Innowacja w GC: ciecz jonowe jako fazy stacjonarne

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Katowice, 23.06.2014
Overview

Structure of a Polysiloxane Polymer Phase

Drawbacks

• Active hydroxyl (-OH) groups at the polymer termini allow a back-biting reaction
  – Resulting in phase degradation
  – Contributing to column bleed
• Chemistry modifications are limited to pendent group changes

R = methyl, phenyl, fluoropropyl, and/or cyanopropyl (polarity increases from left).

x,y = percentage in the overall polymer composition.
Overview
Structure of a Polyethylene Glycol Phase

\[
\text{HO—CH}_2—\text{CH}_2—\text{O—CH}_2—\text{CH}_2—\text{O—CH}_2—\text{CH}_2—\text{OH}
\]

Drawbacks
- Limited to 280 °C maximum temperature
- Active hydroxyl (-OH) groups at the polymer termini allow a back-biting reaction
  - Resulting in phase degradation
  - Contributing to column bleed
- Very limited chemistry modifications possible

\[n = \text{number of monomer repetitions to make the overall polymer.}\]

Carbowax 20M (commonly used to make these) has a MW of 20,000.
Definition, Early Literature, and Use

Ionic liquids are a class of solvents with low melting points that consist of organic cations associated with (inorganic or organic) anions

Ethyl ammonium nitrate \((\text{C}_2\text{H}_5\text{NH}_3^+)(\text{NO}_3^-)\), which has a melting point of 12 °C, was described in 1914

- P. Walden, Bull. Acad. Imper. Sci. (St. Petersburg) 1800 (1914)

Today, they are used as solvents, electrically conducting fluids, and sealants
Structure of an Ionic Liquid Phase

- Numerous combinations of cations, anions and linkers are possible allowing for “tailored” selectivity or application
  - Dicationic (*shown*) or polycationic
  - Cations (imidazolium, phosphonium, pyrrolidinium, …), anions (NTf2-, triflat, tetrafluoroborate, hexafluorophosphate, …), and linkages (alkanes, polyethyleneglycols, different lengths, …) can be changed
  - Pendant groups can be added to cations and/or linkages

Phase used to make the SLB-IL100

1,9-di(3-vinylimidazolium) nonane bis(trifluoromethyl) sulfonyle imide
Ionic Liquids in GC

Several properties make ionic liquids desirable as GC stationary phases:

• Very low volatility…
  – should result in columns with lower bleed and longer life
• Remain in the liquid state over a wide temperature range…
  – should result in columns with extended temperature ranges
• No active hydroxyl (-OH) groups at their termini…
  – should result in columns resistant to damage from moisture/oxygen
• Are inherently highly polar…
  – should result in columns with higher polarity that have lower elution temperatures plus an increased selectivity for polarizable analytes
• Have the broadest range of physical-chemical solvation interactions of any solvent…
  – should result in columns with unique selectivity
• High viscosity…
  – should be easy to coat columns
Polarity scale for GC phases

Above scale: Position/Maximum temperature classical GC phases.
Below scale: Position/Maximum temperature of Ionic Liquid GC phases.
Ionic Liquid GC Columns from Sigma-Aldrich

Application areas include:

**Food & Beverage Applications**
- Fatty Acid Methyl Esters (FAMEs) by degree of unsaturation cis/trans
- Fatty Acid Methyl Ester (FAME) isomers

**GC×GC Applications**
- As the polar column for orthogonal separations

**Petroleum Applications**
- Fatty Acid Methyl Ester (FAME)
- Profile of B20 Biodiesel
- Benzene and other aromatics in gasoline

For more information, visit [sigma-aldrich.com/il-gc](http://sigma-aldrich.com/il-gc)
Selectivity Evaluations
Test Mix Peak IDs and Conditions

Peak IDs (listed in boiling point order)
- Toluene
- Ethylbenzene
- p-Xylene
- Isopropylbenzene (Cumene)
- Cyclohexanone
- 1,2,4-Trimethylbenzene
- 1,2,4,5-Tetramethylbenzene
- n-Tridecane (C13)

