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Bulletin 932

Discovery Zr: Method Development Guidelines

The following information will guide you to the right Discovery Zr column for your separation, and help with developing the best possible method.

Part 1: Understanding Retention on Zirconia (ZrO_2) Particles

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  - Acidic Compounds

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Supelco's expert Technical Service is available to assist you in any manner needed to maximize your success with this or any Supelco product. If you do not find the help or guidance you need in this document, please do not hesitate to call us at 800-359-3041 in North America, or your local Supelco office elsewhere.

Part 1: Understanding Retention on Zirconia (ZrO_2) Particles

A simple explanation of the difference between silica (SiO_2) and zirconia (ZrO_2) as supports for HPLC follows.

pH and Thermal Stability

Silica is by far the most commonly used HPLC support particle. Its benefits are well known. However, there are limitations to silica that preclude its use in certain applications. These restricted areas are: high pH – where the Si-O-Si (siloxane) bonds are not stable, and low pH – where the Si-O-Si-C bonds attaching the bonded phase to the surface can be hydrolyzed. These chemical processes are exacerbated at high temperature. As a result, most silica-based packings are restricted to pH 2 – 8 and temperatures below 60°C.

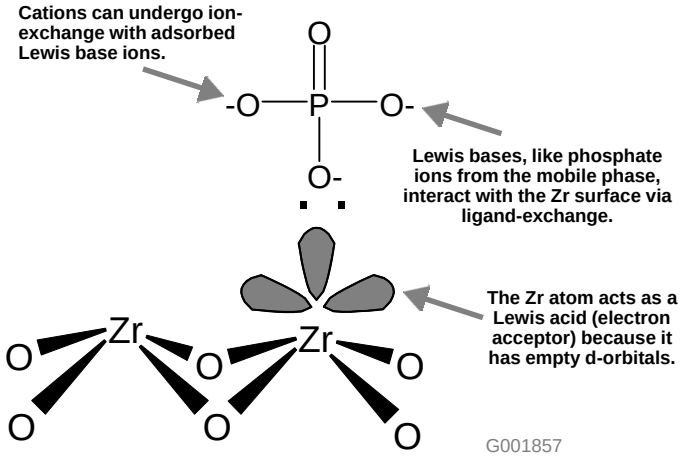
Contrary to silica, the Zr-O-Zr bonds that form the zirconia particle matrix are not susceptible to cleavage due to pH or temperature. As a result, HPLC packings that are based on zirconia particles can be used from pH 1 to 14 and at temperatures up to 200°C, conditions not possible on silica-based supports. It is important to note that the Zr-O-Si bonds are even less stable than Si-O-Si bonds making covalent attachments of organosilanes to the zirconia surface impractical.

However, the Zr atom is fundamentally different from the Si atom. As a result, the Zr-O-Zr bonds have different configuration of electrons. Ionizable analytes interact with zirconia differently than they do with silica. Successful use of the Discovery Zr particles for ionic compounds is dependent upon understanding these differences.

Lewis Acid-Base Chemistry

The zirconium atom in the Zr-O-Zr bond has unfilled d-orbitals, making it an electron pair acceptor (see Figure A). In the Lewis acid-base theory, this makes the Zr atom a Lewis acid. In fact, it is a strong Lewis acid. Lewis acids undergo strong ligand-exchange interactions with Lewis bases. Lewis bases include phosphate, fluoride, acetate, citrate, carboxylate, and hydroxide groups, among others. Zirconia particles will strongly adsorb Lewis bases from the mobile phase and from the sample. The adsorbed Lewis base acts as an ion-exchange site. An example is phosphate, a Lewis base and common HPLC mobile phase buffer ion. The adsorbed phosphate ions can undergo ion-exchange interactions with basic analytes. So with zirconia particles there are two modes of interaction: adsorption or partitioning with the stationary phase and ion-exchange with the adsorbed Lewis base buffer ions or ligand-exchange with Lewis acid zirconium atoms.

