VARIAN

Inspiring Excellence

Comparison of Competitors' Evaporative Light Scattering Detectors

Polymer Laboratories

Now a part of Varian, Inc.

What affects ELSD performance?

Nebulization

- Size of droplet formed: consequently determines size of particle

Evaporation

- Efficiency to remove solvent

Light source

- Intensity
- Wavelength

Nebulization

Increase Neb gas flow ----------- Reduces droplet size

Increase Liquid flow --------------- Increases droplet size

Increase Liquid viscosity -------- Increases droplet size

Ideally, you need the largest droplet size possible, but not too large that it can't be fully evaporated in the drift tube.

Hence, the efficiency of your evaporation step is critical to the performance of an ELSD.

Current Manufacturers of ELS Detectors

Over the last four years, the number of ELSD manufacturers has increased considerably.

Current ELSD manufacturers are:

- Alltech
- Sedere
- Waters
- SofTA
- Schambeck
- ESA
- Polymer Labs

Alltech

ELSD 800

- Light source: 670nm @ 5mW laser diode
- Detector element: Silicon photodiode
- Temperature range: Ambient to 110°C
- Nebulizer gas: Up to 3.0L/min,
- Gas inlet pressure: 15–90psi (1.0–6.0 Bar)
- Typical operating range: 1.0-3.0L/min
- Mobile phase flow rate: 1–5.0mL/min
- Analog outputs: 1V or 10mV full scale

ELSD 2000ES

- Light source: 650nm 30mW Laser diode
- Detector element: Silicon photodiode
- Temperature range: Ambient to 120°C
- Nebulizer gas: Up to 4.0L/min (MFC controlled)
- Gas inlet pressure: 60–80psi
- Typical operating range: 1.0-3.0L/min
- Low temperature operation
- The optical and electronic components have been redesigned to minimize background noise and increase sensitivity.

ELSD 3300ES

- Light source: 650nm 30mW Laser diode
- Silicon photodiode detector
- Temperature range: Ambient to 120°C
- Nebulizer gas: Up to 4.0L/min (MFC controlled)
- Gas inlet pressure: 60–80psi
- Typical operating range: 1.0-3.0L/min
- Low temperature operation
- The optical and electronic components have been redesigned to minimize background noise and increase sensitivity.

Design Features of Alltech's ELSDs

Nebulizer

- Gas flow adjusted for solvent type
- No nebulizer temperature control

Evaporation

- Temperature setting dependent on solvent properties
- Impactor removes the large droplets at low temperatures -limits to how low in temperature can go

Detection

- Laser source @ 650-670nm - scattering efficiency is lower at higher wavelengths but this is compensated by 30mW LASER
- Silicon photodiode detector - optimum sensitivity to red light

Design Features of Sedere's ELSDs

SEDEX 75 LT-ELSD

- Tungsten halogen lamp
- Coiled drift tube
- No mass flow controller
- Different nebulizers for different flow rates

SEDEX 85 LT-ELSD

- Blue light source
- Expanded software functionality
- Mass flow controller
- Remote power-down
- Automatic gas shut-off

Design Features of Sedere's ELSDs

Nebulizer

- 3.0 SLMs of gas used to nebulize solvents under standard conditions
- Large volume nebulizer chamber with a bend removes large droplets
- Nebulizer not temperature controlled
  - cannot connect to SFC systems without modification
- Different size nebulizers for different flow rates

Design Features of Sedere's ELSDs

Evaporation

- Long coiled tube which removes large droplets by centrifugal force and provides laminar flow - potential increase in band broadening
- Longer drift tube means the temperature can be lower, compared to a short tube, for a given solvent
- Longer tubes have greater equilibration times for heating and cooling

Detection

- SEDEX 75 Halogen lamp produces a broad range of wavelengths, but low intensity
- SEDEX 85 uses a blue LED, same as PL-ELS 2100
- PMT gain adjustable

