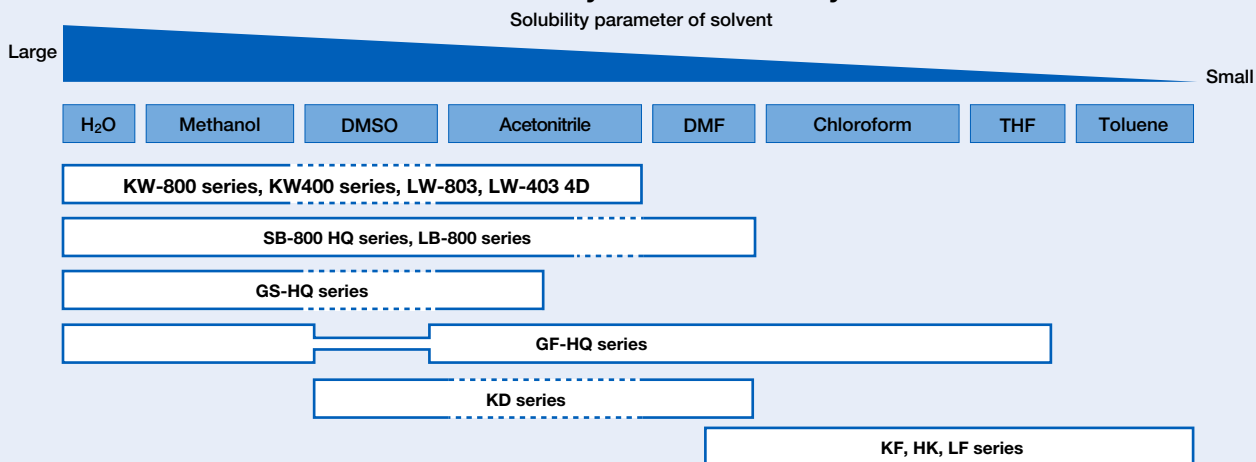


Column Selection (Polymers)

	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
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
Engineering plastics (Polyamides etc.)		HFIP	LF series	56
			GF-HQ series	46
			KD-800 series	50
			HK-400 series	54
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

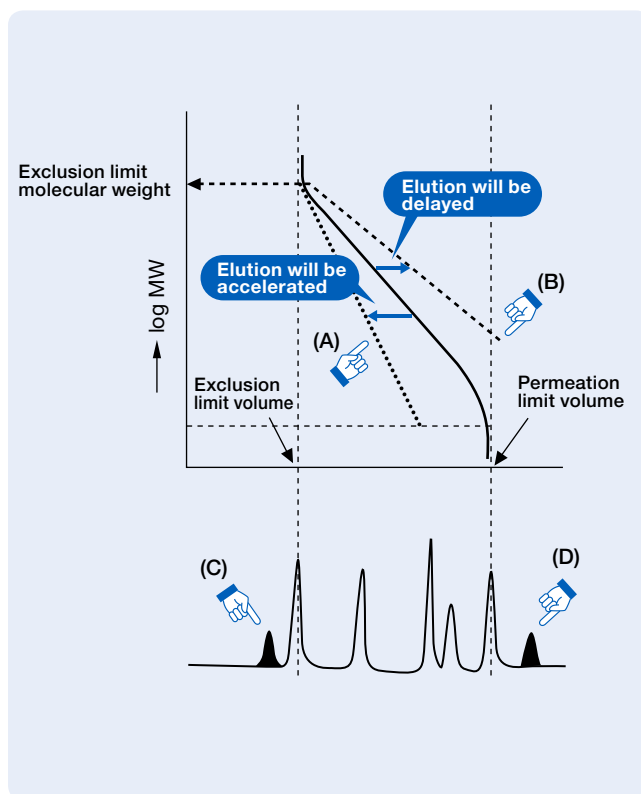
- ◆ Hydrophobic interaction
 - The analyte is adsorbed on the packing material.
 - This delays the analyte elution and results in under estimating the analyte's molecular weight. See (B) and (D).
- ◆ Ionic interaction
 - (1) Ion Exclusion
 - The analyte is repelled from the packing material.
 - This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