Figure A: Lewis Acid Sites on Zirconia



The presence of ion-exchange character is a significant differentiating feature of zirconia-based phases over silica-based phases:

Silica-C18: Reversed phase (partitioning) plus a small degree of H-bonding with Si-OH groups.
Zirconia-phases: Reversed phase (partitioning) plus a large degree of ion-exchange.

Buffer Ions with Zirconia

Because of this Lewis acid-base character, the buffer ions play a larger role in controlling the retention and peak shape on zirconia-based phases than they do on silica-based phases. Non-ionizable compounds are not affected by this ion-exchange mechanism on zirconia. The relative strength of the buffer ions is shown in the Table below. Correct buffering is important to eliminate any unwanted interactions or to enhance desirable interactions with the zirconia surface.

Table 1: Lewis Base Strength of Buffer Ions on Zirconia

Lewis Base	Relative Strength	
Hydroxide	Strongest	Note: With pyrophosphate (PO_4^{3-}) even after one pair of electrons interacts with the Zr d-orbital, there are still two negative charges available for ion-exchange. This is not the case with acetate fluoride, etc.
Phosphate*		
Fluoride		
Citrate		
Sulfate		
Acetate		
Formate		
Chloride	Weakest	

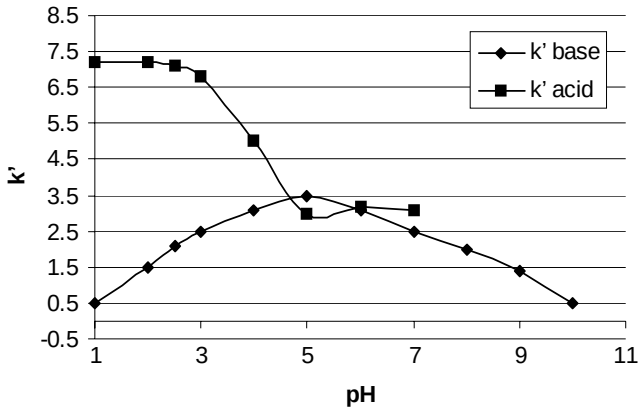
Retention as a Function of pH on Silica vs. Zirconia

Retention vs. pH on is complex on zirconia because there are four competing-augmenting factors: the ionization state of the zirconia, of the adsorbed Lewis base buffer ion, of the analyte, and the change in hydrophobicity of the analyte. In traditional reversed-phase HPLC on silica-based packings, retention increases with increasing pH for basic compounds. It increases with decreasing pH for acidic compounds. However, because ion-exchange plays a large role in retention on zirconia, zirconia's k' vs. pH curve will look different than silica's. The shape of the curve in Figure B below is a model. Each compound will have a different curve depending on their ionic state and the buffer ions present and their concentration.

Basic compounds: Explanation of the effect of pH on retention of basic compounds is complicated since it involves the ionization of the basic analyte, the charge of the zirconia surface, and the adsorbed Lewis base buffer ions. Generally, retention increases with increasing pH, going through a maximum after which it declines. We often develop methods well above the pK_a of the base where ion-exchange interactions are not present and retention is predominately due to hydrophobic interactions. The chemical stability of the zirconia surface allows high pH operation.

Acidic compounds: Below the pK_a of an acid, retention decreases with increasing pH because hydrophobicity of the acid decreases. Above the pK_a of the acid, Lewis acid-base interactions are so strong that we recommend avoiding analyzing compounds with multiple acidic groups on polymer-coated zirconia phases (Zr-PBD and Zr-PS). Instead, use the carbon-coated zirconia (Zr-Carbon and Zr-CarbonC18).

Figure B: Representation of Retention as a Function of pH on Zirconia



Part 2: Guidelines for Choosing a Discovery Zr Column and Selecting and Adjusting Chromatographic Conditions

Part 2: Guidelines for Choosing a Discovery Zr Column and Selecting and Adjusting Chromatographic Conditions

If you're having problems with separations on a traditional silica-based column, use this guide to help you select the right Discovery Zr column. Or, if you're using a Discovery Zr column already, use this guide to help you adjust your conditions to optimize a separation.

