

Barbara H. Stuart

Forensic Analytical Techniques

CRIME SCENE DO NOT CROSS

FORENSIC ANALYTICAL TECHNIQUES

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Contents

Series Preface	xiii
Preface	xv
About the Author	xvii
Acronyms, Abbreviations and Symbols	xix
1 The Chemistry of Forensic Evidence	1
1.1 Introduction	1
1.2 Evidence Types	2
1.2.1 Polymers	2
1.2.2 Fibres	6
1.2.3 Paint	7
1.2.4 Documents	9
1.2.5 Glass	10
1.2.6 Soil	11
1.2.7 Explosives	12
1.2.8 Firearms	14
1.2.9 Arson	14
1.2.10 Body Fluids	16
1.2.11 Drugs and Toxicology	16
1.2.12 Fingerprints	21
1.3 Introduction to Data Analysis	23
1.4 Summary	24
References	24
2 Preliminary Tests	27
2.1 Introduction	27

2.2	Chemical Tests	27
2.2.1	Methods	28
2.2.2	Drugs and Toxicology	28
2.2.3	Body Fluids	29
2.2.4	Gunshot Residue	30
2.2.5	Explosives	31
2.2.6	Paint	31
2.2.7	Documents	32
2.3	Density	32
2.3.1	Methods	32
2.3.2	Glass	33
2.3.3	Soil	33
2.3.4	Polymers	34
2.4	Light Examination	35
2.4.1	Methods	35
2.4.2	Fingerprints	36
2.4.3	Body fluids	38
2.4.4	Documents	38
2.5	Summary	39
	References	39
3	Microscopic Techniques	41
3.1	Introduction	41
3.2	Optical Microscopy	42
3.2.1	Methods	42
3.2.2	Interpretation	44
3.2.3	Fibres	45
3.2.4	Paint	48
3.2.5	Drugs	49
3.2.6	Glass	49
3.2.7	Soil	50
3.2.8	Documents	51
3.2.9	Firearms	51
3.3	Transmission Electron Microscopy	51
3.3.1	Method	52
3.3.2	Interpretation	53
3.3.3	Paint	53
3.4	Scanning Electron Microscopy	54
3.4.1	Methods	54
3.4.2	Interpretation	55
3.4.3	Gunshot Residue	56

3.4.4	Paint	57
3.4.5	Fibres	58
3.4.6	Documents	58
3.4.7	Glass	59
3.5	Atomic Force Microscopy	59
3.5.1	Methods	59
3.5.2	Interpretation	60
3.5.3	Documents	60
3.6	X-Ray Diffraction	60
3.6.1	Methods	62
3.6.2	Interpretation	63
3.6.3	Explosives	63
3.6.4	Paint	63
3.6.5	Drugs	64
3.6.6	Documents	65
3.6.7	Soil	65
3.7	Summary	66
	References	66
4	Molecular Spectroscopy	69
4.1	Introduction	70
4.2	Infrared Spectroscopy	70
4.2.1	Methods	70
4.2.2	Interpretation	73
4.2.3	Paint	74
4.2.4	Fibres	75
4.2.5	Polymers	82
4.2.6	Documents	85
4.2.7	Explosives	86
4.2.8	Drugs	87
4.3	Raman Spectroscopy	89
4.3.1	Methods	90
4.3.2	Interpretation	91
4.3.3	Drugs	91
4.3.4	Paint	93
4.3.5	Fibres	94
4.3.6	Documents	94
4.3.7	Explosives	94
4.4	Ultraviolet–visible Spectroscopy	95
4.4.1	Methods	95
4.4.2	Interpretation	97

4.4.3	Fibres	97
4.4.4	Paint	98
4.4.5	Documents	99
4.4.6	Drugs	99
4.4.7	Toxicology	101
4.5	Fluorescence Spectroscopy	101
4.5.1	Methods	101
4.5.2	Interpretation	102
4.5.3	Body Fluids	102
4.5.4	Toxicology	103
4.5.5	Fibres	104
4.6	Nuclear Magnetic Resonance Spectroscopy	104
4.6.1	Methods	104
4.6.2	Interpretation	105
4.6.3	Drugs	107
4.6.4	Explosives	108
4.7	Summary	109
	References	109
5	Elemental Analysis	113
5.1	Introduction	113
5.2	Atomic Spectrometry	114
5.2.1	Methods	114
5.2.2	Interpretation	115
5.2.3	Glass	115
5.2.4	Gunshot Residue	116
5.2.5	Toxicology	116
5.3	Inductively Coupled Plasma–Mass Spectrometry	117
5.3.1	Methods	117
5.3.2	Interpretation	118
5.3.3	Glass	118
5.3.4	Paint	118
5.3.5	Gunshot Residue	119
5.4	X-Ray Fluorescence Spectroscopy	119
5.4.1	Methods	120
5.4.2	Interpretation	120
5.4.3	Glass	121
5.4.4	Gunshot Residue	122
5.4.5	Paint	122
5.5	Particle-Induced X-Ray Emission Spectroscopy	123
5.5.1	Methods	124
5.5.2	Interpretation	124
5.5.3	Glass	124