Conditions
- columns: 30 m x 0.25 mm I.D., 0.20 µm
- oven: 110 °C
- inj.: 250 °C
- det.: FID, 250 °C
- carrier gas: helium, 26 cm/sec
- injection: 1.0 µL, 100:1 split
- sample: each analyte at various concentrations in isooctane
Test Mix on Ionic Liquid Columns
30 m Columns, 110 °C Isothermal

SLB-IL59

SLB-IL61

SLB-IL76

SLB-IL82

SLB-IL100

SLB-IL111
SLB®-IL60: Unique Selectivity
SLB®-IL60: Improved Resolution

Figure 1. Industrial Solvents on PEG
- Column: PEG 1, 30 m x 0.25 mm ID, 0.25 μm
- Oven: 40 °C (6 min), 8 °C/min to 200 °C (5 min)
- Injection: 1 μL, 1:1000 split
- Detector: TCD, 250 °C

Sample: 36-component industrial solvent mix, each analyte at 0.2% (w/v) in pentane

1. Hexane
2. 1,1-Dichloroethane
3. Methyl formate
4. Acetone
5. Ethyl acetate
6. Methyl acetate
7. trans-1,2-Dichloroethylene
8. Tetrahydrofuran
9. Carbon tetrachloride
10. 1,1,1-Trichloroethane
11. 1,1-Dichloroethane
12. Ethyl acetate
13. Methanol
14. Isopropyl acetate
15. 2-Butanone
16. 1-Propanol
17. Methylene chloride
18. Ethanol
19. Benzene
20. n-Propyl acetate
21. Trichloroethylene
22. 4-Methyl-2-pentene
23. Isobutyl acetate
24. Toluene
25. Chloroform
26. sec-Butanol
27. Toluene
28. n-Decanal
29. 3,4-Dimethane
30. 1,2-Dichloroethane
31. n-Butyl acetate
32. 2-Methylpentane
33. Isobutane
34. Nitromethane
35. Isocynyl acetate
36. Ethylbenzene
37. Mesitylene
38. p-Xylene
39. m-Xylene
40. 5-Methyl-2-hexanone
41. n-Butanol
42. n-Hexanol
43. α-Hydroxy
44. Isocynyl alcohol
45. Chlorobenzene
46. o-Xylene
47. 1,1,2-Trichloroethane
48. Dimethylformamide
49. Diisopropyl alcohol
50. Cyclohexanone
51. 2-Butoxyethanol (Butyl cellosolve)
52. 1,4-Diisopropylacetate
53. 1,2,2-Trichloroethylene
54. 2-Methylanthone
55. 3-Methylphenol
56. 4-Methylphenol

Figure 2. Industrial Solvents on the SLB-IL60
- Column: SLB®-IL60, 30 m x 0.75 mm ID, 0.25 μm (2905-46)

All peak IDs and remaining conditions are the same as in Figure 1.
SLB®-IL60: Lower FID Bleed

Figure 1. FID Bleed Chromatograms

- PEG columns: 30 m x 0.25 mm ID, 0.25 µm
- SLB-IL60 column: 30 m x 0.25 mm ID, 0.20 µm (2952S-I)
- Oven: 50°C (2 min), 15°C/min to column programmed temperature limit (10 min)
- Injector: 250°C
- Carrier gas: helium, 1 ml/min
- Detector: FID, column programmed temperature limit
- Injection: 1 µl, splitless
- Liners: 4 mm ID, split/splitless type, single taper wool packed Focal liner™ design
- Sample: methylene chloride
Comparison of GC-MS TIC Bleed

Commercial WAX column #1 (max temp of 260 °C)

Commercial WAX column #2 (max temp of 280 °C)

SLB-IL76 (max temp of 270 °C)

SLB-IL59 (max temp of 300 °C)

All TICs are on the same Y-scale
SLB®-IL60: Better High Temperature Stability

Figure 1. FID Bleed Levels (pA) During Thermal Stress Test

Figure 2. FID Bleed Levels (pA) Before/After Thermal Stress Test
SLB®-IL60: Better High Temperature Stability

