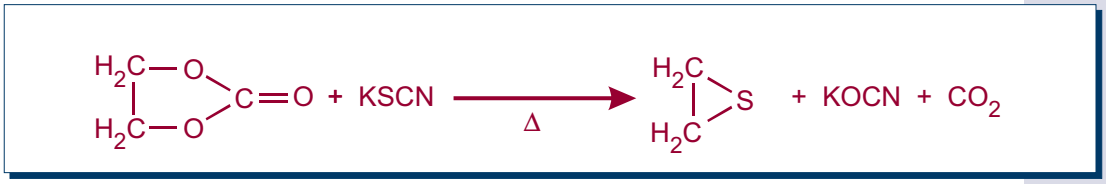
Miscellaneous Reactions

Alkaline hydrolysis of JEFFSOL® EC and PC with potassium carbonate has been shown to be second order; the rate constants are 5.1 x 10^{-2} and 4.7 x 10^{-2} mole^{-1} min^{-1}, respectively, at 0°C.

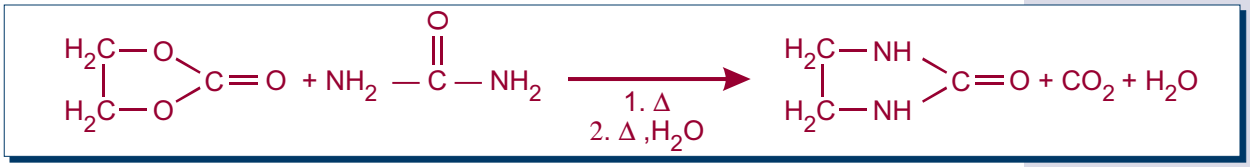




JEFFSOL® EC may be reacted with potassium thiocyanate to give ethylene sulfide.



Ethylene urea may be prepared by reacting JEFFSOL® EC and urea in an autoclave at temperatures around 200°C, followed by heating with water.



HANDLING, STORAGE & SHIPPING

Handling & Storage

JEFFSOL® EC and PC are stable under ordinary storage conditions.

However, there is evidence that in the presence of an acid, base, metal oxide, or salt, the carbonates will decompose with the evolution of carbon dioxide.

The decomposition rate increases with temperature, particularly at 50°C or higher.

The primary decomposition products are alkylene glycol and carbon dioxide.

This may lead to pressure buildup in closed containers to the point that the container may rupture, possibly with explosive force.

Although not all of the variables of this apparently rare phenomenon have been fully investigated, it is recommended that all processing and storage vessels be provided with pressure relief devices.

After factory-filled drums are opened, they, too, should be equipped with a pressure relief device or emptied into a recommended container equipped with a pressure relief device.

JEFFSOL® PC typically contains free propylene oxide in the range of from 5 to 35 ppm and occasionally higher.

Residual propylene oxide can accumulate in the container headspace and be released into the ambient environment.

A special grade of JEFFSOL® PC is available with a specification of <1 ppm propylene oxide in the container headspace.

Loading and blending operations and elevated temperatures may increase propylene oxide concentrations found in the headspace.

The OSHA permissible exposure level for propylene oxide is 100 ppm as an eight-hour time-weighted average.

JEFFSOL® EC and PC have high flash points; however, they can be ignited and must be protected from sources of ignition or static electrical discharge.

All vessels containing these materials should be adequately grounded.

Tanks, pumps, and lines may be cleaned with low pressure steam, rinsed with water, and blown or wiped dry.

If filtration of either product is necessary, a stainless steel 200-mesh screen is recommended.

Thawing Instructions:

JEFFSOL® EC is solid at room temperature. Drums should be thawed in a box maintained at 110-120°F (40-50°C).

The drum bung should be loosened slightly to allow venting during the thawing process. The hot box temperature should never exceed 130°F (55°C).

Once thawed and not used immediately, the head space of each drum should be purged well with dry nitrogen and the drum resealed.

For the thawing of other containers, including isocontainers, the steps outlined below should be followed.

- Record the temperature and pressure of the container upon delivery.
- Connect nitrogen to the container and maintain a 5-10 psig pad on the container during the thawing and unloading process.
- Heat the product to between 110-120°F (40-50°C). Do not exceed 130°F (55°C) maximum.

Hot liquid or steam may be used as the heating media. The temperature of the heating media should not exceed 160°F (70°C).