Waters

ELSD 2040

- Light Source: Tungsten Halogen Lamp
- Detector Element: PMT
- Temperature Range: Ambient to 100°C (?)
- Nebulizer Gas: adjustable 3-60psi,
- Nebulizer set at 0-100% of Drift tube temp
- Gas Inlet Pressure: 65psi min
- High and Low flow nebulizers
  - 0.050-3ml/min
- 2 Analog Outputs: 2V full scale
- Digital Output

Waters

Acquity ELSD

- Designed for UPLC an analysis
- 80Hz Data rate
- Sharp peak shape (1.2 - 1.5sec)
- Stackable
- Digital Output

Design Features of Waters' ELSDs

Nebulizer

- Snap-on design for easy replacement
- Temperature controllable (% of drift tube temp)
- Gas pressure/flow set according to solvent

Evaporation

- Coiled drift tube
- No design features included to operate at low temperatures

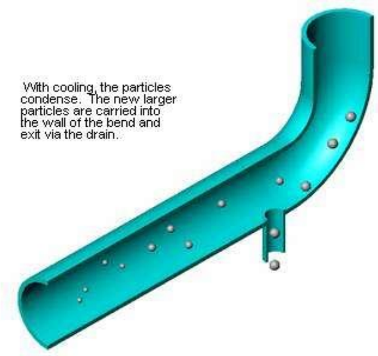
Detection

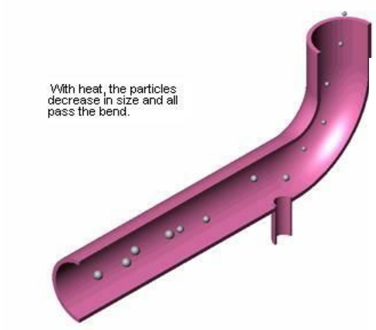
- Halogen lamp – high power, but produces a wide range of wavelengths (mean wavelength ca. 900nm)
- PMT – detector type not optimized for light source
- Heated optics, to prevent condensation onto optical lenses (same as PL-ELS 2100)

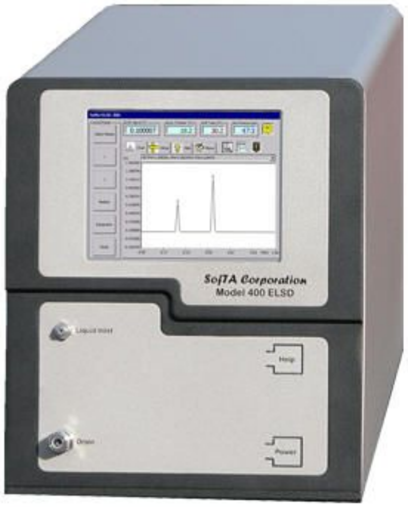
SofTA

ELSD 400

- Light source: 670nm LASER <5mW
- Detector element: Photodiode
- Temperature range: Ambient to 120°C
- Gas inlet pressure 50psi
- Nebulizer chamber 0-80°C
- Analog Output: 0-1V full scale
- Digital Output
- Heated/Cooled Nebulizer Chamber (Thermosplit)







Design Features of SofTA's ELSDs

Nebuliser: Thermo-split Technology

- For difficult to evaporate mobile phases, or high flow rates, the nebulizer chamber walls are cooled
- By making the walls suitably cold, 99+% of an aqueous stream can be diverted away from the evaporative zone
- Nebulizer gas pressure set according to solvent type (no MFC)

Evaporation

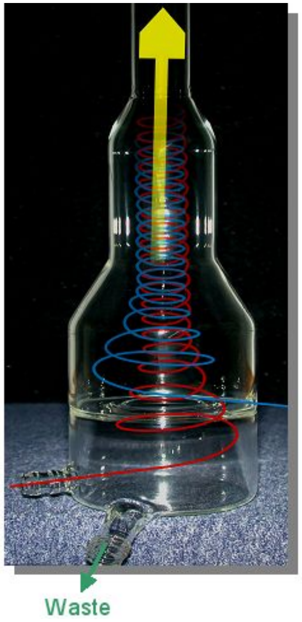
- Heated drift tube (coiled ??) no form of impactor or diffuser