Figure 3. Selectivity Before/After Thermal Stress Test

- Column 1: PEG 3, 30 m x 0.25 mm I.D., 0.25 µm
- Column 2: SLB-IL60, 30 m x 0.25 mm I.D., 0.20 µm (29505-U1)
- Oven: 155 °C (25 min) for PEG 3, 180 °C (25 min) for SLB-IL60
- Injection: 1 µL, 100:1 split
- Detector: FID, 250 °C
- Carrier gas: helium, 20 cm/sec for PEG 3, helium, 25 cm/sec for SLB-IL60
- Liner: 4 mm I.D., split/splitless type, single taper wool packed FocusLiner™ design
- Sample: polar column test mix (47303), 0 analytes, each at 500 µg/mL in methylene chloride
SLB®-IL60: Stability to Loss of Carrier Gas Flow

Figure 1. Performance Before/After Stop Flow Test

- **Column:** SLB-IL60, 30 m x 0.25 mm i.d., 0.20 µm (29505-10)
- ** Oven:** 130°C (25 min)
- **Inj. Temp.:** 250°C
- **Carrier Gas:** helium, 25 cm³/min
- **Detector:** FID, 250°C
- **Injection:** 1 µL, 1001 split
  - **Liner:** 4 mm i.d., split/splitless type, single taper wool packed FocusLiner™ design
- **Sample:** polar column test mix (47303), 9 analytes, each at 500 µg/mL in methylene chloride

1. 2-Octalone
2. n-Pentadecane
3. 1-Octanol
4. n-Hexadecane
5. n-Heptadecane
6. n-Octadecane
7. 2,6-Dimethylphenol
8. 2,6-Dimethylanthline
9. n-Eicosane

Before

After 1st Hour

After 2nd Hour
Air as Carrier Gas - Experimental Design

Columns

Carbowax column, 30 m x 0.25 mm I.D., 0.25 µm
SLB-IL59 column, 30 m x 0.25 mm I.D., 0.20 µm

Conditions

oven: 50 °C (2 min.), 4 °C/min. to 200 °C (15 min.)
 inj.: 250 °C
det.: 250 °C
carrier gas: compressed air, 16 psi constant
injection: 1µL, 50:1 split
sample: Programmed Test Mix
Air as Carrier Gas - Carbowax Column

1st injection

200 °C Ending Oven Temperature!

After 100 injections

After 200 injections
Air as Carrier Gas – Ionic Liquid column

After 120 injections

After 220 injections

After 320 injections

After 420 injections

After 520 injections

After 620 injections

200 °C Ending Oven Temperature!
Applications

Chromatograms:

- Environmental
- Petroleum
- Biofuel
- Chemical
- Agriculture
- Food and Beverage
- Flavor and Fragrance
- Clinical
- General Analytical
Chromatograms (Environmental)
PCBs on SLB-IL82

Low MS bleed.
Alternate selectivity than columns commonly used for this application.
Chromatograms (Environmental)
PAHs on SLB-IL59

Provides resolution of all isomer sets. Low MS bleed.
20 m x 0.18 mm I.D., 0.14 µm column used for timely elution of the heavier PAHs.

11. Benzo[b]fluoranthene
12. Benzo[k]fluoranthene
13. Benzo[j] fluoranthene
15. Indeno[1,2,3-cd]pyrene
16. Dibenzo[a,h]anthracene

Cannot be resolved on non-polar columns

Improved resolution compared to non-polar columns
Achromatograms (Petroleum)
Aromatics in Fuel (Gasoline with Ethanol Additive) on SLB-IL111

2. Ethanol
3. Benzene
4. 2-Butanol
5. MEK

Able to separate benzene (3) from aliphatic hydrocarbons (1), ethanol (2), two internal standards [2-butanol (4) and methyl ethyl ketone (5)], and other aromatics (6-16).
Chromatograms (Petroleum)
Aromatics in Fuel (Gasoline with MTBE/TAME Additive) on SLB-IL111

Resolves benzene (3) from aliphatic hydrocarbons, MTBE (1), TAME (2), and other aromatics (4-14).
Elution of heavy PAHs in a timely manner (<12 minutes).
SLB-IL111 allows petroleum components to elute prior to FAME components. PEG columns are unable to accomplish this.

C16:0 FAME after the C25 n-alkane
Fewer co-elutions observed compared to a polyethylene glycol (PEG) phase.
Partial separation by compound class (aliphatic hydrocarbons before aromatic hydrocarbons).
Chromatograms (Chemical)

Impurities in Toluene on SLB-IL100 (30 m column)

Resolution of toluene from all aromatic impurities, as well as residual aliphatic hydrocarbons.

