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A Concise Review Based on Analytical Method Development and Validation of Amphetamine in Bulk and Marketed Dosage Form

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Abstract

Amphetamine is a central nervous system (CNS) stimulant. It is used in the treatment of attention deficit hyperactivity disorder (ADHD), narcolepsy, and obesity. The HPLC method for Amphetamine both bulk & in combination are given in Table no.1. Includes parameters like matrix, stationary phase, mobile phase composition, detection wavelength RF value, retention time etc. HPTLC method reported in Table no. 2 includes parameter like matrix, stationary phase, mobile phase, RF, DL etc. The table no. 3 includes the GC-MS method for Amphetamine which involve the parameters like Matrix, stationary phase, mobile phase composition, Carrier gas, Retention time, flow rate etc. The table no.4 includes the Capillary Electrophoresis method for Amphetamine which involve the parameters like Matrix, Capillaries wavelength, Separation Voltage, Temperature and pressure etc. Spectrometric methods for Amphetamine include UV-Visible Spectroscopy and IR Spectroscopy.

Keywords: *RP-HPLC, Amphetamine, methamphetamine, Method development and validation*

Introduction

Amphetamine, (RS)-1-phenylpropane-2-amine is a medication for attention deficit hyperactivity disorder (ADHD), narcolepsy, and obesity. Two enantiomers levoamphetamine and dextroamphetamine are found in amphetamine. The D-isomer (Dextroamphetamine) is dominant than the L-isomer. Amphetamine is also used as a sports improver and emotional enhancer and as an aphrodisiac and euphoric recreational. It has been prescribed in many countries and is frequently regulated incorrectly due to the serious health risks involved with recreational applications, and the sale of amphetamines. Amphetamine is analogues of the phenethylamine class. It is also the parent of its own building class, the replaced amphetamines, which contain popular substances including bupropion, cathinone, MDMA and methamphetamine (Figure 1).

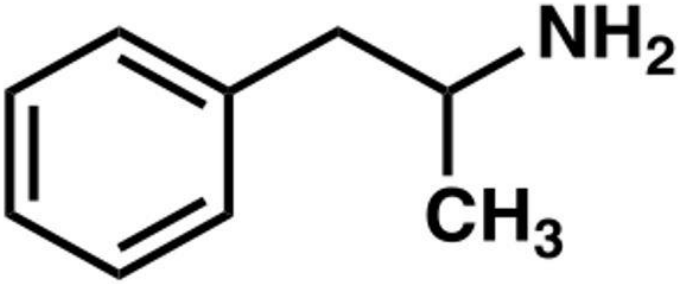

Figure 1: Amphetamine.

Amphetamine Pharmacodynamics

Mechanism of action

Primary mechanism

Enhance the release of norepinephrine, serotonin & dopamine at nerve terminals. Binding amphetamines to presynaptic membrane carriers that are responsible for reuptakes of norepinephrine (NET), dopamine (DAT) and serotonin (SERT), with uptake of amphetamine resulting in ingested of monoamines from cytoplasmic pool into the extracellular space. Amphetamine induces intracellular catecholamine release inside the nerve terminal, allowing the monoamines to be redistributed in the cytoplasmic reservoir from storage vesicles.

Secondary mechanism

Can compete with reuptake of monoamines (competitive substrate). MAO inhibition-MAO is inhibited by high dose of amphetamine; to what extent this contributes to clinical effects is debated. evidence suggests that amphetamines may have species-dependent direct effects that may also contribute to their systemic effects. A new class of G-protein-coupled trace-amine have been recently identified (Figure 2A-2C).

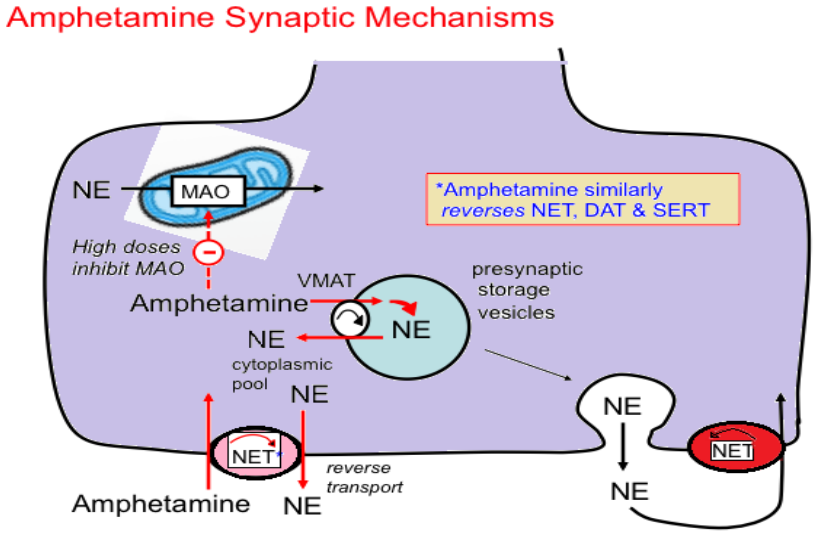

Figure 2A: Mechanism of action of amphetamine.

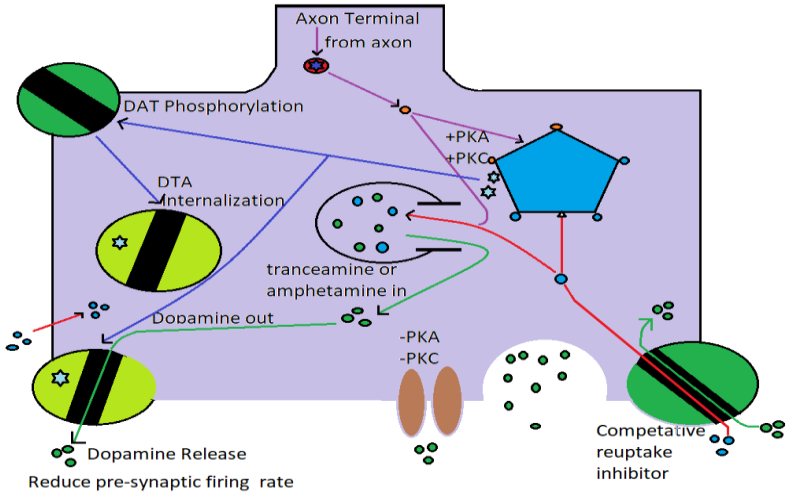

Figure 2B: Mechanism of action of amphetamine.

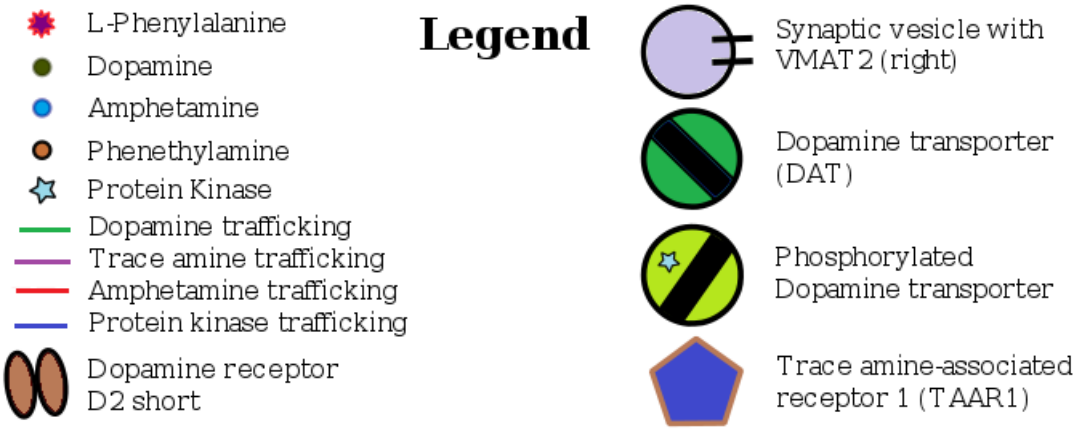

Figure 2C: Mechanism of action of amphetamine.