PROBLEM	COLUMN	STARTING CONDITIONS/COMMENTS	ADJUSTING CONDITIONS
Selectivity / Resolution			
Improved selectivity for bases.	Discovery Zr-PBD Discovery Zr-PS	Use with strong Lewis base (e.g. phosphate, fluoride, etc.), 5-25mM, preferably the ammonium salt. Start with pH 6-8 for weakly retained, hydrophilic bases or pH 1-3 for more strongly retained, hydrophobic bases. A pH >> pK_a of the base is used to eliminate ion exchange, but with a reduction in retention.	Selectivity can be tuned with choice of buffer ion, ionic strength, and pH. Weaker Lewis bases typically reduce retention and may alter selectivity. Higher ionic strength typically reduces retention and improves peak shapes. Retention will increase with pH, up to the pKa of the analyte, thereafter, retention decreases.
Improved selectivity for acids.	Discovery Zr-CarbonC18	Use with phosphate, 5-25mM. Ideally, pH to 2 or lower. Use acetonitrile as organic modifier, or preferably, with 10% (or more) tetrahydrofuran.	If poor peak shapes and/or excessive retention is observed, increase temperature and add/increase THF in the mobile phase.
Improved selectivity for nonelectrolytes, isomers, diastereomers, etc.	Discovery Zr-Carbon Discovery Zr-CarbonC18	Use at temperature greater than 50°C. Use acetonitrile as organic modifier, or preferably, with 10% (or more) tetrahydrofuran. Start with high organic (e.g. 50%).	If poor peak shapes and/or excessive retention is observed, increase temperature and add/increase THF in the mobile phase.
Retention			
Need more retention for polar bases.Currently using near 100% aqueous MP and/or anionic ion pairing reagent.	Discovery Zr-PBD	Use with phosphate, 5-25mM, pH 6-8, preferably the ammonium salt. Can use high aqueous mobile phase.	Weaker Lewis bases typically reduce retention and may alter selectivity. Higher ionic strength typically reduces retention and improves peak shapes. Retention will increase with pH, up to the pKa of the analyte, thereafter, retention decreases.
Need more retention for polar acids.Currently using near 100% aqueous MP and/or cationic ion pairing reagent.	Discovery Zr-CarbonC18	Use with phosphate, 5-25mM. Ideally, pH to 2 or lower. Use acetonitrile as organic modifier, or preferably, with 10% (or more) tetrahydrofuran. Can use high aqueous mobile phase.	If poor peak shapes are observed, increase temperature and add/increase THF in the mobile phase.
Need more retention for polar nonelectrolytes.Currently using near 100% aqueous mobile phase.	Discovery Zr-Carbon Discovery Zr-CarbonC18	Very retentive phases for these compounds. Use acetonitrile as organic modifier, or preferably, with 10% (or more) tetrahydrofuran. Can use high aqueous mobile phase.	If poor peak shapes are observed, increase temperature and add/increase THF in the mobile phase
Need less retention.	Discovery Zr-PS	Least hydrophobic of Discovery Zr phases.	Weaker Lewis bases typically reduce retention and may alter selectivity. Higher ionic strength typically reduces retention and improves peak shapes. Retention will increase with pH, up to the pKa of the analyte, thereafter, retention decreases.

Continued on next page.

Notes:

Compounds with multiple carboxylate groups (e.g. proteins) will act as chelating agents and adsorb irreversibly to the zirconia support. Therefore, we strongly advise against reverse-phase HPLC of proteins on zirconia-based media.

Analytes with conjugated ring systems with little shielding of pi electrons interact strongly with the carbon surface of the Zr-Carbon and Zr-CarbonC18 phases. In these instances, it is useful to add a strong Lewis base to the mobile phase, change the organic modifier to THF or CH_3CN/THF, and increase the temperature of the separation. Methanol is, in general, a poor eluent for these phases and should be avoided.

Continued from previous page.