2. Benzene
3. Toluene
4. Ethylbenzene
Chromatograms (Chemical)
Impurities in Toluene on SLB-IL100 (60 m column)

Excellent resolution of various contaminants in toluene.
Resolution of xylene isomers achieved at an oven temperature of 70 °C.

2. Benzene
3. Toluene
4. Ethylbenzene
5. p-Xylene
6. m-Xylene
7. Cumene
8. 1,4-Dioxane
9. o-Xylene
Resolution of xylene isomers.
Resolution of several methylphenols.
SLB-IL60 can resolve carbon tetrachloride (peak 3) and 1,1,1-trichloroethane (peak 4). Requires 16 minutes on PEG columns, but just 11 minutes on SLB-IL60.
**Chromatograms** *(Chemical)*

**Esters and Ethers on SLB-IL60**

SLB-IL60 is able to separate all analytes, plus a contaminant peak. Cannot be accomplished using a polyethylene glycol (PEG) column.

- 2. Ethyl formate
- 3. Methyl acetate
- 8. Isobutyl acetate
- 9. 1,4-Dioxane
- 11. Isoamyl acetate
- c. Contaminant
Chromatograms (Chemical)
Aromatic Amines (Anilines) on SLB-IL59

Better selectivity for these analytes than with non-polar columns.
Separation of the three toluidine isomers (peaks 3-5) is possible.
Chromatograms (Chemical)
Aromatic Amines (Anilines) on SLB-IL59

Good peak shape and response observed for all compounds.
Greater retention and alternative elution order that achieved with non-polar columns.
Chromatograms (Chemical)
Sulfur Compounds on SLB-IL59

1. Carbon disulfide
2. Ethyl mercaptan
3. Dimethylsulfide
4. Isopropyl mercaptan

No adsorption issues observed.
Compatible with mass spectrometer detectors.
Chromatograms (Agriculture)
Edible Oils on SLB-IL111

Canola Oil

Lard Oil

Palm Oil

Soybean Oil

Sunflower Seed Oil

Suitable to monitor purity and detect adulteration
Chromatograms (Agriculture)
Edible Oils (Rapeseed Oil) on SLB-IL100

Great selectivity towards polarizable analytes (contain double and/or triple C-C bonds).
Unique selectivity compared to columns with a cyanopropyl polysiloxane phase.

6. C18:3
7. C20:0
8. C20:1
Several elution order changes compared to PEG columns. Analysis requires 52 minutes with PEG columns.
Chromatograms (Agriculture)

cis/trans FAME Isomers on SP-2560 and SLB-IL111

Resolution of all 37 FAMEs on both columns, but with different elution orders. SP-2560/SLB-IL111 pairing allows most comprehensive fatty acid composition information possible.
Detailed analysis of C18:1, C18:2, and C18:3 FAME isomers. This level of resolution not possible with columns made with cyanopropyl polysiloxane phase.
Chromatograms (Agriculture)
cis/trans C18:1 FAME Isomers in PHVO on SP-2560 and SLB-IL111

SLB-IL111 provides increased retention of cis isomers relative to trans isomers.
SP-2560/SLB-IL111 pairing allows most comprehensive fatty acid composition information possible.

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Chromatograms (Agriculture)
cis/trans FAME Isomers in Walnuts on SLB-IL111

Body uses ALA (C18:3n3) to make the essential fatty acids (EPA) and (DHA).
SLB-IL111 provides great resolution of walnut fatty acids.
Chromatograms (Food and Beverage)
FAMEs by Degree of Unsaturation on SLB-IL60

Several elution order changes compared to PEG columns.
Analysis requires 52 minutes with PEG columns.

17. C18:1n9c
18. C18:1n9t
19. C18:2n6c
20. C18:2n6t

26. C20:3n6
28. C20:3n3
35. C22:5n3
36. C24:0
37. C22:6n3
Chromatograms (Food and Beverage)
Omega 3 and Omega 6 FAMEs in Menhaden Oil on SLB-IL60

Elution order changes compared to PEG.
Quicker with SLB-IL60 (31 minutes compared to 52 minutes).

