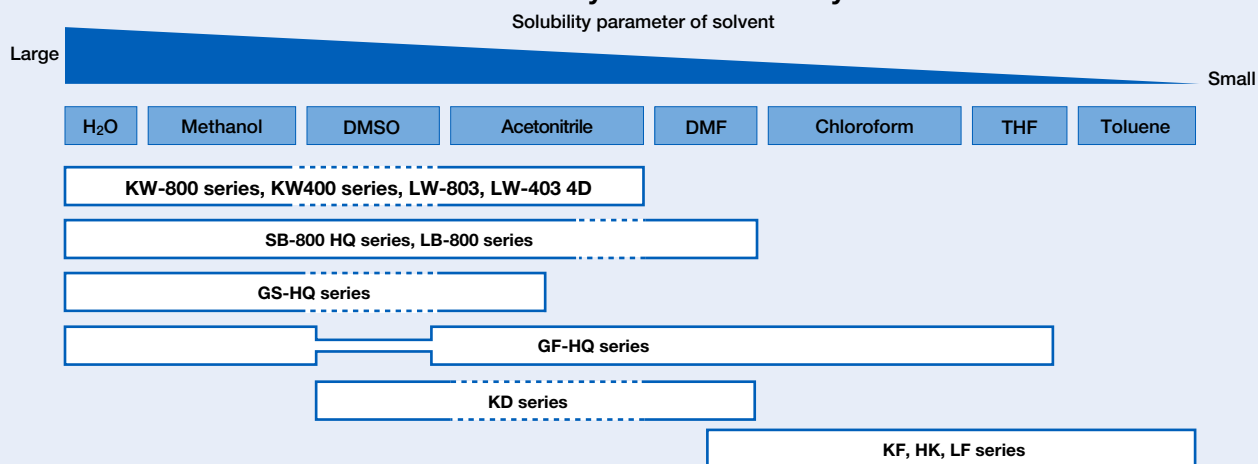


# Column Selection (Polymers)

	Application	Eluent	Column	Page
Aqueous SEC (GFC)	Biological macromolecules (Proteins, Peptides, Nucleic acids, etc.)	Buffer etc.	KW-800 series	36
			KW400 series	36
			LW-803	37
			LW-403 4D	37
	Biological macromolecules (High MW range)	Buffer etc.	SB-800 HQ series	40
			LB-800 series	41
	Water-soluble polymers (Polyacrylamide, etc.)	Water, buffer and aqueous salt solution, etc.	SB-800 HQ series	40
			LB-800 series	41
Organic SEC (GPC)	General polymers	THF	KF-800 series	48
			KF-400HQ series	52
			HK-400 series	54
		Chloroform	LF series	56
			KF-800 series	48
			HK-400 series	54
	Polar polymers (Polyvinylpyrrolidone etc.)	DMF	LF series	56
			SB-800 HQ series	40
			LB-800 series	41
			KD-800 series	50
			HK-400 series	54
			LF series	56
	Engineering plastics (Polyamides etc.)	HFIP	KD-800 series	50
			HK-400 series	54
			LF series	56
Aqueous-Organic SEC			GF-HQ series	46

## Guideline for SEC column selection by solvent usability



See page 60 for the solvent replaceability of organic solvent SEC (GPC) packed columns.

# Precautions for Polar Polymer Analysis

Unexpected interactions in the column can affect the size exclusion chromatography analysis of polar polymers. These interactions may change elution patterns and results in an invalid molecular weight calculation. It is important to reduce these interfering interactions in order to obtain the accurate molecular weight distribution.