Amphetamine pharmacokinetics

AM Absorption: The maximum of the dose (>90%) is absorbed following oral administration of AMP. AMP does not appear to be a substrate or inhibitor of the enteric efflux P-glycoprotein transporter. Product labelling evidence for certain AMP formulations shows that gastrointestinal acidifying agents (for example, guanethidine, reserpine, ascorbic acid, and certain fruit juices) may decrease absorption and can improve the absorption of gastrointestinal alkalinizing agents (for example, sodium bicarbonite). However, there was no detailed inquiry into the effect of the combined use of AMP with the agents that either decrease or increase gastrointestinal pH, including antacids and antagonists of H2-receptor (e.g. famotidine). . A study has assessed the influence of the proton pump inhibitor omeprazole, expected to increase gastrointestinal pH, on the pharmacokinetics of the d-AMP prodrug LDX and MR-MAS. In this study, omeprazole had no significant influence on the extent of absorption of either formulation. Omeprazole and its metabolites should be inhibitors of both CYP2C19 and CYP3A4 but neither of these enzymes is of major significance for the metabolism of LDX or AMP.

Each AMP isomer has a similar rate and extent of absorption. either an IR formulation or earlier MR formulation, foods have small effect on the bioavailability of d-AMP. However, in some types of MR dosage, diet or extremely fat meal intake may considerably extend the Tmax of the two isomers. The consumption of food concomitantly with newer generation MR-AMP formulations and prodrugs generally has no significant influence on the extent of absorption of either AMP isomer, while administration with or directly after a meal resulted in a 1–2-hour delay in attaining Tmax. About the prodrug LDX as well as AMP XR-ODT, administration with food can decrease the Cmax and delay the Tmax of LDX and its liberated AMP, as well as from AMP XR-ODT, respectively. MR-MAS capsules can be opened and sprinkled on a food such as applesauce or yogurt, LDX capsules can be opened and combine with eaten with water. Although the Dexedrine Spansule can be opened quickly, there is little instruction available beyond swallowing the entire dosage type.

AM Distribution: Since absorption of AMP, these are thought to have been absorbed to some extent by red blood cells. The drug distributes quickly to the extravascular space. AMP isomers are calculated to be *16 to 20 per cent bound to plasma proteins. This comparatively low protein binding is associated with other drugs in the bloodstream that accumulate in highly perfumed organs. Accordingly, AMP is commonly spread across the body and rapidly penetrates the central nervous system. Postmortem AMP cerebral spinal fluid concentrations were recorded to be *80 percent of the blood. Although both AMP enantiomers accumulate in the brain, mouse tests have shown that d-AMP can reach higher concentrations. concerning the d-AMP prodrug LDX, mouse tests show that d-AMP readily passes the blood-brain barrier, but the parent prodrug LDX does not. The volume of distribution (Vd) was measured at 3–4 L/kg and is found to rise with an increase in body weight.

AM Metabolism: In humans, AMP is extensively metabolised and is subject to two main oxidative pathways. Aromatic hydroxylation occurs at the para position to form 4-hydroxyamphetamine/ para-hydroxyamphetamine (pharmacologically active metabolite) and which is catalyzed by CYP2D6. Oxidative deamination by N-or α-hydroxylation is the other main oxidative path leading to the production of phenylacetone. Para-hydroxyamphetamine is converted by dopamine β-hydroxylase to p-hydroxynorephedrine. Additionally, β-hydroxylation occurs and is stereoselective for d-AMP to form norephedrine (phenylpropanolamine). Both 4-hydroxyamphetamine and norephedrin are pharmacologically effective.

Aromatic oxidative metabolites are usually subject to secondary sulphate or glucuronic acid conjugation reactions. Flavin-containing monooxygenase type 3 (FMO3) tends to lead to the N-oxygenation of d-and l-AMPs. AMP is therefore oxidised to phenylacetone (1-phenyl-2-propanone), and is then oxidised to benzoic acid and excreted as glycine conjugate to hippuric acid (Figure 3).

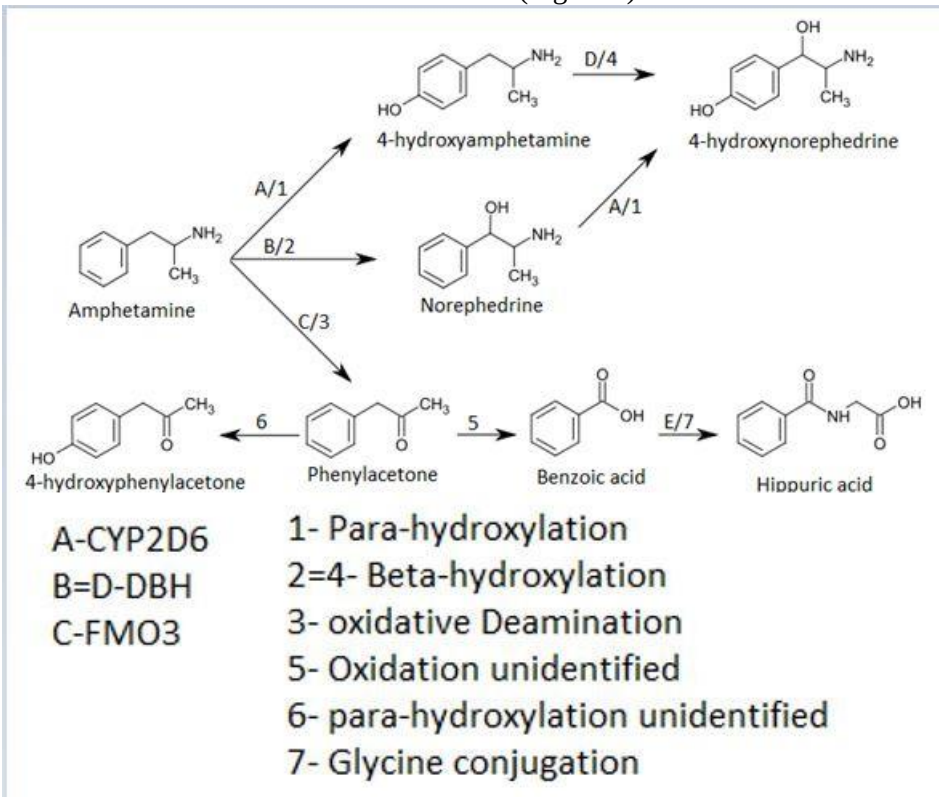

Figure 3: Amphetamine pharmacokinetics.

AM Excretion: AMP is eliminated by the kidneys in a pH-dependent way. At standard urinary pH, 30-40 per cent of the administered AMP dose is excreted as unchanged parent compound with hippuric acid being the second most abundant urinary metabolite. However, since AMP is a poor base with a pKa of 9.9, the urinary recovery of AMPs is strongly dependent on pH and urinary flow rates. The rate of urinary excretion of AMP is highly regulated by urinary pH. Under acidic urine conditions (pH 7.5), AMP is quickly excreted, while the elimination of AMP is prolonged under alkaline urine conditions (pH >7.5).

The widespread literature survey exposed multiple analytical techniques like UV spectrophotometry method, HPLC, HPTLC, LC-MS/MS, for the determination of Amphetamine in bulk and pharmaceutical formulation. These reported methods describe the evaluation of AM in various dosage form in single constituent and in combination with and 4-hydroxy AM, THE, PAR, Caffeine, Ketamine, cocaine, Phenylisothiocyanate, Morphine, Piperidine, desmethylselegiline, selegiline, methylenedioxy, cathinone, spectracles different analytical techniques used to estimate amphetamine.

Analytical accounts on amphetamine

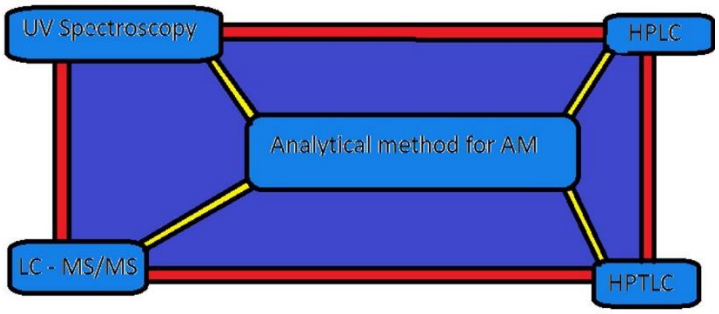

Figure 4: Analytical accounts on amphetamine.