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

Features

LF

- Packed with unique multi-pore gels with a wide pore-size distribution
- Highly linear calibration curve without inflection points
- Achieves highly precise molecular weight distribution determination
- Enables analysis over a wide molecular weight range
- Rapid analysis column (LF-604) and high performance analysis column (LF-404) are also available
- LF-604 and LF-404 reduce solvent use
- 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
F6021041	GPC LF-804	≥ 17,000	6	3,000	8.0 x 300
F6709621	GPC LF-G	(guard column)	6	—	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)

• Rapid analysis downsized columns

* LF-604 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
F6021042	GPC LF-604	≥ 9,000	6	3,000	6.0 x 150
F6709621	GPC LF-G	(guard column)	6	—	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)

• High performance semi-micro columns

* LF-404 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
F6021043	GPC LF-404	≥ 14,000	6	3,000	4.6 x 250
F6709621	GPC LF-G	(guard column)	6	—	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

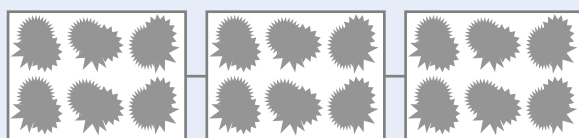
• Measured with polystyrene (eluent: THF)

Product Name	Target Molecular Weight Range	Exclusion Limit
LF-804	300 - 2,000,000	2,000,000
LF-604	300 - 2,000,000	2,000,000
LF-404	300 - 2,000,000	2,000,000

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

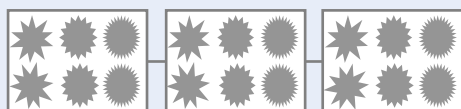
Schematic diagram of linear calibration type packing

Connecting linear calibration type columns (LF series)

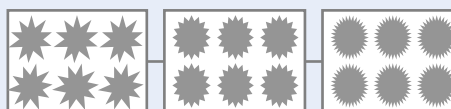


The linear calibration type column covers a broad range of molecular weights with only one kind of packing material.

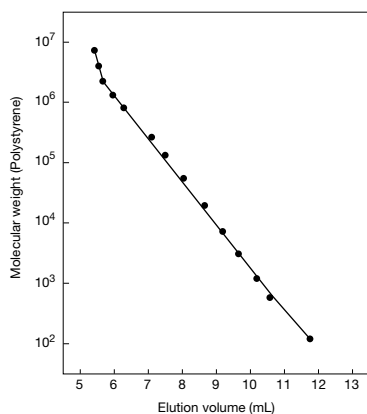
Connecting mixed-gel columns (KF-804L, etc.)



Connecting different single pore-size columns (KF-804 + KF-803 + KF-802, etc.)

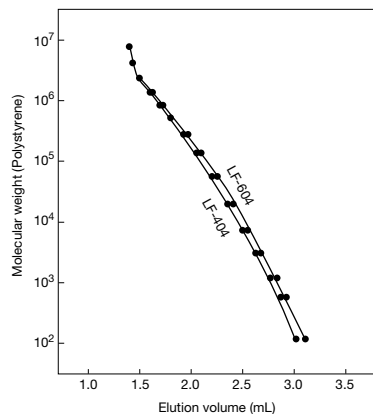


Calibration curve for LF-804 using polystyrene



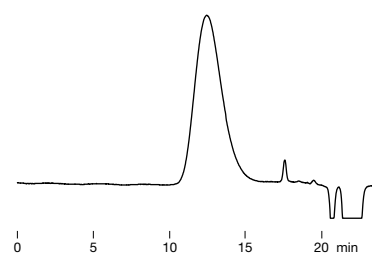
Column : Shodex GPC LF-804
Eluent : THF
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 40 °C

Calibration curves for LF-604 and LF-404 using polystyrene



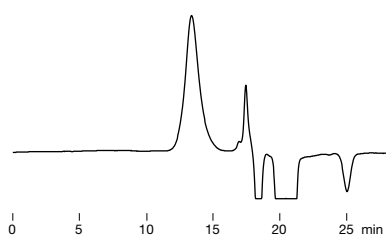
Column : Shodex GPC LF-604, LF-404
Eluent : THF
Flow rate : 0.5 mL/min (LF-604)
 0.3 mL/min (LF-404)
Detector : RI (small cell volume)
Column temp. : 40 °C

