PeakAL: Protons I Have Known and Loved — Fifty shades of grey-market spectra

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^{1}H NMR spectra of 28 alleged psychedelic phenylethanamines from 15 grey-market internet vendors across North America and Europe were acquired and compared. Members from each of the principal phenylethanamine families were analyzed: eleven *para*-substituted 2,5-dimethoxyphenylethanamines (the *2C* and *2C-T* series); four *para*-substituted 3,5-dimethoxyphenylethanamines (mescaline analogues); two β-substituted phenylethanamines; and ten *N*-substituted phenylethanamines with a 2-methoxybenzyl (*NBOMe*), 2-hydroxybenzyl (*NBOH*), or 2,3-methylenedioxybenzyl (*NBMD*) amine moiety. ^{1}H NMR spectra for some of these compounds have not been previously reported to our knowledge. Others have reported on the composition of "mystery pills," single-dose formulations obtained from retail shops and websites. We believe this is the first published survey of bulk "research chemicals" marketed and sold as such. Only one analyte was unequivocally misrepresented. This collection of experimentally uniform spectra may help forensic and harm-reduction organizations identify these compounds, some of which appear only sporadically. The complete spectra are provided as supplementary data.[1]

Keywords: ^{1}H NMR, drug checking, grey markets, research chemicals, phenylethanamines, *N*-benzyl phenylethanamines, *PiHKAL*
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"Once you get a serious spectrum collection,
the tendency is to push it as far as you can."[1]

Introduction

Psychedelic phenylethanamines[2] have been known and studied for decades, generating much interest and enthusiasm in some quarters — and corresponding alarm in others.[3–6] Though drawing less scrutiny than better known psychedelics like LSD or psilocybin, strictly speaking these are not novel materials.[7,8] In contrast, *N*-benzyl phenylethanamines progressed from earliest published reports[9–14] and subsequent research[15,16] to ready grey-market availability and ultimately prohibition — in the UK[17,18] and the USA[19] — in less than 20 years.

Here we report the ^{1}H NMR spectrum of 28 grey-market phenyl ethanamines and *N*-benzyl phenylethanamines. The spectra of ca. 30 grey-market tryptamines will be the subject of a later report.

The advent and rapid expansion of electronic commerce in grey-market research chemicals has been startling.[20–22] Hundreds of formerly obscure substances, once unobtainable to most in any practical sense are now within reach.[23] For some, legal and affordable reach as well. A wide-ranging review of the evolving new-drug landscape is provided by Brandt et al.[24]

Nevertheless, an inherent weakness of grey markets is the absence of regulatory oversight. Fleeting, unreliable, or fraudulent vendors are not uncommon. The reputation of a well-regarded source may, gradually or abruptly, decline. The slide from principled vendor to scam artist is well worn. For the customer, authenticating grey-market products is essential — and a considerable challenge.

Few organizations exist to meet this need. EcstasyData.org, a leading drug-analysis service, has traditionally focused on testing single-dose formulations (e.g. a pill or capsule) held out as "ecstasy." More recently, they expanded their mandate to include research chemicals.[3] However, at $100 per analyte the cost seemed prohibitive for the summary level of analysis provided — a restriction imposed by the Drug Enforcement Administration (DEA).[4]

Fortunately, the University of Toronto offers several forms of analysis for external clients including NMR and mass spectrometry (MS). We wondered if "walk-in" ^{1}H NMR analysis combined with contemporary spectral-analysis software might allow even inexperienced investigators to verify the composition of grey-market research chemicals with a reasonable degree of confidence. The attraction of ^{1}H NMR over MS is threefold: (1) the cost is significantly lower; less than 25 percent, (2) it provides sufficient information to potentially

[1] *pace* Hunter S. Thompson.

[2] Systematic names follow IUPAC Recommendations and Preferred Names 2013 except where noted. Sadly, the beloved and familiar contraction *phenethyl* has officially fallen from grace (i.e. deprecated).[2]

[3] Isomer Design is a supporting partner in EcstasyData.org.

[4] Imposed by "an unpublished administrative rule." See EcstasyData.org.

identify an unknown in the absence of a reference spectrum,[25] and (3) aryl regioisomers are more readily differentiated.

Simply, we wanted to know if the grey-market research chemicals being sold were in fact "as advertised." Would the spectrum be consistent with the substance as alleged? Was this powder labelled *x*, actually *x*, or not? In November 2012, after an engaging discussion with Timothy Burrow, Director of the University of Toronto NMR Facility, we began our investigation to confirm the identity of grey-market research chemicals.

Limitations and bias

Our objective was chiefly to *check* the identity of our unknowns, not unlike how presumptive spot-colour tests are used.[26] It was sufficient to assign a pass/fail grade to an unknown; spectra consistent with published results passed.[1]

We have included every phenylethanamine spectrum acquired — nothing has been excluded. Our analytes were purchased over several years from 15 vendors across North America and Europe. Though we consider this to be a fair representation of the grey market during that time it is not without potential selection bias. While no official regulatory oversight exists for this market, anecdotal reports posted at SafeOrScam.com[2] provided some guidance. Patently disreputable vendors were excluded. Our analytes were not selected *at random* and our findings should be interpreted accordingly.

The "purity" values we report were provided by the verification module of the MestReNova software. Though we do not suggest these values necessarily reflect actual analyte purity, they are comparable in magnitude and implied precision (misleading or not) to vendor-supplied values.[3]

A report by Hays and Cassale[28] became available to us only recently. We regret we were unable to include their extensive findings among the cited literature.

Experimental

Grey-market research chemicals were purchased from internet vendors in Europe, the United States, and Canada, 2009–2014.

Commercially available 2-phenylethan-1-amine HCl (PEA) was purchased from AK Scientific, Inc., Union City, CA. Two *N*-benzylidene phenylethanamines were purchased from Cayman Chemical, Ann Arbor, MI. Licensed software from Mestrelab Research SL, Santiago de Compostela, Spain was used for spectral analysis. Preferred IUPAC names were constructed using licenced software from ACD/Labs, Toronto, Canada.

Analytical data was supplied by Timothy Burrow from November 2012 through August 2014. ^{1}H NMR spectra for analytes **P0** and **P17** were recorded on an Agilent DD2 NMR spectrometer operating at 699.8 MHz and equipped with an HFCN Cold Probe. All other analytes were recorded on an Agilent DD2 NMR spectrometer operating at 499.67 MHz and equipped with an XSens Cold Probe.

Approximately 5 mg of each analyte was placed in a capped glass vial, labelled, and submitted for analysis. Except where noted spectra were acquired in deuterated dimethyl sulfoxide (DMSO-d_6) from single-use ampoules to minimize the presence of water. DMSO-d_6 was chosen to dissolve analytes in free base or salt form along with any impurities which might be present. Dissolution was reportedly facile and complete in every case, leaving no residual insoluble material. Dissolved analytes were loaded without filtering into a 3 mm NMR sample tubes. Spectra acquired in DMSO-d_6 were referenced to the solvent signal at δ = 2.50 ppm.

Results

Analyte structures and codes are shown in Figures 1–3. Analyte codes, substitution patterns, and preferred IUPAC names (PIN) are listed in Table 1. ^{1}H NMR spectral data is summarized in Table 2. Multiplets for moieties common to all scaffolds are grouped together in Table 3. Multiplets for moieties common only to the *N*-benzyl and *N*-benzylidene PEA scaffolds are grouped together in Table 4, ordered by shift. Multiplets for *para*-substituents, β-substituents, and atypical moieties are detailed in Table 5.

[1] If no published spectrum could be found we used the Force of MestReNova software to predict one. *How* to use the Force without succumbing to the Dark Side was revealed in an e-mail from Jedi Master Santi Domínguez, 2013.

[2] SafeOrScam.com has closed, reportedly sacrificed following an attack ca. 8 July 2015. In its place, ostensibly, ScamLogs.com has since appeared.[27]

[3] The *alleged* purity of our analytes routinely implies a precision of ± 0.01%.

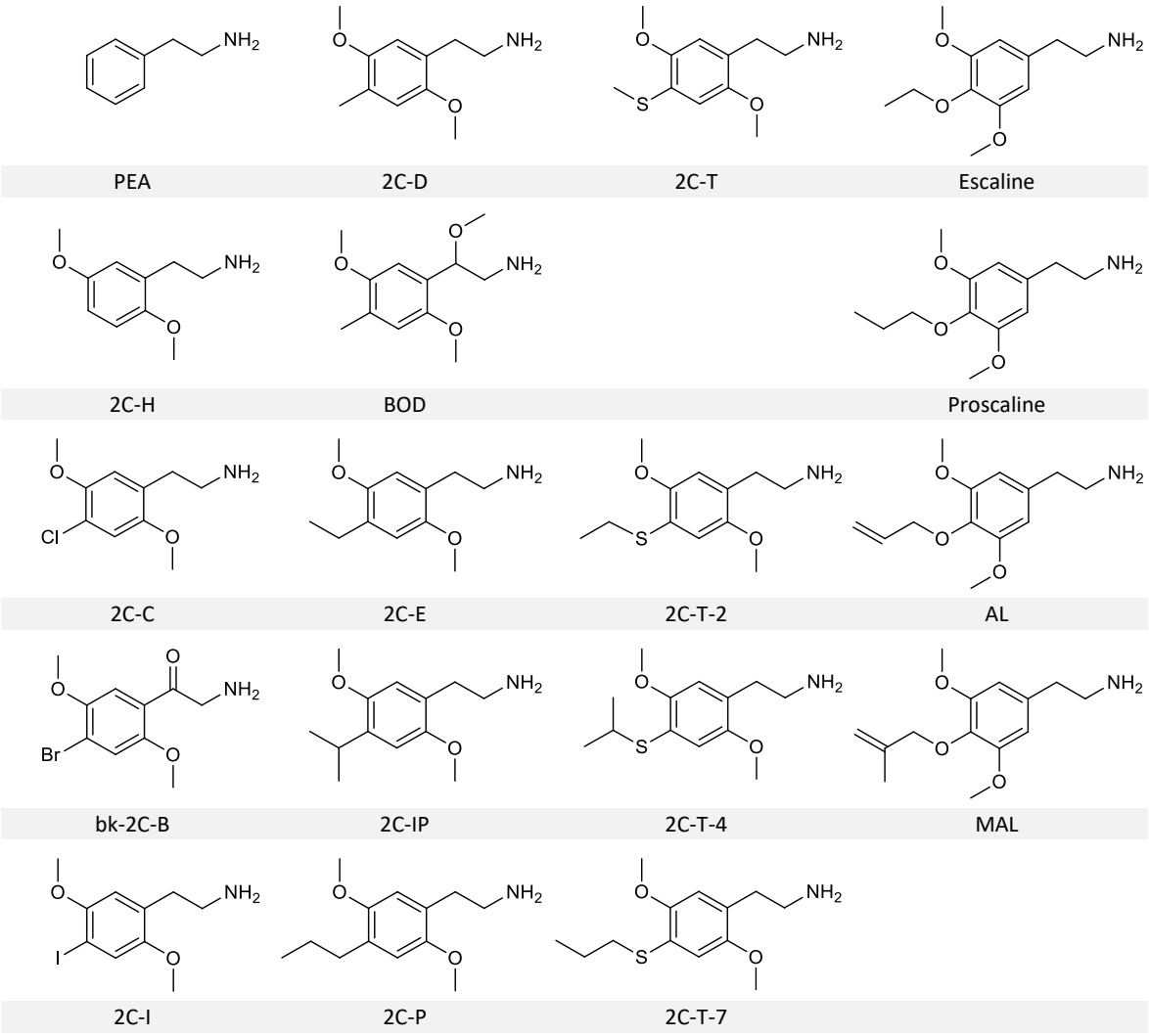


Figure 1: Structures of *N*-unsubstituted (*P* series) analytes

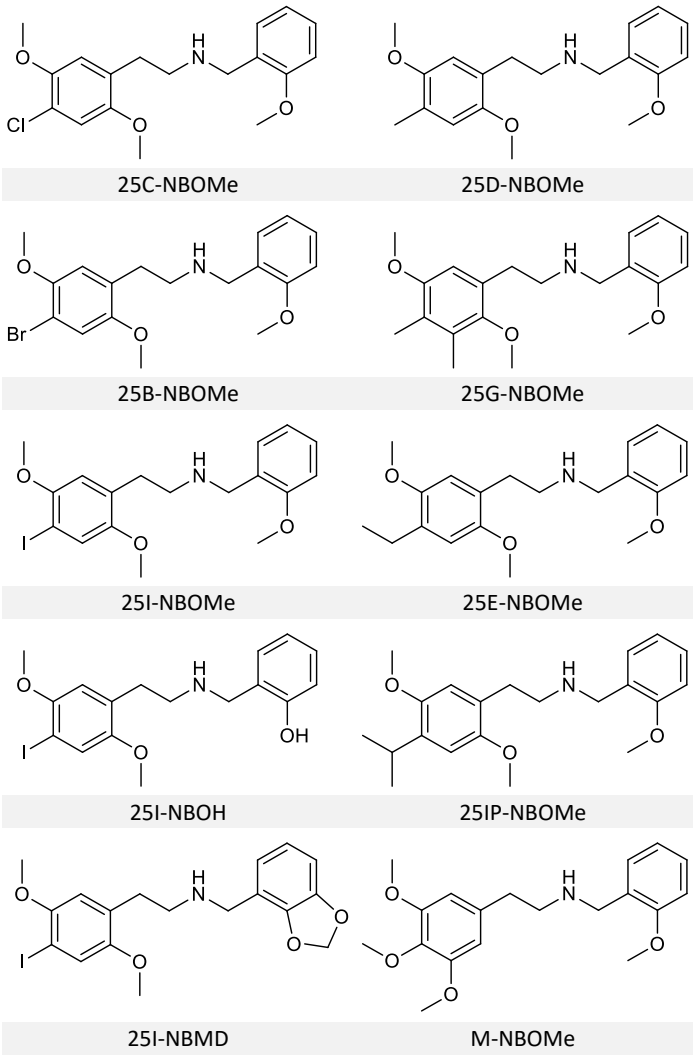


Figure 2: Structures of *N*-benzyl (*B* series) analytes

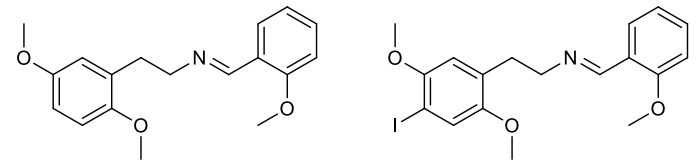
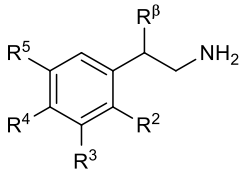
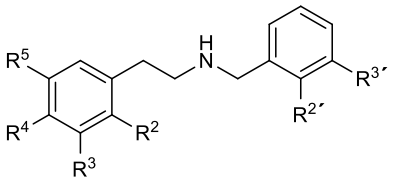


Figure 3: Structures of *N*-benzylidene (*IM* series) analytes

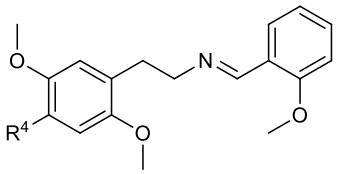
Table 1: Names and scaffold substitution patterns of analytes



