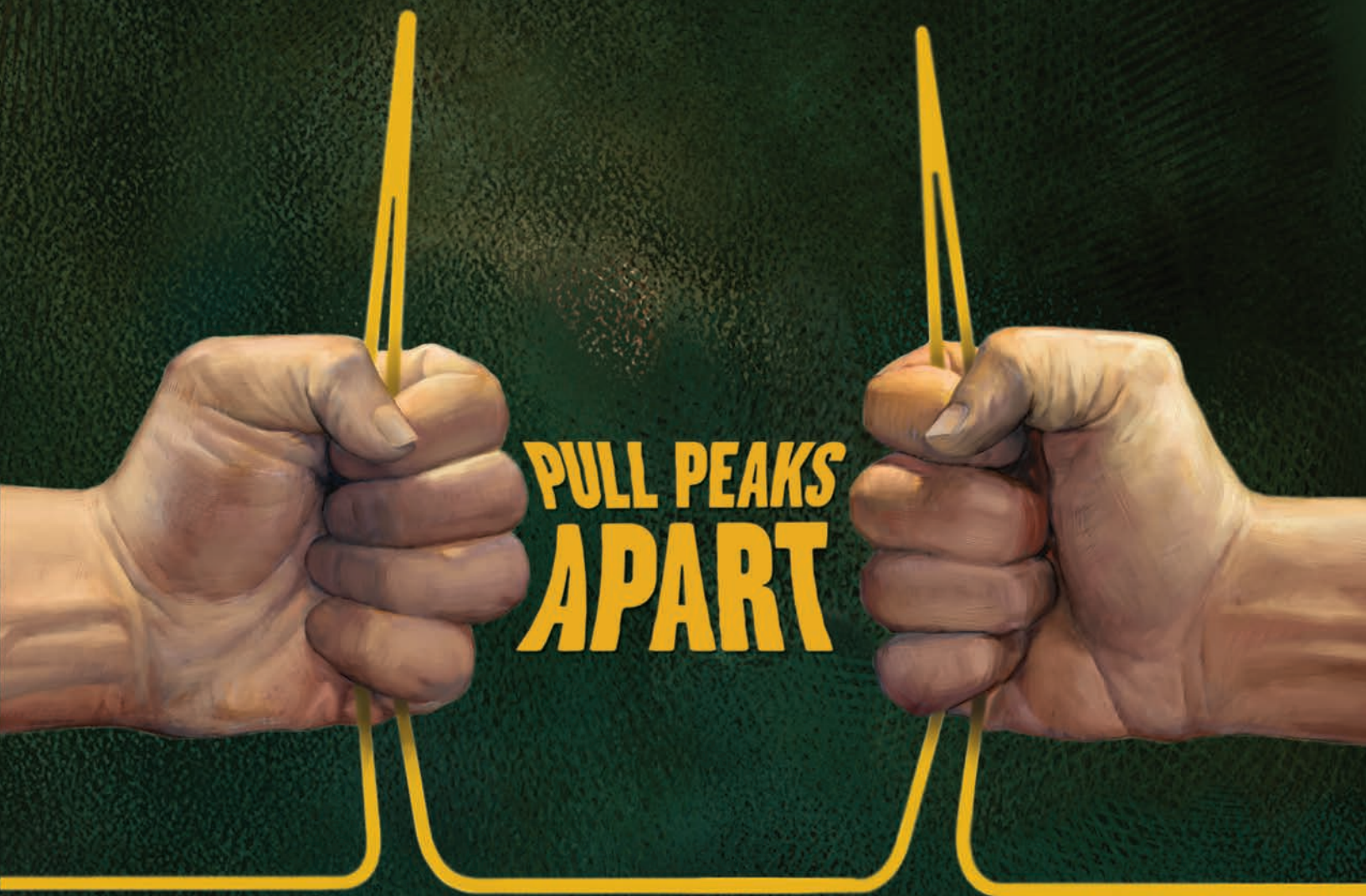


ACE[®] C18-PFP

A C18 bonded phase with the extra selectivity of a pentafluorophenyl (PFP) phase



**PULL PEAKS
APART**



ACE C18-PFP

A new high performance reversed phase column that leverages the advantages of a C18 phase with the extra selectivity of a pentafluorophenyl (PFP) phase. ACE C18-PFP columns separate mixtures not possible with ordinary C18 or PFP columns.

- * Combines C18 and PFP mechanisms of separation to separate mixtures not possible with either phase alone
- * Delivers excellent peak shape, even for bases that tail on other base deactivated C18 columns
- * Improves retention of polar basic compounds for better separations
- * Provides bonded phase stability expected from a C18 phase for long column lifetime and extremely low column bleed. LC/MS compatible
- * Offers compatibility with highly aqueous mobile phases to better separate highly water soluble compounds
- * Dependable column-to-column reproducibility

HPLC columns packed with C18 bonded phases continue to dominate all other types of bonded phases used for reversed-phase separations, and with good reason. C18 phases offer good retention and selectivity for a wide variety of sample types. Plus, C18 phases have proven to be very rugged and reliable as well as reproducible from manufactured batch to manufactured batch. Sure, some brands of C18 phases are better than others, but this is just a matter of the quality that the manufacturer puts into their product. Overall, the versatility, ruggedness and reliability of C18 bonded phases have led to their great popularity.

However, the popularity of C18 bonded phases has obscured the advantages that other bonded phases, such as CN, phenyl, fluorinated, or polar embedded phases can offer. Plus, the perception that other phases are not as reliable as C18 phases, which is based on some truth, has further discouraged the use of other phases. This is unfortunate because there are numerous cases where choosing a phase other than C18 can lead to a better overall separation—improved resolution, faster analysis, higher sensitivity, etc.

A solution to this dilemma is to add selectivity in the form of other retention mechanisms to a C18 bonded phase. This approach has been successfully applied in the development and production of the ACE C18-AR phase where both phenyl and C18 selectivity are combined. Now this technology has been used to combine a pentafluorophenyl (PFP) selectivity with C18 retention and selectivity to create the ACE C18-PFP. The result is a bonded phase with the desirable characteristics of a C18 phase plus the extra selectivity expected from a PFP phase. Table 1 provides an overview of how the ACE C18-PFP compares to typical C18 and PFP phases.

COMPARISON OF BONDED PHASES

Separation Mechanism	C18	PFP	ACE C18-PFP
Hydrophobicity	****	*/**	****
π-π	—	***	***
Dipole-Dipole	—	****	****
Hydrogen Bonding	—	****	****
Shape Selectivity	**	***	****
Phase Characteristics	C18	PFP	ACE C18-PFP
Aqueous compatibility	—	***	***
Bonded phase stability	****	**	****
Lot-to-Lot reproducibility	****	**	****

LEVERAGING SELECTIVITY

The resolution equation explains how variables affect resolution.

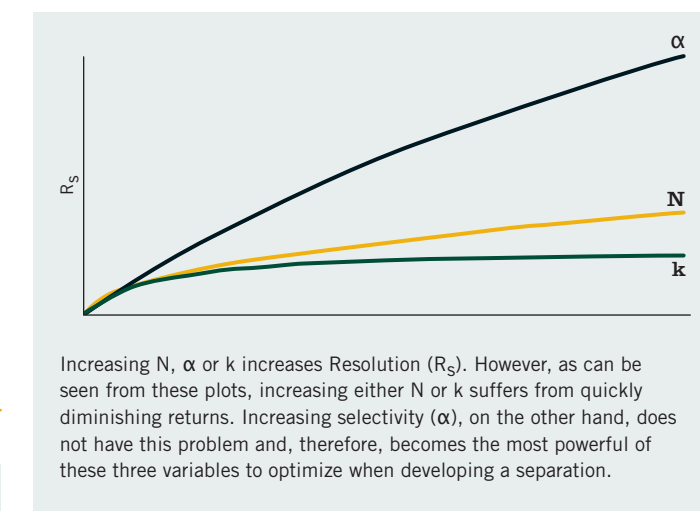
$$R_s = \frac{\sqrt{N}}{4} \left(\frac{\alpha - 1}{\alpha} \right) \left(\frac{k}{1 + k} \right)$$

- R_s : resolution between peaks of interest
- N: theoretical plates
- α : selectivity - the ratio of retention (k values) for two peaks
- k: retention factor - the number of column volumes required to elute a peak

Resolution, R_s , can be increased by increasing either N, k or α . However, increasing either N or k to improve R_s suffers from quickly diminishing returns, as can be seen graphically demonstrated in Figure 1. For example, R_s increases only with the square root of the increase in N. N can be increased by either adding column length or decreasing the particle size of the column packing material, or some combination of the two. Either way, the system back pressure increases with increases in N, so the “cost” of achieving a satisfactory separation by increasing N can be extremely high pressure.