Detection

- LASER diode – same as Alltech
- Photodiode detector

ZAM 3000

- Light source: Tungsten Halogen
- Detector element: Photomultiplier
- Temperature range: Ambient to 70°C
- Nebulizer gas flow: <1L/min
- Drying gas: <2L/min
- Analog output: 0-1V full scale
- Digital output



Design Features of Schambeck's ELSDs

Nebulizer

- For difficult to evaporate mobile phases, or high flow rates, the nebulizer chamber walls are cooled
- By making the walls suitably cold, 99+% of an aqueous stream can be diverted away from the evaporative zone
- Nebulizer gas pressure set according to solvent type (no MFC)

Evaporation

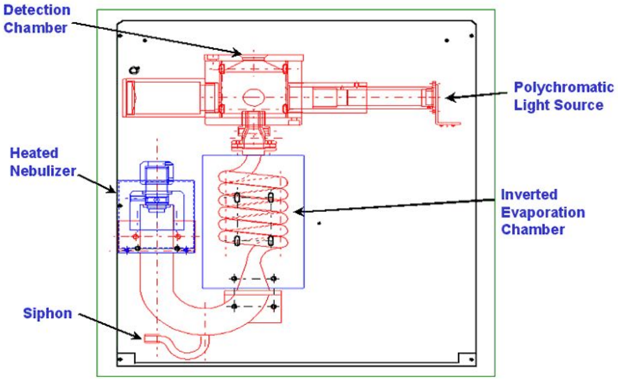
- Heated glass drift tube no form of impactor or diffuser

Detection

- Tungsten Halogen Lamp (av. wavelength ca. 900nm)
- Photomultiplier tube - not optimized for light source

Chromachem ELSD

- Light source: Halogen lamp
- Detector element: Photomultiplier
- Temperature range:
  - Nebulizer: Up to 70°C by 1°C increments
  - Evaporator: Up to 150°C by 1°C increments
- Gas inlet pressure: 0.5 to 3.9 bars (1 to 4 L/min) Helium or Nitrogen
- Mobile phase flow rate: 50µl/min to 4 ml/min
- Digital outputs: RS232



