SPE Redux: Citius, Altius, Fortius Celebrating 30 Years of SPE THE SCIENCE OF WHAT'S POSSIBLE.™

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Waters

A revolution in analytical practice began with first commercial introduction of miniature silica-based column-liquid-solid-extraction devices.

Prior Art—Inspiration



Since fragile flowers such as jasmine, tuberose and daffodil cannot withstand heat, the technique of cold absorption was developed. This technique vas very common in the Grasse region until the first half of the 20th century. Cold absorption consists of spreading a layer of cold odourless fat onto sheets of glass held in frames; this fat is then covered with flowers that are regularly replaced with fresh ones until the fat is saturated with fragrance These perfumed pomades can either be used to manufacture cosmetic products or mechanically washed in alcohol to eliminate the fat, after which the alcohol is evaporated to obtain absolute source: www.fragonard.com]

• Decolorization with charcoal*

- RP column-liquid-solid extraction with XAD-2*
- On-column derivatization*

Original Proposal Sample Preparation Project June 1977 Sample Preparation Project - Feasibility Evaluation

OBJECTIVES:

1. Solve a real analytical problem using LC technology exclusively. (analysis of fat soluble vitamins--A, D, E--in various food matrices and synthetic formulations)

2. Maintain time frame for entire analysis as short as possible, no longer than 30 min from matiix to answer.

3. Find new, faster, more convenient ways to do traditional sample prep operations (filtration, evaporation, concentration, extraction dissolution, crude separations, etc.) using, whenever possible, our LC technology.

4. Establish scope, scale, size, function of a disposable, proprietary product for sample preparation.

5. Establish guidelines and procedures for solving other analytical problems and for creating other disposables for this purpose.

Classic Invention 24 October 1977

- Liquid-liquid partition chromatography*
- Miniature columns for LLP & RP CLSE*
- Invention of radial compression**

* See references in: P.D. McDonald, ISC'98 Rome, Poster; PDF available—search for **PMpISC98** on waters.com ** P.D. McDonald & C.W. Rausch, U.S. Patent 4,250,035 [filed: 1975; issued: 1981]



First product shipped: 17 January 1978: Polyethylene-lined foil pouches maintained moisture specification of silica [1.8–3.2%] indefinitely. Ten-year-old cartridges in unopened pouches still passed rigid LC-retention-factor QC test for water content.

6. Define product(s) or product package(s). (solution to specific analytical problem including protocol, disposables, associated hardware, general research and development package, etc.)

&. Get to product design and development as quickly as possible

Find a new way to do sample prep "using ... LC Technology"

Keys to Rapid Adoption & Sustained Growth

- Convenient, efficient, disposable, miniature column format.
- Reproducible sorbents, QC for SPE.
- Packaging that maintains sorbent/ product integrity until point of use.
- Wide range of initial applications.
- Methods use LC principles.
- C₁₈ [reversed phase] ideal mate for complex aqueous samples: trace enrichment; environmental/food/ ag/biological extracts, etc.
- Competitive explosion after 2.7-yr induction period.
- Commitment to quality.

After **30+ years**, still the most widely referenced SPE product family*

Google	Web	Images	<u>Video</u>	News	Maps	more »	
	"Sep	-Pak"					
Scholar 🔘 BETA							

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Results 1 - 10 of about 52,700 for "Sep-Pak". (0.39 secon

Search

The Use of Sep-Pak™ C18 Cartridges During the Isolation of Gangliosides MA Williams, RH McCluer - Journal of Neurochemistry, 1980 - Blackwell Synerg . Marcia A. Williams and Robert H. McCluer Abstract: The use of Sep-Pak"! C reverse-phase cartridges to adsorb gangliosides from aqueous solutions was studied.... by 182 - Related articles - Web Search - All 2 version

. apid separation of neutral lipids, free fatty acids and polar lipids using prepacked silica **sep-Pak** G Hamilton, K Comai - Lipids, 1988 - Springe .. Using Prepacked Silica Sep-Pak Columns ... Silica Sep-Pak columns (600 mg silica) were purchased from Waters Associates (Milford, MA). ...

uation of the method for use prior to ... pak cartridges for urinary steroid extraction: eval CH Shackleton, JO Whitney - Clin Chim Acta, 1980 - ncbi.nlm.nih.gov 1980 Nov 6;107(3):231-43. Use of Sep-pak cartridges for urinary steroid extraction evaluation of the method for use prior to gas chromatographic analysis. .

serum and other biological fluids: comparison with acid-ethanol treatment and C18 Sep-Pak. S Mohan - Journal of Clinical Endocrinology & Metabolism, 1995 - Endocrine Soc . Biological Fluids: Comparison with Acid-Ethanol Treatment and C., Sep-Pak Separation* ... ethanol cryoprecipitation, C., Sep-Pak separation, formic ... Cited by 62 - Related articles - Web Search - All 3 versions

