THE ANALYSIS
OF CONTROLLED
SUBSTANCES

Michael D. Cole
Anglia Polytechnic University, Cambridge, UK
THE ANALYSIS
OF CONTROLLED
SUBSTANCES
Analytical Techniques in the Sciences (AnTS)

Series Editor: David J. Ando, Consultant, Dartford, Kent, UK

A series of open learning/distance learning books which covers all of the major analytical techniques and their application in the most important areas of physical, life and materials sciences.

Titles available in the Series

Analytical Instrumentation: Performance Characteristics and Quality
Graham Currell, University of the West of England, Bristol, UK

Fundamentals of Electroanalytical Chemistry
Paul M.S. Monk, Manchester Metropolitan University, Manchester, UK

Introduction to Environmental Analysis
Roger N. Reeve, University of Sunderland, UK

Polymer Analysis
Barbara H. Stuart, University of Technology, Sydney, Australia

Chemical Sensors and Biosensors
Brian R. Eggins, University of Ulster at Jordanstown, Northern Ireland, UK

Methods for Environmental Trace Analysis
John R. Dean, Northumbria University, Newcastle, UK

Liquid Chromatography–Mass Spectrometry: An Introduction
Robert E. Ardrey, University of Huddersfield, Huddersfield, UK

The Analysis of Controlled Substances
Michael D. Cole, Anglia Polytechnic University, Cambridge, UK

Forthcoming Titles

Infrared Spectroscopy: Experimentation and Applications
Barbara H. Stuart, University of Technology, Sydney, Australia
THE ANALYSIS OF CONTROLLED SUBSTANCES

Michael D. Cole
Anglia Polytechnic University, Cambridge, UK
For Mum, Dad and Ania, for all of their love, support and encouragement
Contents

Series Preface xi
Preface xiii
Acronyms, Abbreviations and Symbols xv
About the Author xvii

1 Introduction to Drug Trends, Control, Legislation and Analysis 1
   1.1 Introductory Remarks 1
   1.2 International Legislation 2
   1.3 Controlled Substances in the United Kingdom 3
      1.3.1 Background to the Misuse of Drugs Act, 1971 3
      1.3.2 The Provisions of the Misuse of Drugs Act, 1971 3
   1.4 Controlled Substances in the United States 5
   1.5 Controlled Substances in Australia 5
   1.6 The Drug Chemist and Drug Analysis 5
   1.7 Quality Assurance in the Drugs Laboratory 9
   1.8 Presentation of Evidence in Court 10
   References 11

2 Amphetamine and Related Compounds 13
   2.1 Introduction 13
   2.2 Qualitative Identification of Amphetamines 15
      2.2.1 Sampling and Physical Description of Amphetamines 15
      2.2.2 Presumptive Testing of Amphetamines 18
      2.2.3 Thin Layer Chromatography of Amphetamines 19
      2.2.4 Definitive Identification of Amphetamines 20
2.3 Quantification of Amphetamines 25
2.4 Comparison and Profiling of Amphetamine Samples 31
   2.4.1 The Leuckart Synthesis of Amphetamine 32
   2.4.2 The Reductive Amination of Benzyl Methyl Ketone 32
   2.4.3 The Nitrostyrene Synthesis 33
   2.4.4 Impurity Extraction and Sample Comparison 34
References 36

3 The Analysis of LSD 37
3.1 Introduction 37
3.2 Qualitative Identification of LSD 38
   3.2.1 Sampling and Physical Description of LSD Blotter Acid 39
   3.2.2 Extraction of LSD Prior to Analysis 41
   3.2.3 Presumptive Testing for LSD 42
   3.2.4 Thin Layer Chromatography of Samples Containing LSD 43
   3.2.5 Confirmatory Tests for the Presence of LSD 43
References 47

4 Cannabis sativa and Products 49
4.1 Introduction 49
4.2 Origins, Sources and Manufacture of Cannabis 51
4.3 Analytical Sequence, Bulk and Trace Sampling Procedures 53
4.4 Qualitative Identification of Cannabis 54
   4.4.1 Identification of Herbal Material 55
   4.4.2 Identification of Other Materials 57
   4.4.3 Comparison of Cannabis Samples 65
References 72

