The New Hybrid Type Squaramide Fused Amino Alcohol Organocatalyst For Enantioselective Domino Michael Addition/Cyclization Reaction of Oxoindolines with Cyclic 1,3-Diketones

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Supporting Information

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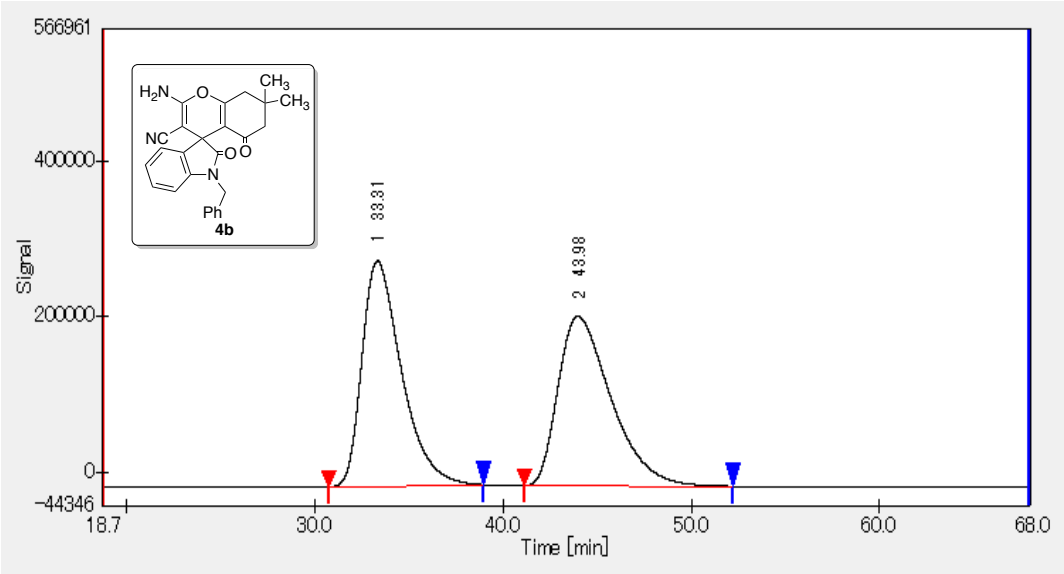
2. HPLC Chromatographs of **4b-r**



No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	33.31	42250203	49.7544	288571	1099.8	1.526	2.281
2	43.98	42667375	50.2456	217292	1084	1.563	*****
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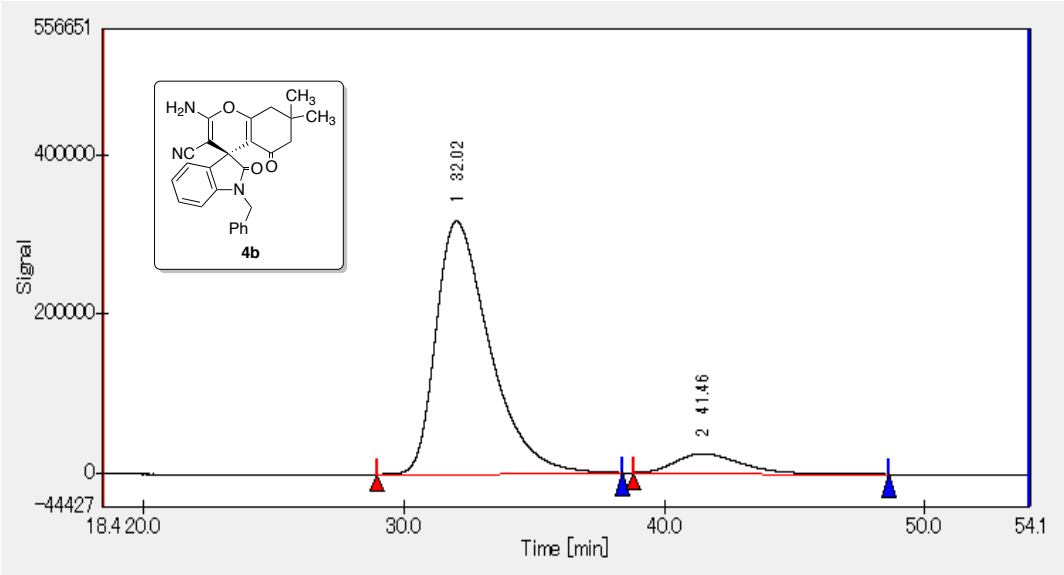
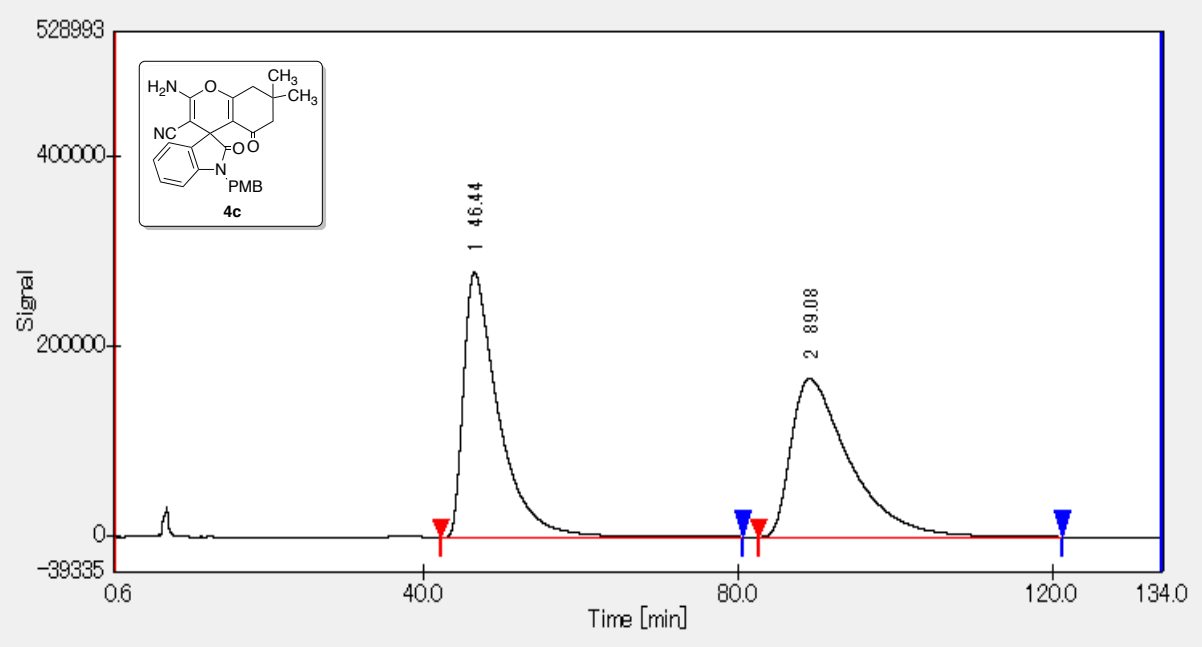
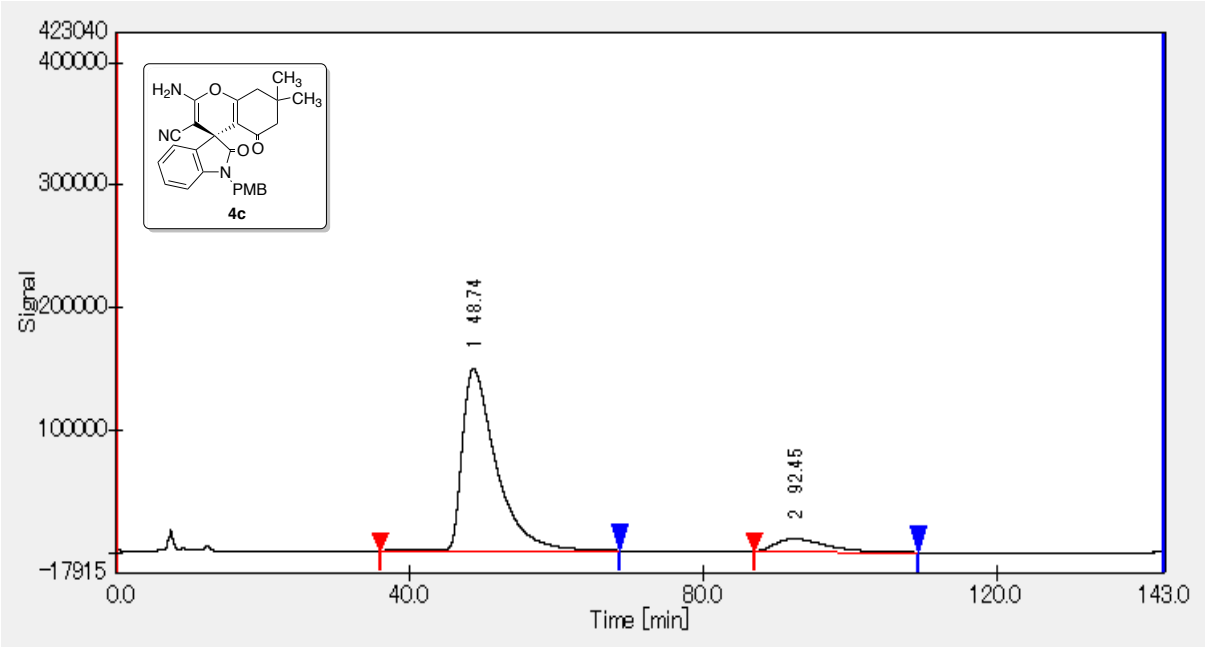


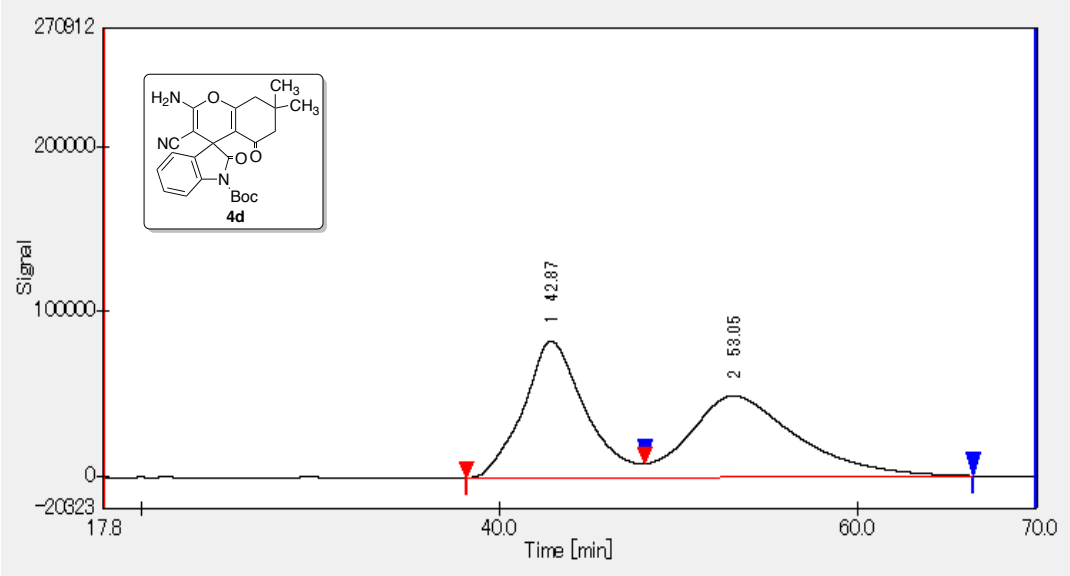
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	32.02	45536322	91.5667	317882	1069.3	1.559	2.209
2	41.46	4193893	8.4333	24442	1280.5	1.323	*****
		49730214	100	342324			



