

# Ascentis® Express HPLC Resource Guide



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Application Articles

Choosing an Alternate  
Phase

Bibliography of Fused-Core  
Publications

Practical Recommendations  
for Success

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## Available Resources

### US Technical Service

phone: 800-359-3041 (US and Canada only)  
814-359-3041  
fax: 800-359-3044/814-359-5468  
email: techservice@sial.com

### EU Technical Services

email: EurTechServ@sial.com

**Internet:** [sigma-aldrich.com/express](http://sigma-aldrich.com/express)

**Webinars:** [sigma-aldrich.com/videos](http://sigma-aldrich.com/videos)  
(available 24 hours/day)

**Email updates:** Fused-Core Report (register  
at [sigma-aldrich.com/express](http://sigma-aldrich.com/express))

**Twitter:** [twitter.com/HPLCSessions](https://twitter.com/HPLCSessions)

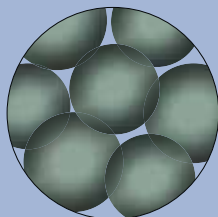
## The Fused-Core® Advantage

### Extreme performance on any LC system

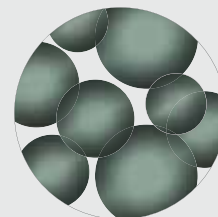
Half the backpressure of sub-2  $\mu\text{m}$  columns  
Twice the performance of 5  $\mu\text{m}$  columns

#### Fused-Core Particles

Narrow Particle  
Size Distribution

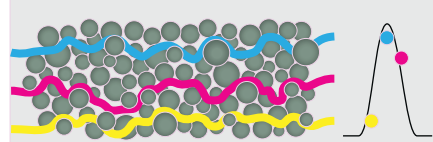
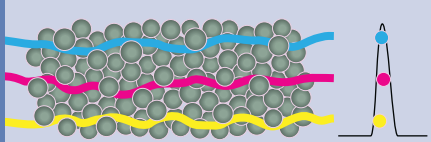


#### Traditional Porous Particles



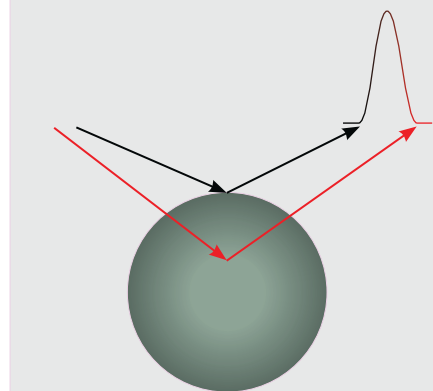
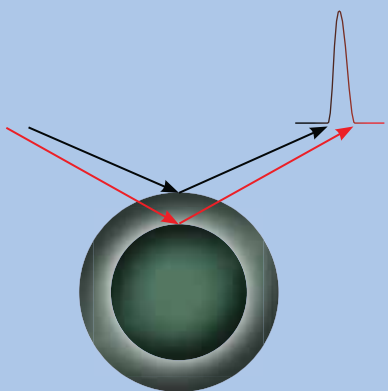
The innovative manufacturing process for Fused-Core particles produces a very narrow particle size distribution. A narrow particle size distribution allows for the use of large porosity frits that resist clogging, resulting in a **more rugged column**. Traditional porous particles are not manufactured in a way to yield extremely narrow particle size distributions.

More  
Consistent  
Bed

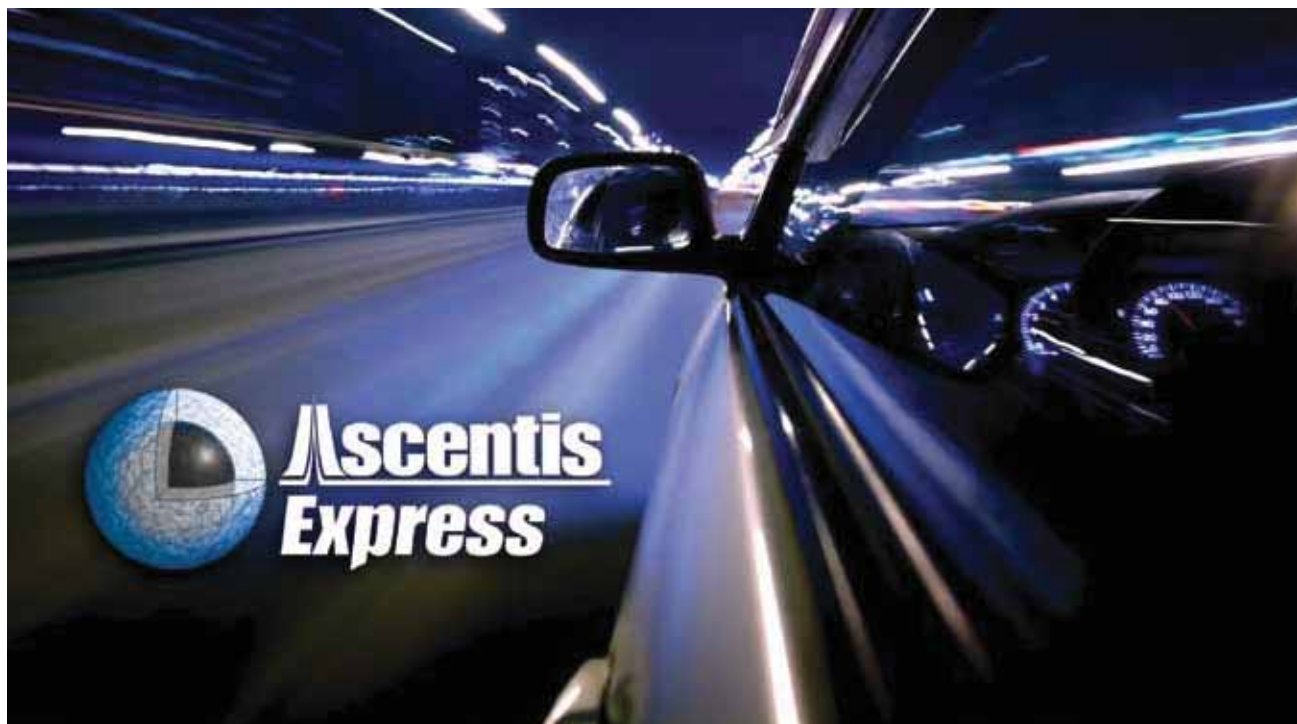


The "A" term in the van Deemter equation accounts for the effects of inhomogeneities in the packed bed of an HPLC column. Narrow particle size distributions form a more consistent packed bed and a consistent path length, **minimizing analyte diffusion** through the column. This eddy diffusion is effectively independent of mobile phase velocity.

Shorter  
Diffusion Path



The short diffusion path of the Fused-Core particle **yields sharper peaks** than traditional porous particle columns. The minimized resistance to mass transfer, the "C" term in the van Deemter equation, of the Fused-Core particle provides sharper peaks than traditional porous particles. The short diffusion path also **permits the use of higher flow rates** without peak broadening.



## Keys to High Speed HPLC with Ascentis Express

### Introduction

Speed refers to the time required to run a complete assay and introduce a new sample (for gradient assays, speed must also include the time required for system re-equilibration). Important goals in HPLC are increasing speed and maintaining resolution. Resolution is controlled by three column performance parameters as shown in Equation 1.

$$R_s = \frac{\sqrt{N}}{4} \cdot \frac{k}{1+k} \cdot \frac{\alpha-1}{\alpha} \quad (1)$$

Resolution refers to the amount of space between peaks. Best analytical performance is achieved when peaks are completely separated ( $R_s = 1.5$  is defined as baseline resolution). Retention factor ( $k$ ) and selectivity factor ( $\alpha$ ) do not change with column length; however, efficiency ( $N$ ) decreases with length unless the particle size is also decreased. Installing a shorter column containing smaller particles can increase speed without degrading resolution because the same number of plates can be maintained. Table 1 shows the history of the development of HPLC particles. Table 2 shows some popular column lengths for several particle types with typical numbers of plates for each column if it is in new condition. Achieving the same number of plates using shorter columns with smaller particles is one key to higher speed under isocratic conditions.

Table 1. Evolution of HPLC Particles





1970s	1980s	1990s	Modern
			
10 µm (Porous)	5 µm (Porous)	3 µm (Porous)	Fused-Core and sub-2 µm

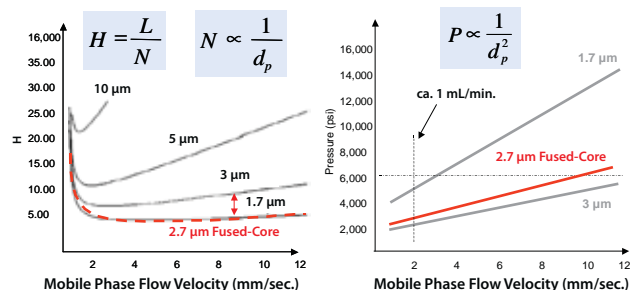
Table 2. Comparison of Three Column Particles

Particle Size (µm)	Column Length (mm)	Bed Efficiency (N/mm)	Total Number of Plates (N)
5	150	100	15,000
5	100	100	10,000
5	50	100	5,000
3	100	150	15,000
3	50	150	7,500
3	30	150	4,500
2.7 Fused-Core	100	250	25,000
2.7 Fused-Core	50	250	12,500
2.7 Fused-Core	30	250	7,500
2.7 Fused-Core	20	250	5,000

HPLC speed has been further improved by operating shorter columns and smaller particles at higher flow rates; however, considerable resolution was sacrificed due to loss of efficiency even with popular 3 µm particles. The reason for this can be seen in Figure 1 where van Deemter plots for different particle sizes are compared.



**Figure 1. van Deemter Plots (Efficiency versus Flow Velocity) and Pressure Plots for Different Particle Types**



Since the slope of the van Deemter plot decreases dramatically with reduction in particle size or change to a Fused-Core design, both  $H$  and  $N$  remain constant even at higher flows. This flat van Deemter plot allows an increase in flow to be combined with a reduction in column length to generate much higher separation speed without significant sacrifice in resolution.

### Decreasing Column Length for Speed

Figure 2 shows an example of how a separation achieved with column geometry of 150 x 3 mm, 5 µm particles and 0.4 mL/min. can be transferred to much shorter column geometry of 50 x 3 mm when higher performance Fused-Core particles are employed with a similar mobile phase. In this case, the Fused-Core particles have about three times the efficiency per unit length of 5 µm particles, so the same separation can be achieved with almost one third the column length. Note that only one third as much solvent is needed because solvent use is directly proportional to column length. This shorter length creates an immediate speed improvement by a factor of three when operated at the same flow velocity. The Fused-Core column was operated at a higher flow rate of 0.6 mL/min. (flow velocity of 3 mm/sec.) so the total increase in speed was four-fold.

### Increasing Flow Rate for Speed

Figure 2 also shows the achievement of even more speed and throughput by increasing flow rate for the 50 x 3 mm column to 1.2 mL/min. (flow velocity of 6 mm/sec.). The relationship that defines speed for an isocratic assay is shown in Equation 2.

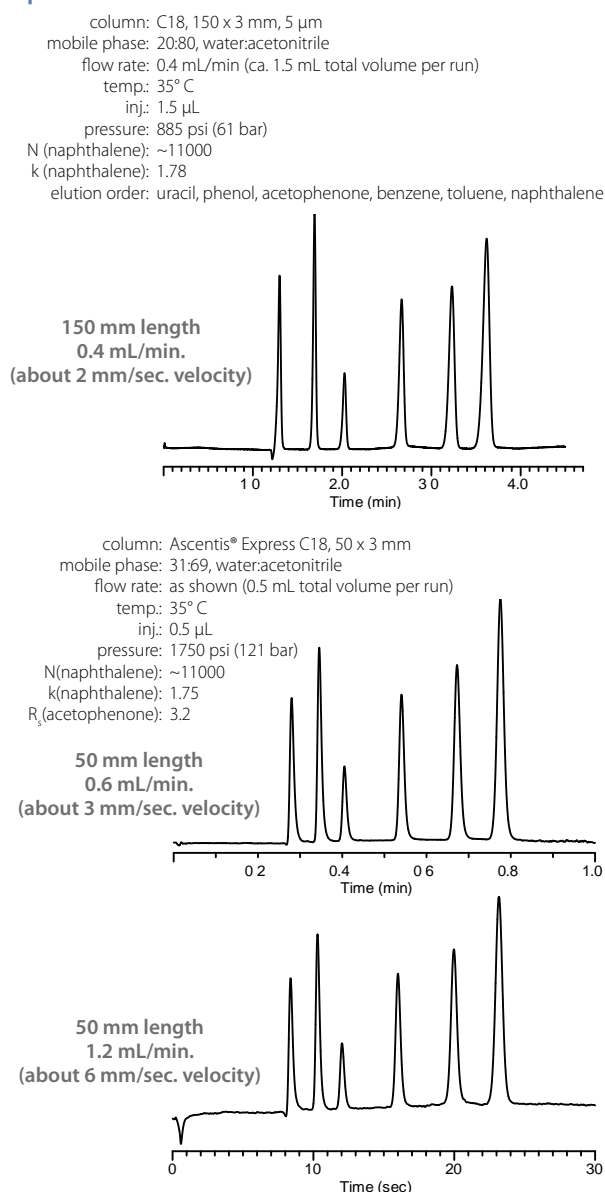
$$\text{Speed} = L/u (1 + k) \quad (2)$$

where  $L$  is column length and  $u$  is flow velocity (usually measured from the retention time for an unretained peak). In this example, a 50 mm column operated at a flow velocity of 6 mm/sec. yields a speed of 8.3 sec. for  $k = 0$  (solvent front or void volume) so a separation with a  $k$  value of 10 or less can be completed in about 90 seconds (see Equation 2). In the 50 x 3 mm example, all peaks elute between  $k = 0$  and  $k = 2$  so the separation is complete in about 25 seconds. Note that very little resolution is sacrificed, which allows peak integration accuracy to be maintained even at high flow velocity.

### Conclusions

1. Fused-Core and sub-2 µm porous particles have higher efficiency per unit length so that shorter columns can accomplish the same separation as longer columns with 5 µm or 3 µm porous particles.
2. Fused-Core 2.7 µm particles achieve the same performance as sub-2 µm particles at pressures which are only slightly higher than 3 µm particles.
3. Both Fused-Core and sub-2 µm particles can be operated at higher flows without losing efficiency and resolution; however, the lower pressure drop of Fused-Core allows higher flow velocities at lower operating pressures.

**Figure 2. Example of using Shorter Columns and Higher Flows with Smaller Particles to Increase Speed**







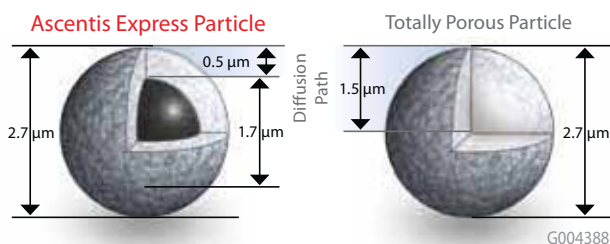
# Ascentis Express F5 HPLC Columns

*Separate Closely Related Compounds*

## Introduction

Ascentis® Express is a high-speed, high-performance liquid chromatography column based on Fused-Core® (Figure 1) particle technology. The Fused-Core particle provides a thin porous shell of high-purity silica surrounding a solid silica core. This particle design exhibits very high column efficiency due to the shallow diffusion paths in the 0.5-micron thick porous shell and the small overall particle size of 2.7 microns. Other features, such as a very narrow particle size distribution and high packing density, result in Ascentis Express columns capable of 240,000 N/m. This is comparable to the efficiency of sub-2  $\mu\text{m}$  particle columns and nearly twice the efficiency possible with 3  $\mu\text{m}$  columns.