5 Diamorphine and Heroin 73
5.1 Introduction 73
5.2 Origins, Sources and Manufacture of Diamorphine 74
5.3 Appearance of Heroin and Associated Paraphernalia 77
5.4 Bulk and Trace Sampling Procedures 78
5.5 Identification, Quantification and Comparison of Heroin Samples 79
   5.5.1 Presumptive Tests for Heroin 80
   5.5.2 Thin Layer Chromatography of Heroin Samples 81
   5.5.3 Gas Chromatographic–Mass Spectroscopic Identification of Heroin 83
   5.5.4 Quantification of Heroin Samples 87
   5.5.5 Comparison of Heroin Samples 92
References 95
9 The Analysis of Controlled Pharmaceutical Drugs – Barbiturates and Benzodiazepines 139

9.1 Introduction 139
9.2 Analysis of Barbiturates and Benzodiazepines 141
  9.2.1 Extraction of Barbiturates and Benzodiazepines from Dose Forms 142
  9.2.2 Presumptive Tests for Barbiturates and Benzodiazepines 142
  9.2.3 TLC of Barbiturates and Benzodiazepines 143
  9.2.4 Confirmatory Analysis of Barbiturates and Benzodiazepines 146
  9.2.5 Quantification of Barbiturates and Benzodiazepines 149

References 151

10 Current Status, Summary and Conclusions 153

  10.1 Current Status of Drug Analysis 153
  10.2 Conclusions 155

Appendices 157

  1 Presumptive (Colour) Tests 157
  2 Less-Common Controlled Substances 159

Responses to Self-Assessment Questions 161

Bibliography 175

Glossary of Terms 179

SI Units and Physical Constants 183

Periodic Table 187

Index 189
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 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, and tables of SI Units and important physical constants, plus 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 control of drugs is an emotive issue and has been, and will continue to be, the subject of much debate. Many drugs have medical uses and these, and others, are also used for ‘recreational’ purposes. A large number are also subject to control at both national and international levels. Many are addictive and their use can sometimes result in antisocial behaviour. Furthermore, their use is often associated with significant health risks, where these are known. It is not the intention of this present book to debate the ‘rights and wrongs’ of drug control and use. While drugs remain controlled, it will be necessary, within the legal context, for the forensic scientist to carry out a number of types of analyses, including the following:

1. Determine whether or not a controlled substance is present.
2. Determine how much of the substance is present.
3. Determine, on occasion, the relationship of drug samples to each other.

Drug analysis is one of the areas of forensic science where it is necessary to carry out an analytical investigation, in this case to prove whether a controlled substance is present or otherwise. In order to achieve this, a number of analyses are required, which must conform to the highest scientific standards. It is the aim of this text to illustrate the analyses that must be undertaken and why, to explain the processes and their underlying chemistry, and to give the reader an insight into why each of the analyses is performed. The book is not exhaustive in describing all of the methods that are available – there is a huge body of scientific literature available, including research methods that have not yet found casework applications. The choice of method will depend upon the resources and equipment available to the analyst, the legislative system in which the analyst is working and the questions being asked. The first chapter outlines the legal context of the analyses, while each of the subsequent chapters describe methods which
can be applied to individual classes of drugs. The methods that are described in this book have, however, been used by the present author and in many examples the data are taken from casework materials, with the methods being known to work. By applying the principles described, the analyst should arrive at sound findings in terms of a particular analysis.

It would not have been possible to write this book without the support and encouragement of a great number of people, including colleagues and friends from around the world, and my family. For this, I thank them all.