P



B



IM

Scaffold *P*

Code	R^2	R^3	R^4	R^5	R^β	Preferred IUPAC name
PEA	H	H	H	H	H	2-phenylethan-1-amine
2C-H	OCH_3	H	H	OCH_3	H	2-(2,5-dimethoxyphenyl)ethan-1-amine
2C-C	OCH_3	H	Cl	OCH_3	H	2-(4-chloro-2,5-dimethoxyphenyl)ethan-1-amine
bk-2C-B	OCH_3	H	Br	OCH_3	=O	2-amino-1-(4-bromo-2,5-dimethoxyphenyl)ethan-1-one
2C-I	OCH_3	H	I	OCH_3	H	2-(4-iodo-2,5-dimethoxyphenyl)ethan-1-amine
2C-D	OCH_3	H	CH_3	OCH_3	H	2-(2,5-dimethoxy-4-methylphenyl)ethan-1-amine
BOD	OCH_3	H	CH_3	OCH_3	OCH_3	2-(2,5-dimethoxy-4-methylphenyl)-2-methoxyethan-1-amine
2C-E	OCH_3	H	CH_2CH_3	OCH_3	H	2-(4-ethyl-2,5-dimethoxyphenyl)ethan-1-amine
2C-IP	OCH_3	H	$CH(CH_3)_2$	OCH_3	H	2-[2,5-dimethoxy-4-(propan-2-yl)phenyl]ethan-1-amine
2C-P	OCH_3	H	$CH_2CH_2CH_3$	OCH_3	H	2-(2,5-dimethoxy-4-propylphenyl)ethan-1-amine
2C-T	OCH_3	H	SCH_3	OCH_3	H	2-[2,5-dimethoxy-4-(methylsulfanyl)phenyl]ethan-1-amine
2C-T-2	OCH_3	H	SCH_2CH_3	OCH_3	H	2-[4-(ethylsulfanyl)-2,5-dimethoxyphenyl]ethan-1-amine
2C-T-4	OCH_3	H	$SCH(CH_3)_2$	OCH_3	H	2-{2,5-dimethoxy-4-[(propan-2-yl)sulfanyl]phenyl}ethan-1-amine
2C-T-7	OCH_3	H	$SCH_2CH_2CH_3$	OCH_3	H	2-[2,5-dimethoxy-4-(propylsulfanyl)phenyl]ethan-1-amine
Escaline	H	OCH_3	OCH_2CH_3	OCH_3	H	2-(4-ethoxy-3,5-dimethoxyphenyl)ethan-1-amine
Proscaline	H	OCH_3	$OCH_2CH_2CH_3$	OCH_3	H	2-(3,5-dimethoxy-4-propoxyphenyl)ethan-1-amine
AL	H	OCH_3	OCH_2CHCH_2	OCH_3	H	2-{3,5-dimethoxy-4-[(prop-2-en-1-yl)oxy]phenyl}ethan-1-amine
MAL	H	OCH_3	$OCH_2C(CH_3)CH_2$	OCH_3	H	2-{3,5-dimethoxy-4-[(2-methylprop-2-en-1-yl)oxy]phenyl}ethan-1-amine

Scaffold *B*

Code	R^2	R^3	R^4	R^5	$R^{2'}$	$R^{3'}$	Preferred IUPAC name
25C-NBOMe	OCH_3	H	Cl	OCH_3	OCH_3	H	2-(4-chloro-2,5-dimethoxyphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25B-NBOMe	OCH_3	H	Br	OCH_3	OCH_3	H	2-(4-bromo-2,5-dimethoxyphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25I-NBOMe	OCH_3	H	I	OCH_3	OCH_3	H	2-(4-iodo-2,5-dimethoxyphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25I-NBOH	OCH_3	H	I	OCH_3	OH	H	2-({[2-(4-iodo-2,5-dimethoxyphenyl)ethyl]amino}methyl)phenol
25I-NBMD	OCH_3	H	I	OCH_3	$-O-CH_2-O-$		*N*-[(2*H*-1,3-benzodioxol-4-yl)methyl]-2-(4-iodo-2,5-dimethoxyphenyl)ethan-1-amine
25D-NBOMe	OCH_3	H	CH_3	OCH_3	OCH_3	H	2-(2,5-dimethoxy-4-methylphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25G-NBOMe	OCH_3	CH_3	CH_3	OCH_3	OCH_3	H	2-(2,5-dimethoxy-3,4-dimethylphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25E-NBOMe	OCH_3	H	CH_2CH_3	OCH_3	OCH_3	H	2-(4-ethyl-2,5-dimethoxyphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
25IP-NBOMe	OCH_3	H	$CH(CH_3)_2$	OCH_3	OCH_3	H	2-[2,5-dimethoxy-4-(propan-2-yl)phenyl]-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine
M-NBOMe	H	OCH_3	OCH_3	OCH_3	OCH_3	H	*N*-[(2-methoxyphenyl)methyl]-2-(3,4,5-trimethoxyphenyl)ethan-1-amine

Scaffold *IM*

Code	R^4	Preferred IUPAC name
25H-NBOMe imine	H	*N*-[2-(2,5-dimethoxyphenyl)ethyl]-1-(2-methoxyphenyl)methanimine
25I-NBOMe imine	I	*N*-[2-(4-iodo-2,5-dimethoxyphenyl)ethyl]-1-(2-methoxyphenyl)methanimine

Table 2: ^{1}H NMR chemical shift, labelled formulation, and calculated purity of analytes

Analyte[a]		*Form*[b]	*Purity*[c]	^{1}H NMR[d]
P0	PEA · HCl	HCl	98[e]	700 MHz DMSO-d_6 δ 8.29 (s, 3H), 7.34 – 7.21 (m, 5H), 3.02 – 2.97 (m, 2H), 2.95 – 2.89 (m, 2H)
P1	2C-H base	U	98.16	500 MHz DMSO-d_6 δ 6.88 – 6.81 (m, 1H), 6.76 – 6.68 (m, 2H), 3.71 (s, 3H), 3.68 (s, 3H), 2.73 – 2.66 (m, 2H), 2.63 – 2.55 (m, 2H), 1.32 (vb s, 2H)
P1[f]	2C-H · HCl	–	98.46	500 MHz DMSO-d_6 δ 8.19 (br s, 3H), 6.94 – 6.87 (m, 1H), 6.82 – 6.76 (m, 2H), 3.74 (s, 3H), 3.69 (s, 3H), 2.98 – 2.91 (m, 2H), 2.88 – 2.81 (m, 2H)
P2	2C-D	U	96.44	500 MHz DMSO-d_6 δ 8.15 (br s, 3H), 6.82 (d, *J* = 0.8 Hz, 1H), 6.78 (s, 1H), 3.73 (s, 6H), 2.97 – 2.89 (m, 2H), 2.87 – 2.80 (m, 2H), 2.13 (d, *J* = 0.7 Hz, 3H)
P3	2C-E	HCl	97.50	500 MHz DMSO-d_6 δ 8.02 (br s, 3H), 6.81 (s, 1H), 6.79 (s, 1H), 3.74 (s, 3H), 3.74 (s, 3H), 3.00 – 2.91 (m, 2H), 2.86 – 2.79 (m, 2H), 2.54 (q, *J* = 7.5 Hz, 2H), 1.11 (t, *J* = 7.5 Hz, 3H)
P4	2C-P	U	93.05	500 MHz DMSO-d_6 δ 8.04 (br s, 3H), 6.79 (s, 2H), 3.74 (s, 3H), 3.73 (s, 3H), 2.99 – 2.90 (m, 2H), 2.86 – 2.79 (m, 2H), 2.51 – 2.45 (m, 2H), 1.60 – 1.45 (m, 2H), 0.89 (t, *J* = 7.4 Hz, 3H)
P4[g]	2C-P	U	–	500 MHz DMF-d_7 δ 8.64 (br s, 3H), 6.99 (s, 1H), 6.87 (s, 1H), 3.82 (s, 3H), 3.80 (s, 3H), 3.26 – 3.19 (m, 2H), 3.10 – 3.03 (m, 2H), 2.59 – 2.52 (m, 2H), 1.63 – 1.52 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H)
P5	2C-IP	HCl	98.12	500 MHz DMSO-d_6 δ 8.00 (br s, 3H), 6.81 (s, 1H), 6.79 (s, 1H), 3.76 (s, 3H), 3.74 (s, 3H), 3.21 (hept, *J* = 6.9 Hz, 1H), 2.99 – 2.92 (m, 2H), 2.85 – 2.78 (m, 2H), 1.15 (d, *J* = 6.9 Hz, 6H)
P6a	2C-E[h]	FB	96.91	500 MHz DMSO-d_6 δ 8.03 (br s, 3H), 6.81 (s, 1H), 6.79 (s, 1H), 3.74 (s, 3H), 3.74 (s, 3H), 2.98 – 2.91 (m, 2H), 2.86 – 2.79 (m, 2H), 2.54 (q, *J* = 7.5 Hz, 2H), 1.11 (t, *J* = 7.5 Hz, 3H)
P6b	2C-C	C	94.94	500 MHz DMSO-d_6 δ 8.18 (br s, 3H), 7.07 (s, 1H), 7.05 (s, 1H), 3.80 (s, 3H), 3.76 (s, 3H), 3.00 – 2.93 (m, 2H), 2.90 – 2.83 (m, 2H)
P7	2C-I	HCl	97.36	500 MHz DMSO-d_6 δ 7.99 (br s, 3H), 7.33 (s, 1H), 6.90 (s, 1H), 3.77 (s, 3H), 3.76 (s, 3H), 3.00 – 2.93 (m, 2H), 2.87 – 2.80 (m, 2H)
P8	2C-T	FB	96.61	500 MHz DMSO-d_6 δ 7.97 (br s, 3H), 6.83 (s, 1H), 6.76 (s, 1H), 3.80 (s, 3H), 3.76 (s, 3H), 2.98 – 2.91 (m, 2H), 2.86 – 2.79 (m, 2H), 2.41 (s, 3H)
P9	2C-T-2	HCl	96.38	500 MHz DMSO-d_6 δ 7.98 (br s, 3H), 6.85 (s, 1H), 6.83 (s, 1H), 3.78 (s, 3H), 3.76 (s, 3H), 3.01 – 2.92 (m, 2H), 2.92 (q, *J* = 7.3 Hz, 2H), 2.86 – 2.79 (m, 2H), 1.23 (t, *J* = 7.3 Hz, 3H)
P10	2C-T-4	U	97.02	500 MHz DMSO-d_6 δ 7.98 (br s, 3H), 6.91 (s, 1H), 6.87 (s, 1H), 3.77 (s, 3H), 3.76 (s, 3H), 3.54 (hept, *J* = 6.6 Hz, 1H), 3.01 – 2.93 (m, 2H), 2.87 – 2.80 (m, 2H), 1.21 (d, *J* = 6.6 Hz, 6H)
P11	2C-T-7	FB	97.81	500 MHz DMSO-d_6 δ 8.02 (br s, 3H), 6.85 (s, 1H), 6.82 (s, 1H), 3.77 (s, 3H), 3.76 (s, 3H), 2.99 – 2.92 (m, 2H), 2.88 (t, *J* = 7.1 Hz, 2H), 2.86 – 2.79 (m, 2H), 1.58 (h, *J* = 7.3 Hz, 2H), 0.98 (t, *J* = 7.3 Hz, 3H)
P12	Escaline	FB	96.92	500 MHz DMSO-d_6 δ 8.22 (br s, 3H), 6.56 (s, 2H), 3.85 (q, *J* = 7.0 Hz, 2H), 3.75 (s, 6H), 3.06 – 2.99 (m, 2H), 2.89 – 2.81 (m, 2H), 1.20 (t, *J* = 7.0 Hz, 3H)
P13a	Proscaline	N/A	96.55	500 MHz DMSO-d_6 δ 8.05 (br s, 3H), 6.56 (s, 2H), 3.79 – 3.72 (m, 8H), 3.07 – 3.00 (m, 2H), 2.85 – 2.78 (m, 2H), 1.61 (h, *J* = 7.1 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H)
P13b	Proscaline	FB	96.72	500 MHz DMSO-d_6 δ 8.20 (br s, 3H), 6.56 (s, 2H), 3.80 – 3.71 (m, 8H), 3.06 – 2.98 (m, 2H), 2.89 – 2.80 (m, 2H), 1.66 – 1.55 (m, 2H), 0.93 (t, *J* = 7.4 Hz, 3H)
P14	AL	C	95.26	500 MHz DMSO-d_6 δ 8.13 (br s, 3H), 6.57 (s, 2H), 5.98 (ddt, *J* = 17.3, 10.4, 5.6 Hz, 1H), 5.28 (dq, *J* = 17.3, 1.8 Hz, 1H), 5.17 – 5.10 (m, 1H), 4.35 (dt, *J* = 5.6, 1.6 Hz, 2H), 3.76 (s, 6H), 3.06 – 2.99 (m, 2H), 2.87 – 2.80 (m, 2H)
P15	MAL	C	92.08	500 MHz DMSO-d_6 δ 8.03 (br s, 3H), 6.56 (s, 2H), 5.02 – 4.97 (m, 1H), 4.89 – 4.83 (m, 1H), 4.27 – 4.22 (m, 2H), 3.76 (s, 6H), 3.06 – 3.00 (m, 2H), 2.86 – 2.78 (m, 2H), 1.81 – 1.76 (m, 3H)
P16	BOD	HCl	97.02	500 MHz DMSO-d_6 δ 8.14 (s, 3H), 6.91 (d, *J* = 0.9 Hz, 1H), 6.82 (s, 1H), 4.78 (dd, *J* = 8.9, 3.9 Hz, 1H), 3.75 (s, 3H), 3.75 (s, 3H), 3.21 (s, 3H), 2.96 – 2.82 (m, 2H), 2.16 (d, *J* = 0.9 Hz, 3H)
P17	bk-2C-B	HCl	89.78	700 MHz DMSO-d_6 δ 8.28 (br s, 3H), 7.59 (s, 1H), 7.43 (s, 1H), 4.31 (q, *J* = 5.2 Hz, 2H), 3.94 (s, 3H), 3.86 (s, 3H)

Table 2: ^{1}H NMR chemical shift, labelled formulation, and calculated purity of analytes