PROBLEM	COLUMN	STARTING CONDITIONS/COMMENTS	ADJUSTING CONDITIONS
Other Problems			
Need more efficiency.	all Discovery Zr columns	Increase temperature. Adjust mobile phase as needed for proper retention.	Selectivity may change with a change in temperature. To minimize this effect, pH >> pKa for bases, and pH << pKa for acids.
Peak tailing - acids	all Discovery Zr columns	Use stronger Lewis base buffer. Use higher concentrations of buffers. Reduce the pH to reduce adsorption with Lewis acid Zr atoms. Increase temperature (especially with Zr-Carbon and Zr-CarbonC18 phases).	Buffer ion, pH, and temperature will alter retention and selectivity as well as peak shape.
Peak tailing - bases	all Discovery Zr columns	Use higher concentrations of buffers. Increase the pH above the pK_a to reduce ion-exchange. Increase temperature.	Buffer ion, pH, and temperature will alter retention and selectivity as well as peak shape.
Decrease analysis time.	all Discovery Zr columns	Increase temperature. Increase flow rate. Adjust mobile phase as needed for proper retention.	Selectivity may change with a change in temperature. To minimize this effect, pH >> pKa for bases, and pH << pKa for acids. May lose efficiency at high flow rates.
Poor column stability/lifetime.	all Discovery Zr columns	Excellent durability and column lifetime. Zr-PS and Zr-PBD stable up to 100°C (150°C with special hardware), pH 1-13. Zr-Carbon and Zr-CarbonC18 stable up to 100°C (200°C with special hardware), pH 1-14.	
Column overloaded – basic analytes	Discovery Zr-PBD Discovery Zr-PS	Use phosphate buffer – provides multiple ion exchange sites.	

Notes:

Compounds with multiple carboxylate groups (e.g. proteins) will act as chelating agents and adsorb irreversibly to the zirconia support. Therefore, we strongly advise against reverse-phase HPLC of proteins on zirconia-based media.

Analytes with conjugated ring systems with little shielding of pi electrons interact strongly with the carbon surface of the Zr-Carbon and Zr-CarbonC18 phases. In these instances, it is useful to add a strong Lewis base to the mobile phase, change the organic modifier to THF or CH_3CN/THF, and increase the temperature of the separation. Methanol is, in general, a poor eluent for these phases and should be avoided.

Part 3: Developing Methods on Discovery Zr-Carbon and Zr-CarbonC18

Discovery Zr-Carbon is very hydrophobic and its rigid surface is excellent for separating geometric isomers. Discovery Zr-CarbonC18 has the shape-selectivity conferred to it by the underlying carbon surface as well as partitioning.

Discussion of Discovery Zr-Carbon and Zr-CarbonC18

Discovery Zr-Carbon is produced by coating zirconia particles with an extremely thin layer of elemental carbon. The resulting phase gives Zr-Carbon a selectivity very different from silica or polymeric reversed-phases. The structural flexibility of the octadecasilyl molecule will conform to most solutes, yielding very little selectivity between analytes with similar hydrophobicities, but different geometries (e.g. isomers, diastereomers). The rigid carbon surface of the Zr-Carbon phase does not allow for the conformation to the shape of the analyte, and retention is therefore more sensitive to the hydrophobic "footprint" of the analyte, rather than its overall hydrophobicity – yielding excellent separations of isomers and diastereomers.

Discovery Zr-CarbonC18 is produced by covalently bonding C18 ligands to the surface of the carbon-clad zirconia. It has both shape selectivity and hydrophobic retention (partitioning). Discovery Zr-CarbonC18 is very different from silica C18 phases, however, as the underlying substrate is carbon/zirconia, and chromatographic characteristics of these materials are imparted to the separation. Discovery Zr-Carbon and Zr-CarbonC18 do exhibit some ion-exchange behavior from accessible Zr sites, but not to the extent of the polymer-coated zirconia phases.

General Method Development Guidelines

Compounds and Conditions to Avoid or be Aware of with Zr-Carbon and Zr-CarbonC18

Analytes with conjugated ring systems with little shielding of the pi electrons interact strongly with the carbon surface. In these instances, it is useful to add a strong Lewis base (like phosphate) to the mobile phase, change the organic modifier to THF or CH_3CN/THF, and increase the temperature of the separation. Avoid methanol as it is not strong enough to elute most compounds.