**Figure 1. Fused-Core Structure of Ascentis Express Compared to Totally Porous Particles**



The pentafluorophenylpropyl stationary phase of Ascentis Express F5 provides a stable, reversed-phase packing with electron-deficient phenyl rings due to the presence of electronegative fluorines. In addition to forming  $\pi$ - $\pi$  and mildly steric interactions, F5 phases also retain compounds by polar interactions. As a result of having both polar and non-polar character, F5 phases can show dual-mode retention

behavior, sometimes producing a “U-shaped” retention as a function of acetonitrile content of the mobile phase, with retention increasing at both low and high concentrations of ACN (reversed-phase and HILIC retention modes). Ascentis Express F5 can be used for basic, acidic, or neutral compounds with alternate selectivity from C18.

- Alternate selectivity to C18
- Retains bases more and hydrophobes less than C18
- Reversed-phase, HILIC, and 100% aqueous applications
- Stable, low bleed for LC-MS and LC-UV

## Mechanisms of Retention on Fluorinated Phases

The use of fluorinated stationary phases in liquid chromatography and hyphenated techniques has become significant in recent years. Early applications in the effective separation of paclitaxel provided such phases much notoriety, however more recent studies focusing on orthogonality to traditional alkyl phases has invited even broader attention. Due to the different retention mechanisms fluorinated stationary phases provide, they are often employed for the separations not easily obtained using common C18 phases. Applications in arenas such as biopharmaceutical, pharmaceutical, natural product and environmental analyses are increasingly being reported.

Fluorinated phases have been shown to exhibit greater ion-exchange character than their alkyl counterparts. Fluorinated phases often provide excellent chromatographic results when analytes to be separated differ in their ionization constants or where some ion-exchange is necessary for the retention of polar metabolites or degradation products. A second important attribute of the fluorinated phases lies in



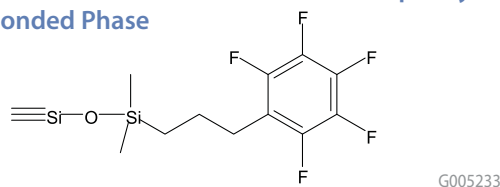
their apparent increased shape selectivity relative to common stationary phase chemistries. Fluorinated phases, therefore, are often superior to their alkyl counterparts for the separation of closely related compounds that differ in size and shape.

In order to effectively utilize this interesting and useful tool, it is important to have a basic understanding of the underlying mechanisms that govern retention and selectivity. This report will focus on two main mechanistic features of fluorinated phases that differentiate them from common alkyl phases; increased ionic interactions relative to alkyl phases and shape selectivity.

### Practical Implications of Alternative Retention Mechanisms

The structure of a popular form of fluorinated phases, pentafluorophenylpropyl (PFP or F5), is shown in Figure 2. The F5 bonded phase exhibits strong dipole potential (polar interaction) from the carbon-fluorine bonds, pi-pi interaction potential and the ability to interact via charge-transfer interactions due to the electronegativity of the fluorine atoms. The relative rigidity of the bonded phase is also believed to provide enhanced shape selectivity of analytes differing in size and spatial attributes.

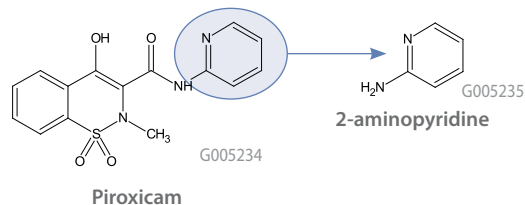
**Figure 2. Chemical Structure of Pentafluorophenyl-propyl Bonded Phase**



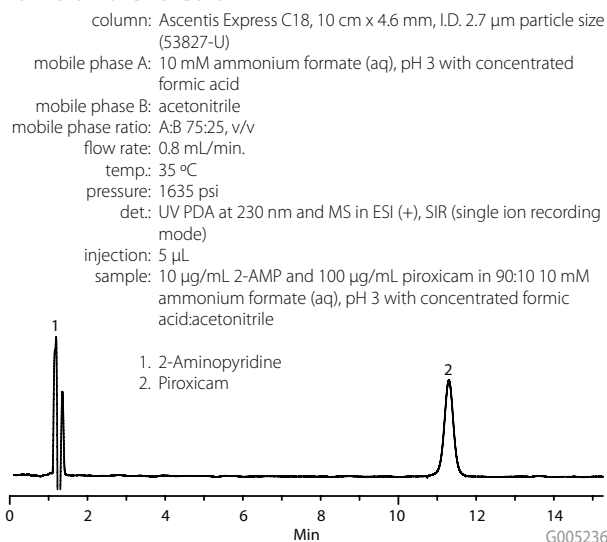
A common short-coming of traditional alkyl phases such as C18 (ODS) and C8 (octyl) is their inability to retain polar compounds. Because the F5 phase exhibits ion-exchange and polar interactions, retention of polar compounds are often achieved. Figure 3 shows the structures of the anti-inflammatory drug piroxicam and a potential synthetic impurity, 2-aminopyridine (2-AMP). 2-AMP is relatively polar ( $\log P = 0.53 \pm 0.27$ ) and thus difficult to retain on a conventional alkyl column. Figure 4 shows the separation of the two analytes using a C18 phase. Retention of piroxicam is easily achieved; however, 2-AMP is unretained and thus not quantifiable. Efforts to lower mobile phase organic content and raise pH to improve retention were ineffective using the alkyl phase. It is possible that retention of 2-AMP may be accomplished through the addition of ion-pair reagents; however, such methods are often difficult to validate and suffer from robustness and ruggedness issues. Figure 5 shows the separation of 2-AMP and piroxicam using a fluorinated phase. In this case, 2-AMP is well retained and separated from the

parent molecule using a simple mobile phase. The retention of 2-AMP demonstrates the availability and utility of the polar and ionic interactions the F5 phase exhibits.

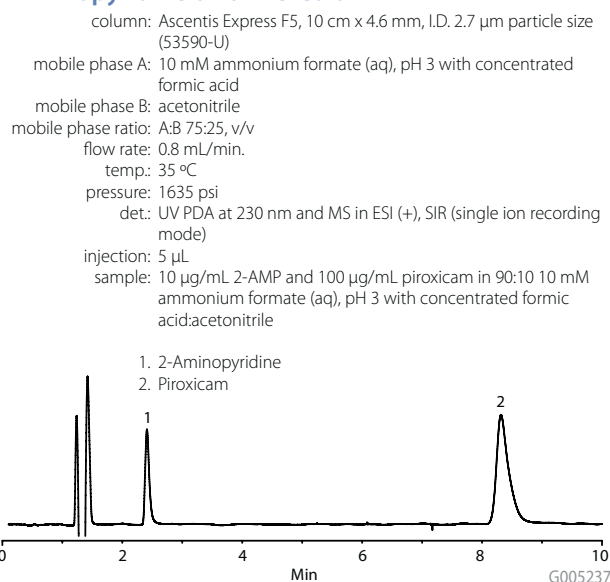
**Figure 3. Structures of Piroxicam and its Potential Impurity, 2-aminopyridine**



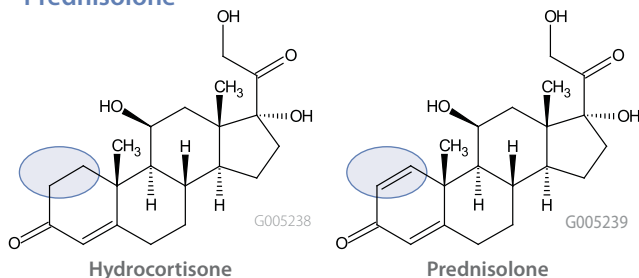
**Figure 4. Separation of Piroxicam and 2-Aminopyridine on a C18 Column**



**Figure 5. Separation of Piroxicam and 2-Aminopyridine on an F5 Column**



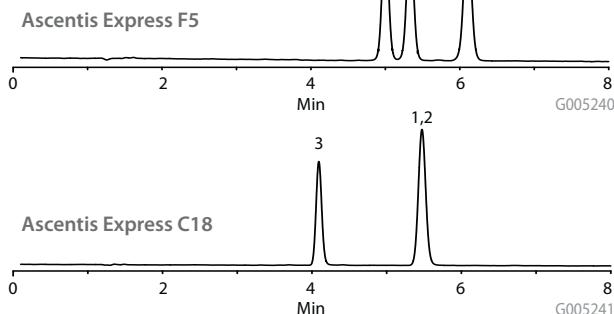
**Figure 6. Structures of Hydrocortisone and Prednisolone**



**Figure 7. Comparison of C18 and F5 for the Separation of Closely Related Steroids**

column(s): Ascentis Express F5 (53590-U) and Ascentis Express C18, 10 cm x 4.6 mm, I.D., 2.7  $\mu$ m particle size (53827-U)  
 mobile phase A: water  
 mobile phase B: methanol  
 mobile phase ratio: A:B 50:50, v/v  
 flow rate: 0.8 mL/min.  
 temp.: 35  $^{\circ}$ C  
 pressure: ~2400 psi  
 det.: UV at 240 nm  
 injection: 5  $\mu$ L  
 sample: 10  $\mu$ g/mL each in 90:10 water:methanol

1. Hydrocortisone
2. Prednisolone
3. Prednisone (IS)



Chromatographers are often faced with the challenge of separating compounds that are very similar in their solubilities. Separation on non-polar phases such as C18 is driven by differential partitioning of analytes, therefore, the alkyl phases are often ineffective in meeting this challenge. Hydrocortisone and prednisolone (see Figure 6) differ by a single double bond. Their solubilities are very similar; however, their shapes differ significantly. Figure 7 shows a comparison of their separation (along with prednisone internal standard (IS) using both a C18 and an F5 stationary phase. The fluorinated phase, apparently due to the enhanced shape selectivity, is shown to provide the separation of these closely related compounds.

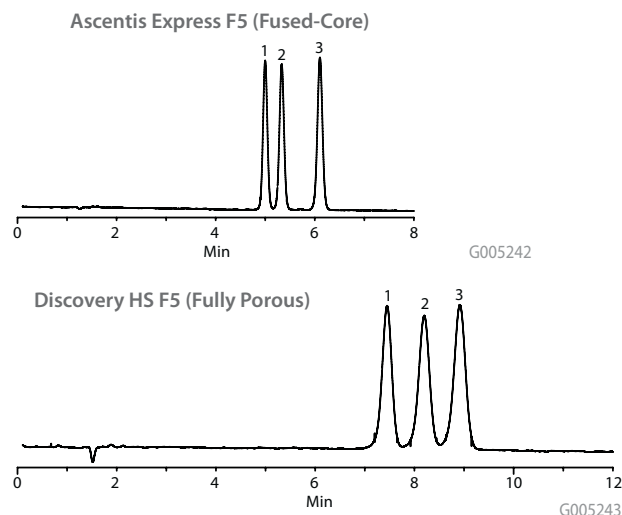
#### Alternate Selectivity with High Efficiency

The F5 bonded phase has recently been introduced on the highly efficient Fused-Core technology platform with the brand name Ascentis Express F5. Figure 8 shows a comparison

**Figure 8. Comparison of Fluorinated Phases Based on Totally Porous and Fused-Core Particle Technologies**

column(s): Ascentis Express F5, 10 cm x 4.6 mm, I.D., 2.7  $\mu$ m particle size (53590-U), Discovery HS F5, 10 cm x 4.6 mm, I.D., 5  $\mu$ m particle size (567515-U)  
 mobile phase A: water  
 mobile phase B: methanol  
 mobile phase ratio: A:B 50:50, v/v  
 flow rate: 0.8 mL/min  
 temp.: 35  $^{\circ}$ C  
 pressure: ~2400 psi Express, ~1000 psi Discovery  
 det.: UV at 240 nm  
 injection: 5  $\mu$ L  
 sample: 10  $\mu$ g/mL each in 90:10 water:methanol

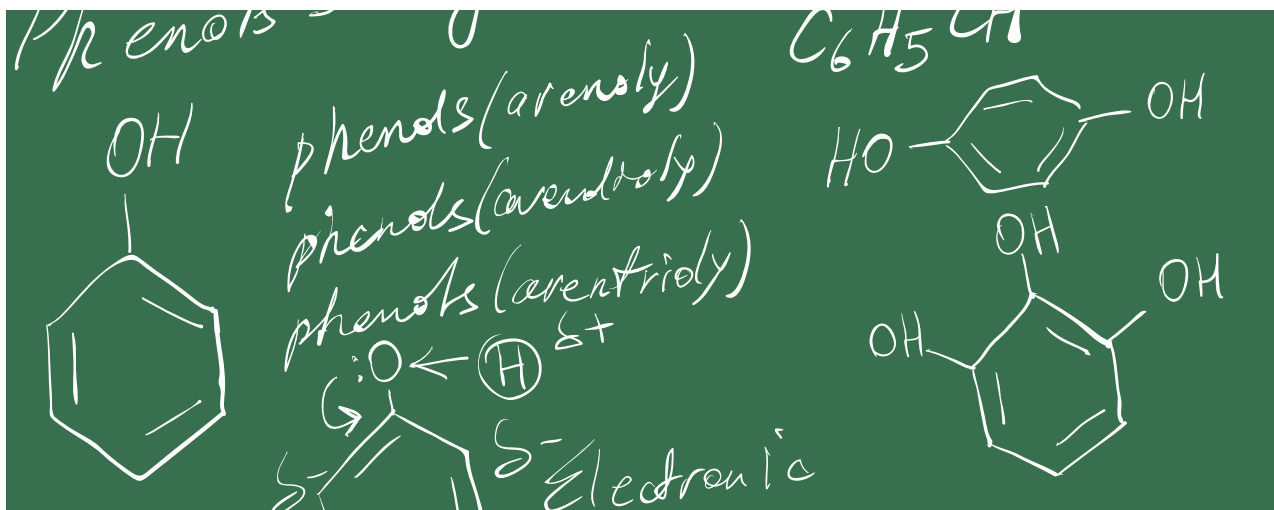
1. Hydrocortisone
2. Prednisolone
3. Prednisone (IS)



of the fully-porous Discovery<sup>®</sup> HS F5 and the new Ascentis Express F5. Similar overall selectivity is observed due to the similar interactions provided by the F5 moiety. A dramatic increase in efficiency due to the Fused-Core particle support is demonstrated when using the Ascentis Express F5.

#### Conclusions

Fluorinated stationary phases exhibit increased ionic and polar interactions relative to common alkyl phases. The rigidity of the F5 bonded phase is also believed to provide increased shape selectivity over commonly used alkyl phases. These alternative mechanisms of retention often provide selectivity not readily achieved on the more traditional phases. Retention and selectivity of highly polar and ionic species as well as separation of closely related neutral compounds have been used to demonstrate the power of the bonded phase chemistry. The recent combination of the selectivity provided by the fluorinated bonded phase and the efficiency of Fused-Core particle technology provides even greater resolution power.



P001388

## Ascentis Express RP-Amide:

*Combining an Embedded Polar Group Stationary Phase and Fused-Core Particles*

Ascentis Express RP-Amide HPLC columns are the most recent product additions to the Supelco HPLC product line. Combining an embedded polar group (EPG) stationary phase with the Fused-Core particles, Ascentis Express RP-Amide provides a host of useful benefits to the HPLC chromatographer. The benefits of the phase technology can be summarized as:

### RP-Amide Benefits

- Alternative reversed-phase selectivity to C18
- Improved peak shape for bases
- 100% aqueous compatible reversed-phase column

While the Ascentis Express C8 and C18 provide classic reversed-phase selectivity, the RP-Amide phase offers an alternative selectivity. Supelco first commercially introduced the EPG phase in 1988. At that time, large tailing factors for basic analytes continued to plague conventional C18 and C8 bonded phases. The EPG phase was found to improve peak shape of basic analytes. The early generation EPG phases were based on a two-step bonding process (Figure 1). The first step was the bonding of an aminopropylsilane to the bare silica surface

creating a surface with amine functionality. In step two, palmitoyl chloride was reacted with the amine to create a long chain amide. Not all amines would be converted in the process, leaving a mixed system. These early generation EPG phases suffer from poor reproducibility.

Next generation phases, including Ascentis Express RP-Amide, are produced using a one-step process (Figure 2). In the single step process, no free amino ligands occur since the amide is introduced as a whole unit. This one-step bonding process yields excellent batch-to-batch reproducibility. Interestingly, not all EPG phases on the market use the modern, one-step bonding approach.