Important Omega 3 fatty acids
11. C18:3n3 (ALA)
17. C20:5n3 (EPA)
19. C22:6n3 (DHA)
Chromatograms (Food and Beverage)
Omega 3 and Omega 6 FAMEs in Fish Oil Capsule on SLB-IL60

Elution order changes compared to PEG.
Quicker with SLB-IL60 (31 minutes compared to 52 minutes).

Important Omega 3 fatty acids
11. C18:3n3 (ALA)
16. C20:5n3 (EPA)
18. C22:6n3 (DHA)
Different ratios observed in salmon compared to menhaden oil and fish oil capsules. Elution order changes compared to PEG columns.

Important Omega 3 fatty acids:
11. C18:3n3 (ALA)
16. C20:5n3 (EPA)
18. C22:6n3 (DHA)
Chromatograms (Food and Beverage)
cis/trans FAME Isomers on SP-2560 and SLB-IL111

Resolution of all 37 FAMEs on both columns, but with different elution orders. SP-2560/SLB-IL111 pairing allows most comprehensive fatty acid composition information possible.
Chromatograms (Food and Beverage)
cis/trans FAME Isomers (C18:1, C18:2, C18:3) on SLB-IL100

Detailed analysis of C18:1, C18:2, and C18:3 FAME isomers. This level of resolution not possible with columns made with cyanopropyl polysiloxane phase.

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Chromatograms (Food and Beverage) 
cis/trans FAME Isomers in Edible Oils on SLB-IL111
A cheese contains a concentration of the fat found in the milk source.
The SLB-IL111 is able to provide separation of many cis/trans C18:1 FAME isomers.
Chromatograms (Food and Beverage)
cis/trans FAME Isomers in Cookies on SLB-IL111

Increased retention of cis isomers relative to trans isomers

Use Ag ion fractionation to enhance identification
Composition of the individual fatty acids in milk is important for nutritional purposes. The SLB-IL111 is able to provide separation of many cis/trans C18:1 FAME isomers.
Composition of the individual fatty acids in milk is important for nutritional purposes. The SLB-IL111 is able to provide separation of many cis/trans C18:1 FAME isomers.
Chromatograms (Food and Beverage)
cis/trans FAME Isomers in Rapeseed Oil on SLB-IL100

Great selectivity towards polarizable analytes (contain double and/or triple C-C bonds).
Unique selectivity compared to columns with a cyanopropyl polysiloxane phase.
Chromatograms (Food and Beverage)
cis/trans FAME Isomers in Ruminant Fat on SLB-IL111

Resolution of C18:2n9c,11t from C18:2n7t,9c (most abundant CLA isomers in ruminant fats).
This is not possible with any other column.

C18:2n9c,11t (rumenic acid)
Chromatograms (Food and Beverage)
cis/trans FAME Isomers in Walnuts on SLB-IL111

Body uses ALA (C18:3n3) to make the essential fatty acids (EPA) and (DHA).
SLB-IL111 provides great resolution of walnut fatty acids.
Chromatograms (Food and Beverage)
PCBs on SLB-IL82

Low MS bleed.
Alternate selectivity than columns commonly used for this application.
Chromatograms (Food and Beverage)
PAHs on SLB-IL59

Provides resolution of all isomer sets. Low MS bleed.
20 m x 0.18 mm I.D., 0.14 µm column used for timely elution of the heavier PAHs.
Chromatograms (Flavor and Fragrance)

Volatile (Potpourri Fragrance Compounds) on SLB-IL60

SLB-IL60 has similar polarity, but employs different interaction mechanisms. In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
SLB-IL59 employs different interaction mechanisms than a PEG. This results in unique selectivity compared to PEG.
Chromatograms (Flavor and Fragrance)
Essential Oils (Lemon) on SLB-IL59, 5 °C/min Ramp Rate

SLB-IL59 employs different interaction mechanisms than a PEG. This results in unique selectivity compared to PEG.
SLB-IL60 has similar polarity, but employs different interaction mechanisms. In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
Chromatograms *(Flavor and Fragrance)*

Essential Oils (Distilled Lime) on SLB-IL60

SLB-IL60 has similar polarity, but employs different interaction mechanisms.