Design Features of ESA's ELSDs

Nebulizer

- Similar design to SEDEX 75

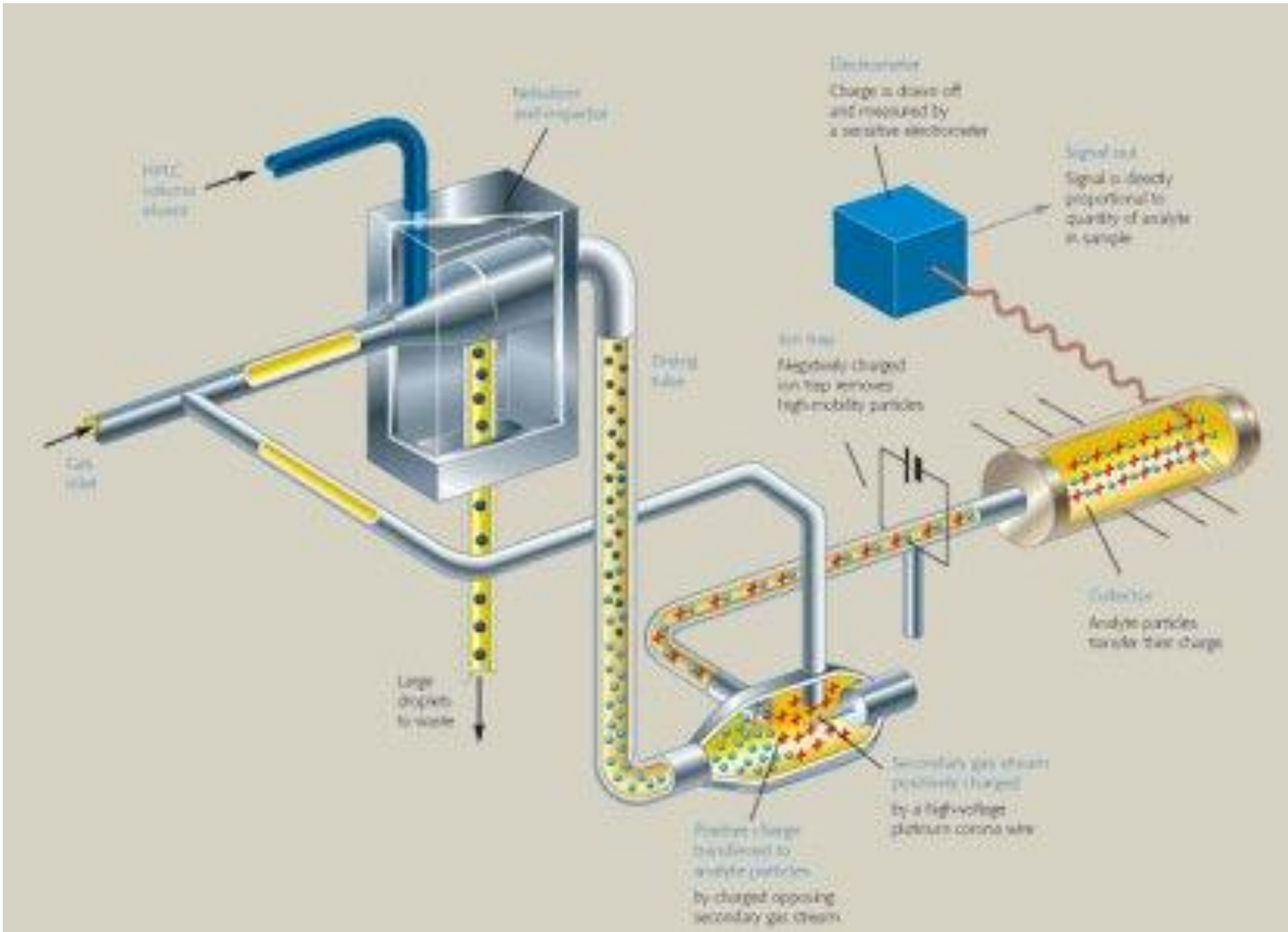
Evaporation

- Similar design to SEDEX 75
- No special design features for low temperature operation

Detection

- Tungsten-Halogen lamp (wavelength ca. 900nm)
- Photomultiplier tube - not optimized for light source

ESA's Charged Aerosol Detector (CAD)



Inspiring Excellence

Charged Aerosol Detector (CAD)

How it works:

- The column eluent is nebulized with nitrogen, before passing into a heated drift tube.
- The droplets are dried to remove mobile phase, producing analyte particles.
- Dried particles are mixed with a secondary stream of positively charged nitrogen as it passes a high-voltage, platinum corona wire.
- This charged gas subsequently imparts a charge onto the stream of analyte particles.
- These streams of charged particles then pass through a charge collector where the magnitude of the imparted charge is measured by a electrometer.
- A signal is generated which is proportional to the quantity of analyte present.

CAD vs ELSD

This is a non-optical technique and therefore is not bound by scattering laws.

- Small particles, which would be missed by ELSD, will be charged and detected by CAD.
- Charging the particles produces a wider dynamic range.
- In principle, the LOD should be better (not necessarily).
- Produce more uniform response between compounds as it is not dependent on particle size.
- Nebulization is not critical, as droplet size is irrelevant, therefore, nebulizer can set to produce smaller particles that will dry more easily.