> >> *50,000* references \geq 8x more than any similar product * Search for 720000860EN

> > on waters.com

& Yuri Tuvim-designed	tubing shrink to form its	tubing outlet. Discarded
SS endfittings (female	own outlet.	inlet fitting. New SPE
Luer hub inlet) in		cartridge format was
rradiation-crosslinked		born.*
polyethylene tube.		David suggested
Tubing was heat-		brand name: SEP-Pak
shrunk tightly around		[<mark>S</mark> ample <mark>E</mark> nrichment &
components.		Purification].
Assembly performed		Sep-Pak® Silica
well but leaked slightly		Cartridge bed: 1 x 2 cm
around SS fittings.		Later, Sep-Pak® C ₁₈
		Cartridge bed: 1 x 1 cm

Z Richard Vivilecchia

outlet fitting & letting

suggested removing

David Lorenz

assembled 2 cc of silica

between porous PE frits

Scholar Preferences Scholar Help

format was suggested me: SEP-Pak nrichment & ak® Silica bed: $1 \times 2 \text{ cm}$ Sep-Pak[®] C₁₈ Cartridge bed: 1 x 1 cm

3 David discovered

that Luer syringe tip

fit snugly into shrunken

* P.D. McDonald, R.V. Vivilecchia, and D.R. Lorenz, U.S. Patent 4,211,658 [1980]



In the first decade, new proprietary as well as open-source cartridge formats were added in response to needs based upon sample volume and matrix, automation, convenience, and safety. The most recent format is the patented 96-well µElution plate.*

*R.P. Fisk et al., *U.S. Patent* 7,723,236 [2004]

A variety of sorbents for normal- and reversed-phase, ion-exchange, chemical-affinity, scavenger/scrubber, and in situ derivatization applications con-

tinue to be developed.

Ongoing GOALS: Citius = Faster [throughput]; Altius = Higher [recovery, reproducibility, sensitivity]; Fortius = Stronger [retention & selectivity]

1996 Invention Water-Wettable HLB Copolymer for Reversed-Phase SPE* Enabling Technology for High-Throughput 96-Well Plates



* E.S.P. Bouvier, R.M. Meirowitz, & P.D. McDonald, U.S. Patents 5,882,521 [1996]; 5,976,367 [1998]; 6,106,721 [1999]; 6,254,780 [2001]; 6,468,422 [2002]; 6,726,842 [2004]; 6,773,583 [2004]; P.J.J. Lee & J.E. O'Gara, U.S. Patents 6,322,695 [2001]; 7,232,520 [2007] HLB = hydrophilic/lipophilic balance





Acknowledgments:

leagues—Joe Arsenault, Dawn Maheu,

and Brian P. Murphy-for their review of,

and helpful suggestions for, this poster.

for Cleanest Extracts,

Ropinirole and citalopram in human plasma [1 ng/mL]; sample prepared with Oasis MCX µElution plate SPE.



Linearity [0.005 to 10 ng/mL]: $r^2 = 0.998$

* U.D. Neue and P.D. McDonald, *Waters Whitepaper* [2005]; search for **720001273EN** on waters.com; E. Chambers, D.M. Wagrowski-Diehl, Z. Lu, and J.R. Mazzeo, J. Chromatogr. B 852(1-2): 22-34 [2007]

High Recovery, Lower LOQ, Minimal Matrix Effects*

UPLC/MS/MS chromatogram of the XIC for a sample of ropinirole in human plasma at the LLOQ of 0.005 ng/mL.**



for Post-Synthesis **Reaction Mixture Cleanup*** CLEANUP PROCEDURES Using PoraPak Rxn CX: Strong Cation-Ion Exchange Catch-and-Elute and Pass-Through Protocols Catch and Elute **Condition Step** 100% methanol Load Step Fraction collected contains acids, neutrals and reaction solven Wash with 100% metha Wash Step Wash Step 100%-methano 00%-methano fraction contain raction contains more impurities, acids and neutrals acids and neutrals Elution Step **Recombine Load** 5% ammoniated and Wash Steps ethanol – fractio contains bases Making SPE a simple tool for

medicinal/synthetic organic chemists

* Details on waters.com; search for **720002747EN** Porapak[™] family of copolymers was first developed more than 40 years ago for GC separations. New Porapak Rxn RP & CX sorbents, introduced August 2008, benefit from this technical heritage.



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In Memoriam

polymeric sorbents, and his pioneering

experiments and mentoring efforts

made Oasis HLB possible.