Membrane Inlet Systems for Portable Mass Spectrometers

Olga Victorova and Viktor Kogan,

Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia.

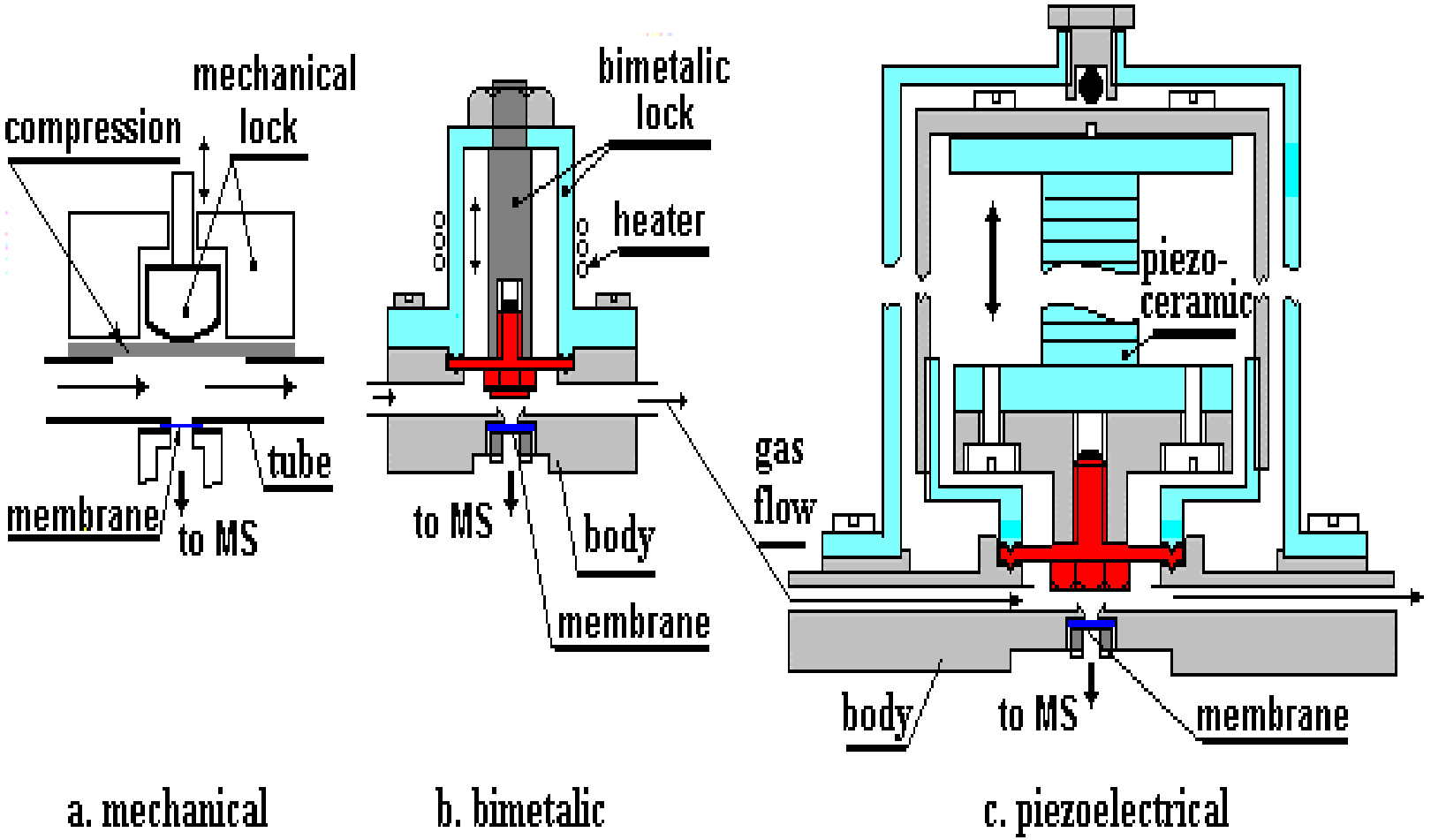
Abstract

Membrane inlet systems of a sample into mass spectrometer equipped with different kinds of locks are described. Its application in the portable mass spectrometers considerably facilitates automation of measuring process.

The results of appication of Levellyn system for detection of volatile organic compounds in air and water samples are presented.