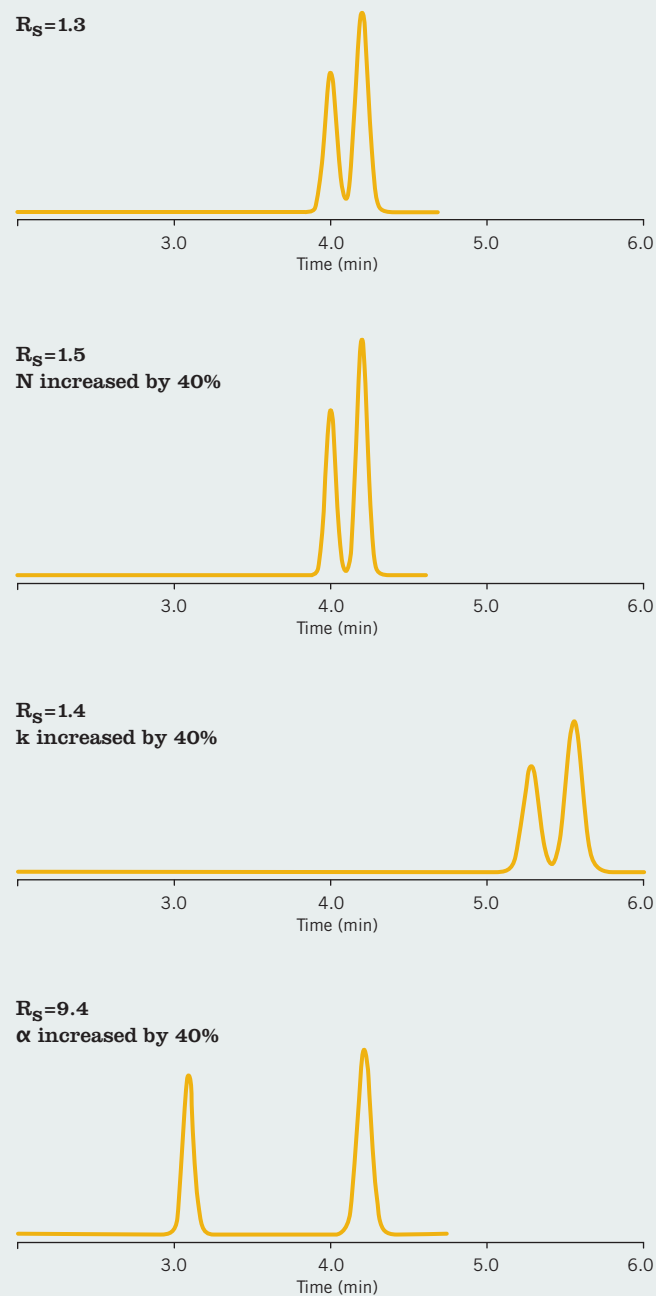
Similarly, increasing retention (k values) will increase R_s , but also with quickly diminishing returns. Increasing k beyond a value of 10 is usually a poor trade-off between R_s and analysis time, as only marginal gains in R_s are achieved with increasing retention times. A graphic representation of this effect can also be seen in Figure 1.

FIGURE 1: The effect of N, α and k on resolution (R_s)



Increasing α increases R_s but, unlike N and k, without the constraint of diminishing returns. Changes in α also have no effect on pressure and only negligible effects on separation time (Figure 2). Therefore, α is the most powerful variable to change when developing a separation. Optimizing α can allow you to achieve satisfactory resolution between all peaks of interest while keeping system back pressure and separation times acceptable.

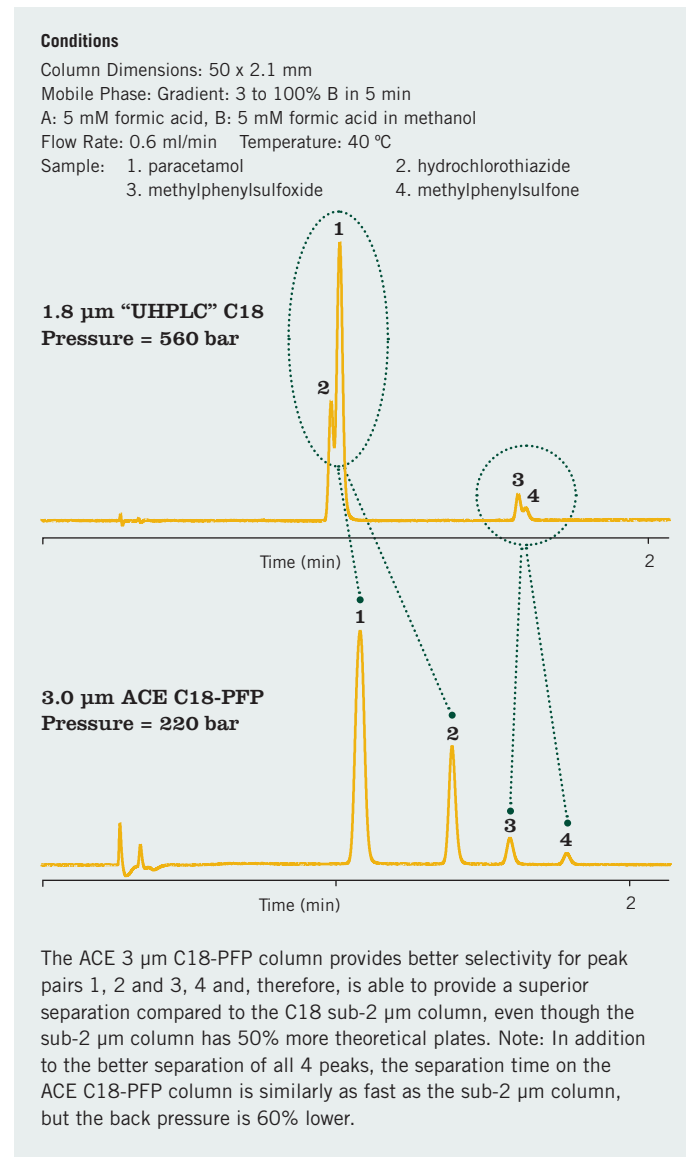
FIGURE 2: The effect of N, k and α on resolution (R_S)



These simulated chromatograms illustrate the effect of N, k and α on R_S . In each case, the variable was increased by 40%. Increasing N by 40% improved R_S from 1.3 to 1.5, but the pressure will also increase substantially. Increasing retention (k) improves R_S slightly, but at the cost of time and sensitivity. Increasing selectivity (α) by 40%, however, yields a huge increase in R_S with no increase in pressure or analysis time.

Much has been made lately about the advantages of using columns packed with very small particles (less than 2 μm) that generate very high efficiency (high plate count). Indeed, these types of columns can deliver very fast separations and high resolution, but you can sometimes develop separations just as fast and with even better resolution with columns that are much more rugged and reliable than the “sub-2 μm ” columns, if you choose the appropriate bonded phase selectivity. Figure 3 illustrates how leveraging the power of selectivity can lead to a better separation than that obtained by trying to force peaks apart using a column with high plate count, and high pressure.

FIGURE 3: Leveraging selectivity to achieve fast, high resolution separations

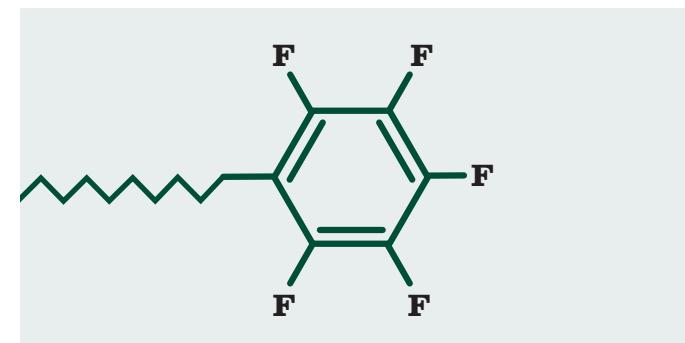


LEVERAGING THE SELECTIVITY OF C18 PLUS PFP

As previously mentioned, the ACE C18-PFP phase possesses the characteristics of both a C18 and a PFP phase. Figure 4 shows a simple schematic of the phase. The additional selectivity offered by

the PFP functionality allows one to leverage the advantages of a C18 phase to achieve better over-all reversed-phase separations. The next section of this product bulletin will review the multiple mechanisms of separation that can be utilized to optimize a separation.

FIGURE 4: Schematic of C18-PFP Phase



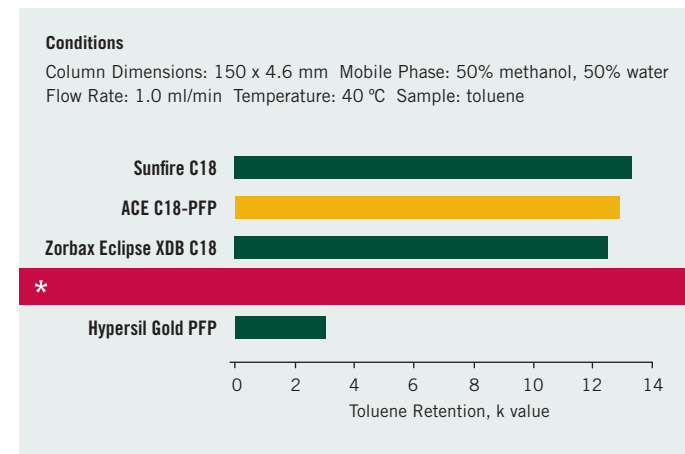
SEPARATION MECHANISMS OFFERED BY THE ACE C18-PFP PHASE

HYDROPHOBIC BINDING INTERACTION

Hydrophobic binding interactions occur primarily between the alkyl chain and solutes and achieves separations based on relative hydrophobicity of solutes. This is the primary mechanism of separation for all C18 columns.