Chromatographic overview

HPLC Method

John F. Bowyer et. al. Outlines an HPLC method for the determination of amphetamine in biological samples using fluorometric detection after derivatization with o-phthaldialdehyde and 3-mercaptopropionic acid. Chromatographic separation was performed with a Supelco LC-18 250 x 4.6 mm I.D, Analytical column 5 µm particle size, A C-130B guard column, 20 x 2 mm I.D. packed with Bondapak Cls/CORASIL, 37-50 µm particle size was placed prior to the analytical column. Mobile phase A consisting of 65% KH2PO 4 (0.05 M, adjusted to pH 5.5 with potassium hydroxide) and 35% methanol, and mobile phase B with inverse proportions of buffer (35%) and methanol (65%). Researchers currently using o-phthaldialdehyde derivatisation and fluorometric amino acid detection should be able to apply this process easily.

Mitsuru Kumihashi et. al. Analytical approach for the simultaneous determination of methamphetamine and its metabolite. amphetamine, in urine using a high performance liquid chromatography column-switching method.Column CAPCELL PAK SCX UG80 (1.5 mm i.d. × 150 mm, polymer coat type strong cationexchange phase) for analysis, Mspak PK-2A (2.0 mm i.d. × 10 mm, hydrophilic copolymers containing N-vinyl acetamide resin) for extraction. The two mobile phases used were as follows: 5 mM of phosphate buffer (pH 6.8, flow rate at 0.7 ml/min) for extraction, and 20 mM of phosphate buffer (pH 5.0) combined with acetonitrile (25/75, v/v, flow rate at 0.2 ml/min) for analysis, this method of using HPLC with column-switching can be used for both qualification and quantification of MA and its metabolite, AM, in urine, especially in forensic cases.

Analytical approach for enantiomeric separation and isolation of amphetamine by high-performance liquid chromatography using chiral crown ether-coated reverse phase packaging. The column was a 0.4 cm I.D. x 15 cm DAICEL CROWNPACK CR(+). The mobile phase was aqueous HClO4 (pH 1.8), The present method was also applied to the enantiomeric separation of norephedrine.

Rosanna Mancinelli et. al. Easy and effective high-performance liquid chromatography fluorimetric method for the determination of amphetamine-derived designer drug. The column was a LiChrocart-Li-Chrospher 100 RP-18 5 µm, 250 mm X 4 mm with precolumn LiChrocart-Li-Chrospher 100 RP-18 5 µm, 4 mm X 4 mm, The mobile phase was freshly prepared with 10 ml of concentrated eluent added to 1200 ml of acetonitrile and 300 ml of ultrapure water. The described procedure could be successfully used for clinical, epidemiological and forensic applications.

F. Sadeghtpour et. al. Rapid analysis of amphetamine by using high-performance liquid chromatography and UV detection. For the isolation of amphetamines, two columns were used: a RP-18 Nucleosil 100, 5 µm and a RP-18-AB Nucleosil 100, 5µm 125 X 4 mm I.D. Mobile phases were composed of phosphate or acetate buffer (depending on the pH, pH adjustment with 1 M HCI or 1 M NaOH) mixed with variable proportions of acetonitrile or methanol.

Natale Alfredo Santagati et. al. An analytical method for Simultaneous determination of amphetamine and one of its metabolites by HPLC with electrochemical detection. Separations were performed on a 5 µm Hypersil ODS RP-18 column (15 cm × 4.6 mm) fitted with a guard column (5 µm Hypersyl ODS RP-18) and eluted isocratically with methanol–sodium hydrogen phosphate buffer (50 mM, pH 5.5) (30:70 v/v) containing trietylamine (0.5% v/v) (TEA) (Table 1).

Table 1: HPLC method for analysis of amphetamine.

S.No.	Drug	Matrix	Method	Stationary Phase	Mobile Phase	Detection(nm)	FR (ml/min)	RT (min)	Detector	Ref.
1	D-AM and 4-hydroxy AM	Rat Urine	HPLC	Phenyl Column	50mM potassium phosphate (pH 3), Method and Acetonitrile	215	1	18.5 Min	UV Detector	[1]
2	AM, MAM, THE, PAR, Caffeine	Illicit seized tablet	HPLC	ZORBAX Column (250X4.6mm, 5 µm)	Acetonitrile, Methanol, buffer (1% of orthophosphoric acid 85%,and 1%Diethylamine 99%	210	1.5	6.72,4.27,3.67,8.40	UV Detector	[2]
3	AM and MAM	Human Hair	HPLC	ODS Column (250X4.6mm, 5µm)	TRIS-HCL buffer (0.1mol/dm,pH 7.0) : Methanol (30:70 v/v)	440	1	35.4, 40.5	Fluorescence detector	[3]
4	AM and MAM	Human Hair	Achiral HPLC	Capcell pak C18 UG 120S5 (250X1.5mm, 5µm)	Phosphate-citrate buffer (pH 4.0): Acetonitrile (50:50v/v)	330	0.1		Fluorescence detector	[4]
			Chiral HPLC	Chiralcel OD-RH (150 X 2mm, 5µm)	Phosphate-citrate buffer (pH 4.0) containing NaPF6(0.3M): Acetonitrile (55:95v/v)	440				
5	AM and its Metabolite	Tn Garment belong to known abuses	RP-HPLC-FL	Daisopak sp-120-5-ODS-N place in a model 860- co column	Phosphate-citrate buffer (pH 4.0) : Acetonitrile (45:55v/v)	440	1	13.3	Fluorescence detector	[5]
			RP-HPLC-UV	Daisopak sp-120-5-ODS-BP, a water 484 tanable	Tris-HCL buffer (0.1M, pH 7.0): Acetonitrile (55:95v/v)	330	1	15.6	UV Detector	

				absorbance detector						
6	AM and Ketamine	Injection and Whole blood extract	UPLC-MS	Waters UPLC BEN C18 (2.1X50mm)	Aqueous pyrrolidine (0.5ml glacial acetic acid and 1ml pyrrolidine in 500ml reagen grade water)and Methanol (50:50) for methanolic standard, 52:48 for whole blood extract	254	0.4			[6]
7	AM, cocaine, and its metabolite	Surface water and wastewater	UPLC-Tandem mass spectrometry	Acquity UPLC BEH C18 Column (50X2.1mm,1.7 µm)	Ammonium acetate (5mM) with 0.1%formic acid (pH 2) and Methanol		0.3	1.5 to 13	UV and MS Detector	[7]
8	d-AM	Biological sample	HPLC	Supelco LC-18 (250X4.6mm, 5µm) C-130B guard column, (20 X 2mm) pack with Bondapak C18/CORASIL, 37-50µm prior to analytical column	65% KH2PO4(0.05M, adjusted to pH 5.5 with potassium hydroxide and 35% Methanol Inverse proportional of buffer (35%) and Methanol (65%)	λexci 340 λemi 440	1.5		Fluorescence detector	[8]
9	Phenylisothiocyanate derivatives and its analoques	Biological fluids	HPLC-APCI-MS or DAD	Superspher Select Ba ECOcart (125X3mm)	50mM ammonium formate buffer (pH 3.0): Acetonitrile (60:40)	250	0.8	8.1		[9]
10	AM	Urine	RP-HPLC	Microsorb using packed with octadecyldimeth	Phosphate buffer: acetonitrile (55:45v/v)	220	0.7	16.3	UV Detector	[10]

				ylsilyl and 2cm Uptight precolumn hand-packed with the octadecyldimeth ylsilyl 5 µm silica gel						
11	AM and MAM	urine	RP-HPLC	Adsorbosphere HS, C-18, (150 mm x 4.6mm, 5µm) (7.5 x 4.6-mm) guard column with the same packing as the analytical column	Water:methanol (60:40)	340	1		UV Detector	[11]
12	AM amd Morphine	Meconium	HPLC-Diode-Array Detection	Supelcosil LC-18 DB, (150 x 4.6mm, 5µm)	potassium dihydrogen phosphate (0.077M) in water-methanol-acetonitrile-tetrahydrofuran-triethylamine (600:100:25:7:1.5, v/v/v/v/v	204	1		UV Detector (A Waters 996 diode-array detect)	[12]
13	AM, MAM and piperidine	human urine	HPLC-chemiluminesc ence detection		acetonitrile-water (7:3, v/v) containing 1 mM imidazole, with a pH of 7.0 adjusted with nitric acid.				chemilum inescence detection	[13]
14	Retention Indexes of Drugs, Drug	ionized basic drugs and nonionized drugs	HPLC	Zorbax RX (880967.901) HPLC columns (250 x 4.6 mm,	Acetonitrile (E. Merck Ominisolv, AX0142-1), methanol (E. Merck Ominisolv, MX0488-1),		2		Hewlett-Packard 1040 diodearra	[14]