## ~ Interfering interactions likely to be observed ~

### Interactions between the analyte and the packing materials

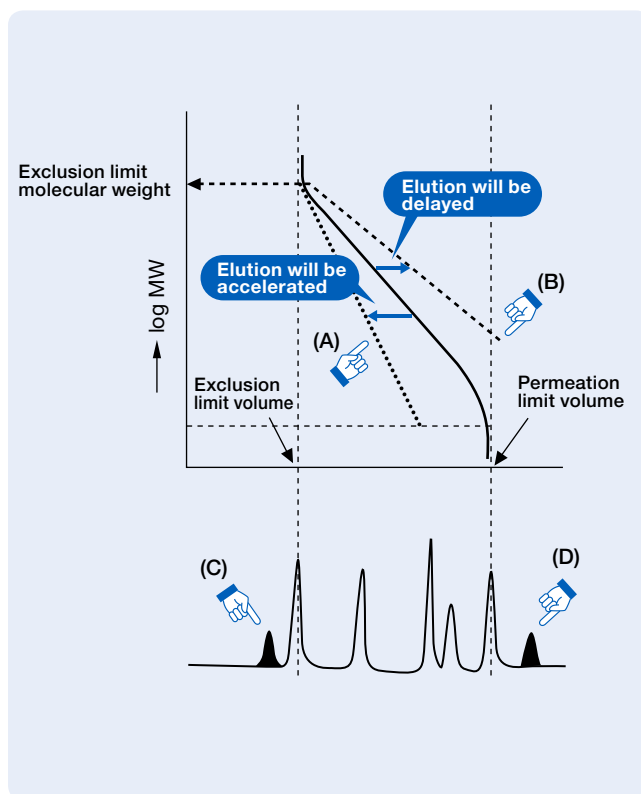
- ◆ Hydrophobic interaction
  - The analyte is adsorbed on the packing material.
  - This delays the analyte elution and results in under estimating the analyte's molecular weight. See (B) and (D).
- ◆ Ionic interaction
  - (1) Ion Exclusion
    - The analyte is repelled from the packing material.
    - This accelerates the analyte elution and results in over estimating the analyte's molecular weight. See (A) and (C).
  - (2) Ion Exchange
    - The analyte is adsorbed onto the packing material.
    - This delays the analyte elution and results in under estimating the analyte's molecular weight. See (B) and (D).

### Interaction within and between the analyte

- ◆ Ionic repulsion effects observed within the multivalent macromolecules causes structure expansion
  - This accelerates the analyte elution and results in over estimating the analyte's molecular weight. See (A).
- ◆ Association between the molecules
  - This accelerates the analyte elution and results in over estimating the analyte's molecular weight. See (A).

### Interactions between the analyte and the solvent

- ◆ The multivalent ion in the solvent works as a bridge to bind ionic molecules (analyte).



## Methods to reduce interactions

### Aqueous SEC (GFC)

#### Ionic interaction

- ◆ Add salt into the eluent

#### Hydrophobic interaction

- ◆ Increase the analyte dissociation
  - Cationic polymer → Lower the eluent pH
  - Anionic polymer → Higher the eluent pH
- ◆ Lower the eluent polarity
  - e.g. Add acetonitrile or methanol

### Organic SEC (GPC)

#### Ionic interaction

- ◆ Add salt into the eluent
  - e.g. Add LiBr to DMF
  - Add  $\text{CF}_3\text{COONa}$  to HFIP

#### Hydrophobic interaction

- ◆ Lower the eluent polarity
  - e.g. Change the eluent from DMF to THF

#### Hydrophilic interaction

- ◆ Increase the eluent polarity
  - e.g. Change the eluent from THF to DMF

# Organic SEC (GPC) Columns: General Analysis (DMF)

<https://www.shodex.de/gpc-kd-columns-dmf>

## Features

- **KD-800**
  - Standard organic solvent SEC (GPC) column
  - Supports a wide range of applications from low to high molecular weight compounds
  - Fulfills USP-NF L21 requirements