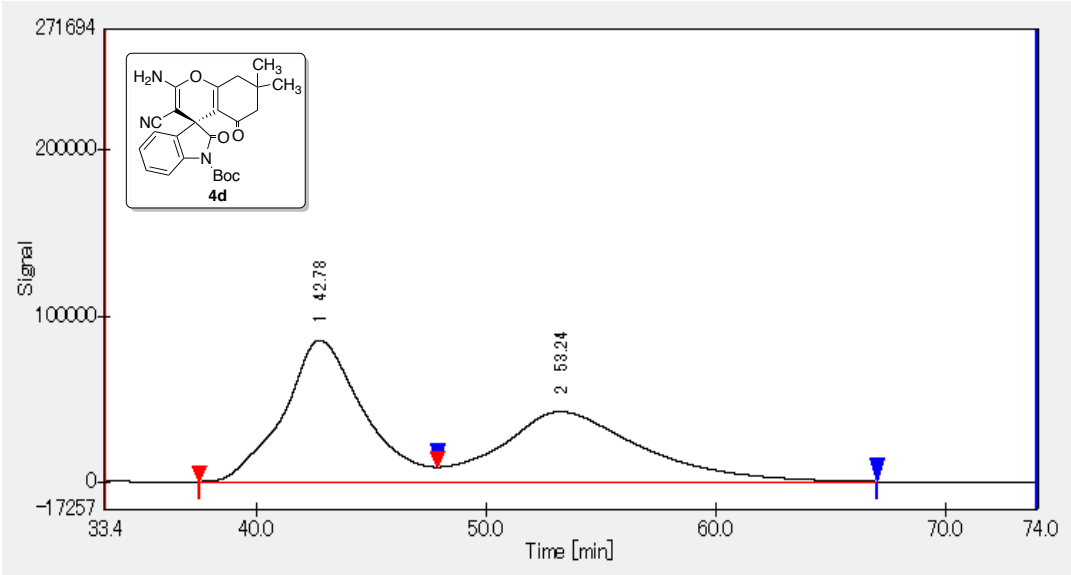
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	46.44	86017132	50.0195	277991	459.9	2.167	3.686
2	89.08	85949967	49.9805	166146	606	2.048	*****
		1.72E+08	100	444137			



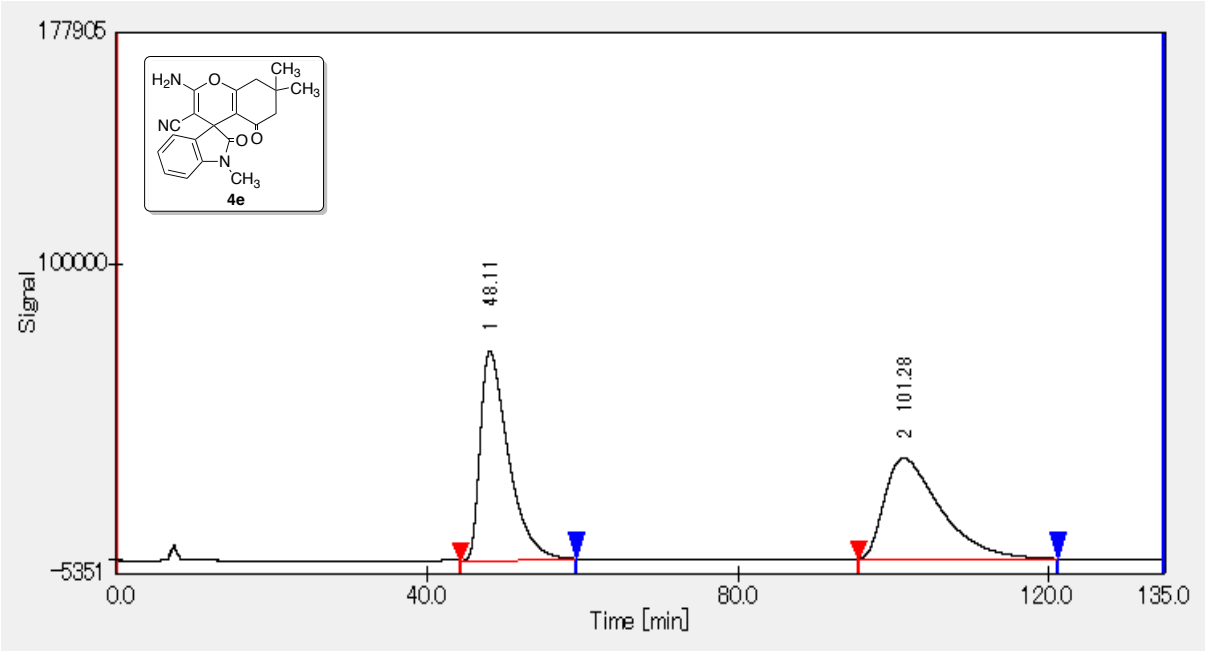
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	48.74	47943928	90.7739	148675	485.8	2.028	4.03
2	92.45	4872937	9.2261	10327	829.1	1.608	*****
		52816865	100	159002			



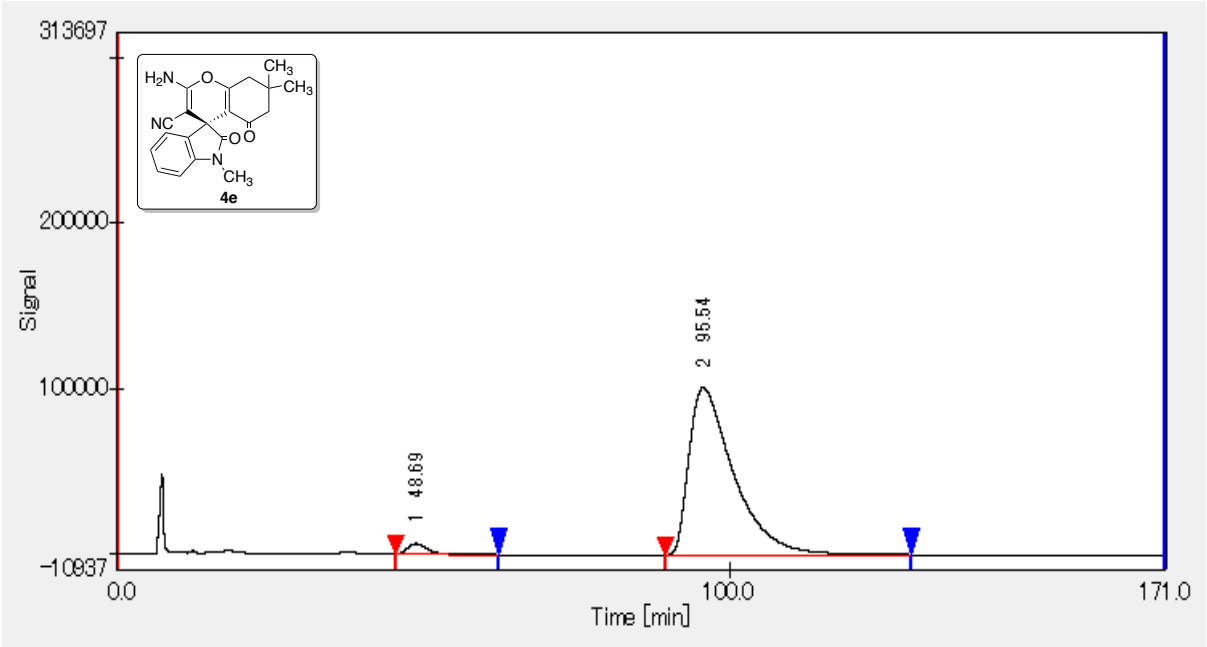
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	42.87	19780874	49.4146	82620	725.1	*****	1.174
2	53.05	20249548	50.5854	49084	374	*****	*****
		40030422	100	131704			



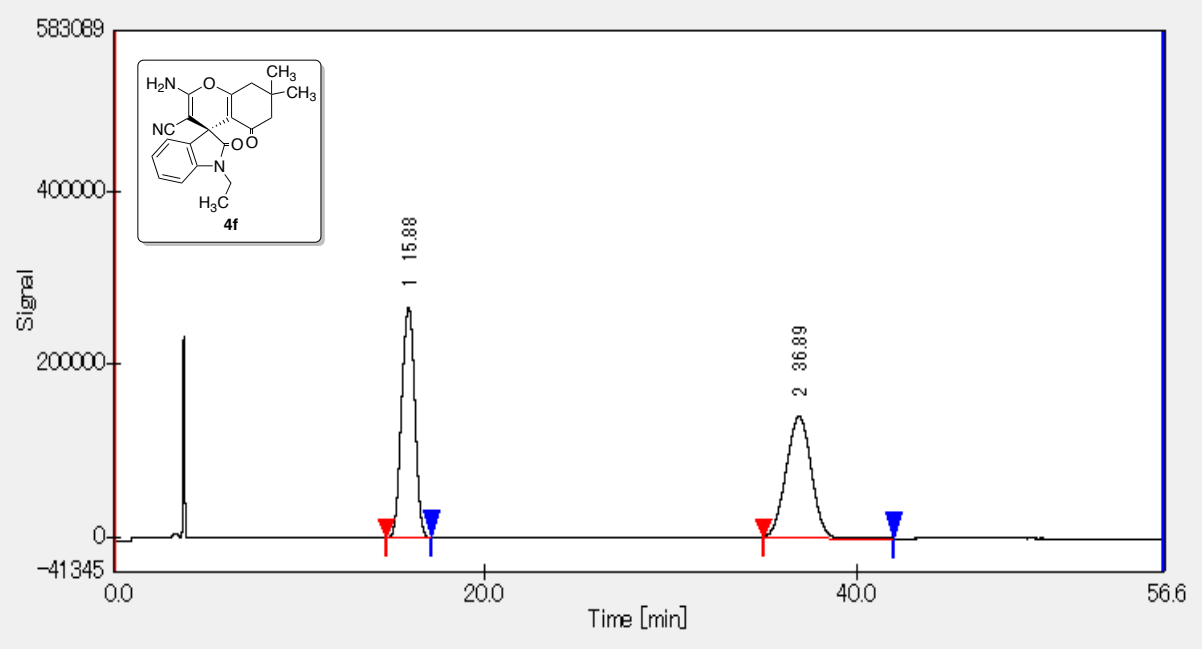
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	42.78	20527526	53.651	85081	711	*****	1.187
2	53.24	17733721	46.349	42043	360.4	*****	*****
		38261247	100	127124			