Toluene is a good probe for measuring relative hydrophobicity of different bonded phases. The more hydrophobic phases will retain toluene longer. As expected, ACE C18-PFP has similar hydrophobicity and, therefore, similar hydrophobic binding interactions as other C18 phases. Typical PFP phases have much weaker hydrophobicity (Figure 5).

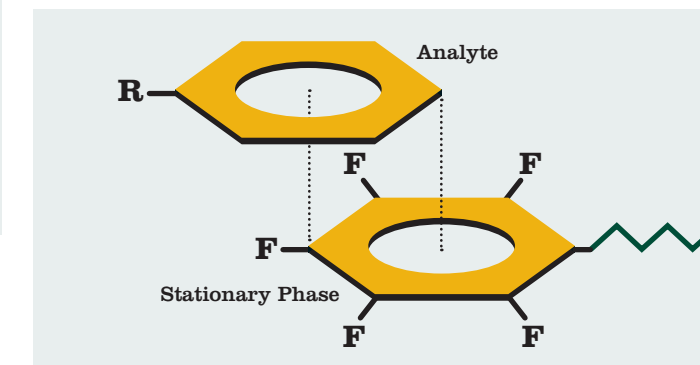
FIGURE 5: Comparison of relative hydrophobicity of different bonded phases



π - π INTERACTION

π - π interactions are intermolecular overlapping of p-orbitals in p-conjugated systems. Figure 6 provides a cartoon representation of the π - π interactions between an aromatic analyte and the aromatic group of the stationary phase. This π - π interaction provides a mechanism of separation that is a significant contributor to the separating power of the ACE C18-PFP bonded phase.

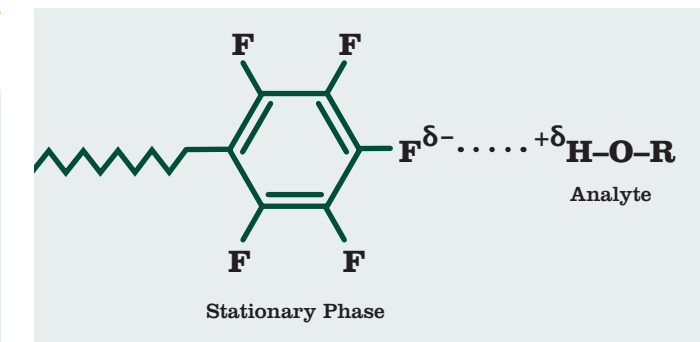
FIGURE 6: Schematic of π - π interactions



HYDROGEN BONDING

Hydrogen bonding is a type of dipole-dipole interaction that occurs when the interaction involves hydrogen bonded to a heteroatom, such as oxygen, nitrogen or sulfur. Hydrogen bonding occurs between the hydrogen atom and the electronegative fluorine atoms of the pentafluorophenyl group (Figure 7).

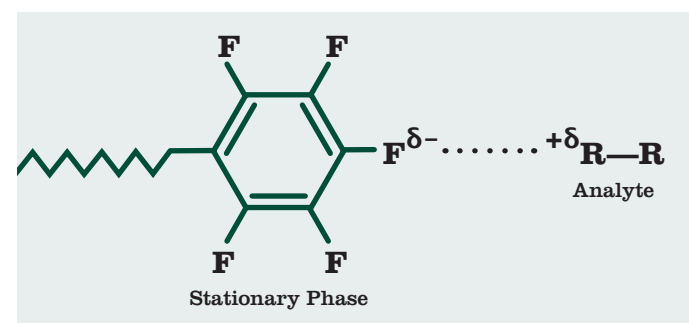
FIGURE 7: Hydrogen bonding occurs between a hydrogen atom of an analyte and the electronegative fluorine atoms of the pentafluorophenyl group.



DIPOLE-DIPOLE INTERACTION

Polar molecules have electric dipole moments by virtue of the existence of partial charges on their atoms. Dipole-dipole interactions occur when electric moments (dipoles) of molecules are attracted to oppositely charged dipoles of the bonded phase. The interaction energy depends on the strength and relative orientation of the two dipoles. Although this type of interaction is weaker than hydrogen bonding, it can still add selectivity advantages when trying to separate compounds that are poorly resolved on a typical C18 phase.

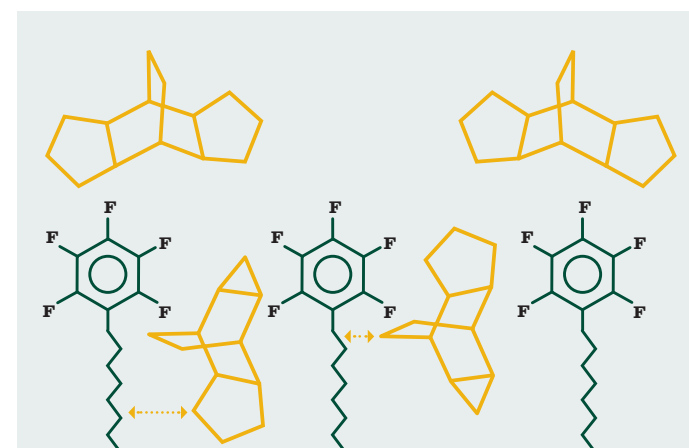
FIGURE 8: Dipole-dipole interaction occurs when electric moments (dipoles) of molecules are attracted to oppositely charged dipoles of the bonded phase.



SHAPE SELECTIVITY

Fluorine adds significant structural rigidity to the bonded phase. This rigidity can sterically hinder the way some molecules interact with both the PFP group and/or the alkyl chain. The amount of hindrance will vary according to the shape of the molecule in solution, permitting stronger interaction with some molecules than others. In this way the ACE C18-PFP is able to achieve separation of compounds based on shape selectivity that may not be possible with a typical C18 that lacks a rigid structure.

FIGURE 9: Fluorine adds significant structural rigidity to the bonded phase, thereby hindering interaction between the bonded phase and some molecules and permitting better interaction with other molecules, depending on their shape in solution. This selective interaction based on shape provides a useful mechanism for separations.



ADVANTAGE OF ACE C18-PFP OVER C18 OR PFP

One obvious reason to try the ACE C18-PFP is when a typical C18 phase is unable to achieve a satisfactory separation of all analytes of interest in a sample mixture. If one C18 column fails to provide adequate selectivity for all analytes in your sample mix, then it is highly likely that other C18 columns will also fail to provide adequate selectivity. Even increasing N and/or retention (k), as we have previously seen, may only yield marginal improvement in the separation, but at a cost of higher pressure and/or longer analysis time. In some cases the selectivity on a C18 phase may be so poor that it is clearly

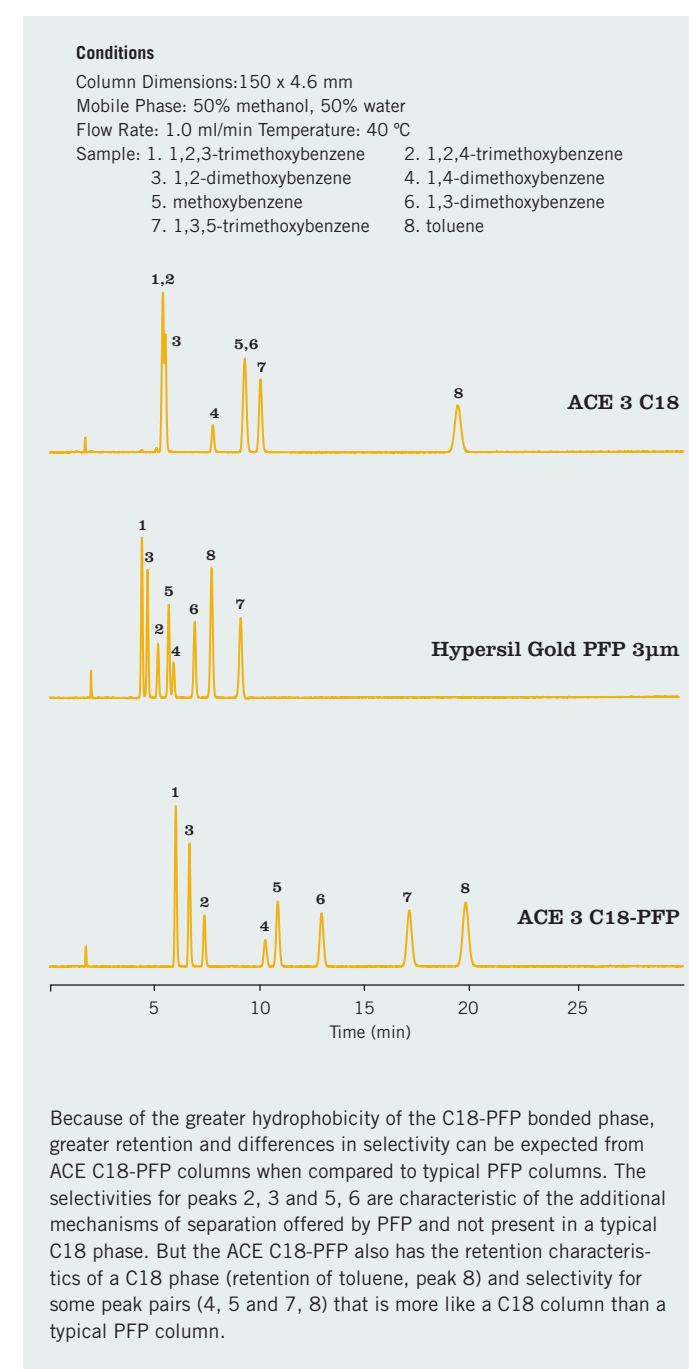
a waste of time to pursue trying to use this type of phase, even if pressure and analysis time is not a concern. A better approach is to apply different or additional separation mechanisms that are available with other types of bonded phases. Figure 10 provides a good example of how this approach can be applied successfully.