### • Standard columns [ KD-800 series is made to order. ]

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Pore Size (Å)	Column Size (mm) I.D. x Length
F6028210	<b>GPC KD-801</b>	≥ 17,000	6	50	<b>8.0 x 300</b>
F6028220	<b>GPC KD-802</b>	≥ 17,000	6	150	<b>8.0 x 300</b>
F6028225	<b>GPC KD-802.5</b>	≥ 17,000	6	300	<b>8.0 x 300</b>
F6028230	<b>GPC KD-803</b>	≥ 17,000	6	500	<b>8.0 x 300</b>
F6028240	<b>GPC KD-804</b>	≥ 17,000	7	1,500	<b>8.0 x 300</b>
F6028250	<b>GPC KD-805</b>	≥ 11,000	10	5,000	<b>8.0 x 300</b>
F6028260	<b>GPC KD-806</b>	≥ 11,000	10	10,000	<b>8.0 x 300</b>
F6028290	<b>GPC KD-806M</b>	≥ 13,000	10	10,000	<b>8.0 x 300</b>
F6028270	<b>GPC KD-807</b>	≥ 6,000	18	20,000	<b>8.0 x 300</b>
F6700411	<b>GPC KD-G 4A</b>	(guard column)	8	—	<b>4.6 x 10</b>

KD-806M is a mixed-gel column capable of analyzing samples over a wide range of molecular weight distribution. See page 60 for solvent replacement applicability of Organic SEC (GPC) columns.

Base Material: Styrene divinylbenzene copolymer  
Shipping Solvent: N,N-Dimethylformamide (DMF)

### Target molecular weight range and exclusion limit

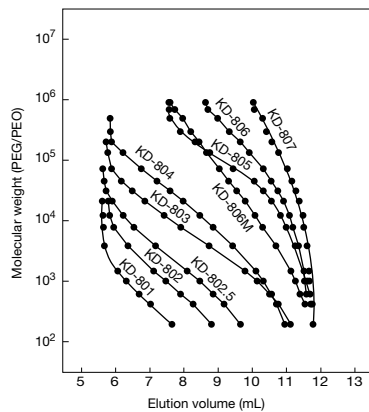
#### • Measured with \*PEG/PEO (eluent: DMF)

Product Name	Target Molecular Weight Range	Exclusion Limit	Product Name	Target Molecular Weight Range	Exclusion Limit
<b>KD-801</b>	100 - 1,500	2,500	<b>KD-805</b>	30,000 - ** (4,000,000)	** (4,000,000)
<b>KD-802</b>	200 - 4,000	7,000	<b>KD-806</b>	30,000 - ** (40,000,000)	** (40,000,000)
<b>KD-802.5</b>	400 - 10,000	20,000	<b>KD-806M</b>	1,000 - ** (40,000,000)	** (40,000,000)
<b>KD-803</b>	1,000 - 50,000	70,000	<b>KD-807</b>	50,000 - ** (200,000,000)	** (200,000,000)
<b>KD-804</b>	4,000 - 200,000	200,000			

Please use the above tables for reference purposes only when selecting columns.

\*PEG: polyethylene glycol  
\*PEO: polyethylene oxide  
\*\* ( ) Estimated value

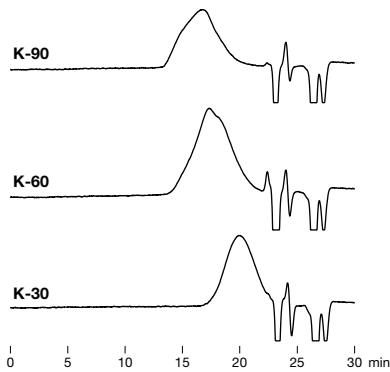
## Calibration curves for KD-800 series using PEG/PEO



Column : Shodex GPC KD-800 series  
 Eluent : DMF  
 Flow rate : 1.0 mL/min  
 Detector : RI  
 Column temp. : 40 °C

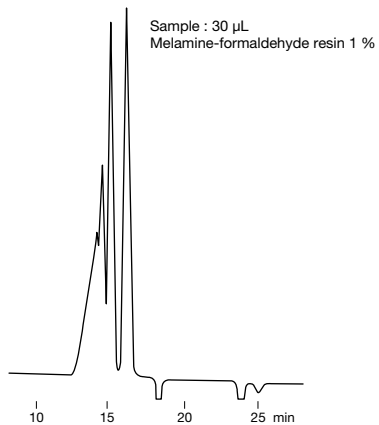
## Polyvinylpyrrolidones

Sample : Polyvinylpyrrolidone 0.1 % each, 100  $\mu$ L



Column : Shodex GPC KD-806M x 2  
 Eluent : 10 mM LiBr in DMF  
 Flow rate : 1.0 mL/min  
 Detector : RI  
 Column temp. : 50 °C