Analyte[a]		*Form*[b]	*Purity*[c]	^{1}H NMR[d]
B1	25B-NBOMe	HCl	98.32	500 MHz DMSO-d_6 δ 9.18 (br s, 2H), 7.49 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H), 7.19 (s, 1H), 7.08 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.02 (s, 1H), 7.00 (td, *J* = 7.4, 1.1 Hz, 1H), 4.11 (s, 2H), 3.83 (s, 3H), 3.79 (s, 3H), 3.75 (s, 3H), 3.10 – 3.03 (m, 2H), 3.00 – 2.93 (m, 2H)
B2	25C-NBOMe	HCl	98.56	500 MHz DMSO-d_6 δ 9.23 (br s, 2H), 7.50 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.2, 7.4, 1.7 Hz, 1H), 7.14 – 7.05 (m, 1H), 7.08 (s, 1H), 7.04 (s, 1H), 7.00 (td, *J* = 7.5, 1.1 Hz, 1H), 4.11 (s, 2H), 3.83 (s, 3H), 3.80 (s, 3H), 3.74 (s, 3H), 3.10 – 3.01 (m, 2H), 3.03 – 2.94 (m, 2H)
B3	25I-NBOMe	HCl	97.59	500 MHz DMSO-d_6 δ 9.15 (br s, 2H), 7.48 (dd, *J* = 7.5, 1.8 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H), 7.32 (s, 1H), 7.08 (dd, *J* = 8.3, 1.0 Hz, 1H), 6.99 (td, *J* = 7.4, 1.1 Hz, 1H), 6.90 (s, 1H), 4.11 (s, 2H), 3.83 (s, 3H), 3.77 (s, 3H), 3.73 (s, 2H), 3.09 – 3.00 (m, 2H), 2.99 – 2.92 (m, 2H)
B4	25I-NBOH	HCl	96.72	500 MHz DMSO-d_6 δ 9.22 (vb s, 3H), 7.39 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.32 (s, 1H), 7.23 (ddd, *J* = 8.1, 7.3, 1.7 Hz, 1H), 6.97 (dd, *J* = 8.2, 1.1 Hz, 1H), 6.89 (s, 1H), 6.84 (td, *J* = 7.4, 1.1 Hz, 1H), 4.09 (s, 2H), 3.77 (s, 3H), 3.74 (s, 3H), 3.09 – 3.02 (m, 2H), 3.00 – 2.91 (m, 2H)
B5[i]	25I-NBMD	FB	96.42	500 MHz DMSO-d_6 δ 7.25 (s, 1H), 6.84 (s, 1H), 6.86 – 6.78 (m, 1H), 6.81 – 6.72 (m, 2H), 5.96 (s, 2H), 3.73 (s, 3H), 3.71 (d, *J* = 0.3 Hz, 3H), 3.66 (d, *J* = 0.6 Hz, 2H), 2.69 – 2.65 (m, 4H), 1.98 (br s, 1H)
B6	25D-NBOMe	HCl	97.39	500 MHz DMSO-d_6 δ 9.18 (br s, 2H), 7.49 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H), 7.08 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.00 (td, *J* = 7.5, 1.1 Hz, 1H), 6.88 – 6.79 (m, 1H), 6.77 (s, 1H), 4.11 (s, 2H), 3.83 (s, 3H), 3.73 (s, 3H), 3.71 (s, 3H), 3.10 – 2.96 (m, 2H), 3.00 – 2.88 (m, 2H), 2.13 (d, *J* = 0.7 Hz, 3H)
B7	25E-NBOMe	HCl	98.67	500 MHz DMSO-d_6 δ 9.20 (br s, 2H), 7.49 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H), 7.09 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.00 (td, *J* = 7.5, 1.0 Hz, 1H), 6.80 (s, 1H), 6.78 (s, 1H), 4.12 (s, 2H), 3.83 (s, 3H), 3.73 (s, 3H), 3.72 (s, 3H), 3.07 – 2.99 (m, 2H), 2.98 – 2.91 (m, 2H), 2.53 (q, *J* = 7.4 Hz, 2H), 1.11 (t, *J* = 7.5 Hz, 3H)
B8	25IP-NBOMe	HCl	98.59	500 MHz DMSO-d_6 δ 9.22 (br s, 2H), 7.50 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.4, 1.7 Hz, 1H), 7.08 (dd, *J* = 8.4, 1.0 Hz, 1H), 6.99 (td, *J* = 7.4, 1.0 Hz, 1H), 6.80 (s, 1H), 6.79 (s, 1H), 4.12 (s, 2H), 3.83 (s, 3H), 3.73 (s, 3H), 3.73 (s, 3H), 3.21 (hept, *J* = 6.9 Hz, 1H), 3.07 – 2.99 (m, 2H), 2.98 – 2.91 (m, 2H), 1.15 (d, *J* = 6.9 Hz, 6H)
B9	25G-NBOMe	HCl	96.11	500 MHz DMSO-d_6 δ 9.29 (br s, 2H), 7.52 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H), 7.09 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.00 (td, *J* = 7.5, 1.0 Hz, 1H), 6.66 (s, 1H), 4.14 (s, 2H), 3.84 (s, 3H), 3.73 (s, 3H), 3.58 (s, 3H), 3.11 – 3.02 (m, 2H), 3.05 – 2.95 (m, 2H), 2.12 (s, 3H), 2.04 (s, 3H)
B10	M-NBOMe	HCl	96.07	500 MHz DMSO-d_6 9.33 (br s, 2H), 7.53 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.41 (ddd, *J* = 8.2, 7.4, 1.7 Hz, 1H), 7.08 (dd, *J* = 8.4, 1.0 Hz, 1H), 6.99 (td, *J* = 7.5, 1.0 Hz, 1H), 6.55 (s, 2H), 4.11 (s, 2H), 3.83 (s, 3H), 3.76 (s, 6H), 3.62 (s, 3H), 3.16 – 3.08 (m, 2H), 3.00 – 2.93 (m, 2H)
IM1	25H-NBOMe imine	soln	> 95[e]	500 MHz DMSO-d_6 δ 8.56 (s, 1H), 7.82 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.42 (ddd, *J* = 8.3, 7.3, 1.8 Hz, 1H), 7.08 (dd, *J* = 8.4, 1.0 Hz, 1H), 6.98 (tt, *J* = 7.5, 0.8 Hz, 1H), 6.87 (d, *J* = 8.8 Hz, 1H), 6.78 (d, *J* = 3.1 Hz, 1H), 6.72 (dd, *J* = 8.8, 3.1 Hz, 1H), 3.82 (s, 3H), 3.74 (s, 3H), 3.75 – 3.68 (m, 2H), 3.65 (s, 3H), 2.84 (t, *J* = 7.5 Hz, 2H)
IM2	25I-NBOMe imine	soln	> 95[e]	500 MHz DMSO-d_6 δ 8.54 (s, 1H), 7.82 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.42 (ddd, *J* = 8.3, 7.3, 1.8 Hz, 1H), 7.28 (s, 1H), 7.08 (dd, *J* = 8.3, 1.0 Hz, 1H), 6.97 (tt, *J* = 7.5, 0.8 Hz, 1H), 6.87 (s, 1H), 3.82 (s, 3H), 3.75 (s, 3H), 3.76 – 3.69 (m, 2H), 3.69 (s, 3H), 2.85 (t, *J* = 7.3 Hz, 2H)

[a] Formulated as the aminium salt except where noted.

[b] The stated formulation of the analyte, where provided: C, conflicting claims made on analyte packaging and supporting documentation; HCl, hydrochloride; FB, free base; soln: in methyl acetate solution; N/A, not available; U, unspecified.

[c] The per cent ratio of the total analyte integral over the total spectrum integral a*s* reported by Mestrelab's MestReNova software except where noted.

[d] br, broad; d, doublet; h, hextet; hept, heptet; obs, partially obscured; m, multiplet; q, quartet; s, singlet; t, triplet; vb, very broad; *J*, coupling constant; Ph, phenyl.

[e] Purity as labelled by vendor.

[f] Converted to the hydrochloride salt from the supplied free base oil following Shulgin and Shulgin,[3] recrystallized in oxolane (tetrahydrofuran).

[g] A second spectrum acquired in DMF-d_7 resolved a multiplet partially obscured in the original spectrum acquired in DMSO-d_6.

[h] Alleged and sold as 2C-C, a claim unsupported by the spectrum which strongly suggests 2C-E.

[i] Formulated as the free base.

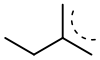
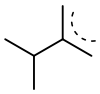
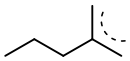
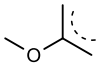
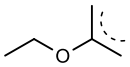
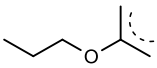
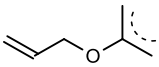
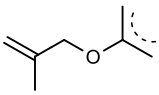
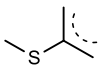
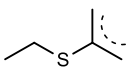
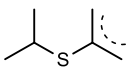
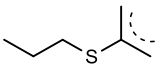
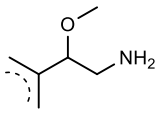
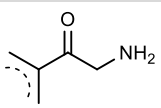
Table 3: Multiplets for phenylethanamine, *N*-benzyl phenylethanamine, and *N*-benzylidene phenylethanamine scaffold moieties

Analyte		NH_2^+ | NH_3^+ | 2′-O*H*	2-*H* | 3-*H* | 6-*H*		2-OCH_3 | 3-OCH_3 | 5-OCH_3 | 2′-OCH_3			α-H_2 | β-H_2		N*H* | NH_2
P0	PEA · HCl	8.29 (br s, 3H)	7.34 – 7.21 (m, 5H)					3.02 – 2.97 (m, 2H),	2.95 – 2.89 (m, 2H)	
P1	2C-H base		6.88 – 6.81 (m, 1H),	6.76 – 6.68 (m, 2H)	3.71 (s, 3H),	3.68 (s, 3H)		2.73 – 2.66 (m, 2H),	2.63 – 2.55 (m, 2H)	1.32 (vb s, 2H)
P1	2C-H · HCl	8.19 (br s, 3H)	6.94 – 6.87 (m, 1H),	6.82 – 6.76 (m, 2H)	3.74 (s, 3H),	3.69 (s, 3H)		2.98 – 2.91 (m, 2H),	2.88 – 2.81 (m, 2H)	
P2	2C-D	8.15 (br s, 3H)	6.82 (d, *J* = 0.8 Hz, 1H),	6.78 (s, 1H)	3.73 (s, 6H)			2.97 – 2.89 (m, 2H),	2.87 – 2.80 (m, 2H)	
P3	2C-E	8.02 (br s, 3H)	6.81 (s, 1H),	6.79 (s, 1H)	3.74 (s, 3H),	3.74 (s, 3H)		3.00 – 2.91 (m, 2H),	2.86 – 2.79 (m, 2H)	
P4	2C-P	8.04 (br s, 3H)	6.79 (s, 2H)		3.74 (s, 3H),	3.73 (s, 3H)		2.99 – 2.90 (m, 2H),	2.86 – 2.79 (m, 2H)	
P4	2C-P in DMF-d_7	8.64 (br s, 3H)	6.99 (s, 1H),	6.87 (s, 1H)	3.82 (s, 3H),	3.80 (s, 3H)		3.26 – 3.19 (m, 2H),	3.10 – 3.03 (m, 2H)	
P5	2C-IP	8.00 (br s, 3H)	6.81 (s, 1H),	6.79 (s, 1H)	3.76 (s, 3H),	3.74 (s, 3H)		2.99 – 2.92 (m, 2H),	2.85 – 2.78 (m, 2H)	
P6a	2C-E	8.03 (br s, 3H)	6.81 (s, 1H),	6.79 (s, 1H)	3.74 (s, 3H),	3.74 (s, 3H)		2.98 – 2.91 (m, 2H),	2.86 – 2.79 (m, 2H)	
P6b	2C-C	8.18 (br s, 3H)	7.07 (s, 1H),	7.05 (s, 1H)	3.80 (s, 3H),	3.76 (s, 3H)		3.00 – 2.93 (m, 2H),	2.90 – 2.83 (m, 2H)	
P7	2C-I	7.99 (br s, 3H)	7.33 (s, 1H),	6.90 (s, 1H)	3.77 (s, 3H),	3.76 (s, 3H)		3.00 – 2.93 (m, 2H),	2.87 – 2.80 (m, 2H)	
P8	2C-T	7.97 (br s, 3H)	6.83 (s, 1H),	6.76 (s, 1H)	3.80 (s, 3H),	3.76 (s, 3H)		2.98 – 2.91 (m, 2H),	2.86 – 2.79 (m, 2H)	
P9	2C-T-2	7.98 (br s, 3H)	6.85 (s, 1H),	6.83 (s, 1H)	3.78 (s, 3H),	3.76 (s, 3H)		3.01 – 2.92 (m, 2H),	2.86 – 2.79 (m, 2H)	
P10	2C-T-4	7.98 (br s, 3H)	6.91 (s, 1H),	6.87 (s, 1H)	3.77 (s, 3H),	3.76 (s, 3H)		3.01 – 2.93 (m, 2H),	2.87 – 2.80 (m, 2H)	
P11	2C-T-7	8.02 (br s, 3H)	6.85 (s, 1H),	6.82 (s, 1H)	3.77 (s, 3H),	3.76 (s, 3H)		2.99 – 2.92 (m, 2H),	2.86 – 2.79 (m, 2H)	
P12	Escaline	8.22 (br s, 3H)	6.56 (s, 2H)		3.75 (s, 6H)			3.06 – 2.99 (m, 2H),	2.89 – 2.81 (m, 2H)	
P13a	Proscaline	8.05 (br s, 3H)	6.56 (s, 2H)		3.76 (s, 6H)			3.07 – 3.00 (m, 2H),	2.85 – 2.78 (m, 2H)	
P13b	Proscaline	8.20 (br s, 3H)	6.56 (s, 2H)		3.75 (s, 6H)			3.06 – 2.98 (m, 2H),	2.89 – 2.80 (m, 2H)	
P14	AL	8.13 (br s, 3H)	6.57 (s, 2H)		3.76 (s, 6H)			3.06 – 2.99 (m, 2H),	2.87 – 2.80 (m, 2H)	
P15	MAL	8.03 (br s, 3H)	6.56 (s, 2H)		3.76 (s, 6H)			3.06 – 3.00 (m, 2H),	2.86 – 2.78 (m, 2H)	
P16	BOD	8.14 (br s, 3H)	6.91 (d, *J* = 0.9 Hz, 1H),	6.82 (s, 1H)	3.75 (s, 3H),	3.75 (s, 3H)		2.96 – 2.82 (m, 2H)		
P17	bk-2C-B	8.28 (br s, 3H)	7.59 (s, 1H),	7.43 (s, 1H)	3.94 (s, 3H),	3.86 (s, 3H)				
B1	25B-NBOMe	9.18 (br s, 2H)	7.19 (s, 1H),	7.02 (s, 1H)	3.83 (s, 3H),	3.79 (s, 3H),	3.75 (s, 3H)	3.10 – 3.03 (m, 2H),	3.00 – 2.93 (m, 2H)	
B2	25C-NBOMe	9.23 (br s, 2H)	7.08 (s, 1H),	7.04 (s, 1H)	3.83 (s, 3H),	3.80 (s, 3H),	3.74 (s, 3H)	3.10 – 3.01 (m, 2H),	3.03 – 2.94 (m, 2H)	
B3	25I-NBOMe	9.15 (br s, 2H)	7.32 (s, 1H),	6.90 (s, 1H)	3.83 (s, 3H),	3.77 (s, 3H),	3.73 (s, 2H)	3.09 – 3.00 (m, 2H),	2.99 – 2.92 (m, 2H)	
B4	25I-NBOH	9.22 (vb s, 3H)	7.32 (s, 1H),	6.89 (s, 1H)	3.77 (s, 3H),	3.74 (s, 3H)		3.09 – 3.02 (m, 2H),	3.00 – 2.91 (m, 2H)	
B5	25I-NBMD		7.25 (s, 1H),	6.84 (s, 1H)	3.73 (s, 3H),	3.71 (d, *J* = 0.3 Hz, 3H)		2.69 – 2.65 (m, 4H)		1.98 (br s, 1H)
B6	25D-NBOMe	9.18 (br s, 2H)	6.88 – 6.79 (m, 1H),	6.77 (s, 1H)	3.83 (s, 3H),	3.73 (s, 3H),	3.71 (s, 3H)	3.10 – 2.96 (m, 2H),	3.00 – 2.88 (m, 2H)	
B7	25E-NBOMe	9.20 (br s, 2H)	6.80 (s, 1H),	6.78 (s, 1H)	3.83 (s, 3H),	3.73 (s, 3H),	3.72 (s, 3H)	3.07 – 2.99 (m, 2H),	2.98 – 2.91 (m, 2H)	
B8	25IP-NBOMe	9.22 (br s, 2H)	6.80 (s, 1H),	6.79 (s, 1H)	3.83 (s, 3H),	3.73 (s, 3H),	3.73 (s, 3H)	3.07 – 2.99 (m, 2H),	2.98 – 2.91 (m, 2H)	
B9	25G-NBOMe	9.29 (br s, 2H)	6.66 (s, 1H)		3.84 (s, 3H),	3.73 (s, 3H),	3.58 (s, 3H)	3.11 – 3.02 (m, 2H),	3.05 – 2.95 (m, 2H)	
B10	M-NBOMe	9.33 (br s, 2H)	6.55 (s, 2H)		3.83 (s, 3H),	3.76 (s, 6H)		3.16 – 3.08 (m, 2H),	3.00 – 2.93 (m, 2H)	
IM1	25H-NBOMe imine		6.87 (d, *J* = 8.8 Hz, 1H), 6.72 (dd, *J* = 8.8, 3.1 Hz, 1H)	6.78 (d, *J* = 3.1 Hz, 1H)	3.82 (s, 3H),	3.74 (s, 3H),	3.65 (s, 3H)	3.75 – 3.68 (m, 2H),	2.84 (t, *J* = 7.5 Hz, 2H)	
IM2	25I- NBOMe imine		7.28 (s, 1H),	6.87 (s, 1H)	3.82 (s, 3H),	3.75 (s, 3H),	3.69 (s, 3H)	3.76 – 3.69 (m, 2H),	2.85 (t, *J* = 7.3 Hz, 2H)	