CAD vs ELSD

The technique is dependent on nebulization and evaporation stages.

- It is gradient sensitive - the response will change as solvent composition changes.
- Change in solvent composition makes the technique difficult to apply to unknowns.
- Highly volatile compounds will be lost through evaporation.
- It is not a linear technique (but is slightly better than ELSD), so unknown quantification is difficult.
- Some buffers, such as TEA, can cause problems.
- Not all compounds charge easily, so LOD is still compound dependent.

Overview of ELSD Sales

Global ELSD Market - *ca.* 1000-1500 units/year

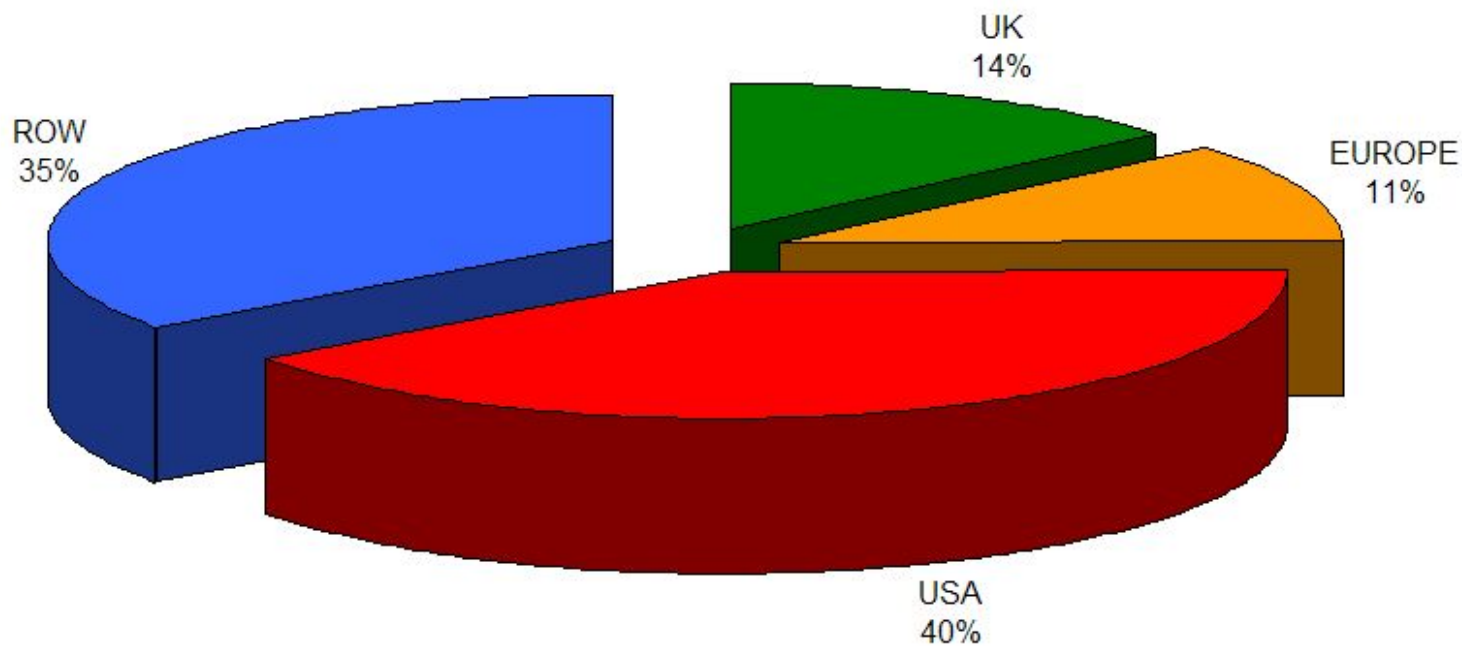
PL shares

- *ca.* 25% of the market
  - 80% PL-ELS 2100
  - 20% PL-ELS 1000

Main Competitors

- Sedere
- Alltech
- ESA/Eurosep
- Waters

ELSD Sales by Region



VARIAN

Competitor Overview

Detector	Positioning Benefit	PL-ELS1000	PL-ELS2100	SEDEX 75	SEDEX LT-ELSD 85	WATERS 2420	ALLTECH 2000 ES	Chromachem (ESA)	SofTA ELSD 400
US List Price ($)	We are the best value?	14950	14950						
Light Source	Lower wavelengths provide better scattering efficeincy for small particles.	Tungsten Halogen (500-600nm)	LED @480nm	Tungsten Halogen (500-600nm)	Blue LED (480nm)	Tungsten Halogen (500-600nm)	Laser diode @650nm 30mW	Tungsten Halogen (500-600nm)	Laser diode @670nm <5mW
	LEDs are a cool source, so internal heating does not occur which could limit detection of semi-volatile compounds		*Cool light source*						
Detection	Detector module should match the wavelength of light source for maximum sensitivity. PMT is is sensitive to ca.480nm. Photodiode sensitive to ca. 650nm.	Photodiode	Photomultiplier tube (PMT)	Photomultiplier tube (PMT)	Photomultiplier tube (PMT)	Photomultiplier tube (PMT)	Silicon photodiode	Photomultiplier tube (PMT)	Photodiode
Evap tube design	Shorter tubes give less dispersion (i.e. sharper peaks) than longer coiled tubes. Longer tubes provide longer drying times, so temperatures are often set lower than shorter tubes.	Straight Short tube (30cm)	Straight Short tube (30cm) Has an additional gas input during evaporation to offset the need to increase the temperatue compared to longer tubes. Can evaporate water at 25C.	Coiled drift tube (>30cm)	Coiled drift tube (>30cm)	?	Dual mode operation	Inverted coil	Drift tube with bend to remove large droplets