The performance capabilities of multimembrane inlet systems with non-steady-state sample injection mode for air sample analysis are reviewed. Results of numerical simulation and experimental are discussed.

membrane inlets with different lock systems

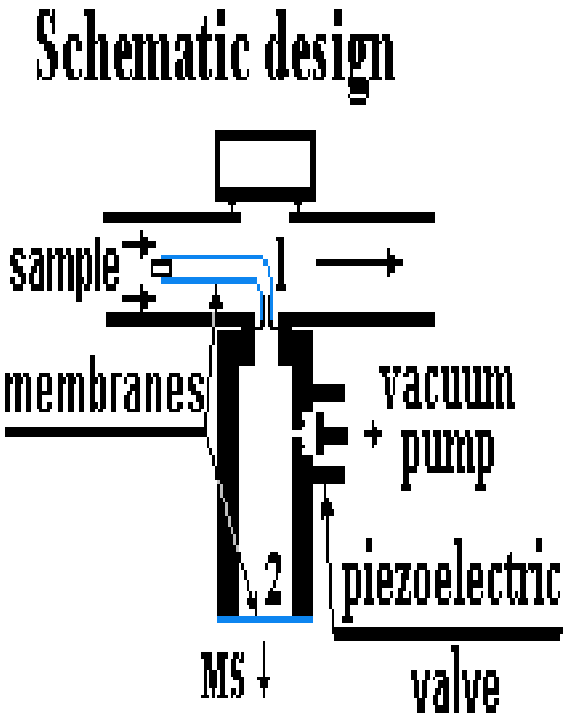


a. mechanical

b. bimetalic

c. piezoelectrical

The enrichment effect of Llewellyn system:



$$\text{if} \begin{cases} J_{valve}(j) \sim J_2(j) * 10; & j-\text{compound} \\ J_{valve}(m) \sim J_2(m) * 10 * \sigma''_j / \sigma''_m; & m-\text{matrix} \end{cases}$$

$$\text{then} \begin{cases} P_{v\,j} \sim P_{0\,j}/10 \\ P_{v\,m} \sim P_{0\,m}/(10 * \sigma'_j/\sigma'_m) \end{cases} \quad (\text{for } S_1 \sim S_2; \sigma' \sim \sigma'')$$

$$\text{and} \quad \frac{J_2(j)/P_{v\,j}}{J_2(m)/P_{v\,m}} \sim \sigma''_j/\sigma''_m; \quad \frac{J_2(j)/P_{0\,j}}{J_2(m)/P_{0\,m}} \sim (\sigma'_j/\sigma'_m)(\sigma''_j/\sigma''_m)$$

taking into account molecular flow throgh the valve

$$E = \sqrt{M_j/M_m}\,(\sigma_j/\sigma_m)^2 \quad \text{if} \quad \sigma' = \sigma''$$

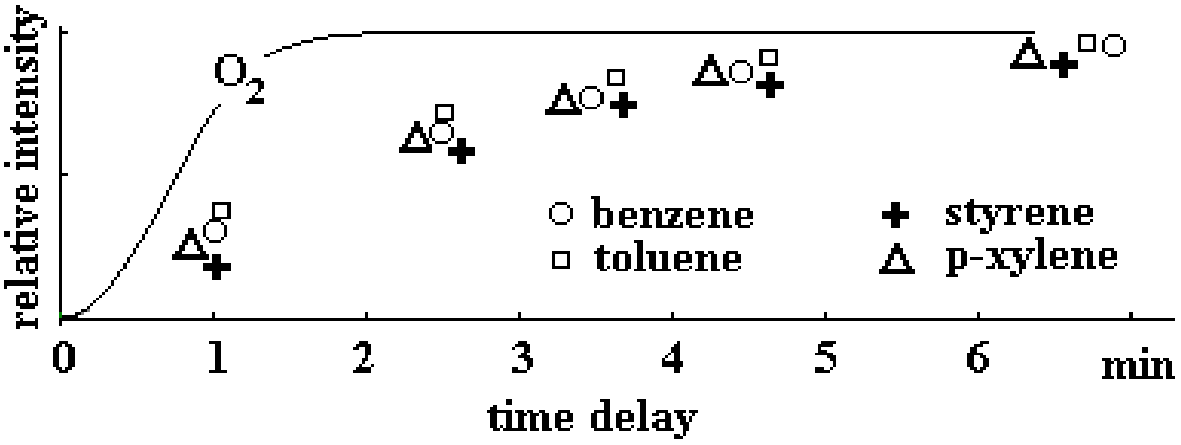
Portable mass spectrometer with Llewellyn's inlet system