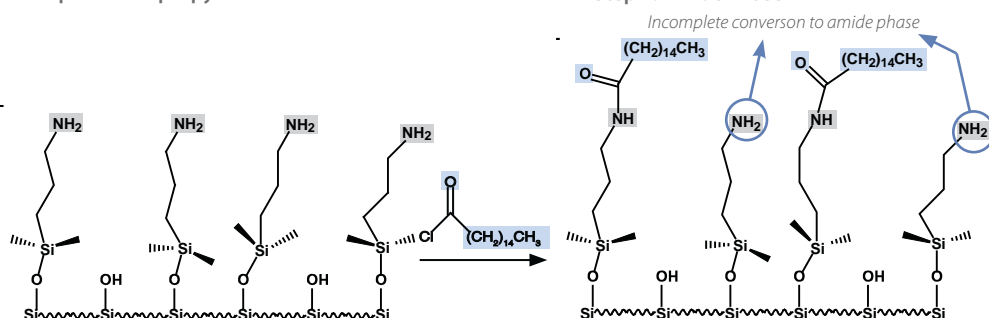
### Improved Peak Shape for Basic Compounds

As previously mentioned, Ascentis Express RP-Amide phase reduces silanol interactions with basic analytes improving peak shape. A good test to demonstrate this effect is highly basic compounds using a mobile phase pH of 7. At this pH, many of the residual silanols are in the ionized form and the basic compounds are protonated.

**Figure 1. Early Generation Two-step Bonding Process for EPG Amide Phases**

Step 1. Aminopropyl Phase

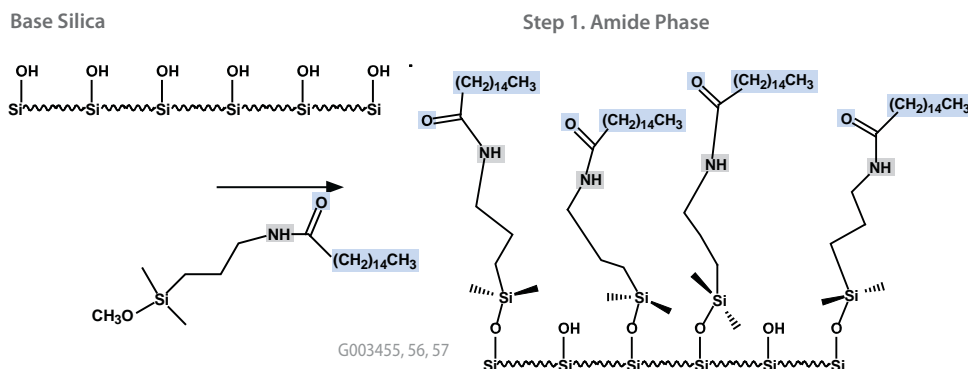
Step 2. Amide Phase



G003453, 54



**Figure 2. Next Generation One-step Bonding Process for EPG Amide Phases**



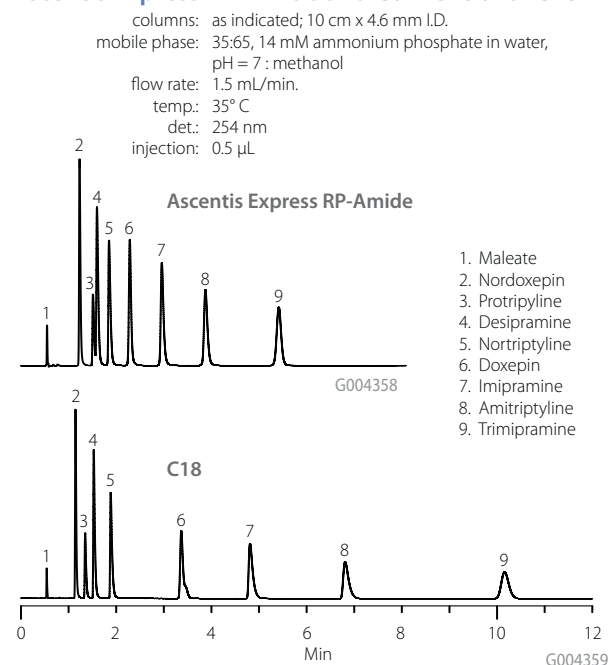
The protonated (charged) bases interact with the charged silanols via ion exchange and result in a tailing peak. A test mix of tricyclic antidepressants was analyzed on Ascentis Express RP-Amide and a C18 column with a mobile phase pH of 7 (Figure 3). As shown in Figure 3, the RP-Amide produces more symmetrical peaks than the C18 for these difficult test probes. Asymmetry data is summarized in Figure 4 for doxepin, imipramine, and amitriptyline.

### Alternative Selectivity

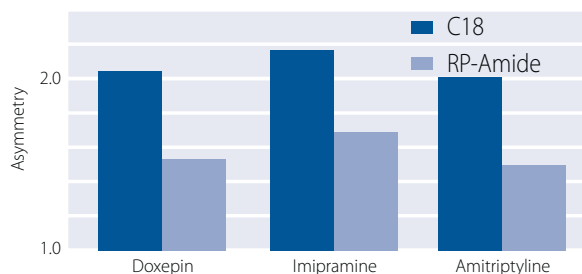
Ascentis Express RP-Amide provides increased selectivity for polar compounds, especially those that can act as a hydrogen-bond donor. Phenols, carboxylic acids, amines, and to a lesser extent, alcohols show enhanced retention on the RP-Amide phase when compared to neutral, non-polar analytes. An example of the power of the hydrogen bonding mechanism is shown in Figure 5. The phenolic nature of catechols and resorcinols provides a good test for demonstrating enhanced selectivity of the RP-Amide phase. The RP-Amide phase shows complete baseline resolution of these related compounds while the C18 phase shows reduced retention, resolution, and selectivity for the phenolics. In comparing the Ascentis Express RP-Amide to the Waters™ BEH Shield RP18, a competitive EPG phase, the selectivity is very similar. The difference in this example is the Ascentis Express RP-Amide yields a backpressure half of the 1.7  $\mu$ m column. This difference in backpressure means the Ascentis Express column is suitable for traditional HPLC systems while the 1.7  $\mu$ m column is not.

The selectivity differences between the RP-Amide and the C18 can be a useful tool in method development. In many cases, when peaks co-elute on a C18 phase, the RP-Amide can be substituted to achieve separation without a change in mobile phase.

**Figure 3. Separation of Tricyclic Antidepressants on Ascentis Express RP-Amide and Conventional C18**



**Figure 4. Asymmetry Factors for Difficult Bases on Ascentis Express RP-Amide and Conventional C18**

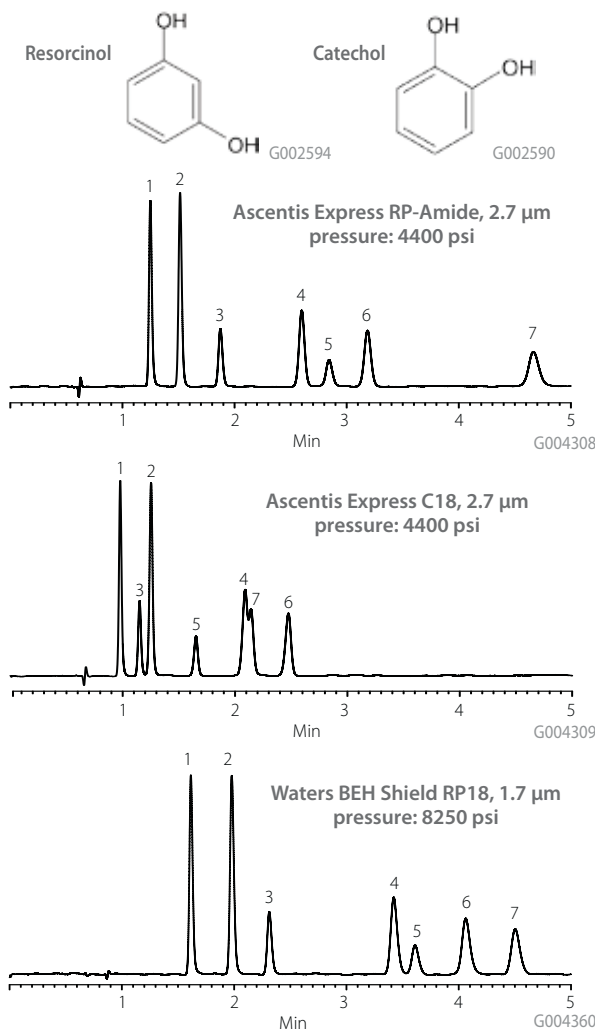




**Figure 5. Separation of Phenolics on Ascenis Express RP-Amide & C18, & Waters BEH Shield RP18, 1.7  $\mu$ m**

columns: as indicated; 10 cm x 2.1 mm I.D.  
mobile phase A: 20 mM phosphoric acid, pH 2 (unadjusted)  
mobile phase B: water  
mobile phase C: acetonitrile  
mobile phase ratios: A:B:C = 75:5:20  
flow rate: 0.3 mL/min.  
temp.: 35° C  
det.: 270 nm  
injection: 1  $\mu$ L  
sample: 50 mg/L ea. in  
20 mM phosphoric acid

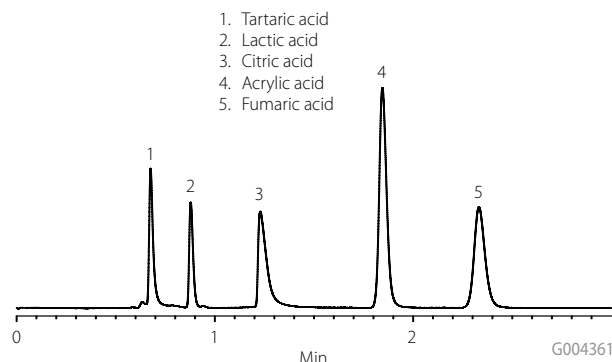
1. Resorcinol
2. Catechol
3. 2-Methylresorcinol
4. 4-Methylcatechol
5. 2,5-Dimethylresorcinol
6. 3-Methylcatechol
7. 4-Nitrocatechol



**Figure 6. Separation of Small Organic Acids Under 100% Aqueous Conditions**

column: Ascentis Express RP-Amide, 10 cm x 2.1 mm I.D.  
mobile phase: 0.1% TFA (v/v) in water  
flow rate: 0.3 mL/min.  
temp.: 35° C  
det.: 210 nm  
injection: 1  $\mu$ L  
sample: in mobile phase; tartaric acid, 2 g/L; lactic acid, citric acid, 4 g/L; acrylic acid, 0.5 g/L; fumaric acid, 0.2 g/L

1. Tartaric acid
2. Lactic acid
3. Citric acid
4. Acrylic acid
5. Fumaric acid



### Aqueous Compatible Reversed-Phase Column

Ascentis Express RP-Amide provides stable and reproducible analyte retention in 100% aqueous mobile phases. Many C18 phases are known to suffer from phase collapse under highly aqueous mobile phase conditions causing loss of retention. Shown in Figure 6 is a mix of organic acids analyzed under 100% aqueous conditions. Excellent selectivity and peak shape is noted for all the test probes, even citric acid, which is a notoriously difficult analyte.

### Conclusion

Ascentis Express RP-Amide is a blend of modern phase technology and innovative particle technology. The Fused-Core particle provides benefits in terms of speed, resolution, sensitivity, and ruggedness. The one-step RP-Amide bonding chemistry provides benefits in terms of selectivity, aqueous stability, and improved peak shape for bases.

### Practical Recommendations for Success

- Use 0.005 in. I.D. inlet and outlet tubes. Broadening is much less sensitive to the tube length than to the I.D. Minimize lengths of the inlet and outlet tubes for best performance, but do not worry about having a few extra centimeters of length if it makes maintenance or column installation easier.
- If high pressure becomes a problem, then use acetonitrile as modifier and elevate the column temperature whenever possible. If methanol, THF, or another more viscous modifier is required, then elevating the temperature becomes even more beneficial. Even a modest temperature increase will greatly reduce the mobile phase viscosity and the required pressure while improving mass transfer.
- Use only 4.6 mm diameter Fused-Core columns on conventional HPLC systems to minimize broadening problems from the remaining system components. Extra column broadening worsens as the column diameter is decreased.
- Keep the sample volumes small — 5  $\mu$ L or less if the peaks of interest elute early ( $k = 1$ ). Up to 20  $\mu$ L is acceptable if  $k$  exceeds 10.
- Avoid sample solvents that are stronger than the mobile phase.
- Use data rates of 10 Hz or greater, and watch out for bunching factors.



P001389

# Ascentis Express Phenyl-Hexyl:

*Combining the popular Phenyl-Hexyl Stationary Phase and Fused-Core Particles*

The vast majority of UHPLC separations have been carried out with C18 columns in the classic reversed-phase (RP) mode; however, suppliers now offer many different phases. Although no one would dispute the fact that UHPLC columns with different phases are needed, very little has been published yet on the performance that can be expected from UHPLC columns having different, complementary selectivity to C18 and C8. Two of the most popular polar-RP phases are RP-Amide, which is often categorized as an embedded polar-group phase, and Phenyl, which can interact with solutes by  $\pi$ - $\pi$  mechanisms. A brief retention and selectivity comparison for the Ascentis Express column family is given in Table 1.

C18 and C8 phases are highly popular because they are stable, reproducible, and easy-to-use. Retention correlates closely with log P values, which have been established for many solutes. Solute ionization causes retention to decrease in a predictable manner and is relatively easy to control by adding dilute acids, bases, and buffers to the mobile phase. Changing the organic component of the mobile phase between acetonitrile and methanol (or other solvents) allows the user to tweak resolution because solvation affects phase structure and selectivity. Temperature is also a useful variable for optimizing phase selectivity. Columns with C18 and C8 phases will frequently give optimum resolution when solutes are nonpolar or slightly polar; however, columns with polar-RP phases such as RP-Amide or Phenyl-Hexyl will often show improved retention and selectivity for more polar solutes. It should be emphasized that even polar-RP phases have a significant alkyl phase character in addition to their polar character. The same mobile phase solvents and techniques may be employed with polar-RP phases, with comparable phase stability to C18.

The RP-Amide phase is complementary to C18 because the amide group has several unique features: 1) strong interaction by H-bonding when solutes can donate or accept protons, 2) effective shielding of silanols by internal H-bonding between

**Table 1. Brief Overview of Ascentis Express Column Retention and Selectivity**

Ascentis Express Fused-Core Phase	Principle Retention Mode	Principle Solute Interaction
C18	Reversed-Phase (RP)	Hydrophobic (dispersive)
C8	Reversed-Phase (RP)	Hydrophobic (dispersive)
RP-Amide	RP with embedded polarity	Hydrophobic and H-bonding
Phenyl-Hexyl	RP with pendant aromaticity	Hydrophobic and $\pi$ - $\pi$
HILIC (Silica)	HILIC (or normal phase)	Hydrophilic (dipole, H-bonding, ion exchange)
F5	Reversed-Phase or HILIC	Hydrophobic and Hydrophilic (dipole, ion-exchange)

amide group and silica surface, and 3) the ability to wet and operate well, even in 100% aqueous solvents. H-bonding allows solutes with carboxyl and phenol groups to be retained much longer and separate much better on RP-Amide than on C18 or C8. Shielding prevents solutes with amino groups from interacting with silanols and can result in shorter retention and sharper peaks on amide phases. Another interesting feature of amide phases is that methanol and other alcohols become much stronger solvents when H-bonding between phase and solute occurs. Except for the special situations listed above, an RP-Amide phase often performs similar to C18 due to the long alkyl chain extending away from the surface.

The Phenyl phase has unique selectivity arising from solute interaction with the aromatic ring and its delocalized electrons. It is complementary (orthogonal) to both C18 and RP-Amide phases because of this unique aromaticity. An unsubstituted phenyl ring is a  $\pi$ -donor or Lewis base, which interacts strongly with  $\pi$ -acceptors and any electron-deficient Lewis acid. Phenyl phases also tend to exhibit good shape selectivity, which may originate from solute multipoint interaction with the planar ring system. More retention and selectivity will often be observed for solutes with aromatic electron-withdrawing groups (fluorine, nitro, etc.) or with a delocalized heterocyclic ring system such as the benzodiazepine compounds.



