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<table>
<thead>
<tr>
<th>Safe</th>
<th>Gas Generator</th>
<th>Gas Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Minimal gas storage volume</td>
<td>• Health and safety risk during transportation and handling</td>
</tr>
<tr>
<td></td>
<td>• Low pressure storage</td>
<td>• Gas stored at high pressures in large volumes</td>
</tr>
<tr>
<td></td>
<td>• Compromised stackable solution available</td>
<td>• Potential for undetected leaks from pipework from cylinder banks</td>
</tr>
<tr>
<td></td>
<td>• Once installed, the system needs only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• infrequent maintenance</td>
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</table>

<table>
<thead>
<tr>
<th>Convenient</th>
<th>Gas Generator</th>
<th>Gas Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Produce gas on demand with</td>
<td>• Cylinder must be monitored to avoid running out of gas</td>
</tr>
<tr>
<td></td>
<td>• consistent purity</td>
<td>• Difficult to manoeuvre and requires frequent handling</td>
</tr>
<tr>
<td></td>
<td>• Compact stackable solution available</td>
<td>• A large cylinder bank or dewar can take up valuable work space</td>
</tr>
<tr>
<td></td>
<td>• providing up to 3 gases</td>
<td>• Depending on usage, cylinders can require frequent changeovers</td>
</tr>
<tr>
<td></td>
<td>• Once installed, the system needs only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• infrequent maintenance</td>
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<table>
<thead>
<tr>
<th>Consistent</th>
<th>Gas Generator</th>
<th>Gas Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Consistent purity</td>
<td>• Inconsistent purity from cylinder to cylinder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmentally Friendly</th>
<th>Gas Generator</th>
<th>Gas Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• No more deliveries or collections</td>
<td>• High energy requirements for compression and purification of gas</td>
</tr>
<tr>
<td></td>
<td>• Energy efficient</td>
<td>• Cylinders must be transported, often long distances by road</td>
</tr>
<tr>
<td></td>
<td>• Reduced carbon footprint</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economical</th>
<th>Gas Generator</th>
<th>Gas Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Low ongoing costs</td>
<td>• Increasing delivery and rental costs year-on-year</td>
</tr>
<tr>
<td></td>
<td>• 24/7 gas production</td>
<td>• Instrument down-time during cylinder changeovers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can run out at inconvenient times</td>
</tr>
</tbody>
</table>

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Quantifying Trace-level PAHs

Investigating sample preparation recoveries for PAHs in complex plant matrices
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Optimizing Gas Chromatography Using Column Dimensions

Optimizing gas chromatography (GC) separations typically involves making some informed choices around stationary-phase chemistry and column temperature programmes.


**MULTIMEDIA HIGHLIGHTS**

powered by **crawford scientific**
Polycyclic aromatic hydrocarbons (PAHs) are small nonpolar compounds, consisting of multiple aromatic rings deriving from pyrogenic (3), petrogenic (4), and biological origin (5). Pyrogenic PAHs are formed by a variety of combustion processes under low oxygen conditions. Sources of pyrogenic PAHs are destructive distillation of coal into coke and coal tar, thermal cracking of petroleum residuals into lighter hydrocarbons, incomplete combustion of motor fuels in cars and trucks, and incomplete combustion of wood in forest fires. Pyrogenic PAHs are generally found at higher concentrations in urban areas and in locations close to major sources of PAHs.

Petrogenic PAHs occur in crude oils which are found due to widespread transportation, storage, and use of crude oil products. Major sources are oceanic and freshwater oil spills (6), underground and above ground storage tank leaks, and the accumulation of vast numbers of small releases of gasoline, motor oil and related substances associated with transportation (7). On the other hand, it is well-known that PAHs can also be produced biologically. For example, they can be synthesized by certain plants and bacteria or formed during the degradation of vegetative matter. The mode of PAHs formation can either be natural or anthropogenic (8). As a result of their importance, the

Quantification of European Union (EU)-priority polycyclic aromatic hydrocarbons (PAHs) in plant matrices is a crucial task. Various methods for enrichment and preconcentration, such as the preloaded-pipette tip solid-phase extraction (SPE) (1), are available. Nevertheless, analyte recovery as a result of homogenization, sample preparation, and extraction are rarely discussed in the field of phytopharmacy. This study deals with the recovery in dry plant extracts, which are typically used in phytopharmaceuticals and reflect the actual polycyclic aromatic hydrocarbon content in the commercially available end product (2). The aim of this study was to monitor benzo[a]pyrene, benzo[a]anthracene, chrysene, and benzo[b]fluoranthene loss of spiked samples as a result of commonly-used sample pretreatment, extraction, filtering, and evaporating techniques in 1:1 (v/v) cyclohexane–ethyl acetate primulae flos and sambuci flos dry extracts. Results showed that improper sample preparation can lead to false results. In the case of benzo[a]pyrene with a deviation of 155% from the theoretical true value.

KEY POINTS
- HPLC–FLD can be used to quantify trace amounts of PAHs in complex plant matrices.
- Sample preparation plays a major role in the quantification of PAHs.
- Nitrogen evaporation performs best for solvent evaporation.
- Automated enrichment strategy using pre-loaded SPE columns enables a quick and accurate method for determining PAH4 in herbal matrices.

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European Commission introduced maximum residue values for benzo[a]pyrene and a sum parameter of benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene in food, herbs, and dietary supplements (9). These four PAHs were chosen according to the European Food Safety Authority (EFSA) Journal (10). 9714 PAH analyses were performed in 33 food categories and the information value of PAH8 (benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenzo[a,h]anthracene, and benzo[g,h,i]perylene), PAH4 (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene) and PAH2 (benzo[a]pyrene and chrysene) was compared. The sum of PAH8, PAH2, and PAH4 was calculated and compared. PAH2 and PAH4 or PAH8 showed a correlation of 0.92. PAH4 and PAH8 revealed a correlation value of 0.99. Therefore, the focus of the publication was put on the subset of the PAH4, because they are required by the legislation. Screening a larger subset of PAHs could provide additional value (10).

In the near future phytopharmaceuticals are also likely to receive maximum residue values. Therefore, an accurate quantification method is mandatory, whose performance relies on an efficient extraction and a selective enrichment procedure.

Quantification of PAHs is mainly performed using high performance liquid chromatography fluorescence detector (HPLC–FLD) (11–16), or gas chromatography mass spectrometry (GC–MS) (17–19). Furthermore, liquid chromatography–atmospheric pressure photoionization–mass spectrometry (LC–APPI–MS) (20–22) techniques and also two dimensional GC (GC×GC) methods are reported (23).

In terms of European Union (EU) priority, PAHs benzo[c]fluorene, benzo[a]anthracene, chrysene, 5-methylchrysene, benzo(j)fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, dibenzo[a,l]pyrene, dibenzo[a,h]anthracene, benzo[g,h,i]perylene, indeno[1,2,3-cd]pyrene, dibenzo[a,e]pyrene, dibenzo[a,i]pyrene, dibenzo[a,h]pyrene, and cyclopenta(c,d)pyrene, HPLC–FLD methods have the disadvantage that only 15 of the 16 PAHs can be separated. This is because cyclopenta(c,d)pyrene shows no fluorescence. For the Environmental Protection Agency (EPA)-priority PAHs, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene,

![FIGURE 1: Chromatographic separation of benzo[a]pyrene, benzo[a]anthracene, chrysene, and benzo[b]fluoranthene.](image)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Linearity</th>
<th>Repeatability</th>
<th>Limits</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regression equation</td>
<td>R²</td>
<td>intra-day RSD (%)</td>
<td>inter-day RSD (%)</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>y = 0.958 x + 3.767</td>
<td>0.998</td>
<td>0.62</td>
<td>2.37</td>
</tr>
<tr>
<td>Benzo[b]fluorene</td>
<td>y = 0.388 x + 1.651</td>
<td>0.999</td>
<td>0.78</td>
<td>2.17</td>
</tr>
<tr>
<td>Chrysene</td>
<td>y = 0.1041 x + 0.7908</td>
<td>0.998</td>
<td>0.92</td>
<td>1.40</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>y = 0.3931 x + 2.2453</td>
<td>0.999</td>
<td>1.04</td>
<td>3.47</td>
</tr>
</tbody>
</table>

* n = 10  
* b n = 30  

---

**TABLE 1: Performance evaluation of the applied analytical method**
benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[a,h]anthracene, benzo[g,h,i]perylene, and indeno[1,2,3-c,d]pyrene, the situation is similar. Acenaphthylene cannot be resolved in HPLC–FLD due to the lack of fluorescence. GC–MS analysis can overcome this issue, but is limited by the low volatility of high-molecular-weight PAHs. Dibenzopyrenes elute only at very high temperatures, very close to or above the thermal stability of the column, therefore decreasing the column lifetime drastically (24). Nevertheless, GC–MS has been recommended in many official methods for the analysis of PAHs (25). Liquid chromatography–electrospray ionization–mass spectrometry (LC–ESI–MS) techniques need a post-column derivatization, such as tropylium ions or silver ions, and are therefore not very attractive (26,27). LC–APPI–MS methods are a good alternative and are mainly used for quantification of PAHs in complex matrix, using a high-resolution mass spectrometer (28–30).

PAH quantification methods include external calibration, internal calibration, and standard addition methods. For GC–MS and APPI–MS methods, mainly internal standard calibrations are used. The standard method is the use of isotopic forms of target PAHs (31,32). Isotopic forms of all the EU-priority PAHs and the EPA-priority PAHs are available. In March 2020 an automated pipette tip solid-phase extraction (SPE) method was published (1). The introduced method employs the analytical scheme described in this study, and standards are preloaded on a poly(styrene/divinylbenzene) SPE resin, therefore enabling rapid quantification without the need for standard preparation. Furthermore, the method was subjected to various tea samples, as well as contaminated *Primulae flos* samples.

To remove interfering compounds, sample clean-up is of the utmost importance. Gel permeation chromatography (GPC) is primarily used for that (33,34), and manual and

### TABLE 2: Stability of PAH mix solutions over 10 consecutive days

<table>
<thead>
<tr>
<th>Analytes</th>
<th>Condition</th>
<th>Day 2 Recovery (%)</th>
<th>Day 5 Recovery (%)</th>
<th>Day 10 Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzo[a]pyrene</td>
<td>LT</td>
<td>99.11 ± 0.40</td>
<td>96.83 ± 0.52</td>
<td>96.90 ± 0.42</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>100.4 ± 0.3</td>
<td>98.38 ± 0.94</td>
<td>97.83 ± 0.82</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>LT</td>
<td>100.3 ± 0.8</td>
<td>98.18 ± 0.66</td>
<td>97.89 ± 0.71</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>101.5 ± 1.4</td>
<td>98.9 ± 1.7</td>
<td>100.1 ± 0.7</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>LT</td>
<td>100.5 ± 0.0</td>
<td>97.78 ± 0.28</td>
<td>97.47 ± 0.16</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>99.56 ± 0.57</td>
<td>97.93 ± 0.76</td>
<td>98.48 ± 0.85</td>
</tr>
<tr>
<td>Chrysene</td>
<td>LT</td>
<td>98.93 ± 0.15</td>
<td>98.18 ± 0.20</td>
<td>97.65 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>100.8 ± 1.2</td>
<td>98.1 ± 1.5</td>
<td>99.14 ± 0.24</td>
</tr>
</tbody>
</table>

### TABLE 3: Analyte recovery after plant grinding using a rotary mill

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Recovery of analyte (%)</th>
<th>Primulae flos</th>
<th>Sambuci flos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzo[a]pyrene</td>
<td>79.74 ± 0.73</td>
<td>75.21 ± 0.42</td>
<td></td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>87.95 ± 0.30</td>
<td>83.0 ± 1.5</td>
<td></td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>81.22 ± 0.47</td>
<td>78.54 ± 0.42</td>
<td></td>
</tr>
<tr>
<td>Chrysene</td>
<td>85.81 ± 0.79</td>
<td>82.6 ± 1.5</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 4: Analyte recovery after evaporation leading to a dry extract

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Recovery of analyte (%)</th>
<th>standard polypropylene falcon tubes</th>
<th>Glass eprouvettes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SpeedVac</td>
<td>Nitrogen evaporation</td>
<td>SpeedVac</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>52.13 ± 0.71</td>
<td>71.05 ± 0.44</td>
<td>67.69 ± 0.24</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>57.11 ± 0.62</td>
<td>79.95 ± 0.69</td>
<td>74.57 ± 0.38</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>53.79 ± 0.88</td>
<td>74.96 ± 0.36</td>
<td>69.61 ± 0.21</td>
</tr>
<tr>
<td>Chrysene</td>
<td>56.91 ± 0.73</td>
<td>80.57 ± 0.57</td>
<td>74.6 ± 1.6</td>
</tr>
</tbody>
</table>
automated SPE methods are reported (1,35,36). In recent years, HPLC–FLD methods have also shown that they are capable of distinguishing alkylated PAHs from PAHs. In FDA method C-002.01, HPLC–FLD was used to quantify EPA PAHs in a complex sea food matrix. The method is able to separate alkylated PAHs from PAHs and allows an accurate quantification. The method was validated according to Level 3 Multi-laboratory validation (MLV) (37).

Nevertheless, all these methods rely on plant sample homogenization by grinding and extraction using a highly apolar solvent composition, consisting of cyclohexane and ethylacetate or dichloromethane. Afterwards the PAHs are preconcentrated using SPE with silica gel, florisil alumina, polystyrene-divinylbenzene (38), saponification, liquid–liquid extraction or gel permeation chromatography. All of these solutions have one thing in common; a solvent change is necessary and therefore the extraction solvent needs to be evaporated. Most described methods use nitrogen evaporation or vacuum evaporation. Furthermore, many methods use filtration steps, applying polytetrafluoroethylene (PTFE) or regenerated cellulose (RC) filters. Another key fact represents the used vial material. PAHs are likely to adsorb on the surface of polypropylene falcon tubes. Therefore, a closer look on the recovery of benzo[a]pyrene, benzo[a]anthracene, chrysene, and benzo[b]fluoranthene during these steps is necessary.