5.6	Neutron Activation Analysis	125
5.7	Summary	125
	References	126
6	Mass Spectrometry	129
6.1	Introduction	129
6.2	Molecular Mass Spectrometry	129
6.2.1	Methods	130
6.2.2	Interpretation	132
6.2.3	Drugs	132
6.2.4	Explosives	134
6.3	Isotope Ratio Mass Spectrometry	134
6.3.1	Methods	135
6.3.2	Interpretation	136
6.3.3	Drugs	136
6.3.4	Explosives	136
6.4	Ion Mobility Spectrometry	137
6.4.1	Methods	137
6.4.2	Interpretation	137
6.4.3	Explosives	138
6.4.4	Drugs	138
6.5	Summary	140
	References	140
7	Separation Techniques	143
7.1	Introduction	144
7.2	Paper Chromatography	144
7.2.1	Methods	144
7.2.2	Interpretation	144
7.2.3	Documents	145
7.3	Thin Layer Chromatography	145
7.3.1	Methods	146
7.3.2	Interpretation	146
7.3.3	Drugs	146
7.3.4	Documents	147
7.3.5	Fibres	148
7.3.6	Explosives	148
7.4	Gas Chromatography	149
7.4.1	Methods	149
7.4.2	Interpretation	150
7.4.3	Drugs	150
7.4.4	Toxicology	152

7.4.5	Arson Residues	154
7.4.6	Explosives	155
7.5	Liquid Chromatography	155
7.5.1	Methods	155
7.5.2	Interpretation	156
7.5.3	Drugs and Toxicology	156
7.5.4	Fibres	158
7.6	Ion Chromatography	159
7.6.1	Methods	159
7.6.2	Interpretation	159
7.6.3	Explosives	159
7.7	Capillary Electrophoresis	161
7.7.1	Methods	161
7.7.2	Interpretation	162
7.7.3	Drugs and Toxicology	162
7.7.4	Explosives and Gunshot Residues	163
7.8	Summary	163
	References	164
8	Thermal Analysis	167
8.1	Introduction	167
8.2	Pyrolysis Techniques	168
8.2.1	Methods	168
8.2.2	Interpretation	168
8.2.3	Paint	169
8.2.4	Fibres	170
8.2.5	Polymers	170
8.2.6	Documents	171
8.3	Differential Scanning Calorimetry and Differential Thermal Analysis	171
8.3.1	Methods	171
8.3.2	Interpretation	171
8.3.3	Polymers	173
8.3.4	Fibres	173
8.4	Thermogravimetric Analysis	174
8.4.1	Methods	174
8.4.2	Interpretation	176
8.4.3	Polymers	177
8.4.4	Explosives and Arson Residues	177
8.5	Summary	178
	References	178

<i>Contents</i>	xi
Responses to Self-Assessment Questions	181
Bibliography	195
Glossary of Terms	197
SI Units and Physical Constants	203
Periodic Table	207
Index	209

Series Preface

There has been a rapid expansion in the provision of further education in recent years, which has brought with it the need to provide more flexible methods of teaching in order to satisfy the requirements of an increasingly more diverse type of student. In this respect, the open learning approach has proved to be a valuable and effective teaching method, in particular for those students who for a variety of reasons cannot pursue full-time traditional courses. As a result, John Wiley & Sons, Ltd first published the Analytical Chemistry by Open Learning (ACOL) series of textbooks in the late 1980s. This series, which covers all of the major analytical techniques, rapidly established itself as a valuable teaching resource, providing a convenient and flexible means of studying for those people who, on account of their individual circumstances, were not able to take advantage of more conventional methods of education in this particular subject area.

Following upon the success of the ACOL series, which by its very name is predominately concerned with analytical chemistry, the Analytical Techniques in the Sciences (AnTS) series of open learning texts has now been introduced with the aim of providing a broader coverage of the many areas of science in which analytical techniques and methods are now increasingly applied. With this in mind, the AnTS series of texts seeks to provide a range of books which will cover not only the actual techniques themselves, but also those scientific disciplines which have a necessary requirement for analytical characterization methods.