## UHPLC Results with Ascentis Express Phenyl-Hexyl

In general, more than twice the column efficiency of 5  $\mu\text{m}$  particles can be expected for all Ascentis Express Fused-Core columns at pressures that are easily managed with all HPLC instruments. Note that 20,000 plates have been achieved for a 10 cm x 3 mm I.D. column operating at optimum flow. A Jasco X-LC HPLC instrument was used for the study. Figure 1 illustrates the benzodiazepine chemical structures used in this study. As shown in Figure 2, the selectivity of Ascentis Express Phenyl-Hexyl is very similar to that of other commercial Phenyl columns, so methods can be readily transferred between columns. The difference in efficiency and pressure drop for the two porous 3  $\mu\text{m}$  columns can be explained by different particle size distributions.

Figures 3-4 show comparisons of five benzodiazepines separated on the four Ascentis Express RP phases in water:acetonitrile and water:methanol mobile phases. No additives were employed in order to observe the interaction between these polar solutes and the different phases; however, a dilute buffer will normally be used for development of a validated method. The addition of 10-20 mM buffer at neutral pH typically has little or no effect upon the separation with these highly deactivated column phases.

Note that overall retention in acetonitrile is similar for the four bonded phases, but elution order is different. The two less polar compounds, diazepam and desmethyldiazepam, elute late and show the same order for all columns due to predominance of hydrophobic interactions. The more polar solutes, however, elute earlier and interact differently with Phenyl-Hexyl and the other phases.

### Reference

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Figure 1. Benzodiazepine Structures

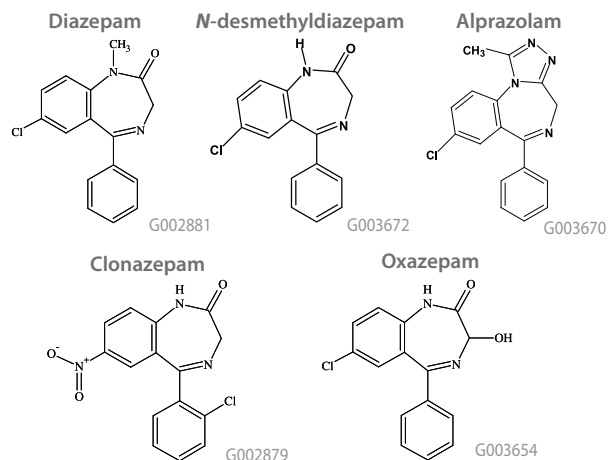
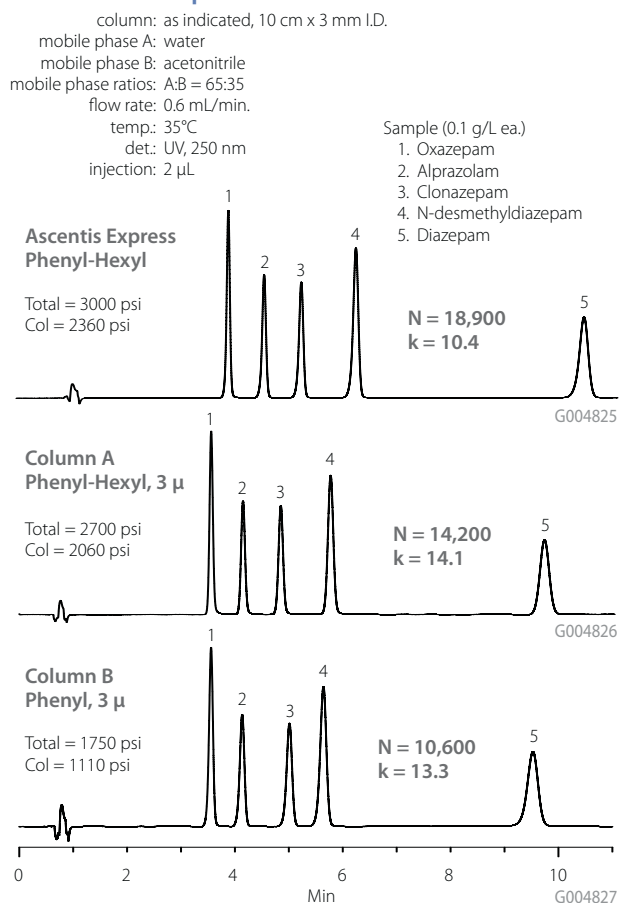


Figure 2. Comparison of Phenyl Column Selectivity for Benzodiazepines

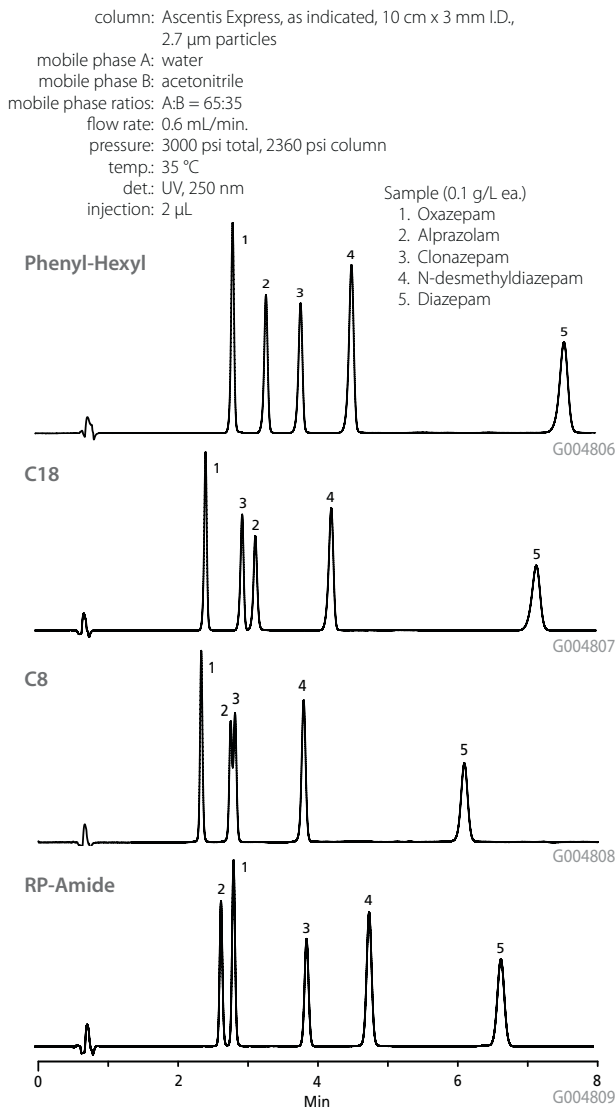




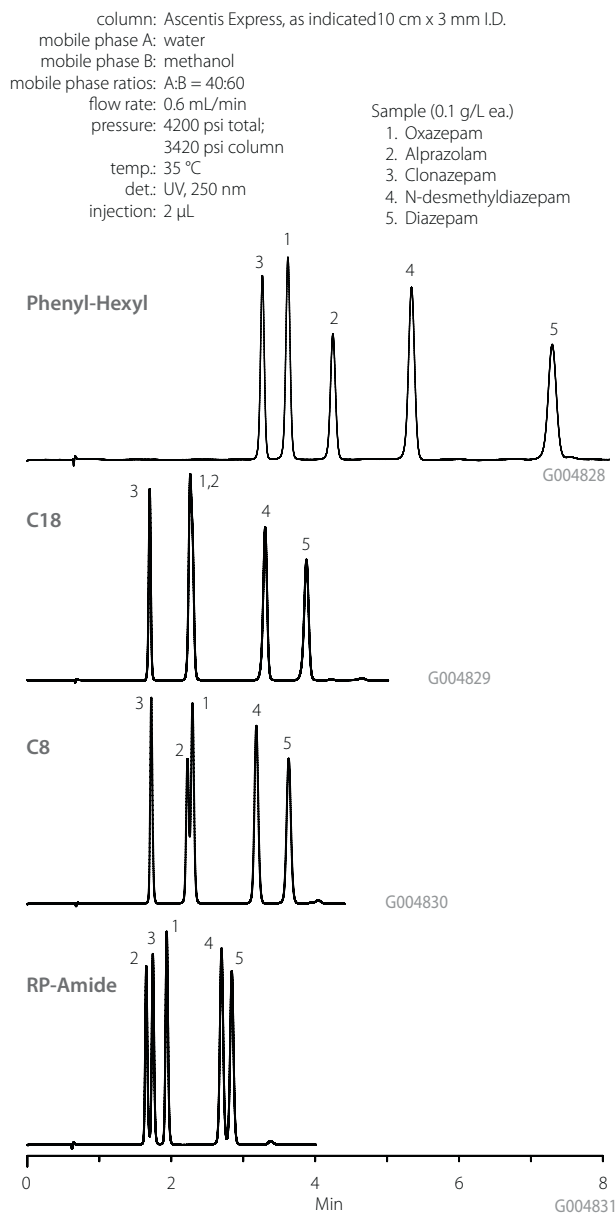
With this test sample and operating conditions, three of the four Ascentis Express RP columns provide good resolution with different selectivity, however, Phenyl-Hexyl shows the best retention and selectivity.

A switch to water:methanol in Figure 4 shows a dramatic change in retention for Ascentis Express Phenyl-Hexyl. In water:methanol mobile phase, the phenyl group interacts much more strongly than the other phases with the solute heterocyclic ring system, presumably by a  $\pi$ - $\pi$  mechanism. Kazakevitch (1) has published evidence that methanol forms only monolayer coverage on aromatic phases (and also thinly solvates other phases), which allows the aromatic selectivity to shine through more strongly. Elution order for the polar compounds also changes from that of water:acetonitrile conditions. For this test sample, Ascentis Express Phenyl-Hexyl selectivity is clearly superior in water:methanol to the other phases.

### Figure 3. Benzodiazepines in 35% Acetonitrile Mobile Phase with no Additive



### Figure 4. Benzodiazepines in 60% Methanol Mobile Phase with no Additive



### Conclusion

A new Phenyl-Hexyl phase has been paired with Fused-Core particles to complete the primary Ascentis Express column family. High performance with lower pressure drop than other UHPLC columns has been confirmed for all Fused-Core particle phases. Ascentis Express Phenyl-Hexyl correlates well to other Phenyl phases for easy method development or method transfer. Selectivity for benzodiazepine compounds has been compared to the other Ascentis Express RP phases in water:acetonitrile and water:methanol. The extra retention possible with Phenyl phases in water:methanol has been demonstrated for these heterocyclic aromatic compounds. The potential for faster, more sensitive assays using Ascentis Express Phenyl-Hexyl and all Ascentis Express phases has been shown.



## Accelerated Bioanalytical LC-MS-MS Using Ascentis Express Fused-Core HPLC Columns

Fast bioanalysis requires the use of short columns packed with high efficiency particles. The use of HPLC columns packed with Fused-Core particles and sub-2  $\mu\text{m}$  porous particles have led the way in these demanding analyses. They significantly enhance resolution and speed by producing either higher efficiency for the same column length or equivalent efficiency with a shorter column length. The use of ultra-high performance liquid chromatography (UHPLC) comes at a price of much higher pressure when sub-2  $\mu\text{m}$  particles are employed. As an attractive alternative, the revolutionary Ascentis Express 2.7  $\mu\text{m}$  Fused-Core silica particle has quickly become accepted because it is equivalent in performance to particles in the sub-2  $\mu\text{m}$  range. With a very narrow particle size distribution, Ascentis Express columns employ conventional 2  $\mu\text{m}$  frits and operate ruggedly at much lower pressures that are within the operating limits of conventional HPLC instruments.

The goal of this work was to demonstrate the ease of converting traditional multi-minute assays on a 50 mm Discovery® C18 column to one-minute assays using 20 mm Ascentis Express columns on an HPLC configured for LC-MS-MS bioanalysis (Agilent 1100/ABI 3200 Q Trap MS-MS). The assay integrity and quality had to be maintained in the conversion. In addition, samples were extracted from plasma based on a published method (1) and analyzed by LC-MS-MS. These extraction conditions are shown in Table 1.

Table 2 shows the compounds, their MS-MS transitions, columns and chromatographic conditions used. The slopes of

each gradient were adjusted to accommodate the 20 and 50 mm column lengths. Flow rates differ because the Discovery C18 5  $\mu\text{m}$  column is typically used at 0.5 mL/min in these analyses while a 1 mL/min flow rate would be more likely used with the Ascentis Express to take advantage of the higher efficiency that can be obtained at this higher flow rate.

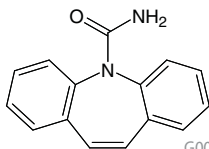
Figure 1a shows the compound mix separated in less than 0.5 minutes on the Ascentis Express HPLC column. Figure 1b shows the separation taking about 2 minutes. Excellent resolution is seen in both bases. Table 3 shows the peak width at half height measurement for both compounds. As expected the Ascentis Express phase shows much narrower peak width, indicating better efficiency for this column, even at the flow rate of 1 mL/min in a 2.1 mm column.

**Table 1. Sample Preparation Procedure (1)**

1. Prepare 5000 ng/mL sample in rat plasma by taking 5  $\mu\text{L}$  of a mix carbamazepine and dehydronifedipine (1mg/mL each in methanol) and spike 1 mL of rat plasma.
2. Vortex 1 min, take 25  $\mu\text{L}$  of plasma and 200  $\mu\text{L}$  of acetonitrile to crash proteins.
3. Centrifuge at 10,000 rpm for 1 minute. Remove 100  $\mu\text{L}$  supernatant and add 200  $\mu\text{L}$  of water. Vortex 1 minute.
4. Inject 2  $\mu\text{L}$ .

**Table 2. Experimental Conditions****1. Compounds Used in this Study:****Dehydronifedipine****Monoisotopic Mass = 344.100836 Da**

MS/MS Transition: 345.1 → 284.2

**Carbamazepine****Monoisotopic Mass = 236.094963 Da**

MS/MS Transition: 237.18 → 194.2

**2. LC-MS-MS Conditions:**

column: Ascentis Express C18, 2 cm x 2.1 mm I.D., 2.7 µm particles (53799-U)

Discovery C18, 5 cm x 2.1 mm I.D., 5 µm particles (50494721)

mobile phase A: 0.1% acetic acid in 95:5 water:acetonitrile

mobile phase B: 0.1% acetic acid in acetonitrile

flow rate: see gradient table below

temp.: 40 °C

det.: ABI 3200 Q Trap MS-MS

injection: 2 µL

sample: carbamazepine, dehydronifedipine

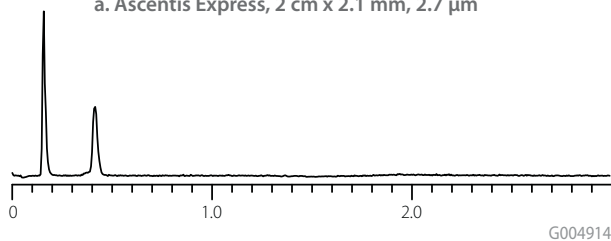
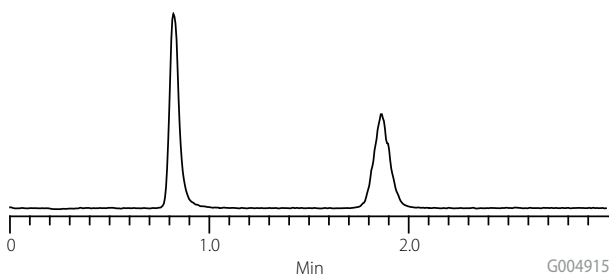
back pressure: both less than 3000 psi

**3. Gradient Tables:**column: Ascentis Express, 2 cm x 2.1 mm, 2.7 µm  
flow rate: 1 mL/min

Min	%A	%B
0.00	70	30
0.75	5	95
0.85	5	95
0.90	70	30
1.00	70	30

column: Discovery C18, 5 cm x 2.1 mm, 5 µm  
flow rate: 0.5 mL/min

Min	%A	%B
0.0	70	30
1.5	5	95
1.7	5	95
1.8	70	30
2.0	70	30

**Figure 1. Chromatographic Comparison of Fused-Core vs. Porous Particles****a. Ascentis Express, 2 cm x 2.1 mm, 2.7 µm****b. Discovery C18, 5 cm x 2.1 mm, 5 µm****Table 3. Peak Width Comparison**

Column	Flow Rate	Peak Width (carbamazepine)	Peak Width (dehydronifedipine)
Ascentis Express C18, 2 cm x 2.1 mm, 2.7 µm	1 mL/min	0.019	0.028
Discovery C18, 5 cm x 2.1 mm, 5 µm	0.5 mL/min	0.049	0.095

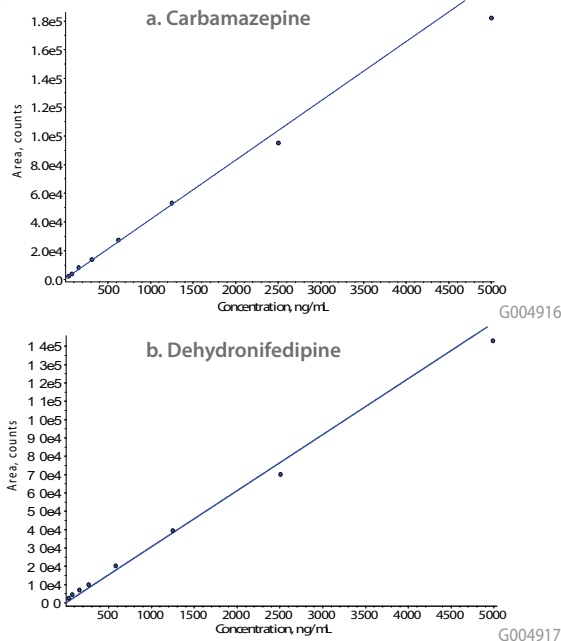
**Figure 2. Calibration Curves**

Figure 2 shows a calibration curve for the dehydronifedipine and carbamazepine. The calibration standards were prepared in plasma and extracted using the method in Table 1. Good linearity was obtained over the range studied. Calibration curves are shown using a linear plot with  $1/x^2$  weighting.