	Metabolites , and Drug Derivatives			)	and o-phosphoric acid				y detector	
15	AMPHETAMINE-RELATED COMPOUNDS	urine	HPLC	MPLC guard column (30 x 4.6 mm) packed with Spheri-5 RP-18 (Brownlee, Santa Clara, U.S.A.), a separation column (250 x 4.6mm) packed with Inertsil ODS-2 (Gasukuro Kogyo, Tokyo, Japan)	The ratios of acetonitrile-water were 8:2 (v/v) for the separation of CBI (cyanobenzflisoindole) derivatives, 7:3 for Dns derivatives and 6:4 for NBD derivatives.	λex-343nm, λem-530nm for Dns derivatives. λex-418nm, λem- 483nm for CBI. λex-470nm, λex-530nm for NBD	1	15	CHEMILUMINESCENCE AND FLUORESCENCE DETECTIONS	[15]
16	AM and 462 Related compounds		HPLC	125-mm Spherisorb S5W silica column (125 or 250 x 4.9 mm) and methanolic ammonium perchlorate (10 mA4, pH 6.7) as eluent.		254	2		UV and fluorescence detection	[16]
17	AM, MAM and its metabolite	urine	HPLC	column CAPCELL PAK SCX UG80 (1.5 × 150 mm,	5 mM of phosphate buffer (pH 6.8) for extraction, and 20 mM of phosphate buffer (pH 5.0) combined with	210	0.7 for extraction, 0.2 for analysi	17.47 for extraction and 19.27 for analysis	L-7400 UV-detector	[17]

				polymer coat type strong cationexchange phase, Shiseido, Tokyo, Japan) for analysis, Mspak PK-2A (2.0 × 10 mm, hydrophilic copolymers containing N-vinyl acetamide resin, Shodex, Tokyo, Japan) for extraction.	acetonitrile (25/75, v/v) for analysis.		s.			
18	AM	extraction of impurities from illicit amphetamine samples	HPLC	C 18 Spheri-5 Brownlee Labs. MPLCTM cartridges (Santa Clara, CA, U.S.A.), and the guard column (30 x 4.6 mm) was directly connected to the analytical column (100 x 4.6 mm)	acetonitrile-water gradient.	220 and 254	1	3.57 (N-Formylamphetamine	diode array UV detected connected to the liquid chromato graph.	[18]
19	d-AM and l-AM	urine	HPLC	DAICEL CROWNPACK CR(+) (Daicel Chemicals, Japan). (0.4 cm	aqueous HClO, (pH 1.8)	200 and 254.	1		photodiod e array UV-VIS detector (SPDM6	[19]

				x 15 cm)					A, Shimadzu)	
20	amphetamine-derived designer drugs (MDA MDEA MBDB MDMA)	urine, serum, saliva and street samples	HPLC–fluorimetric	LiChrocart-Li-Chrospher 100 RP-18 5 µm (250 X 34 mm) with precolumn LiChrocart-LiChrospher 100 RP-18 5 µm (4 X 4 mm)	10 ml of concentrated eluent added to 1200 ml of acetonitrile and 300 ml of ultrapure water	ƛex-290, ƛem-320	1	4.35,4.65,4.53,4.94 respectively for AM/ 6.03,6.39,6.23,6.77 resp. For MDEA/6.96,7.29,7.12 ,7.53 resp. for MBDB/8.84,9.39,8.85 ,9.50 resp. for MDMA	fluorimetric detector	[20]
21	AM, MAM and desmethylselegiline	plasma	HPLC	Supersphere RP 18 e µm (125 x 4 mm) (SRD, Vienna, Austria)	19 % acetonitrile/27% methanol 54% buffer (v/v) AND 75 % acetonitrile, 25 % buffer (v/v)		2		fluorescence detector FP-920	[21]
22	AM and MAM	hair specimen	HPLC	Chiralcel OB and OJ, (25 cm × 4.6 cm), Diacel Ind. Co., Tokyo, Japan. two columns were connected in series.	n-hexane and isopropanol (9:1, v/v)	220	1	23.8 for d-Ac-MAMP, 27.4 for d-Ac-AMP	UV detector	[22]
23	AM and MAM	rat urine	HPLC	Chiralcel OB or OJ	Hexane and 2-propanol (9: 1, v/v)	220	1 for individual, 1.4 for combine column	d-AM:30.4&l-AM:16.2 for OB column, d-AM:16.9 &l-AM:16.3 for OJ column, d-AM:24.4 ± 0.10&l-AM 17.0±0.10 for PB + OJ	UV detector	[23]
24	AM, MAM,	human hair	HPLC	Daisopack-SP-120-5- ODS BP	acetonitrile–methanol–water (30:40:30, v/v/v%)	Λex- 325 and λem- 430 nm	0.3	21,26,19,23 respectively	fluorescence	[24]

	MDA and MDMA			semi-micro column (250 × 2 mm 5 µm Daiso, Osaka)					detection	
25	AM and MAM	human hair	HPLC	guard column (30 mmX4.6 mm) packed with TSK Guardgel ODS-80TM (Tosoh, Tokyo, Japan), a Shimpack CLC-C18 separation column (150X6 mm, particle size 5 µm, Shimadzu)	methanol-water (54:46, v/v) containing 30 mM sodium 1-octanesulfonate		1		Chemiluminescence Detection	[25]
26	AM and MAM	plasma and hair samples	HPLC	Daisopak SP-120-5- ODS-BP (250 × 4.6 mm, 5 µm, Daiso, Osaka, Japan)	acetonitrile–citrate buffer (0.01 m, pH 4.0; 55:45, v/v) for plasma samples, methanol–acetonitrile–citrate buffer (0.01 m, pH 4.0; 45:20:37.5, v/v/v)	ƛex-325 and ƛem- 430	1 for plasma samples,1.1 for hair sample	27, 32	fluorescence detection	[26]
27	AM, MAM, Enantiomers, Desmethylselegiline and Selegiline	Hair Samples	HPLC–ESI-MS	semi-micro octadesyl silica (ODS) column	methanol and ammonium formate buffer		0.1			[27]
28	AM isomers	urine	HPLC	Supe1cosi1 LC-(S)-naphthy1-urea column (25	hexane: propan-z-ol : acetonitrile (97: 1: 2)	240	2	30	LCD6AV detector	[28]

				x 4·6 mm)						
29	AM, MAM AND Methylenedioxy Derivatives	Meconium	HPLC - MS	Waters Xterra RP 18 column (150 × 2.1 mm; 5 µm)	10 mM ammonium bicarbonate, pH 9.0, and (B) methanol		0.3		electrospray ionization detection	[29]
30	AM and MAM	urine	HPLC	Eurospher-100 C18 column (250 ×4.6 mm, with 10 µm)	20 mmol/L phosphate buffer (pH adjusted to 4.0 using hydrochloric acid) and acetonitrile (85: 15)	210	1		Knauer-K2500 UVVis detector	[30]
31	AM	illicit drugs	HPLC	RP-18 Nucleosil 100, 5 µm and RP-18-AB Nucleosil 100, 5 µm (125X4 mm)	phosphate or acetate buffer (depending on the pH, pH adjustment with 1 M HCI or 1 M NaOH) mixed with variable proportions of acetonitrile or methanol.	200	1		UV detection	[31]
32	AM and one of its metabolites		HPLC	5 µm Hypersil ODS RP-18 column (15 cm×4.6 mm) fitted with a guard column 5 µm Hypersyl ODS RP-18	methanol–sodium hydrogen phosphate buffer (50 mM, pH 5.5) (30:70 v/v)	276	1		electrochemical detection	[32]
33	AM	human urine	HPLC	ODS-3 column (250 mm × 4.0 mm, with 5 µm particle size)			1		ultraviolet detection	[32]
34	AM and its metabolites	Rat urine	RP-HPLC	Waters Spherisorb 5 µm ODS2 (4.6 250 mm)	methanol and ammonium buffer, pH 5.45 with 0.16% triethylamine	236	initial 12 min-1.3,	28	variable wavelength detector	[33]

