

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

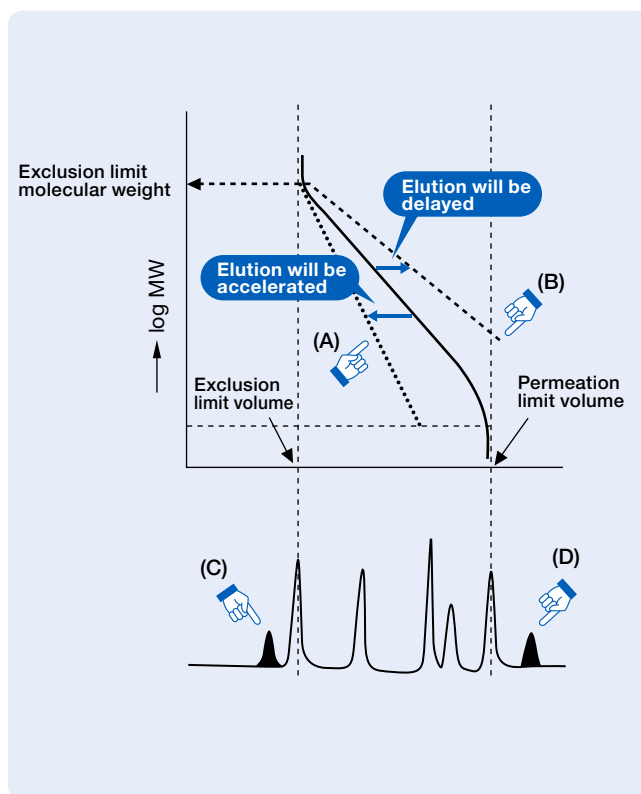
- ◆ Hydrophobic interaction
 - The analyte is adsorbed on the packing material.
 - This delays the analyte elution and results in under estimating the analyte's molecular weight. See (B) and (D).
- ◆ Ionic interaction
 - (1) Ion Exclusion
 - The analyte is repelled from the packing material.
 - This 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 CF_3COONa 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 (THF)

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

Features

- **KF-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

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Pore Size (Å)	Column Size (mm) I.D. x Length
F6028010	GPC KF-801	≥ 18,000	6	50	8.0 x 300
F6028020	GPC KF-802	≥ 18,000	6	150	8.0 x 300
F6028025	GPC KF-802.5	≥ 18,000	6	300	8.0 x 300
F6028030	GPC KF-803	≥ 18,000	6	500	8.0 x 300
F6027030	GPC KF-803L	≥ 18,000	6	500	8.0 x 300
F6028040	GPC KF-804	≥ 18,000	7	1,500	8.0 x 300
F6027040	GPC KF-804L	≥ 18,000	7	1,500	8.0 x 300
F6028050	GPC KF-805	≥ 11,000	10	5,000	8.0 x 300
F6027050	GPC KF-805L	≥ 11,000	10	5,000	8.0 x 300
F6028090	GPC KF-806M	≥ 13,000	10	10,000	8.0 x 300
F6027060	GPC KF-806L	≥ 11,000	10	10,000	8.0 x 300
F6027070	GPC KF-807L	≥ 6,000	18	20,000	8.0 x 300
F6700300	GPC KF-G 4A	(guard column)	8	—	4.6 x 10

The columns with 'L' or 'M' at the end of column names are mixed-gel columns 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: Tetrahydrofuran (THF)

Target molecular weight range and exclusion limit

• Measured with polystyrene (eluent: THF)

Product Name	Target Molecular Weight Range	Exclusion Limit	Product Name	Target Molecular Weight Range	Exclusion Limit
KF-801	100 - 700	1,500	KF-804L	100 - 300,000	400,000
KF-802	300 - 3,000	5,000	KF-805	50,000 - 2,000,000	4,000,000
KF-802.5	300 - 8,000	20,000	KF-805L	300 - 2,000,000	4,000,000
KF-803	1,000 - 50,000	70,000	KF-806M	1,000 - * (20,000,000)	* (20,000,000)
KF-803L	100 - 50,000	70,000	KF-806L	300 - * (20,000,000)	* (20,000,000)
KF-804	7,000 - 300,000	400,000	KF-807L	300 - * (200,000,000)	* (200,000,000)