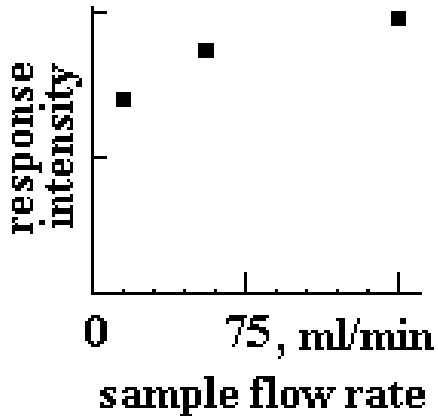
experimental results : gas analysis

- first capillary membrane, (id) 0.63 x (od) 1.18 mm , l=30 mm ;
- second sheet membrane, 0.1 mm thickness, S=30 mm^2;
- head space vapor-gas source, sample rate 150 ml/min ;

	VOCs				air constituents			
j	benzene	toluene	styrene	p-xylene	CO_2	Ar	O_2	N_2
	2.2 ppm	1.8 ppm	1.2 ppm	1.2 ppm	air			
E	$2.6*10^5$	$5.5*10^5$	$8.5*10^5$	$10.5*10^5$	310	6.5	4.1	1

Response



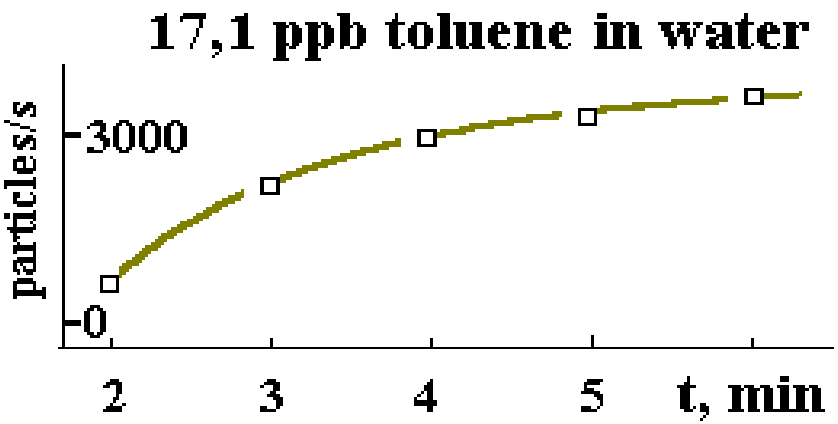


experimental results : water analysis

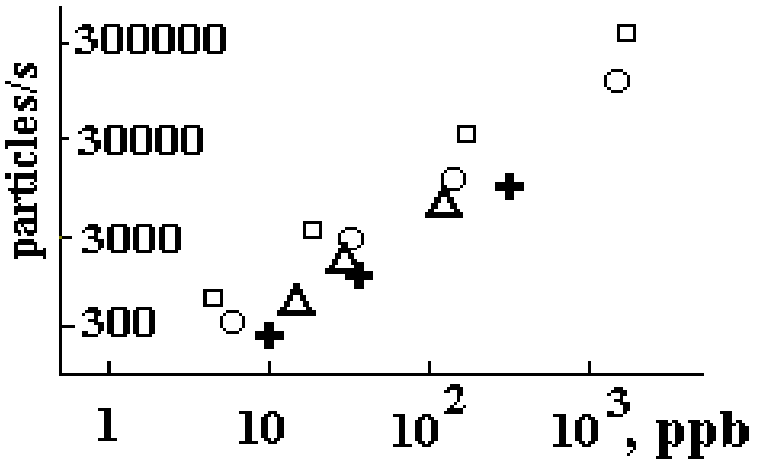
(sample rate 100 ml/min)

compound, j	dichloro - benzene	toluene	1,2-dichloro - ethane	chloroform	phenol
solubility, m%, $100\, m_j/(m_j+m_w)$	(25°C) **0.014**	(5°C) **0.063**	(25°C) **0.75**	(25°C) **0.80**	(25°C) **8.66**
detection limit	**1 ppb**	**1 ppb**	**1 ppb**	**5 ppb**	**5 ppm**

Response delay



Linearity

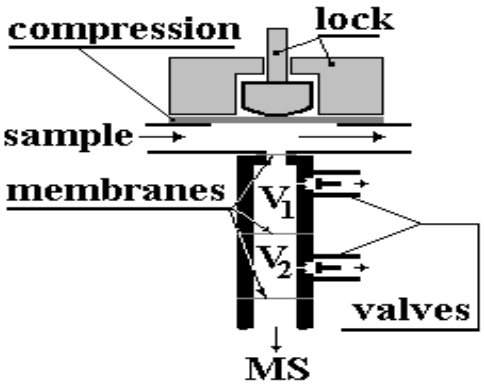


data with 4 minute delay

○ dichlorobenzene (75),
▫ toluene (91+92),
△ 1,2-dichloroethane (62),
✚ chloroform (83+85)