The demands of increased speed and resolution are vital factors to scientists that work in the area of bioanalytical research. In this work presented here, the benefits of short Fused-Core columns have been demonstrated. The integrity and quality of the analysis was maintained in transferring from totally porous to Fused-Core particles, fast gradients were possible using traditional LC pumps and the Ascentis Express columns have been shown to be rugged and provide good results with greater than 2 years of use (1) in these types of bioanalytical assays.

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- Title:** Curcumin Structure-Function, Bioavailability, and Efficacy in Models of Neuroinflammation and Alzheimer's Disease  
**Authors:** Aynun N. Begum, Mychica R. Jones, Giselle P. Lim, Takashi Morihara, Peter Kim, Dennis D. Heath  
**Affiliation:** Dept. of Medicine & Neurology & Psychiatry & Biobehavioral Sciences and the Semel Institute, UCLA, Los Angeles, CA; Greater LA Healthcare System, Geriatric Research Education Clinical Center, Sepulveda, CA; Cancer Prevention & Control Program, Moores UCSD Cancer Center, UCSD, San Diego, CA; Dept. of Post-Genomics & Diseases, Division of Psychiatry & Behavioral Proteomics, Osaka University Graduate School of Medicine, Osaka, Japan  
**Journal:** J Pharmacol Exp Ther., 2008, 196-208
- Title:** Liposome-Encapsulated Curcumin Suppresses Growth of Head and Neck Squamous Cell Carcinoma In vitro and in Xenografts through the Inhibition of Nuclear Factor κB by an AKT-Independent Pathway  
**Authors:** Dorothy Wang, Mysore S. Veena, Kerry Stevenson, Christopher Tang, Baran Ho, Jeffrey D. Suh  
**Affiliation:** Dept. of Surgery & Pathology, VA Greater LA Healthcare System; David Geffen School of Medicine, UCLA, Los Angeles, CA; Dept of Psychiatry & Biobehavioral Science, Semel Institute, UCLA, Los Angeles, CA; Dept. of Experimental Therapeutics, MD Anderson Cancer Center, University of Texas, Houston, TX  
**Journal:** Clinical Cancer Research, 2008
- Title:** Analysis of Impurities in Streptomycin and Dihydrostreptomycin by Hydrophilic Interaction Chromatography/Electrospray Ionization Quadrupole Ion Trap/Time-of-Flight Mass Spectrometry  
**Authors:** Shin-ichi Kawano  
**Affiliation:** Analytical Applications Dept., Shimadzu Corp., Kyoto, Japan  
**Journal:** Rapid Communications in Mass. Spectrometry, 2009, 907-914
- Title:** Determination of Fatty Alcohol Ethoxylates by Derivatization with Phthalic Anhydride followed by Liquid Chromatography with UV-vis Detection  
**Authors:** G. Ramis-Ramos, A. Micó-Tormos, E. F. Simó-Alfonso  
**Affiliation:** Dept de Química Analítica, Universitat de València, Valencia, Spain  
**Journal:** Journal of Chromatography A, 2009, 47-53
- Title:** Highly Efficient Peptide Separations in Proteomics: Part 1. Unidimensional High Performance Liquid Chromatography  
**Authors:** Koen Sandra, Mahan Moshir, Filip D'hondt, Katleen Verleysen, Koen Kas, Pat Sandra  
**Affiliation:** Dept. of Chemical Engineering, Vrije Universiteit Brussel, Brussels, Belgium  
**Journal:** Journal of Chromatography B, 2008, 48-63
- Title:** Multidimensional LCxLC analysis of Phenolic and Flavone Natural Antioxidants with UV-electrochemical coulometric and MS Detection  
**Authors:** Tomáš Hájek, Veronika Škerková, Petr Česla, Katerina Vynuchalova, Pavel Jandera  
**Affiliation:** Dept of Analytical Chemistry, University of Pardubice, Pardubice, Czech Republic  
**Journal:** Journal of Separation Science, 2008, 3309-3328
- Title:** Separation of Natural Product using columns packed with Fused-Core Particles  
**Authors:** P. Yang, G.R. Litwinski, M. Pursch, T. McCabe, K. Kuppanan  
**Affiliation:** The Dow Chemical Company, Analytical Sciences, Midland, MI  
**Journal:** J. Sep Sci., 2009, 1816-1822





# Ascentis Express Peptide ES-C18 Expands into Bioseparations

## Introduction

Ascentis Express Peptide ES-C18 columns were specifically engineered to separate higher molecular weight compounds such as peptides and small proteins. These columns contain advanced Fused-Core particles that have bigger pores (160 Å versus 90 Å in standard Ascentis Express), which greatly expands the application range for Ascentis Express columns.

## Key Applications for Ascentis Express Peptide ES-C18:

- Pharmaceutical/therapeutic peptides
- Peptide mapping
- Natural and synthetic peptide analysis
- Oligonucleotide analysis

## Key Advantages:

- Higher peak capacity providing greater resolution
- Amenable to higher flow rates for faster analysis
- Exceptional ruggedness providing long column lifetime

Ascentis Express Peptide ES-C18 columns utilize a steric-protected C18 bonded-phase with extremely high resistance to acid-catalyzed hydrolysis of the siloxane bond that attaches the C18 chain to the surface. Thus, the combination of low pH and elevated temperature operation of the column is well tolerated. Peptide separations are efficiently conducted using low pH mobile phase modifiers, often at 0.01-0.1% concentration, most popularly employing trifluoroacetic acid (TFA), and the related perfluorocarboxylic acids, pentafluoropropionic acid (PFPA) and heptafluorobutyric acid (HFBA). These acids exhibit desirable low UV transparency, volatility, and peptide ion-pairing properties. Additional opportunities for low pH operation include the normal short chain carboxylic acids, formic acid and acetic acid, as well as mineral acids, such as phosphoric acid (0.001-0.02 M).

Shown in Figure 1 is the chromatographic separation of a peptide mix. The peptide mix contains a range of peptides in terms of molecular weight, basicity, and hydrophobicity. Excellent peak shape and peak width are achieved with a standard acetonitrile gradient and 0.1% TFA modifier. The

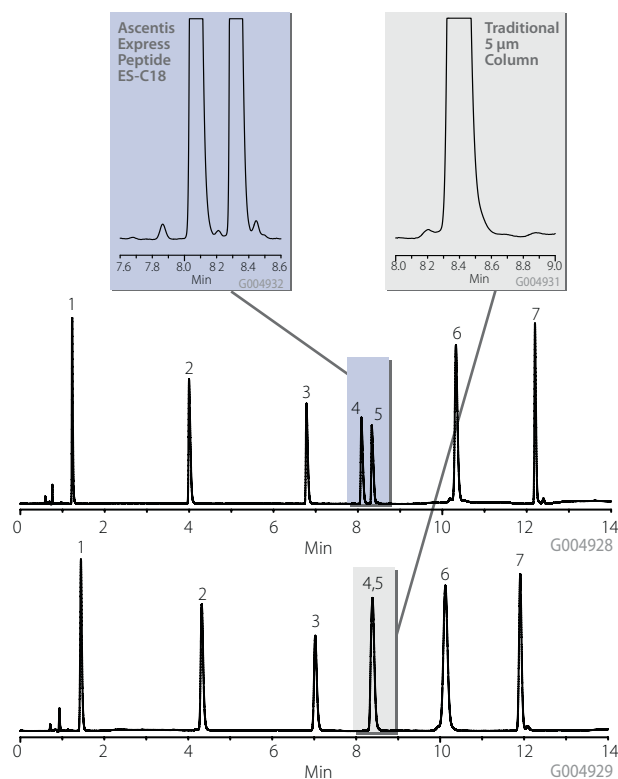
resolution of small baseline impurities are shown in the inset, demonstrating the resolving power of the Ascentis Express Peptide ES-C18 column versus a traditional 5 µm column.

**Figure 1. Comparison of Peptide Test Mix with Ascentis Express Peptide ES-C18 and Traditional Column**

column: Ascentis Express Peptide ES-C18, 10 cm x 4.6 mm I.D. (53324-U)  
mobile phase A: 10% acetonitrile / 90% water / 0.1% trifluoroacetic acid  
mobile phase B: 75% acetonitrile / 25% water / 0.1% trifluoroacetic acid  
gradient: 0% to 50% B in 15 min  
flow rate: 1.5 mL/min.  
det: UV at 220 nm  
temp: 30 °C  
injection: 5 µL

### Peptide Test Mix

1. Gly-Tyr	MW = 252
2. Val-Tyr-Val	MW = 379
3. Met Enkephalin	MW = 574
4. Angiotensin II	MW = 1032
5. Leu-Enkephalin	MW = 555.62
6. Ribonuclease	MW = 13,700
7. Bovine Insulin	MW = 5733





P001390

# Rapid, Sensitive, General-Purpose Cleaning Validation Using Ascentis Express HPLC Columns



## Contributed Article

The following was generated by an outside source using Sigma-Aldrich products. Technical content provided by:

**S. Bannister, M. Talbott, F. Hanciles**  
Xcelience LLC, Tampa, FL

Verification of the removal of drug residue from multi-product manufacturing equipment is required by GMP regulations and the suitability of applied analytical methods is judged with a combination of sensitivity, selectivity, and because the release of equipment is dependent - speed. The FDA does not set quantitative acceptance specifications, but the commonly used limit is based on not more than 0.1% of a dose carried over into a single dose of the next product. Translation of this into an analytical limit combines the total product contact area, the mass (or volume) of product contacting the surface, the mass (or volume) of each dose unit, the sampled area, the rinse volume and the fraction of the rinse sample used for analysis. The requisite limits are commonly measured in ng/mL of injected sample.

The ubiquity of HPLC in drug analysis makes it an attractive choice for cleaning validation. Methods qualified for cleaning validation are often adaptations of drug-substance methods. The original methods are capable of determining the drug and its related impurities, but the ability to simultaneously measure multiple closely related analytes comes at the expense of run time and is not needed in cleaning validation.

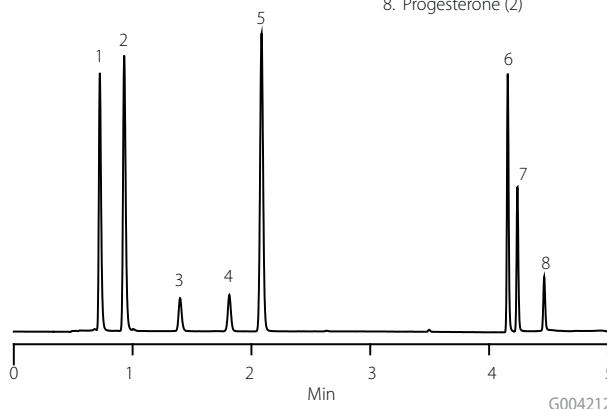
This work was undertaken to investigate the use of rapid gradients using recently introduced FCP columns on conventional instrumentation in the development of general-purpose methods for cleaning validation. The benefits include high sensitivity and reductions in the time needed to set up and run the method.

**Figure 1. Acidic and Neutral Drug Panel**

column: Ascentis Express C18, 10 cm x 4.6 mm I.D. (53827-U)  
mobile phase A: water with 0.1% phosphoric acid  
mobile phase B: acetonitrile with 0.1% phosphoric acid  
temp: ambient

flow rate: 1.76 mL/min  
det: UV at 215 nm  
inj: 100 µL  
gradient: Min %A %B  
0 70 30  
2 60 40  
4 5 95

1. Hydrochlorothiazide (9)
2. Chlorthalidone (2)
3. Prednisolone (2)
4. Pravastatin (4)
5. Carbamazepine (2)
6. Diclofenac (14)
7. Ibuprofen (15)
8. Progesterone (2)



G004212

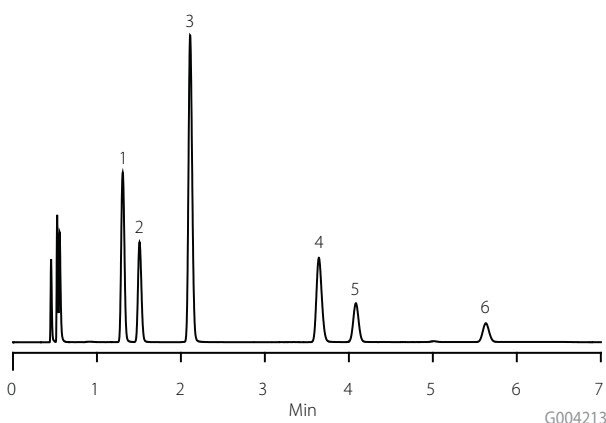




**Figure 2. Basic Drug Panel**

column: Ascentis Express C18, 10 cm x 4.6 mm I.D. (53827-U)  
mobile phase A: water with 0.05M potassium phosphate and 0.1% TEA  
and 0.6% OSA-Na at pH = 2.9  
mobile phase B: acetonitrile  
temp.: ambient  
flow rate: 1.76 mL/min  
det.: UV at 215 nm  
inj.: 100 µL  
gradient: Min %A %B  
0 63 37  
5 59 41

1. Quinidine (5)
2. Dipyridamole (29)
3. Propranolol (12)
4. Haloperidol (8)
5. Amlodipine (29)
6. Fluoxetine (3)



Resolution, limits of detection and quantitation, and run time in HPLC analyses are improved by reducing the width of eluted bands. Contributions to bandwidth include both column (particle size, packing structure and resistance to mass transfer in the stationary and mobile phases) and extracolumn volumes (injection, unswept and tubing). Columns packed with 5 µm fully porous particles have been the standard for conventional HPLC for twenty-five years. Smaller-particle packings (3 µm) have been available almost as long and offer on conventional instrumentation, but require higher pumping pressures due to lower bed permeability. Efficiency can be further increased by the use of particles smaller than 3 µm but only with the use of instrumentation optimized with respect to both pressure and extra-column effects.

Supelco has recently introduced reversed-phase packings based on 2.7 µm silica particles in which a 0.5 µm layer of 90-Å porous silica has been deposited onto a 1.7 µm solid spherical core. Advantages of columns packed with these particles include high efficiency, lower backpressure due to a very narrow particle size distribution, and smaller efficiency losses with increasing velocity due to improved mass-transfer kinetics in the shallow porous layer. The narrow particle size distribution allows the use of larger pore column frits, which combined with the greater stability of the packed bed should produce longer column lifetimes in routine use.