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

* () Estimated value

Organic SEC (GPC) Columns: Solvent-Peak Separation

Features

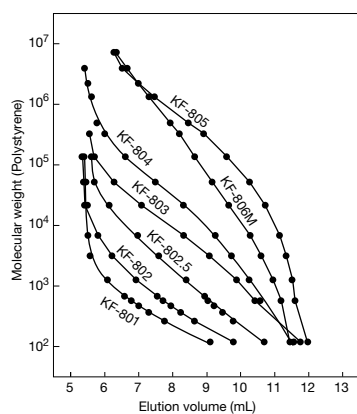
- **KF-800D**
- Use this column in combination with a linear column
- Accurate molecular weight distribution of polymers and oligomers are achieved by shifting the elutions of monomers, polymer additives, and solvent-peak in the lower molecular region

• Solvent-peak separation column

Product Code	Product Name	Column Combination	Particle Size (µm)	Column Size (mm) I.D. x Length
F6709350	GPC KF-800D	KF-805L, 806L, 806M, 807L	10	8.0 x 100

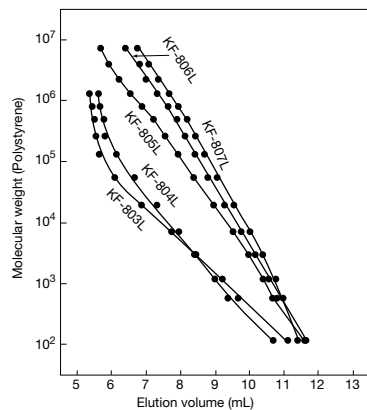
Base Material: Styrene divinylbenzene copolymer
Shipping Solvent: Tetrahydrofuran (THF)

Calibration curves for KF-800 series using polystyrene



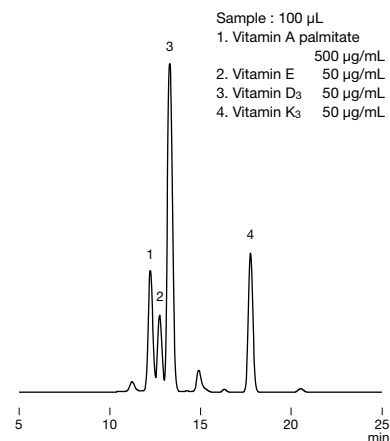
Column : Shodex GPC KF-800 series
Eluent : THF
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 40 °C

Calibration curves for KF-800L (linear type) series using polystyrene



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

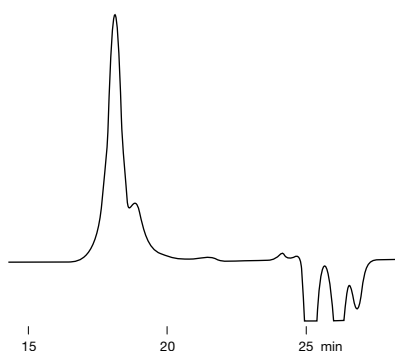
Fat-soluble vitamins



Column : Shodex GPC KF-801 x 2
Eluent : THF
Flow rate : 1.0 mL/min
Detector : UV (280 nm)
Column temp. : 40 °C

Styrene isoprene ABA block copolymer

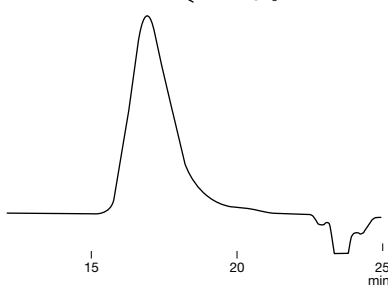
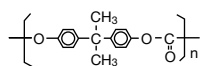
Sample : Styrene isoprene ABA block copolymer



Column : Shodex GPC KF-806M x 2
Eluent : THF
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 30 °C

Polycarbonate resin

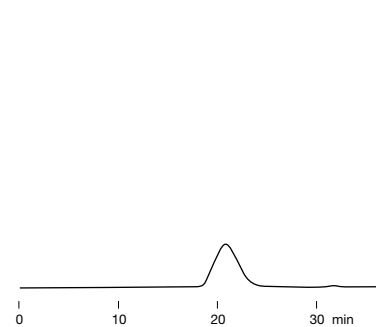
Sample : Polycarbonate resin 0.1 %, 100 μ L



Column : Shodex GPC KF-806L x 2
Eluent : THF
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 40 °C

Raw rubber

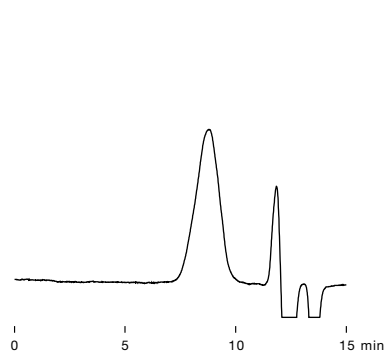
Sample : Rubber 0.1 %, 300 μ L



Column : Shodex GPC KF-806M x 2
 + KF-802
Eluent : Toluene
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : Room temp.