Table 4: Multiplets for *N*-benzyl phenylethanamine and *N*-benzylidene phenylethanamine scaffold moieties

Analyte		3′-*H* | 4′-*H* | 5′-*H* | 6′-*H*				2′-O-C*H*$_2$-O-3′	α′-*H*$_2$
B1	25B-NBOMe	7.49 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H),	7.08 (dd, *J* = 8.4, 1.0 Hz, 1H),	7.00 (td, *J* = 7.4, 1.1 Hz, 1H)		4.11 (s, 2H)
B2	25C-NBOMe	7.50 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.2, 7.4, 1.7 Hz, 1H),	7.14 – 7.05 (m, 1H),	7.00 (td, *J* = 7.5, 1.1 Hz, 1H)		4.11 (s, 2H)
B3	25I-NBOMe	7.48 (dd, *J* = 7.5, 1.8 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H),	7.08 (dd, *J* = 8.3, 1.0 Hz, 1H),	6.99 (td, *J* = 7.4, 1.1 Hz, 1H)		4.11 (s, 2H)
B4	25I-NBOH	7.39 (dd, *J* = 7.6, 1.7 Hz, 1H),	7.23 (ddd, *J* = 8.1, 7.3, 1.7 Hz, 1H),	6.97 (dd, *J* = 8.2, 1.1 Hz, 1H),	6.84 (td, *J* = 7.4, 1.1 Hz, 1H)		4.09 (s, 2H)
B5	25I-NBMD			6.86 – 6.78 (m, 1H),	6.81 – 6.72 (m, 2H)	5.96 (s, 2H)	3.66 (d, *J* = 0.6 Hz, 2H)
B6	25D-NBOMe	7.49 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H),	7.08 (dd, *J* = 8.3, 1.0 Hz, 1H),	7.00 (td, *J* = 7.5, 1.1 Hz, 1H)		4.11 (s, 2H)
B7	25E-NBOMe	7.49 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H),	7.09 (dd, *J* = 8.3, 1.0 Hz, 1H),	7.00 (td, *J* = 7.5, 1.0 Hz, 1H)		4.12 (s, 2H)
B8	25IP-NBOMe	7.50 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.4, 1.7 Hz, 1H),	7.08 (dd, *J* = 8.4, 1.0 Hz, 1H),	6.99 (td, *J* = 7.4, 1.0 Hz, 1H)		4.12 (s, 2H)
B9	25G-NBOMe	7.52 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.3, 7.5, 1.7 Hz, 1H),	7.09 (dd, *J* = 8.4, 1.0 Hz, 1H),	7.00 (td, *J* = 7.5, 1.0 Hz, 1H)		4.14 (s, 2H)
B10	M-NBOMe	7.53 (dd, *J* = 7.5, 1.7 Hz, 1H),	7.41 (ddd, *J* = 8.2, 7.4, 1.7 Hz, 1H),	7.08 (dd, *J* = 8.4, 1.0 Hz, 1H),	6.99 (td, *J* = 7.5, 1.0 Hz, 1H)		4.11 (s, 2H)
IM1	25H-NBOMe imine	7.82 (dd, *J* = 7.7, 1.8 Hz, 1H),	7.42 (ddd, *J* = 8.3, 7.3, 1.8 Hz, 1H),	7.08 (dd, *J* = 8.4, 1.0 Hz, 1H),	6.98 (tt, *J* = 7.5, 0.8 Hz, 1H)		
IM2	25I-NBOMe imine	7.82 (dd, *J* = 7.7, 1.8 Hz, 1H),	7.42 (ddd, *J* = 8.3, 7.3, 1.8 Hz, 1H),	7.08 (dd, *J* = 8.3, 1.0 Hz, 1H),	6.97 (tt, *J* = 7.5, 0.8 Hz, 1H)		

Table 5: Multiplets for phenyl 4-substituents, β-substituents, and other atypical moieties. Preferred IUPAC names precede · deprecated names.

4-methyl		C*H*$_3$ - Ph		C*H*$_3$ - Ph
	**P2**: 2C-D	2.13 (d, *J* = 0.7 Hz, 3H)	**B6**: 25D-NBOMe	2.13 (d, *J* = 0.7 Hz, 3H)
	P16: BOD	2.16 (d, *J* = 0.9 Hz, 3H)	**B9**: 25G-NBOMe	2.04 (s, 3H), 2.12 (s, 3H)
4-ethyl		C*H*$_3$ - CH$_2$ - Ph	CH$_3$ - C*H*$_2$ - Ph	
	**P3**: 2C-E	1.11 (t, *J* = 7.5 Hz, 3H)	2.54 (q, *J* = 7.5 Hz, 2H)	
	B7: 25E-NBOMe	1.11 (t, *J* = 7.5 Hz, 3H)	2.53 (q, *J* = 7.4 Hz, 2H)	
4-propan-2-yl · isopropyl		(C*H*$_3$)$_2$ - CH - Ph	(CH$_3$)$_2$ - C*H* - Ph	
	**P5**: 2C-IP	1.15 (d, *J* = 6.9 Hz, 6H)	3.21 (hept, *J* = 6.9 Hz, 1H)	
	B8: 25IP-NBOMe	1.15 (d, *J* = 6.9 Hz, 6H)	3.21 (hept, *J* = 6.9 Hz, 1H)	
4-propyl		C*H*$_3$ - CH$_2$ - CH$_2$ - Ph	CH$_3$ - C*H*$_2$ - CH$_2$ - Ph	CH$_3$ - CH$_2$ - C*H*$_2$ - Ph
	**P4**: 2C-P	0.89 (t, *J* = 7.4 Hz, 3H)	1.60 – 1.45 (m, 2H)	2.51 – 2.45 (m, 2H)
	P4: 2C-P in DMF-d_7	0.92 (t, *J* = 7.4 Hz, 3H)	1.63 – 1.52 (m, 2H)	2.59 – 2.52 (m, 2H)
4-methoxy		C*H*$_3$ - O - Ph		
	**B10**: M-NBOMe	3.62 (s, 3H)		
4-ethoxy		C*H*$_3$ - CH$_2$ - O - Ph	CH$_3$ - C*H*$_2$ - O - Ph	
	**P12**: Escaline	1.20 (t, *J* = 7.0 Hz, 3H)	3.85 (q, *J* = 7.0 Hz, 2H)	
4-propoxy		C*H*$_3$ - CH$_2$ - CH$_2$ - O - Ph	CH$_3$ - C*H*$_2$ - CH$_2$ - O - Ph	CH$_3$ - CH$_2$ - C*H*$_2$ - O - Ph
	**P13a**: Proscaline	0.94 (t, *J* = 7.4 Hz, 3H)	1.61 (h, *J* = 7.1 Hz, 2H)	3.79 – 3.72 (m, 2H) obs.
	P13b: Proscaline	0.93 (t, *J* = 7.4 Hz, 3H)	1.66 – 1.55 (m, 2H)	3.80 – 3.71 (m, 2H) obs.
4-(prop-2-en-1-yl)oxy · allyloxy		C*H*$_2$ = CH - CH$_2$ - O - Ph	CH$_2$ = C*H* - CH$_2$ - O - Ph	CH$_2$ = CH - C*H*$_2$ - O - Ph
	**P14**: AL	5.28 (dq, *J* = 17.3, 1.8 Hz, 1H) 5.17 – 5.10 (m, 1H)	5.98 (ddt, *J* = 17.3, 10.4, 5.6 Hz, 1H)	4.35 (dt, *J* = 5.6, 1.6 Hz, 2H)
4-(2-methylprop-2-en-1-yl)oxy · methallyloxy		C*H*$_2$ = C (CH$_3$) - CH$_2$ - O - Ph	CH$_2$ = C (C*H*$_3$) - CH$_2$ - O - Ph	C*H*$_2$ = C (CH$_3$) - C*H*$_2$ - O - Ph
	**P15**: MAL	5.02 – 4.97 (m, 1H) 4.89 – 4.83 (m, 1H)	1.81 – 1.76 (m, 3H)	4.27 – 4.22 (m, 2H)
4-methylsulfanyl · methylthio		C*H*$_3$ - S - Ph		
	**P8**: 2C-T	2.41 (s, 3H)		
4-ethylsulfanyl · ethylthio		C*H*$_3$ - CH$_2$ - S - Ph	CH$_3$ - C*H*$_2$ - S - Ph	
	**P9**: 2C-T-2	1.23 (t, *J* = 7.3 Hz, 3H)	2.92 (q, *J* = 7.3 Hz, 2H)	
4-(propan-2-yl)sulfanyl · isopropylthio		(C*H*$_3$)$_2$ - CH - S - Ph	(CH$_3$)$_2$ - C*H* - S - Ph	
	**P10**: 2C-T-4	1.21 (d, *J* = 6.6 Hz, 6H)	3.54 (hept, *J* = 6.6 Hz, 1H)	
4-propylsulfanyl · propylthio		C*H*$_3$ - CH$_2$ - CH$_2$ - S - Ph	CH$_3$ - C*H*$_2$ - CH$_2$ - S - Ph	CH$_3$ - CH$_2$ - C*H*$_2$ - S - Ph
	**P11**: 2C-T-7	0.98 (t, *J* = 7.3 Hz, 3H)	1.58 (h, *J* = 7.3 Hz, 2H)	2.88 (t, *J* = 7.1 Hz, 2H)
β-methoxy		β - *H*	β - O - C*H*$_3$	α - *H*$_2$
	**P16**: BOD	4.78 (dd, *J* = 8.9, 3.9 Hz, 1H)	3.21 (s, 3H)	2.96 – 2.82 (m, 2H)
β-oxo · keto		α - *H*$_2$		
	**P17**: bk-2C-B	4.31 (q, *J* = 5.2 Hz, 2H)		

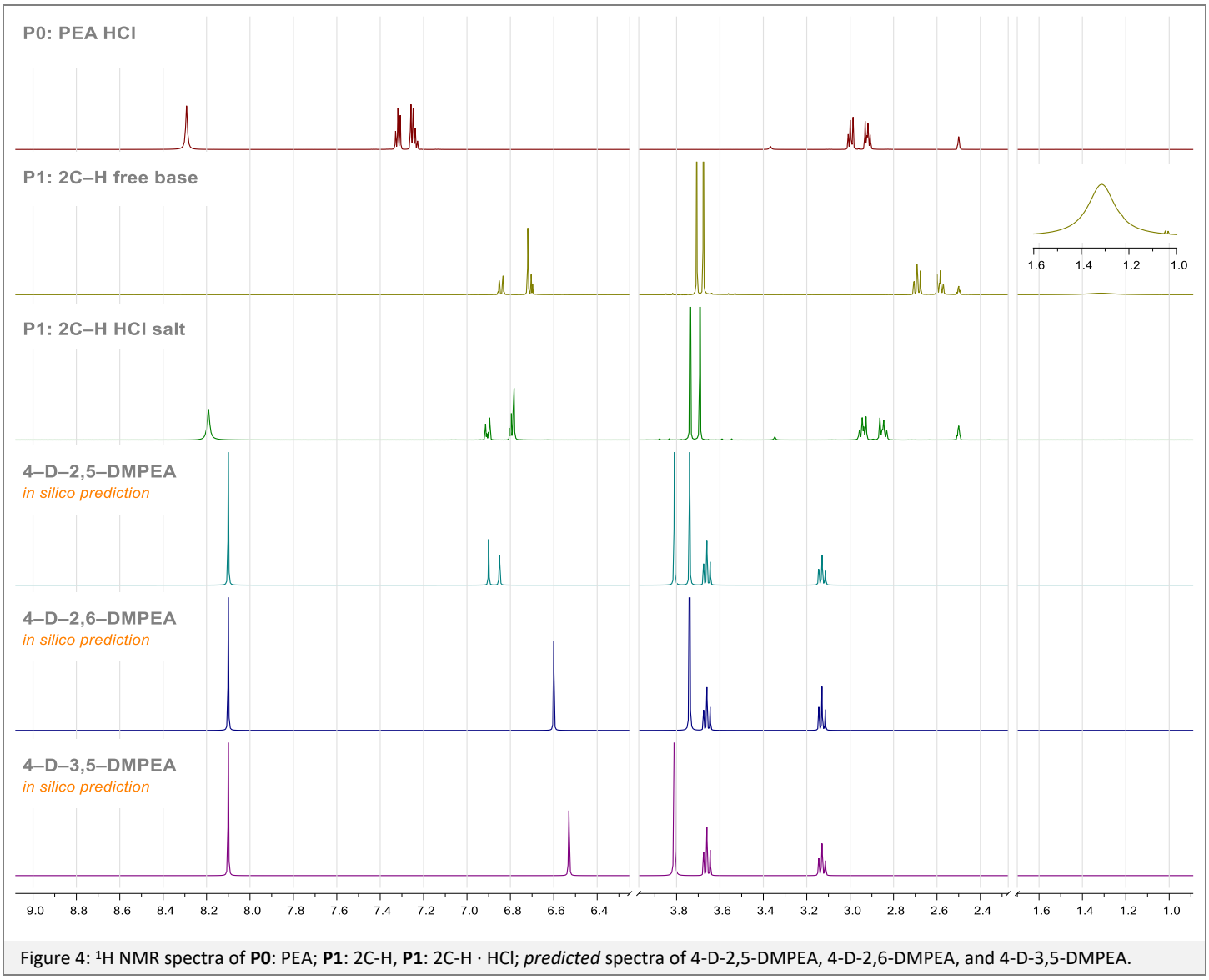


Figure 4: ^{1}H NMR spectra of **P0**: PEA; **P1**: 2C-H, **P1**: 2C-H · HCl; *predicted* spectra of 4-D-2,5-DMPEA, 4-D-2,6-DMPEA, and 4-D-3,5-DMPEA.

Analysis

Almost all of the analytes appear to be formulated as simple aminium salts e.g. a hydrochloride, facilitating comparison. The protonated aminium resonance typically appears as a broad singlet, near or downfield of 8 ppm in primary amines; 9.15 ppm in secondary amines. The unprotonated amine group found in the two free base analytes resonates as a very broad singlet upfield of 2 ppm (cf. **P1**: 2C-H · HCl vs. 2C-H in Figure 4). The quintet at 2.50 ppm is characteristic of trace amounts of the partially deuterated solvent DMSO-d_5.

The phenyl ring substitution patterns most often encountered are the 2,5- and 3,5-dimethoxy with *para*-substitution. Though purported TMA-6 [1] has occasionally been seen, the 2,6-dimethoxy pattern appears largely absent from the grey market.