The high resolving power of gradient elution in the analysis of closely related substances is the result of the reduction of peak width as a band moves through the column. The back of the band is accelerated by the stronger solvent. A broad gradient will elute a wide range of substances and a steep gradient will elute them quickly.

### Versatile Separations

To judge the utility of Ascentis Express columns in cleaning validation, an Agilent 1100 component system with standard components (including a 10 mm/13 µL flow cell) was used to develop a short gradient separation using Ascentis Express C18, 10 cm x 4.6 mm for each of two panels: eight acidic or neutral drugs (AN) and six basic drugs (B). For each separation, the flow rate was 1.76 mL/min, detection was at 215 nm, and 100 µL injections were made of aqueous solutions representing the final equipment rinse. The separations are shown in Figures 1 & 2. Limits of detection (ng/mL) are listed next to each analyte in Figures 1 and 2.

These separations demonstrate the capabilities of Ascentis Express columns on conventional, robust, instrumentation in rapid analyses of multiple drugs at low ppb levels suitable for development as methods for cleaning validations in multiproduct manufacturing facilities.

### Selecting the Right Buffer

A partial list of common buffers and their corresponding useful pH range is supplied. Perhaps the most common buffer in HPLC is the phosphate ion. Although, with the growth of LC-MS, volatile buffers such as TFA, acetate, formate, and ammonia are becoming more frequently used. Remember, the purpose of a buffer in the mobile phase is to inhibit a pH change in the mobile phase after the introduction of a sample. When developing a method, it is important to select a mobile phase with a final pH at least one pH unit away from any analytes pK value. As a

rule of thumb, one should work within a ±1 pH unit of the buffer pKa. Typical buffer concentrations for HPLC tend to be 10-100 millimolar level.

Buffer	pKa @ 25 °C	Useful pH Range
Trifluoroacetic acid (TFA)	0.5	<1.5
Phosphate 1	2.1	1.1 - 3.1
Formate	3.8	2.8 - 4.8
Acetate	4.8	3.8 - 5.8
Phosphate 2	7.2	6.2 - 8.2
Ammonia	9.2	8.2 - 10.2
Phosphate 3	12.3	11.3 - 13.3





7

## Improving the Current USP Method for the Analysis of Lansoprazole Drug Substance Using Ascentis Express HPLC Columns



### Contributed Article

The following was generated by an outside source using Sigma-Aldrich products. Technical content provided by:

**Kai Li, Jiajie He, and Xiaoya Ding**  
PPD - 8551 Research Way, Suite 90, Middleton, WI 53562

### Introduction

Compendial methods from the USP (United States Pharmacopeia) are widely used in pharmaceutical drug product and raw materials testing. However, not all methods in the USP use modern technologies. In chromatographic methods, it is not uncommon that older brands of columns are specified. Therefore, the USP methods are under continuous revision to improve existing procedures or to allow the user to obtain better results.

*Due to the improved resolving power of Fused-Core particles, the method was optimized with a shorter runtime without sacrificing resolution.*

In an effort to improve the compliance of drug product, drug substance, and excipient monographs with current scientific/regulatory standards, USP is seeking the submission of proposals for improved methods. The intent is to replace the

current procedures that may be deficient, flawed, or unsafe (e.g. <http://www.usp.org/USPNF/submitMonograph/improve-Mon.html>). Requests for revision of an existing monograph are encouraged by USP in light of advances in analytical technologies. Furthermore, ease of operation, suitability for automation, and potential for high-throughput analysis can be considered in a revision. To develop the best possible analytical test method for its intended use, a fully integrated method development process such as the selection of column, mobile phase, detection technology, and LC hardware by utilizing the most advanced technologies viable should be considered to ensure the methods are robust, consistent, and easy to use.

In this study, the USP method for lansoprazole was considered for improvement. Several drawbacks in the current USP monograph for lansoprazole prompted the investigation. These drawbacks include sample solution instability, use of different columns and samples preparations for the evaluation of assay and impurity, the requirement of using internal standard for assay and a long HPLC runtime (60 min). A new HPLC column, Ascentis Express C18, based on Fused-Core particle technology was investigated for this study. The Ascentis Express HPLC column claims high efficiencies as a result of a 0.5  $\mu\text{m}$  layer of porous silica on a 1.7  $\mu\text{m}$  solid silica core. An additional advantage to the column is that standard HPLC instrumentation can be used as opposed to UHPLC that is required for sub-2  $\mu\text{m}$  columns.



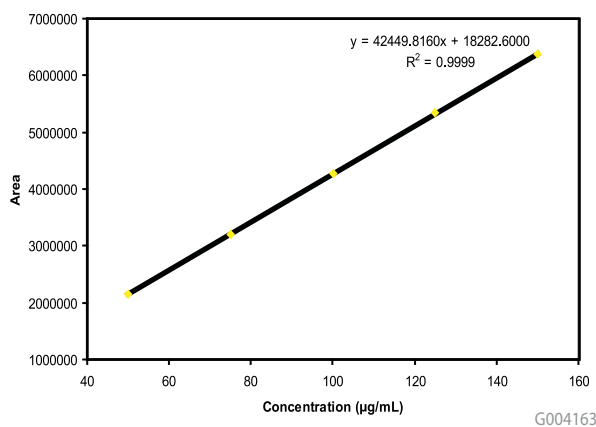
## Results and Discussion

Initially, a traditional 5  $\mu\text{m}$  C18 column as specified in the USP monograph was compared to the 2.7  $\mu\text{m}$  Ascentis Express C18 using the standard USP conditions for chromatographic purity for lansoprazole (1, 2). Improved resolution and sensitivity were obtained using the Fused-Core column that allowed us to make several significant improvements to the

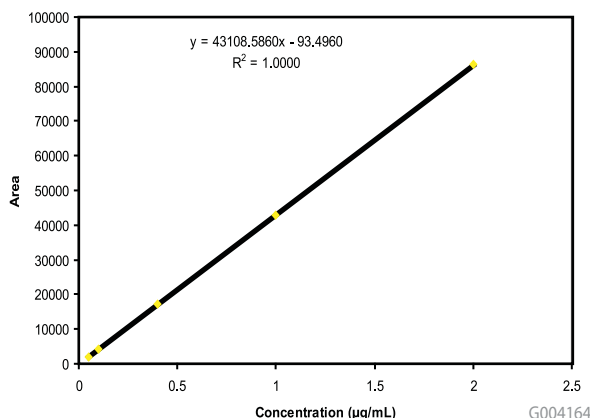
**Table 1. Method Parameters for Improved Lansoprazole Method**

column:	Ascentis Express C18, 15 cm x 4.6 mm, 2.7 $\mu\text{m}$ (53829-U)
mobile phase A:	Water
mobile phase B:	Acetonitrile: 0.5% Triethylamine in Water, pH=7.0 [80:20]
flow rate:	0.8 mL/minute
column temp.:	Ambient
autosampler Temp.:	5 $^{\circ}\text{C}$
injector volume:	15 $\mu\text{L}$
detector wavelength:	285 nm
run time:	40 min
gradient:	Time (Min) %A %B
	0.0 90 10
	30.0 20 80
	35.0 20 80
	35.1 90 10
	40.0 90 10

**Figure 1. Linearity Curve from 50 to 150% Nominal Concentration**

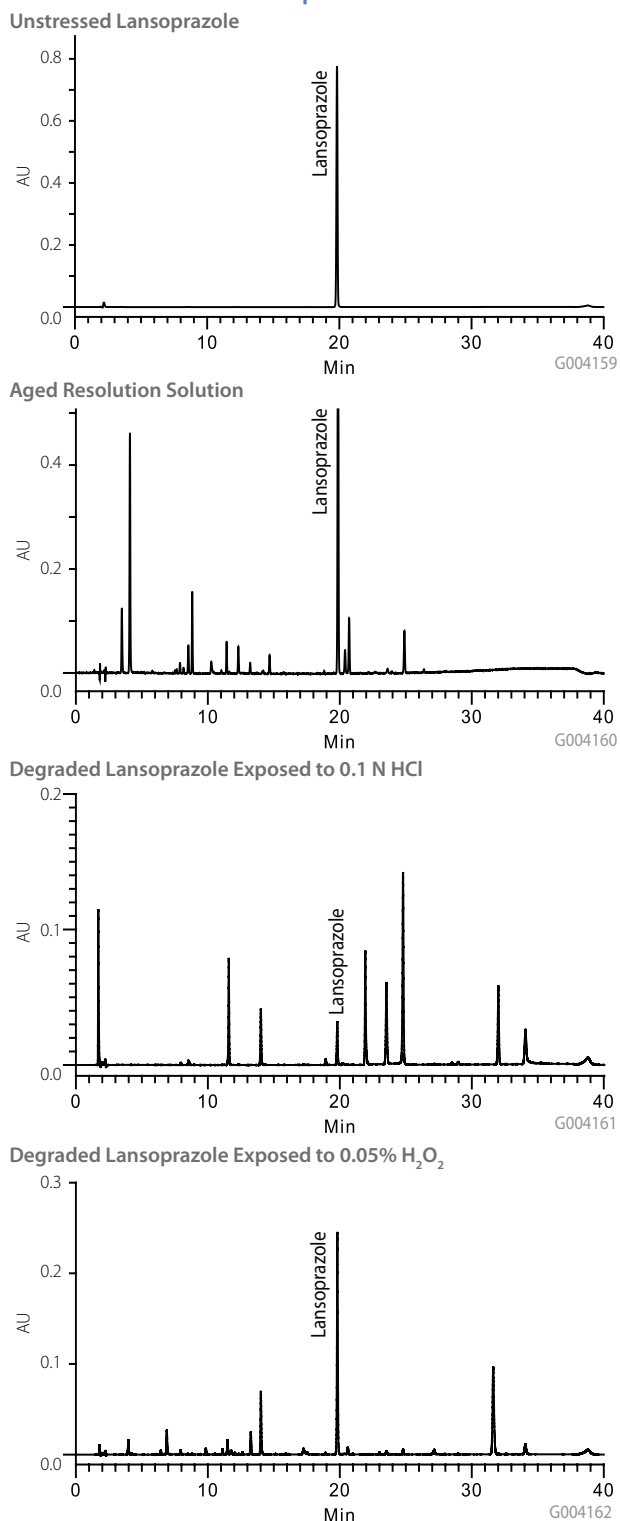


**Figure 2. Linearity Curve from 0.05 to 2.0% Nominal Concentration**



method. Due to the improved resolving power of Fused-Core particles, the method was optimized with a shorter runtime without sacrificing resolution. The total run time was reduced from 60 min to 40 min (Table 1). Moreover, the improved sensitivity allowed for the reduction in concentration of the test sample for chromatographic purity from 250 mg/mL to

**Figure 3. Analysis of Lansoprazole Using Improved Method with Ascentis Express C18 HPLC Column**



100 mg/mL, the level required for assay in the USP monograph. Therefore, simultaneous evaluation of assay and chromatographic purity is achieved. Finally, a change of diluent pH, was implemented to improve sample solution stability removing the requirement of injecting sample within 10 minutes after preparation.

The new method was shown to be linear from 0.05% to 150% of nominal concentration of 100 mg/mL, with quantitation limit less than 0.05%. The broad range of linearity allows for simultaneous impurity and assay analysis. The linearity data are shown in Figures 1 and 2. The RSD of 5 replicate injections of standard solution was 0.11%. In additional experiments, the method was evaluated by analysis of degraded lansoprazole drug substance. Lansoprazole was stressed under four separate conditions by exposure to acid, base, heat and hydrogen peroxide. The chromatograms of the acid and peroxide exposed drug substance along with the unstressed drug substance are shown for reference. The resolving power of the Ascentis Express HPLC column makes it very suitable for these types of studies.

## Conclusion

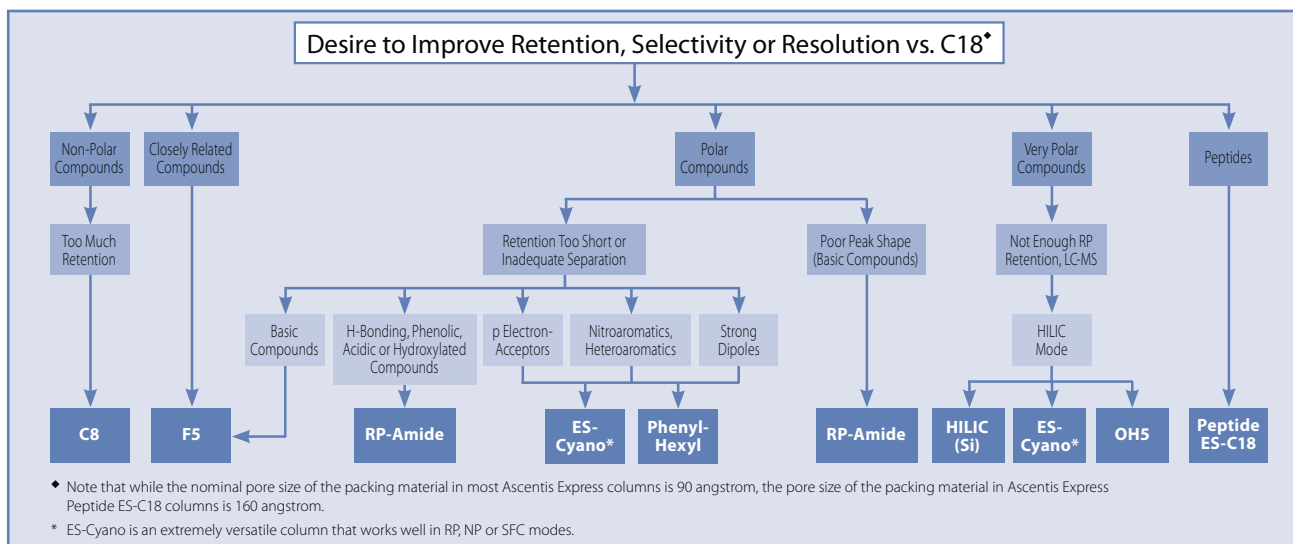
The method developed using 2.7  $\mu\text{m}$  Fused-Core C18 column provided significant improvements in comparison with the original USP method in terms of resolution, run time and sensitivity. As a result, the consolidated single method can be used for both assay and impurity quantitation. The advantages of Fused-Core columns as an alternative for sub-2  $\mu\text{m}$  columns without using new UHPLC instruments could be appealing for pharmaceutical testing. Furthermore, this paper has presented one of the ways (a road map) that could be utilized by analytical scientists in the pharmaceutical field to improve USP monographs for their intended purposes using modern analytical technologies.

## References

1. USP Monograph: Lansoprazole, USP 30-NF 25 through second supplement.
2. Pharmacopeial Forum, In-Process Revision, Lansoprazole, Vol. 32(6), 1710-1712 (2006).

## Selecting an Ascentis Express Phase

Ascentis Express C18 is the first choice for starting a new method. However, when a C18 doesn't give the desired separation or your sample contains compounds that are known to be difficult to retain or resolve on a C18, consider changing stationary phases. The range of selectivity provided by Ascentis Express makes this easy. The flow chart below helps guide in the selection of an Ascentis Express phase, based on the particular compound type or separation challenge.



## Guidelines for Preparing Mobile Phases

It should be understood that slight variations in pH and buffer concentration could have a dramatic affect on the chromatographic process; consistent and specific techniques should be a regular practice in the preparation of mobile phases. A common practice is to place a sufficient amount of pure water into a volumetric flask and add an accurate amount of buffer. The pH of the solution should be adjusted,

if necessary, and then dilute to final volume of water prior to adding or blending of organic solvents. Then, add a volumetrically measured amount of organic solvent to obtain the final mobile phase. Thorough blending, degassing, and filtering prior to use is also recommended.