Polylactic Acid

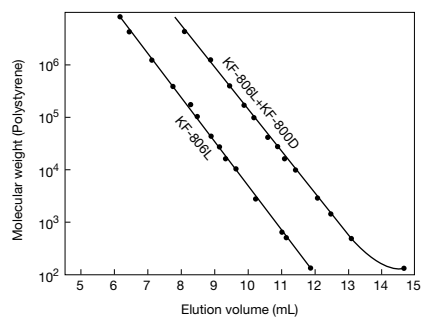
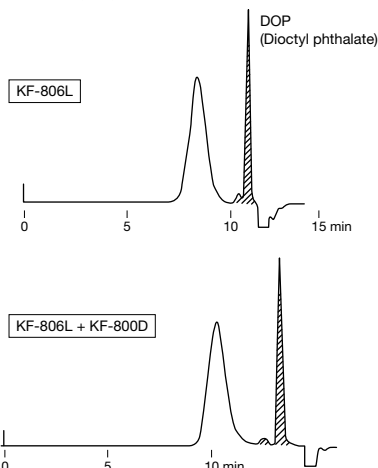
Sample : Polylactic acid 0.2 %, 50 μ L



Column : Shodex GPC KF-806M
Eluent : Chloroform
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 30 °C

Effects of solvent-peak separation column

Sample : Poly(vinyl chloride)



Column : Shodex GPC KF-806L
 Shodex GPC KF-806L + KF-800D
Eluent : THF
Flow rate : 1.0 mL/min
Detector : RI

Organic SEC (GPC) Columns: High Performance Analysis

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

Features

KF-400HQ

- About 1.5 times better separation performance than standard columns, obtains higher resolution
- About 4 times better sensitivity than that of standard columns, supports high sensitivity analysis
- The amount of solvent used is reduced to about a third
- Improved applicability of solvent replacement
- Fulfills USP-NF L21 requirements

• High performance semi-micro columns

* KF-400HQ series is recommended to be used with semi-micro type devices.

Product Code	Product Name	Plate Number (TP/column)	Particle Size (µm)	Pore Size (Å)	Column Size (mm) I.D. x Length
F6028111	GPC KF-401HQ	≥ 25,000	3	50	4.6 x 250
F6028112	GPC KF-402HQ	≥ 25,000	3	150	4.6 x 250
F6028114	GPC KF-402.5HQ	≥ 25,000	3	300	4.6 x 250
F6028116	GPC KF-403HQ	≥ 25,000	3	500	4.6 x 250
F6700300	GPC KF-G 4A	(guard column)	8	—	4.6 x 10

See page 60 for solvent replacement applicability of Organic SEC (GPC) columns.

Base Material: Styrene divinylbenzene copolymer
Shipping Solvent: Tetrahydrofuran (THF)

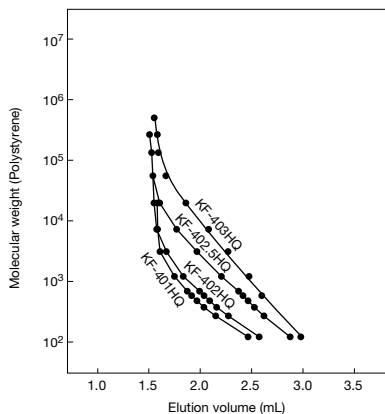
Target molecular weight range and exclusion limit

• Measured with polystyrene (eluent: THF)

Product Name	Target Molecular Weight Range	Exclusion Limit
KF-401HQ	100 - 700	1,500
KF-402HQ	200 - 1,500	4,000
KF-402.5HQ	300 - 10,000	20,000
KF-403HQ	600 - 50,000	70,000

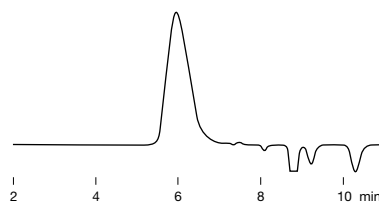
Please use the above tables for reference purposes only when selecting columns.