A 4-substituted 2,5-dimethoxy spectrum typically exhibits a discrete 3H singlet for each methoxy substituent and a discrete 1H singlet for each unsubstituted aryl hydrogen. The methoxy groups are not magnetically equivalent, nor are the aryl hydrogens, and each may resonate at a discrete shift. In some cases, these singlet resonances may overlap or appear isochronous, which has particularly been reported in the earlier literature.

In a 4-substituted 3,5- or 2,6-dimethoxy spectrum, both methoxy substituents are magnetically equivalent by symmetry, as are both aryl hydrogens. The methoxy groups appear as a single 6H singlet, the aryl hydrogen as a 2H singlet. Figure 4 shows *predicted* spectra for 2-(4-deuterophenyl)ethan-1-amine with 2,5-, 3,5-, and 2,6-dimethoxy substitution. The 4-deutero substituent functions as a placeholder keeping the simulation free of spurious peaks arising from *ortho*- and *meta*-coupling of the aryl hydrogen.

[1] TMA-6: 1-(2,4,6-trimethoxyphenyl)propan-2-amine.

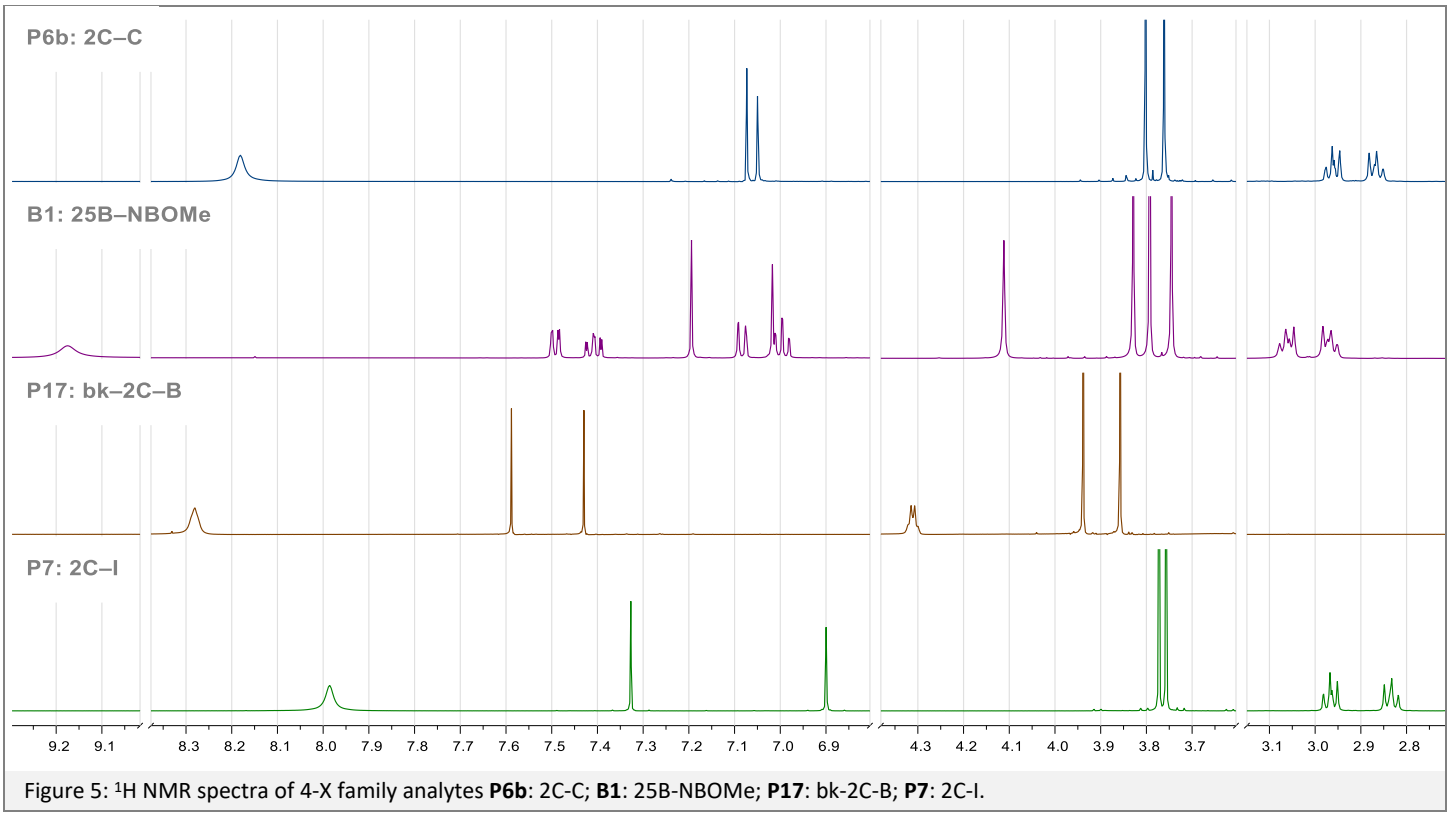


Figure 5: ^{1}H NMR spectra of 4-X family analytes **P6b**: 2C-C; **B1**: 25B-NBOMe; **P17**: bk-2C-B; **P7**: 2C-I.

^{1}H NMR spectra have been reported for 2C-H in DMSO-d_6,[29] in $CDCl_3$,[15,30] and in D_2O;[31–33] and for the NBOMe analogue 25H-NBOMe[1] in DMSO-d_6.[29] Shaler and Padden have compared ^{1}H NMR spectra of the base and the hydrobromide salt of the α-methylated homologue[2] in $CDCl_3$.[34] ^{1}H NMR spectra have been reported for the *N*,α-dimethyl homologues (i.e. the methamphetamine analogues) of 13 mono-, di-, and tri-methoxyphenylethanamines in $CDCl_3$.[35]

The 4-X family: 4-halo-2,5-dimethoxyphenyl pattern

Members of the 4-X family share a 4-halo-2,5-dimethoxyphenyl substitution pattern, with a bromo, chloro or iodo *para*-substituent. Shulgin reported the 4-fluoro analogue[3] largely inactive even at 250 mg, an order of magnitude less potent than of the other three.[3] Alleged 2C-F has been advertised on the grey market lately. None has been obtained and its actual composition is unknown.

Regulatory hurdles precluded obtaining the controlled 4-bromo analogue, 2C-B.[36] However, the 2C-B ring substitution pattern is present in other, more recent arrivals to the grey market. Samples alleged to be 25B-NBOMe and bk-2C-B, uncontrolled analogues of 2C-B, were purchased instead.

The 4-X spectra in Figures 5 and 6 show a clear correlation between the 4-halo substituent and the shift of the two phenyl hydrogen. Table 6 compares our findings (shaded rows) with reported data acquired in DMSO-d_6. The consistency of the shift separation (Δδ) suggests a facile method for differentiating the 4-halo substituent of 4-X family compounds.

Table 6: Phenyl peak shift separation in ppm for 4-X family compounds

	Compound	Source	← δ	δ →	Δ δ
Chloro	2C-C	**P6b**	7.07	7.05	0.02
	25C-NBOMe	**B2**	7.08	7.04	0.04
	25C-NBOMe	Hansen et al.[37: 3a]	7.08	7.04	0.04
Bromo	2C-B	Martins [29: 8]	7.21	7.00	0.21
	bk-2C-B	**P17**	7.59	7.43	0.16
	bk-2C-B	Power et al.[38: 3]	7.60	7.44	0.16
	DOB	Heim [15: 35]	7.21	7.04	0.17
	DOB	Martins [29: 9]	7.20	7.01	0.19
	25B-NBOMe	**B1**	7.19	7.02	0.17
	25B-NBOMe	Hansen et al.[37: 2a]	7.17	7.01	0.16
Iodo	2C-I	**P7**	7.33	6.90	0.43
	25I-NBOMe	**B3**	7.32	6.90	0.42
	25I-NBOMe	Hansen et al.[37: 1a]	7.32	6.91	0.41
	25I-NBOH	**B4**	7.32	6.89	0.43
	25I-NBOH	Hansen et al.[37: 1b]	7.30	6.88	0.42
	25I-NBOH	Heim [15: 235]	7.32	6.90	0.42
	25I-NBMD	**B5**	7.25	6.84	0.41
	25I-NBMD	Hansen et al.[37: 1d]	7.30	6.88	0.42
	DOI	Heim [15: 36]	7.34	6.91	0.43
	25I-NBOMe imine	**IM2**	7.28	6.87	0.41

[1] 25H-NBOMe: 2-(2,5-dimethoxyphenyl)-*N*-[(2-methoxyphenyl)methyl]ethan-1-amine.
[2] 2,5-DMA: 1-(2,5-dimethoxyphenyl)propan-2-amine. The ambiguous code DMA may refer to 2,5-DMA or 3,4-DMA.
[3] 2C-F: 2-(4-fluoro-2,5-dimethoxyphenyl)ethan-1-amine.

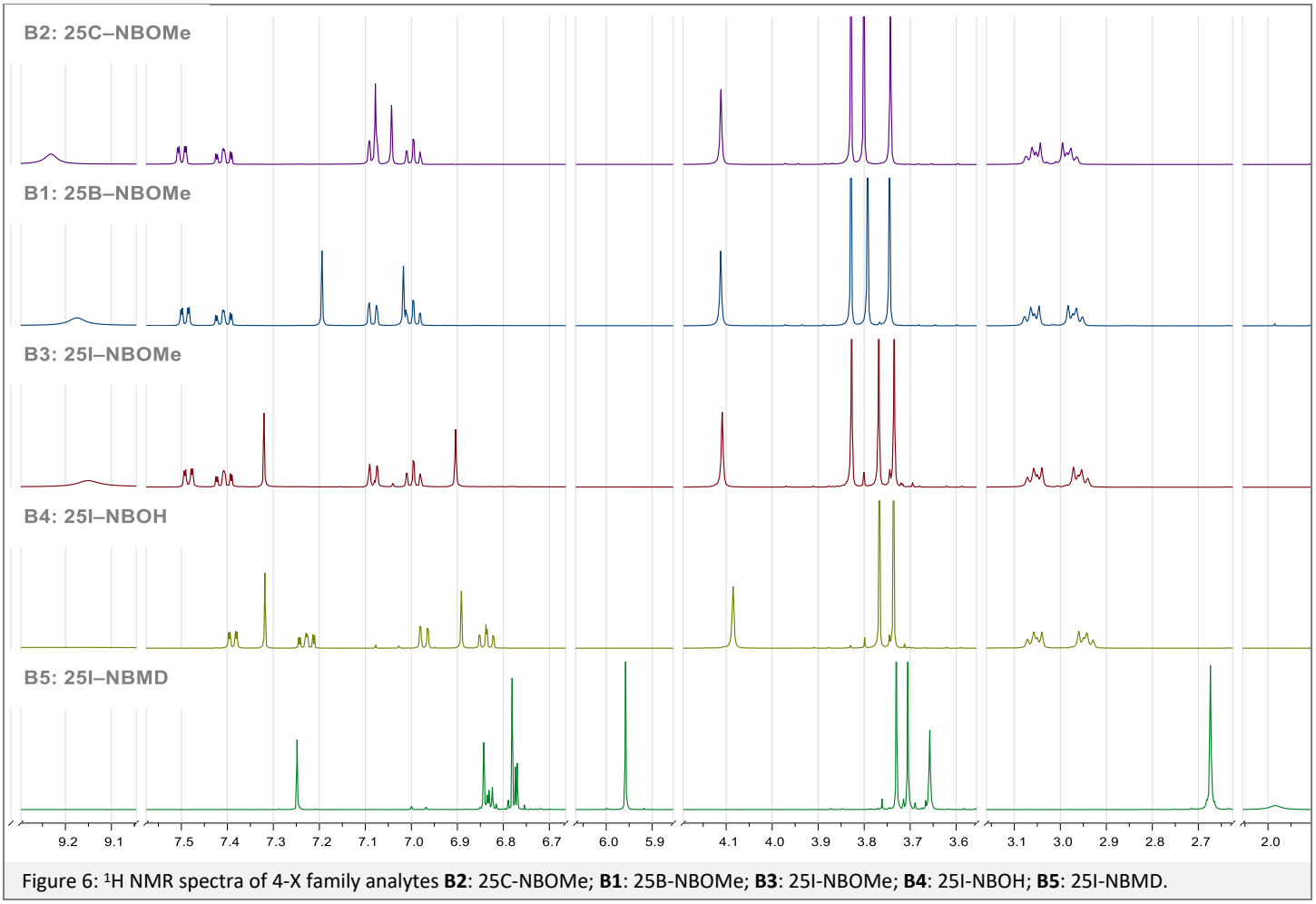


Figure 6: ^{1}H NMR spectra of 4-X family analytes **B2**: 25C-NBOMe; **B1**: 25B-NBOMe; **B3**: 25I-NBOMe; **B4**: 25I-NBOH; **B5**: 25I-NBMD.

P17: bk-2C-B is the only β-oxo[1] phenylethanamine we have seen and our only analyte of this kind. In contrast, a plethora of grey-market β-oxo-phenylpropamines and higher homologues ("cathinones") are on offer, typically as secondary or cyclic amines.

The effects of the β-oxo group is readily seen in Figure 5. The highly conserved pair of 2H α- and β-multiplets seen in the other three spectra are replaced by a 2H pseudo-quartet from the α methylene protons, while the 3H aminium peak shows a trace of triplet symmetry. This suggests possible coupling, as reported in an unattributed analysis of ^{1}H, ^{13}C, and 2-D spectra.[39] A similar pseudo-quartet appears in the supplementary data of the analysis by Power et al.[38] The aryl methoxy peaks are shifted noticeably downfield and the aryl hydrogen peaks even more so though their separation is not appreciably effected (see Table 6).

^{1}H NMR spectra of two additional analogues of 25I-NBOMe are shown in Figure 6. The NBOMe moiety is replaced by a 2-hydroxybenzyl group (NBOH) in analyte **B4**: 25I-NBOH, and by 2*H*-(1,3-benzodioxol-4-yl)methyl group (NBMD) in analyte **B5**: 25I-NBMD.[2]

Comparing the **B3**: 25I-NBOMe and **B4**: 25I-NBOH spectra, in the latter only two 3H singlet methoxy peaks are present, reflecting the loss of the benzyl methoxy group; the characteristic multiplet pattern of the four benzyl protons is shifted upfield about 0.13 ppm on average; and in place of a broad 2H aminium peak at 9.15 ppm we found a very broad 3H peak spanning ca. 2 ppm at 9.22 ppm (not discernable in Figure 6; see Table 3). This signal may result from intramolecular hydrogen bonding and proton exchange between the phenolic *ortho*-hydroxyl group of the NBOH moiety and the protonated amine, perhaps facilitated by the hydrogen-bond accepting solvent. However, both Heim[15] and Hansen[16,37] report a discrete and sharp phenolic peak in DMSO-d_6.

The spectrum of analyte **B5**: 25I-NBMD is markedly different from its NBOMe and NBOH analogues. It appears to be the only *N*-benzyl analyte formulated as the free amine rather than an aminium salt, consistent with the presence of a 1H upfield peak

[1] Though the prefix *bk-* for *beta-* or β-*keto* is widely used, *oxo* is now the preferred IUPAC prefix and *keto* is deprecated.

[2] *NBMD* stems from *N-BenzylMethyleneDioxy*. IUPAC has ruled *methylenedioxy* unacceptably ambiguous (is it –OCH_2O– or –CH_2OO– ?) and deprecated.