Analytical instrumentation continues to increase in sophistication, and as a consequence, the range of materials that can now be almost routinely analysed has increased accordingly. Books in this series which are concerned with the techniques themselves will reflect such advances in analytical instrumentation, while at the same time providing full and detailed discussions of the fundamental concepts and theories of the particular analytical method being considered. Such books will cover a variety of techniques, including general instrumental analysis, spectroscopy, chromatography, electrophoresis, tandem techniques, electroanalytical methods, X-ray analysis and other significant topics. In addition, books in

the series will include the application of analytical techniques in areas such as environmental science, the life sciences, clinical analysis, food science, forensic analysis, pharmaceutical science, conservation and archaeology, polymer science and general solid-state materials science.

Written by experts in their own particular fields, the books are presented in an easy-to-read, user-friendly style, with each chapter including both learning objectives and summaries of the subject matter being covered. The progress of the reader can be assessed by the use of frequent self-assessment questions (SAQs) and discussion questions (DQs), along with their corresponding reinforcing or remedial responses, which appear regularly throughout the texts. The books are thus eminently suitable both for self-study applications and for forming the basis of industrial company in-house training schemes. Each text also contains a large amount of supplementary material, including bibliographies, lists of acronyms and abbreviations, tables of SI units and important physical constants and, where appropriate, glossaries and references to literature sources.

It is therefore hoped that this present series of textbooks will prove to be a useful and valuable source of teaching material, both for individual students and for teachers of science courses.

*Dave Ando
Dartford, UK*

Preface

The public profile of forensic science has dramatically increased in recent decades and there has been a corresponding rise in the number of students undertaking forensic science degree courses at a tertiary level with the view to a professional career in this field. During this period the application of modern analytical techniques to the examination of forensic problems has expanded, particularly due to the development of small and portable cost-effective instrumentation. The availability of new techniques has led to a greater choice of tools that can be employed to analyse forensic specimens. An understanding of a broad range of analytical tools is required by today's forensic chemists and is an important aspect of their training.

The aim of this book is to provide an overview of the most commonly used analytical techniques that are of interest to forensic chemists. A clear description of how each technique works and how to prepare specimens for analysis is provided. Some techniques are widely used as standard methods, while others are yet to be established but show great potential. An explanation of how to analyse the data obtained is also provided and, for each technique, the most common forensic applications are described. There are specific issues to consider when examining forensic samples. Apart from the applicability of a technique, the issues of dealing with small quantities of material, whether a technique is non-destructive and the cost and/or portability for fieldwork must be considered.

The reader will note that there is a deliberate focus on forensic chemistry and physical evidence. Topics such as DNA analysis are intentionally not dealt with here, and forensic biology topics are well covered elsewhere. The focus here is on how to analyse samples once collected – the process of evidence collection is, of course, an important aspect of a forensic scientist's training and is an expansive topic in its own right. This book is designed for students who are undertaking a forensic chemistry based programme and require a sound knowledge of analytical techniques. Some basic tertiary mathematical and chemistry knowledge is

assumed. The book will also provide a useful reference for forensic practitioners who may be interested in investigating new forms of evidence or techniques.

I hope that this book helps fill a gap in the world of forensic textbooks. Naturally many forensic science textbooks focus on the collection of evidence, but this book will provide a resource for the teaching of forensic analytical techniques. I would like to acknowledge the valuable conversations with and the data provided by a multitude of hardworking forensic scientists in police forces, law enforcement agencies and universities – not just in Australia, but worldwide. A special thanks to my colleagues and students past and present in the Centre of Forensic Science and the School of Chemistry and Forensic Science at the University of Technology, Sydney.

About the Author

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Barbara Stuart holds the position of Associate Professor at the School of Chemistry and Forensic Science and the Centre for Forensic Science at the University of Technology, Sydney (UTS) in Australia. She received BSc (Hons) and MSc degrees in chemistry from the University of Sydney in Australia and gained her PhD at Imperial College in London in 1993. Barbara held the position of lecturer at the University of Greenwich, London before returning to Australia to take up a position at UTS in 1995. Barbara has contributed to the teaching of a broad range of topics in the chemistry, forensic and materials programmes at UTS. She also has active research interests in the fields of forensic taphonomy and archaeology, as well as in materials conservation and environmental science, and has published many papers on these topics. Barbara is also the author of five other books published by John Wiley & Sons: *Modern Infrared Spectroscopy* and *Biological Applications of Infrared Spectroscopy*, both in the ACOL series of open learning texts, and *Polymer Analysis* and *Infrared Spectroscopy: Fundamentals and Applications* in the current AnTS series of texts, as well as *Analytical Techniques in Materials Conservation*.