FIGURE 10: Achieving a better separation by applying additional mechanisms of separation



Why not just use a regular PFP column? It is true that a typical PFP column may on occasions provide adequate selectivity to generate a satisfactory separation. However, strong hydrophobic interaction does often contribute significant advantages to the separation. Figure 11 illustrates the additional retention and the dramatic difference in selectivity that the ACE C18-PFP provides compared to typical PFP columns. Plus, as will be discussed later, the ACE C18-PFP offers the additional benefits of stability and reproducibility.

FIGURE 11: ACE C18-PFP columns offer greater retention and dramatic differences in selectivity compared to typical PFP columns.



THE IMPORTANCE OF PEAK SHAPE

Peak tailing can reduce resolution, decrease sensitivity and even interfere with accuracy and precision (Figures 12 and 13). There are many potential causes of peak tailing, but the primary cause when separating bases is interaction between acidic silanols on the surface of the silica stationary phase support particles and amine groups on analytes (Figure 14).

FIGURE 12: Effect of peak tailing on resolution and sensitivity

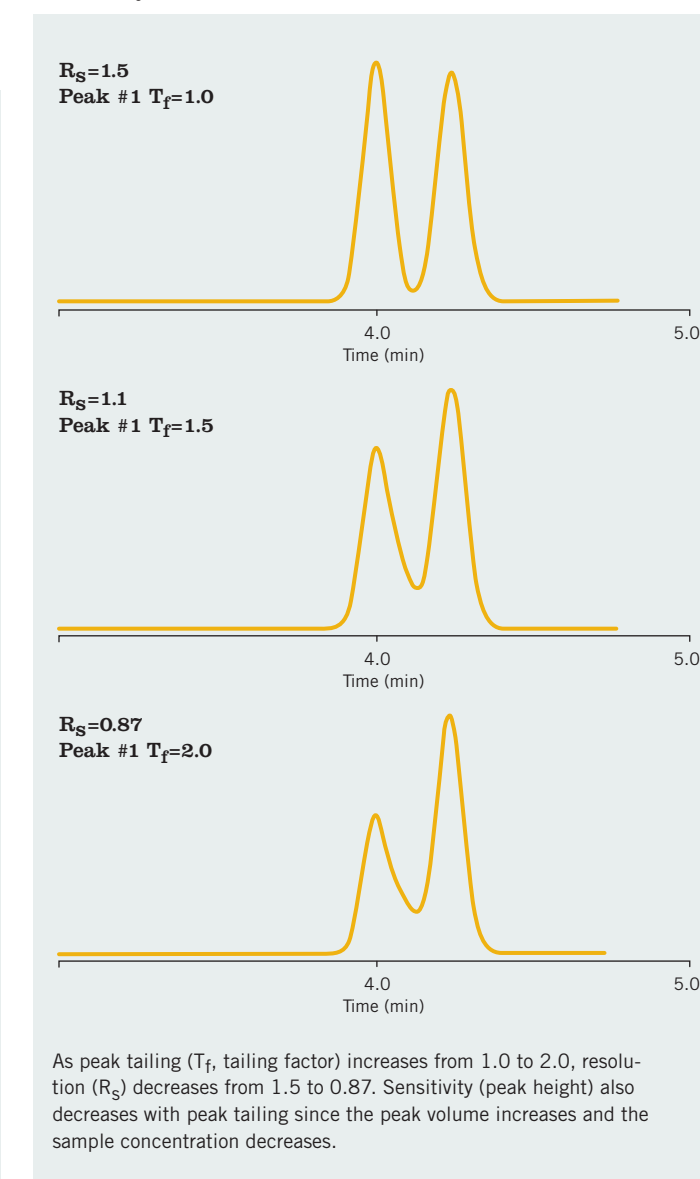


FIGURE 13: Effect of peak tailing on accuracy and precision

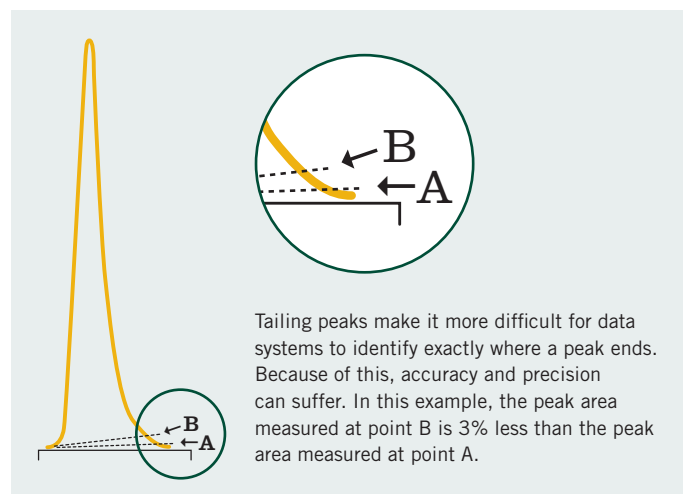


FIGURE 14: Peak tailing interaction

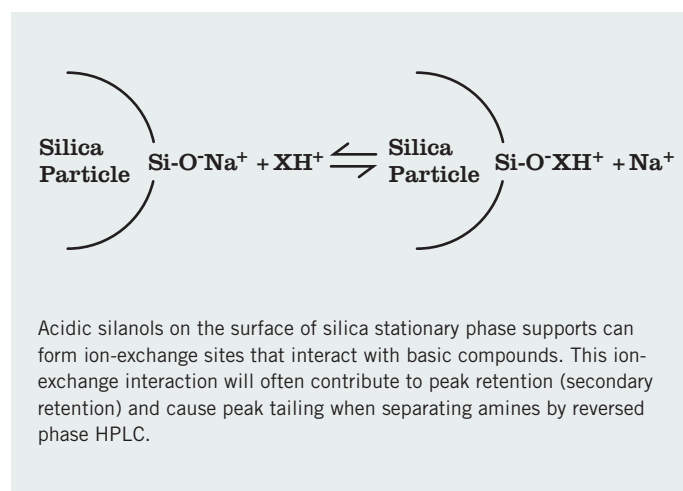
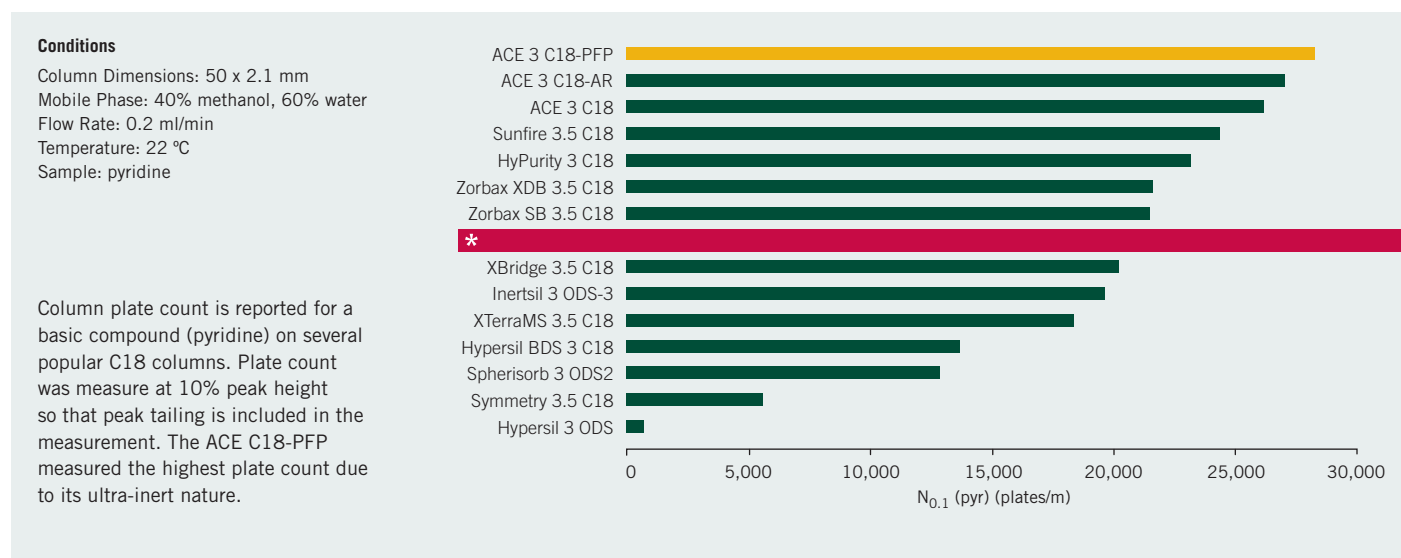


FIGURE 15: Comparison of peak tailing



*** DATA REDACTED PENDING RESOLUTION OF THREAT OF LEGAL ACTION FROM LAW FIRM HIRED BY PHENOMENEX.**



Like all ACE phases, ACE C18-PFP is manufactured using ultra-pure silica with extremely low silanol activity as the stationary phase support. The C18-PFP phase is densely bonded to the ultra-pure silica and then exhaustively end-capped using proprietary technology to bond to all available silanols. The result is an ultra-inert phase that virtually eliminates peak tailing due to silanol interaction.