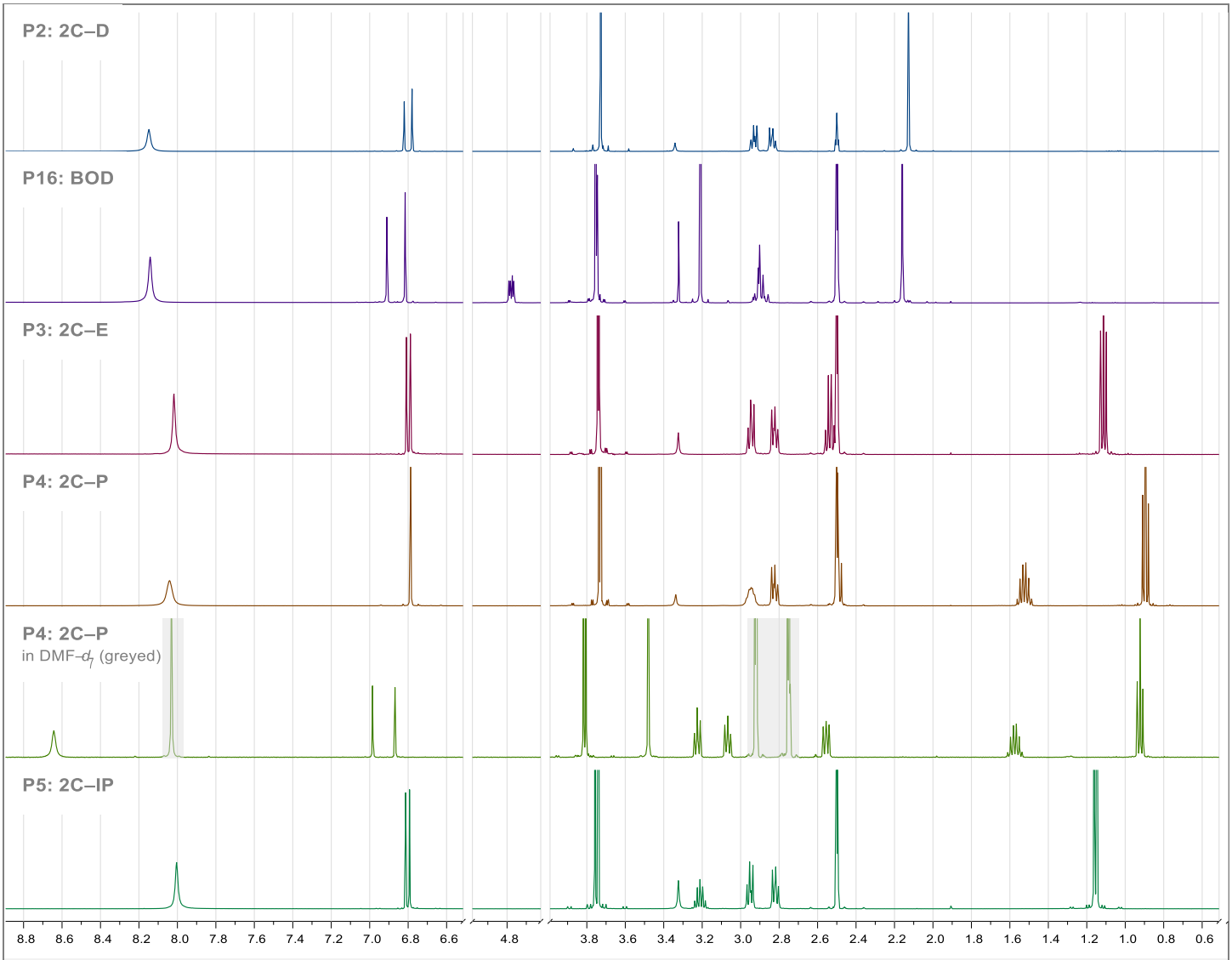


Figure 7: ^{1}H NMR spectra of 4-R family analytes **P2**: 2C-D; **P16**: BOD; **P3**: 2C-E; **P4**: 2C-P; **P4**: 2C-P in DMF-d7; **P5**: 2C-IP.

at 1.98 ppm, the absence of any 2H downfield peak, and the substantial upfield shift of the entire spectrum (cf. **P1** as the free base vs. the hydrochloride salt in Figure 4). Also, the α- and β-methylene groups have coalesced into a 4H multiplet, the familiar splitting pattern of the NBOMe/NBOH benzyl protons is absent, and a 2H singlet from the benzodioxole methylene group is seen at 5.96 ppm.

^{1}H NMR spectra have been reported for 2C-B in DMSO-d_6,[29] in $CDCl_3$,[15,40] in CD_3OD,[41–43] and in D_2O[31,32,42,44]; for 2C-C in $CDCl_3$ [45,46] and in D_2O[31,46]; for 2C-I in $CDCl_3$[43] and in D_2O[31,32,47,48]; for bk-2C-B in DMSO-d_6[38,39] and in $CDCl_3$.[49]

^{1}H NMR spectra have been reported for 25B-NBOMe in DMSO-d_6[16,37] and in $CDCl_3$[15,50]; for 25C-NBOMe in DMSO-d_6,[37] in $CDCl_3$,[51] and in CD_3OD[16,52]; for 25I-NBOMe in DMSO-d_6,[16,37,53] in $CDCl_3$,[15,54–56] and in CD_3OD[57]; for 25I-NBOH in DMSO-d_6[15,16,37]; for 25I-NBMD in DMSO-d_6.[16,37]

The 4-R family: 4-alkyl-2,5-dimethoxyphenyl pattern

Five primary amine analytes (Figure 7) and four secondary amine analytes (Figure 8) share the 4-alkyl-2,5-dimethoxyphenyl pattern where the 4-alkyl substituent is methyl (**P2**: 2C-D, **P16**: BOD, **B6**: 25D-NBOMe), ethyl (**P3**: 2C-E, **B7**: 25E-NBOMe), propyl (**P4**: 2C-P), or isopropyl (**P5**: 2C-IP, **B8**: 25IP-NBOMe). Analyte **B9**: 25G-NBOMe is the 3,4-dimethyl homologue of **B6**. Fortunately, the 4-alkyl substitution introduces additional peaks while leaving the core (**P1**: 2C-H) spectrum essentially undisturbed, simplifying analysis.

In analyte **P2**: 2C-D the line broadening of the 4-methyl peak (apparent 3H singlet at 2.13 ppm arises from long range coupling to the *ortho*-hydrogen at ring position 3, which shows similar line broadening. Analogous coupling is seen in the β-methoxy analogue **P16**: BOD, and the NBOMe analogue **B6**: NBOMe. The coupling constants are consistent with the published value of 0.7 Hz.[58]

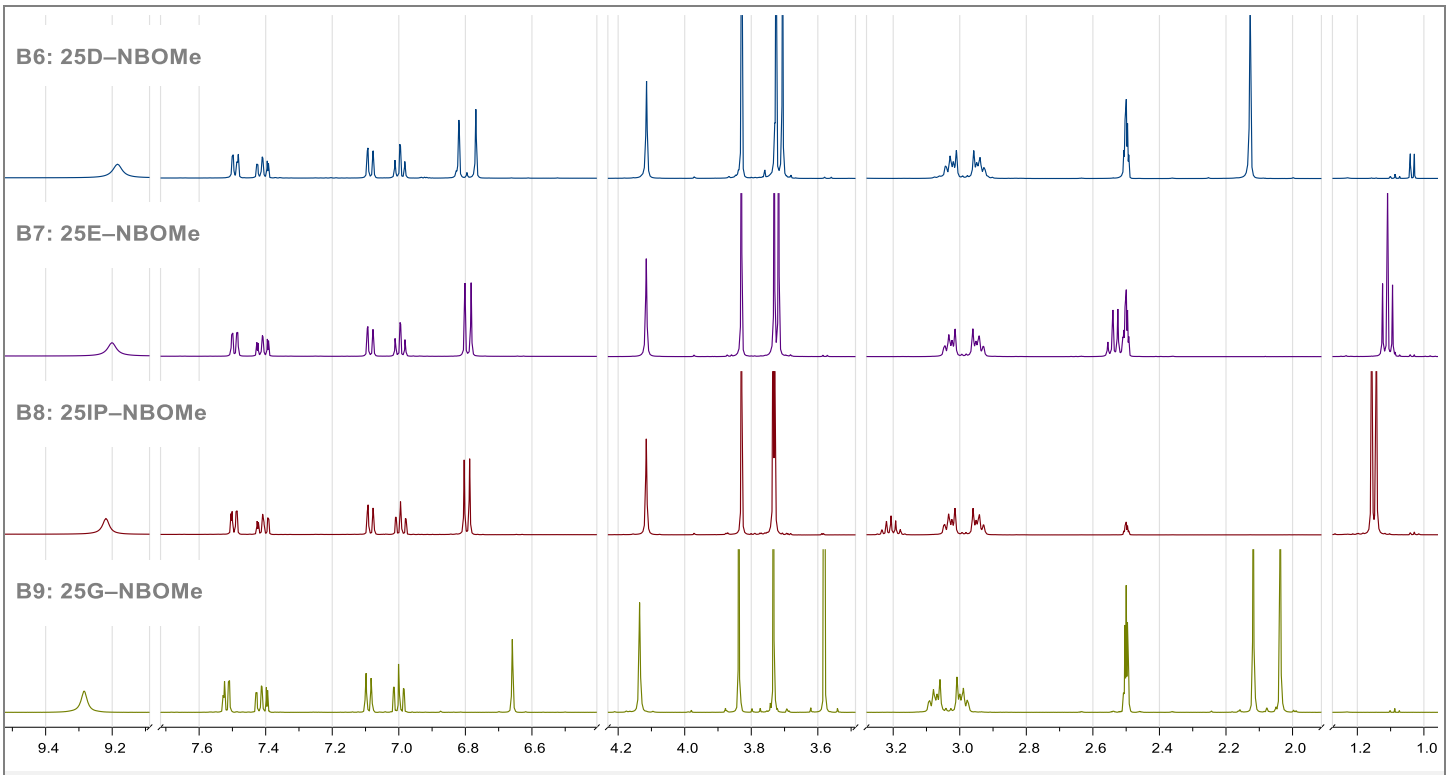


Figure 8: ^{1}H NMR spectra of **B6**: 25D-NBOMe; **B7**: 25E-NBOMe; **B8**: 25IP-NBOMe; **B9**: 25G-NBOMe.

In the **P3**: 2C-E spectrum, the classical ethyl group splitting pattern is seen: a 2H quartet and 3H triplet. Similarly, the isopropyl group of **P5**: 2C-IP is readily identified by the characteristic methine proton 1H heptet signal and the 6H doublet signal from the adjacent, isochronous methyl groups.

The DMSO-d_6 solvent signal at 2.50 ppm hinders interpretation of the **P4**: 2C-P spectrum by obscuring the expected 2H triplet of the propyl group while the corresponding 2H multiplet and 3H triplet are clearly present. A second spectrum, acquired in deuterated *N,N*-dimethylformamide (DMF-d_7), allows for an unobstructed view of the propyl multiplet.

Interestingly, though the 3H triplet of the terminal methyl moiety appears typical, much like the corresponding peak seen in **P3**: 2C-E, the splitting pattern of the methylene protons is more complex. The methylene group alpha to the ring does not split as a simple first-order triplet, nor does the methylene group beta to the ring split as a first-order hextet. The same divergence from simple first-order splitting is seen in the other propyl-substituted analytes.

^{1}H NMR spectra have been reported for 2C-D in $CDCl_3$; for the regioisomer iso-2C-D[1] in $CDCl_3$ and in CD_3OD[59]; for 2C-E in DMSO-d_6[60] and in D_2O[61]; for 2C-P in D_2O[48]; for BOD in $CDCl_3$[62] and in D_2O.[63] We have not found ^{1}H NMR spectra reported for 2C-IP or 25IP-NBOMe.

^{1}H NMR spectra have been reported for 25D-NBOMe in DMSO-d_6[16,37,64]; for 25E-NBOMe in DMSO-d_6[16,37,64] and in $CDCl_3$[65]; for 25G-NBOMe in DMSO-d_6.[64]

[1] iso-2C-D: 2-(2,4-dimethoxy-3-methylphenyl)ethan-1-amine.

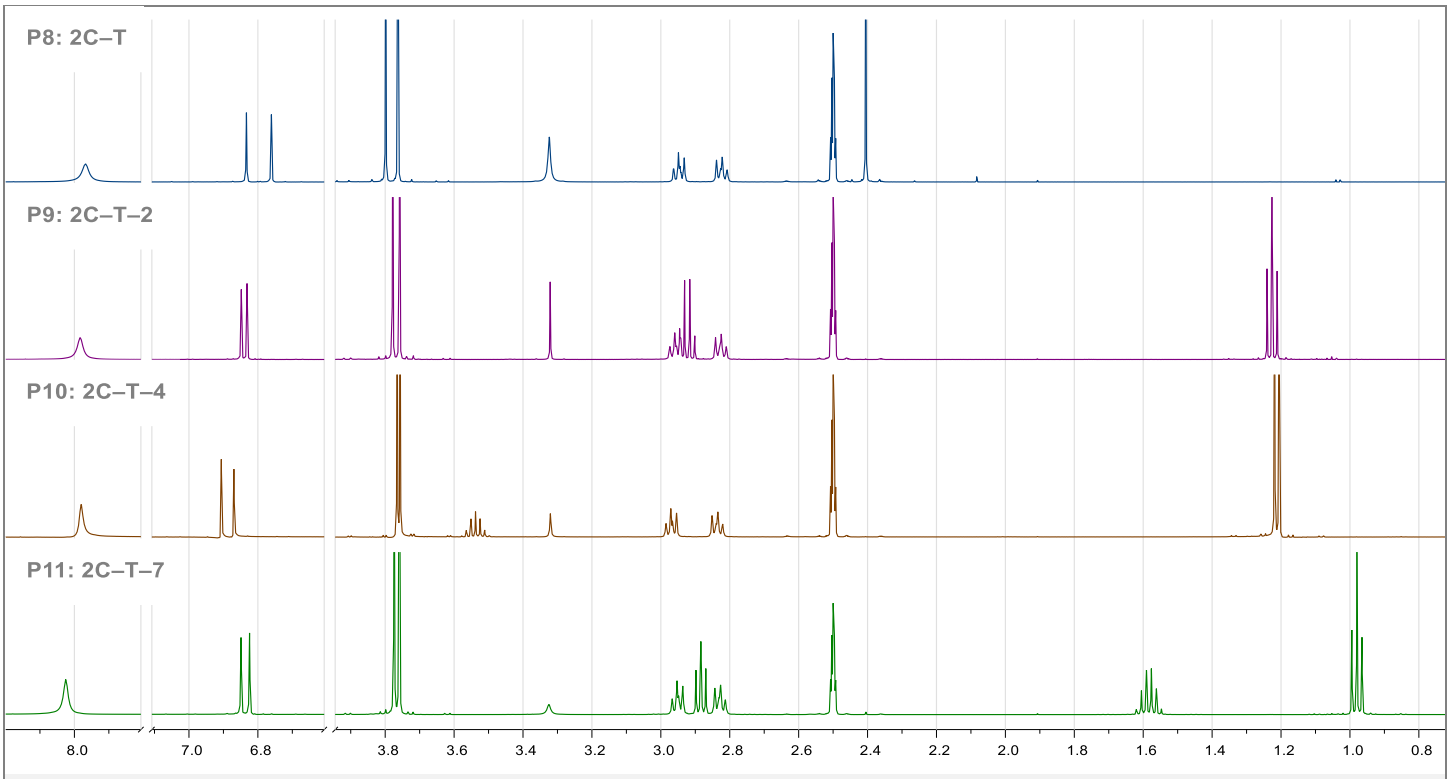


Figure 9: ^{1}H NMR spectra of 4-RS family analytes **P8**: 2C-T; **P9**: 2C-T-2; **P10**: 2C-T-4; **P11**: 2C-T-7.