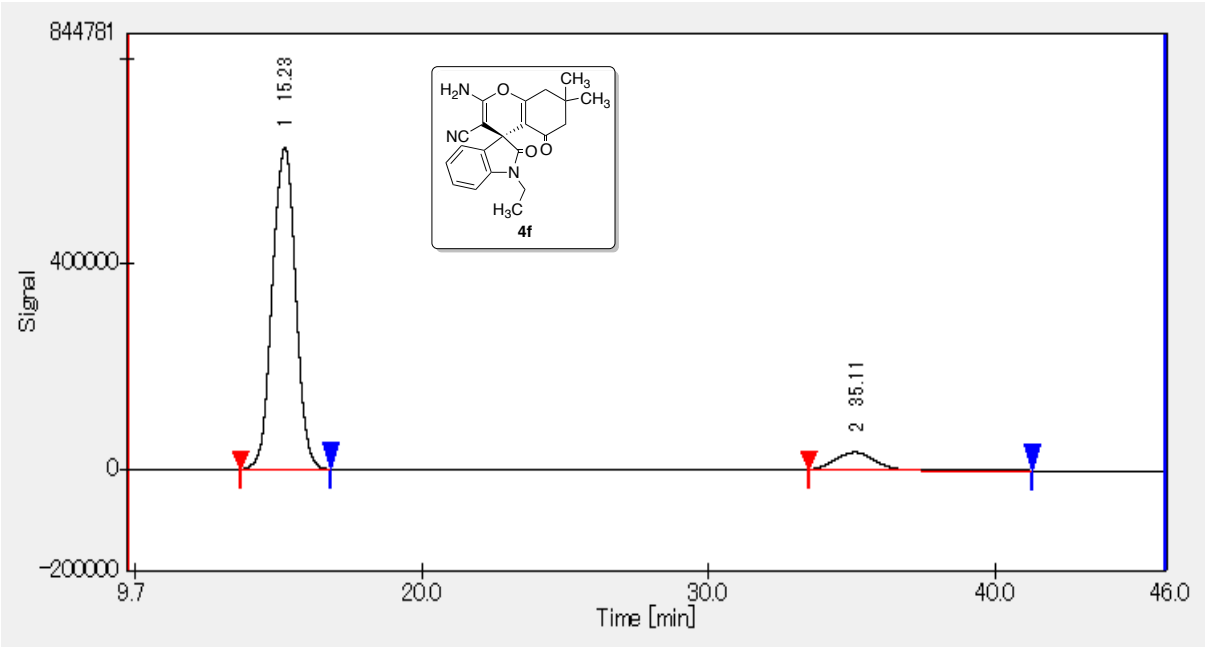
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	48.11	17807493	50.9593	70879	764.2	1.83	5.087
2	101.28	17137062	49.0407	34145	844.4	1.888	*****
		34944554	100	105024			



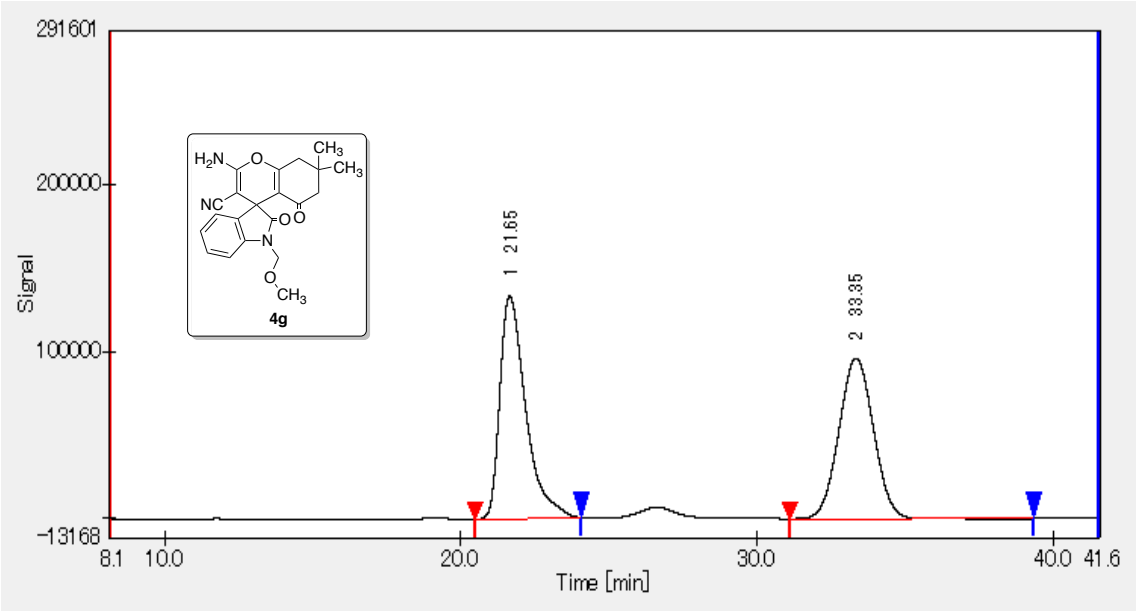
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	48.69	1483284	2.8114	6387	998.4	1.462	4.624
2	95.54	51277118	97.1886	101149	734.7	2.073	*****
		52760402	100	107536			



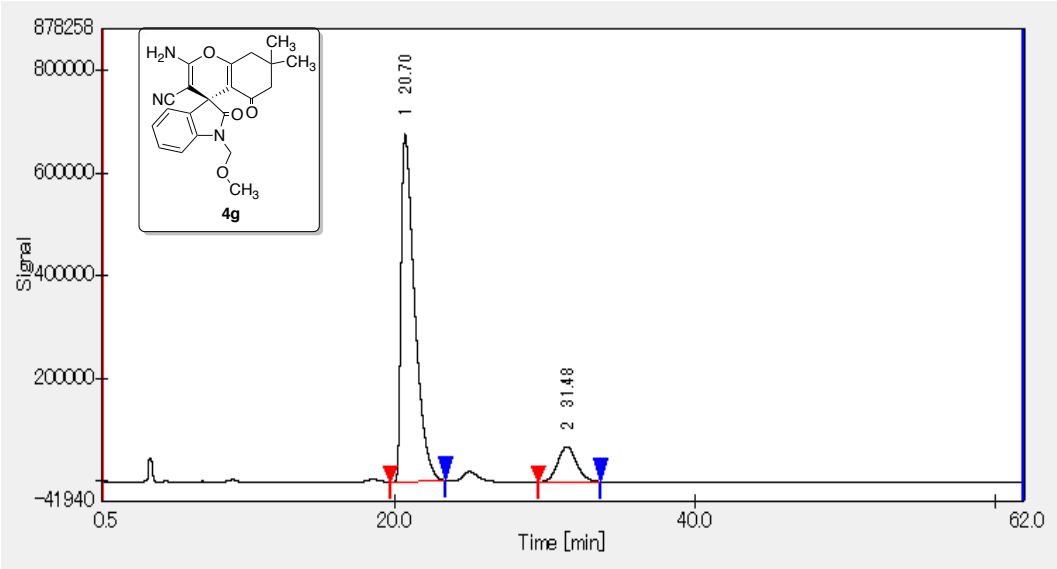
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	15.88	13211841	50.3065	266057	2473.1	0.969	11.148
2	36.89	13050841	49.6935	139513	3505.2	0.992	*****
		26262682	100	405570			



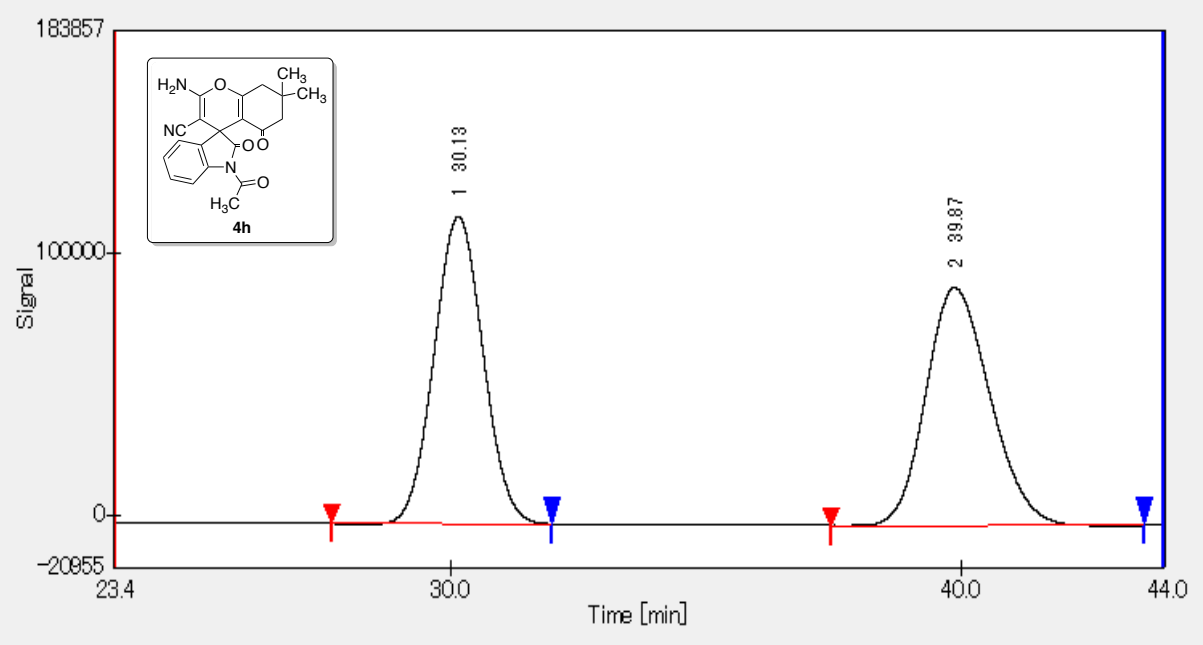
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	15.23	35526078	91.5883	626420	1728	0.992	9.965
2	35.11	3262823	8.4117	33846	3096.6	1.049	*****
		38788901	100	660266			