Figure 15 compares peak tailing of pyridine on several popular “base deactivated” C18 columns. ACE C18 columns, including ACE C18-PFP, show the lowest peak tailing (highest plate count for pyridine) under the conditions indicated.

THE IMPORTANCE OF COLUMN REPRODUCIBILITY

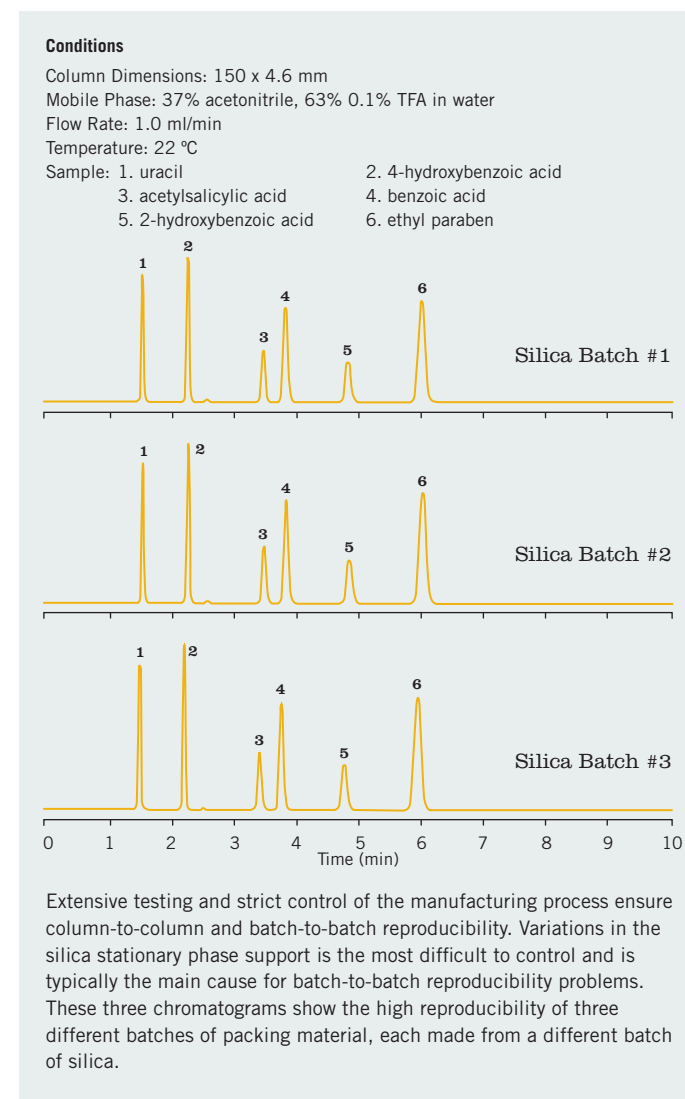
It is gratifying to find a column and mobile phase conditions that yield a satisfactory separation. But, if the column is not reproducible from lot-to-lot and/or exhibits an unacceptably short lifetime, then much of your hard work will have been wasted and you will have to continue your search for an acceptable column. The reproducibility and durability of a column should be considered early in the column selection process to avoid wasting time and effort.

There are three major contributors to poor batch-to-batch stationary phase reproducibility: variation in polar activity of the silica stationary phase support due to variations in trace metal contamination and the relative population of acidic silanols, variations in the surface area of the silica stationary phase support, and inefficient and poorly controlled bonding chemistry. ACE C18-PFP is designed to avoid these problems. Ultra-pure silica with extremely low silanol activity is used as the stationary phase support. Furthermore, the silica particles have well controlled pore size and particle size distribution. Finally, the bonded phase is efficiently and reproducibly bonded to this silica. Such design parameters yield C18-PFP columns that are highly reproducible from column-to-column and from batch-to-batch.

In spite of the purity of the silica or the efficiency of the bonding process, the only way to ensure the quality and reproducibility of the stationary phase and packed columns is through strict control of the

manufacturing process. This requires extensive testing and the more rigorous the testing, the better the quality of the column will be. ACE C18-PFP columns, like all ACE columns, are subjected to the most rigorous testing in the industry. Consequently, ACE columns have rightfully earned their reputation as the highest quality and most reproducible columns commercially available (Figure 16).

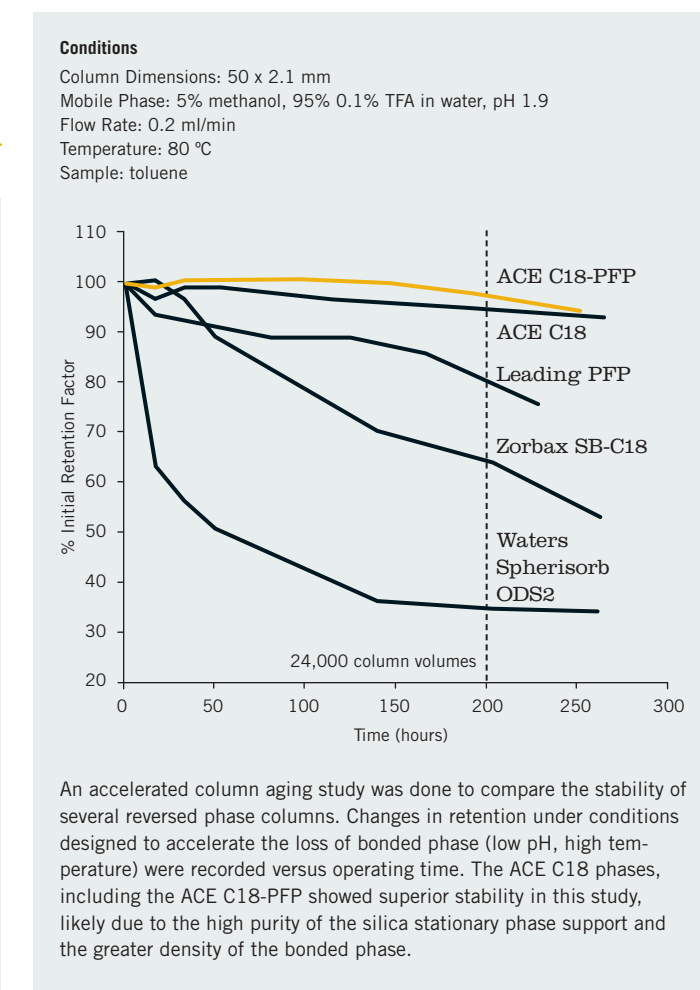
FIGURE 16: ACE C18-PFP batch-to-batch reproducibility



LEVERAGING A LONGER ALKYL CHAIN LENGTH FOR BETTER COLUMN DURABILITY

At low pH, column deterioration can occur due to hydrolysis of the siloxane bond and the subsequent loss of bonded phase. Loss in retention is observed when this occurs, occasionally accompanied by changes in selectivity and increases in peak broadening or tailing. The type of bonded phase, the purity of the silica stationary phase support and the bonding density all affect column stability at low pH. For example, the longer the alkyl chain length of the bonded phase the more stable it is. This is why C18 bonded phases are considered to be more durable than other bonded phases, such as C4, cyanopropyl, phenethyl, etc.