The 4-RS family: 4-alkylsulfanyl-2,5-dimethoxyphenyl pattern

The 4-RS family analytes (Figure 9) are sulfide[1] analogues of 4-R family compounds, the result of interposing a sulfur atom between the phenyl ring and 4-alkyl substituent. Four of the analytes are members of this family, each a primary amine, where the alkyl substituent is methylsulfanyl (**P8**: 2C-T), ethylsulfanyl (**P9**: 2C-T-2) isopropylsulfanyl (**P10**: 2C-T-4), or propylsulfanyl (**P11**: 2C-T-7).

The splitting pattern arising from a particular alkyl substituent is the same in either family, e.g. 4-ethyl and 4-ethylsulfanyl. However, the alkyl-peak shifts of the 4-RS compounds are further downfield.

We have not seen the corresponding *ether* analogous on the grey market, the 4-alkoxy-2,5-dimethoxyphenylethanamine series. They have received scant mention in the literature — Shulgin includes only one in *PiHKAL*,[3] an unenthusiastic account of 2C-O-4.[2]

Cheng and Castagnoli report shifts between 3.97 and 3.78 ppm for the three methoxy substituents of 2C-O,[3] the 4-oxy analogue of 2C-T, a substantial and indicative downfield shift.[66]

^{1}H NMR spectra have been reported for 2C-T-2 in $CDCl_3$,[67] in CD_3OD,[43] and in D_2O[48,68]; for 2C-T-4 in $CDCl_3$,[69] and in D_2O[48]; for 2C-T-7 in $CDCl_3$,[69] in CD_3OD,[43] and in D_2O.[48,70]

We have not found ^{1}H NMR spectra reported for 2C-T. The ^{1}H NMR spectrum *has* been reported for the α-methyl homologue[4] of 2C-T in D_2O,[48] and for the α-methyl, α-ethyl, and *N*-methyl homologues of the 2C-T series (and the Ψ-2C-T series[5]) in D_2O.[71] Trachsel has synthesized additional members of the 2C-T series and has reported their spectra in D_2O.[72]

[1] Formerly *thioether*.
[2] 2C-O-4: 2-[2,5-dimethoxy-4-(propan-2-yloxy)phenyl]ethan-1-amine.
[3] 2C-O or 2,4,5-TMPEA: 2-(2,4,5-trimethoxyphenyl)ethan-1-amine.
[4] ALEPH or DOT: 1-[2,5-dimethoxy-4-(methylsulfanyl)phenyl]propan-2-amine.
[5] Alexander T. Shulgin introduced the prefix Ψ (Psi) as a notation for the 2,4,6-regioisomer of the corresponding 2,4,5-substituted compound.

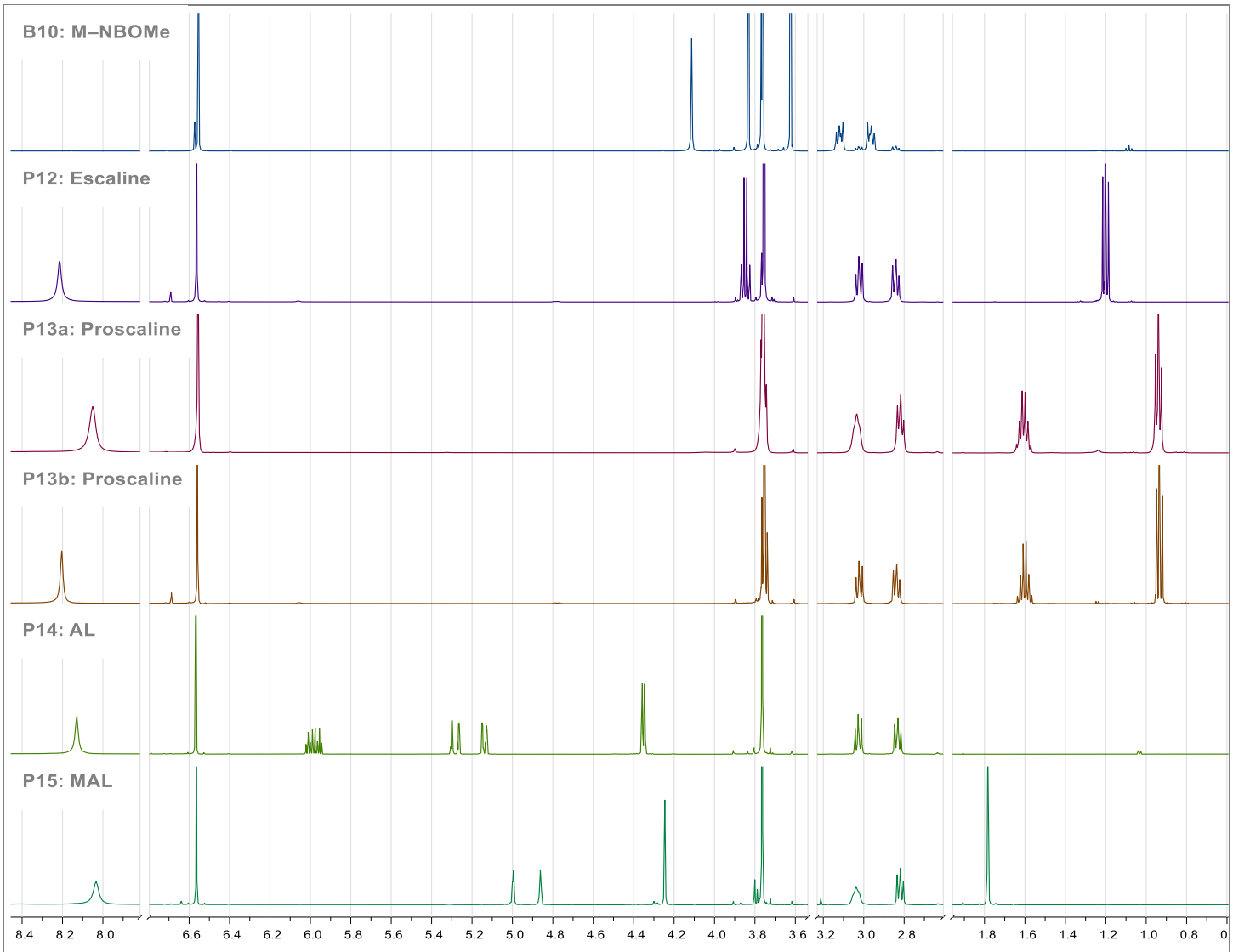


Figure 10: ^{1}H NMR spectra of 4-RO family analytes **B10**: M-NBOMe; **P12**: Escaline; **P13a, P13b:** Proscaline; **P14**: AL; **P15**: MAL.

The 4-RO family: 4-alk[en]yloxy-3,5-dimethoxyphenyl pattern

Turning from the 2,5- to the 3,5-dimethoxy substitution pattern, the 4-RO family compounds are analogues of the natural product mescaline,[1] sometimes called "scalines."[73] Being a controlled substance in Canada, we were unable to include mescaline among our analytes. However, the NBOMe analogue of mescaline is not controlled and was obtained instead.

Six of the analytes belong to the 4-RO family, having a *para*-substituent of methoxy (**B10**: M-NBOMe), ethoxy (**P12**: Escaline), propoxy (**P13a, P13b:** Proscaline), allyloxy (**P14**: AL), and methallyloxy (**P15**: MAL).[2]

As noted previously, the symmetrical ring substitution of the 4-RO compounds is evident from the 6H methoxy and 2H aryl proton peaks ca. 3.75 and 6.56 ppm, respectively. Here, as with the 4-R family, *para*-substitution leaves the spectrum otherwise undisturbed.

^{1}H NMR spectra have been reported for mescaline in DMSO-d_6[29,74] and in $CDCl_3$[75–77]; for proscaline in DMSO-d_6.[53] We have not found ^{1}H NMR spectra reported for M-NBOMe, escaline, AL, or MAL. ^{1}H NMR spectra have been reported for the α-methyl homologues of proscaline,[3] AL,[4] and MAL[5] in D_2O.[78] ^{1}H NMR spectra have been reported for TMA,[6] the α-

[1] Mescaline or M: 2-(3,4,5-trimethoxyphenyl)ethan-1-amine.

[2] While *allyloxy* remains acceptable *in general*, prop-2-en-1-yloxy is the PIN. However, *methallyloxy* and *methylallyloxy* are deprecated; (2-methylprop-2-en-1-yl)oxy is the PIN. We've opted for brevity over dogma in this case.

[3] 3C-P: 1-(3,5-dimethoxy-4-propoxyphenyl)propan-2-amine.

[4] 3C-AL: 1-[3,5-dimethoxy-4-(prop-2-en-1-yloxy)phenyl]propan-2-amine.

[5] 3C-MAL: 1-{3,5-dimethoxy-4-[(2-methylprop-2-en-1-yl)oxy]phenyl}propan-2-amine.

[6] TMA: 1-(3,4,5-trimethoxyphenyl)propan-2-amine.

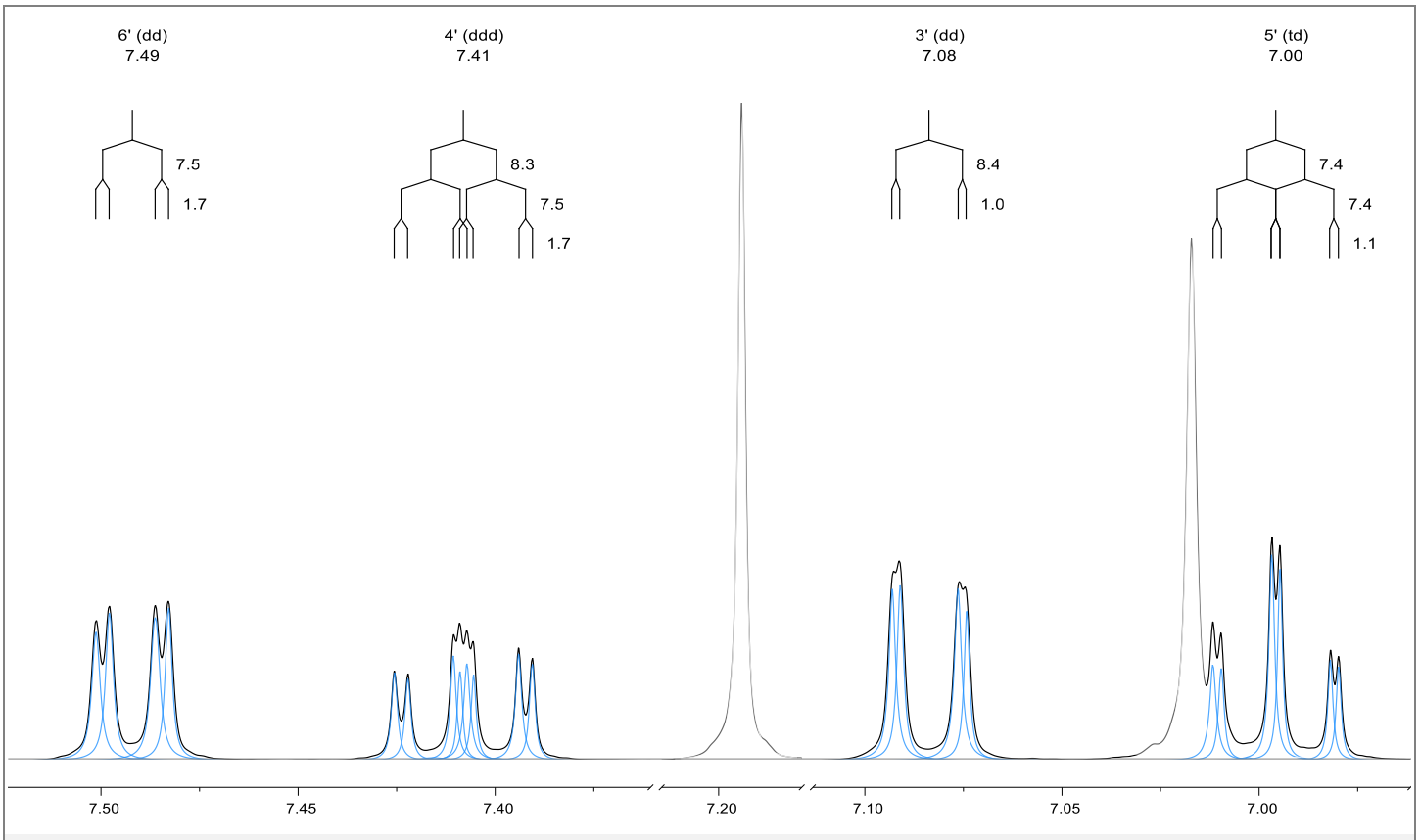


Figure 11: The aryl-proton region of **B1**: 25B-NBOMe displays the characteristic splitting pattern (with *J*-tree) seen in NBOMe and NBOH spectra. Phenyl proton singlets are in grey, benzyl proton multiplets are in black, and deconvoluted component peaks are in blue.

methyl homologue of mescaline, and for TMA-2[1] and TMA-6,[2] two regioisomers of interest, in CD_3OD.[79]

Recently, a regioisomer of mescaline, isomescaline,[3] was prepared and the ^{1}H NMR spectrum in DMSO-d_6 reported by Martins.[30] Reportedly without activity, it seems an unlikely candidate for the grey market.[3]

The NBOMe and NBOH splitting pattern

The *N*-benzyl protons of the NBOMe and NBOH analytes resonate with a distinctive splitting pattern and at highly consistent shifts of 7.5–7.0 ppm (see Table 4). The NBOMe splitting pattern is consistent with a largely first-order ABCD spin system having six coupling constants: three ortho ($^3J_{3'4'}$, $^3J_{4'5'}$, $^3J_{5'6'}$ ≈ 8.0 Hz), two meta ($^4J_{3'5'}$, $^4J_{4'6'}$ ≈ 2.5 Hz), and one para ($^5J_{3'6'}$ ≈ 0). The aryl region of the **B1**: 25B-NBOMe spectrum and the first-order *J*-tree analysis is shown in Figure 11.

Each of the *outer* two protons (3′ and 6′) is *ortho*- and *meta*-coupled to the *inner* protons (4′ and 5′) and appears as a doublet of doublets (dd). The two inner protons are also *ortho*-coupled to each other, producing a further split into a doublet of doublet of doublets (ddd). Because the *ortho*-coupling constants are quite close — less than 1 Hz apart — a ddd coupling may appear as a triplet of doublets (td). There is no apparent *para*-coupling between the outer protons.

Interestingly, both the shifts and the *ordering* of the benzyl peaks may depend on the solvent. Published NBOMe spectra acquired in DMSO-d_6 align quite closely with our own and retain the 6′, 4′, 3′, 5′ multiplet sequence.[37 supp. data] In contrast, for a spectrum of 25C-NBOMe acquired in $CDCl_3$ the overall splitting pattern is preserved but the ordering is not, becoming 6′, 4′, 5′, 3′.[51] Multiplets 3′ and 5′ have traded places.

[1] TMA-2: 1-(2,4,5-trimethoxyphenyl)propan-2-amine.
[2] TMA-6: 1-(2,4,6-trimethoxyphenyl)propan-2-amine.
[3] Isomescaline or IM: 2-(2,3,4-trimethoxyphenyl)ethan-1-amine.