Organic Modifier

If the retention of an analyte is unknown, begin with an organic modifier-rich mobile phase. 50% is typically a good starting point to ensure timely elution. Adjust the organic content by steps of 10-15% to achieve elution of compounds with a k' ranging from 1-20.

Any common HPLC organic modifier may be used, however, tetrahydrofuran (THF) has been shown to provide the best peak shapes and efficiencies. Acetonitrile is the second choice, and methanol is typically not used unless necessary. Changing the organic modifier may alter the selectivity.

For ionic compounds, a "U-shaped" retention profile is sometimes observed. At low organic concentrations, typical reverse-phase behavior is observed (i.e. an increase in % organic results in decreased retention). At higher organic concentrations, however, normal phase behavior is observed (i.e. an increase in % organic results in increased retention). The % organic for the minimum retention varies as it is compound dependent.

Buffer Ions

For non-ionic compounds, buffers are not needed. For ionic compounds, choice of buffer ion, ionic strength, mobile phase additives, and pH will affect retention and selectivity. Any common HPLC buffer ion or additive may be used, and these phases are completely stable at pH 1-14. pH of the mobile phase affects both the charge of the zirconia surface and the charge state of the analyte. For ionic compounds, increasing the ionic strength of the mobile phase will typically improve peak shapes.

Temperature

A minimum operating temperature of 50°C is recommended. To decrease analysis time and improve peak shape and efficiency increase the temperature up to 100°C or 200°C with special custom hardware.

Specific Recommendations Based on Analyte

Neutral Compounds

- Use water/tetrahydrofuran (THF) or water/acetonitrile mobile phases with at least 5% THF present.
- Use elevated temperatures whenever possible.

Acidic Compounds

- Start with 5-25mM phosphate in the aqueous component of the mobile phase.
- The addition of a fluoride salt (5-20mM) may be used to alter retention and selectivity at pH > 4. Fluoride should not be added to a mobile phase with a pH < 4 because hydrofluoric acid will cause damage to the HPLC instrument and column.
- The use of ammonium salts is preferred over potassium or sodium salts.
- A mobile phase with a pH < pK_a of the analyte may be used to suppress ionization and eliminate ion exchange behavior.
- A minimum of 5% THF is recommended for improved peak shape.
- Use elevated temperature when possible.

Basic Compounds

- Use buffer systems containing a strong Lewis base (e.g. phosphate, fluoride, acetate, hydroxide, etc.).
- A good starting point is 5-25mM phosphate, pH 6-8, for weakly retained, hydrophilic bases. A pH between 1 and 3 is a good starting point for more strongly retained, hydrophobic bases. A pH below 2 is best obtained with the use of an appropriate concentration of phosphoric acid (5-25mM), and sulfuric acid (10-100mM).
- A mobile phase with a pH > pK_a of the analyte may be used to suppress ionization and eliminate ion exchange behavior.
- Other strong Lewis base buffer ions or added salts may be used to alter retention and selectivity. Typically, weaker Lewis bases will reduce retention, but the effect on selectivity is compound dependent.
- The use of ammonium salts is preferred over potassium or sodium salts.
- Use elevated temperature when possible.

Part 4: Developing Methods on Discovery Zr-PBD and Zr-PS

Discovery Zr-PBD is a general-purpose polymer-coated zirconia phase, very similar to silica-C18. Zr-PS is useful for alternative selectivity or when retention less than a Zr-PBD or C18-silica is desired.

Discussion of Discovery Zr-PBD and Zr-PS

Discovery Zr-PBD and Zr-PS are produced by coating zirconia particles with an extremely stable and thin layer of polybutadiene (PBD) or polystyrene (PS) polymer. The resulting chemical selectivity for non-ionic analytes is similar to a silica based alkyl (C8 or C18) or phenyl stationary phase, for PBD and PS, respectively. For ionic compounds, however, there are secondary interactions (ion-exchange) with the zirconia substrate that play a significant role in the retention and selectivity of the analytes. The zirconia surface is very active and the secondary interactions can be exploited to fine-tune the separation with the proper selection of buffer ion, ionic strength, mobile phase additives, and/or pH. Additionally, the secondary interactions can be eliminated, if desired, by utilizing a mobile phase with a pH above the pK_a for basic analytes, or pH below pK_a for acidic analytes.