To view a listing of suitable HPLC and LC-MS additives and solvents, visit [sigma-aldrich.com/lc-ms-solvents](http://sigma-aldrich.com/lc-ms-solvents)



## Profiling of *Stevia rebaudiana* Extract by Accurate Mass Using HILIC and Reversed-Phase Chromatography

### Introduction

There is growing public interest in low-calorie alternatives to carbohydrate-based sweeteners. Synthetic sweeteners are often regarded as having an undesirable aftertaste. Recent publications have shown a dramatic increase in attention toward natural extracts including the *Stevia rebaudiana* plant, not only for its sweetening effect but also for additional health benefits attributed to the plant. The major sweetening components are stevioside, rebaudioside A, rebaudioside C, and dulcoside A, each of which is over 300 times sweeter than sucrose-based sweeteners. The concern with the human consumption of the stevia leaf had been attributed to the possible mutagenic properties of steviol, but more recent studies conducted by the World Health Organization have established the safety for steviol and its glycosides.

In this study, an evaluation of the *Stevia rebaudiana* plant extract was conducted using modern chromatographic and mass spectrometry techniques for the determination of extracted components. The purpose was to evaluate the utility of performing two different modes of chromatographic separation for component identification. An accurate mass time of flight (TOF) mass spectrometer was used in the detection and identification of components. A novel software package was then utilized for the determination of common components between the two chromatographic modes and to depict the impact of chromatographic selectivity.

The concept behind the study was to utilize both reversed-phase chromatography and HILIC chromatography for the determination of extract components. By using two different modes of selectivity, components that co-retain, do not retain, or do not elute under one chromatographic mode may be resolved under a separate mode. By resolving a component chromatographically, a more accurate assessment of the component can be made without relying specifically on accurate mass data.

In particular, HILIC chromatography allows for alternative selectivity by utilizing a highly polar stationary phase with a relatively non polar mobile phase. Under HILIC conditions, the partitioning of analytes is achieved through a preferential solvation of an aqueous environment on the polar surface. More polar analytes will partition more into the surface solvent and thus be retained longer than a less polar analyte. In addition to the partitioning, the polar surface of the stationary phase allows for adsorptive interactions via hydrogen bonding, dipole, etc. When ionic samples are separated, the potential for ion-exchange interactions also exists and in many cases becomes the dominant retention mechanism. Using silica-based stationary phases, ionized surface silanol groups may interact via ion-exchange with positively charged analytes.



## Experimental

In this study, both reversed-phase and HILIC separations were conducted using the Ascentis® Express RP-Amide and Ascentis Express HILIC. The polar embedded group of the Amide was chosen over traditional C18 phases to increase the retention of the polar analytes in the stevia extract. The Ascentis HILIC allowed for alternative selectivities for polar analytes. Because of the large amount of unknown components in the stevia extract, using both reversed-phase and HILIC modes enabled orthogonal selectivity to resolve co-retained components and enable better determination of components in the extract with confirmation between the two modes.

Stevia leaves were obtained from Sigma Aldrich (S5381). Sample extraction of the stevia leaves was performed by weighing 400 mg of crushed stevia leaves into a 7 mL amber vial. A total of 4 mL of 50:50 acetonitrile:water was added and the sample was vortexed and sonicated for 3 minutes. The sample was then centrifuged for 2 minutes at 15000 rpm. The supernatant was then collected and analyzed directly.

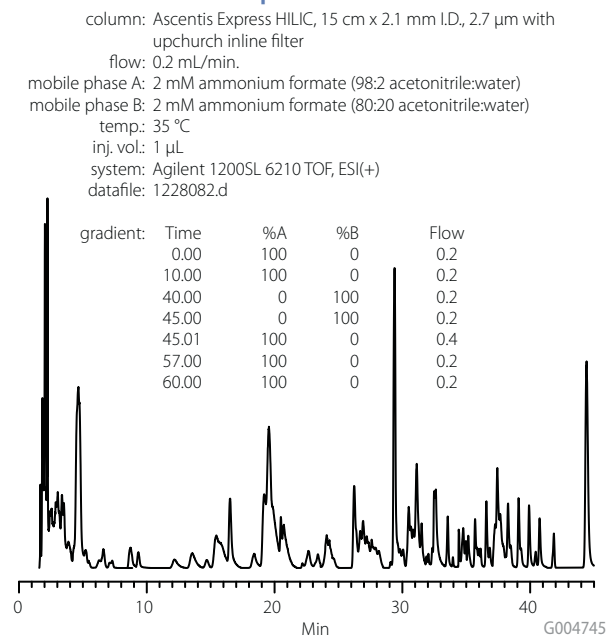
The sample extract was analyzed using a gradient elution profile for both HILIC and reversed-phase chromatographic modes. Analysis was conducted using an Agilent® 1200SL Rapid Resolution system in sequence with an Agilent 6210 TOF mass spectrometer. The TOF enabled the use of accurate mass for determination of components. The acquired data was processed using the Mass Hunter software package. The data was pushed to the Mass Profiler package for statistical comparison of the two chromatographic modes. This software package enabled the identification of common components between the two

chromatographic separations of the stevia extract. By performing this type of statistical comparison, the components attributed to the stevia extract were differentiated from components attributed to chromatographic anomalies. From this comparison the major components of the stevia extract were determined. Available standards were then used to confirm the identification of several of the components.

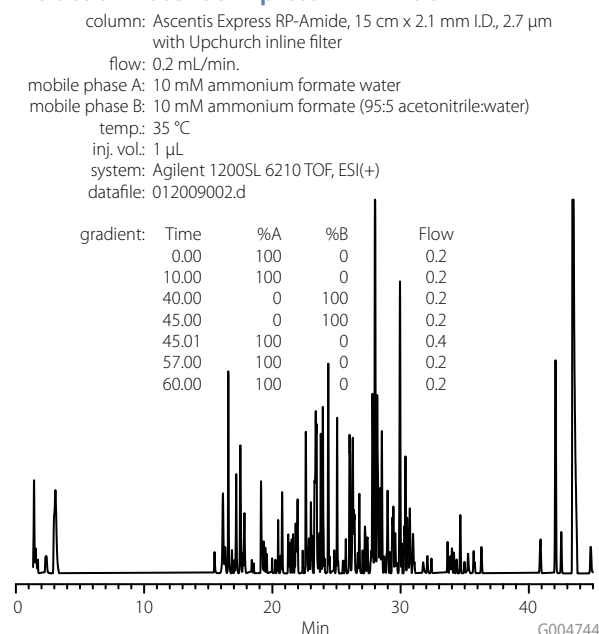
## Results and Discussion

Figure 1 and Figure 2 represent the total ion chromatogram for the stevia extract under both HILIC and reversed-phase conditions. Both of these chromatographic separations demonstrate the complexity of the stevia extract. Table 1 depicts the major components that were common in both the reversed-phase and HILIC separations of the stevia extract. More than 250 components were identified with this comparison, but only the major components were targeted in this study. The highlighted components in Table 1 depict co-retention of analytes under reversed-phase conditions. A good example of using this orthogonal approach is observed in the case of steviobioside and ducloside A. Under the reversed-phase separation, these components were co-retained. By performing the separation under HILIC conditions, steviobioside and ducloside A were well separated. Other unidentified major components that were unresolved under the reversed-phase conditions were also separated under the HILIC conditions. The data in Table 1 also depicts the selectivity difference between the two chromatographic modes. Polar components that were poorly retained in the reversed-phase conditions were strongly

**Figure 1. Component Chromatogram of Stevia Extract on Ascentis Express HILIC**



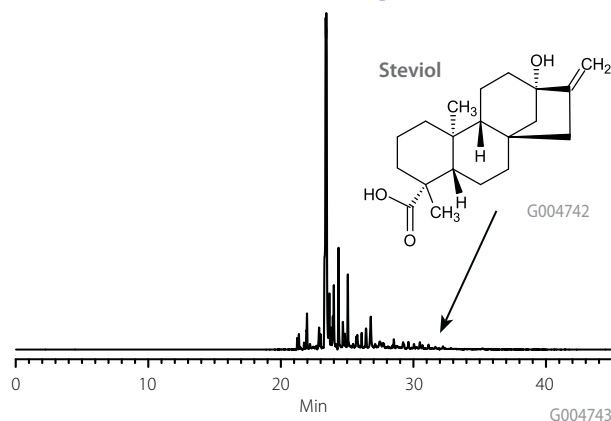
**Figure 2. Component Chromatogram of Stevia Extract on Ascentis Express RP-Amide**



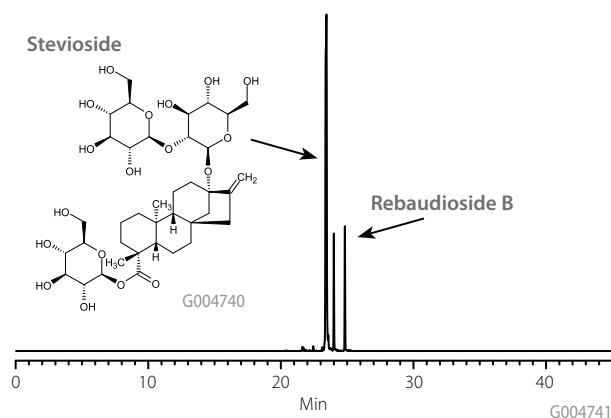
**Table 1. Major Component Retention Comparison Between HILIC and Reversed-Phase Modes**

Component	Accurate Mass	Ascentis Express HILIC	Ascentis Express RP-Amide
		RT	RT
	137.0476	44.397	1.429
	120.0574	34.695	3.075
	102.0473	29.394	3.077
	368.1698	18.414	15.502
	120.0574	31.082	17.166
	402.1518	15.471	17.196
	162.1405	8.727	19.128
	378.2242	8.736	19.13
Rebaudioside A/E	966.4281	34.439	21.755
	516.1254	20.784	23.016
	498.1154	20.714	23.016
Stevioside	804.3743	26.52	23.63
Steviolbioside	642.3234	19.213	24.356
Dulcoside A	788.3817	26.247	24.475
	338.2448	2.248	25.737
	176.1555	2.049	26.026
	284.2134	3.372	26.028
	246.1977	3.359	26.06
	380.255	2.002	26.672
	284.2131	2.811	27.881
	360.083	1.867	28.187
	444.2002	1.825	30.391
Steviol	318.2186	1.91	32.19
	592.2655	2.239	42.539

**Figure 3. Stevia Extract on Ascentis Express RP-Amide, Extracted Ion Chromatogram for Steviol**



**Figure 4. Stevia Extract on Ascentis Express RP-Amide, Extracted Ion Chromatogram for Stevioside**



retained under HILIC conditions. In two cases, where known components were identified, it was necessary to use standards to confirm their retention. Figures 3 and 4 depict the extracted ion chromatogram for the accurate mass of steviol and stevioside. As can be seen in both chromatograms, multiple peaks are observed for each of the accurate masses. In the case of stevioside, it is isobaric with rebaudioside B making identification difficult. A stevioside standard (Sigma Aldrich) was used for positive identification. In addition, the reversed-phase separation of the extract resulted in multiple peaks observed for the accurate mass of steviol. This was due to fragments from additional glycosides that resulted in a steviol fragment ion, again it was necessary to confirm the steviol retention with a standard.

## Conclusions

The profiling of the *Stevia rebaudiana* extract demonstrates the utility of performing orthogonal chromatographic modes when handling complex samples. The two modes of chromatography were complimentary for the determination of major components from the stevia extract. In most cases where coelution occurred in one chromatographic mode, the components were separated under the orthogonal mode. Though component identification was made easier through the accurate mass of the TOF, it was still necessary to have good chromatographic resolution to confirm component identity. In both cases, the Fused-Core™ particle demonstrated the ability to perform complex matrix analysis in both HILIC and reversed-phase separations.



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- Ultra-high Performance using Fused-Core HPLC Columns
- The Use of Alternate Selectivity in Reversed-Phase HPLC
- Introduction to Ascentis HPLC Columns
- HPLC Instrument Bandwidth and Optimizing Systems for High-Performance
- High-Performance HPLC Fittings and Interconnects

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## Colors of the World: Fast Separation of Dyes with Ascentis Express

Dyes surround us everywhere every day. They can be found in common places like the printing ink in magazines or books and in plastics, textiles, and leather, but also in unusual places like diesel fuel and tattoo color. Most of these synthetic colors are based on aromatic ring structures containing heteroatoms and tend to have a high potential for causing cancer; as a result, they are not intended for use in food coloring. But since 2003, there have been several incidents of Sudan I contamination in chili powder. This situation necessitates the analysis of spice mixtures to determine if they have been adulterated (1, 2).

Further, a sensitive HPLC method is needed for quality control testing of dyes and the identification of byproducts. Supelco's Ascentis Express HPLC columns provide outstanding sensitivity and resolution for such applications.

### Method Development for Dyes

Table 1 contains a list of dyes added to one sample and dissolved in a mixture of methanol and acetonitrile. The sample was injected on an Ascentis Express C8 HPLC column under varying mobile phase conditions to determine the best separation.

**Table 1. Structure and Mass of the Dyes in the Sample Mixture. Most of the Compounds are Detected as [M+H]<sup>+</sup> Ions except (5), which gives [M]<sup>+</sup> Ions**

Peak No.	Structure	Name / Exact Mass	Peak No.	Structure	Name / Exact Mass
1	G004779 	<b>Parafuchsin</b> C <sub>19</sub> H <sub>17</sub> N <sub>3</sub> 287.142247	5	G004783 	<b>Malachite Green</b> C <sub>23</sub> H <sub>25</sub> N <sub>2</sub> 329.201773
2	G004780 	<b>Basic Fuchsin</b> C <sub>20</sub> H <sub>19</sub> N <sub>3</sub> 301.157897	6	G004784 	<b>Sudan III</b> C <sub>22</sub> H <sub>16</sub> N <sub>4</sub> O 352.132411
3	G004781 	<b>Methylfuchsin</b> C <sub>21</sub> H <sub>21</sub> N <sub>3</sub> 315.173547	7	G004785 	<b>Sudan 410</b> C <sub>26</sub> H <sub>24</sub> N <sub>4</sub> O 408.195011
4	G004782 	<b>Newfuchsin</b> C <sub>22</sub> H <sub>23</sub> N <sub>3</sub> 329.189197			

**Table 2. Initial and Final HPLC Method Settings for Separation of the Seven Dyes Listed in Table 1, After Optimization****Fixed Parameters**

column: Ascentis Express C8, 10 cm × 4.6 mm I.D., 2.7 μm particles  
flow rate: 0.8 mL/min  
temp: 55 °C  
UV DAD: 200–950 nm  
MS: ESI(+), SPS target 500 m/z, stability 100%, trap lvl. 100%, optimize normal, range 100–1500 m/z, nebulizer 50 psi, dry gas 12 L/min, dry temp. 365 °C.  
injection volume: 3 μL  
run time: 25 min (5 min posttime)

**Variable Parameters****Initial Conditions**

solvents: (A) water with 0.1% formic acid  
(B) acetonitrile

gradients:	Time	%A	%B
	0.0	75	25%
	1.5	75	25%
	15.0	0	100%
	22.0	0	100%
	25.0	75	25%

**Final Conditions**

(A) water with 0.1% formic acid  
(B) acetonitrile:methanol (90:10)

Time	%A	%B
0.0	75	25%
1.5	75	25%
15.0	2	98%
22.0	2	98%
25.0	75	25%

tion parameters. Temperature, injection volume, detector settings, and flow rate were kept constant.