							From 12 to 12.5 min-1.5			
35	AM derivatives	Human urine	HPLC – UV	Waters Spherisorb C18 5 µm ODS2 (4.6 × 250 mm)	methanol:ammonium acetate buffer 0.05 m containing 0.1% triethylamine, pH 3.9.	210	(Time-FR) (0-0.7,8-0.7,9-1.2,19-1.2,21-1.4,35-1.4		UV wavelength detector	[34]
36	AM and MAM		CHIRAL PHASE HPLC-MS	Regis Pirkle Covalent Phenylglytine column (25 cm x 4.5 cm) and a Regis Pirkle Ionic Phenylglycine column (25 cm x 4.5 cm)	2-propanol-hexane (1:99)	254		l-AM 18, d-MAM 27	UV detection	[35]
38	AM and MAM	hair	HPLC	L- column ODS (4.6 x 250 mm)	1 mM imidazole buffer (adjusted to pH 7.0 with nitric acid) and acetonitrile (2:3, v/v)	254	1	8.2 and 9.8 respectively	CLD-10A chemiluminescence detection	[36]
39	AM	human urine	HPLC	(25 cm x 34 mm) silica HPLC column	hexane (145 ml); water saturated ethyl acetate (35 ml); chloroform (40 ml); ethanol (20 ml)	visible region (450 nm), UV region (260 nm)	1	AM-7, MAM-5	Waters multiwavelength detector (Model 490	[37]

40	AM and Cathinone		HPLC-UV	LiChrospher 100 RP-18e, 250 x 4 mm, 5 µm and LiChrospher 100 RP-8e, 250 x 4 mm, 5 µm	methanol:water 2.5:97.5 ± 2% sulfated ß-cyclodextrin	240 and 270	1	R-AM 8, S-AM 12	UV detection	[38]
41	AM and MAM	Urine	HPLC	Shiseido 5 µm RP-18, (250 x 4.6 mm) column	0.02 M sodium phosphate buffer pH 4.2, acetonitrile, and dimethylamine in a ratio of 68.8:31:0.2 (v/v)	254	0.2		LCD 2563	39
42	AM	human urine	HPLC	Vercopak Inertsil 5-ODS-80A column, (3.2× 250 mm, 5 µm , Vercotech, Taipei, Taiwan) with an on-line filter	Acetonitrile-water (70:30, v/v)	Excitation-443, fluorescence-500	0.5	10.3	fluorescence detection	[40]
43	AM	Urine	Immunoassays , HPLC, and GC-MS	150 x 4.6-mm internal diameter column with a 20 x 4-mm internal diameter precolumn packed with 3 µm Spherisorb C-18 ODS-1	water containing 8.5 g H3PO4 (85%) and 280 µL hexylamine and mixture of 702 mL acetonitrile and 91.6 mL water containing 8.5 g H3PO4 (85%) and 280 µL hexylamine per liter	198	150 µL/min	8.15	DAD	[41]

Table 2: HPTLC method for analysis of amphetamine.

S. No.	Drug	Matrix	Method	Stationary phase	Mobile Phase	Detection(nm)	Rf	DL	Ref.
1	AM	Meconium	2- HPTLC	HPTLC aluminium sheets or glass plates, Kieselgel 60 10 x 10 cm	A1 – ethylacetate-methanol-ammonia 85:10:5, A2 – methanol-ammonia 99:1, B1 – ethylacetate-methanol-ammonia 85:10:5, B2 – acetone-water-ammonia 20:20:1.	254		0.05µg/spotS	[42]
			1 dimensional HPLC		chloroform-2-propanol-ammonia 20:20:1.7.				
2	AM	Urine	HPTLC	Precoated HPTLC-plates with silica gel G 60 F254	S1-Toluene-methanol-ammonia cone. (50:50:1), S2-Propanol-(2)-n-heptane-ammonia cone. (50:50:1), S3-Chloroform -cyclohexane-methanol (40:40:20), S4-Toluenemethanol-acetic acid (95:2.5:2.5), S5-Chloroform-dioxane-ethyl acetate-ammonia cone. (25:65:5:5), S6-Dichlormethane-methanol (50:10).	254	S1-57, S2-20, S3-35, S4-26, S5-__,S6-	S1 and S2-200, S3-25, S4 and S5-20, S6__ng/spot	43

Table 3: Gas Chromatography/mass spectrometry method for analysis of amphetamine.

Sr. No.	Drug	Matrix	Method	Stationary Phase	Carrier gas	Rt(min)	Flow-rate	Ref.
1	AM, Cocaine, and Opiates	Human Hair	Gas Chromatography/Mass Spectrometry	30 m X 0.25 mm i.d. (5% diphenyl-95% dimethyl polysiloxane)	Helium		1 mL/min	[44]
2	AM and its derivatives	Hair	Gas Chromatography–Mass Spectrometry	30 m30.25 mm HP-5 race analysis column (5% PH ME Siloxane, film thickness 0.25 mm)	Helium	6.5	0.7 ml/min	[45]
3	Cathinones	Synthetic Cathinones in Oral Fluid	Solid-Phase Microextraction (SPME)/GC-MS	15 m x 0.25 mm x 21 0.25 µm (15 m x 0.25 mm x 21 0.25 µm)	Helium		1 mL/min	[46]

HPTLC Method

Skender et al. [42] and Gentili et al. [43] Identify Drugs of Abuse by using High-Performance Thin-Layer Chromatography, Chromatographic separation was performed with Precoated HPTLC-plates, silica gel G 60 F_{254}. Solvent system 1: Toluene-methanol-ammonia cone. (50:50:1); Solvent system 2: Propanol-(2)-n-heptane-ammonia cone. (50:50:1); Solvent system 3: Chloroform -cyclohexane-methanol (40:40:20); Solvent system 4: Toluenemethanol-acetic acid (95:2.5:2.5); Solvent system 5: Chloroform-dioxane-ethyl acetate-ammonia cone. (25:65:5:5); and Solvent system 6: Dichlormethane-methanol (50:10). This work describes a rapid and sensitive screening system for several basic drugs of abuse based on the combination of high-performance thin-layer chromatography with fluorescent reagents (Table 2).

Gas chromatography/mass spectrometry

Correll et al. Quantitative measurement of amphetamine, morphine, and opiate in human hair by gas chromatography/mass spectrometry. The chromatographic column was RTX-5 (5% diphenyl-95% dimethyl polysiloxane, 30 m 0.25 mm i.d.) and Ultra-pure grade helium was used as the carrier gas [44].

Hyötyläinen et al. Simultaneous identification of amphetamine-like substances through headspace solid-phase micro-extraction and gas chromatography – mass spectrometry. A 30 m X 0.25 mm i.d HP-5 trace analysis column (5% PH ME Siloxane, film thickness 0.25 mm), were used. Helium was used as a carrier gas at a 0.7 ml/min flow rate (Table 3) [45].

Capillary electrophoresis

Płotka et al. Determination of opioid analogues, caffeine and amphetamine in biological fluids by capillary electrophoresis utilising marker technique. The capillaries were 23 cm x 50 µm I.D. for fast screening and 67 cm x 50 µm I.D. for quantification. Separation Voltages was 20 kV for fast Screening and 25 kV for Quantification [47].

Taschwer et al. [48] development of a capillary zone electrophoresis method including a factorial design and simplex optimisation for analysis of amphetamine, amphetamine analogues, cocaine, and heroin. Capillary: total length 50 cm, effective length 42 cm, internal diameter 50 mm. Separation Voltages was 20 kV. Lastly, the method was successfully applied to analyse street samples.

Chiral separations of amphetamine derivatives and cathinone: a comparative analysis of capillary electrochromatography, supercritical fluid chromatography and three liquid chromatography modes.The capillaries were 33.5 cm With An Effective Packed Length of 25 cm. The voltage to perform the experiments was set to 10 kV [49].

Enantiomeric separation and isolation of amphetamine related compound through capillary zone electrophoresis using native and derivatized β-cyclodextrin as chiral additives.capillary were used for the separation of amphetamines: A non-coated fused silica capillary (Hewlett-Packard; 48.5 cm total length, 40 cm effective length, 50µm I.D.) was kept at a constant temperature of 20 ± 0.1°C and the applied voltage was 20 kV [50].

Analysis of illicit amphetamine seizures by capillary electrophoresis. Qualitative and quantitative analyses were performed with 72 cm x 75 µm I.D. fused-silica capillary tubes with an effective length of 50 cm to the detector window. For quantitative work, the instrument was operated at -15 kV and at a temperature of 30°C [51].