General Method Development Guidelines

Compounds and Conditions to Avoid or be Aware of with Zr-PBD and Zr-PS

Compounds with multiple carboxylate groups (e.g. proteins) will act as chelating agents and adsorb irreversibly to reversed-phase zirconia supports. Therefore, we strongly advise against RPLC of proteins on zirconia-based media.

Organic Modifier

If the retention of an analyte is unknown (i.e. no experience with any compound of similar structure), begin with an organic modifier-rich mobile phase. 50% is typically a good starting point to ensure timely elution. Adjust the organic content by steps of 10-15% to achieve elution of compounds with a k' ranging from 1-20. Any typical HPLC organic modifier may be used, however, acetonitrile and tetrahydrofuran have been shown to provide the best peak shapes and efficiencies. Changing the organic modifier may alter the selectivity.

For ionic compounds, a "U-shaped" retention profile is often observed. At low organic concentrations, typical reverse-phase behavior is observed (i.e. an increase in % organic results in decreased retention). At higher organic concentrations, however, normal-phase behavior is observed (i.e. an increase in % organic results in increased retention). The % organic for the minimum retention varies as it is compound dependent.

Buffer Ions

For ionic compounds, choice of buffer ion, ionic strength, mobile phase additives, and pH will affect retention and selectivity. Any typical HPLC buffer ion or additive may be used, and these phases are completely stable at pH 1-13. pH of the mobile phase affects both the charge of the zirconia surface and the charge state of the analyte. For ionic compounds, increasing the ionic strength of the mobile phase will typically improve peak shapes.

Temperature

Temperature may be increased up to 100°C (150°C with special hardware) to decrease analysis time and to improve peak shape and efficiency.

Specific Recommendations Based on Analyte

Neutral Compounds

- Choose a mobile phase just as you would if using a C18-silica. However, the % organic should be modified to account for reduced hydrophobicity of these phases. A good starting point would be about 20% less organic modifier for PBD and 30% less for PS.
- Use elevated temperature when possible.

Acidic Compounds

- The zirconia surface contains a larger number of Zr(IV) sites which are strong, hard Lewis acids. In water, these sites form coordinate-covalent bonds with water molecules. If a stronger, hard Lewis base (e.g. carboxylate anion) is injected into the column, it will displace the water and become quite tightly bound. The slow desorption will produce a broad tailed peak. Therefore, the mobile phase must contain a relatively high concentration of a stronger, harder Lewis base (e.g. phosphate or fluoride).
- Use at least 20mM phosphate in the aqueous component of the mobile phase.
- The addition of a fluoride salt (5-20mM) may be used to alter retention and selectivity at pH > 4. Fluoride should not be added to a mobile phase with a pH < 4 because hydrofluoric acid will cause damage to the HPLC instrument and column.
- The use of ammonium salts is preferred over potassium or sodium salts.
- A mobile phase with a pH << pK_a of the analyte may be used to suppress ionization and eliminate ion exchange behavior.
- Use elevated temperature when possible.
- Compounds with multiple carboxylate groups (e.g. proteins) will act as chelating agents and adsorb irreversibly to reverse phase zirconia supports. Therefore, we strongly advise against RPLC of proteins on zirconia-based media.

Basic Compounds

- Use buffer systems containing a strong Lewis base (e.g. phosphate, fluoride, acetate, hydroxide, etc.).
- A good starting point is 5-25mM phosphate, pH 6-8, for weakly retained, hydrophilic bases. A pH of 1-3 is a good starting point for more strongly retained, hydrophobic bases. A pH below 2 is best obtained with the use of an appropriate concentration of phosphoric acid (5-25mM), and sulfuric acid (10-100mM).
- Retention will increase with an increase in pH, up to the pK_a of the analyte. Further increase in pH will reduce retention as ionic interactions have been eliminated.
- A mobile phase with a pH >> pK_a of the analyte may be used to suppress ionization and eliminate ion-exchange behavior, although with a concomitant reduction in retention.
- Other strong Lewis base buffer ions or added salts may be used to alter retention and selectivity. Typically, weaker Lewis bases will reduce retention, but the effect on selectivity is compound dependent.
- Higher ionic strength typically decreases retention of basic analytes, but will yield better peak shapes.
- The use of ammonium salts is preferred over potassium or sodium salts.
- Use elevated temperature when possible.