**Experimental Reagents and Materials:** Benzo[a]pyrene (≥96.0%), benzo[a]anthracene (99.0%), benzo[b]fluoranthene (98.0%), chrysene (98.0%), and ethylacetate (99.8%) were purchased from Sigma Aldrich (Buchs, Switzerland). Acetonitrile (ACN) and methanol (MeOH) both in HPLC grade (Chromasolv) were purchased from Honeywell Riedel-de Haen (Seelze, Germany). Tetrahydrofuran (THF) and cyclohexane were acquired from Merck KGaA (Darmstadt, Germany). HPLC grade water was obtained from a Milli-Q water purification system by Millipore (Bedford, USA). 50 mL polypropylene centrifuge tubes with screw caps, PTFE, and Phenex-RC syringe filters (porosity 0.45 µm) were purchased from VWR International (Radnor, USA) and Phenomenex (Torrance, USA), respectively. 2 mL Injekt syringes from Braun (Melsungen, Germany) were used.
Primulae flos and sambuci flos samples were provided by Kwizda Kräuterhandel GmbH (Linz, Austria).

Instrumentation: All samples and standard solutions were measured using an Agilent 1100 Series HPLC System (Santa Clara, USA) equipped with a G1321A fluorescence detector (FLD), a G1315B diode array detector (DAD), a G1316A thermostatted column compartment, a G1329A autosampler, equipped with a G1330B thermostat, and a G1311A quaternary pump with G1322A degasser. Analyses were performed using a Pinnacle II PAH analytical column (150 mm × 4.6 mm, 4-µm, Restek Corporation, Pennsylvania, USA). Mobile phase was a composition of 5% tetrahydrofuran in water (eluent A) and acetonitrile (eluent B). A gradient programme was executed using the following steps (min/% of eluent B): 0/80, 8/95, 9/80, 11/80. The flow rate was set to 1.5 mL/min and the injection volume was 10 µL. Column oven temperature was set to 30 °C and autosampler temperature was set to 4 °C. Determination of benzo[a]anthracene and chrysene was executed at an excitation wavelength of 270 nm and an emission wavelength of 390 nm. For benzo[b]fluoranthene and benzo[a]pyrene an excitation wavelength of 270 nm and an emission wavelength of 430 nm was used. Method validation was accomplished according to international guidelines. Therefore, parameters such as accuracy, instrumental limits, linearity, repeatability, method precision, and stability of analytes were determined. Linearity was examined using a standard solution of benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene at concentrations between 25% and 200% of target concentration (200 µg/L). For the determination of the repeatability a standard solution of 200 µg/L was prepared. Ten replicates were measured each day, to examine the intra-day repeatability. For the inter-day repeatability, three samples were measured each day for 10 consecutive days. Accuracy was investigated by spiking sambuci flos and primulae flos extracts with benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene standard solutions at three different concentrations. Limit of detection (LOD) and limit of quantitation (LOQ) were determined from a calibration curve at concentrations ranging from 0.01 to 0.8 µg/mL. Calculations of instrumental limits were executed referring to DIN32645: 2008–11. Chromatographic separation is highlighted in Figure 1. During the method development phase, special attention was paid to avoid coelution of the EU-priority PAHs. Method development started with method 2 and the parameters were as follows: Pinnacle II PAH analytical column (4.6 × 150 mm, 4-µm, Restek Corporation, Pennsylvania, USA) was used. Mobile phase was a composition of 5% tetrahydrofuran in water (eluent A) and acetonitrile (eluent B). A gradient programme was executed using the following steps (min/% of eluent B): 0/70, 7/75, 23.5/100, 34/70, 38.7/70. The flow rate was set to 1.5 mL/min and the injection volume was 10 µL. Column oven temperature was set to 30 °C and autosampler temperature was set to 4 °C. Excitation wavelength was set to 230 nm; emission wavelengths to 390 nm, 430 nm, 460 nm and 512 nm. Figure 2 shows a measurement of the EU-priority PAHs: benzo[c]fluorene, 4-Methylchrysene, (5) Benzo[k]fluoranthene, (7) Benzo[a]anthracene, (8) Benzo[a]pyrene, (9) Dibenzo[a,l]pyrene, (10) Dibenzo[a]anthracene, (11) Benzo[ghi]perylene, (12) Indeno[1,2,3-cd]pyrene, (13) Dibenzo[a,e]pyrene, (14) Dibenzo(a,i)pyrene, (15) Dibenzo(a,h)pyrene.
benzo[a]anthracene, chrysene, 5-methylchrysene, benzo(j) fluoranthene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[a,l]pyrene, dibenzo[a,h] anthracene, benzo[g,h,i]perylene, indeno[1,2,3-cd]pyrene, dibenzo[a,e]pyrene, dibenzo(a,i)pyrene, dibenzo(a,h) pyrene, and cyclopenta(c,d)pyrene at a concentration of 800 ppb. Cyclopenta(c,d)pyrene could not be resolved as it shows no fluorescence. When optimizing the method for 15 PAHs, care was taken to ensure that no coelution of the other PAHs occurs in the final method for four PAHs.

Degradation of the employed analytes in standard solution was studied over 10 consecutive days. Therefore, standard mix solution was stored at 4 °C in the dark and the amount of each analyte was determined daily.

Plant material was homogenized using a ZM 200 centrifugal mill from Retsch (Haan, Germany) equipped with a 0.5 mm trapezoidal sieve with a 24-tooth rotor. Ultrasound-assisted extraction was performed using an Ultrasonic Cleaner USC-TH from VWR International (Radnor, USA). Evaporation of supernatants was executed on a Concentrator plus from Eppendorf (Hamburg, Germany) or on an evaporator EVA-VIS-72 from VLM Korrosions-Prüftechnik, Labortechnik & Dienstleistungen GmbH (Bielefeld, Germany).

Preparation of Standard Solutions: First 2 mg ± 0.10 mg of the four PAH standard substances (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene) were separately dissolved in 60 mL methanol in a 100 mL volumetric flask. These stock solutions were further used for preparation of four standard mix solutions containing all four PAH standard substances: mix 1 (800 µg/ L), mix 2 (500 µg/ L), mix 3 (200 µg/ L) and mix 4 (3000 µg/ L). Therefore, the required volume of stock solution was mixed with 50 mL methanol in a 100 mL volumetric flask, homogenized and filled up with methanol to 100 mL. Working standard solutions were prepared on a weekly basis and stored at 4 °C in the dark.

Stability Evaluation of Standard Solutions: Evaluation of the stability of dissolved PAH standard substances was accomplished using the prepared standard solution mix 1, 2 and 3 (see “Preparation of Standard Solutions” section). These standard solutions were aliquoted into 1.5 mL HPLC amber glass vials (Bruckner Analysentechnik, Linz, Austria) and stored at 4 °C in the autosampler or at room temperature on a laboratory bench. Solutions were analyzed and quantified using HPLC–FLD (see “Reagents and Materials” section) over a time range of 10 days. All experiments were performed in duplicate.

Analyte Recovery After Filtration: The determination of analyte recovery after filtration was tested for PTFE and cellulose filters (see “Reagents and Materials” section) by filtering 1.5 mL of PAH standard mix 2 (see “Preparation of Standard Solutions” section) using 2 mL syringes. The permeate was collected and analyzed using the HPLC–FLD described in the “Reagents and Materials” section. Analysis was performed in duplicate.

Analyte Recovery After Sample Preparation: Evaluation of the analyte recovery during sample preparation was accomplished by spiking 15 g ± 10 mg of sambuci flos plant material with 5 mL of PAH standard mix 4 (see “Preparation of Standard Solutions” section). The plant material was left for a duration of 12 h in the dark to ensure complete evaporation of the solvent. The spiked plant material was then powdered using a ZM 200 centrifugal mill from Retsch (Haan,
Germany) equipped with a 24-tooth rotor and a 0.5 mm sieve at 18000 rpm. 1 g ± 1 mg of the ground plant material was extracted in 5 mL methanol using 2 min ultrasonic assisted extraction (UAE) prior to PAH quantification (see “Reagents and Materials” section). Additionally, the same procedure was performed using liquid nitrogen for cooling the samples before pulverization. The experiment was performed in duplicate. The same experimental conditions were used for determination of analyte loss as a result of different extraction vessel materials using glass eprouvettes and standard polypropylene falcon tubes.

Results and Discussion

HPLC–FLD Method Validation: Important validation parameters were determined to highlight the applicability of the developed method. Individual results for all target analytes are summarized in Table 1. Analyte concentrations between 25% and 200% of target concentration showed excellent linearity with regression coefficients between 0.998 and 0.9996. The acquired values for LOD varied between 10.66 and 12.46 µg/L and LOQ values were obtained between 37.88 and 44.13 µg/L. In the overall method using SPE and a preconcentration factor of 10, these values correspond to a LOD of 1.66 and 1.25 µg/kg and a LOQ of 3.78 and 4.41 µg/kg plant material. Intra-day (n = 10) and inter-day (n = 30) repeatability demonstrated minimal differences, verified by RSD values below 1.04% for intra-day and 3.47% for inter-day repeatability. Stability of all proposed analytes in the standard mixture was recorded using HPLC–FLD. The mixture was measured over a time range of 10 days. Results showed that the concentration did not decrease below 96.90% ± 0.42%. Accuracy was determined at 50%, 100 %, and 150% of target concentration. Mean recoveries showed values ranging from 98.1% to 101.5%. RSDs ranged from 0.1% to 2.4%.

Stability Analyses: The analyses of the differently-concentrated PAH standard mix solutions did not show a significant decrease of the analytes over the period of 10 days, neither at low temperature (LT) conditions nor at room temperature (RT) conditions. Representative for the stability of the PAH mix solutions, the observations on the stability of the 500 µg/L PAH mix at both LT and RT conditions are listed in Table 2.

Analyte Recovery Analysis: The use of filters did not show a significant difference in concentration of benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, or chrysene. But grinding of plant material, the evaporation for generating a dry extract, and the usage of different extraction vessel materials had a significant impact on analyte loss.
By using a rotary mill for plant grinding, the recovery of PAHs decreased from 88.0% to 75.2% (RSD < 1.6%). Cooling the samples using liquid nitrogen did not have a significant effect. Results for primulae flos and sambuci flos extracts are shown in Table 3.

Evaporation using vacuum evaporation revealed recoveries between 74.6–52.1% (RSD < 1.7%), while evaporation using nitrogen evaporation showed significantly higher recovery between 83.8–71.1% (RSD < 1.0%). The usage of glass eprouvettes showed a significant improvement between 3–18%. Results are highlighted in Table 4.

**Calculation of the Deviation from the Theoretical True Value:** Figure 4 shows a model calculation of the cumulated effect of the determined PAH losses during sample preparation. In the SPE procedure described by Stuppner et al. (1), a preconcentration factor of 10 was used. If contaminated plant material with a benzo[a]pyrene concentration of 1 µg/kg would be examined, 10 µg/L should be detected at the end of the analysis. In this model calculation, different evaporation techniques, including vacuum concentration and nitrogen evaporation, using various vial materials were used. As a result of the slight differences in the grinding step, the average recovery of the grinding was used. In the best case, when using a nitrogen evaporator with glass eprouvettes, a value of 17.3 µg/L was obtained, which results in a deviation of 73% from the theoretical true value. However, the worst case results in a deviation of 155% from the theoretical true value. Therefore, an analysis of PAH loss during extraction and pretreatment and the introduction of a correction factor is necessary.

**Conclusion**

In summary, the stability assessments of the standard solutions benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene revealed no significant decrease or increase in the concentration over a period of ten consecutive days.

These findings are consistent with published literature. The main influence on PAH stability is photo degradation, and can be reduced by using amber glass vials (39). The use of PTFE and RC syringe filters did not show a significant influence either. Using a rotary mill for plant milling, the recovery rates of the PAHs were reduced to 88.0% and 75.2% (RSD < 1.6%). Cooling using liquid nitrogen did not improve
the PAH loss either. Evaporation during solvent exchange showed the greatest influence, with polypropylene tubes and the vacuum evaporation method giving a recovery between 56.91–52.13% (RSD < 0.89%) for the investigated PAHs. These results do not match the existing literature. In literature a recovery of more than 90% was reported using 1-hexanol or 1-octanol as keeper substances. In addition, the samples were not evaporated to dryness to improve recovery, which is not practical for routine use (40). Using glass eprouvettes, the recovery values were improved from 67.7% to 74.6% (RSD < 1.6%). These results are consistent with the literature. Adsorption on polypropylene labware can also be overcome by liquid–liquid extraction (LLE) (40,41). Best results were obtained using a nitrogen evaporator with glass eprouvettes, with recovery rates varying between 76.67 and 83.82% (RSD < 0.95%). This is also in line with the existing literature. Rotary evaporation is described as a faster method with comparable recovery. However, nitrogen evaporation systems that can evaporate 72 samples in parallel offer benefits in terms of evaporation time and labour costs compared with rotary evaporation (40). The application of nitrogen vaporization has increased in recent publications and is therefore consistent with the results of this study (42). The model calculation (see “Calculation of the Deviation from the Theoretical True Value” section) also showed that nitrogen evaporation with glass vials produced the best results. However, an analysis of the PAH loss during extraction and pretreatment and the introduction of a correction factor are required.

The combination of these results with the findings published by Stuppner et al. (1) offers a valid method for PAH4 determination in plant matrix. In this study, a liquid handling robotic system was used in combination with an SPE-enrichment strategy using pre-loaded standards on poly(styrene-co-divinylbenzene) micro columns. For this purpose, the standards proposed by the EU PAH4 benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and chrysene were used. The advantage is that the PAH standards can directly be pre-loaded by the manufacturer and the user does not have to prepare a standard solution or handle toxic standard substances. The PAHs are quantified using the standard addition method and 12 samples can be handled over a period of 17 min. Recoveries ranging from 90–103% (RSD < 8%) for PAH standards and 90–95% (RSD < 10%) for spiked plant extracts were achieved (1). The process is illustrated in Figure 5. The combination of the proposed method and the automatic enrichment strategy using pre-loaded SPE columns enables a quick and accurate method for determining PAH4 in herbal matrices such as primulae flos and sambuci flos.

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References
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Bioinert and biocompatible liquid chromatography (LC) systems are becoming more commonplace in laboratories, but the majority of biomolecule separations still use LC systems composed primarily of stainless steel parts. Can passivation or mobile phase additives improve separations on these systems for metal-sensitive biomolecules?

In the March 2020 installment of “LC Troubleshooting” we started a series of articles on the topic of biomolecule separations, and discussed the use of biocompatible components, including column hardware and parts of the liquid chromatography (LC) flow path (1). Bioinert high performance liquid chromatography (HPLC) systems and column hardware are great potential solutions for the analysis of biomolecules that are sensitive to metal interaction. However, as a user, you may not have access to these systems, and even if you do it is prudent to anticipate separation problems that might arise due to different materials in the system. For example, a recent study of an iron-free HPLC system that utilized titanium pump heads documented the negative effect of leached titanium ions on peak shape and retention of metal-sensitive analytes (2). Therefore, it is best to utilize a system suitability test, for example, a mixture of standards that contains metal-sensitive compounds, that not only reflects the health of the chromatography system, but is also relevant to the molecules you are analysing. Importantly, even among nominally identical HPLC systems, the overall level of metal interaction that a sensitive analyte might experience is variable, depending on the condition of the system components themselves. In this article, we discuss mitigation strategies for traditional stainless steel HPLC systems when bioinert versions are either unavailable or insufficient for the analysis of metal-sensitive biomolecules.