An analytical method for Simultaneous analysis of some amphetamine derivatives in urine by nonaqueous capillary electrophoresis coupled to electrospray ionization mass spectrometry. The separation was performed in a fused-silica capillary of 75 cm (22 cm from inlet to UV detector) X 50 µm I.D. at constant voltage of 30 kV. Finally, the described method was successfully applied to the analysis of amphetamines in urine after a liquid–liquid extraction [52].

Methamphetamine and similar compounds are determined by capillary electrophoresis with UV and laser-induced fluorescence detection. Separation voltage, 10 kV for CZE and 15 kV for MEKC; fused-silica capillary (50 cmX75 µm I.D.), effective length of 37.5 cm; temperature, 250C (Table 4) [53].

Table 4: Capillary electrophoresis method for analysis of amphetamine.

S. No.	Drug	Matrix	Method	Detection (nm)	Capillaries (fused-silica capillary)	Separation Voltages	Temp./Pressure	Ref.
1	AM	Human Serum and Urine	Capillary Zone Electrophoresis (CZE) and Micellar Electrokinetic Capillary Chromatography (MEKC)	200 and 220 nm	23 cm x 50 µm I.D. for fast screening and 67 cm x 50 µm I.D. for quantification, separation lengths being 16 and 60 cm, respectively.	20 kV for fast Screening and 25 kV for Quantification	20°C /30 mbar Pressure for 5 s	[54]
2	AM		Capillary Zone Electrophoresis (CZE)	200 nm	Total Length 50 cm, Effective Length 42 cm, Internal Diameter 50 mm	20 kV	20°C/50 mbar for 10 s	[55]
4	Cathinone, Amphetamine-Derivatives		Capillary Electrochromatography (CEC)	214 nm	33.5 cm With an Effective Packed Length of 25 cm	10 kV	25 ◦C/5.5 bar	[56]
5			CE–UV (capillary electrophoresis-Ultraviolet) and CE–LIF (capillary electrophoresis–laser induced fluorescence) CE–LIF	266 and 262 nm				[57]
6	AM	Urine Sample (With Extraction) Urine Sample (With Direct Injection	Capillary Electrophoresis (CE)/UV					[58]
7	3,4-methylenedioxymethamphetamine	Human Urine	Capillary Electrophoresis–Fluorescence Spectroscopy	λex = 280nm/λem = 320nm	(40 cm X 75 µm)	0-30 kV	22oC	[59]
8	AM		Capillary Zone Electrophoresis	214 nm.	(48.5 cm Total Length, 40 cm Effective Length, 50/µm I.D.)	20 kV	20 ± 0. 1°C	[60]
9	AM	Illicit	Capillary Electrophoresis	254 nm	72 cm x 75 µm I. D	-15 kV	30°C	[61]
10	AM and its		Capillary Electrophoresis-	Latter	55 cm long, 50 µm i.d., 360	25 kV	20°C / 100 mbar	[62]

	Derivatives		Tandem Mass Spectrometry (CE-MS/MS)		µm o.d. With Inner Wall Coated with Polyvinyl Alcohol (PVA)		for 5 s	
11	Amphetamine Analogues	Illicit Street-grade Samples	Capillary Zone Electrophoresis Using Capacitively Coupled Contactless Conductivity Detection	200 nm	90 cm 50.0 µm id And Effective Lengths of 81.5 (UV) and 77 cm (C4 D)	30 kV	25oC/30 mbar for 5 s	[63]
12	AM	Urine	Capillary Electrophoresis Coupled to Electrospray Ionization Mass Spectrometry	200 nm	75 cm (22 cm From Inlet to UV Detector) 350 mm I. D	30 kV	15oC/50 mbar for 4 s	[64]
13	AM		Reversed-Polarity Capillary Electrophoresis/ Positive Ion Electrospray Ionization Tandem Mass Spectrometry		50 µm ID X 375 µm OD X 56 cm	4.2 kV	15oC/50 mbar for 4 s of Standard Sample Solution And 1 s 50 mbar of Impurity Analysis	[64]
14	AM		Capillary Electrophoresis	195 nm	50 µm i.d. 32.5 cm	For Chiral Analysis -12 kV, For Achiral Separation +5 kV	15 oC/50 mbar for 1 s	[66]
15	AM	Urine	Capillary Electrophoresis with UV And Laser-Induced Fluorescence Detection	210 nm	(50 cm375 µm I.D.), Effective Length of 37.5 cm	10 kV For CZE And 15 kV for MEKC	250C/1 s With 0.5 p.s.i	[67]
16	Amphetamine Analogues		Capillary Electrophoresis	200 nm	(60.2 cm Total Length, 50 cm Length to Detector, 75 µm ID, 360 µm OD)	-18 kV	250C/0.5 psi For 3 min	[68]
17	AM	Human Whole Blood	Capillary Electrophoresis	210 nm	50 cm × 50 µm i.d	10 kV	35 mbar For 10 s	[69]

Spectrophotometric overview

UV-Visible spectroscopy method

Amphetamine-induced increase in planarian locomotor activity and block by UV light. He reports the amphetamine (10 AM) produced the opposite result was also reversed by UV light. These findings the effects of dopaminergic ligands and UV light on pLMV are linked to involvement with the neurotransmitter transduction mechanism.

Application of Derivative UV-Visible Spectroscopy in Forensic Toxicology. The Analytical work was performed by using two instruments: the HewlettPackard 8450A diode-array spectrometer and the Pye-Unicam model SP8-150. Presentation of UV-visible absorption data in derivatives mode has tremendous potential as an aid to the identification of drugs [68].

The applications of ultraviolet and visible methods as applied to the analysis of foods, water quality,tropospheric substances and identification of Metals, Nonmetals, Organic Compounds, Simultaneous and Multiwavelength Determinations, Derivative Determinations, Reaction Rate Determinations, Flow Injection Determinations, Photoacoustic and Thermal Lens Determinations. He's analyse amphetamine in urine by using sodium 1,2-naphthoquinone-4-sulfonate reagent [69].

Identify Amphetamines and Similar Synthetic Drugs by Second Derivative Ultraviolet Spectrometry. The experimental work was carried out with a Perkin-Elmer UV-VIS recording spectrophotometer Model 200 using quartz cells of 1-cm path length. In this paper outlines an easy and straightforward process for distinguishing between amphetamine, phenethylamine, phentermine, ephedrine, and meperidine by second derivative UV-spectrophotometry [70-72].

ATR-FTIR method

Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) and Chemometrics are used for rapid quantification of methamphetamine. Triplicate spectra were acquired using a Thermo Scientific Nicolet™ 8700 Research FTIR Spectrometer with a single bounce diamond crystal ATR Smart iTR™ accessory which has a 1.5 mm active sample area, 2 µm penetration at 1000 cm^{-1} and ZnSe focusing optics. This paper has established new robust methods using ATR-FTIR and PLS as simple and inexpensive alternatives to current methods. UPLC-UV of MA quantification process.

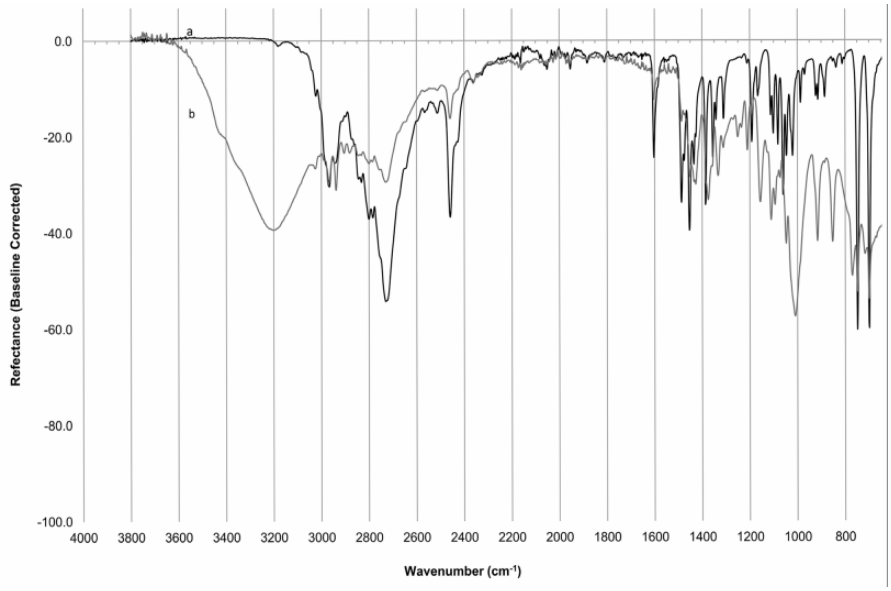

Figure 4: Typical ATR-FTIR spectra of methamphetamine.