Temperature Range									
(i) Nebuliser	A Heated Nebuliser is not essential for HPLC operation, but is a pre-requiste when used in conjunction with SFC systems.	30-220°C	ambient-90°C	N/A (heating neb requires optional water jacket)	N/A (heating neb requires optional water jacket)	Heated 0-100% of evaporator temp	N/A	upto 70°C	0-80°C (active cooling on nebuliser chamber)
(ii) Evaporator	For semi-volatile compounds, temperatures should be as low as possible (i.e. 30°C). For maximum sensitvity in water, evaporator should be able to reach 100°C. For high temperature GPC, operating temperatures need to be >200°C Typical operating temperature of most ELSDs is 40°C	30-300°C Optional heated transfer line for HTGPC	ambient-120°C	ambient -100°C	ambient -85°C	5-100°C	ambient-120°C	upto 150°C	ambient to 120°C
Nebuliser Geometry	No difference on performance	Orthoganol (cross-flow)	Concentric	Concentric	Concentric	Concentric	Concentric	Concentric	Concentric ???
Gas Consumption	Maximum gas consumption is meaningless. It is the typical operating gas flow that is important. A low working gas consumption is favourable. Longer coiled tubes often require high gas flows to sweep the sample through the system.	upto 2.0 SLM	upto 3.25 SLM	< 3.5 L/min*	< 3 L/min*	?	<4.0L/min*	1-2L/min (1-2.0 bar)	ca. 1 SLM
		typical operating amount 0.8 SLM	typical operating amount 1.4 SLM	typical operating amount 3.0 SLM	unknown	unknown	unknown	unknown	unknown
Gas flow Control	A mass flow controller ensures a steady flow of nebulisation gas, which in turn guarantees constant performance	Mass Flow controller (inlet pressure of 60-100 psi)	Mass Flow controller (inlet pressure of 60-100 psi)	N/A	Yes ?	Mass Flow controller (inlet pressure of >65 psi)	Mass Flow controller (inlet pressure of 60-80 psi)	Not stated	Yes ? Requires 50 psi
(i) Gas Shut Off	Reduces lab costs, especially for those with bottled gas supplies	YES (& gas save mode)	YES (after 15 mins in standby)	NO	YES	YES	YES	YES	YES