Calibration curves for KF-400HQ series using polystyrene



Column : Shodex GPC KF-400HQ series
Eluent : THF
Flow rate : 0.3 mL/min
Detector : RI (small cell volume)
Column temp. : 40 °C

Liquid paraffin

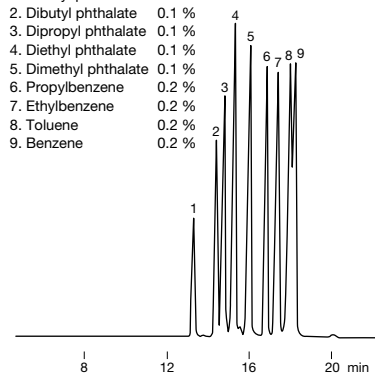
Sample : Liquid paraffin 1 %, 5 μ L

Column : Shodex GPC KF-401HQ
Eluent : Chloroform
Flow rate : 0.3 mL/min
Detector : RI (small cell volume)
Column temp. : 40 °C

Phthalates

Sample : 10 μ L

1. Dioctyl phthalate 0.1 %
2. Dibutyl phthalate 0.1 %
3. Dipropyl phthalate 0.1 %
4. Diethyl phthalate 0.1 %
5. Dimethyl phthalate 0.1 %
6. Propylbenzene 0.2 %
7. Ethylbenzene 0.2 %
8. Toluene 0.2 %
9. Benzene 0.2 %

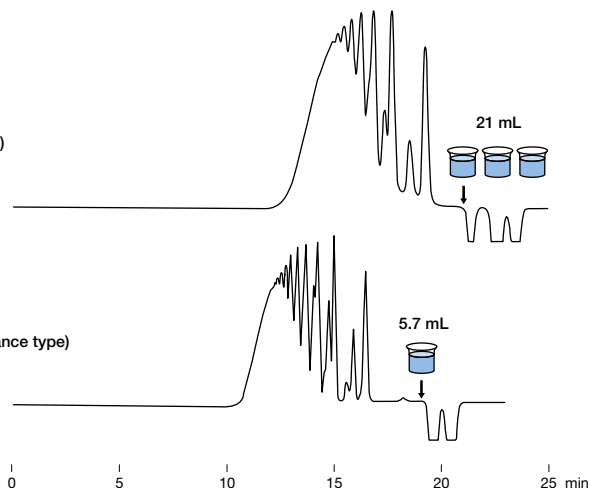


Column : Shodex GPC KF-401HQ x 2
Eluent : THF
Flow rate : 0.3 mL/min
Detector : UV (254 nm) (small cell volume)
Column temp. : 40 °C

Comparison of standard and high performance type columns

(Standard type)
 KF-802.5 x 2
 50 μ L injection

(High performance type)
 KF-402.5HQ x 2
 10 μ L injection



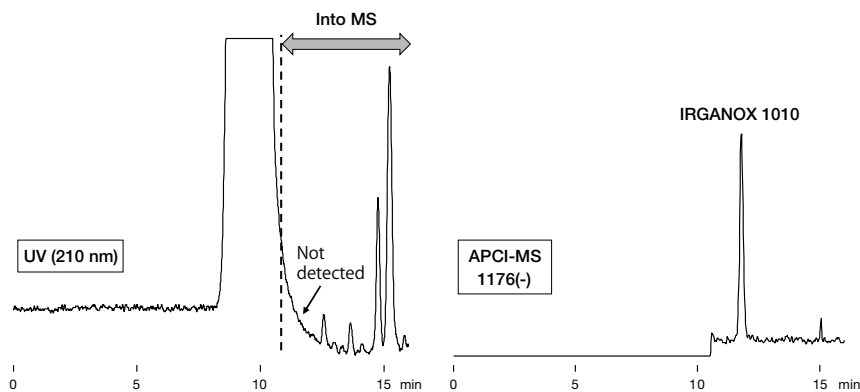
Sample : EPON1001 0.2 %

Having 1.5 times more theoretical plate number than standard column, KF-402.5HQ provides improved resolution especially for the separation of small to medium molecular weight substances. High performance type columns use less than one third of solvent per analysis compared to standard type columns do.

Column : Shodex GPC KF-802.5 x 2
 Shodex GPC KF-402.5HQ x 2
Eluent : THF
Flow rate : 1.0 mL/min (KF-802.5)
 0.3 mL/min (KF-402.5HQ)
Detector : RI (conventional type) (KF-802.5)
 RI (small cell volume) (KF-402.5HQ)
Column temp. : 40 °C

LC/MS analysis of antioxidant (IRGANOX 1010) in a cup of instant noodles (styrene foam)

Generally, pretreatment is required for additives analysis in polymers. By using a size exclusion chromatography column, it separates the additives from polymers, and only the low molecular weight region containing the additive is introduced into a mass spectrometer (MS). Therefore, sample pretreatment is not required, and thus a simple and rapid detection can be expected.