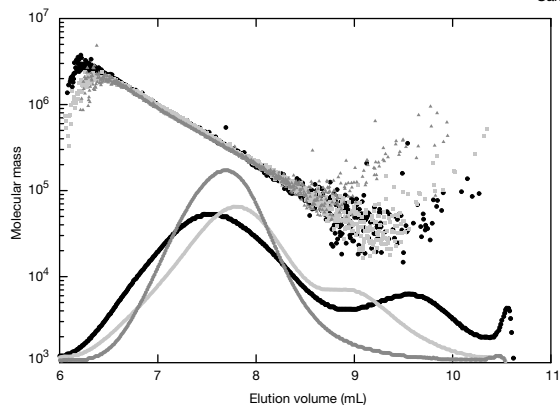
## Melamine formaldehyde resin



Column : Shodex GPC KD-802 x 2  
 Eluent : 10 mM LiBr in DMF  
 Flow rate : 1.0 mL/min  
 Detector : RI  
 Column temp. : 50 °C

## Celluloses

Sample : Cellulose ca. 0.05 % each, 100  $\mu$ L



Cellulose is difficult to dissolve and repeated solvent replacement is required to prepare the cellulose solution. The time required to completely dissolve cellulose depends on the solvent type, crystallinity and molecular weight of the cellulose. This can be 1 to 60 days.

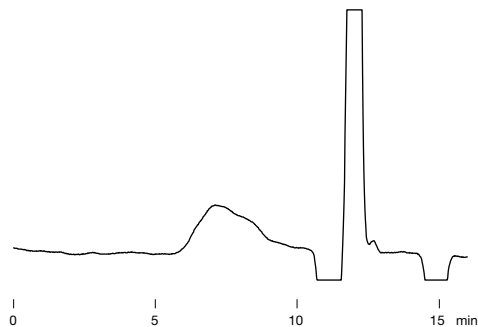
Column : Shodex GPC KD-806M  
 Eluent : 1 % LiCl in \*DMI  
 Flow rate : 0.5 mL/min  
 Detector : RI, MALS (Multi angle light scattering)  
 Column temp. : 60 °C

Data provided by Dr. Masahiko Yanagisawa,  
 Isogai group, Graduate School of Agricultural and  
 Life Sciences, The University of Tokyo

\*DMI: 1,3-dimethyl-2-imidazolidinone

## Potato starch

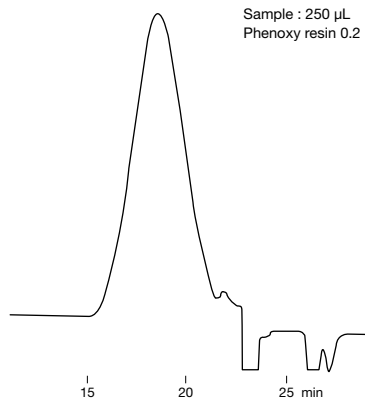
Sample : 100  $\mu$ L  
 Potato starch in DMSO 0.1 %  
 (dissolved at 80 °C)



Column : Shodex GPC KD-806M  
 Eluent : 10 mM LiBr in DMSO/DMF = 75/25  
 Flow rate : 1.0 mL/min  
 Detector : RI  
 Column temp. : 50 °C

## Phenoxy resin

Sample : 250  $\mu$ L  
 Phenoxy resin 0.2 %



Column : Shodex GPC KD-806M x 2  
 Eluent : 10 mM in DMF  
 Flow rate : 1.0 mL/min  
 Detector : RI  
 Column temp. : 50 °C

# Organic SEC (GPC) Columns: Preparative

• **Preparative columns** [ Preparative columns are made to order. ]