Competitor Overview

Detector	Positioning Benefit	PL-ELS1000	PL-ELS2100	SEDEX 75	SEDEX LT-ELSD 85	WATERS 2420	ALLTECH 2000 ES	Chromachem (ESA)	SofTA ELSD 400
Eluent Flow range	The larger the operating range the less need there is for multiple nebulisers. Higher flow rates are better for Prep-scale Chromatography	0.3 -5.0 ml/min	0.2 -5.0 ml/min. Has been operated at 50µL, but performance cannot be guaranteed at flow rates below 200µL.	0.1-5ml/min (standard)	5µl/min to 5ml/min (standard)	0.3-3ml/min (standard neb)	upto 5.0ml/min	20µl -3ml/min	upto 5ml/min
	Nebs that can operate below flow rates of 200µL/min are suited for micro LC, but often such low flow rates need a different design of instrument to minimise dispersion	40µl -500 µl/min (PL-ELS 1000 micro ELSD)		10-150µl/min (micro nebuliser)	4 nebuliser options for different flow rates. Total flow range of 10µL to 5ml/min	50-500µl/min (micro neb)	?		
Output	Analogue is the standard ouput, but digital output is vecoming more favourable	Analogue (0-1v & 0-10V)	Analogue (0-1 V) Can have a digital output from the serial port	Analogue 0-10mV & 0-1V	Analogue 0-1V	Analogue 0.1-2.0V Digital 24bit, 10Hz ethernet connection	Analogue 0-10mV & 0-1V	Analogue 0-1V	Analogue 0-10mV & 0-5V
Sensitivity	Is used to compare ELSD performance, but there is no standard compound or method. ELSD LODs are often stated from direct injection which gives a higher value than on-column. And some compound respond better than others. The only true way to compare ELSD performance is by head-to-head comparisons in the lab.	<5ng Glucose (on column 4.6mm ID)	<5ng Glucose (on column 4.6mm ID) *Detects volatiles at 25°C in water*	?	<200pg (direct / on column ??)	?	?	<10ng glucose Direct inj	Not Stated 4.5 orders of magnitude !!
Peak Shape/Broadening	Sharper peaks allow faster separations. (see evap tube design)	Excellent /low dispersion	min peak width 3sec	Poor/ suffers from tailing due to long drift tube	N/A	?	?	?	min peak width 3sec
Detector control	ELSDs are typically designed to operated as stand-alone units.	Remote control	Keypad on front of unit	Keypad on front of unit	Keypad on front of unit	24 Keypad on front of unit	Front LCD display with keypad	Keypad	Keypad
PC control	PC control via software is standard, functionality depends on vendor	ELS 1000 Control software	ELS 2100 Control software	YES	YES	Masslynx v4.0 SP2 Empower Software	Windows based PC control	Not Stated	No- Unit has built in data aquisition
Additonal Features	Can often be the deciding factor when performance is equal	Time constant	Gain Function (adjust ouput for full scale sensitivity) Data smoothing LED intensity adjustable for prep-scale LC	Adjustable Gain settings (1-12)	Adjustable Gain settings (1-12)	Gain Function (adjust ouput for full scale sensitivity) Data smoothing		Secrutiy function Digital processing Programmable attenuation	Colour Touch screen display Print directly from instrument
Dimensions (weight)	The smaller the better.	17.5x48x43 cm (15kg)	20x45x41.5 cm (11kg)	36x50.4 x50 cm (20kg)	25x48 x55 cm (20kg)	28.8x19x50 cm (13.6kg)	31.8x58.4x54.8cm (16kg)	46x23x48cm (14.5kg)	60x30x50 cm (20.5kg)

Polymer Laboratories

Now a part of Varian, Inc.

VARIAN