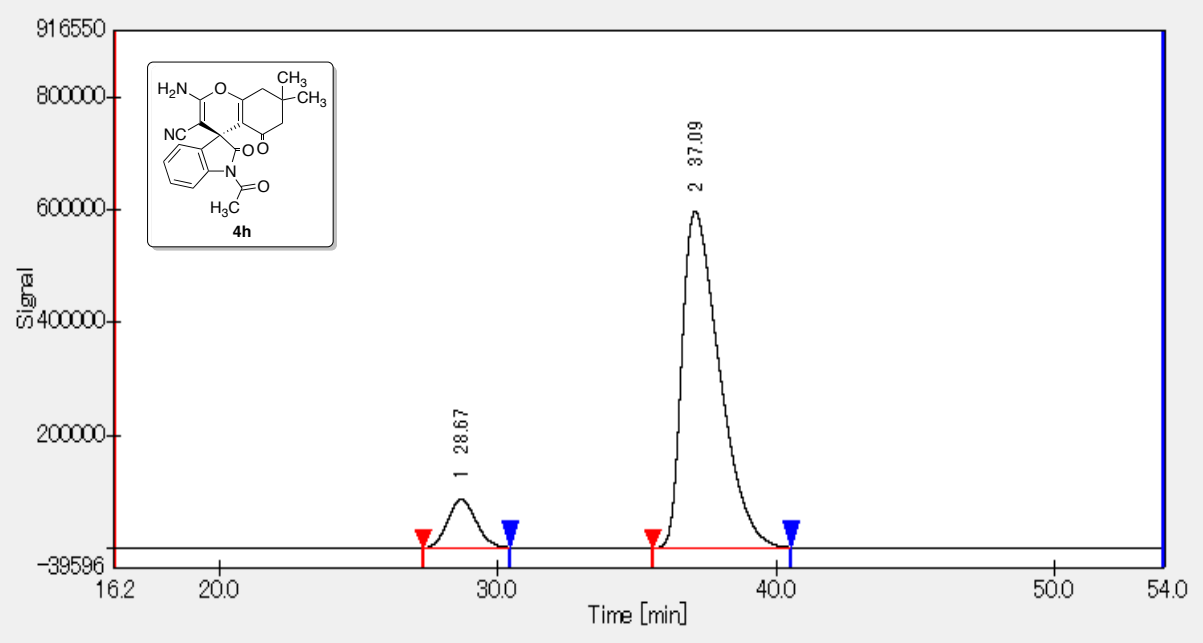
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	21.65	8123007	50.9573	134098	2774.8	1.709	6.152
2	33.35	7817799	49.0427	96334	3811.6	1.036	*****
		15940805	100	230432			



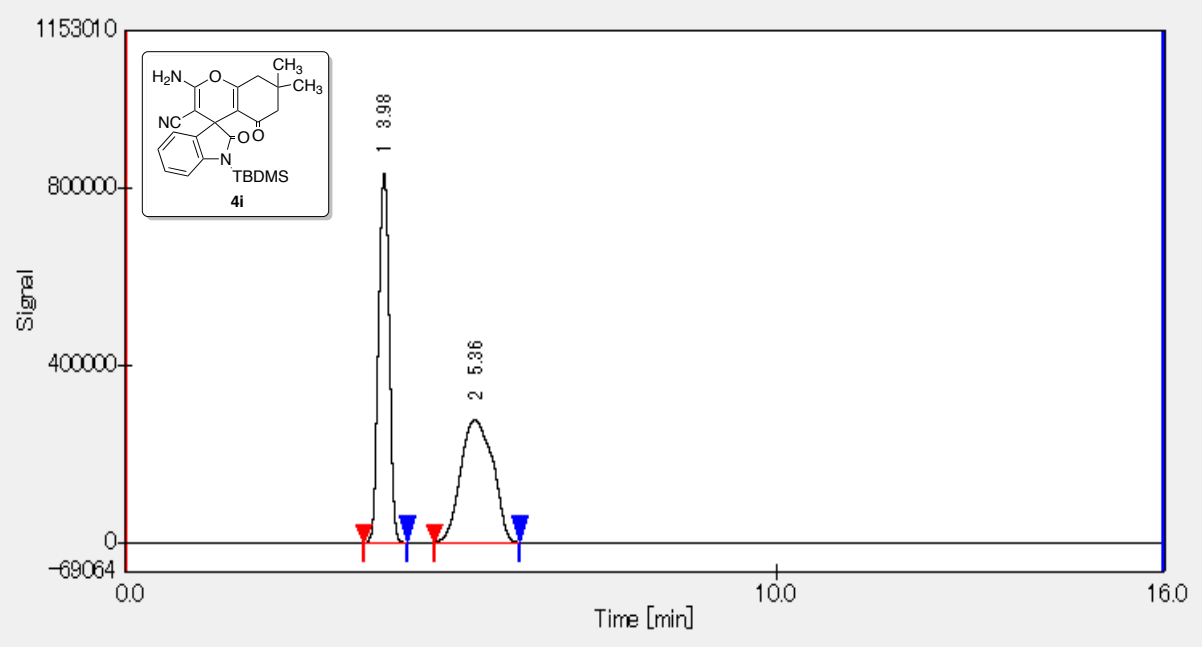
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	20.7	42480951	87.6727	676242	2275.9	2.19	5.275
2	31.48	5973050	12.3273	68397	2871.7	1.091	*****
		48454001	100	744639			



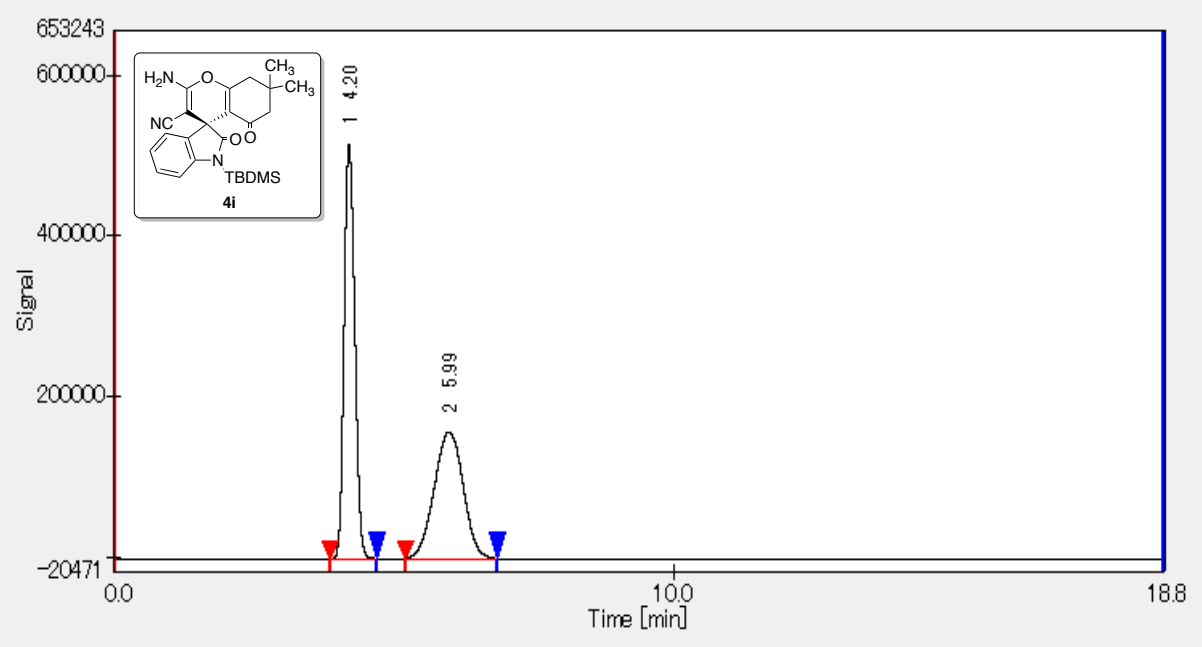
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	30.13	7838416	49.7575	117117	4541.8	1.044	4.716
2	39.87	7914814	50.2425	90611	4637.4	1.178	*****
			15753230	100	207728		



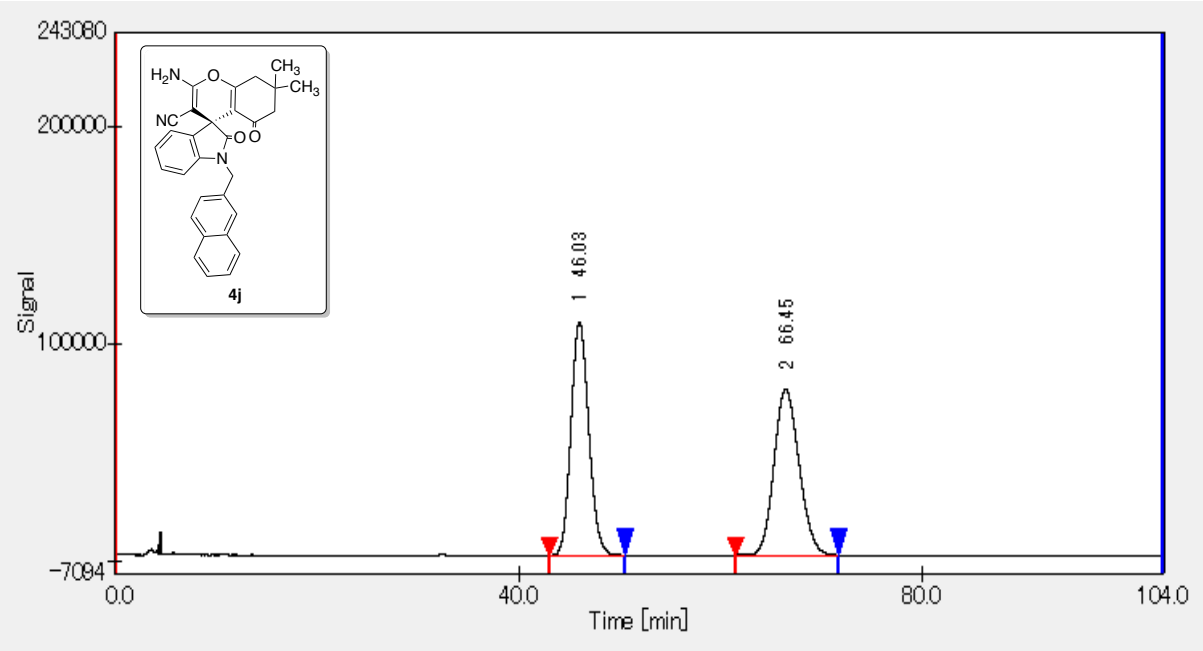
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	28.67	6106120	9.8016	85872	3598.4	1.115	3.785
2	37.09	56191173	90.1984	599002	3421.6	1.682	*****
		62297293	100	684874			