What Can Be Done About Issues Related to Bioinertness?

Stainless steel (SS) and other chromium-based alloys are widely used materials in many industries, including the construction, automotive, energy, food, aerospace, and biomedical fields. Although SS is a rust-resistant alloy, passivation remains a critical step in maximising the corrosion resistance of components and parts fabricated from SS (3–5). Passivation is typically the first procedure implemented for improving the chromatography of metal-sensitive biomolecules using SS-containing HPLC components. In general, the term passivation describes any treatment of a metal surface that removes prior corrosion and prevents future corrosion for some period of time. There are different grades of SS, and the quality of the SS directly affects its resistance to corrosion. The two most utilized grades of SS are 304 and 316, with various types of 316 SS material utilized for different purposes. Grade 304 contains 18% chromium and 8% nickel, while grade 316 contains 16% chromium, 10% nickel, and 2% molybdenum. Importantly, the inclusion of the molybdenum alloy in grade 316 SS improves its corrosion resistance compared to grade 304 SS, particularly against saline- or chloride-containing solutions. However, even for high quality SS, corrosion can still occur at levels sufficient to cause trouble for bio-separations (6–9). Passivation procedures for SS usually involve chemical treatment that removes surface rust while maintaining alloyed chromium. Nitric, phosphoric, or citric acid are the typical chemicals of choice for passivation procedures. During the passivation procedure, a protective chromium oxide ($\text{Cr}_2\text{O}_3$) layer is formed on the SS surface, and the iron at the surface is dissolved selectively (10).
The concentration of Cr$_2$O$_3$ and the depth of the protective layer depend on the acid concentration, temperature, and duration of the passivation step (11). In a study that compared nitric acid, citric acid, and Citisurf (a commercially available citrate-based passivation agent) the authors found that the content of iron oxide (Fe$_2$O$_3$) rapidly decreases in the protective layer within the first 2 h of passivation, while chromium oxide content increases (12). The American Society for Testing and Materials (ASTM) International A967 standard, Standardization Specification for Chemical Passivation Treatments for Stainless Steel Parts, is an important industry document that specifies various passivation procedures for SS. Readers interested in learning more about SS passivation procedures will find this standard document to be a rich resource (13).

In an initial pilot study of our own, we passivated an HPLC system using 0.5 wt% phosphoric acid in acetonitrile:water (90:10), comparing chromatographic results before and after the acid wash. Here, peak shapes for the small molecule adenosine monophosphate (AMP) were symmetrical prior to passivation. However, for metabolites with more phosphate groups, such as adenosine diphosphate (ADP) and adenosine triphosphate (ATP), severely tailed peaks were observed prior to the acid wash. These peaks are all shown in the first row of Figure 1. After overnight flushing using the passivation solution, much sharper peaks were observed for both ADP and ATP. The mass spectrometry (MS) signal for ATP was also slightly higher following the phosphoric acid wash. In contrast, the signal for AMP was reduced after the wash, which could be due to residual phosphoric acid still in the system suppressing the ionisation of AMP. Furthermore, the peak shapes for some organic acids (malate and citrate) also improved following the phosphoric acid wash (Figure 1b). However, the peak shapes for malate and citrate, even after the passivation procedure, still showed a lot of tailing, leaving room for further improvement. In this case, additional steps were required to mitigate interactions between the analytes and metals in the HPLC system (14–16).

In a different study, we set out to examine whether SS columns could be passivated using the same phosphoric acid washing procedure. It is important to note that not all columns can be safely treated with these conditions, because the stationary phase may not be chemically stable at low pH (17). Please be sure to check the recommendations of the manufacturer regarding the appropriate mobile phase pH range for a given column. In this example, we studied the peak shapes of an intact monoclonal antibody (mAb) and cytochrome c analyzed using a size-exclusion column coupled to a UV detector. After the passivation solution was flowed through the bioinert HPLC system and SS analytical column overnight, a sharper chromatographic mAb peak with reduced tailing factor (Tf) was observed (Figure 2a and 2b). Interestingly, the use of PEEK-lined column hardware loaded with the same SEC particles still yielded the best chromatographic results with the lowest Tf (Figure 2c). This trend becomes more apparent with cytochrome c, (Figure 2d, 2e, and 2f). These results suggest that passivation alone may be insufficient and equipping the experimental setup with bioinert materials (for example, connecting capillaries and column hardware) would yield better results for biomolecules prone to interact with metal surfaces.

**When Passivation is Not Enough: Use Mobile-Phase Additives**

As described in the previous section, the principle aim of passivation procedures is to remove prior corrosion and prevent future corrosion for some period of time. However, passivation alone may not be enough to facilitate high quality biomolecule separations in situations where parts of an HPLC pump leach trace levels of metals (for example, titanium or iron) into the mobile phase (2,18), or when the sample matrix is contaminated with metals. Different types of metal chelators (compounds that sequester metal atoms) have been used as

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mobile-phase additives to improve separation performance for analytes that are sensitive to the presence of metals in the analytical system. These metal chelators have been used in a variety of ways including spiking them directly into samples, injecting them into the LC system between sample analyses, and using them as mobile phase additives. When they are used as mobile-phase additives, one must consider the target analytes for each specific application and how the mobile-phase additive could potentially interfere with the analysis.

For example, citric acid has been used as a mobile-phase additive to improve the analysis of phosphopeptides in reversed-phase separations (7). Ethylenediaminetetraacetic acid (EDTA) is another well known metal chelator that is effective for improving the peak shape of metal-sensitive metabolites separated using normal-phase chromatography (15,16) and for the separation of monoclonal antibodies using cation-exchange chromatography (CEX) (19). More recently, medronic acid was used as a mobile-phase additive to improve the peak shape and signal for polar metabolites and phosphopeptides (20). In Figure 3, medronic acid is also shown to improve the peak shape of fluorescently labelled N-glycans separated on an amide HILIC column. The later eluting structures each contain two sialic acid groups, giving them a strong tendency to interact with trace amounts of metal in the system. Rather than taking the system offline for passivation, the addition of a very low concentration of medronic acid to the aqueous mobile phase resolves the problem immediately. Furthermore, this benefit persists for at least one week after returning to the use of mobile phase without medronic acid.

**Potential Pitfalls of Using Mobile-Phase Additives to Improve Biomolecule Peak Shape**

Although mobile-phase additives are an attractive option to yield better bioanalytical results, a few caveats associated with this approach need to be considered.

**Ion Suppression:** It has been well documented that the use of EDTA as a mobile phase additive is associated with ion suppression effects that reduce the signal of target analytes when hyphenated with MS detection (17,20). When using mobile-phase additives, the benefit is that the passivation of an HPLC system can be continuously maintained, but it is important to keep in mind that the right dose of additive concentration is required for optimal analysis, and this must be determined empirically on a case-by-case basis. For example, use of medronic acid at high concentrations (for instance, 10 μM) can still cause ion suppression, and use of medronic acid at low concentrations (for example, 0.5 and 1 μM) may not yield the optimal chromatographic results (20).
Persistence in the HPLC System:
Another important consideration is whether the additive poses a risk to future work by slowly leaching from the LC system, even after switching to mobile phases that do not contain the additive. For example, EDTA has been reported to be retained on reversed-phase columns when used as a mobile-phase additive for phosphopeptide analysis (7). Moreover, due to EDTA’s low solubility under acidic pH conditions (0.1% formic acid), precipitation of EDTA has been observed at the ESI nebulizer needle, and can result in blockage of analytical columns; obviously these are both undesirable outcomes for any LC method. In contrast, citric acid was found to be more amenable to prolonged use as a mobile-phase additive (7).

Summary
In this installment of “LC Troubleshooting”, we have discussed approaches that can improve the analysis of biomolecules prone to strong interaction with metal components in LC systems or trace metals present in the sample flow path. The two methods that we described here include chemical passivation and use of metal chelators as mobile-phase additives. If corrosion or rusting of an LC system is suspected, the system should be passivated. Next, if applicable, mobile-phase additives could be used to chelate any trace metals leached from pump heads or other metal components, or metals present in the sample matrix. Lastly, bioinert instrument components and column hardware still represent the best option for preventing adsorption of proteins on instrument components and column hardware. In particular, the use of bioinert materials where the biomolecules may directly interact with these surfaces is recommended. For example, use of PEEK-lined capillaries between the injector and detector is recommended, as is the use of PEEK-lined column hardware to limit potential metal-interaction sites. Understanding the pros and cons of passivation approaches and mobile-phase additives should support the development of effective and robust methods for accurate and reproducible analysis of biomolecules.

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FIGURE 3: Separation of glycans released from a mAb on HILIC columns: (a) Gradient HILIC separation with acetonitrile in bottle B and an aqueous solution of 50 mM formic acid adjusted to pH 4.5 with ammonium hydroxide in bottle A; (b) Gradient HILIC separation with acetonitrile in bottle B and an aqueous solution of 5 µM medronic acid and 50 mM formic acid adjusted to pH 4.5 with ammonium hydroxide in bottle A; (c) overlaid chromatograms of the results are shown to illustrate the improved peak shape for the released mAb glycans. Figure axes labels are Acquisition Time (min) for x-axis and Response Units for y-axis.

(a) Control

(b) 5 µM Medronic Acid

(c) Overlay

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Industrious Innovations in Polymer Analysis

LCGC Europe spoke to Ton Brooijmans, from DSM Coating Resins in The Netherlands, about the array of innovative techniques he has recently implemented in his laboratory to analyse polymers. These include the development of a selective derivatization technique followed by size-exclusion chromatography (SEC) to analyze polymeric carboxylic acid functionality, the benefits of non-aqueous ion-exchange chromatography (NAIEC) for analysing synthetic macromolecules, and the important role of pyrolysis gas chromatography (Py-GC–MS) in polymer analysis. Brooijmans also discusses future trends in this application area.

Interview by Alasdair Matheson, Editor-in-Chief, LCGC Europe

Q. You recently developed an innovative selective derivatization technique followed by size-exclusion chromatography (SEC) to analyze polymeric carboxylic acid functionality for heterogeneity analysis studies (1). Why is this type of analysis important?

A: In the field of polymers – as in society at large – we need to make more sustainable choices. There is an ever-increasing shift from traditional solvent-borne coating systems towards more “ecologically-friendly” water-borne polymers. In many water-borne polymer systems, carboxylic acid-functional monomers are incorporated to develop water-dispersibility of non-water-soluble polymer particles. These acid functionalities in the polymeric backbone are mainly responsible for the polymer particle size, shape, and stability and are thus a very important parameter in the development of a coating application. Although there is a vast field of polymer analysis or polymer separation techniques available, little is known about the actual incorporation of such functional monomers. If we can understand the distribution of these monomers along the polymer chain better, we have tools to steer the development of new and more efficient water-borne polymer systems. The technique we devised here is one of the tools that we recently developed to obtain more insights into the incorporation of acid-functionality in these polymer types.

Q. What is innovative about this approach and what benefits does it offer the analyst? What aspect was most challenging when developing this method?

A: The key aspect of this approach is the specific derivatization of the acid functionality in the polymers. Many analysts in the field of chromatography use derivatization for certain applications, mainly in the field of small molecules. Derivatization of polymers is rather challenging with respect to derivatization efficiency over the full molar mass range, and therefore, this approach is less frequently practiced for large polymers. We have used a class of chemicals, phenacylbromides, to selectively transform the carboxylic acid-functionality in the polymers to phenacylesters. These phenacylester moieties show a very distinct UV-absorption. By combining a SEC setup with both refractive index (dRI) and UV detection, we have two concentration traces: dRI for the polymer concentration, and UV for the (derivatized) acid concentration. Next to the usual molecular weight distribution...
we would get from a traditional SEC-analysis, we can also obtain the content of incorporated acidic monomer and the distribution of these monomer types over the molecular weight. This gives us more insight in the actual incorporation of these monomers, and can possibly link polymer synthesis conditions to polymer properties. A clear advantage is that this approach can be performed in any polymer analysis laboratory because it uses generic chemicals and LC equipment.

Ideally, a derivatization step in any kind of analysis should be selective, complete, reproducible and fast. It has proven to be quite a challenge to find the right chemical approach to tick all these boxes, but the phenacylbromide reagent with a tertiary amine catalyst using N-methyl pyrrolidone as solvent quickly showed its value. The derivatization agent specifically reacts with carboxylic acid functionality, has more than 99% efficiency which is reached directly upon simple mixing of the dissolved polymer with the reagent/catalyst. The ease of use of this approach is another clear advantage for polymer analysts. The general idea of this selective derivatization approach can be extended for other polymer functionalities, provided that the appropriate reagent (conditions) can be identified.

Q. You also use targeted labelling of carboxylic acid functionality followed by pyrolysis gas chromatography (Py-GC) for acid monomer analysis in water-borne polymers. What advantages does Py-GC offer here (and in general)?
A: Pyrolysis-GC is a very powerful characterization technique, which is able to provide detailed compositional information of known or unknown polymers by thermally breaking down polymers into their monomeric units (or derivatives thereof), which are often volatile enough to be separated and characterized by GC. Even solid samples may be introduced into the pyrolysis chamber, eliminating the need for sample solubilization. Pyrolysis-GC can be performed fast, is reproducible, and can reveal even low concentrations of incorporated species.

The mentioned derivatization protocol in the SEC approach is also of value in the analysis of polymer using pyrolysis-gas chromatography mass spectrometry (Py-GC–MS) (2). Under pyrolysis conditions, materials which bear active hydrogens, such as amine-, hydroxyl- and carboxylic acid functionalities have the tendency to undergo unwanted side-reactions such as dehydration and decarboxylation. In many cases, these side-reactions result in the formation of non-volatile residues, resulting in a loss of information from the pyrolysis analysis because you are no longer looking at the complete composition. If one is able to derivatize these active hydrogen sites with a non-functional group, such as an alkyl-, phenacyl- or trimethylsilyl group, these side reactions can be negated. Due to the water-borne character of many of the samples we analyze, many alkylation-or silylation approaches were found to be less suitable, but by applying the described phenacylation, monomers that were once not analyzable by pyrolysis now appear in the pyrogram. Next to the overall composition, we can now discern different acidic monomer types at low levels of incorporation.

