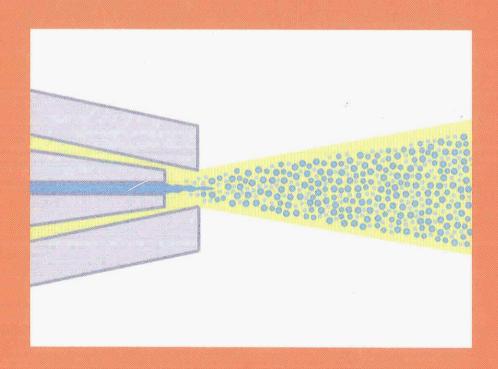


Liquid Sample Introduction in ICP Spectrometry A Practical Guide

José-Luis Todoli and Jean-Michel Mermet



Contents

1.	Introduction							
2.	Specifications of a Sample Introduction System to be Used with an ICP							
-	2.1	Introduction						
	2.2	Physic	al propertie	es of a plasma	4			
	2.3			by the plasma	5			
	2.4			ate and droplet velocity	6			
	2.5		~	/aporization	8			
	2.6	Plasma	9					
	2.7		Organic solvents					
	2.8	Ideal aerosol						
	2.9	Chemical resistance						
	2.10	Other	constraints	in sample introduction systems	15			
3.	Pneu	matic N	lebulizer D	Design Control of the	17			
	3.1	Introdu	action		1.7			
	3.2							
		3.2.1	Wave ger	neration	19			
		3.2.2	Wave gro	owing and break-up	20			
		3.2.3	Need for	a supersonic gas velocity	20			
		3.2.4	Main pne	eumatic nebulizer designs used in ICP spectrometry	22			
		3.2.5	Sample d	lelivery	23			
	3.3	Pneum	ntric nebulizers	24				
		3.3.1	Principle		24			
		3.3.2	Different	designs	27			
		3.3.3	Possibilit	y of free liquid uptake rate	31			
		3.3.4	Critical d	limensions	32			
		3.3.5	Renebuliz	zation	35			
		3.3.6	Nebulizer	r tip blocking	37			
		3.3.7	Acrosol o	drop characteristics	39			
			3.3.7.1	Influence of the gas and delivery rates on drop				
				size distribution	39			
			3.3.7.2	Spatial distribution and velocity	43 45			
	3.4	Cross-flow nebulizers						
	3.5	High-solids nebulizers						
	3.6							
		3.6.1	Principle		50			
		3.6.2	Critical d	dimensions	52			
	3.7	Comparison of the different conventional pneumatic nebulizers						
	3.8	Pneun	iatie mieror	nebulizers	57			
		3.8.1	High-Eff	iciency Nebulizer (HEN)	59			
		382	-	ncentric Nebulizer (MCN)	60			

	3.8.3	MicroMist nebulizer (MMN)	61				
		` '	61				
	3.8.4	PFA micronebulizer (PFAN)	62				
	3.8.5	Demountable concentric micronebulizers	63				
	3.8.6	High-efficiency cross-flow micronebulizer (HECFMN)	64				
	3.8.7	Parallel-Path Micronebulizer (PPMN)	65				
	3.8.8	Sonic-Spray Nebulizer (SSN)	65				
	3.8.9	Oscillating-Capillary Nebulizer (OCN)	66				
	3.8.10	High-Solids MicroNebulizer (HSMN)	66				
	3.8.11	Direct-Injection Nebulizers	67				
		3.8.11.1 Direct-Injection Nebulizer (DIN)	67				
		3.8.11.2 Direct-Injection High-Efficiency Nebulizer (DIHEN)	68				
		3.8.11.3 Vulkan Direct-Injection Nebulizer	71				
3.9	Compa	Comparison of micronebulizers					
Spra	y Chaml	ber Design	77				
4.1	Introdu	ection	77				
4.2	Aeroso	l transport phenomena	78				
	4.2.1	Droplet evaporation	79				
	4.2.2	Droplet coagulation	84				
	4.2.3	Droplet impacts	88				
4.3		ent spray chambers designs	90				
	4.3.1	Pouble-pass spray chamber	90				
	4.3.2	Cyclonic type spray chamber	97				
	4.3.3	Single-pass spray chambers	104				
4.4		rison of conventional spray chambers	104				
4.5	-	- ·	107				
+ .J	Low inner volume spray chambers						
	4.5.1	Aerosol transport and signal production processes at low liquid	110				
	4.5.0	flow rates	110				
	4.5.2	Low inner volume spray chamber designs	113				
	4.5.3	Tandem systems	117				
4.6	Conciu	sions on spray chambers	118				
_							
	Ivation S		119				
5.1	Introdu	ection	119				
5.2		ew of the effect of the solvent in ICP-AES and ICP-MS	120				
5.3	Process	ses occurring inside a desolvation system	122				
	5.3.1	Solvent evaporation	122				
	5.3.2	Nucleation or recondensation	124				
5.4	Acroso	l heating	125				
	5.4.1	Indirect aerosol heating	125				
	5.4.2	Radiative aerosol heating	127				
5.5		t removal	129				
	5.5.1	Solvent condensation	129				
		5.5.1.1 Nucleation problem in the condenser	129				
		5.5.1.2 Main condensation systems	130				
	5.5.2	Solvent removal through membranes	130				