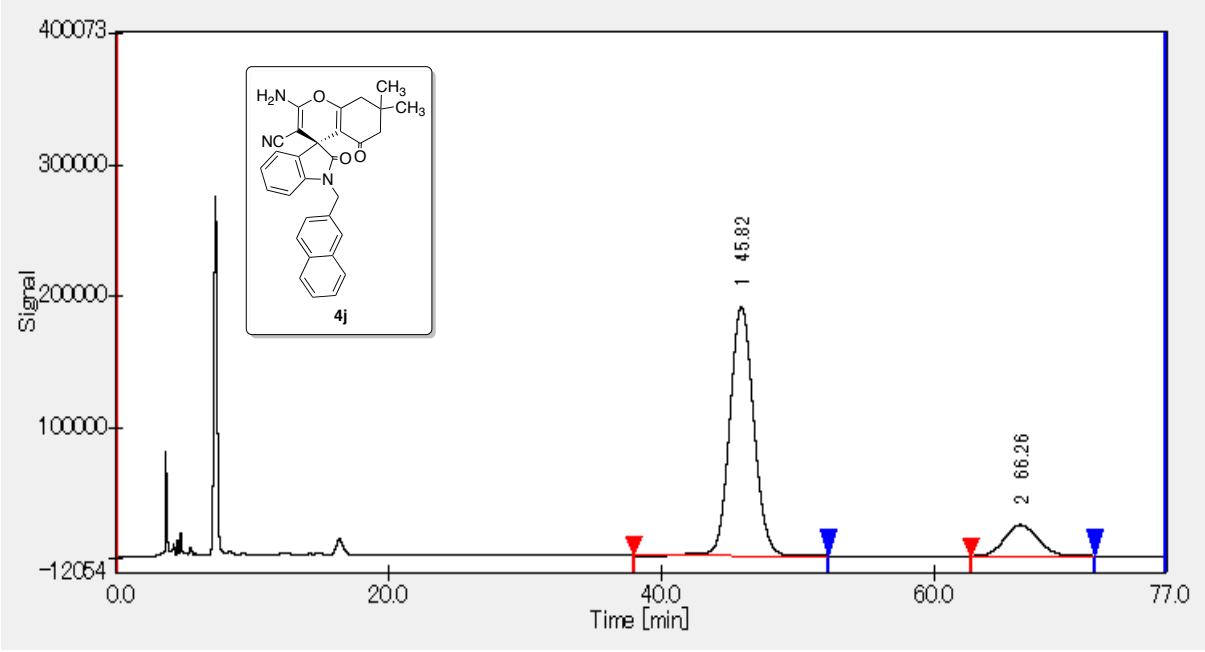
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	3.98	9665464	50.2839	835296	2939.6	0.99	2.415
2	5.36	9556319	49.7161	276389	629.4	1.07	*****
		19221783	100	1111685			



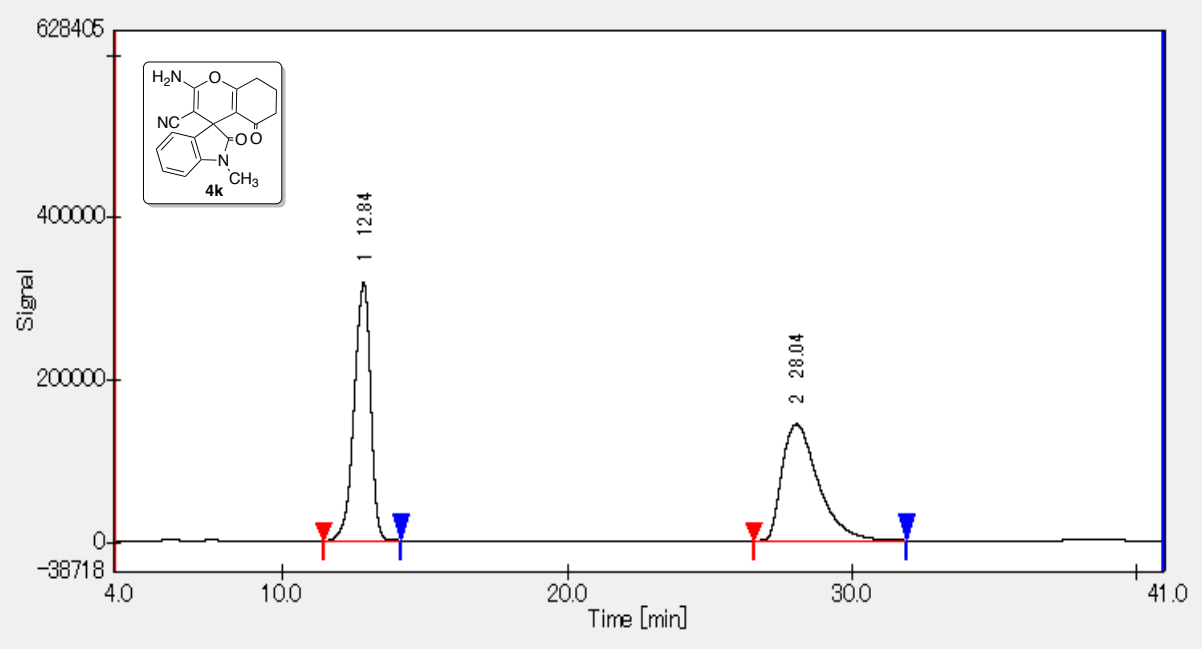
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	4.2	6802814	54.3735	515639	2415.9	1.13	2.759
2	5.99	5708446	45.6265	157847	631.1	0.985	*****
		12511259	100	673486			



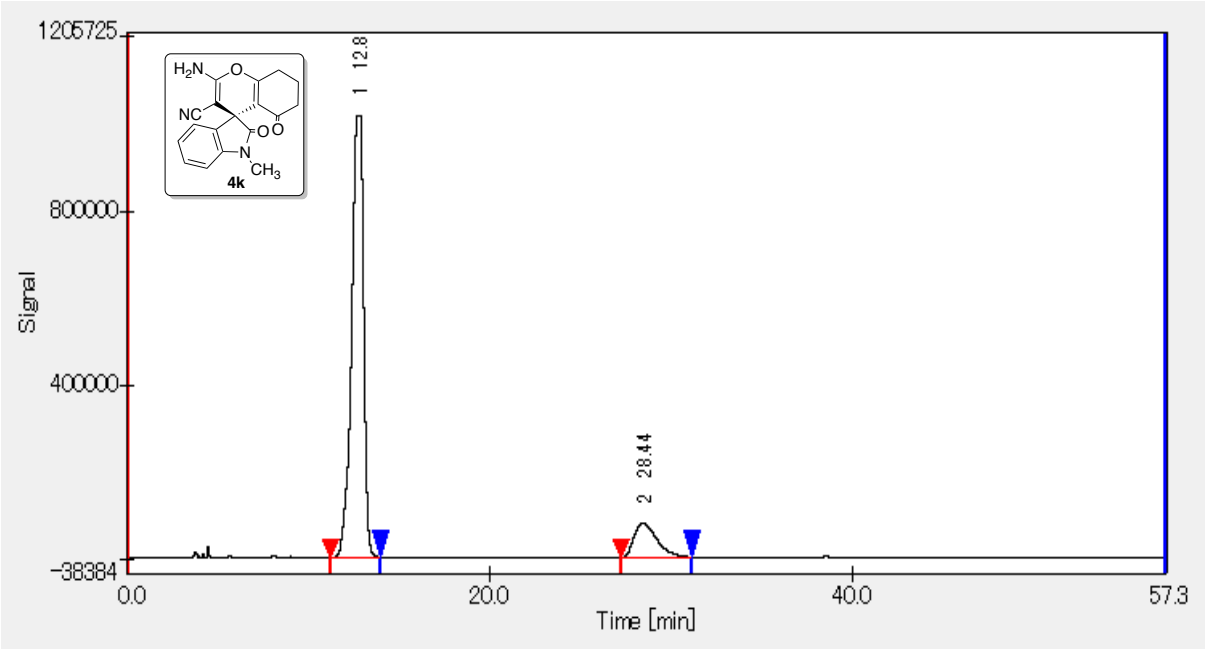
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	46.03	13174526	49.8377	107934	3182.8	1.124	5.17
2	66.45	13260350	50.1623	76470	3288	1.14	*****
		26434877	100	184404			



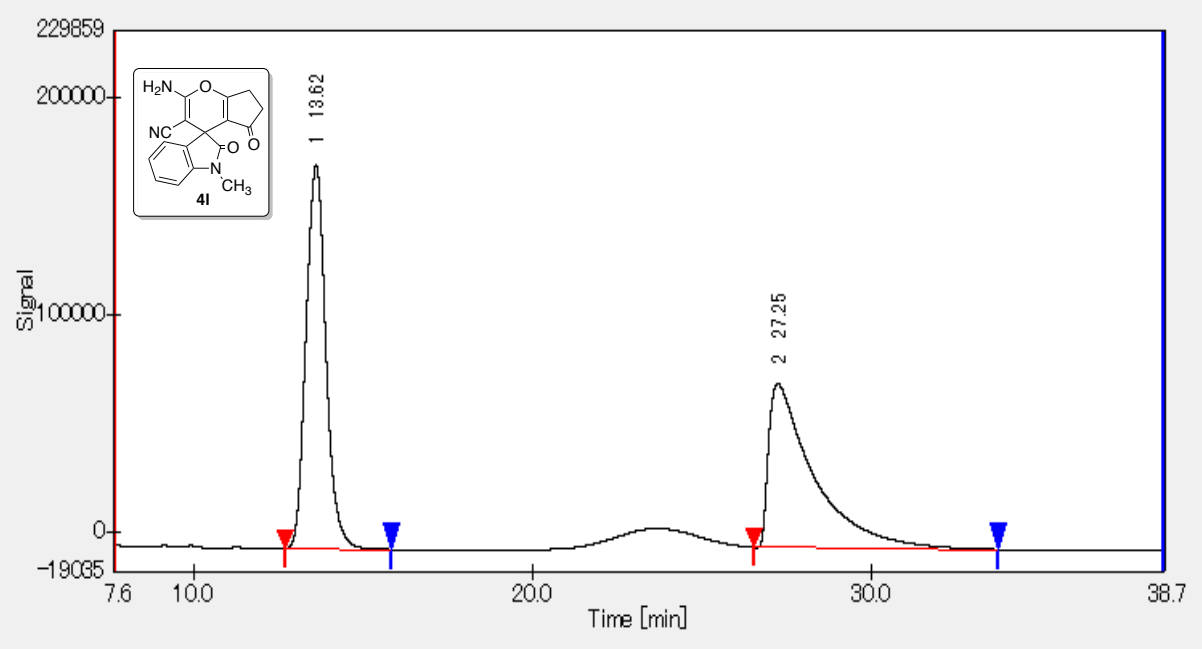
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	45.82	23289874	85.5259	189832	3206	1.083	5.302
2	66.26	3941504	14.4741	23519	3510.9	1.094	*****
		27231378	100	213351			