Polyurethane

Sample : Polyurethane 0.1 %, 20 μ L

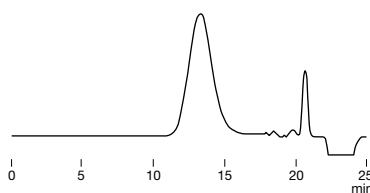
Column : Shodex GPC LF-404 x 2
Eluent : THF
Flow rate : 0.3 mL/min
Detector : RI (small cell volume)
Column temp. : 40 °C

Xylan

Sample : Xylan 0.1 %, 100 μ L

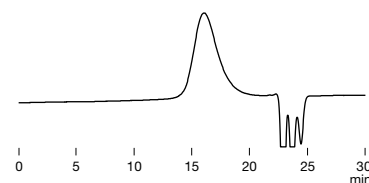
Column : Shodex GPC LF-804
Eluent : 20 mM H₃PO₄ + 20 mM LiBr
 in DMSO/DMF = 80/20
Flow rate : 0.6 mL/min
Detector : RI
Column temp. : 50 °C

Polyamide (Nylon 6/6)

Sample : Nylon 6/6 0.1 %, 20 μ L

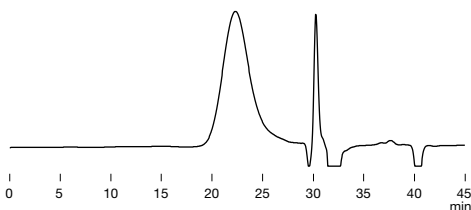
Column : Shodex GPC LF-404
Eluent : 5 mM CF₃COONa in HFIP
Flow rate : 0.15 mL/min
Detector : RI (small cell volume)
Column temp. : 40 °C

Polymethyl methacrylate

Sample : Polymethyl methacrylate, 100 μ L

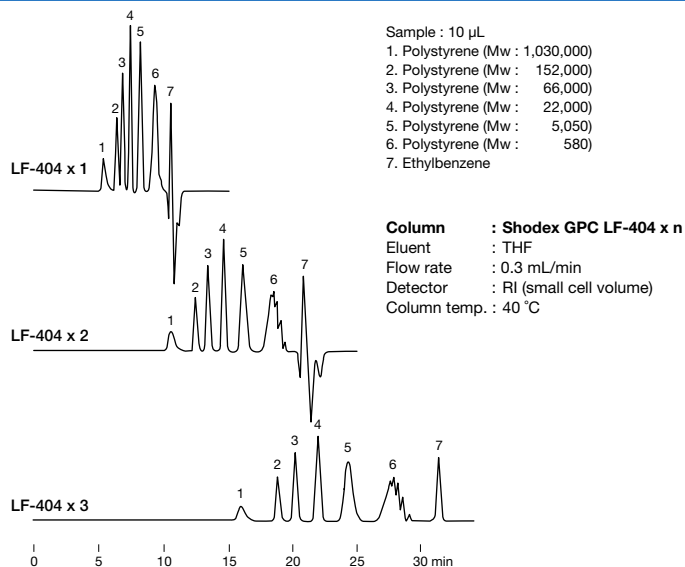
Column : Shodex GPC LF-804 x 2
Eluent : Methyl ethyl ketone
Flow rate : 1.0 mL/min
Detector : RI
Column temp. : 40 °C

Polyamic acid

Sample : Poly(pyromellitic dianhydride-co-4,4'-oxydianiline), 100 μ L

Column : Shodex GPC LF-804 x 2
Eluent : 30 mM LiBr + 30 mM H₃PO₄ in NMP
Flow rate : 0.7 mL/min
Detector : RI
Column temp. : 50 °C

Effects of using multiple LF-404 columns for the separation of polystyrenes



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

×

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>

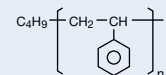
Features

- 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

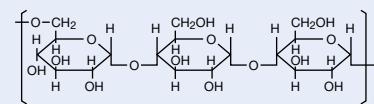
Standard kit

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