References

1. Law MY, Moody DE. Simultaneous quantitation of amphetamine and 4′-hydroxyamphetamine by high performance liquid chromatography. J Liquid Chromatogr Related Technol 1995; 18:2029-43.
2. Sultan M. Simultaneous HPLC determination and validation of amphetamine, methamphetamine, caffeine, paracetamol and theophylline in illicit seized tablets. Int J Pharm Pharm Sci 2014; 6:294-298.
3. Al-Dirbashi O, Kuroda N, Nakashima K, et al. HPLC with fluorescence detection of methamphetamine and amphetamine in

segmentally analyzed human hair. Analyst 1999; 124:493-497.

4. Al-Dirbashi OY, Kuroda N, Wada M, et al. Quantification of methamphetamine, amphetamine and enantiomers by semi-micro column HPLC with fluorescence detection; applications on abusers' single hair analyses. Biomed Chromatography 2000; 14:293-300.
5. Apollonio LG, Pianca DJ, Whittall IR, et al. A demonstration of the use of ultra-performance liquid chromatography–mass spectrometry [UPLC/MS] in the determination of amphetamine-type substances and ketamine for forensic and toxicological analysis. J Chromatogr B 2006; 836:111-115.
6. Bijlsma L, Sancho JV, Pitarch E, et al. Simultaneous ultra-high-pressure liquid chromatography–tandem mass spectrometry determination of amphetamine and amphetamine-like stimulants, cocaine and its metabolites, and a cannabis metabolite in surface water and urban wastewater. J Chromatogr 2009; 1216:3078-3089.
7. Bogusz MJ, Kala M, Maier RD. Determination of phenylisothiocyanate derivatives of amphetamine and its analogues in biological fluids by HPLC-APCI-MS or DAD. J Anal Toxicol 1997; 21:59-69.
8. Bowyer JF, Clausing P, Newport GD. Determination of d-amphetamine in biological samples using high-performance liquid chromatography after precolumn derivatization with o-phthaldialdehyde and 3-mercaptopropionic acid. J Chromatogr Biomed Sci Appl 1995; 666:241-50.
9. Fisher DH, Bourque AJ. Quantification of amphetamine in urine: solid-phase extraction, polymeric-reagent derivatization and reversed-phase high-performance liquid chromatography. J Chromatogr B 1993; 614:142-7.
10. Foster BS, Gilbert DD, Hutchaleelaha A, et al. Enantiomeric determination of amphetamine and methamphetamine in urine by precolumn derivatization with Marfey's reagent and HPLC. J Anal Toxicol 1998; 22:265-269.
11. Franssen RM, Stolk LM, Van den Brand W, et al. Analysis of morphine and amphetamine in meconium with immunoassay and HPLC-diode-array detection. J Anal Toxicol 1994; 18:294-5.
12. Hayakawa K, Imaizumi N, Ishikura H, et al. Determination of methamphetamine, amphetamine and piperidine in human urine by high-performance liquid chromatography with chemiluminescence detection. J Chromatogr A 1990; 515:459-66.
13. Hill DW, Kind AJ. Reversed-phase solvent-gradient HPLC retention indexes of drugs. J Anal Toxicol 1994; 18:233-42.
14. Hayakawa K, Hasegawa K, Imaizumi N, et al. Determination of amphetamine-related compounds by high-performance liquid chromatography with chemiluminescence and fluorescence detections. J Chromatogr A 1991; 464:343-52.
15. Jane I, McKinnon A, Flanagan RJ. High-performance liquid chromatographic analysis of basic drugs on silica columns using non-aqueous ionic eluents: II. Application of uv, fluorescence and electrochemical oxidation detection. J Chromatogr A 1985; 323:191-225.
16. Kumihashi M, Ameno K, Shibayama T, et al. Simultaneous determination of methamphetamine and its metabolite, amphetamine, in urine using a high performance liquid chromatography column-switching method. J Chromatogr B 2007; 845:180-183.
17. Lambrechts M, Rasmussen KE. Use of bonded-phase silica sorbents for rapid sampling of impurities in illicit amphetamine for high-performance liquid chromatographic analyses. J Chromatogr A 1985; 331:339-48.
18. Makino Y, Ohta S, Hirobe M. Enantiomeric separation of amphetamine by high-performance liquid chromatography using chiral crown ether-coated reversed-phase packing: application to forensic analysis. Forensic Sci Int 1996; 78:65-70.
19. Mancinelli R, Gentili S, Guiducci MS, et al. Simple and reliable high-performance liquid chromatography fluorimetric procedure for the determination of amphetamine-derived designer drugs. J Chromatogr B 1999; 735:243-53.
20. Mascher H, Göd B, Kikuta C. Determination of desmethyl-selegiline, methamphetamine and amphetamine-the main metabolites of selegiline in plasma by HPLC after derivatization. J Liquid Chromatogr Related Technol 1997; 20:797-809.

21. Nagai T, Sato M, Nagai T, et al. A new analytical method for stereoisomers of methamphetamine and amphetamine and its application to forensic toxicology. Clin Biochem 1989; 22:439-442.
22. Nagai T, Kamiyama S. Assay of the optical isomers of methamphetamine and amphetamine in rat urine using high-performance liquid chromatography with chiral cellulose-based columns. J Chromatogr B 1990; 525:203-209.
23. Nakamura S, Tomita M, Wada M, et al. Quantification of MDMA and MDA in abusers' hair samples by semi-micro column HPLC with fluorescence detection. Biomed Chromatogr 2006; 20:622-627.
24. Nakashima K, Suetsugu K, Yoshida K, et al. High performance liquid chromatography with chemiluminescence detection of methamphetamine and its related compounds using 4-(N, N-dimethylaminosulphonyl)-7-fluoro-2, 1, 3-benzoxadiazole. Biomed Chromatogr 1992; 6:149-154.
25. Nakashima K, Kaddoumi A, Ishida Y, et al. Determination of methamphetamine and amphetamine in abusers' plasma and hair samples with HPLC-FL. Biomed Chromatogr 2003; 17:471-476.
26. Nishida K, Itoh S, Inoue N, et al. High-performance liquid chromatographic-mass spectrometric determination of methamphetamine and amphetamine enantiomers, desmethylselegiline and selegiline, in hair samples of long-term methamphetamine abusers or selegiline users. J Anal Toxicol 2006; 30:232-237.
27. Palfrey S, Labib M. A simple HPLC method for the separation of amphetamine isomers in urine and its application in differentiating between ‘street’amphetamine and prescribed D-Amphetamine. Annals Clin Biochem 1996; 33:344-346.
28. Pichini S, Pacifici R, Pellegrini M, et al. Development and validation of a high-performance liquid chromatography− mass spectrometry assay for determination of amphetamine, methamphetamine, and methylenedioxy derivatives in meconium. Anal Chem 2004; 76:2124-2132.
29. Tehrani MS, Givianrad MH, Mahoor N. Surfactant-assisted dispersive liquid–liquid microextraction followed by high-performance liquid chromatography for determination of amphetamine and methamphetamine in urine samples. Anal Methods 2012; 4:1357-1364.
30. Sadeghipour F, Giroud C, Rivier L, et al. Rapid determination of amphetamines by high-performance liquid chromatography with UV detection. J Chromatogr A 1997; 761:71-78.
31. Santagati NA, Ferrara G, Marrazzo A, et al. Simultaneous determination of amphetamine and one of its metabolites by HPLC with electrochemical detection. J Pharm Biomed Anal 2002; 30:247-255.
32. Seidi S, Yamini Y, Baheri T, et al. Electrokinetic extraction on artificial liquid membranes of amphetamine-type stimulants from urine samples followed by high performance liquid chromatography analysis. J Chromatogr A 2011; 1218:3958-3965.
33. Soares ME, Carvalho M, Carmo H, et al. Simultaneous determination of amphetamine derivatives in human urine after SPE extraction and HPLC-UV analysis. Biomed Chromatogr 2004; 18:125-31.
34. Hayes SM, Liu RH, Tsang WS, et al. Enantiomeric composition analysis of amphetamine and methamphetamine by chiral phase high-performance liquid chromatography-mass spectrometry. J Chromatogr A 1987; 398:239-246.
35. Takayama N, Tanaka S, Kizu R, et al. High-performance liquid chromatography study on effects of permanent wave, dye and decolorant treatments on methamphetamine and amphetamine in hair. Biomed Chromatogr 1999; 13:257-261.
36. Talwar D, Watson ID, Stewart MJ. Routine analysis of amphetamine class drugs as their naphthaquinone derivatives in human urine by high-performance liquid chromatography. J Chromatogr B Biomed Sci Appl 1999; 735:229-240.
37. Trocewicz J. Sample preparation of amphetamine and methamphetamine by means of supported liquid membrane technique for high-performance liquid chromatography analysis. J Separ Sci 2001; 24:587-92.
38. Wang TK, Fuh MS. Determination of amphetamine in human urine by dansyl derivatization and high-performance liquid chromatography with fluorescence detection. J

Chromatogr B Biomed Sci Appl 1996; 686:285-90.