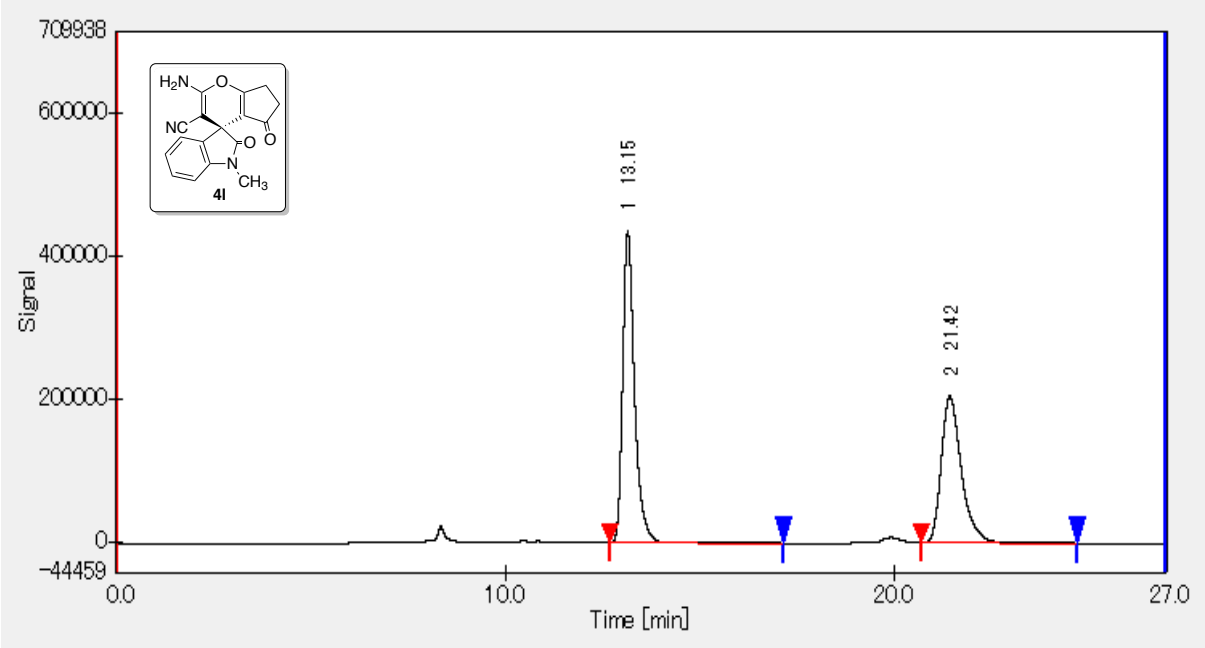
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	12.84	12738685	50.0749	318002	2405.1	0.842	8.85
2	28.04	12700573	49.9251	143196	2207.4	1.628	*****
		25439258	100	461198			



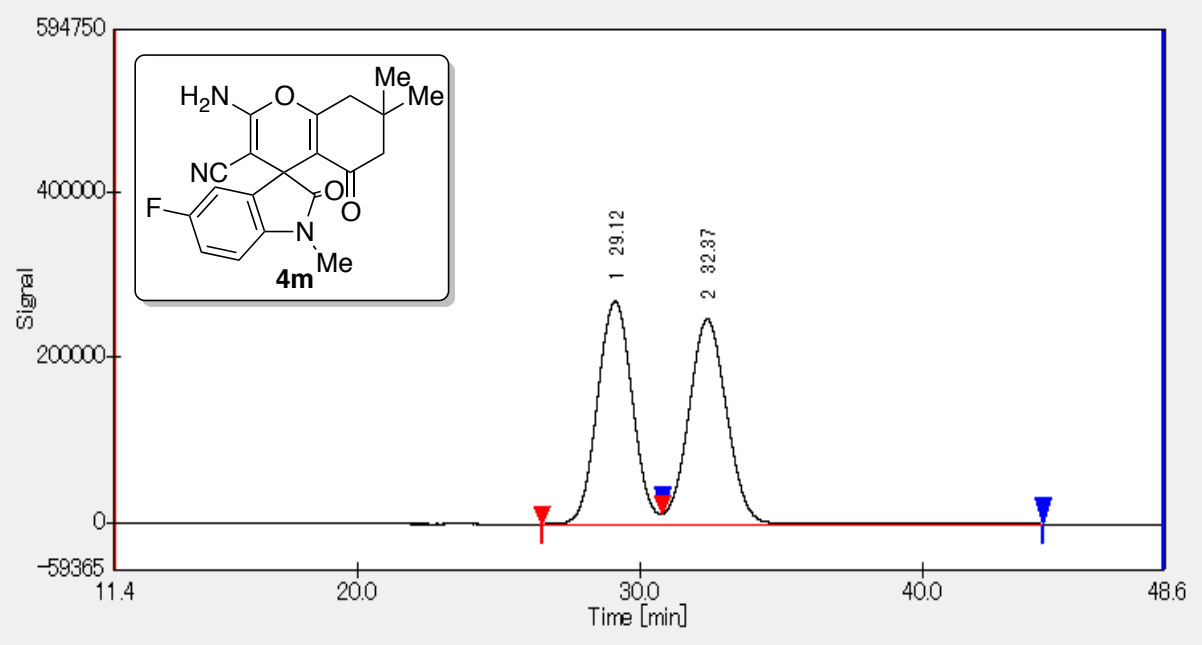
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	12.81	46767762	87.1935	1013708	1827.3	0.764	8.725
2	28.44	6868998	12.8065	78163	2276.2	1.511	*****
		53636760	100	1091871			



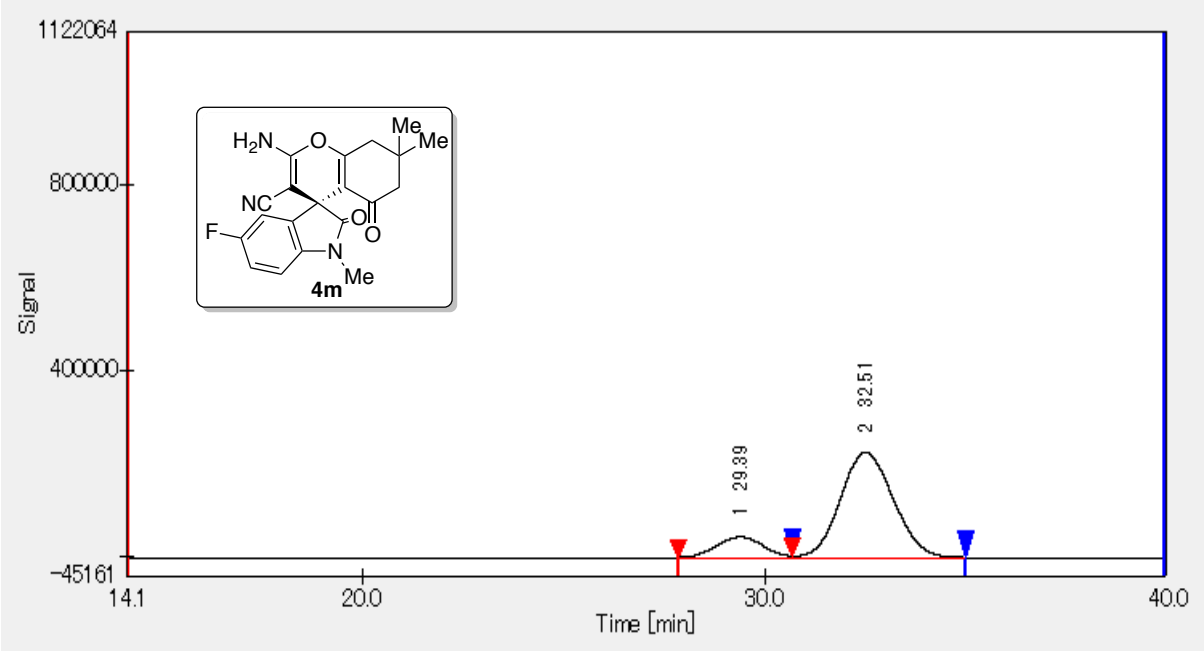
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	13.62	7212661	50.8141	176578	2541.9	1.127	7.047
2	27.25	6981539	49.1859	75284	1529.9	4.246	*****
		14194200	100	251862			



No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	13.15	9205943	55.5808	435734	8096.7	1.406	10.531
2	21.42	7357224	44.4192	203901	7546.4	1.386	*****
		16563166	100	639635			



No	Rt(min)	Area	Area (%)	Heights	NTP	Symmetry	Resolution
1	29.12	23162075	50.1587	269774	2602.6	1.044	1.368
2	32.37	23015535	49.8413	247941	2751.1	*****	*****
		46177610	100	517715			