Q. You also devised an inventive approach to separate synthetic macromolecules by non-aqueous ion-exchange chromatography (NAIEC) (3)? Why did you select ion-exchange chromatography (IEC) in this case?
A: The presence of acidic monomers in polymer systems and the deprotonation of these moieties in aqueous environments essentially results in a polyelectrolyte. Our plan was to exploit the presence of these charged groups to separate synthetic macromolecules much like one would separate proteins (3). Obviously, our polymer systems are not water-soluble, which posed some serious analytical challenges. For instance, pK_a of the acidic monomers is shifted to considerably higher values in organic solvents compared to water, which results in essentially neutral carboxylic acids in non-aqueous conditions. The combination of N-methyl pyrrolidone solvent (which has a high dielectric constant, \( \varepsilon = 32.0 \), enabling the dissociation of ion pairs into free ions) with a so-called superbase (tetramethylguanidine) results in...
dissolved macromolecules with anionic functionalities. Using a polymeric strong anion exchange (SAX) high performance liquid chromatography (HPLC) column, combined with high-temperature evaporative light scattering (HT-ELSD) as detector, we were able—for the first time ever—to separate these macromolecules selectively by their number of incorporated anionic groups (4).

Q. What benefits does NAIEC provide in this application?
A: Chromatographic techniques that are used to characterize synthetic macromolecules (aside from SEC/hydrodynamic chromatography [HDC]) separate mainly on enthalpic differences between mobile and stationary phase. Most commonly, normal or reversed-phase liquid adsorption chromatography (LAC) approaches are used for the characterization of compositional differences between samples (5–7). A major drawback of these approaches is that this enthalpic difference applies to the complete polymer—all monomer types—or polarities will have their own contribution to the overall enthalpy of the system. Although very useful for copolymers, these separations fail to accurately describe compositional separations for more complex polymer systems (and most industrial copolymer systems are very complex). The ion-exchange approach we describe selectively separates macromolecules on their (deprotonated) acid monomer units, regardless of the polarity of the comonomers. This can reveal more information on polymer heterogeneity, specifically separating polymers on a single functionality: something that was not possible before. It is therefore a very useful addition to the portfolio of polymer separation techniques.

Q. Could NAIEC be useful in other polymer applications?
A: As single-parameter polymer separations are very rare, the ion-exchange approach can provide different distribution information than is currently available. However, like SEC or LAC, it is still a one-dimensional approach. The coupling of this technique with other polymer separation techniques could further enhance its value. We are working towards incorporating this technique in two-dimensional LC approaches, such as NAIEC×SEC and NAIEC×LAC. This two-dimensional approach can possibly unravel more information on the polymer microstructure.
Q. From an analytical perspective, are there any developments in polymer analysis and in separation science generally, that you are finding exciting at the moment?

A: We need to understand our increasingly complex copolymers better, especially if we want to accelerate the transition into more sustainable materials, such as replacing oil-based monomers with bio-based alternatives, reducing carbon footprint and more. Hyphenation is the magic word, and especially the coupling of so-called single-parameter separations (that is, NAIEC × SEC) which reveals insight into the correlation of specific polymer functionality distributions. Over the last few years, tremendous advances have been made in solving fundamental difficulties and exploring new separations and their coupling in the applicability of multi-dimensional separation methodologies (8,9). These approaches will conquer more and more ground in many laboratories in the years to come. In conclusion, the continuous development in the field of multidimensional separation techniques is expected (at least in the field of polymer analysis) to become an indispensable tool to make sure we are able to further develop quality coating solutions with a favourable ecological profile.

References
ACD/Labs

Company Description
ACD/Labs provides software for analytical R&D. We help scientists plan, understand, and report their experiments with tools that integrate data from multiple techniques, instruments, and vendors. Our software handles experimental data from chromatography, NMR, mass spectrometry, optical techniques, and more. We also provide tools for chromatographic method development, physicochemical-property prediction, and product-development tracking.

Our software is used by companies worldwide, in industries like pharma/biotech, chemicals, consumer packaged goods, agrochemicals and petrochemicals, and in government and academic institutions.

Chief Chromatographic Techniques Supported
- Gas chromatography
- Liquid chromatography
- Ultrahigh/High performance liquid chromatography
- Hydrophilic interaction chromatography
- Capillary electrophoresis
- Ion exchange chromatography
- Reversed-phase chromatography
- Normal-phase chromatography

Markets Served
Our clients and partners include R&D organizations in pharmaceuticals, biotechnology, fine chemicals, specialty chemicals, CROs, CMOs, food & beverage, consumer packaged goods, agrochemicals, petrochemicals, academia, and government. We serve clients worldwide.

Major Products/Services
ACD/Labs provides software for analysing data from LC/UV/MS, GC/MS, NMR, and optical experiments. Our platform, Spectrus, handles data formats from all major instrument vendors. Based on Spectrus, our chromatography products help scientists assemble disparate data for QbD method development. These products include:
- ACD/Method Selection Suite for method development through prediction of physicochemical properties and simulation of gradient, resolution, and temperature effects.
- ACD/AutoChrom for direct control of LC instruments, to automate method development according to user-guided strategies.

Advanced Chemistry Development, Inc. (ACD/Labs)
Venture House, 2 Arlington Square, Bracknell, UK, RG12 1WA
E-mail info@acdlabs.com
Website www.acdlabs.com
Number of Employees Europe: 130
Outside of Europe: 50
Year Founded 1994
Advanced Materials Technology

Company Description
Founded in 2005, Advanced Materials Technology is an innovative product development and manufacturing company in the separation sciences focused on groundbreaking technology to solve the unsolvable! From pioneering Fused-Core® technology with the first commercially available sub-3-µm superficially porous particle, the HALO® product line has revolutionized HPLC separations for small molecule and large molecule separations.

With over 120 years of ingenuity in design and manufacturing, Advanced Materials Technology continues to be a leader in novel superficially porous particle development enabling high efficiency and reliability for scientists involved in both small and large molecule separations.

Chief Chromatographic Techniques Supported
- Reverse-phase (U)HPLC separations
- HILIC separations
- Small molecule (U)HPLC separations
- Large molecule (U)HPLC separations

Markets Served
- Pharmaceutical
- Biopharmaceutical
- Food and beverage
- Environmental
- Industrial

Major Products/Services
At Advanced Materials Technology we combine our 150 years of silica engineering experience to deliver HALO® superficially porous particle (U)HPLC columns. Unlike other companies we are solely focused on the development of this technology.

Facilities
Advanced Materials Technology, located in Wilmington, Delaware, USA, consists of R&D, applications, QA/QC, manufacturing, and marketing departments. Chemists and engineers operate in fully equipped state-of-the-art laboratories. AMT is a company of innovators that continues to grow and deliver enabling separation materials to market. Our incredible team is our greatest resource.

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Website
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Year Founded
2005
Air Products

Company Description
Air Products is one of the world’s largest merchant gas and chemicals companies, offering an extensive range of industrial and specialty gases. Our supply network and world-class logistical capabilities allow us to respond rapidly to the demands of our customers wherever they are.

The company had fiscal 2018 sales of $8.9 billion from operations in 50 countries. Approximately 16 000 passionate, talented and committed employees from diverse backgrounds are driven by Air Products’ higher purpose to create innovative solutions that benefit the environment, enhance sustainability, and address the challenges facing customers, communities, and the world.

Facilities
We are geographically diversified with over 750 production facilities and operations across 50 countries.

Chief Chromatographic Techniques Supported
- Gas chromatography (GC)
- Gas chromatography with mass spectrometry (GC–MS)
- Gas chromatography with flame-ionization detection (GC–FID)
- Gas chromatography with electron-capture detection (GC–ECD)

Markets Served
Many industries, including analytical, pharmaceutical, electronics, and petrochemical, benefit from the unique properties of specialty gases that help to improve yields, optimise performance, and lower costs. Specialty gases represent gases that are rare or ultra-high purity (99.995% and above).

Major Products/Services
From the specialty gases range Air Products’ ultra-high purity gases are exclusively supplied from our BIP® cylinders; this combination produces gases that are up to 300 times purer than normal gas cylinders. By starting with ultra-pure gas and delivering it through our award-winning BIP® technology, we can guarantee the lowest levels of impurities available in the marketplace today. BIP® gases are the ideal choice for gas chromatography where impurities in the carrier gas can potentially cause baseline noise and damage in the column.
**Company Description**
For over 30 years Antec Scientific has been the world’s leading supplier of analytical instrumentation based on electrochemistry (EC). Antec’s line of instruments include electrochemical detectors (ECD), analyzers built on high performance liquid chromatography (HPLC) with ECD, and electrochemical reactors for use with mass spectrometry (EC–MS) and for electrochemical synthesis.

**Chief Chromatographic Techniques Supported**
- HPLC–ECD
- UHPLC–ECD
- Electrochemistry-MS (EC–MS)
- Electrochemical synthesis

**Markets Served**
For sensitive analysis of carbohydrates in F&B, lactose intolerance, etc., high-performance anion exchange chromatography with pulsed amperometric detection is the technique of choice.

The analysis of **antibiotics** according to USP and EP monographs is another market served, alongside the sensitive analysis of **neurotransmitters** in brain microdialysates.

Electrochemistry-MS allows for superior characterization of immunotherapeutics (mAbs) in MS **proteomics**. In drug metabolism EC–MS has been applied for fast prediction of drug metabolism including rapid metabolite synthesis.

**Major Products/Services**
**DECADE™ Elite Electrochemical Detector**
The DECADE™ Elite has become the benchmark in detection and can be used with any third party HPLC system. Different flow cells are available to cover a broad range of applications.

**ALEXYS™ Analyzers**
They consist of HPLC with ECD and are built for highest performance and ease-in-use. Guaranteed applications have been developed for neurotransmitter, clinical/diagnostics, food/beverage, environmental, and drugs/pharmaceuticals analyses.

**ROXY™ EC System for MS and Synthesis**
The on-line coupling of EC–MS allows for direct measurement of the generated oxidation or reduction products. Applications range from proteomics, drug metabolism, to environmental degradation testing including the rapid synthesis of metabolites and degradants.

**Facilities**
R&D along with production are housed in the Antec Scientific headquarters located in Zoeterwoude, The Netherlands. The facility is dedicated to the continuous development of EC instruments and applications and ensures stringent quality control guidelines. The USA market is directly served by Antec Scientific’s subsidiary located in Boston, Massachusetts.

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**Website**
www.AntecScientific.com

**Number of Employees**
Europe: 17
Outside of Europe: 3

**Year Founded**
1990
Company Description
Avantor®, a Fortune 500 company, is a leading global provider of mission-critical products and services to customers in the biopharma, healthcare, education & government, and advanced technologies & applied materials industries. Our portfolio is used in virtually every stage of the most important research, development, and production activities in the industries we serve. One of our greatest strengths comes from having a global infrastructure that is strategically located to support the needs of our customers. Our global footprint enables us to serve more than 225,000 customer locations and gives us extensive access to research laboratories and scientists in more than 180 countries.

For more information, visit avantorsciences.com or vwr.com.

Chief Chromatographic Techniques Supported
• HPLC
• UHPLC
• LC–MS
• GC
• Flash chromatography
• Preparative chromatography
• TLC
• FPLC

Markets Served
Through our channel brand, VWR, part of Avantor, we offer an integrated, seamless purchasing experience that is optimized for the way our customers do business in all industry segments including:
• Pharma
• Biopharma
• Food and beverage
• Education
• Industry
• Clinical

Major Products/Services
Our extensive LC–MS portfolio empowers discovery, development, and routine analysis through cutting-edge chromatography solutions covering the whole workflow including our range of Avantor® ACE® HPLC and UHPLC columns, high quality solvents and consumables, VWR Hitachi HPLC and UHPLC systems, and bespoke services.

Facilities
Our footprint provides us full proximity to the development and manufacturing operations of our customers. We have more than 200 manufacturing, distribution, and sales centres in over 30 countries, including 7 innovation centres, conducting both proprietary and customer-specific development activities, 13 cGMP manufacturing facilities supporting our material technology platforms, and 19 ISO-certified distribution facilities.

Avantor
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E-mail
Chromsupport@avantorsciences.com
Website
www.avantorsciences.com
www.vwr.com
Number of Employees
Europe: 5000+
Outside of Europe: 12 000+
Year Founded
1904
Biotech AB

Company Description
Biotech supplies innovative fluidic components to instrument manufacturers, distributors and end-users around the world. As a Global Premium Distributor for IDEX we have special know-how about their assortment and can provide you with the right mix of products for a successful fluidic system.

No troubles with bubbles: We specialize in chromatography and finding solutions to issues with gases and bubbles in fluidic systems. By using our advanced degassers, the laboratory can optimize the performance of its analytical instruments and chromatographic equipment. Our degassing solutions save the industry both time and money by avoiding production disruptions caused by bubbles in the fluidic lines.

Chief Chromatographic Techniques Supported
- HPLC
- UHPLC
- GPC
- Preparative chromatography
- SFC
- ION-chromatography

Markets Served
- OEM-customers
- Instrument Developers
- Distributors
- End-users

Major Products/Services
- Column Hardware
- Degassing & Debubbling
- DEGASi Stand Alone Degassers
- Detectors
- Fittings & Connectors
- HPLC/UHPLC Columns
- HPLC Filters & Frits
- Knitted Delay/reaction Coils
- Level Sensor
- Pumps
- Smart Saver – USB Solvent Recycler
- Tubing
- Valves
- OEM Solutions
- Service and Support

Facilities
Biotech AB (HQ) is situated on the Onsala peninsula on the Swedish Westcoast near Gothenburg City and Landvetter International Airport. We operate globally and have subsidiaries in US and Japan to give you the best service and support.
Ellutia

Company Description
Ellutia offers a range of gas chromatographs, GC accessories, software, and consumables. Ellutia’s instruments are designed and manufactured in the UK at the company headquarters. The instruments are designed to be compact with great energy efficiency, whilst also delivering industry standard analytical performance. Ellutia works closely with its customers and regularly produces fully customized systems tailored to their individual requirements rather than delivering off-the-shelf products. It is this working relationship with customers and the flexibility to adapt that sets Ellutia apart from other GC manufacturers.