In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
Chromatograms (Flavor and Fragrance)
Essential Oils (Patchouli) on SLB-IL60

SLB-IL60 has similar polarity, but employs different interaction mechanisms. In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
SLB-IL59 employs different interaction mechanisms than a PEG.
This results in unique selectivity compared to PEG.
Chromatograms (Flavor and Fragrance)
Essential Oils (Kennewick Peppermint) on SLB-IL60

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Chromatograms (Flavor and Fragrance)
Essential Oils (Petitgrain) on SLB-IL60, 75 °C Initial Oven Temp.

SLB-IL60 has similar polarity, but employs different interaction mechanisms. In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
Chromatograms (Flavor and Fragrance)
Essential Oils (Spearmint) on SLB-IL59, 50 °C Initial Oven Temp.

SLB-IL59 employs different interaction mechanisms than a PEG.
This results in unique selectivity compared to PEG.
Chromatograms (Flavor and Fragrance)
Essential Oils (Spearmint) on SLB-IL59, 80 °C Initial Oven Temp.

SLB-IL59 employs different interaction mechanisms than a PEG.
This results in unique selectivity compared to PEG.
**Chromatograms** *(Flavor and Fragrance)*  
Essential Oils (Native Spearmint) on SLB-IL60

SLB-IL60 has similar polarity, but employs different interaction mechanisms.  
In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
Chromatograms (Flavor and Fragrance)
Essential Oils (Scotch Spearmint) on SLB-IL60

SLB-IL60 has similar polarity, but employs different interaction mechanisms. In addition to unique selectivity, the SLB-IL60 allows a faster analysis with the same run conditions.
Chromatograms (Clinical)
FAMEs by Degree of Unsaturation on SLB-IL60

Several elution order changes compared to PEG columns.
Analysis requires 52 minutes with PEG columns.

17. C18:1n9c
18. C18:1n9t
19. C18:2n6c
20. C18:2n6t
26. C20:3n6
28. C20:3n3
35. C22:5n3
36. C24:0
37. C22:6n3
Chromatograms (Clinical)
cis/trans FAME Isomers on SP-2560 and SLB-IL111

Resolution of all 37 FAMEs on both columns, but with different elution orders. SP-2560/SLB-IL111 pairing allows most comprehensive fatty acid composition information possible.
Chromatograms (Clinical)
cis/trans FAME Isomers (C18:1, C18:2, C18:3) on SLB-IL100

Detailed analysis of C18:1, C18:2, and C18:3 FAME isomers.
This level of resolution not possible with columns made with cyanopropyl polysiloxane phase.

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DHA is important to brain development in infants.
SLB-IL111 provides resolution of many FAMEs, including ALA, EPA, and DHA
Chromatograms (Clinical)
cis/trans FAME Isomers in Human Plasma on SLB-IL111

Health care providers may be interested in levels of individual fatty acids.
SLB-IL111 provides separation of many trans (peaks 21-25) and cis (peaks 26-30) C18:1 fatty acids.