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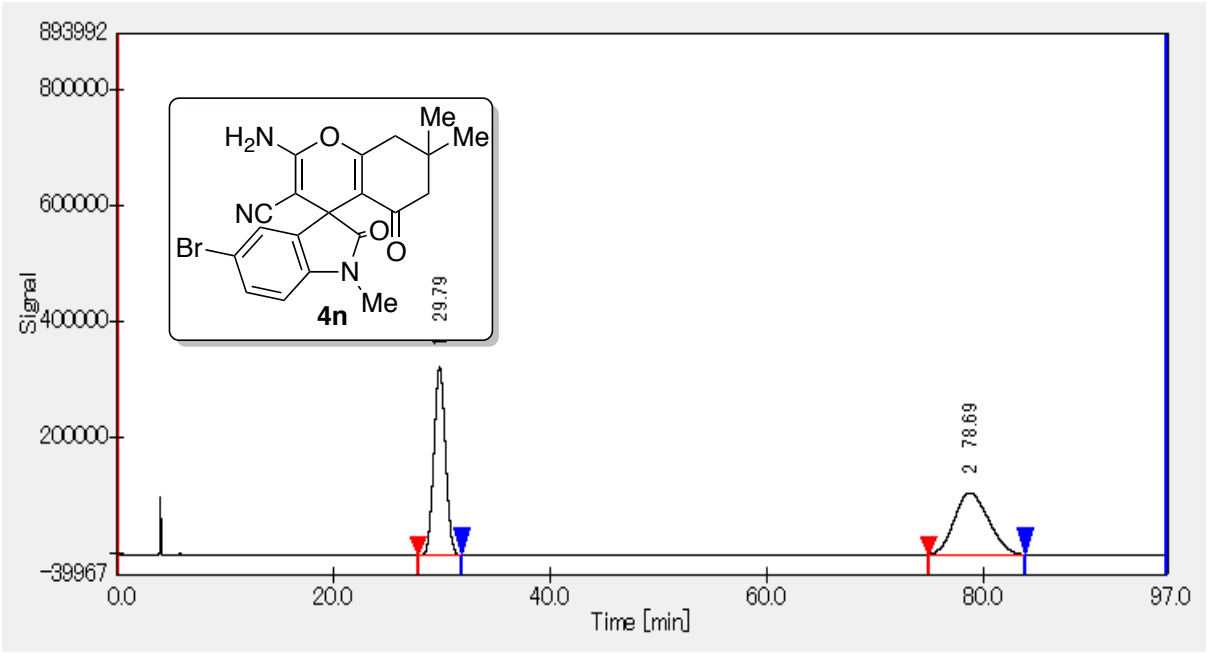
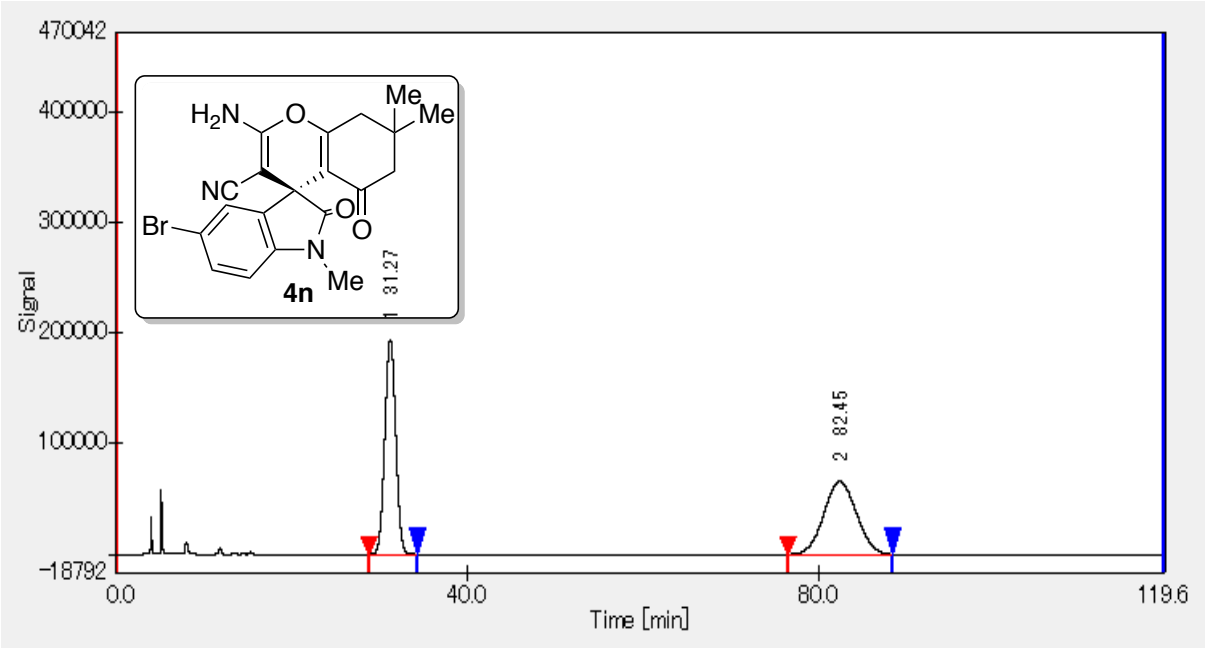
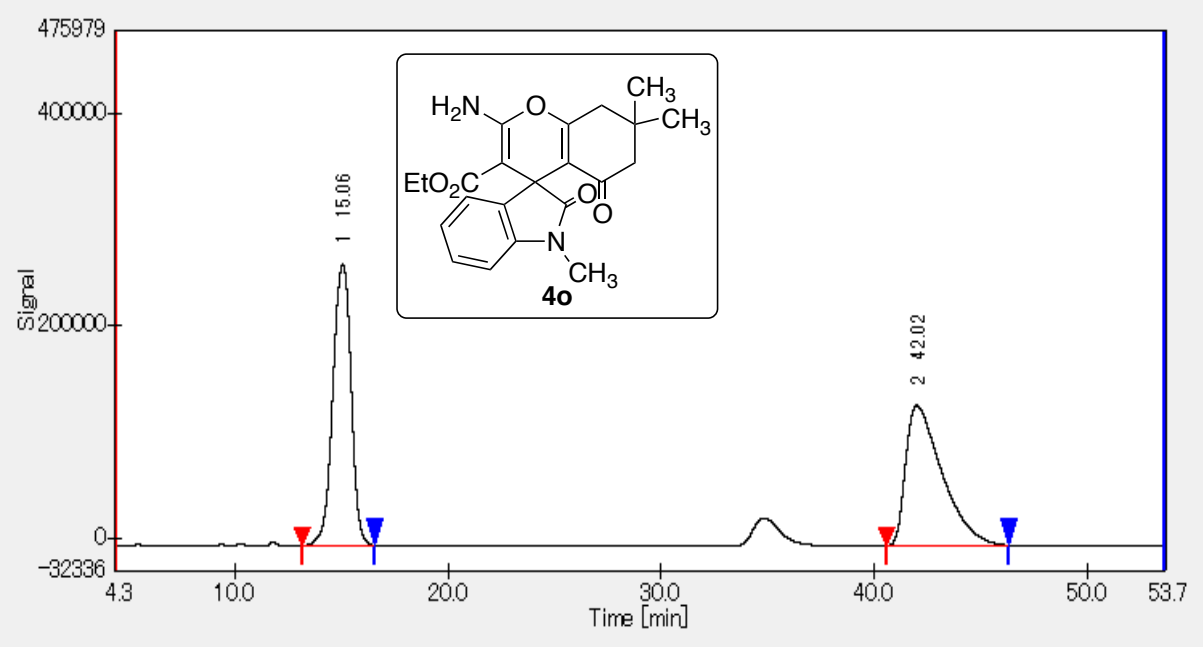
1	29.39	3527546	14.6124	43766	3006.8	*****	1.367
2	32.51	20613240	85.3876	225576	2863.5	1.081	*****
		24140786	100	269342			



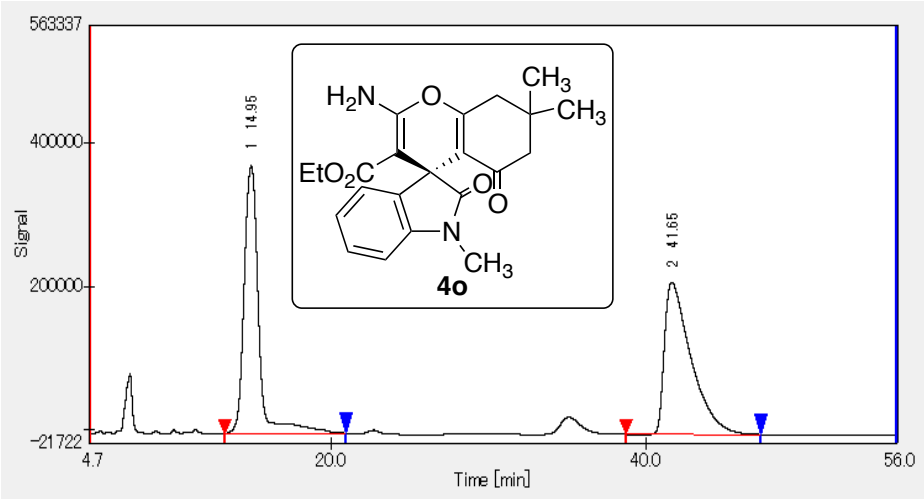
No	Rt (min)	Area	Area (%)	Heights	NTP	Symmetry	Resolution
1	29.79	24200675	50.8189	324952	3580.4	1.04	12.419
2	78.69	23420778	49.1811	106495	2861.8	1.153	*****
		47621453	100	431447			



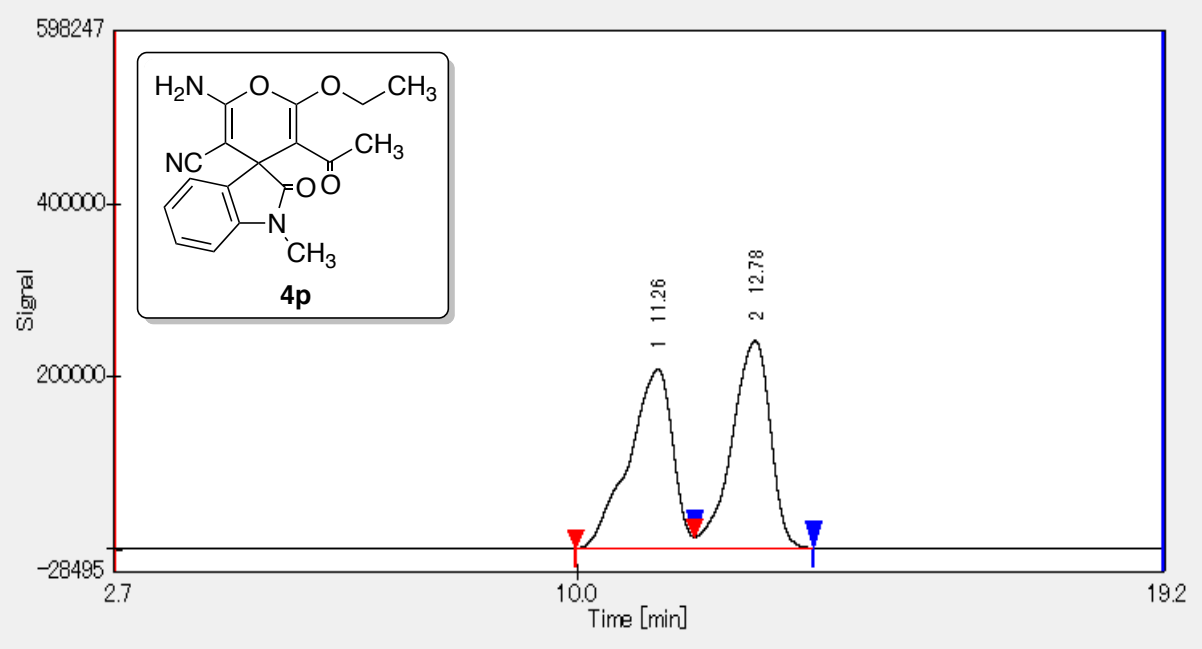
No	Rt (min)	Area	Area (%)	Heights	NTP	Symmetry	Resolution
1	31.27	16826523	49.632	194512	2998.6	1.017	11.122
2	82.45	17076024	50.368	65862	2272.8	1.037	*****
		33902547	100	260374			



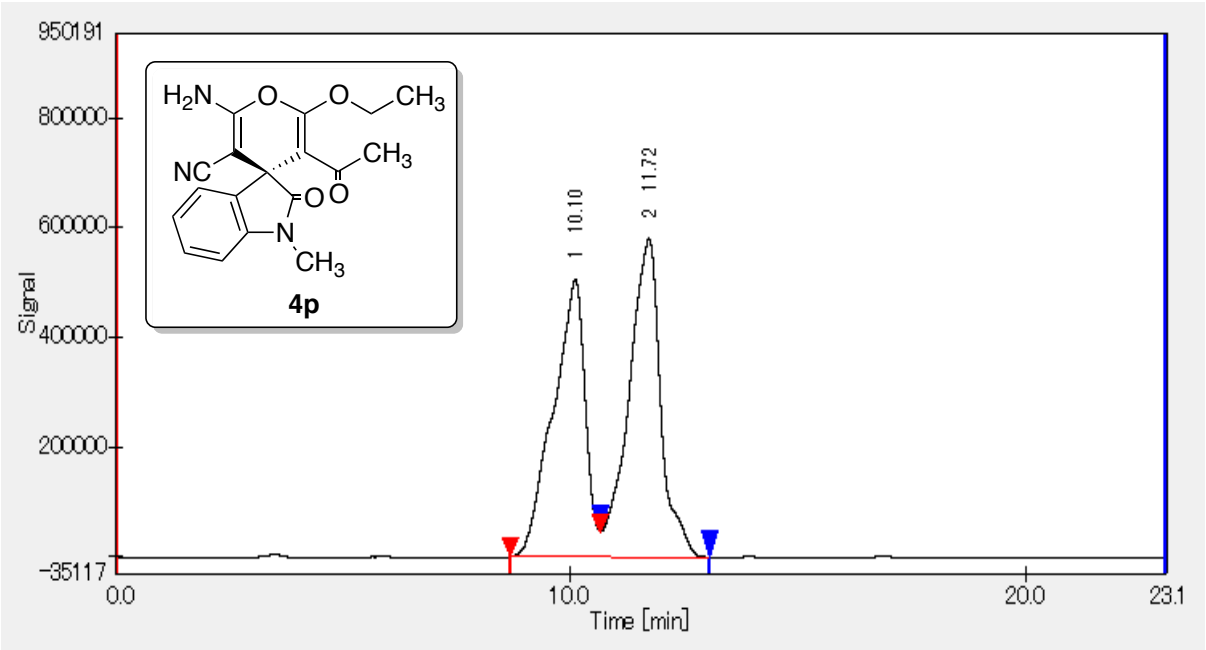
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	15.06	15766467	50.1142	264006	1585.4	0.927	11.219
2	42.02	15694599	49.8858	131985	2603.3	2.004	*****
		31461067	100	395991			