39. Zhao H, Brenneisen R, Scholer A, et al. Profiles of urine samples taken from ecstasy users at rave parties: analysis by immunoassays, HPLC, and GC-MS. J Anal Toxicol 2001; 25:258-269.
40. http://www.forensicscience.pl/pfs/43_novakova.pdf
41. Gübitz G, Wintersteiger R. Identification of drugs of abuse by high-performance thin-layer chromatography. J Anal Toxicol 1980; 4:141-4.
42. Skender L, Karačić V, Brčić I, et al. Quantitative determination of amphetamines, cocaine, and opiates in human hair by gas chromatography/mass spectrometry. Forensic Sci Int 2002; 125:120-126.
43. Gentili S, Torresi A, Marsili R, et al. Simultaneous detection of amphetamine-like drugs with headspace solid-phase microextraction and gas chromatography–mass spectrometry. J Chromatogr B 2002; 780:183-192.
44. Correll D. Development of a rapid SPME/GC-MS method for the detection and quantification of synthetic cathinones in oral fluid.
45. Hyötyläinen T, Sirén H, Riekkola ML. Determination of morphine analogues, caffeine and amphetamine in biological fluids by capillary electrophoresis with the marker technique. J Chromatogr A 1996; 735:439-47.
46. Dahlén J, von Eckardstein S. Development of a capillary zone electrophoresis method including a factorial design and simplex optimisation for analysis of amphetamine, amphetamine analogues, cocaine, and heroin. Forensic Sci Int 2006; 157:93-105.
47. Płotka JM, Biziuk M, Morrison C. Common methods for the chiral determination of amphetamine and related compounds I. Gas, liquid and thin-layer chromatography. Trends Anal Chem 2011; 30:1139-58.
48. Taschwer M, Seidl Y, Mohr S, et al. Chiral separation of cathinone and amphetamine derivatives by HPLC/UV using sulfated ß-cyclodextrin as chiral mobile phase additive. Chirality 2014; 26:411-418.
49. Chen KF, Lee H, Liu JT, et al. A microwave-assisted fluorescent labeling method for the separation and detection of amphetamine-like designer drugs by capillary electrophoresis. Forensic Sci Int 2013; 228:95-99.
50. Chen KF, Lee H, Liu JT, et al. A microwave-assisted fluorescent labeling method for the separation and detection of amphetamine-like designer drugs by capillary electrophoresis. Forensic Sci Int 2013; 228:95-99.
51. Chung YL, Liu JT, Lin CH. On-line identification of 3, 4-methylenedioxymethamphetamine in human urine by non-aqueous capillary electrophoresis–fluorescence spectroscopy at 77 K. J Chromatogr B: Biomed Sci Appl 2001; 759:219-226.
52. Cladrowa-Runge S, Hirz R, Kenndler E, et al. Enantiomeric separation of amphetamine related drugs by capillary zone electrophoresis using native and derivatized β-cyclodextrin as chiral additives. J Chromatogr A 1995; 710:339-345.
53. Trenerry VC, Robertson J, Wells RJ. Analysis of illicit amphetamine seizures by capillary electrophoresis. J Chromatogr A 1995; 708:169-176.
54. dos Santos VB, Daniel D, Singh M, et al. Amphetamine and derivatives in natural weight loss pills and dietary supplements by capillary electrophoresis-tandem mass spectrometry. J Chromatogr B 2016; 1038:19-25.
55. Epple R, Blanes L, Beavis A, et al. Analysis of amphetamine-type substances by capillary zone electrophoresis using capacitively coupled contactless conductivity detection. Electrophoresis 2010; 31:2608-2613.
56. Geiser L, Cherkaoui S, Veuthey JL. Simultaneous analysis of some amphetamine derivatives in urine by nonaqueous capillary electrophoresis coupled to electrospray ionization mass spectrometry. J Chromatogr A 2000; 895:111-121.
57. Iwata YT, Kanamori T, Ohmae Y, et al. Chiral analysis of amphetamine-type stimulants using reversed-polarity capillary electrophoresis/positive ion electrospray ionization tandem mass spectrometry. Electrophoresis 2003; 24:1770-1776.
58. Iwata YT, Inoue H, Kuwayama K, et al. Forensic application of chiral separation of amphetamine-type stimulants to impurity analysis of seized methamphetamine by

capillary electrophoresis. Forensic Sci Int 2006; 161:92-96.
59. Kuroda N, Nomura R, Al-Dirbashi O, et al. Determination of methamphetamine and related compounds by capillary electrophoresis with UV and laser-induced fluorescence detection. J Chromatogr A 1998; 798:325-334.
60. Meng P, Fang N, Wang M, et al. Analysis of amphetamine, methamphetamine and methylenedioxy-methamphetamine by micellar capillary electrophoresis using cation-selective exhaustive injection. Electrophoresis 2006; 27:3210-3217.
61. Nieddu M, Boatto G, Carta A, et al. Simultaneous determination of ten amphetamine designer drugs in human whole blood by capillary electrophoresis with diode array detection. Biomed Chromatogr 2005; 19:737-42.
62. Piette V, Parmentier F. Analysis of illicit amphetamine seizures by capillary zone electrophoresis. J Chromatogr A 2002; 979:345-52.
63. Ramseier A, Heeren FV, Thormann W. Analysis of fluorescein isothiocyanate derivatized amphetamine and analogs in human urine by capillary electrophoresis in chip-based and fused-silica capillary instrumentation. Electrophoresis 1998; 19:2967-75.
64. Gill R, Bal TS, Moffat AC. The application of derivative UV-visible spectroscopy in forensic toxicology. J Forensic Sci Society 1982; 22:165-71.
65. Hargis LG, Howell JA, Sutton RE. Ultraviolet and light absorption spectrometry. Anal Chem 1996; 68:169-84.
66. Lawrence AH, MacNeil JD. Identification of amphetamine and related illicit drugs by second derivative ultraviolet spectrometry. Anal Chem 1982; 54:2385-2387.
67. Raffa RB, Martley AF. Amphetamine-induced increase in planarian locomotor activity and block by UV light. Brain Res 2005; 1031:138-40.
68. Hughes J, Ayoko G, Collett S, et al. Rapid quantification of methamphetamine: using attenuated total reflectance fourier transform infrared spectroscopy (ATR-FTIR) and chemometrics. PloS One 2013; 8:e69609.
69. Markowitz JS, Patrick KS. The clinical pharmacokinetics of amphetamines utilized in the treatment of attention-deficit/hyperactivity disorder. J Child Adol Psychopharmacol 2017; 27:678-89.
70. Jahangir MA, Taleuzzaman M, Alam MJ, Soni A, Beg S. Analytical quality by design for capillary electrophoresis. InHandbook of Analytical Quality by Design 2021 Jan 1 (pp. 115-132). Academic Press.
71. Muheem A, Shakeel F, Zafar S, Jahangir MA, Warsi MH, Jain GK, Ahmad FJ. Development and validation of stability indicating liquid chromatographic (RP-HPLC) method for estimation of ubidecarenone in bulk drug and formulations using quality by design (QBD) approach. Brazilian Journal of Pharmaceutical Sciences. 2018 Mar 5;53.
72. Taleuzzamana M, Jahangirb A, Gilania SJ. Quantification and identification of bioactive eugenol in Myristica fragrans seeds using validated high performance thin layer chromatography technique. Pharm. Anal. Acta. 2017;8:E563.

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