<https://www.shodex.de/gpc-preparative-columns>

## GPC KF-2000 series

Shipping Solvent: Tetrahydrofuran (THF)

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Column Size (mm) I.D. x Length	Standard Column
F6102401	<b>GPC KF-2001</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-801
F6102402	<b>GPC KF-2002</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-802
F6102425	<b>GPC KF-2002.5</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-802.5
F6102403	<b>GPC KF-2003</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-803
F6102404	<b>GPC KF-2004</b>	≥ 14,000	7	<b>20.0 x 300</b>	KF-804
F6102405	<b>GPC KF-2005</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-805
F6102406	<b>GPC KF-2006</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-806
F6102409	<b>GPC KF-2006M</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-806M
F6700406	<b>GPC KF-G 8B</b>	(guard column)	15	<b>8.0 x 50</b>	(guard column)

KF-2006M is a mixed-gel column capable of analyzing samples over a wide range of molecular weight distribution.

Base Material: Styrene divinylbenzene copolymer

## GPC K-2000 series

Shipping Solvent: Chloroform

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Column Size (mm) I.D. x Length	Standard Column
F6102301	<b>GPC K-2001</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-801
F6102312	<b>GPC K-2002</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-802
F6102315	<b>GPC K-2002.5</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-802.5
F6102303	<b>GPC K-2003</b>	≥ 18,000	6	<b>20.0 x 300</b>	KF-803
F6102304	<b>GPC K-2004</b>	≥ 14,000	7	<b>20.0 x 300</b>	KF-804
F6102305	<b>GPC K-2005</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-805
F6102306	<b>GPC K-2006</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-806
F6102309	<b>GPC K-2006M</b>	≥ 10,000	10	<b>20.0 x 300</b>	KF-806M
F6700407	<b>GPC K-G 8B</b>	(guard column)	15	<b>8.0 x 50</b>	(guard column)

K-2006M is a mixed-gel column capable of analyzing samples over a wide range of molecular weight distribution.

Base Material: Styrene divinylbenzene copolymer

## [ Customized columns ]

### GPC H-2000 series

Shipping Solvent: Chloroform

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Column Size (mm) I.D. x Length	Standard Column
F6102001	<b>GPC H-2001</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-801
F6102002	<b>GPC H-2002</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-802
F6102025	<b>GPC H-2002.5</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-802.5
F6102003	<b>GPC H-2003</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-803
F6102004	<b>GPC H-2004</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-804
F6102005	<b>GPC H-2005</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-805
F6102006	<b>GPC H-2006</b>	≥ 13,000	15	<b>20.0 x 500</b>	KF-806
F6102009	<b>GPC H-2006M</b>	≥ 12,000	15	<b>20.0 x 500</b>	KF-806M
F6700310	<b>GPC H-G 8B</b>	(guard column)	15	<b>8.0 x 50</b>	(guard column)

H-2006M is a mixed-gel column capable of analyzing samples over a wide range of molecular weight distribution.

Base Material: Styrene divinylbenzene copolymer

### GPC KF-5000 series

Shipping Solvent: Tetrahydrofuran (THF)

Product Code	Product Name	Particle Size (µm)	Column Size (mm) I.D. x Length	Standard Column
F6108010	<b>GPC KF-5001</b>	15	<b>50.0 x 300</b>	KF-801
F6108020	<b>GPC KF-5002</b>	15	<b>50.0 x 300</b>	KF-802
F6108025	<b>GPC KF-5002.5</b>	15	<b>50.0 x 300</b>	KF-802.5
F6108030	<b>GPC KF-5003</b>	15	<b>50.0 x 300</b>	KF-803
F6108040	<b>GPC KF-5004</b>	15	<b>50.0 x 300</b>	KF-804
F6700408	<b>GPC KF-G 20C</b>	15	<b>20.0 x 100</b>	(guard column)