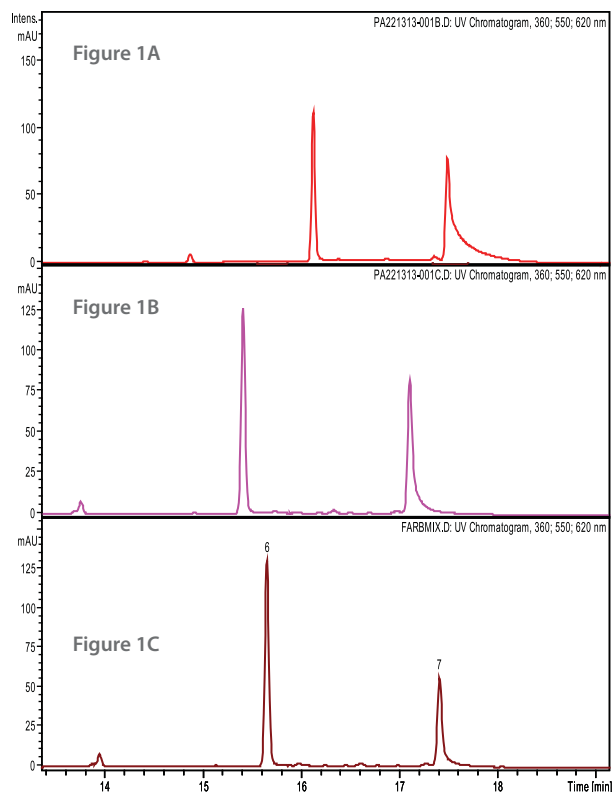
The chemical and physical properties of the dyes differ strongly, so the first step in developing a suitable HPLC method was the use of a gradient run ranging from 25% acetonitrile to 100% acetonitrile (B) and 0.1% formic acid in water as an aqueous counterpart (A). The UV chromatogram of the combined wavelengths 360, 550, and 620 nm showed good chromatography of all compounds except for the poor peak shape of Sudan 410 at 17.35 minutes (Figure 1A).

To optimize that peak shape, methanol was added to the organic mobile phase (acetonitrile:methanol, 90:10); the gradient run was repeated, resulting in better peak shape for Sudan 410 (Figure 1B). In a final experiment, the gradient profile was changed and optimum conditions were attained (see Table 2). Figure 1C shows the step-by-step improvements in the chromatography.

Only three runs were needed to get the final method, showing how easy and fast it is to develop methods with Ascentis Express columns. Further, Ascentis Express columns contain Fused-Core particles that allow for faster run times; even separations performed on standard HPLC systems can be sped up by up to 30% with Ascentis Express.

Figure 1 shows UV chromatograms of Sudan III (Peak 6) and Sudan 410 (Peak 7) after three optimization steps. An organic phase mixture of methanol:acetonitrile (10:90) and a final gradient composition of 98% organic mobile phase resulted in the best overall peak shapes with a minimum of tailing of compounds (Peak 7). Figure 3 shows the final chromatogram with very good separation of all analytes.

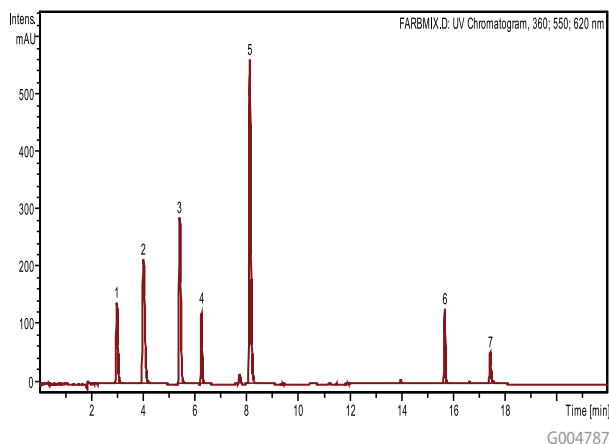
Figure 2 is a UV chromatogram of the final HPLC method. Resolution, sensitivity, and peak symmetry were optimal for all analytes. The total run time on a standard HPLC instrument (Agilent 1100) was 25 minutes, but the separation could easily be performed faster on ultra-performance instruments.

**Figure 1. UV Chromatograms of Sudan III and Sudan 410. (A) Initial Conditions, (B) Addition of Methanol to Mobile Phase, (C) Final Conditions after Adjusting Gradient**

G004786

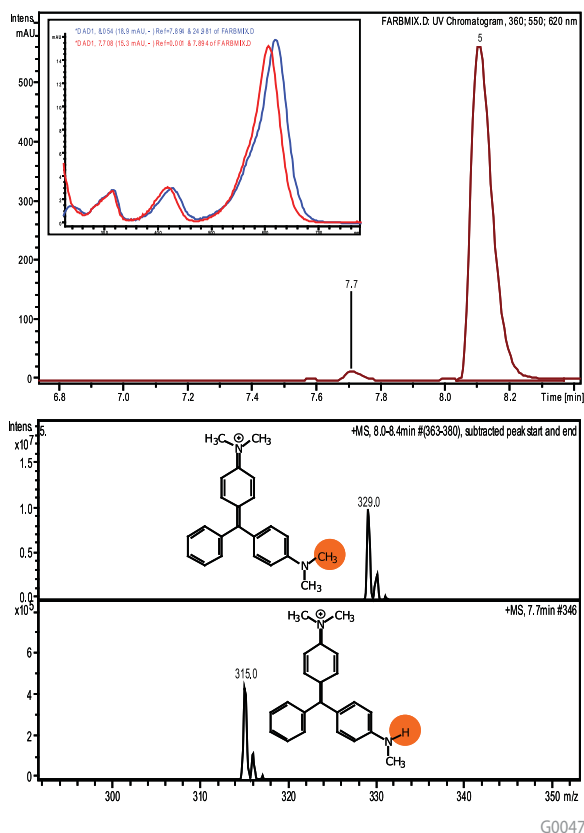


**Figure 2. UV Chromatogram of the Final HPLC Method**



**Figure 3. Expanded View of UV Chromatogram Showing Unknown Impurity at 7.7 min. and Malachite Green (5)**

The inset shows the UV spectra of malachite green (blue) and the unknown impurity (red). The mass spectra are of malachite green (top) and unknown impurity (bottom).



## Ascentis Express HPLC Columns: High Efficiency and LC-MS Compatibility

Using Ascentis Express columns on standard HPLC, fast LC, and ultra-performance instruments can yield heightened sensitivity (Figure 2). Mass detectors in LC-MS systems are very sensitive to contaminants in solvents and column bleed, both of which are very low with Ascentis Express columns combined with the right set of Fluka® LC-MS solvents and additives. Both aspects, high efficiency and low column bleed, are basic requirements in trace analysis of small target analyte concentrations or in identification of byproducts which may influence dramatically the quality and application of dyes. Figure 3 shows an example of the identification of low concentrations of byproducts even in very complex mixtures. The unknown substance at the retention time of 7.68 minutes shows a nearly identical UV spectrum to Malachite Green (Peak 5 at 8.10 minutes), but the mass is 14 Da lower. This may correspond to the exchange of a methyl residue with a proton at a position in the Malachite Green molecule that has no influence on the chromophore. Only the displayed molecular structures fit the UV and mass spectroscopic results.

To get optimal results from your LC-MS system and accurate UV and mass spectra of impurities with a high signal-to-noise level, it is best to use high purity LC-MS solvents from Fluka and high performance HPLC columns such as Ascentis Express from Supelco.

### References

1. Commission Decision. Official Journal of the European Union. L154/114. June 10, 2003.
2. Rapid Alert System for Food and Feed (RASFF). 2004. Annual Report. European Commission of Health & Consumer Protection Directorate General.

## Ascentis Express Properties

### Stationary Phase Support

- Ultra-pure, Type B silica
- 1.7  $\mu\text{m}$  solid core particle with 0.5  $\mu\text{m}$  porous silica shell (effective 2.7  $\mu\text{m}$ )
- 150  $\text{m}^2/\text{gram}$  surface area (comparable to  $\sim 225 \text{ m}^2/\text{g}$  porous particle)
- 90  $\text{\AA}$  pore size, 160  $\text{\AA}$  for Peptide ES C18

### Bonded Phase

	Coverage $\mu\text{moles}/\text{m}^2$	pH Range	Endcapping
<b>C18</b>	3.5	2-9	Yes
<b>C8</b>	3.7	2-9	Yes
<b>RP-Amide</b>	3.0	2-9	Yes
<b>HILIC</b>	n/a	2-8	No
<b>Phenyl-Hexyl</b>	3.4	2-9	Yes
<b>Peptide ES-C18</b>	3.5	1-9	No
<b>F5</b>	3.5	1-9	Yes



## Ascentis Express FAQs

### What is unique about Ascentis Express?

Ascentis Express columns provide a breakthrough in HPLC performance. Based on Fused-Core particle technology, Ascentis Express provides the benefits of sub-2  $\mu\text{m}$  particles but at much lower backpressure. These benefits include the capability of providing fast HPLC and higher resolution chromatography. The Fused-Core particle consists of a 1.7  $\mu\text{m}$  solid core and a 0.5  $\mu\text{m}$  porous shell. A major benefit of the Fused-Core particle is the small diffusion path (0.5  $\mu\text{m}$ ) compared to conventional fully porous particles. The shorter diffusion path reduces axial dispersion of solutes and minimizes peak broadening.

### Can I use Ascentis Express on any type of HPLC system?

Ascentis Express HPLC columns are capable of use on standard HPLC systems as well as UHPLC systems. Columns are packed in high pressure hardware capable of withstanding the pressures used in UHPLC systems.

### Is there anything I need to do to my HPLC system to use Ascentis Express?

Nothing special is required to use Ascentis Express HPLC columns. To obtain the full benefits of Ascentis Express, one should minimize dispersion or instrument bandwidth in the HPLC system (tubing, detector flow cell) as well as confirm the detector response system is set at a fast level. For more information, request Guidelines for Optimizing Systems for Ascentis Express Columns (T407102) or visit [sigma-aldrich.com/express](http://sigma-aldrich.com/express) and download.

### Can I use Ascentis Express on a UHPLC system?

Yes. Ascentis Express columns are packed in a way making them suitable for these ultra high pressure instruments. In fact, Ascentis Express outperforms sub-2  $\mu\text{m}$  columns on many applications since Ascentis Express provides the benefits of sub-2  $\mu\text{m}$  particles but at much lower backpressure.

### Can Ascentis Express columns be used for LC-MS?

Ascentis Express Fused-Core particles were designed with LC-MS in mind. Even extremely short column lengths exhibit sufficient plate counts to show high resolving power. The flat van Deemter plots permit resolution to be maintained at very high flow rates to maximize sample throughput. All Ascentis stationary phases have been evaluated for MS compatibility during their development, and the Express phases are no exception. A bonus of Ascentis Express columns for high throughput UHPLC and LC-MS is that they are extremely rugged and highly resistant to plugging, a very common failure mode for competitor columns.

### What flow rate should I use with Ascentis Express columns?

Based on the minimum in the van Deemter curves, higher flows than 5  $\mu\text{m}$  particle columns are required in order to maximize Ascentis Express column efficiency.

Ascentis Express HPLC Column ID	Suggested Starting Point for Flow Rate
4.6 mm I.D.	1.6 mL/min
3.0 mm I.D.	0.8 mL/min
2.1 mm I.D.	0.4 mL/min

### Key Technical Literature (available by request through technical service)

Code	Publication Title
T409113	Method Optimization using Alternative Selectivities in Fused-Core Particle HPLC Column Technology
T409110	Increased Bioanalytical Throughput Using Fused-Core HPLC with Selective Phospholipid Depletion
T409041	Extended Performance of LC Instruments with Fused-Core Particle Columns
T408141	Utilizing Fused-Core Technology for LC-MS Applications
T408088	Transfer and Speedup of Methods to Fused-Core Particle Columns
T408087	Optimization of HPLC Instrumentation for High Efficiency Separations
T408077	Achieving Sub-2 $\mu\text{m}$ LC-MS Performance at Moderate Pressures using Fused-Core Particle Technology
T408035	High-Resolution HPLC Through Coupling Columns
T408034	High Resolution HPLC Performance Under Both Isocratic and Gradient Conditions
T408033	Achieving Optimum UHPLC Column Performance by Measuring and Reducing Overall System Dispersion
T408031	Achieving Ultra-HPLC Column Performance with Older Instruments
T407127	Achieving Efficient Bioanalytical Separations at Moderate Pressures using Fused-Core Particle Technology
T407078	Optimizing HPLC Particles and Column Dimensions for Fast, Efficient Separations
T407102	Guidelines for Optimizing Performance with Ascentis Express HPLC Columns
T408143	Guide to Dispersion Measurement

# Selecting *YOUR* Ascentis Express HPLC column

## Which column ID is best for my needs?

If you are doing Mass Spec ..... **2.1 mm I.D.**  
 If you want solvent savings ..... **3.0 mm I.D.**  
 If you are doing standard HPLC ..... **4.6 mm I.D.**

## Which column length is best for my needs?

If you want to maximize the speed of your application ..... **2 to 7.5 cm**  
 If you want a balance of resolution and speed ..... **10 cm**  
 If you want the best resolution possible ..... **15 cm**

## What flow rate is best for my needs?

If you are using a column with a 4.6 mm ID ..... **1.6 to 2.4 mL/min\***  
 If you are using a column with a 3.0 mm ID ..... **0.8 to 2.0 mL/min\***  
 If you are using a column with a 2.1 mm ID ..... **0.4 to 1.8 mL/min\***

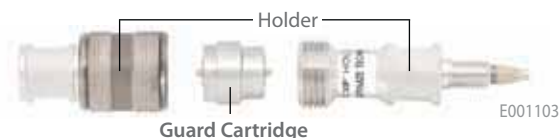
\* Higher flow rates can be used.

## Ordering Information

I.D.	Length	C18	C8	Phenyl-Hexyl	HILIC	RP-Amide	F5	Peptide ES -C18
<b>Ascentis Express Columns</b>								
2.1 mm	2 cm	53799-U	53795-U	53798-U	—	53797-U	53592-U	—
2.1 mm	3 cm	53802-U	53839-U	53332-U	53933-U	53910-U	53566-U	53299-U
2.1 mm	5 cm	53822-U	53831-U	53334-U	53934-U	53911-U	53567-U	53301-U
2.1 mm	7.5 cm	53804-U	53843-U	53335-U	53938-U	53912-U	53568-U	53304-U
2.1 mm	10 cm	53823-U	53832-U	53336-U	53939-U	53913-U	53569-U	53306-U
2.1 mm	15 cm	53825-U	53834-U	53338-U	53946-U	53914-U	53571-U	53307-U
3.0 mm	3 cm	53805-U	53844-U	53341-U	53964-U	53915-U	53574-U	53308-U
3.0 mm	5 cm	53811-U	53848-U	53342-U	53967-U	53916-U	53576-U	53311-U
3.0 mm	7.5 cm	53812-U	53849-U	53343-U	53969-U	53917-U	53577-U	53312-U
3.0 mm	10 cm	53814-U	53852-U	53345-U	53970-U	53918-U	53578-U	53313-U
3.0 mm	15 cm	53816-U	53853-U	53346-U	53972-U	53919-U	53579-U	53314-U
4.6 mm	3 cm	53818-U	53857-U	53347-U	53974-U	53921-U	53581-U	53316-U
4.6 mm	5 cm	53826-U	53836-U	53348-U	53975-U	53922-U	53583-U	53318-U
4.6 mm	7.5 cm	53819-U	53858-U	53351-U	53977-U	53923-U	53584-U	53323-U
4.6 mm	10 cm	53827-U	53837-U	53352-U	53979-U	53929-U	53590-U	53324-U
4.6 mm	15 cm	53829-U	53838-U	53353-U	53981-U	53931-U	53591-U	53328-U
<b>Ascentis Express Guard Cartridges, Pk of 3</b>								
2.1 mm	—	53501-U	53509-U	53524-U	53520-U	53514-U	53594-U	—
3.0 mm	—	53504-U	53511-U	53526-U	53521-U	53516-U	53597-U	—
4.6 mm	—	53508-U	53512-U	53531-U	53523-U	53519-U	53599-U	—
<b>Capillary Ascentis Express Columns</b>								
75 µm	5 cm	53982-U	53983-U					
75 µm	15 cm	54219-U	54229-U					
100 µm	5 cm	53985-U	53987-U					
100 µm	15 cm	54256-U	54260-U					
200 µm	5 cm	53989-U	53991-U					
200 µm	15 cm	54261-U	54262-U					
300 µm	5 cm	53992-U	53997-U					
300 µm	15 cm	54271-U	54272-U					
500 µm	5 cm	53998-U	53999-U					
500 µm	15 cm	54273-U	54275-U					

## Ascentis Express Guard Columns

Description	Cat. No.
<b>Universal Guard Holder</b>	
Holder w/EXP Titanium Hybrid Ferrule (cartridge not included)	53500-U



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