If steam is used, it should be controlled not to exceed 5 psig.

The melting process may take 3-5 days to completely melt the ethylene carbonate in drums as well as bulk containers.

Transfer Lines:

Transfer lines should be at least two inches in diameter and may be constructed of carbon steel or stainless steel.

Preferred gasket material is Teflon*. JEFFSOL® EC transfer lines should be steam-traced and insulated to prevent line plugging.

For flexible connections, stainless steel hoses are preferred. Lines which are insulated and steam-traced should be preheated for 15 to 30 minutes with low-pressure steam before being put into service.

Pumps:

Rotary or centrifugal pumps of carbon steel or stainless steel construction may be used to pump JEFFSOL® EC and PC. Pumps which are to be used for JEFFSOL® EC should be preheated by placing live steam on the uninsulated pump or by wrapping the pump with copper tubing, insulating, and circulating low-pressure steam through the tubing.

Satisfactory pump gasket materials include Teflon, EPR, neoprene, natural rubber, cork, and polyethylene. Unsatisfactory gasket materials are Buna N, Hypalon*, and Viton*.

*Registered trademarks of DuPont Company

HANDLING, STORAGE & SHIPPING
(continued)

Tanks:

Tanks for JEFFSOL® EC and PC may be constructed of carbon steel or stainless steel.

Because of the decomposition potential of carbonates, the tanks should be equipped with pressure relief devices and have an inert gas pad.

Tanks for JEFFSOL® EC must be insulated and equipped with internal, stainless steel, low-pressure steam coils for heating.

The temperature of the JEFFSOL® EC should be kept below 120°F and the skin temperature of the coils should not be higher than the minimum required to melt the product.

A liquid recirculation pump will speed melting of the JEFFSOL® EC.

Shipping

Shipping Information

Delivery of JEFFSOL® EC and PC can be made in tank trucks or tank cars.

Tank cars are of welded carbon steel construction with bottom unloading fittings.

Tank trucks are of stainless steel construction and are equipped with pumps and hoses, if requested.

Equipment in JEFFSOL® EC service is insulated and has steam coils.

Drums of JEFFSOL® EC, net weight 550 pounds (approximately 55 gallons), and drums of JEFFSOL® PC, net weight 550 pounds (approximately 55 gallons), can be shipped promptly from local warehouses in carload, truckload, and smaller quantities.

JEFFSOL® EC and JEFFSOL® PC are not DOT-regulated commodities.

JEFFSOL® PC Health and Safety

Acute/ShortTerm Toxicity:

JEFFSOL® PC is practically nontoxic to rats by a single oral exposure or to rabbits by a single dermal exposure.

JEFFSOL® PC is minimally irritating to the eyes and skin of rabbits.

JEFFSOL® PC did not produce dermal sensitization in laboratory animals.

Subchronic, Neurotox, Chronic, and Developmental Toxicity:

Rats ingesting 5,000 mg/kg/day of JEFFSOL® PC did not show any signs of toxicity directly attributable to the test article. No significant findings were noted with regard to clinical chemistry, hematology, or histopathological evaluations.

Rats exposed to JEFFSOL® PC at aerosol concentrations of up to 1,000 mg/m^3 showed only signs of ocular irritation.

Neurotoxicity evaluations (acute and subchronic) with JEFFSOL® PC did not demonstrate any neurotoxicity. Histopathologic examination of the nervous systems of the study animals did not reveal any evidence of neuropathology.

JEFFSOL® PC applied to mice dermally twice weekly for two years with no effort to remove the material between applications was not dermally carcinogenic, and did not produce any evidence of abnormal dermal lesions or systemic toxicity from this exposure.

Pregnant female rats orally receiving JEFFSOL® PC at concentrations of up to 5,000 mg/kg/day over the period of fetal development showed some evidence of maternal toxicity in the high-dose group, however, there were no significant findings with regard to all recorded fertility parameters, viable/nonviable fetuses, fetal sex distribution, or fetal body weights and no fetal skeletal or visceral malformations were observed.

Genetic Toxicity:

JEFFSOL® PC did not demonstrate any evidence of chromosomal damage, mutagenicity, or DNA damage in the gene-tox test systems.

JEFFSOL® BC Health & Safety

Acute/ShortTerm Toxicity:

JEFFSOL® BC is practically nontoxic to rats by a single oral exposure or to rabbits by a single dermal exposure.