Base Material: Styrene divinylbenzene copolymer

### GPC K-5000 series

Shipping Solvent: Chloroform

Product Code	Product Name	Particle Size (µm)	Column Size (mm) I.D. x Length	Standard Column
F6109010	<b>GPC K-5001</b>	15	<b>50.0 x 300</b>	KF-801
F6109020	<b>GPC K-5002</b>	15	<b>50.0 x 300</b>	KF-802
F6109025	<b>GPC K-5002.5</b>	15	<b>50.0 x 300</b>	KF-802.5
F6109030	<b>GPC K-5003</b>	15	<b>50.0 x 300</b>	KF-803
F6109040	<b>GPC K-5004</b>	15	<b>50.0 x 300</b>	KF-804
F6700409	<b>GPC K-G 20C</b>	15	<b>20.0 x 100</b>	(guard column)

Base Material: Styrene divinylbenzene copolymer

# Solvent Replacement Applicability of Organic SEC (GPC) Columns

Solvent	Product Name									
	Shipping Solvent : THF						Shipping Solvent : DMF			
	KF-801	KF-802 KF-802.5 KF-803L KF-804L	KF-803	KF-804 KF-805 KF-805L KF-806M KF-806L KF-807L	KF-401HQ KF-402HQ KF-402.5HQ	KF-403HQ	LF-804 LF-604 LF-404	KD-801 KD-802 KD-802.5	KD-803	KD-804 KD-805 KD-806 KD-807 KD-806M
Tetrahydrofuran (THF)	✓	✓	✓	✓	✓	✓	✓	×	×	✓
Chloroform	✓	✓	✓	✓	✓	✓	✓	×	×	✓
Carbon tetrachloride	×	✓	✓	✓			✓	×	×	✓
Benzene	✓	✓	✓	✓	✓	✓		×	✓	✓
Toluene	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
p-Xylene	×	✓	✓	✓	✓	✓		×	✓	✓
o-Dichlorobenzene (ODCB)	×	×	✓	✓	✓	✓		×	✓	✓
1,2,4-Trichlorobenzene (TCB)	×	×	✓	✓	✓	✓		×	✓	✓
Dioxane	×	✓	✓	✓				×	✓	✓
Diethyl ether	×	×	✓	✓				×	✓	✓
Ethyl acetate	×	×	✓	✓				×	×	✓
Acetone	×	×	✓	✓	✓	✓		×	✓	✓
Methyl ethyl ketone	×	×	✓	✓	✓	✓	✓	×	✓	✓
N,N-Dimethylformamide (DMF)	×	×	✓	✓	✓*	✓*	✓*	✓	✓	✓
N,N-Dimethylacetamide (DMAc)	×	×	✓	✓	✓*	✓*	✓*	×	✓	✓
Hexafluoroisopropanol (HFIP)	×	×	×	✓	×	△*	✓*	×	✓	✓
m-Cresol	×	×	✓	✓				×	✓	✓
o-Chlorophenol	×	×	✓	✓				×	✓	✓
Quinoline	×	×	✓	✓				×	✓	✓
N-Methyl-2-pyrrolidone (NMP)	×	×	✓	✓	✓*	✓*	✓*	×	✓	✓
Dimethyl sulfoxide (DMSO)	×	×	×	×	△*	✓*	✓*	×	×	✓
30 % m-Cresol/Chloroform	×	✓	✓	✓			✓	×	✓	✓
30 % o-Chlorophenol/Chloroform	×	✓	✓	✓			✓	×	✓	✓
30 % HFIP/Chloroform	×	✓	✓	✓				×	✓	✓
Hexane	×	×	×	×	×	×	×	×	×	×
Acetonitrile	×	×	×	×	×	×	×	×	×	×
Methanol	×	×	×	×	×	×	×	×	×	×
Water	×	×	×	×	×	×	×	×	×	×

✓ : Solvent replacement possible

△ : Solvent replacement possible, but this may cause column performance to deteriorate slightly

\* : Usable at 40 °C or higher

× : Solvent replacement not possible

See page 66 for solvent replacement method for Organic SEC (GPC) columns.