FIGURE 17: Accelerated column aging study proves ACE C18-PFP ruggedness

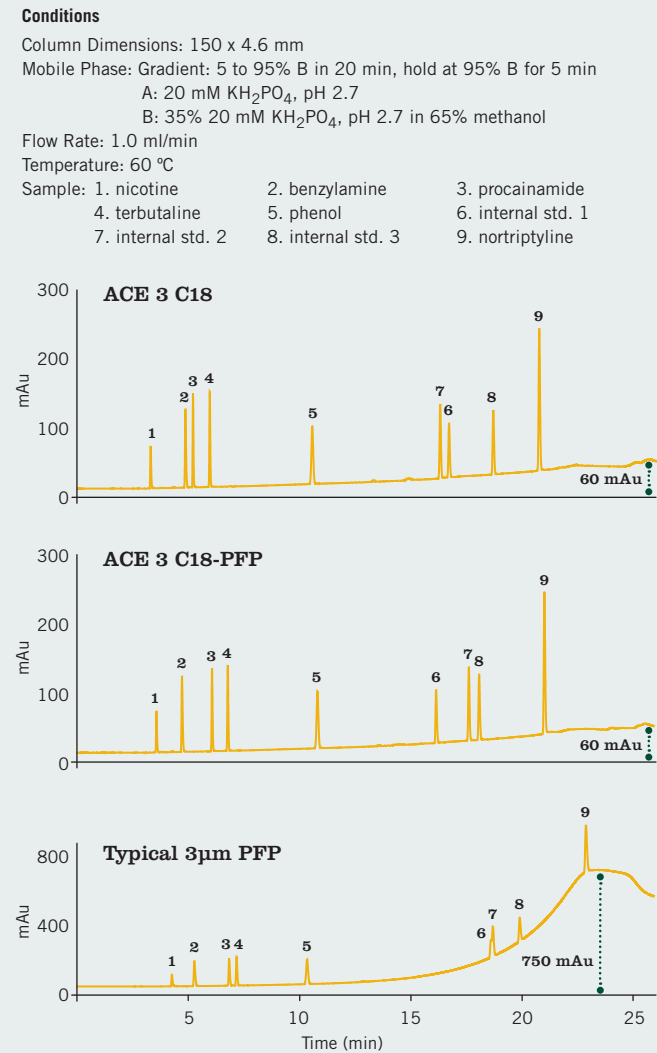


Pentafluorophenyl phases have, in general, not been considered as stable as C18 phases. The ACE C18-PFP, however, demonstrates a stability that equals the most stable C18 phases. Figure 17 illustrates this by comparing an ACE C18-PFP column to a highly robust C18 (ACE C18), an “acid stabilized” C18 (Zorbax SB-C18), a typical low purity silica C18 and a typical PFP column under conditions designed to accelerate loss of bonded phase.

Poor bonded phase stability not only affects column reliability and lifetime, it can also interfere with some detectors. Unlike typical C18 phases, the pentafluorophenyl group has strong UV adsorption and when running under gradient conditions some typical PFP phases will exhibit a “hump” in the baseline at the end of the gradient. This is due to PFP eluting from the column. This can be even more of a problem in LC/MS applications where PFP eluting from the column can interfere with detection and measurement of the analyte of interest. This elution of bonded phase from a column is generally referred to as column bleed.

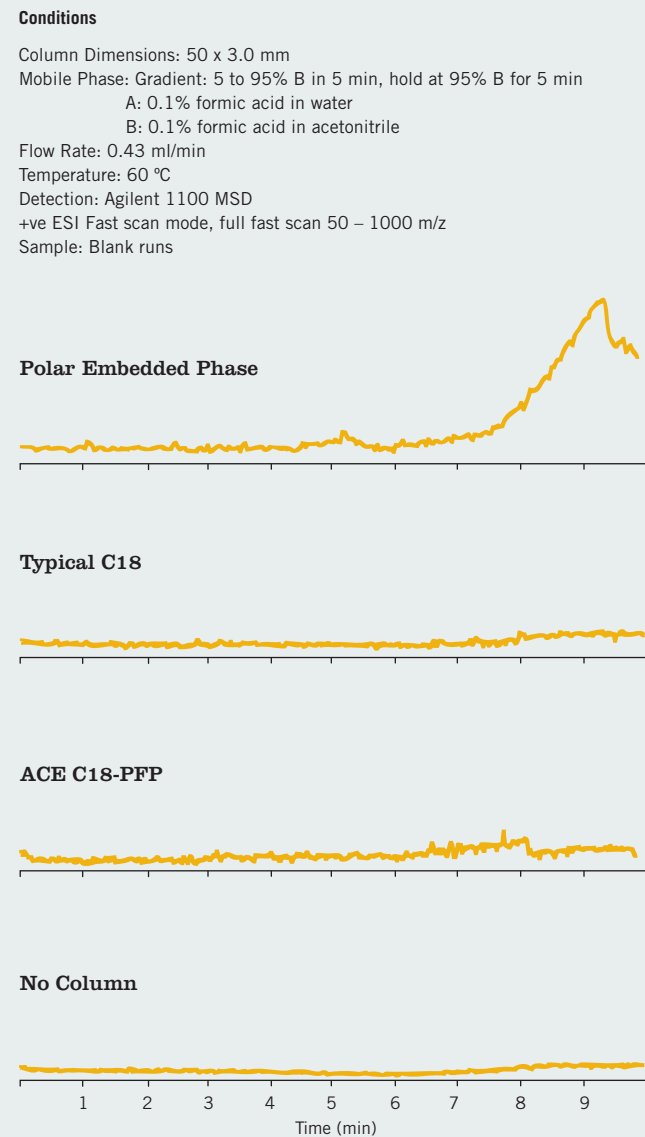
Figure 18 compares column bleed for a C18, an ACE C18-PFP, and a typical PFP column when using UV detection. Figure 19 illustrates how column bleed affects MS detection. In both cases the ACE C18-PFP exhibits minimum bleed and proves itself an appropriate column to use for applications where column bleed is a concern.

FIGURE 18: ACE C18-PFP exhibits low column bleed expected from a C18 bonded phase



Because pentafluorophenyl has strong UV adsorption, any loss of bonded phase will show up as a “hump” at the end of a gradient run when using a UV detector. This is illustrated in the chromatogram labeled “Typical 3µm PFP”. The ACE C18-PFP column, run under the identical conditions as the typical PFP column, shows no such indication of loss of bonded phase.

FIGURE 19: The low column bleed for ACE C18-PFP columns make them ideal for LC/MS applications



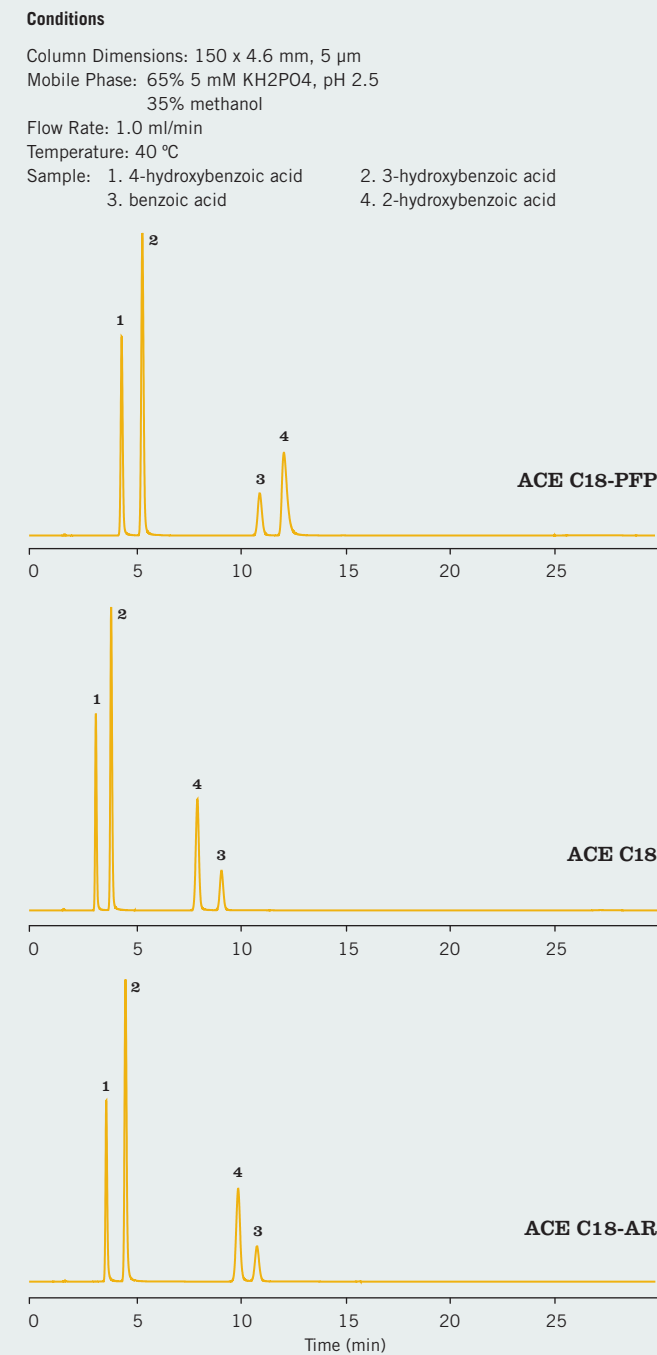
Column bleed can interfere with detection and measurement of analytes of interest in LC/MS applications. The first (top) total ion chromatogram shows how column bleed, in this case from a column packed with a polar embedded phase, can interfere with mass spec detection. The C18 column and the ACE C18-PFP column show no column bleed. The low bleed characteristics of ACE C18-PFP columns make them well suited for LC/MS applications.