Sample : 5 μ L
 Cup of instant noodles (styrene foam) 1000 mg/L

Column : Shodex GPC KF-402HQ x 2
Eluent : THF
Flow rate : 0.3 mL/min
Detector : UV (210 nm), APCI-MS (SIM)
Column temp. : 40 °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	GPC KF-2001	≥ 18,000	6	20.0 x 300	KF-801
F6102402	GPC KF-2002	≥ 18,000	6	20.0 x 300	KF-802
F6102425	GPC KF-2002.5	≥ 18,000	6	20.0 x 300	KF-802.5
F6102403	GPC KF-2003	≥ 18,000	6	20.0 x 300	KF-803
F6102404	GPC KF-2004	≥ 14,000	7	20.0 x 300	KF-804
F6102405	GPC KF-2005	≥ 10,000	10	20.0 x 300	KF-805
F6102406	GPC KF-2006	≥ 10,000	10	20.0 x 300	KF-806
F6102409	GPC KF-2006M	≥ 10,000	10	20.0 x 300	KF-806M
F6700406	GPC KF-G 8B	(guard column)	15	8.0 x 50	(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	GPC K-2001	≥ 18,000	6	20.0 x 300	KF-801
F6102312	GPC K-2002	≥ 18,000	6	20.0 x 300	KF-802
F6102315	GPC K-2002.5	≥ 18,000	6	20.0 x 300	KF-802.5
F6102303	GPC K-2003	≥ 18,000	6	20.0 x 300	KF-803
F6102304	GPC K-2004	≥ 14,000	7	20.0 x 300	KF-804
F6102305	GPC K-2005	≥ 10,000	10	20.0 x 300	KF-805
F6102306	GPC K-2006	≥ 10,000	10	20.0 x 300	KF-806
F6102309	GPC K-2006M	≥ 10,000	10	20.0 x 300	KF-806M
F6700407	GPC K-G 8B	(guard column)	15	8.0 x 50	(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	GPC H-2001	≥ 13,000	15	20.0 x 500	KF-801
F6102002	GPC H-2002	≥ 13,000	15	20.0 x 500	KF-802
F6102025	GPC H-2002.5	≥ 13,000	15	20.0 x 500	KF-802.5
F6102003	GPC H-2003	≥ 13,000	15	20.0 x 500	KF-803
F6102004	GPC H-2004	≥ 13,000	15	20.0 x 500	KF-804
F6102005	GPC H-2005	≥ 13,000	15	20.0 x 500	KF-805
F6102006	GPC H-2006	≥ 13,000	15	20.0 x 500	KF-806
F6102009	GPC H-2006M	≥ 12,000	15	20.0 x 500	KF-806M
F6700310	GPC H-G 8B	(guard column)	15	8.0 x 50	(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	GPC KF-5001	15	50.0 x 300	KF-801
F6108020	GPC KF-5002	15	50.0 x 300	KF-802
F6108025	GPC KF-5002.5	15	50.0 x 300	KF-802.5
F6108030	GPC KF-5003	15	50.0 x 300	KF-803
F6108040	GPC KF-5004	15	50.0 x 300	KF-804
F6700408	GPC KF-G 20C	15	20.0 x 100	(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	GPC K-5001	15	50.0 x 300	KF-801
F6109020	GPC K-5002	15	50.0 x 300	KF-802
F6109025	GPC K-5002.5	15	50.0 x 300	KF-802.5
F6109030	GPC K-5003	15	50.0 x 300	KF-803
F6109040	GPC K-5004	15	50.0 x 300	KF-804
F6700409	GPC K-G 20C	15	20.0 x 100	(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>

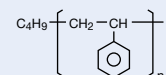
Features

- 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	STANDARD SL-105	0.5 g x 10 kinds	580 - 18,000
F8602105	STANDARD SM-105	0.5 g x 10 kinds	1,180 - 3,210,000
F8603075	STANDARD SH-75	0.5 g x 7 kinds	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	STANDARD M-75	0.5 g x 7 kinds	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

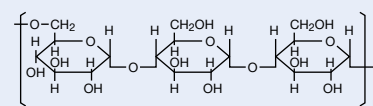
Standard kit

Product Code	Product Name	Contents	Molecular Weight (Mp) Range
F8400000	STANDARD P-82	0.2 g x 8 kinds	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