# Calibration Standards for SEC

## Polystyrene (PS)

<https://www.shodex.de/calibration-standards-for-sec>

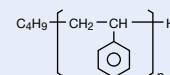
### Features

- SL-105**
  - For organic solvent SEC (GPC)
- SM-105**
  - Less branched polystyrene with anionic polymerization
- SH-75**
  - Easily soluble in tetrahydrofuran (THF), chloroform, toluene, and o-dichlorobenzene (ODCB)

### Standard kit

Product Code	Product Name	Contents	Molecular Weight (Mp) Range
F8601105	<b>STANDARD SL-105</b>	<b>0.5 g x 10 kinds</b>	580 - 18,000
F8602105	<b>STANDARD SM-105</b>	<b>0.5 g x 10 kinds</b>	1,180 - 3,210,000
F8603075	<b>STANDARD SH-75</b>	<b>0.5 g x 7 kinds</b>	662,000 - 6,550,000

#### Structural formula of S series



### ◆ SL-105

Std.No.	Mp	Mw/Mn
S-18	18,000	1.02
S-13	13,400	1.02
S-9.8	9,320	1.02
S-6.7	6,660	1.03
S-4.9	4,910	1.03
S-3.3	3,320	1.04
S-2.0	1,990	1.05
S-1.2	1,180	1.07
S-0.9	940	1.07
S-0.6	580	1.13

### ◆ SM-105

Std.No.	Mp	Mw/Mn
S-3210	3,210,000	1.06
S-1570	1,570,000	1.04
S-607	607,000	1.03
S-298	298,000	1.04
S-129	129,000	1.03
S-49	49,400	1.04
S-17	17,100	1.03
S-6.3	6,250	1.03
S-3.3	3,320	1.04
S-1.2	1,180	1.06

### ◆ SH-75

Std.No.	Mp	Mw/Mn
S-6550	6,550,000	1.07
S-3550	3,550,000	1.05
S-3020	3,020,000	1.03
S-2330	2,330,000	1.03
S-1860	1,860,000	1.04
S-885	885,000	1.05
S-662	662,000	1.04

(Note)  
Molecular weights (Mp, Mw/Mn) of each standard kit may vary depending on production lot.

## Polymethylmethacrylate (PMMA)

### Features

- M-75**
  - For organic solvent SEC (GPC)
  - Narrow molecular weight distribution range
  - Easily soluble in hexafluoroisopropanol (HFIP) and dimethylformamide (DMF)

### Standard kit

Product Code	Product Name	Contents	Molecular Weight (Mp) Range
F8604075	<b>STANDARD M-75</b>	<b>0.5 g x 7 kinds</b>	3,310 - 1,020,000

(Note)  
Molecular weights (Mp, Mw/Mn) of a standard kit may vary depending on production lot.

### ◆ M-75

Std.No.	Mp	Mw/Mn
M-1020	1,020,000	1.04
M-539	539,000	1.02
M-210	210,000	1.02
M-60	60,300	1.02
M-20	20,500	1.04
M-6.9	6,940	1.10
M-3.3	3,310	1.09

## Pullulan

### Features

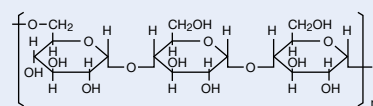
- P-82**
  - For aqueous SEC (GFC)
  - Unbranched pullulan standard
  - High solubility in water eliminates the possibility of recrystallization

### Standard kit

Product Code	Product Name	Contents	Molecular Weight (Mp) Range
F8400000	<b>STANDARD P-82</b>	<b>0.2 g x 8 kinds</b>	6,300 - 739,000

(Note)  
Molecular weights (Mp, Mw/Mn) of a standard kit may vary depending on production lot.

#### Structural formula of P series



### ◆ P-82

Std.No.	Mp	Mw/Mn
P-800	739,000	1.24
P-400	348,000	1.33
P-200	216,000	1.22
P-100	107,000	1.12
P-50	49,400	1.08
P-20	22,000	1.08
P-10	9,800	1.07
P-5	6,300	1.09