Mike Cole
Anglia Polytechnic University, Cambridge, UK
# Acronyms, Abbreviations and Symbols

## General

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td>absorbance unit</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>DNA</td>
<td>deoxyribonucleic acid</td>
</tr>
<tr>
<td>ENFSI</td>
<td>European Network of Forensic Science Institutes</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier-transform infrared (spectroscopy)</td>
</tr>
<tr>
<td>GC-ECD</td>
<td>gas chromatography, employing electron-capture detection</td>
</tr>
<tr>
<td>GC-FID</td>
<td>gas chromatography, employing flame-ionization detection</td>
</tr>
<tr>
<td>GC–MS</td>
<td>gas chromatography–mass spectrometry</td>
</tr>
<tr>
<td>HIV</td>
<td>human immunodeficiency virus</td>
</tr>
<tr>
<td>HPLC</td>
<td>high performance liquid chromatography</td>
</tr>
<tr>
<td>i.d.</td>
<td>internal diameter</td>
</tr>
<tr>
<td>IR</td>
<td>infrared</td>
</tr>
<tr>
<td>LLE</td>
<td>liquid–liquid extraction</td>
</tr>
<tr>
<td>PPE</td>
<td>personal protective equipment</td>
</tr>
<tr>
<td>QA</td>
<td>quality assurance</td>
</tr>
<tr>
<td>SIM</td>
<td>selected-ion monitoring</td>
</tr>
<tr>
<td>SPE</td>
<td>solid-phase extraction</td>
</tr>
<tr>
<td>TIC</td>
<td>total ion current</td>
</tr>
<tr>
<td>TLC</td>
<td>thin layer chromatography</td>
</tr>
<tr>
<td>UNDCP</td>
<td>United Nations Drug Control Programme</td>
</tr>
<tr>
<td>UV</td>
<td>ultraviolet</td>
</tr>
</tbody>
</table>

- \(d_f\) film thickness (of chromatography column)
- \(M_r\) relative molecular weight
$m/z$ mass-to-charge ratio
$R$ correlation coefficient
$R^2$ coefficient of determination
$R_f$ retardation factor (or relative front value)
$t_R$ retention time (chromatography)

$\lambda_{\text{max}}$ wavelength of maximum absorption in a UV spectrum

### Chemical Species

- **BMK** benzyl methyl ketone
- **BSTFA** bis(trimethylsilyl)trifluoroacetamide
- **CBD** cannabidiol
- **CBN** cannabinol
- **TMS** trimethylsilyl
- **THC** tetrahydrocannabinol
- **LSD** lysergic acid diethylamide
- **MDA** 3,4-methylenedioxyamphetamine
- **MDEA** 3,4-methylenedioxyethylamphetamine
- **MDMA** 3,4-methylenedioxymethylamphetamine
- **MSTFA** $N$-methyl-$N$-(trimethylsilyl)-2,2,2-trifluoroacetamide
- **N,O-BSA** $N,O$-bis(trimethylsilyl)acetamide
- **ODS** octadecasilyl
- **PCP** phencyclidine
- **HFBA** heptafluorobutyric anhydride
Michael Cole graduated from the University of Cambridge in 1986 with a degree in Natural Sciences. From there his career progressed when he obtained a Ph.D. in Natural Product Chemistry from the University of London in 1990, having studied both at this university and The Royal Botanic Gardens, Kew, UK. In 1990, he joined the staff of the Forensic Science Unit at the University of Strathclyde as a short-course tutor, from where he progressed to Director of the Unit in 2000. In July 2001, Michael was appointed Professor of Forensic Science at Anglia Polytechnic University, Cambridge, where he now heads the Department of Forensic Science and Chemistry.

In addition to university duties, Michael was chairman of the European Network of Forensic Science Institutes Working Group on Drugs and Lead Assessor for the Council for the Registration of Forensic Practitioners Drugs Section, and has undertaken drug-related forensic casework in the UK and overseas. He has published a number of papers on drug analysis, particularly in the area of methods of drug identification and profiling.

Teaching and training in forensic science has always interested Michael and he has developed a number of short courses and integrated lecture courses, with a particular emphasis on drug analysis. These have been delivered in the UK, Europe, North and South America and in the Far East. Michael is particularly keen to continue to develop the educational provision in this discipline.
Chapter 1

Introduction to Drug Trends, Control, Legislation and Analysis

Learning Objectives

- To appreciate the problem of increasing drug use.
- To be aware of the international legislation relating to drugs.
- To be aware of the legislation in relation to the control of drugs in the United Kingdom, the United States and Australia.
- To appreciate the role of the drugs chemist in drugs analysis.
- To understand the need for quality assurance in the drugs laboratory.
- To gain an understanding of the ways to facilitate evidence presentation in court.