Acronyms, Abbreviations and Symbols

AAS	atomic absorption spectrometry
AES	atomic emission spectrometry
AFM	atomic force microscopy
ALS	alternate light source
ANN	artificial neural network
APCI	atmospheric pressure chemical ionization
ATR	attenuated total reflectance
BAC	blood alcohol concentration
BSA	<i>N,O</i> -bistrimethylsilylic acid
BSE	backscattered electron
BSTFA	<i>N,O</i> -bistrimethylsilyltrifluoroacetamide
CE	capillary electrophoresis
CI	chemical ionization
CNS	central nervous system
COHb	carboxyhaemoglobin
CZE	capillary zone electrophoresis
Δn	birefringence
DAC	diamond anvil cell
DAD	diode array detector
DART	direct analysis in real time
DC	direct current
DESI	desorption electrospray ionization
DFO	1,8-diazafluoren-9-one
DRIFT	diffuse reflectance infrared by Fourier transform
DSC	differential scanning calorimetry
DTA	differential thermal analysis
DTG	derivative thermogravimetric

ECD	electron capture detector
EDS	energy dispersive X-ray spectroscopy
EDX	energy-dispersive X-ray analysis
EDXRF	energy-dispersive X-ray fluorescence
EELS	electron energy loss spectroscopy
EI	electron ionization
ESEM	environmental scanning electron microscopy
ESI	electrospray ionization
FID	flame ionization detector
GC	gas chromatography
GHB	gamma-hydroxybutyric acid
GFAAS	graphite furnace atomic absorption spectrometry
GRIM	Glass Refractive Index Measurement
GSR	gunshot residue
Hb	haemoglobin
HCA	hierarchical clustering analysis
HDPE	high-density polyethylene
HPLC	high-performance liquid chromatography
IBA	ion beam analysis
IC	ion chromatography
ICDD	International Centre for Diffraction Data
ICP–MS	inductively coupled plasma–mass spectrometry
ILR	ignitable liquid residue
IMS	ion mobility spectrometry
IRMS	isotope ratio mass spectrometry
LC	liquid chromatography
LDA	linear discriminant analysis
LDPE	low-density polyethylene
LIBS	laser-induced breakdown spectroscopy
MDA	methylenedioxymphetamine
MDMA	methylenedioxymethylamphetamine
MDEA	3,4-methylenedioxyethylamphetamine
MECC	micellar electrokinetic capillary chromatography (<i>also</i> MEKC)
MI	medullary index
MS	mass spectrometry
MSP	microspectrophotometry
MSTFA	<i>N</i> -methyl- <i>M</i> -trimethylsilyltrifluoroacetamide
<i>m/z</i>	mass-to-charge (ratio)
NMR	nuclear magnetic resonance
NOE	Nuclear Overhauser Effect
NRA	nuclear reaction analysis
PC	paper chromatography

PCA	principal component analysis
PD	physical developer
PDMS	polydimethylsiloxane
PE	polyethylene
PET	poly(ethylene terephthalate)
PETN	pentaerythritol tetranitrate
PIXE	particle-induced X-ray emission
PLM	polarizing light microscope
PMMA	poly(methyl methacrylate)
PP	polypropylene
ppb	parts per billion
ppm	parts per million
PS	polystyrene
PSA	prostate-specific antigen (test)
PVC	poly(vinyl chloride)
ρ	density
R^2	coefficient of determination
RBS	Rutherford back scattering spectrometry
RF	radiofrequency
RI	reflective index
RRS	resonance Raman spectroscopy
SAN	styrene-acrylonitrile
SAP	seminal acid phosphatase
SBR	styrene-butadiene rubber
SE	secondary electron
SEM	scanning electron microscopy
SERS	surface-enhanced Raman spectroscopy
SIMS	secondary ion mass spectrometry
SIM	selected ion monitoring
SPE	solid-phase extraction
SPME	solid-phase microextraction
TEA	thermal energy analyser
TEM	transmission electron microscopy
TFAA	trifluoroacetic anhydride
TGA	thermogravimetric analysis
THC	Δ^9 -tetrahydrocannabinol
THM	thermally assisted hydrolysis methylation
TLC	thin layer chromatography
TMAH	tetramethylammonium hydroxide
TMB	tetramethylbenzidine
TOF	time-of-flight
TOF-SIMS	time-of-flight secondary ion mass spectrometry