Chief Chromatographic Techniques Supported
• Gas chromatography
• Ultra-fast gas chromatography
• Multidimensional chromatography
• Hyphenated chromatography techniques

Markets Served
Ellutia’s products can be found in a wide range of industries including:
• Brewing and malting
• Food testing
• Packaging testing
• Permeation testing
• Education
• Forensic laboratories
• Agro-chemical
• Cosmetics
• Cannabis analysis
• Toy production
• High purity gas
• Natural gas
• Environmental testing
• Defense and security

Major Products/Services
• Custom chromatography systems: Ellutia will work with the customer to develop bespoke chromatography solutions that cannot be addressed by off-the-shelf instruments.
• 200 Series GC: A compact and versatile single channel gas chromatograph.
• 500 Series GC: Unique gas chromatography allowing conventional, fast, and ultra-fast chromatography.
• High Purity Gas Analyzer: A rack-mounted GC for detecting impurities in gas to extremely low levels.
• 800 Series TEA: Nitro, nitroso, and nitrogen detector that can be interfaced with almost any GC system.
• Ellution Chromatography Data Station: Software for collecting and processing data from a GC system.
• 7000 Flowmeter: A compact handheld flowmeter for accurately setting flows on a GC system.

Facilities
Ellutia’s new purpose-built headquarters are located just outside Cambridge in the UK. This facility hosts the main research and development laboratories and is where all of the instruments are manufactured and tested. Outside of the UK, Ellutia also has an office in Germany and a sales and service organization in the USA.

Ellutia
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Website
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Number of Employees
Europe: 21
Outside of Europe: 3
Year Founded
1994
Frontier Laboratories Ltd.

Company Description
Frontier Laboratories Ltd., is a world-leading family-owned company in analytical pyrolysis, based in Japan. For three decades, the focus of the company has been on research, development, and production of analytical pyrolyzers for materials characterization, μReactors for catalyst screening, and high-temperature stable Ultra Allloy (UA) columns for GC–MS analysis of polymeric materials.

Frontier Laboratories also produces chromatographic accessories to support and/or automate Pyrolysis-GC–MS-based characterization of polymers or other materials.

Frontier Laboratories collaborates worldwide with factory-trained distribution partners who represent GC–MS vendors in specific regions. These business partners sell and support Frontier Laboratories’ products.

Chief Chromatographic Techniques Supported
• Pyrolysis-GC/MS
• Pyrolysis-GC/FID
• TD–GC/MS
• EGA-MS
• Reactive Pyrolysis-GC/MS

Markets Served
Frontier Laboratories serves many markets, including automotive, coating, energy, petrochemistry, electronics, forensic and cultural heritage, environment, geochemistry, adhesives, elastomers, and catalysts.

Major Products and Services
The **multishot pyrolyzer EGA/PY-3030D** (Figure 1) for material characterization enables single shot pyrolysis, as well as thermal desorption, heart cut, and evolved gas analysis, according to Frontier Laboratories’ method map (Figure 2). Extraordinary reproducibility is ensured by the accurate temperature controlled ceramic heater (+/- 0.1 °C) and inert surfaces.

**μ-Reactors** for rapid characterization of catalysts concerning temperature, surface area (contact time), atmosphere, pressure, effective lifetime, and activity regeneration.

**Ultra-Alloy** (UA) capillary columns with various separation phases and high flexibility, high temperature, and contamination resistances.

**F-Search** (Ver. 3.6) is a patented polymer and additive search software and libraries with 1000 polymers and 500 additives stored.

Facilities
Headquarter and production are based in Koriyama, Fukushima, Japan. Technical and marketing offices are located in North America, Germany, Singapore, China, Russia, and Japan.

**Frontier Laboratories Europe**
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**E-mail**
michael@frontier-lab.com
**Website**
www.flab-europe.com
**Number of Employees**
Europe: 1
Outside of Europe: 60
**Year Founded**
1991
Company Description
GERSTEL develops and produces automated sample preparation and sample introduction accessories for GC–MS and LC–MS. GERSTEL technology enhances productivity, reduces solvent use, and significantly improves detection limits. GERSTEL is the leading Agilent Technologies Premier Solutions Partner worldwide, providing modules and complete systems with integrated software control. GERSTEL accessories are compatible with all standard systems.

Chief Chromatographic Techniques Supported
• Autosamplers for GC–MS and LC–MS
• Automated sample preparation for GC–MS and LC–MS
• Filtration, centrifugation, and evaporation
• Liquid addition, derivatization, generating standards
• Automated solid-phase extraction (SPE)
• On-line SPE with disposable cartridges (SPEXos)
• Dynamic headspace, thermal desorption, and pyrolysis
• Headspace and solid-phase microextraction (SPME)
• Twister and Stir Bar Sorptive Extraction (SBSE)
• PTV and large-volume injection
• Automated Liner Exchange (ALEX)
• Multicolumn and multidimensional GC systems
• Olfactory detection and preparative fraction collection

Markets Served
• Food, beverage, flavour, and fragrance
• Personal care and cosmetics
• Forensic
• Metabolomics
• Polymers and packaging
• Automotive material emissions
• Environmental and industrial hygiene
• Pharmaceuticals

Major Products/Services
• MultiPurpose Sampler (MPS): Autosampler and sample preparation robot for GC–MS and LC–MS
• Filtration, Centrifugation, Addition of standards
• Extraction, solvent evaporation, weighing
• GERSTEL SPE based on std. dimension cartridges
• Thermal desorption of VOCs/SVOCs up to n-C40+
• Headspace and solid-phase microextraction (SPME)
• Dynamic HeadSpace (DHS) concentration of VOCs
• Stir Bar Sorptive Extraction (SBSE) GERSTEL Twister

Facilities
Steady growth over 50 years has resulted in the need for ever-larger facilities. The energy-efficient GERSTEL headquarters in Mülheim an der Ruhr, Germany, were inaugurated in 2007 with room to grow. Offices with application laboratories are located in Germany, the US, China, Singapore, and Japan. These, along with partner laboratories in other territories, enable GERSTEL to support its unique solutions worldwide.

GERSTEL
Eberhard-Gerstel-Platz 1, 45473 Mülheim an der Ruhr, Germany
E-mail gerstel@gerstel.com
Website www.gerstel.com
Number of Employees
Europe: 170
Outside of Europe: 50
Year Founded
1967
Company Description
Goodfellow is a leading global supplier of specialist materials to meet the research, development and production requirements of science and industry. The Company has an extensive range of over 70,000 catalogue products in multiple forms available off the shelf, most subject to free delivery within 48 hours and with no minimum order quantities.

With over 6,000 customers supported by a worldwide network of offices, agents and distributors, Goodfellow also offers a comprehensive range of bespoke processing services. The team is comprised of fellow scientists and engineers with extensive knowledge of materials and processing.

Chief Chromatographic Techniques Supported
The Company supports the industry with research materials used within general research and development within the scientific community.

Markets Served
Goodfellow materials are used across a wide range of science, industry, and R&D applications and markets, from electronics and engineering to pharmaceutical and academia.

Major Products/Services
With a portfolio of over 70,000 catalogue products in multiple forms, Goodfellow supports science and industry with multiple research materials and offering technical knowledge to customers.

Facilities
Goodfellow has offices around the world, including France, Germany, USA and China. The Company has a worldwide network of distributors supporting our customers.
Company Description
Greyhound Chromatography has been supplying high quality chromatography consumables to Research and Analysis laboratories around the world for 39 years. Greyhound’s Managing Director, Paul Massie, founded the company which operates from its UK facility, located in Birkenhead, Merseyside. Greyhound Chromatography is a leading global manufacturer and distributor of the highest quality chromatography columns, certified reference standards and materials, research chemicals, solvents, reagents, and laboratory consumables available today. Greyhound supplies scientists working in all disciplines, including HPLC and Gas Chromatography. Greyhound Chromatography is probably the leading single source of chromatography products and chemical standards anywhere in the world.

Chief Chromatographic Techniques Supported
All chromatography techniques, including:
- Chiral chromatography
- Derivatives analysis
- Environmental analysis
- GC and GC–MS
- LC–MS
- HPLC and UHPLC
- ICP, ICP–MS
- AA (Atomic Adsorption) spectroscopy
- Ion chromatography
- SPE and SPME
- TLC

Markets Served
Testing reference standards, chemicals, solvents and reagents, laboratory consumables, for analysis and research & development laboratories:

**Cosmetics**
**Environmental**: water, air, soil
**Energy**: electricity, gas, solar, atomic, renewables
**Food**
**Fragrance**: including additives to consumer products
**Chemical**: anything classed as a chemical that is present in the manufacture or use of consumables
**Petrochemical**: oil, gas, petroleum
**Pharmaceutical**: testing standards

Major Products/Services
Analytical syringes, balances and scales, organic/inorganic reference standards and materials, diluters and dispensers, fittings, flash cartridges, gas filters, gas purifiers/filters/traps, gas regulators, GC columns, GC derivatisation reagents, GC ferrules; seals & inlet liners, HPLC columns; pumps, column heaters & lamps, maintenance tools, membrane filters, TLC consumables, pipettes and tips, prep silica, reagents, solvents, solvent safety solutions, SPE cartridges, syringe accessories, syringe filters, tubing, valves, vials/caps/septa, vial accessories, well plates.

Facilities
Greyhound Chromatography operates from a warehouse and office facility, with 5,500 sq ft capacity. Approx. 3,500 sq ft are used as warehouse storage with temperature controlled zones that include refrigerators and a freezer for product storage. Temperatures are recorded and monitored. An external temperature-controlled container is used to store flammable liquids.

Greyhound Chromatography and Allied Chemicals
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E-mail
info@greyhoundchrom.com
Website
www.greyhoundchrom.com
Number of Employees
15
Year Founded
1981
HILICON AB

Company Description
HILICON AB is a leading company in developing and manufacturing hydrophilic interaction liquid chromatography (HILIC) products for the separation of polar and hydrophilic compounds. Four column chemistries in UHPLC and HPLC formats, iHILIC®-Fusion, iHILIC®-Fusion(+), iHILIC®-Fusion(P), and iHILIC®-(P) Classic, provide customized and complementary selectivity, excellent durability, and ultralow column bleeding. The columns are versatile for the LC–MS analysis of polar compounds in “omics” research, food and beverage analysis, pharmaceutical discovery, environmental studies, and clinical diagnostics. In addition, HILICON also offers iSPE®-HILIC cartridges and 96-well plates for HILIC sample preparation in solid phase extraction (SPE). These are very useful for studies in glycans, glycopeptides, and other polar compounds.

Chief Chromatographic Techniques Supported
• HILIC
• UHPLC
• HPLC
• LC–MS
• HILIC SPE

Markets Served
Our high-performance HILIC products are used in various applications related to the analysis of polar compounds. The major markets are:
• Omics research, that is, metabolomics, proteomics, lipidomics, glycomics
• Pharmaceutical
• Clinical diagnostics
• Life science
• Food and beverage
• Environmental
• Forensic

Major Products/Services
• iHILIC®-Fusion, silica-based column, pH 2–8; 1.8, 3.5, and 5 µm
• iHILIC®-Fusion(+), silica-based column, pH 2–8; 1.8, 3.5, and 5 µm
• iHILIC®-Fusion(P), polymer-based column, pH 1–10; 5 µm
• iHILIC®-(P) Classic, polymer-based column, pH 1–10; 5 µm
• iSPE®-HILIC, in single cartridge and 96-well plate
• HILIC method development for separation of polar compounds

Facilities
HILICON started its business in Umeå Biotech Incubator inside Uminova Science Park in Umeå, Sweden in 2014. In 2018, we moved out from the incubator and steadily grew our HILIC chromatography business and facility size in Uminova Science Park. We moved into a new, wholly renovated site in spring of 2020.

HILICON AB
Tvistevägen 48A, SE-90736 Umeå, Sweden
E-mail info@hilicon.com
Website www.hilicon.com
Number of Employees Under 10
Year Founded 2014
Company Description
ionBench, manufacturer of mobile benches for scientific instruments, and especially designed for LC/GC and MS. We are the expert in standard and custom designed LC and MS laboratory furniture. Our products are designed to ease the day-to-day use of your LC/GC and MS, by providing a significant number of features that makes your working conditions better:

- Quieter environment with an integrated noise reduction enclosure, including cooling
- Fully movable bench
- Vacuum pumps stored on a specific patented absorbing vibration rack
- Better ergonomics and security in labs, by using a bench designed for your application taking into consideration your specific requirements!

Markets Served
ionBench supplies pharmaceutical, environmental, clinical and university laboratories all over the world.

Major Products/Services
Bench MS: dedicated benches with many features for your mass spectrometer.
Bench LC: electronically height-adjustable benches; improves safety and LC/MS performance.
ionDesk: electronically height-adjustable desk; improves your working conditions.
ionLCdesk: work smarter by combining LC and informatics on a height adjustable bench. Custom benches also available.
KNAUER Wissenschaftliche Geräte GmbH

Company Description
Based in Berlin, Knauer has been serving the sciences since 1962. With a highly qualified staff of more than 140 employees, of which 40% are women, we develop and manufacture scientific instruments of superior quality like liquid chromatography systems and components, including:

- Analytical HPLC/UHPLC
- Preparative HPLC
- Fast protein liquid chromatography (FPLC)
- Multi-column chromatography/SMB
- Osmometry

Knauer valves, pumps, detectors, and other components are also used for many liquid handling processes aside from HPLC and are popular with industry customers who want custom solutions (OEM).

We support technological advancement today and in the future.

Chief Chromatographic Techniques Supported
- Analytical HPLC and UHPLC
- Preparative HPLC
- Fast protein liquid chromatography (FPLC)
- Simulated moving bed chromatography (SMBC)
- Sample preparation

Markets Served
Knauer HPLC systems and components are used in research and development, quality control, and production laboratories around the world. Customers are typically governmental and industrial organizations as well as universities.

The main fields of application include chemical, pharmaceutical, life science, and food research (analysis and purification) as well as the environmental sector.

Knauer also manufactures most of its product range for a number of OEM customers.

Major Products/Services
- AZURA Analytical HPLC and UHPLC systems providing powerful and adaptable solutions
- AZURA Bio purification systems for protein cleaning tasks (FPLC)
- AZURA Preparative HPLC for small molecule purifications
- AZURA SMBC systems for continuous chromatography
- High-pressure dosing/metering pumps
- Flow-through monitoring/detection
- Method development service
- Maintenance programs
- KNAUER academy for chromatography training
- Rent-an-expert

Facilities
Knauer develops, manufactures, and markets its complete line of instruments at its headquarters in Berlin, Germany. The products are distributed to more than 60 countries through a worldwide network of dealers, who receive regular training in Berlin. Sustainability and corporate responsibility are a matter of the heart to Knauer.