5.6	Design of solvent reduction systems				
	5.6.1		stated spray chambers	134	
	5.6.2	Two-ste	p desolvation systems	135	
	5.6.3		e-step desolvation systems	136	
	5.6.4		tion systems based on the use of membranes	137	
	5.6.5		re desolvation systems	139	
	5.6.6		tion systems for the analysis of microsamples	140	
5.7	Comp	arison amo	ong different desolvation systems	142	
Mati	rix Effe	ets		147	
6.1	Introd	uction		147	
	6.1.1	Effect of	f physical properties on the sample introduction		
		system p	performance	148	
		6.1.1.1	Effects on the aerosol generation	148	
		6.1.1.2	Effects on the aerosol transport	149	
6.2	-		ganic acids	150	
	6.2.1		effects caused by inorganic acids	151	
		6.2.1.1	Influence on the sample uptake rate	151	
		6.2.1.2	Influence on the acrosol characteristics	151	
	(00	6.2.1.3	Effect on the solution transport rate	152	
	6.2.2 6.2.3		n the excitation/ionization cell	153	
	0.2.3	6.2.3.1	f acids on analytical results: Key variables Acid concentration and nature	154	
		6.2.3.1		155	
		6.2.3.3	Effect of the plasma observation game and	156	
		0.2.3.3	Effect of the plasma observation zone and observation mode	150	
		6.2.3,4	Effect of additional variables	158 159	
		6.2.3.5	Effect on the equilibration time	159	
	6.2.4		s for overcoming acid effects	160	
6.3			asily ionized elements	162	
0.0	6.3.1		effects caused by easily ionized elements	163	
		6.3.1.1	Influence on the aerosol characteristics	163	
		6.3.1.2	Effect on the solution transport rate	163	
	6.3.2		n the excitation/ionization cell	164	
	6.3.3		Effect of elements on ICP-AES analytical results: Key variables		
		6.3.3.1	Effect of the interfering element concentration and nature	165 166	
		6.3.3.2	Effect of the analyte line properties	167	
		6.3.3.3	Effect of the nebulizer gas flow rate and hf power	167	
		6.3.3.4	Effect of the plasma-observation zone	168	
		6.3.3.5	Effect of the plasma observation mode	169	
		6.3.3.6	Influence of the liquid flow rate	170	
		6.3.3.7	Effect of the liquid sample introduction system	170	
	6.3.4		d mechanisms explaining the matrix effects in ICP-AES	171	
	6.3.5		f elements on ICP-MS analytical results: Key variables	172	
		6.3.5.1	Effect of the nebulizer gas flow rate	173	
		6.3.5.2	Effect of the plasma-sampling position	174	
		6.3.5.3	Influence of the interferent and analyte properties and		
			concomitant concentration	174	

5.

Additional variables 6.3.5.5 Proposed mechanisms explaining the matrix effects in ICP-MS 176 6.3.6 6.3.7 Methods for overcoming elemental matrix effects 178 Internal standard and related methods 178 6.3.7.1 6.3.7.2 Methods based on empirical modeling 180 6.3.7.3 Methods based on the use of multivariate calibration 180

Effect of the spectrometer configuration

6.3.5.4

6.4

7.1 7.2

7.3

7.4

7.5

7.6

7.7

7.8

7.9

8.1

8.2

8.3

Acronyms

References

Index

8.

7.10

techniques 6.3.7.4 Sample treatment and other methods

Contents

174 175

181 181

182

183

185

191

192

197

198

198

202

205

205

205

206 208

212 2.13

217

217

218

219

233

235

285

Effects on the performance of sample introduction system Plasma effects

Organic solvents 6.4.1 6.4.2 Effect of the operating conditions Effect of the solvent nature

6.4.3 6.4.4 Effect of the liquid sample introduction system and the related 6.4.5 parameters Conventional liquid sample introduction systems 6.4.5.1

186 187 187 Low sample consumption systems 187 6.4.5.2 Desolvation systems 188 64.5.3 6.5 190 Conclusions Selection and Maintenance of Sample Introduction Systems 191 7.

Sample introduction systems for particular kinds of samples or applications

Operation, maintenance and troubleshooting of parallel path nebulizers

Operation, maintenance and troubleshooting of spray chambers

Description of applications of low sample consumption systems

Selecting a liquid sample introduction system: General aspects

Liquid sample introduction system

Selecting an aerosol transport device

Use of Mg as a test element

Measurement of the Mg II/Mg I ratio

Operation and troubleshooting of concentric nebulizers

Selecting a nebulizer

Procedure

Peristaltic pump

Diagnosis

7.7.1

7.7.2

7.7.3

Applications

Introduction

Selected applications