1.1 Introductory Remarks

The problems associated with psychotropic drugs and controlled substances have been, and continue to be, the subject of much debate. Regardless of one’s views, however, there remains the fact that a number of drugs are controlled substances. There is now a considerable body of evidence that the number of people using controlled substances for non-medical purposes is increasing. Data from the United Kingdom (Figure 1.1) is mirrored by that collected from the international community.

Within the legal and forensic science context, in order to prove that an offence has been committed, it is necessary to prove that a drug is present, and, if required, to determine the amount of the drug and its relationship to other samples. It is essential for those working in this area to understand how such analyses are
carried out. In order to select, and critically evaluate, such analyses, it is also necessary to have an overview of the corresponding legislation in the jurisdiction in which one is working.

### 1.2 International Legislation

Within the international context, controls on drugs are set out in three treaties issued by the United Nations, namely:


Signatories to these treaties implement control through domestic laws. In the United Kingdom, the principle legislative document for drug control is the Misuse of Drugs Act, 1971. This has been the subject of 14 modification orders and is accompanied by the Misuse of Drugs Act (Regulations), 1985, which was superseded by the Misuse of Drugs Act (Regulations), 2001.

Within the United States, the situation is further complicated because drugs are scheduled at the Federal level, but there may also be legislation at the State and County levels.
1.3 Controlled Substances in the United Kingdom

1.3.1 Background to the Misuse of Drugs Act, 1971

In the UK today, the legislative documents that are used to control drugs of abuse are the Misuse of Drugs Act, 1971, its amendments and modification orders, and the Misuse of Drugs Act (Regulations), 2001, which supersedes the Misuse of Drugs Act (Regulations), 1985. In essence, the Misuse of Drugs Act, 1971 defines what may not be done with respect to these compounds, while the Misuse of Drugs Act (Regulations), 2001 defines what may be done under the appropriately controlled circumstances. Similarly, customs offences, such as ‘knowingly evading prohibition on unauthorized import/export of controlled substances’, are regulated by the Customs and Excise Management Act, 1979.

Historically, in the United Kingdom the Dangerous Drugs Act, 1951 simply controlled vegetable narcotics, such as Cannabis sativa (cannabis) and opium, and a few chemically related synthetic substances. This was superseded by the Dangerous Drugs Act, 1964, which organized the controlled drugs into three schedules based on internationally accepted principles. This was the first time that stimulants, used as anorectics, such as amphetamine and its analogues, were included in British Law. It also introduced some specific offences in relation to cannabis. In 1965, a new act, i.e. the Dangerous Drugs Act, 1965, combined the provisions of the Dangerous Drugs Act, 1951 with those of the Dangerous Drugs Act, 1964, as well as providing a more comprehensive definition of herbal cannabis as ‘the fruiting and flowering tops of any plant of the genus Cannabis’. Since the forensic scientist still came across difficulties in discriminating fragmented plant parts which could still be a potent source of the active constituents of the plant, herbal cannabis was therefore redefined in the Misuse of Drugs Act, 1971 as: ‘all the aerial parts, except the lignified stem and the non-viable seed, of any plant of the genus Cannabis’.

Another problem to be corrected by the Misuse of Drugs Act 1971 was that of the analogues of amphetamines, which were defined as: ‘structurally derived by substitution in the side-chain or by ring closure therein’ in the Act of 1965. Several compounds, such as ephedrine, were specifically excepted, but over 90 others were not purposely included. This was corrected by naming the specific compounds. Care was taken to re-phrase the wording so that certain chemical compounds, having the potential to become drugs of abuse, which might not yet have been available, generally referred to as ‘designer drugs’, would still be included. References were made, for example, to ‘ether and ester derivatives’ and to the ‘stereoisomers’ of several compounds.

1.3.2 The Provisions of the Misuse of Drugs Act, 1971

The Misuse of Drugs Act, 1971 lists controlled substances in three classes in Schedule 2 to the Act. Class A drugs have the greatest propensity to cause