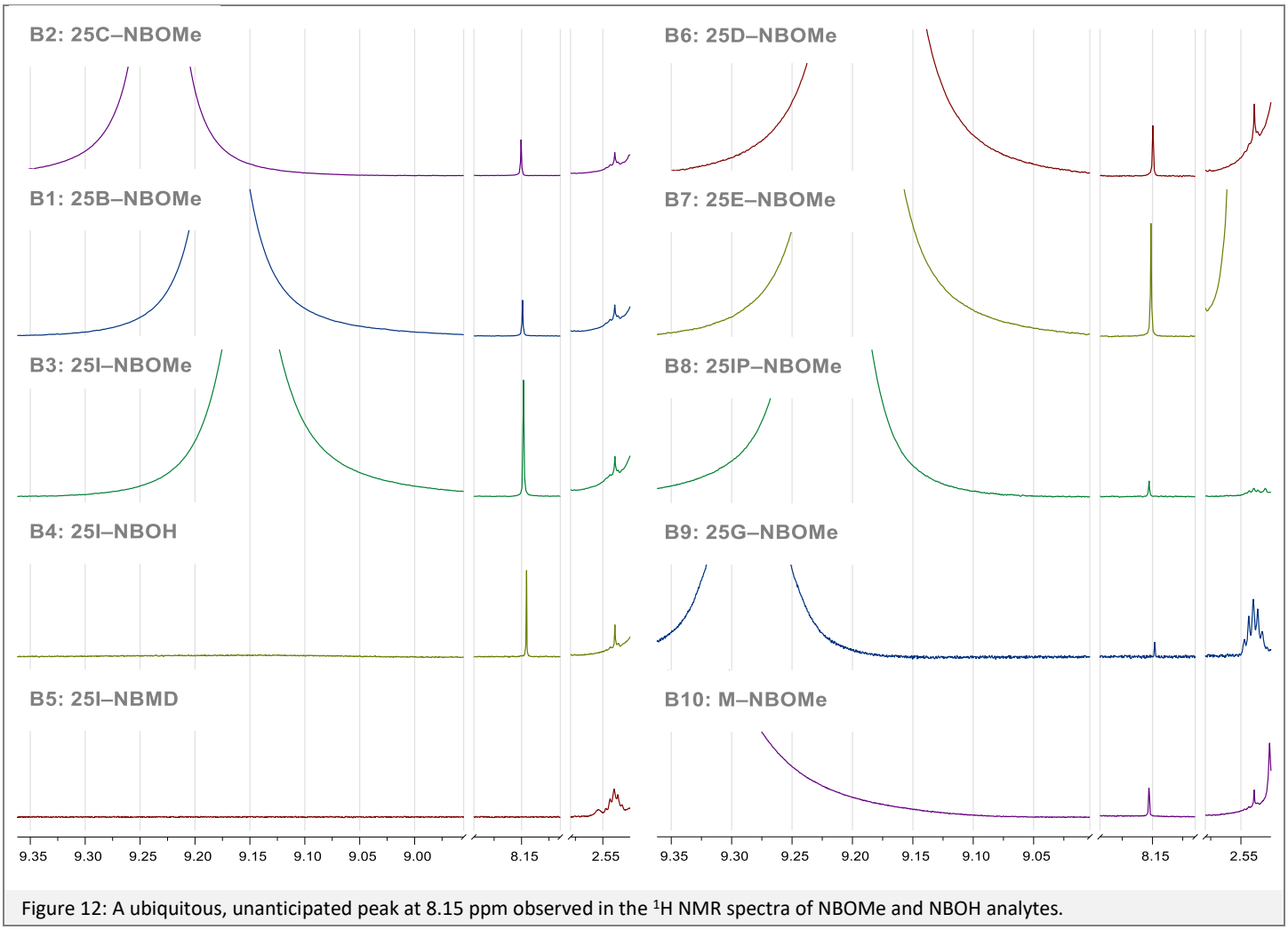


Figure 12: A ubiquitous, unanticipated peak at 8.15 ppm observed in the ^{1}H NMR spectra of NBOMe and NBOH analytes.

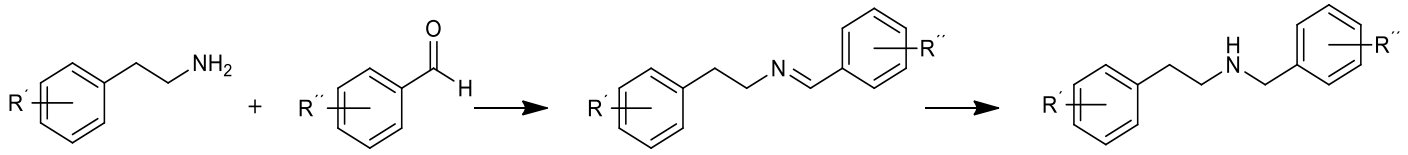
A ubiquitous, unanticipated peak at 8.15 ppm

A characteristic peak was noted in the spectrum for 9 of the 10 *N*-benzyl analytes (Figure 12). We initially suspected the sharp singlet at 8.15 ppm was the signal from residual amounts of the benzaldehyde precursors. However, literature shifts were notable more downfield than anticipated, appearing around 10.2-10.3 ppm.[80,81]

Following the synthetic route outlined by Casale and Hays (Scheme 1), we wondered if the peak could be coming from traces of the unreduced imine intermediate of the reductive amination of the parent phenethylamine with the respective benzaldehyde.[82] Kappe et al. reported a singlet at 8.15 ppm in the spectrum of the unsubstituted imine (*E*)-1-phenyl-*N*-(2-phenylethyl)methanimine (***1***), which seemed promising.[83]

To test this hypothesis we acquired the ^{1}H NMR spectra of two commercially available *N*-benzylidene phenylethanamines: **IM1**: 25H-NBOMe imine (***2***) and **IM2**: 25I-NBOMe imine (***3***).

The spectra of the reference did not conclusively match the observed impurities for the respective compounds. The imine analog of 25H-NBOMe, **IM1**, gave a singlet at 8.56 ppm; **IM2**, the imine analog of 25I-NBOMe, a singlet at 8.54 ppm. The distinct shifts from the observed 8.13–8.15 ppm shift made the imine an unlikely candidate. Potentials precursors 2-methoxybenzaldehyde, 1,3-benzodioxole-4-carbaldehyde, the unsubstituted primary phenylethanamines, and residual solvents were each investigated but proved unsupported by



Scheme 1: Synthetic route to *N*-benzyl phenylethanamines via the *N*-benzylidene, following Casale and Hays.[82]

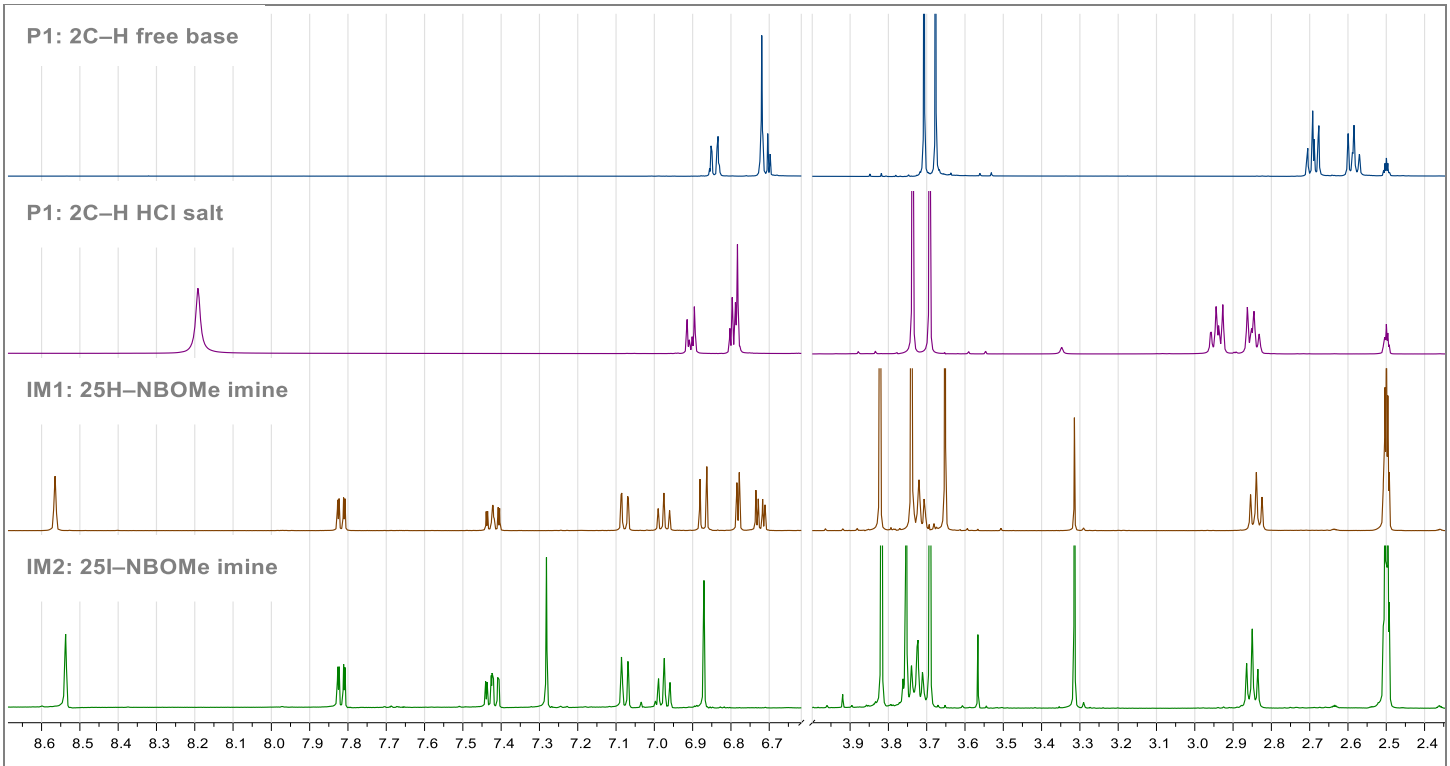


Figure 13: ^{1}H NMR spectra of **P1**: 2C-H as the free base and the hydrochloride salt; **IM1**: 25H-NBOMe imine; **IM2**: 25I-NBOMe imine.

experimental, predicted, or literature ^{1}H NMR shift values. Though this peak might indeed be an artifact of Scheme 1 we did not pursue this line any further.

The spectrum of **B5**: 25I-NBMD is unique among the *N*-benzyl analytes in having no peak at 8.15 ppm. We believe **B5** is also the only free base *N*-benzyl analyte, having a broad upfield amine peak and no downfield aminium peak. Our analytes include primary, secondary, and tertiary amines; the peak at 8.15 ppm is present only in the spectra of protonated secondary amines.

In each case the peak's shift is precisely 8.15 ppm, while the shift the aminium peaks differ by as much as 0.18 ppm. This seems to rule out the peaks being somehow coupled. No correlation was found between the area of the two peaks, further evidence against coupling.

Approaching the problem from another angle we searched the literature for peaks of shift 8.15 ppm. Robertson et al.[84] report conditions where the formyl proton of dimethylformamide (DMF) resonates as a sharp singlet at 8.15 ppm in DMSO-d_6. Though reporting a shift of ca. 7.95 ppm in free DMF, they found the formyl proton signal moves downfield to 8.15 ppm when the amine lone pair forms a hydrogen bond and the quaternary amine orbitals undergo sp^3 hybridization. With the loss of the nitrogen π-orbital, the delocalized bonding found in free DMF is lost (see Figure 15), rotation about the C–N bond is no longer inhibited, and the amine methyl groups become equivalent, resonating as a 6H singlet at 2.54 ppm.

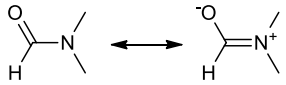
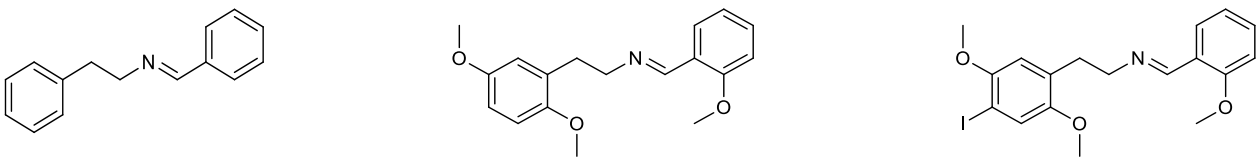


Figure 15: Dimethylformamide resonance structures.

Though the majority of the spectra stacked in Figure 12 indeed include a peak at 2.54 ppm, the protonated DMF theory would seem to demand the area of the upfield dimethyl peak be six times the area of the downfield formyl peak. Tantalizing but far from conclusive. A more satisfactory explanation must await further investigation.

We have not found ^{1}H NMR spectra reported for 25H-NBOMe



1 ***2*** ***3***

Figure 14: Structure of *N*-benzylidene phenylethanamines

imine or 25I-NBOMe imine. Spectra in $CDCl_3$ are available from the vendor, Cayman Chemical.

Conclusion

We found only one clear case of significant misrepresentation among our analytes. Analyte **P6a** was sold and labelled as 2C-C, a claim unsupported by the ^{1}H NMR spectrum which suggests 2C-E. In addition, the spectrum of **P6a** aligns closely with that of **P3**: 2C-E, purchased from the same vendor around the same time. It seems likely analyte **P6a** was mislabelled by the vendor.

Fortunately, because 2C-C and 2C-E are active at comparable levels[3] this did not constitute a public health emergency as happened in 2009, for example, when the extremely potent and long-acting compound bromo-dragonFLY[1] was sold as 2C-B-FLY,[2] an order of magnitude less active.[21,85] Furthermore, the vendor of the mislabelled 2C-E closed several years ago.

On reflection — and the future of open, "legitimate" research

> *"Experience is essential and to become really proficient in this area, you need to critically examine literally* thousands *of spectra."* [86]

When we began this investigation our knowledge of NMR was limited, as was our experience interpreting spectra. The sophisticated and highly regarded Mestrelab software may, in retrospect, have inspired unrealistic expectations that interpreting spectra would be simple, even intuitive. Remarkably, as our investigation progressed so too did our intuition. As a non-traditional, self-directed approach to the study of NMR we found it highly effective. As a potential technique for harm reduction we concede "walk-in" ^{1}H NMR analysis is unlikely to supplant spot-colour testing any time soon.

The legal status of phenylethanamines in Canada has long been clear.[36] A terse notice released 1 August 2015 may muddy the water. Health Canada proposes to add "2C-phenethylamines and their salts, derivatives, and isomers, and the salts of their derivatives and isomers" to Schedule III of the Controlled Drugs and Substances Act (CDSA).[87,88]

What that *means* is far from clear — no elaboration is provided and the CDSA is equally unhelpful, absent any definition for *2C-phenethylamine*, *salt*, *derivative*, or *isomer*. The legal status of a substance may be contested when made woolly, even if by design — what fresh *grey area* is this? Unfortunately, the inevitable consequences of further barriers to open, legitimate research are well documented.[89–95]

[1] Bromo-dragonFLY: 1-(8-bromobenzo[1,2-*b*:4,5-*b*′]difuran-4-yl)propan-2-amine.

[2] 2C-B-FLY: 2-(8-bromo-2,3,6,7-tetrahydrobenzo[1,2-*b*:4,5-*b*′]difuran-4-yl) ethan-1-amine.

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Finally and with deep regret we mark the loss of distinguished psychedelic researcher and author Alexander "Sasha" Shulgin.

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