JEFFSOL® BC is minimally irritating to the eyes and skin of rabbits.

JEFFSOL® BC did not produce dermal sensitization in laboratory animals.

Rats ingesting JEFFSOL®BC at concentrations of 0, 500 or 1000 mg/kg/day for 28 consecutive days produced persistent and statistically significant changes in body weight gain for male and female rats in the 1000 mg/kg/day group, and a statistically significant decrease in food consumption for male rats in the 1000 mg/kg/day group.

There were no significant findings with regard to clinical pathology and histopathological evaluations for either dosage group.

Genetic Toxicity

JEFFSOL® BC did not demonstrate any evidence of chromosomal damage, mutagenicity, or DNA damage in the gene-tox test systems.

JEFFSOL® EC Health and Safety

Acute/ShortTerm Toxicity:

JEFFSOL® EC is practically nontoxic to rabbits by single dermal exposures.

JEFFSOL® EC is practically non-toxic to rodents by single oral exposures, however other studies have indicated that these results may not predict the toxicity of JEFFSOL® EC to humans.

JEFFSOL® EC is non-irritating to the skin of rabbits and moderately irritating to the eyes of rabbits.

JEFFSOL® EC has failed to produce symptoms of skin sensitization in animal studies or in human patch tests.

Subchronic Dermal Toxicity:

JEFFSOL® EC did not produce any evidence of dermal irritation, systemic toxicity, or significant gross necropsy or histopathological findings at concentrations of up to 2 mg/kg/day.

Oral Toxicity:

Subacute exposure studies using dogs, and longer-term studies using rats, have shown significant levels of liver and kidney damage and subsequent death from ingestion of ethylene carbonate (JEFFSOL® EC).

The clinical and histopathological effects observed in the dog and rat studies indicate developing liver damage, followed by more pronounced kidney effects, with symptoms of uremia, anuria, increased blood urea-nitrogen values and coma. These symptoms and effects are similar to those observed from repeated oral exposures to ethylene glycol, which at that time was a suspected, but unconfirmed, metabolite of JEFFSOL® EC.

A subsequent study investigating the metabolism of ethylene carbonate demonstrated that ethylene carbonate is quickly and extensively metabolized to ethylene glycol following ingestion.

JEFFSOL® EC orally administered to female rats over the period of fetal development produced reduced maternal body weight gain and fetal birth defects at a dosage of 3000 mg/kg/day. In addition, reduced body weight gain the in the fetus was observed in the 1500 mg/kg/day dosage group. These findings are consistent with developmental toxicity effects observed following the ingestion of ethylene glycol.

Genetic Toxicity:

JEFFSOL® EC did not demonstrate any evidence of mutagenicity or DNA damage in the gene-tox test systems.

For additional and detailed information on the health and safety of the Huntsman JEFFSOL® Carbonates, please contact your Huntsman sales or marketing representative.

HUNTSMAN

AVAILABLE JEFFSOL® LITERATURE

Products

JEFFSOL® Ethylene Carbonate	1094
JEFFSOL® Propylene Carbonate	1025
JEFFSOL® Propylene Carbonate - CA	1139
JEFFSOL® Propylene Carbonate - NF	1140
JEFFSOL® Propylene Carbonate - NF	1140E (Europe)
JEFFSOL® Butylene Carbonate	1134
JEFFSOL® EC-25, EC-50, EC-75	1101
UltraPure™ Propylene Carbonate	1110
UltraPure™ Ethylene Carbonate	1124
JEFFSOL® Carbonates Polymer Solubility Data	1088
JEFFSOL® Carbonates Comparative Solvents Data	1089
CARBALINK™ HPC, Hydroxypropylcarbamate	1132
JEFFSOL® Ethylene Carbonate	1108E (Europe)
JEFFSOL® Propylene Carbonate	1103E (Europe)
JEFFSOL® EC-25 and JEFFSOL® EC-50	1107E (Europe)

Applications

JEFFSOL® Ethylene Carbonate & Propylene Carbonate Miscibility Chart	1090
HUNTSMAN Miscibility Predictor Chart	1092
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JEFFSOL® Alkylene Carbonates in Industrial Cleaner Formulations	uncoded
JEFFSOL® Alkylene Carbonates in Tub & Tile Formulations	uncoded

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