APPLYING THE MECHANISMS OF SEPARATION OFFERED BY ACE C18-PFP

A strong argument can be made that the ACE C18-PFP merits being the first column to try when beginning development of a reversed-phase separation. The ACE C18-PFP offers the same hydrophobic binding interaction as other C18s, plus exhibits the other desirable characteristics of a C18 bonded phase, such as stability and

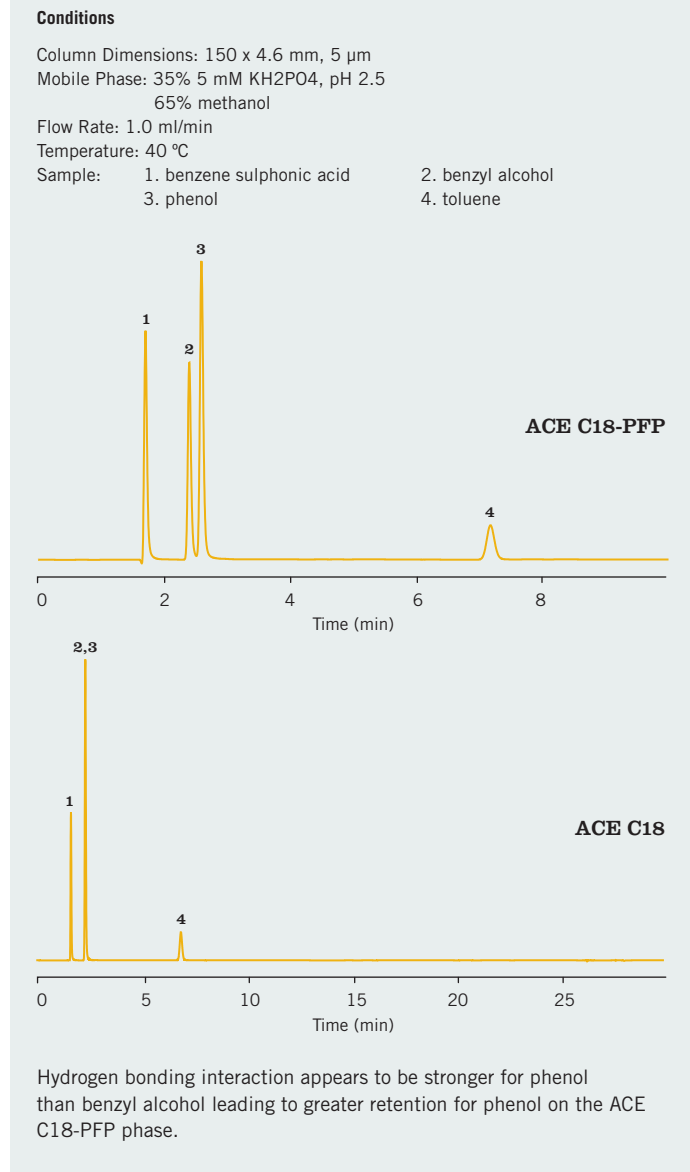
reproducibility. Plus, ACE C18-PFP columns offer several additional mechanisms of separation that can leverage the C18 phase to achieve acceptable resolution for all compounds of interest. We will explore a variety of separations where the added selectivity of the PFP group facilitates improved separations over what can be achieved with either a typical C18 or PFP phase alone.

FIGURE 20: Hydroxybenzoic acid isomers



Hydrogen bonding interaction appears to be responsible for the peak elution order reversal on the ACE C18-PFP compared to the ACE C18 and ACE C18-AR phases.

FIGURE 21: Phenolic selectivity



Hydrogen bonding interaction appears to be stronger for phenol than benzyl alcohol leading to greater retention for phenol on the ACE C18-PFP phase.

FIGURE 22: Acidic analytes

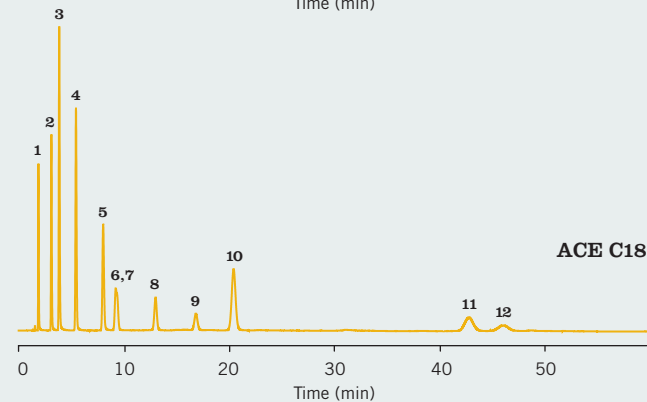
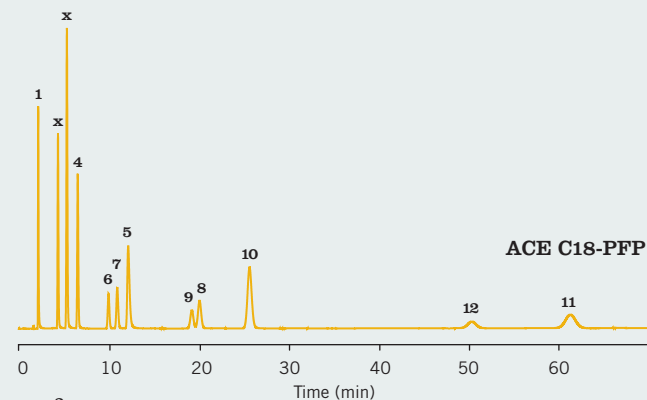
Conditions

Column Dimensions: 150 x 4.6 mm, 5 µm
Mobile Phase: 65% 5 mM KH₂PO₄, pH 2.5
35% methanol

Flow Rate: 1.0 ml/min

Temperature: 40 °C

Sample: 1. benzene sulphonic acid 2. 4-hydroxybenzoic acid
3. 3-hydroxybenzoic acid 4. phenol
5. 2-hydroxybenzoic acid 6. sorbic acid
7. benzoic acid 8. dimethylphthalate
9. 3-phenylpropionic acid 10. cinnamic acid
11. 4-hydroxybenzoic acid propyl ester 12. toluene



The additional mechanisms of separation provided by the ACE C18-PFP phase provide dramatically different selectivity compared to a typical C18 phase, including several reversals in peak elution order.

FIGURE 23: Catecholamines

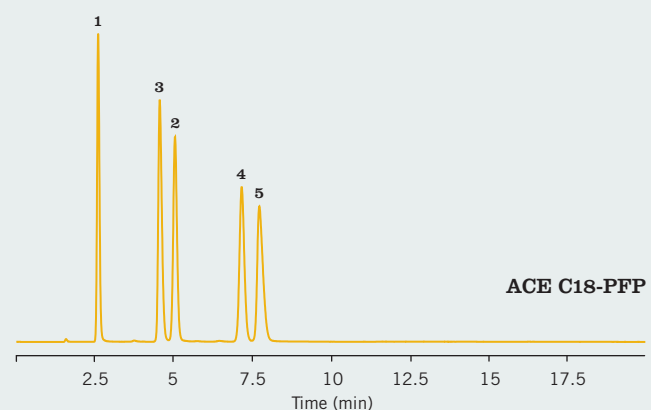
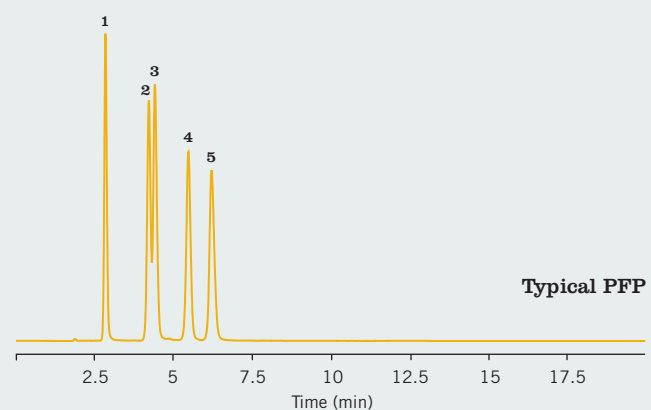
Conditions

Column Configuration: 150 x 4.6 mm, 5 µm
Mobile Phase: 12.5 mM ammonium formate in water, pH 3.0

Flow Rate: 1.0 ml/min

Temperature: 22 °C

Sample: 1. norepinephrine 2. levodopa
3. epinephrine 4. tyrosine
5. dopamine



This separation of catecholamines illustrates how strong hydrophobic binding interaction on the ACE C18-PFP provides a better separation of levodopa and epinephrine than is achieved by a typical PFP with weak hydrophobic binding interaction.