KNAUER Wissenschaftliche Geräte GmbH
Hegauer Weg 38, 14163 Berlin, Germany
E-mail info@knauer.net
Website www.knauer.net
Number of Employees ~140
Year Founded 1962

LCGC Europe August 2020
Company Description
Since 1911, MACHEREY-NAGEL has represented high quality, innovation, and reliability in analytical chemistry and the life sciences. As one of today’s leading manufacturers, MN offers a broad range of products for chromatography, filtration, rapid tests, water analysis, and bioanalysis.

MN’s expertise in the manufacture of chromatography media is based on many years of experience in silica technology. The development of the spherical HPLC silica NUCLEOSIL® and the introduction of commercially available ready-to-use TLC plates and sheets are just two milestones emphasizing the pioneering tasks of MN in promoting these separation techniques.

Chief Chromatographic Techniques Supported
- SPE and flash chromatography
- HPLC
- TLC
- GC
- Chromatographic accessories
  (for example, syringe filters, vials, and caps)

Markets Served
MN serves laboratories all over the world with HPLC, GC, and SPE columns, TLC plates and sheets, syringe filters or suitable vials and caps. Customers from many different industries (for example, the food and beverage industry, pharmaceutical industry and healthcare, chemical industry, institutes for environmental analysis, biotechnology, universities, and research institutes) benefit from optimal and reliable solutions for analytical tasks in method development and routine analysis.

Major Products/Services
NUCLEOSIL®, one of the first spherical silica gels in the 1970s, is still packed in stainless steel columns by MN. These columns with various C<sub>18</sub> modifications are reliable workhorses and are validated in many drug testing methods. In recent years, new highly pure and ultra-spherical HPLC and UHPLC silica gels followed. Today, the product range of totally porous NUCLEODUR® and fused-core NUCLEOSHELL® columns comprise more than 25 stationary phases, targeted to daily routine analysis as well as for method development in HPLC. More information: www.mn-net.com/HPLC

MACHEREY-NAGEL, a pioneer in thin-layer chromatography, is still manufacturing glass plates as well as aluminium and plastic sheets coated with silica gels and other sorbents for TLC and HPTLC. The modern glass plates SIL HD and Nano-SIL HD are characterized by outstanding dyeability, good wettability, and abrasion resistance as a result of an optimized binder system. More information: www.mn-net.com/TLC

Classical CHROMABOND® silica gel phases with various modifications (for example, C<sub>18</sub>, C<sub>8</sub>, NH<sub>2</sub>, OH, CN) and modern polymeric resins are widely used for sample preparation in environmental analysis, food safety control, or clinical applications. The hydrophilic-lipophilic balanced polymeric SPE adsorbent CHROMABOND® HLB and the CHROMABOND® HR-Xpert line of polystyrene-divinyl based reversed-phase and mixed-mode ion-exchange resins offer a full toolbox of innovative SPE products. More information: www.mn-net.com/SPE

Facilities
Branches in France, Switzerland, and the United States, as well as a globally operating network of distributors in more than 150 countries, ensure worldwide availability of MN products and services.

MACHEREY-NAGEL GmbH & Co. KG
Neumann-Neander-Str. 6-8, 52355 Düren, Germany
E-mail
info@mn-net.com
Website
www.mn-net.com
Number of Employees
Europe: 700
Outside of Europe: 20
Year Founded
1911

www.mn-net.com
Markes International

Company Description
Markes International, an industry leader in extraction and enrichment technology for trace organic analysis, manufactures a range of instrumentation and software that enhances the analytical capability and productivity of GC–MS systems.

Chief Chromatographic Techniques Supported
- Thermal desorption (TD) as a sample concentration and introduction technique for GC
- Automated sample preparation and concentration (headspace, headspace-trap, SPME, SPME-trap, and high capacity sorbent extraction)
- Time-of-flight mass spectrometry (TOF-MS) for GC and GC×GC
- GC–MS data reprocessing software

Markets Served
- Defence/Homeland security
- Environmental
- Food and fragrance
- Forensic and toxicology
- Metabolomics
- Petrochemical
Markes’ global customer base includes major industry, government agencies, academia, and the contract service laboratory sector.

Major Products/Services
Markes is globally recognized for its innovation, high-quality products, unrivalled technical expertise, and high level of customer service within the field of separation science. As a global technology leader of thermal desorption and other sample preparation for GC, Markes has introduced many highly successful products and technologies to the laboratory, enabling analysts to discover more and deliver more.
- A range of analytical thermal desorption systems for tube, online, and canister sampling (products include: UNITY-xr, TD100-xr, TT24-7 and CIA Advantage-xr)
- Centri: A breakthrough in automated sample extraction and enrichment for GC–MS
- Micro-Chamber/Thermal Extractor for fast sampling of emissions from products and materials
- TC-20 sorbent tube conditioner
- Wide range of supplies and consumables for sample preparation (extraction and enrichment)

Facilities
Markes International's factory, technical centre, and headquarters are located near Cardiff, UK. The company also has technical centres in Germany, USA, and China. It also supports a global distributor network. Markes and its sister company, SepSolve Analytical Ltd, are a companies of the Schauenburg Analytics Ltd group.

Markes International Ltd.
Gwaun Elai Medi-Science Campus, Llantrisant, RCT, UK
Markes International GmbH
Bieberer Straße 1–7, 63065 Offenbach am Main, Germany
Markes International, Inc.
2355 Gold Meadow Way, Gold River, California, USA
Markes Instruments (Shanghai) Co., Ltd
Unit 1002, Building 1, No.418, Guilin Road, Shanghai 200233, P.R. China
Telephone
+44 (0)1443 230 935 (UK)
+49 (0)69 6681089-10 (Germany)
+1 866 483 5684 (toll-free) (USA)
+86 21 5465 1216 (China)
E-mail
enquiries@markes.com
Website
www.markes.com
Number of Employees
160
Year Founded
1997
Molnár-Institute for Applied Chromatography

Company Description
Founded in 1981, Molnár-Institute develops DryLab®, a software for (U)HPLC modeling for a world-wide market. Its powerful modules allow for the most sophisticated method development as required across pharma industries. Analytical scientists use DryLab to understand a method’s chromatographic interactions, reduce runtimes and assess robustness while conforming to Analytical Quality by Design (AQbD) standards.

Molnár-Institute is registered vendor to the US FDA, CDC and other regulatory bodies. DryLab has pioneered systematic, knowledge-based analytical development outcomes long before regulatory agencies across the world encouraged such submissions. Widely implemented by thought leaders, DryLab’s in-silico modeling contributes substantially to the paradigm shift towards a science- and risk-driven perspective on HPLC Quality Control and Assurance.

Chief Chromatographic Techniques Supported
• Each LC-technique (RP, NP, HIC, IEX [salt-, or pH], HILIC) that applies non-covalent interactions between the phases (stationary and mobile), in order to separate the analytes (small or large molecules)
• Gas chromatography

Markets Served
Molnár-Institute is devoted to improving global healthcare and to ensuring the development of safe and effective products in the pharmaceutical, life science, and food industries worldwide.

Major Products/Services
• DryLab—visual software for modelling robust and high-quality HPLC methods
• Method development services
• Training on the application of DryLab software for efficient HPLC method development.

DryLab®
by MOLNÁR-INSTITUTE

Molnár-Institute for Applied Chromatography
Schneegloeckchenstrasse 47, 10407 Berlin, Germany
E-mail info@molnar-institute.com
Website http://drylab.com/
Number of Employees 10
Year Founded 1981

www.chromatographyonline.com
Company Description
Introducing micro-chip manufacturing technology in analytical chromatography, PharmaFluidics uses a lithographic etching process to create a perfectly ordered separation bed on a silicon chip. PharmaFluidics wants to bring liquid chromatography to a next level of efficiency in all aspects, by providing separation devices with an unprecedented reproducibility and robustness, in a format that enables extreme user-friendliness and resolution, and opens the way to further miniaturization and integration, in the fields of -omics, biopharma and clinical diagnostics.

Chief Chromatographic Techniques Supported
- Nano LC–MS
- Capillary LC–MS

Markets Served
The μPAC™ micro-Chip based chromatography columns are commercially available for proteomic, lipidomic, and metabolomic profiling, with specific applications in bio-marker, diagnostics, and drug research and development.

μPAC™ also enables a very detailed characterization of biopharmaceuticals and biosimilars, detecting amino acid substitutions and post-translational modifications and allowing exhaustive HCP monitoring.

Major Products/Services
To serve your custom separation needs, μPAC™ nano LC columns (<2.5 μL/min) (50–200 cm) and μPAC™ capLC columns (1–15 μL/min) are equipped with connectors matching your application. Stationary phase chemistry is currently focusing on reversed phase HPLC C18 separations for applications in metabolomics, proteomics and lipidomics, but also mAb and ADC characterization, as well as host cell proteins detection and quantification.

For fast and easy cleanup and enrichment of peptide samples prior to injection, PharmaFluidics also offers a trapping column compatible with the reversed-phase analytical C18 nano-LC columns.

Facilities
PharmaFluidics’ headquarters are located in the Ghent Science Park (Belgium), a vibrant ecosystem of international corporate R&D centers, public research institutes and high-tech start-up and scale-up companies. PharmaFluidics’ products are available globally through a direct sales team and a network of international distribution partners.
Postnova Analytics GmbH

Company Description
Postnova Analytics offers the worldwide unique FFF-Platform, which is a range of different field-flow fractionation (FFF) and light scattering systems (MALS) for advanced separation, fractionation, and characterization of nanoparticles, proteins, polymers, and bio-macromolecules. Postnova offers a truly complete FFF-MALS product range, which is widely used for applications in biopharmaceutical, nanotechnology, environmental, food, cosmetics, and polymer science. The Postnova FFF-Platform can also be ideally coupled to dynamic light scattering (Malvern Zetasizer Nano DLS) and inductively coupled plasma-mass spectrometry (Agilent Technologies ICP-MS), which provides high resolution size and molar mass separations as well as characterization and element speciation.

Chief Chromatographic Techniques Supported
• Field-flow fractionation (FFF)
• Asymmetric FFF
• Thermal FFF
• Centrifugal FFF
• Multi-angle light scattering (MALS)

Facilities
EMEAI
Postnova Analytics GmbH
Max-Planck-Strasse 14
86899 Landsberg, Germany
Tel: +49 8191 985 688 0
Fax: +49 8191 985 688 99
info@postnova.com

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Postnova Analytics UK Ltd.
Unit 64, Malvern Hills Science Park,
Malvern, Worcestershire
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Tel: +44 1684 585167
info.uk@postnova.com

NORTH AMERICA
Postnova Analytics Inc.
230 South, 500 East, Suite 110
Salt Lake City, UT 84102, USA
Tel: +1 801 5212 004
Fax: +49 8191 98568899
info.usa@postnova.com

Postnova Analytics
Max-Planck-Strasse 14, 86899
Landsberg am Lech, Germany
E-mail
info@postnova.com
Website
www.postnova.com
PSS GmbH

Company Description
Perfect Separation Solutions for characterizing polymers, biopolymers, polysaccharides, and proteins. PSS is fully dedicated to the advancement of macromolecular liquid chromatography by developing true solutions and providing competent and personal support. Based on excellent products and cutting-edge technology, PSS designs easy-to-use and powerful systems for QC and R&D. From a single molar mass reference material, contract analysis, and consulting, to turn-key systems for GPC/SEC multi-detection with light scattering, viscometry, mass spectrometry, or fully compliant GPC/SEC for the pharmaceutical industry: PSS offers products and services required for successful macromolecular analysis with expert support.

Chief Chromatographic Techniques Supported
- Size-exclusion chromatography (SEC)
- Gel permeation chromatography (GPC)
- Gel filtration chromatography (GFC)
- High temperature GPC
- Interaction polymer chromatography (IPC)
- Two-dimensional chromatography (2D)
- GPC/SEC viscometry/light scattering/triple
- GPC/SEC – mass spectrometry

Markets Served
Fully featured PSS applications provide solutions for the analysis of natural and synthetic macromolecules for:
- Biopharma
- Chemical manufacturing
- Food analysis
- Medical analysis
- Pharmaceutical analysis

Major Products/Services
GPC/SEC Standards and Kits
- Certified reference materials
- MALDI kits
- Viscosity and light scattering validation kits
- ReadyCal kits
- Tailor-made polymers

High Resolution Columns
- GPC/SEC columns for all organic eluents and aqueous eluents
- For high- and low-molecular-weight synthetic and biopolymers
- For micro GPC/SEC up to preparative scale

Instrumentation and Software
- SECCurity® GPC/SEC, IPC, and 2D systems and components
- Light scattering detectors
- Viscometers
- WinGPC UniChrom Macromolecular Chromatography Data System
- PoroCheck software for inverse GPC

Analytical Service Lab
- Contract analysis
- Molar mass determination
- Branching/structure information
- Method development and transfer
- Complete product deformulation
- Consulting

GPC/SEC Training and Support
- Full services from installation to validation, operation, and repair
- GPC/SEC, IPC, 2D, and software training schools
- GPC/SEC, IPC, and 2D in-house training
- User meetings

Facilities
PSS headquarters are located in Mainz, Germany. PSS also has offices in the USA and The Netherlands, and works with a network of distributor partners in most other countries around the world.

PSS GmbH
In der Dalheimer Wiese 5, D-55120 Mainz, Germany
E-mail
info@pss-polymer.com
Websites
www.pss-polymer.com
www.pss-shop.com
Year Founded
1985
Q1 Scientific

Company Description
Founded in Ireland in 2012, Q1 Scientific is a pioneer and a world leader in the provision of outsourced, environmentally controlled stability storage for the Pharmaceutical, Medical Device, Life Science, and Food industries.

Q1 Scientific is revolutionising the way pharmaceutical companies store their products, helping to improve the speed it takes for drugs to reach the marketplace along with saving pharmaceutical companies the expense of building and monitoring storage chambers. They were the first company in the sector to establish in Ireland and are now global leaders in pharmaceutical storage services.

Chief Chromatographic Techniques Supported
• Stability storage for all key ICH climatic zones
• R&D custom storage conditions
• Biobanking
• Disaster recovery
• Retain storage
• Sample management
• Thermal cycling
• Photostability exposure

Markets Served
Q1 Scientific clients are mainly large multinational companies, predominantly Irish based firms including both indigenous businesses as well as well-known multinationals. In addition, we also store samples from companies in the UK, Norway, Germany, the rest of Europe, and the US, who manufacture products that are destined for the European market.