Part 5: Discovery Zr Product Listing

Description	Cat. No.
Discovery Zr-Carbon	
3 micron	
5cm x 2.1mm	**65725-U**
7.5cm x 2.1mm	**65726-U**
15cm x 2.1mm	**65727-U**
5cm x 4.6mm	**65728-U**
7.5cm x 4.6mm	**65729-U**
15cm x 4.6mm	**65730-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65821-U**
1cm x 4mm Supelguard Cartridge Kit	**65823-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65822-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65824-U**
5 micron	
5cm x 2.1mm	**65731-U**
15cm x 2.1mm	**65732-U**
5cm x 4.6mm	**65734-U**
15cm x 4.6mm	**65735-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65826-U**
1cm x 4mm Supelguard Cartridge Kit	**65828-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65827-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65829-U**
Discovery Zr-CarbonC18	
3 micron	
5cm x 2.1mm	**65701-U**
7.5cm x 2.1mm	**65702-U**
15cm x 2.1mm	**65703-U**
5cm x 4.6mm	**65704-U**
7.5cm x 4.6mm	**65705-U**
15cm x 4.6mm	**65706-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65801-U**
1cm x 4mm Supelguard Cartridge Kit	**65803-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65802-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65804-U**
5 micron	
5cm x 2.1mm	**65707-U**
15cm x 2.1mm	**65708-U**
5cm x 4.6mm	**65710-U**
15cm x 4.6mm	**65711-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65805-U**
1cm x 4mm Supelguard Cartridge Kit	**65807-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65806-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65808-U**

Description	Cat. No.
Discovery Zr-PBD	
3 micron	
5cm x 2.1mm	**65713-U**
7.5cm x 2.1mm	**65714-U**
15cm x 2.1mm	**65715-U**
5cm x 4.6mm	**65716-U**
7.5cm x 4.6mm	**65717-U**
15cm x 4.6mm	**65718-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65811-U**
1cm x 4mm Supelguard Cartridge Kit	**65813-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65812-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65814-U**
5 micron	
5cm x 2.1mm	**65719-U**
15cm x 2.1mm	**65720-U**
5cm x 4.6mm	**65722-U**
15cm x 4.6mm	**65723-U**
25cm x 4.6mm	**65724-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65815-U**
1cm x 4mm Supelguard Cartridge Kit	**65817-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65816-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65818-U**
Discovery Zr-PS	
3 micron	
5cm x 2.1mm	**65737-U**
7.5cm x 2.1mm	**65738-U**
15cm x 2.1mm	**65739-U**
5cm x 4.6mm	**65740-U**
7.5cm x 4.6mm	**65741-U**
15cm x 4.6mm	**65742-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65841-U**
1cm x 4mm Supelguard Cartridge Kit	**65843-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65842-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65844-U**
5 micron	
5cm x 2.1mm	**65743-U**
15cm x 2.1mm	**65744-U**
5cm x 4.6mm	**65746-U**
15cm x 4.6mm	**65747-U**
25cm x 4.6mm	**65748-U**
1cm x 2.1mm Supelguard Cartridge Kit	**65845-U**
1cm x 4mm Supelguard Cartridge Kit	**65847-U**
1cm x 2.1mm Supelguard Cartridges, pk. of 2	**65846-U**
1cm x 4mm Supelguard Cartridges, pk. of 2	**65848-U**

NOTE: Special hardware for operation between 100°C and 200°C is available as a custom order. Please inquire.

Trademark
Discovery - Sigma-Aldrich Co.

Order/Customer Service 800-247-6628, 800-325-3010 ● Fax 800-325-5052 ● E-mail supelco@sial.com
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