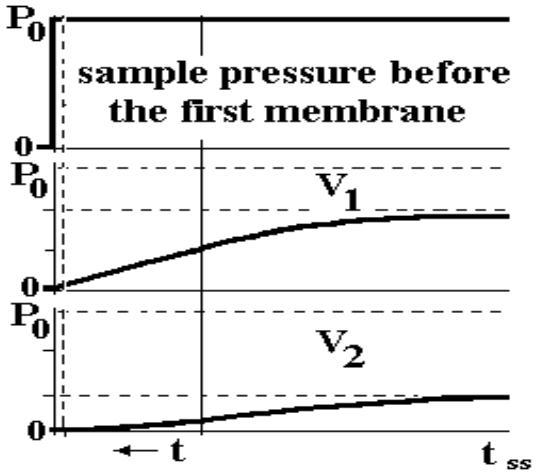
Tree sheet (30 μm) membrane system
(head-space vapor gas source, sample flow rate 150 ml/min)

a) Schematic design of a three membrane inlet

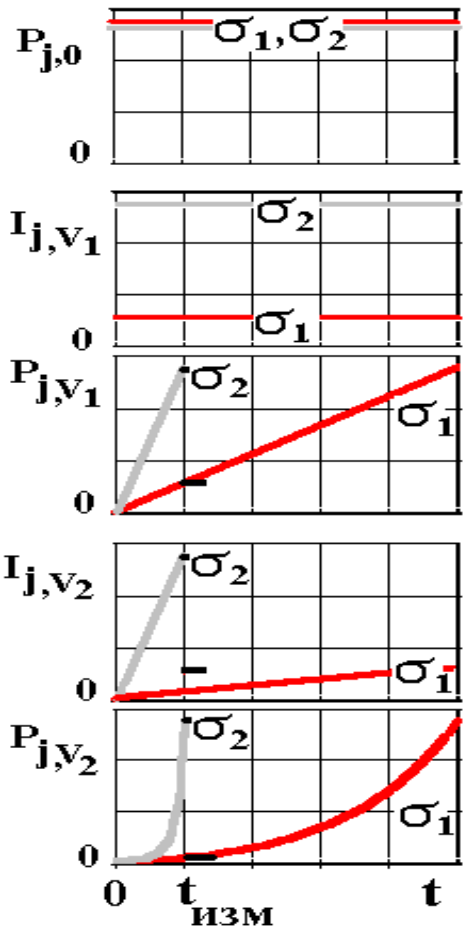


Pressure into the inlet during each stop-flow cycle

b) time scale $t \sim t_{ss}$



c) time scale $t << t_{ss}$, $\tau = 0$



compounds $j = 1, 2$;

$\sigma_2 > \sigma_1$; $P_{1,0} = P_{2,0}$

$I_{j,V_1} \simeq P_{j,0} \sigma_j S/l$

$P_{j,V_1} \simeq I_{j,V_1} t / V \simeq$

$\simeq P_{j,0} t^1 \sigma_j^1 S/l/V$ } N=1

$I_{j,V_2} \simeq P_{j,V_1} \sigma_j S/l \simeq$

$\simeq P_{j,0} t^1 \sigma_j^2 S^2/l^2/V$

$P_{j,V_2} \simeq I_{j,V_2} t / V \simeq$

$\simeq P_{j,0} t^2 \sigma_j^2 S^2/l^2/V^2$ } N=2

N=3

$$I_{j,V_{MC}} \simeq P_{j,V_2} \sigma_j S/l \simeq P_{j,0} t^2 \sigma_j^3 S^3/l^3/V^2$$

$$E_{2/1} = \frac{I_{2,MC}}{P_{2,0}} / \frac{I_{1,MC}}{P_{1,0}} \simeq (\sigma_2/\sigma_1)^3$$

	Enrichment effect for VOCs				and for air constituents			
j	benzene	toluene	styrene	p-xylene	CO_2	Ar	O_2	N_2
	2.2 ppm	1.8 ppm	1.2 ppm	1.2 ppm	air			
E(t=45s)	$0.6(3)\times10^5$	$0.7(5)\times10^5$	$0.4(3)\times10^5$	$0.5(8)\times10^5$	650	13	7	1
E_{max}	$\simeq 10^6 - 10^7$				700	13	7	1

Linearity of the response