We store samples on behalf of companies from a wide range of industries including:
• Food
• Medical Device
• Life Sciences
• Pharmaceutical

Major Products/Services
At Q1 Scientific we understand the strict requirements, time sensitive nature, and physical challenge of stability storage. Through outsourcing your stability storage to Q1 Scientific you can eliminate sample management challenges. We offer:
• Stability storage conditions for all key ICH climatic zones; suitable for long term, intermediate and accelerated stability trials under various temperature and humidity requirements
• Flexible storage capacity that can flex with your requirements
• A ‘Pay for use’ model which eliminates waste and unseen maintenance, service and security costs with no unexpected facility costs
• A primary or contingency storage solution and disaster recovery capability

Facilities
Located in Waterford, Ireland we have a cGMP storage facility where all equipment is validated, all conditions tightly controlled, and all samples continuously monitored.

Clients can access their stability study data remotely through a secure website portal providing you with full sample visibility.

Q1 Scientific
Westside Business Park, Old Kilmeaden Road,
Waterford, Ireland
Telephone
+00353 51 355 977
E-mail
info@q1scientific.com
Website
www.q1scientific.com
Number of Employees
12
Year Founded
2012
Restek Corporation

Company Description
For over 30 years, Restek has been a leader in developing technologies and manufacturing products for gas and liquid chromatography (GC and LC), including columns, reference standards, sample preparation materials, accessories, and more. We have decades of hands-on, practical experience in chemistry, chromatography, and engineering, and our reputation for going the extra mile with Plus 1 customer service and top-performing products is well known throughout the chromatography community. Restek is proud to assist analysts around the world with monitoring the quality and safety of air, water, soil, food, pharmaceuticals, and petroleum. We proactively offer integrated solutions—products, applications, and assistance—perfectly matched to your needs, regardless of your industry. www.restek.com

Chief Chromatographic Techniques Supported
- UHPLC
- HPLC
- LC–MS
- GC
- GC–MS
- GC×GC

Markets Served
- Air monitoring
- Chemical
- Clinical
- Environmental
- Food safety
- Forensic
- Industrial hygiene
- Petrochemical
- Pharmaceutical

Major Products/Services
Plus 1 Service in everything we do. Living this corporate core value every day ensures we will surpass your expectations every time you contact us! Our customer service team will suggest time- and money-saving options and is dedicated to getting your products to you fast. Our technical service chemists can help you from set-up to method development. Visit our website where you can blog with our chemists and review an extensive library of technical publications, chromatograms, product documentation, step-by-step guides, interactive calculators, videos, and educational material.

Restek’s commitment to continuous innovation in chromatography sets us apart from our competitors. We introduce and stock hundreds of new products every year, designed by chromatographers for chromatographers.

- Exceptional columns for UHPLC, HPLC, LC–MS, GC, GC–MS, and GC×GC
- Innovative accessories, instrument replacement parts, and consumables
- Air monitoring canisters and sampling supplies
- Sample prep products
- Reference standards: stock and custom-prepared formulations
- Thousands of innovative products, hundreds of chromatograms

Facilities
Restek opened for business in 1985 in a small business incubator in central Pennsylvania. Today, more than 500 employee-owners work, play, and celebrate milestones in a state-of-the-art 140 000-square-foot facility in Pennsylvania, in our research facility in California, and in our subsidiary locations in China, England, France, Germany, Italy, and Japan.

Restek Corporation
110 Benner Circle, Bellefonte, Pennsylvania 16823, USA
Telephone (814) 353 1300
Fax (814) 353 1309
E-mail support@restek.com
Website www.restek.com
Number of Employees 500+
Year Founded 1985
Company Description
SEDERE produces and distributes the most complete product line of low-temperature evaporative light-scattering detection (LT-ELSD). As the industry leader, SEDERE leverages decades of experience and customer knowledge to continually raise the bar for high-sensitivity, high-flexibility and high-fidelity detector performance for chromatography laboratories.

The unparalleled selection of six LT-ELSD models can match both high performance requirements and budget for all chromatography applications from basic research to quality control and purification.

Chief Chromatographic Techniques Supported
- HPLC (reverse, normal, Hilic)
- UHPLC (reverse, normal, Hilic)
- SFC
- Purification
- Low flowrates

Markets Served
Our main customers are working in the Pharma, Food, Cosmetic, or Chemical industries. Our product are sold in both R&D laboratories and quality control laboratories.

Major Products/Services
- SEDEX LT-ELSD Model 100LT
- SEDEX LT-ELSD Model 90LT
- SEDEX LT-ELSD Model 85LT
- SEDEX LT-ELSD Model 80LT
- SEDEX LT-ELSD Model LC
- SEDEX LT-ELSD Model FP
- Drivers for SEDEX detectors for integration in Openlab (all editions), Chromeleon, Clarity

Facilities
SEDERE’s headquarters are located nearby Paris in Alfortville. All SEDERE products are developed and manufactured in France in our Olivet factory.
SepSolve Analytical Ltd

Company Description
SepSolve Analytical provides analytical platforms for separation scientists, including equipment for automated sample introduction, advanced GC separation, state-of-the-art mass spectrometry and powerful data analysis.

With many years of experience in the field and access to a range of leading equipment suppliers, SepSolve is very well placed to advise on the most difficult challenges in analytical science, helping analysts to discover more and deliver more — in everything from environmental monitoring and biomarker discovery to petrochemical analysis, food aroma profiling and more.

SepSolve Analytical Ltd, and its sister company Markes International, are part of the Schauenburg Analytics Ltd group of companies.

Chief Chromatographic Techniques Supported
• GC and GC×GC (and associated software)
• TOF-MS
• Sample preparation (extraction and enrichment): Thermal desorption, SPME and SPME-trap, High-capacity sorptive extraction, Headspace and Headspace-trap

Markets Served
• Biomarker discovery
• Food and drink
• Petrochemical
• Fragrance
• Environmental
• Tobacco and e-cigarettes
• Cannabis

Major Products/Services
The wide range of products and techniques offered by SepSolve includes the company’s own INSIGHT® flow modulator, ChromSpace® software for GC and GCxGC, and BenchTOF range of time-of-flight mass spectrometers with groundbreaking simultaneous hard- and soft-ionisation technology—Tandem Ionisation®. SepSolve also offers sample preparation equipment, robotic autosamplers and thermal desorbers from leading global suppliers including CTC Analytics, GL Sciences, and Markes International.

Facilities
SepSolve has offices and demonstration laboratories in Peterborough, UK, and Waterloo, Canada, and works closely with partners to support customers worldwide, with facilities in countries including the US, Germany, and China.
Shimadzu Europa GmbH

Company Description
Shimadzu is one of the worldwide leading manufacturers of analytical instrumentation, and for over 50 years, the European headquarters have been located in Duisburg, Germany. The company's equipment and systems are used as essential tools for research, development, and quality control of consumer goods in all areas of pharmaceutical and environmental industries, food safety testing, consumer protection, and healthcare, to contribute to society through science and technology. Chromatography, mass spectrometry, spectroscopy, life sciences, and material testing make up a homogeneous yet versatile offering. Along with many “industry first” technologies and products Shimadzu has created and invented since 1875, there has also been the exceptional achievement of the 2002 Nobel Prize for Chemistry to Shimadzu engineer Koichi Tanaka for his outstanding contributions in the field of mass spectrometry. Shimadzu is focused on top quality when developing products, including ease of operation and optimum service. The company manufactures according to internationally renowned quality standards, including Pharmacopeia, ISO, FDA, GLP, and GMP.

Chief Chromatographic Techniques Supported
• HPLC
• SFC
• SFE–SFC–MS
• GC
• LC–MS
• GC–MS
• Multidimensional chromatography
• Comprehensive chromatography
• Columns and consumables

Markets Served
Shimadzu’s analyzers and equipment are applied in the food industry, clinical and pharmaceutical field, automotive industry, chemical, petrochemical, life sciences and biotech, cosmetics, semiconductor, and nutrition industries, as well as in the flavours and fragrances business. Research institutes, privately-run laboratories, administrations, and universities complete the list of clients. The systems are used in routine and high-end applications, process, and quality control, as well as R&D.

Major Products/Services
Ion Chromatograph HIC-ESP
The new HIC-ESP ion chromatograph features the same low carry-over and excellent injection precision characteristics of Shimadzu HPLCs to ensure highly reliable results in quantitative ion analysis. The newly developed, low-volume anion suppressor minimizes band spreading to achieve the highest sensitivity, providing stable functionality even over long periods of operation, while the system’s small footprint offers more efficient use of laboratory bench space. The HIC-ESP covers a wide range of applications in environmental testing, pharma, chemistry and food sciences.
**LCMS-8060NX system**

The new LCMS-8060NX offers world-class sensitivity and detection speed with further improvements in ease-of-use and robustness. It also features innovative improvements to promote sample ionization, enabling high-sensitivity analysis even for compounds that are difficult to ionize. The system benefits research and development as well as routine analysis, and targets industries such as chemical, pharmaceutical, food safety, environmental analysis, and the clinical market.

**Facilities**

Shimadzu operates production facilities and distribution centres in 74 countries. In the European headquarters in Germany, the Laboratory World provides testing and training facilities for customers from all over Europe. With over 1500 m² floor space, Shimadzu’s entire product range is available—from chromatographs, spectrophotometers, TOC analyzers, mass spectrometers, and balances to material testing machines. In Europe, Shimadzu runs subsidiaries and branches in Austria, Albania, Belgium, Bosnia, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, France, Germany, Hungary, Italy, Luxembourg, Macedonia, Montenegro, Moscow, The Netherlands, Russia, Romania, Serbia, Slovakia, Sweden, Switzerland, and the United Kingdom.
Company Description
Tosoh Bioscience is an acknowledged global leader in liquid chromatography with a focus on bioseparations. Our team of chromatography experts enables our biopharma partners to provide safe and efficient therapies against life threatening diseases.

The portfolio encompasses (U)HPLC columns and media for the analysis and purification of biomolecules. The bioseparation products are supplemented by LenS₃ MALS detectors and EcoSEC GPC/SEC instruments with matching columns for the characterization of natural and synthetic polymers.

Tosoh has a proud history of innovation in size-exclusion chromatography (SEC). TSKgel SW columns have become the industry’s standard for QC of antibodies by SEC.

Chief Chromatographic Techniques Supported
- HPLC and UHPLC columns
- Media for purification by preparative chromatography
- MALS detector for GPC, HPLC, and UHPLC
- GPC systems and columns
- Size-exclusion chromatography (SEC)

Markets Served
The key markets served are life sciences and the biopharmaceutical industry. Our products are used in R&D, manufacturing, and quality control. Typical applications are the purification of therapeutic proteins in lab, pilot, and production scale, as well as their characterization by (U)HPLC. The GPC instruments and columns for polymer analysis are applied in chemical and petrochemical industry.

Major Products/Services
We offer a comprehensive line of (U)HPLC columns and downstream processing solutions, such as screening tools, prepacked columns, and media. Our new LenS₃ MALS detector is compatible with GPC, HPLC, and UHPLC. For polymer characterization, we offer a line of EcoSEC GPC/SEC instruments with matching columns. TOYOPEARL® and TSKgel® are renowned for their quality and reliability. They cover all common LC modes, including ion exchange, hydrophobic interaction (HIC), reversed phase, hydrophilic interaction (HILIC), size exclusion, mixed mode, and affinity.

Latest developments comprise SEC UHPLC columns and a FcγRIIa receptor affinity column for fast evaluation of mAb glycoforms and biologic activity.

Facilities
Headquartered in Griesheim, Germany, Tosoh Bioscience’s European operations offer extensive technical support such as application development and workshops. Tosoh Bioscience is part of the Tosoh Group, a Japanese chemical and specialty products group with over 100 companies worldwide and a workforce of about 13,000 people.

Tosoh Bioscience GmbH
Im Leuschnerpark 4, 64347 Griesheim, Germany

E-mail
Info.tbg@tosoh.com

Website
www.tosohbioscience.de

Year Founded
1989

www.chromatographyonline.com
**Company Description**
UCT is a vertically integrated manufacturer of high-quality sample prep and U/HPLC column products. We combine this with world-class technical support. Product lines include solid-phase extraction (SPE) cartridges/well plates, QuEChERS tubes, Selectra® U/HPLC columns, extraction manifolds, SPEVAP solvent evaporation system, and Selectrasil® reagents and enzymes.

**Chief Chromatographic Techniques Supported**
- Solid-phase extraction
- QuEChERS
- Filtration
- Enzyme hydrolysis
- HPLC/LC–MS/GC–MS

**Markets Served**
Founded in 1986, UCT has grown to be a respected leader in the drug testing, pharmaceutical, clinical, environmental, agricultural, specialty chemical, and cannabis testing markets. Our wide range of highly reproducible solid-phase extraction columns allow the chromatographer a consistent extraction technique, and our expertise in silane manufacturing allows greater control of the chemical processes involved in producing our high-quality bonded phases.

**Major Products/Services**
Product lines include solid-phase extraction (SPE) cartridges and well plates, QuEChERS tubes, Selectra® U/HPLC columns, extraction manifolds, Selectrasil® reagents and enzymes, and Clean-Up® Metal Scavenging phases. UCT also offers world-class technical support for all product lines.

**Facilities**
UCT was founded in 1986 in Horsham, Pennsylvania, United States. Headquarters was relocated to Bristol, Pennsylvania following the acquisition of the specialty chemical branch of Huls America (formerly Petrarch®) to allow for vertical integration. In 1999, UCT expanded to a second manufacturing facility in Lewistown, Pennsylvania. Lastly, in 2015, UCT Ireland was established in Wexford, Ireland, as a secondary manufacturing facility to better service our European customers and partners.
Wyatt Technology

Company Description
Wyatt Technology, a 35-year-old family-owned and operated enterprise, is the world’s largest company dedicated to SEC-MALS instruments for absolute macromolecular characterization. Our products provide techniques for characterizing macromolecules and nanoparticles in solution, in order to determine molar mass, size, charge, and interactions. Wyatt’s extensive applications laboratories and its full-time staff (including more than 30 PhD scientists) means our customers receive deep technical expertise and support. To ensure the personal touch, “Light Scattering University” (LSU) is included with most instrument purchases. We bring you to Santa Barbara, California, USA, to demystify light scattering and explain how to get the most from your Wyatt Technology equipment. Because we don’t just build instruments, we build relationships.

Chief Chromatographic Techniques Supported
• SEC and GPC
• UHPLC and APC
• Field-flow fractionation

Markets Served
Wyatt’s products are the most widely used multi-angle light scattering (MALS) instruments in the world. They are employed in thousands of laboratories, including companies involved in biotechnology, pharmaceutical development, and chemical/petrochemical research, in addition to government national laboratories and academic facilities.