FIGURE 24: Natural products

Conditions

Column Configuration: 50 x 2.1 mm, 3 µm

Mobile Phase: Gradient: 3 to 100% B in 5 minutes, hold at 100% B for 1 min

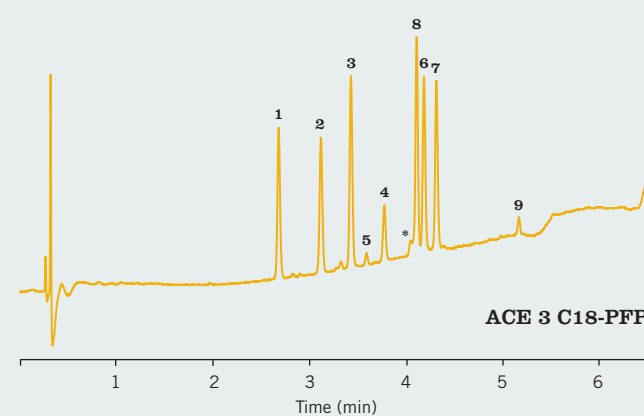
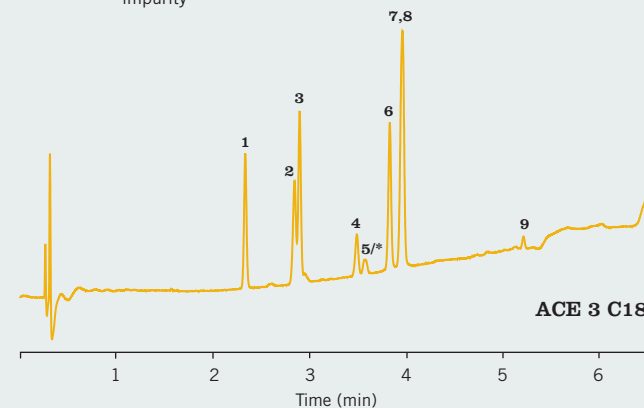
A: 0.1% formic acid in water

B: 0.1% formic acid in methanol

Flow Rate: 0.6 ml/min

Temperature: 40 °C

Sample: 1. rutin 2. juglone 3. quercetin
4. plumbagin 5. digoxin 6. chrysin
7. galangin 8. piperine 9. gossypol
* impurity



ACE C18-PFP exhibits the same retention characteristics of a typical C18 phase, but the additional selectivity of the PFP group yield an improved separation for these plant extracts.

Caveat: Separation of organic compounds by reversed phase liquid chromatography involves complex interactions between solutes, mobile phase and stationary phase that are still not well understood. The examples cited in this discussion of mechanisms of separation should be considered illustrations of how these mechanisms may affect a separation but they should not necessarily be viewed as an explanation of which mechanism is dominant. More fully understanding mechanisms of separation remains an area of ongoing research.

LEVERAGE THE ADVANTAGES OF ACE C18-PFP

- * Combines C18 and PFP mechanisms of separation to separate mixtures not possible with either phase alone.
- * Delivers excellent peak shape, even for bases that tail on other base deactivated C18 columns
- * Improves retention of polar basic compounds for better separations
- * Provides bonded phase stability expected from a C18 phase for long column lifetime and extremely low column bleed. LC/MS compatible.
- * Offers compatibility with highly aqueous mobile phases to better separate highly water soluble compounds.
- * Dependable column-to-column reproducibility

ACE C18-PFP Specifications:

STATIONARY PHASE SUPPORT

- Ultra-pure, spherical, "Type B" silica
- 5 µm and 3 µm particle size
- 100 Å pore size
- 300 m²/gram

BONDED PHASE

- 15.5% Carbon load
- Densely bonded and exhaustively endcapped
- pH range 2 to 8
- Maximum temperature of 60 °C

To Place An Order:

MAC-MOD ANALYTICAL
103 Commons Court, P.O. Box 587
Chadds Ford, PA 19317
 Phone: **800-441-7508**
 Fax: **610-358-5993**
 Website: **www.mac-mod.com**
 Email: **info@mac-mod.com**

ACE C18-PFP Parts & Price List:

ANALYTICAL COLUMNS

Dimension (mm)	Particle Size (µm)	Part Number	Price
4.6 x 250	5	ACE-1210-2546	\$615.00
4.6 x 150	5	ACE-1210-1546	\$560.00
4.6 x 150	3	ACE-1110-1546	\$615.00
4.6 x 100	5	ACE-1210-1046	\$480.00
4.6 x 100	3	ACE-1110-1046	\$520.00
4.6 x 75	5	ACE-1210-7546	\$470.00
4.6 x 75	3	ACE-1110-7546	\$495.00
4.6 x 50	5	ACE-1210-0546	\$400.00
4.6 x 50	3	ACE-1110-0546	\$435.00
4.6 x 30	5	ACE-1210-0346	\$375.00
4.6 x 30	3	ACE-1110-0346	\$400.00
4.6 x 20	5	ACE-1210-0246	\$375.00
4.6 x 20	3	ACE-1110-0246	\$375.00
3.0 x 250	5	ACE-1210-2503	\$615.00
3.0 x 150	5	ACE-1210-1503	\$560.00
3.0 x 150	3	ACE-1110-1503	\$615.00
3.0 x 100	5	ACE-1210-1003	\$480.00
3.0 x 100	3	ACE-1110-1003	\$520.00
3.0 x 75	5	ACE-1210-7503	\$470.00
3.0 x 75	3	ACE-1110-7503	\$495.00
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3.0 x 30	5	ACE-1210-0303	\$375.00
3.0 x 30	3	ACE-1110-0303	\$400.00
3.0 x 20	5	ACE-1210-0203	\$375.00
3.0 x 20	3	ACE-1110-0203	\$375.00

NARROW BORE COLUMNS

Dimension (mm)	Particle Size (µm)	Part Number	Price
2.1 x 250	5	ACE-1210-2502	\$615.00
2.1 x 150	5	ACE-1210-1502	\$560.00
2.1 x 150	3	ACE-1110-1502	\$615.00
2.1 x 100	5	ACE-1210-1002	\$480.00
2.1 x 100	3	ACE-1110-1002	\$520.00
2.1 x 75	5	ACE-1210-7502	\$470.00
2.1 x 75	3	ACE-1110-7502	\$495.00
2.1 x 50	5	ACE-1210-0502	\$400.00
2.1 x 50	3	ACE-1110-0502	\$435.00
2.1 x 30	5	ACE-1210-0302	\$375.00
2.1 x 30	3	ACE-1110-0302	\$400.00
2.1 x 20	5	ACE-1210-0202	\$375.00
2.1 x 20	3	ACE-1110-0202	\$375.00
1.0 x 250	5	ACE-1210-2501	\$615.00
1.0 x 150	5	ACE-1210-1501	\$560.00
1.0 x 150	3	ACE-1110-1501	\$615.00
1.0 x 100	5	ACE-1210-1001	\$480.00
1.0 x 100	3	ACE-1110-1001	\$520.00
1.0 x 75	5	ACE-1210-7501	\$470.00
1.0 x 75	3	ACE-1110-7501	\$495.00
1.0 x 50	5	ACE-1210-0501	\$400.00
1.0 x 50	3	ACE-1110-0501	\$435.00

Guard Cartridges for 3.0 and 4.6 mm ID analytical columns. Five guard cartridges per pack. Holder (H0005) required.

Dimension (mm)	Particle Size (µm)	Part Number	Price
3.0 x 10	5	ACE-1210-0103GD	\$275.00
3.0 x 10	3	ACE-1110-0103GD	\$275.00
Integral guard holder for above		H0005	\$190.00

Guard Cartridges for 2.1 mm ID narrow bore columns. Five guard cartridges per pack. Holder (H0004) required.

Dimension (mm)	Particle Size (µm)	Part Number	Price
2.1 x 10	5	ACE-1210-0102GD	\$275.00
2.1 x 10	3	ACE-1110-0102GD	\$275.00
Integral guard holder for above		H0004	\$190.00

Guard Cartridges for 1.0 mm ID narrow bore columns. Five guard cartridges per pack. Holder (H0001) and column coupler (C0001) required.

Dimension (mm)	Particle Size (µm)	Part Number	Price
1.0 x 10	5	ACE-1210-0101GD	\$275.00
1.0 x 10	3	ACE-1110-0101GD	\$275.00
Guard holder for above		H0001	\$190.00

PREPARATIVE COLUMNS

Dimension (mm)	Particle Size (µm)	Part Number	Price
10.0 x 50	5	ACE-1210-0510	\$800.00
10.0 x 75	5	ACE-1210-7510	\$910.00
10.0 x 150	5	ACE-1210-1510	\$1,115.00
10.0 x 250	5	ACE-1210-2510	\$1,390.00
21.2 x 50	5	ACE-1210-0520	\$1,525.00
21.2 x 50	10	ACE-1310-0520	\$1,390.00
21.2 x 75	5	ACE-1210-7520	\$1,755.00
21.2 x 75	10	ACE-1310-7520	\$1,565.00
21.2 x 100	5	ACE-1210-1020	\$1,990.00
21.2 x 100	10	ACE-1310-1020	\$1,730.00
21.2 x 150	5	ACE-1210-1520	\$2,510.00
21.2 x 150	10	ACE-1310-1520	\$2,075.00
21.2 x 250	5	ACE-1210-2520	\$3,465.00
21.2 x 250	10	ACE-1310-2520	\$2,790.00

Guard Cartridges for 10 and 21.2 mm ID preparative columns. Three guard cartridges per pack. Holder (H0002) and column coupler (C0001) required.

Dimension (mm)	Particle Size (µm)	Part Number	Price
10 x 10	5	ACE-1210-0110GD	\$280.00
10 x 10	10	ACE-1310-0110GD	\$280.00
Guard holder for above		H0002	\$230.00



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