20. C18:0
21-25. C18:1 trans
26. C18:1n9c
26-30. C18:1 cis
31. C20:0
Summary

GC phases based on Ionic Liquids:
- have a different selectivity compared to conventional phases
- allow for shorter analysis times
- provide lower bleeding and long lifetime
- offer a broader temperature range compared to conventional polar phases
- improve multidimensional separations (orthogonal selectivity and high thermal stability of polar phase)
## Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLB-IL59</td>
<td>Phase: Non-bonded; 1,12-Di(triethylphosphonium)dodecane bis(trifluoromethylsulfonyl)imide</td>
<td>L x I.D. 15 m x 0.10 mm, df 0.08 (\mu) m</td>
</tr>
<tr>
<td></td>
<td>Temp. Limits: Subambient to 300 °C (Isothermal or programmed)</td>
<td></td>
</tr>
<tr>
<td>28880-U</td>
<td>SLB-IL59 Capillary GC Column</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.20 (\mu) m</td>
</tr>
<tr>
<td>28891-U</td>
<td>SLB-IL59 Capillary GC Column</td>
<td></td>
</tr>
<tr>
<td>SLB-IL60</td>
<td>Phase: Non-bonded; 1,12-Di(triethylphosphonium)dodecane bis(trifluoromethylsulfonyl)imide</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.20 (\mu) m</td>
</tr>
<tr>
<td></td>
<td>Temp. Limits: 35 °C to 300 °C (Isothermal or programmed)</td>
<td></td>
</tr>
<tr>
<td>29505-U</td>
<td>SLB-IL60 Capillary GC Column</td>
<td></td>
</tr>
<tr>
<td>SLB-IL61</td>
<td>Phase: Non-bonded; 1,12-Di(triethylphosphonium)dodecane bis(trifluoromethylsulfonyl)imide</td>
<td>L x I.D. 15 m x 0.10 mm, df 0.08 (\mu) m</td>
</tr>
<tr>
<td></td>
<td>Temp. Limits: 40 °C to 290 °C (Isothermal or programmed)</td>
<td></td>
</tr>
<tr>
<td>29484-U</td>
<td>SLB-IL61 Capillary GC Column</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.20 (\mu) m</td>
</tr>
<tr>
<td>29486-U</td>
<td>SLB-IL61 Capillary GC Column</td>
<td></td>
</tr>
<tr>
<td>SLB-IL76</td>
<td>Phase: Non-bonded; Tri(triethylphosphoniumhexanamido)triethylaminebis(trifluoromethylsulfonyl)imide</td>
<td>L x I.D. 15 m x 0.10 mm, df 0.08 (\mu) m</td>
</tr>
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<td></td>
<td>Temp. Limits: Subambient to 270 °C (Isothermal or programmed)</td>
<td></td>
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<tr>
<td>28909-U</td>
<td>SLB-IL76 Capillary GC Column</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.20 (\mu) m</td>
</tr>
<tr>
<td>28913-U</td>
<td>SLB-IL76 Capillary GC Column</td>
<td></td>
</tr>
</tbody>
</table>

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## Ordering Information

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Description</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLB-IL82</td>
<td>Capillary GC Column</td>
<td>L x I.D. 15 m x 0.10 mm, df 0.08 μm</td>
</tr>
<tr>
<td>SLB-IL82</td>
<td>Capillary GC Column</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.25 μm</td>
</tr>
<tr>
<td>SLB-IL100</td>
<td>Capillary GC Column</td>
<td>L x I.D. 15 m x 0.10 mm, df 0.08 μm</td>
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<tr>
<td>SLB-IL100</td>
<td>Capillary GC Column</td>
<td>L x I.D. 20 m x 0.18 mm, df 0.14 μm</td>
</tr>
<tr>
<td>SLB-IL100</td>
<td>Capillary GC Column</td>
<td>L x I.D. 30 m x 0.25 mm, df 0.20 μm</td>
</tr>
<tr>
<td>SLB-IL100</td>
<td>Capillary GC Column</td>
<td>L x I.D. 60 m x 0.25 mm, df 0.20 μm</td>
</tr>
<tr>
<td>SLB-IL111</td>
<td>Capillary GC Column</td>
<td>L x I.D. 60 m x 0.32 mm, df 0.26 μm</td>
</tr>
</tbody>
</table>

1731,39 \(\div\) 5389,98 PLN netto
To Learn More…

Visit our ionic liquid GC column landing page (sigma-aldrich.com/il-gc) at the Sigma-Aldrich web site
Download or request “Supelco Ionic Liquid GC Columns: Applications”
Download or request “Supelco Ionic Liquid GC Columns: Bibliography”
Related Products
Maximize Performance! Brochure (T407103 JWE)

- 28-page, 4-color, bundling brochure

- Lists common replacement items (septa, liners, ferrules, solvents, syringes, vials, purifiers, and much more)

- For several GC makes/models (Agilent/HP, PerkinElmer, Shimadzu, Thermo, and Varian)

A ‘must-have’ for all GC labs!
Can be downloaded from <sigma-aldrich.com/gc-learning>.
Resources
Complementary Pieces

• “Introduction to the Technology”
  – What are ionic liquid GC columns?
  – How do they relate to non-ionic liquid GC columns and to one another?
  – Selectivity information
  – Details about each phase

• “Bibliography”
  – Peer-reviewed journal articles leading up to and beyond the seminal 2005 JACS (Journal of the American Chemical Society) article
  – Updated periodically

Both pieces can be downloaded from <sigma-aldrich.com/il-gc-lit>. 
Dziękuję za uwagę!