Major Products/Services
WTC’s family of instruments include:
• DAWN: An 18-angle SEC-MALS instrument used at ambient, elevated, and below ambient temperatures for polymers, particles, and biopolymers.
• miniDAWN: A SEC-MALS instrument ideal for proteins and peptides and molar mass materials below 1 million Da.
• microDAWN: The world’s first MALS instrument for UHPLC. Compatible with all UHPLC systems for molar mass and size determinations.
• Eclipse FFF system: For separation of macromolecules and nanoparticles in solution.
• Optilab: The most advanced RI detector in the world with 256 times the detection power and 50 times the dynamic range of any other RI detector. The Optilab can be operated below or above ambient temperature and determine $dn/dc$ at the same wavelength of light as the light scattering instrument.
• microOptilab: The world’s first refractive index (RI) detector for UHPLC. Operates at the same wavelength of light as the microDAWN.
• WyattQELS: A dynamic light-scattering module integrated with the DAWN, miniDAWN, or microDAWN to determine particle sizes as small as 1 nm.
• ViscoStar viscometer: A state-of-the-art intrinsic viscosity instrument that can be operated above or below ambient temperature with its precise Peltier thermostatic controls.

Facility
WTC maintains more than 60,000 square feet of R&D, manufacturing, and application laboratories in Santa Barbara, California, USA.
YMC Europe GmbH

Company Description
YMC offers a wide range of innovative chromatography products, which includes UHPLC/HPLC columns (YMC-Triart), BioLC columns (YMC-SEC MAB, BioPro IEX/HIC), chiral columns (immobilized/coated CHIRAL ART), bulk media for preparative chromatography, glass columns for MPLC, and pilot columns. In addition, YMC provides an on-demand service for application support and method development. This product range, developed and engineered in YMC facilities, is available worldwide and is supported by dedicated YMC product specialists. YMC’s extensive distribution network guarantees availability of all YMC products in countries all over the world.

Individual seminars and training are available either in the facilities in Dinslaken, Germany, or at customer’s own site.

Chief Chromatographic Techniques Supported
- UHPLC/HPLC
- Reversed phase/normal phase/HILIC
- BioLC
- Chiral LC
- SEC
- IEX
- HIC
- Preparative/process LC

Markets Served
- Pharma
- Food and beverage
- Agriculture
- Forensics and toxicology
- Clinic
- Life science
- Environment

Major Products/Services
- UHPLC/HPLC columns
- Micro LC/nano LC columns
- (semi) Preparative columns
- Preparative bulk media
- Lab-scale glass columns
- Pilot-scale columns
- Method scouting
- Method development
- Purification service
- Seminars and training

Facilities
- YMC Europe GmbH, Dinslaken, Germany
- YMC Schweiz GmbH, Basel, Switzerland
- YMC Co., Ltd., Kyoto, Japan
- YMC America Inc., Allentown, USA
- YMC India Ltd, New Delhi, India
- YMC Taiwan Co., Ltd, Taipei City, Taiwan
- YMC Korea Co., Ltd., Korea
- YMC Co., Ltd. Shanghai Rep. Office, China
- YMC Singapore Tradelinks Pte. Ltd., Singapore

YMC Europe GmbH
Schöttmannshof 19, 46539 Dinslaken, Germany
E-mail
info@ymc.de
Website
www.ymc.de
Number of Employees
45
Year Founded
1993
Sample Preparation
Microlute SLE 96-well plates and cartridges enable the extraction of a wide range of acidic, basic, and neutral analytes from biological samples with greater reproducibility, according to the company. With no inversions, shaking or pipetting required, Microlute SLE reportedly overcomes sample handling issues commonly associated with traditional liquid–liquid extraction.

www.microplates.com/microlute-sle/
Porvair Sciences Ltd, Wrexham, UK.

FID Gas Station
The VICI FID gas station combines the reliability of the VICI DBS hydrogen and zero-air generators into one compact and convenient package, according to the company. Available in high- and ultrahigh purity for all GC detector and carrier gas applications. The generator is available in two styles: flat for placement under a GC, or the Tower. Available in H₂ flow ranges up to 1 L/min and 10.5 bar.

www.vicidbs.com
VICI AG International, Schenkon, Switzerland.

EAF4 System
Postnova’s simultaneous electrical and asymmetrical flow field-flow fractionation (EAF4) system is designed to enhance the separation and characterization of biopharmaceutical, environmental, and nanomaterials. In an EAF2000 system electrical and cross flow fields are applied simultaneously to enable separations by particle size and particle charge based on electrophoretic mobility to characterize complex proteins, antibodies, and viruses as well as environmental and charged nanoparticles or polymers.

www.postnova.com
Postnova Analytics GmbH, Landberg, Germany.

Method Translator
Pro EZLC method translation software makes it possible to scale down an existing LC method to a smaller column format so that users can speed up run time, increase sample throughput, and reduce solvent use, according to the company. The user can input current column dimensions and method conditions, then specify the dimensions of the new column that they want to try.

www.restek.com/Pages/Pro-EZLC-Method-Translator
Restek Corporation, Bellefonte, Pennsylvania, USA.

Pulsation Pump
At low flow rates of 0.5 mL/min or lower, check valves become a variable factor for flow volume and pulsation. The GL Sciences’ MP-22 No-Pulsation pump does not use any check valves, instead it uses a fast switching valve. Together with the linear-driven pistons, this results in stable flows and pressure, even with low flows, according to the company.

www.glsciences.eu

HIC Columns
YMC’s latest HIC column, BioPro HIC HT, is used for biopharmaceuticals, such as antibody-drug-conjugates. Higher flow rates are reportedly applicable due to extremely high-pressure stability, which allows very short run times and high throughput. BioPro HIC HT columns are suitable for DAR determination with high resolution as a result of a novel and optimized surface chemistry, according to the company.

https://ymc.de/hydrophic-interaction-columns.html
YMC Europe GmbH, Dinslaken, Germany.
Degasser
The novel Flat Film Degasser reportedly offers a wide flow range and chemical compatibility, while reducing flow resistance. A variable vacuum control enables the degassing process to be fully optimized for users’ needs. The Flat Film Degasser will soon be available as an OEM solution or as a stand-alone version in the DEGASi series.

www.biotechfluidics.com
Biotech AB, Onsala, Sweden.

MALS Detector
The microDAWN can be coupled to any UHPLC–SEC system to determine absolute molecular weights and sizes of polymers, peptides, or proteins without resorting to column calibration or reference standards. According to the company, the microDAWN produces minimal band broadening to maintain the narrow peaks typical of UHPLC.

www.wyatt.com/microDAWN
Wyatt Technology, Santa Barbara, California, USA.

µPAC Column
The 200-cm µPAC is designed for comprehensive proteomics, whereas the 50-cm µPAC column is designed to perform higher throughput analyses with shorter gradient times. In addition, the µPAC Trapping columns were developed with identical morphology to ensure excellent chromatographic performance and to fulfill the demands of peptide sample enrichment, according to the company.

www.pharmafluidics.com
PharmaFluidics, Ghent, Belgium.

Ion Chromatography System
Shimadzu’s IC system with anion suppressor minimizes band spreading and achieves high sensitivity and reliable performance for the quantitative determination of anions. According to the company, the suppressor provides stable functionality over long periods of operation. The system features a compact design and integrates with Shimadzu’s LabSolutions.

www.shimadzu.eu
Shimadzu Europa GmbH, Duisburg, Germany.

HILIC Columns
iHILIC-Fusion(P) and iHILIC-(P) Classic are two lines of polymeric HILIC columns with different surface chemistries. They provide complementary selectivity and ultra-low column bleeding. According to the company, the columns are particularly suitable for LC-MS based analysis of hydrophilic/polar compounds at pH 1-10.

www.hilicon.com
Hilicon AB, Umeå, Sweden.

HPLC System
The Thermo Scientific Vanquish Core HPLC Systems have been designed to optimize analysis and QC workflows. Through automatic determination of solvent and waste levels, and background monitoring of system health, instrument uptime is maximized for dependable results regardless of user experience. The systems offer simple method transfer and easy integration with many leading CDSs.

www.thermofisher.com
Thermo Fisher Scientific, San Jose, California, USA.
Positive Pressure Manifold
UCT’s 48-position positive pressure manifold offers rugged performance but now also has a streamlined, compact footprint, according to the company.

www.unitedchem.com
UCT, Inc., Bristol, Pennsylvania, USA.

Gas Generator
The NG-Castore XL iQ generator uses a silent technology (from 48 dB only) combining a scroll compressor and an inverter for an on-demand supply of pure nitrogen to the applications. According to the company, it is designed for all LC–MS and evaporation applications on the market because of requirements in terms of gas, flow, and pressure.

www.LNI-swissgas.eu
LNI Swissgas Srl, Milan, Italy.

Solid Phase GC-FTIR
Spectra Analysis’ DiscovIR GC-FTIR focuses on the real-time connection of infrared spectroscopy to gas chromatography. Temperature-controlled, vacuum deposition of the GC-eluted peaks onto a rotating IR-transparent disc ensures high-resolution IR fingerprinting in an accurate and reproducible way, and opens the gateway for rapid discrimination between regioisomers, a challenging area for MS, according to the company.

https://spectra-analysis.com
Spectra Analysis, Marlborough, Massachusetts, USA.

Electrochemistry-MS
The Roxy Exceed is a new generation potentiostat dedicated to on-line coupling of electrochemistry with mass spectrometry (MS). The system supports DC, scan, and pulse mode and can be controlled from any LC–MS system. The instrument is suitable for predicting drug metabolism, and for MS proteomics.

www.AntecScientific.com

Column Selection App
Columns are the heart of any GPC/SEC system. However, it can be a challenge to find the best matching column from the wide range of options. PSS has therefore developed the Column Selection App to support users. The app offers the following choices: How to Replace Existing Columns, Column Recommendations, USP methods/EP methods, and Application Searches.

www.psscolumnselector.com
PSS GmbH, Mainz, Germany.

Hydrogen Generator
The Precision Hydrogen Trace generators are designed for GC carrier gas use and detectors requiring hydrogen fuel gas, such as FID and FPD. With three flow rate models, 250cc/min, 500cc/min and 1200cc/min, one generator is capable of supplying multiple GC instruments and can be stacked with nitrogen and zero air Precision models for a complete, space-saving GC gas solution with no need for cylinders.

www.peaksscientific.com
Peak Scientific, Scotland, UK.
### Crimp Closure
Extremely tight sealing and excellent analytical purity are of great importance, especially in the headspace area. A new 20-mm crimp closure with Silicone/PTFE liner (Pharma-Fix) from Macherey-Nagel meets these demands. This closure is characterized by high analytical purity and high temperature resistance, good penetration properties and excellent sealing.

[www.mn-net.com](http://www.mn-net.com)
Macherey-Nagel GmbH & Co. KG, Düren, Germany.

### Sampling Tubes
Markes’ industry-standard-sized thermal desorption tubes are manufactured to the highest quality to deliver optimum results, according to the company. The complete range of tube materials and sorbent packings offer flexibility, making them suitable for VOC and SVOC analysis for all TD applications, including environmental air monitoring, fragrance analysis, and breath monitoring.

[http://chem.markes.com/sampling-tubes](http://chem.markes.com/sampling-tubes)
Markes International Ltd., Llantrisant, UK.

### Pulsation Pump
At low flow rates of 0.5 mL/min or lower, check valves become a variable factor for flow volume and pulsation. The GL Sciences’ MP-22 No-Pulsation pump does not use any check valves, instead it uses a fast switching valve. Together with the linear-driven pistons, this results in stable flows and pressure, even with low flows, according to the company.

[www.glsciences.eu](http://www.glsciences.eu)

### Dynamic Headspace System
The Dynamic Headspace System (DHS 3.5) holds up to four times more sorbent, resulting in improved recovery, accuracy, and limits of quantitation, according to the company. Standard 3.5” tubes can be used for trapping. The DHS 3.5, Thermal Desorber TD 3.5+, and MultiPurpose Sampler MPS can process 120 samples in one run. The optional DHS large holds 250, 500, and 1000 mL containers.

[www.gerstel.com](http://www.gerstel.com)
Gerstel GmbH & Co. KG, Mülheim an der Ruhr, Germany.

### Purge Valve
The purge valve complete with a PTFE frit is an appropriate option to use with Agilent HPLC instruments. This purge valve has been engineered and tested to be equivalent to the corresponding OEM product. The valve uses a replaceable gold seal and a PTFE frit to protect the HPLC system.

[www.sciencix.com](http://www.sciencix.com)
Sciencix, Burnsville, Minnesota, USA.

### SEC-MALS Detector
The LenS, MALS Detector for GPC, HPLC, and UHPLC is based on an approach related to light scattering technology. The proprietary design increases S/N and extends the range of size determination (Rg) down to a few nanometres. According to the company, the instrument is a sensitive detector for the characterization of polymers, proteins, or antibodies by SEC-MALS.

[www.tosohbioscience.de](http://www.tosohbioscience.de)
Tosoh Bioscience GmbH, Griesheim, Germany.

### Purge Valve
The purge valve complete with a PTFE frit is an appropriate option to use with Agilent HPLC instruments. This purge valve has been engineered and tested to be equivalent to the corresponding OEM product. The valve uses a replaceable gold seal and a PTFE frit to protect the HPLC system.

[www.sciencix.com](http://www.sciencix.com)
Sciencix, Burnsville, Minnesota, USA.
ADVANCING THE SCIENCE OF CHIRAL CHROMATOGRAPHY

INTRODUCING CHIRALPAK® IJ

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✓ Robust to withstand all mobile phase combinations
✓ Designed for HPLC and SFC to improve methods for challenging separations

DAICEL is committed to advancing chiral chromatography by developing innovative & reliable columns optimized to accelerate your projects.

WWW.CHIRALTECH.COM
Enhanced performance

Sensitivity and robustness

The new LCMS-8060NX culminates Shimadzu’s expertise in triple quadrupole MS. Its Analytical Intelligence functions improve user operational efficiency and productivity in the workflow. World-class sensitivity meets ultra-high detection speed. The LCMS-8060NX benefits method development and routine analysis in pharmaceutical, clinical, environmental and food safety applications.

World-class sensitivity through new heated ESI built-in expanding parameters for real world samples

Speed beyond comparison due to data acquisition with unmatched scan speed and shortest polarity switching time

Superior robustness based on new UF-Qarray II and QF-Lens II technologies as well as new IonFocus unit balancing robustness and sensitivity

Automated workflow from analysis to data processing greatly improving efficiency, user operation and productivity

www.shimadzu.eu/enhanced-performance