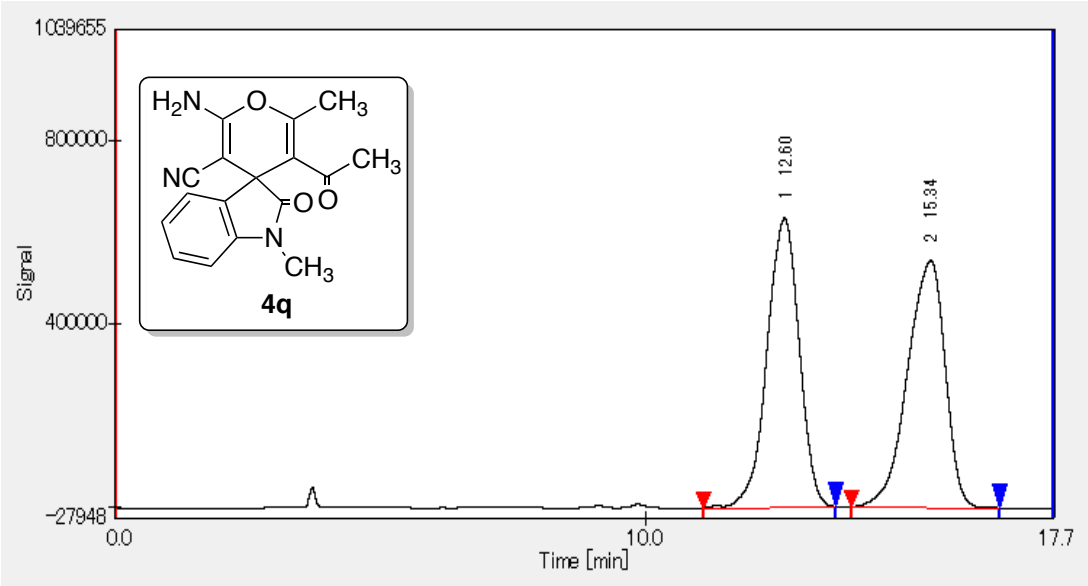
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	14.95	24216280	49.2231	374286	1600.3	1.053	11.126
2	41.65	24980690	50.7769	213168	2539.3	2.35	*****
		49196970	100	587454			



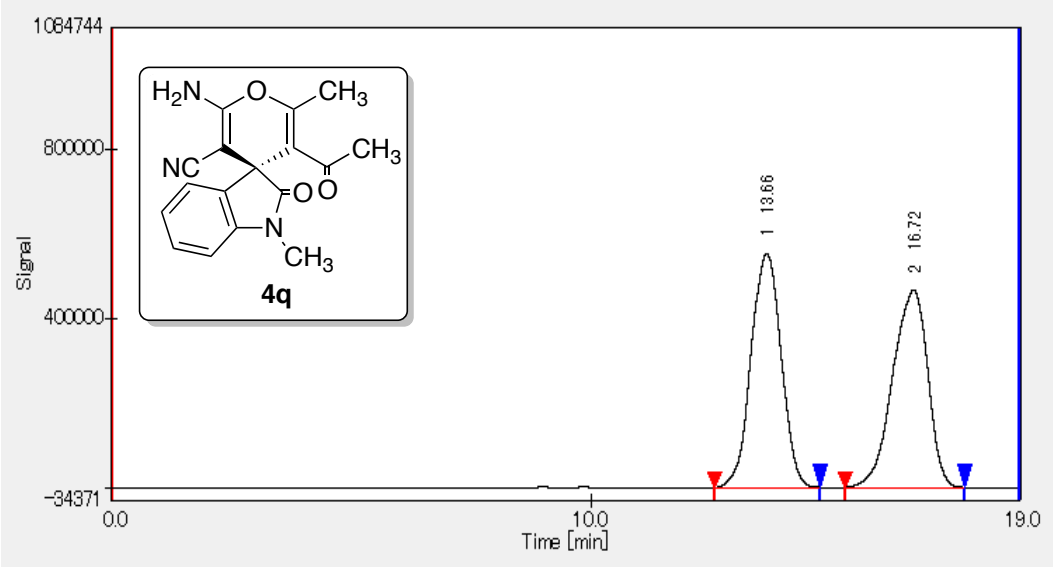
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	11.26	9941890	49.5818	207887	1253.2	*****	1.277
2	12.78	10109588	50.4182	240162	2086	*****	*****
		20051478	100	448049			



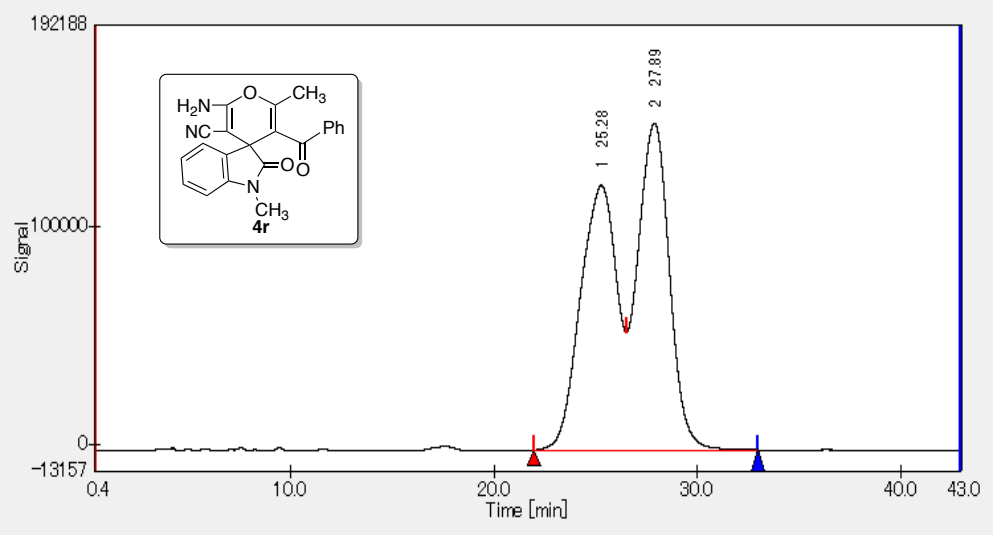
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	10.1	24739354	46.6594	506425	966.9	*****	1.251
2	11.72	28281805	53.3406	580529	1309.8	*****	*****
		53021160	100	1086954			



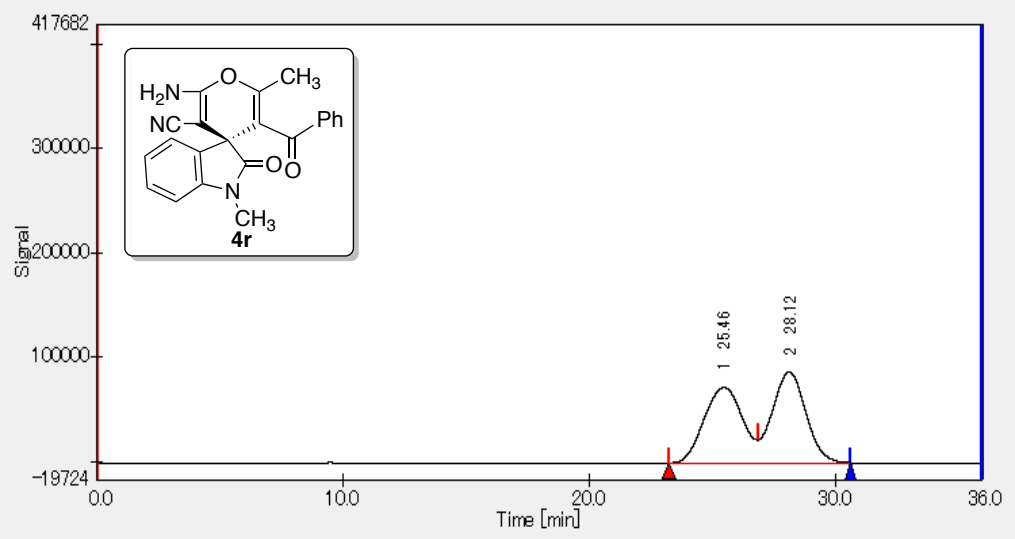
No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	12.6	26594951	50.1033	630761	2056.5	0.91	2.295
2	15.34	26485246	49.8967	539053	2302.2	0.824	*****
		53080198	100	1169814			



No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	13.66	24217473	50.4458	553616	2318.6	0.974	2.5
2	16.72	23789488	49.5542	467506	2582.3	0.842	*****
		48006962	100	1021122			

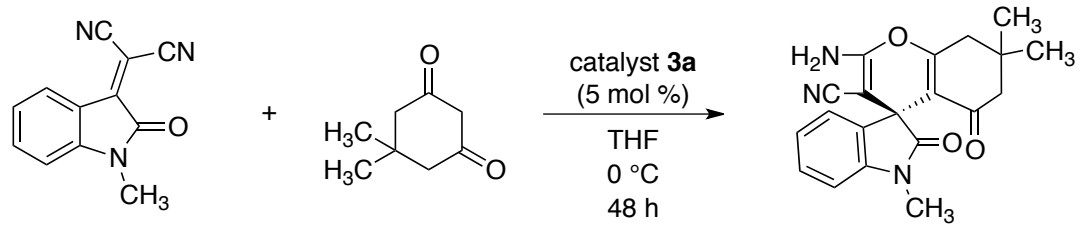


No	Rt(min)	Area	Area (%)	Height	NTP	Symmetry	Resolution
1	25.28	15269436	48.2001	121750	919	*****	0.836
2	27.89	16409815	51.7999	150411	1477.8	*****	*****
		31679251	100	272161			



No	Rt(min)	Area	Area(%)	Height	NTP	Symmetry	Resolution
1	25.46	7997271	49.0036	72784	1214.8	*****	0.973
2	28.12	8322478	50.9964	87462	1974.9	*****	*****
		16319749	100	160246			

Gram-scale experiment:



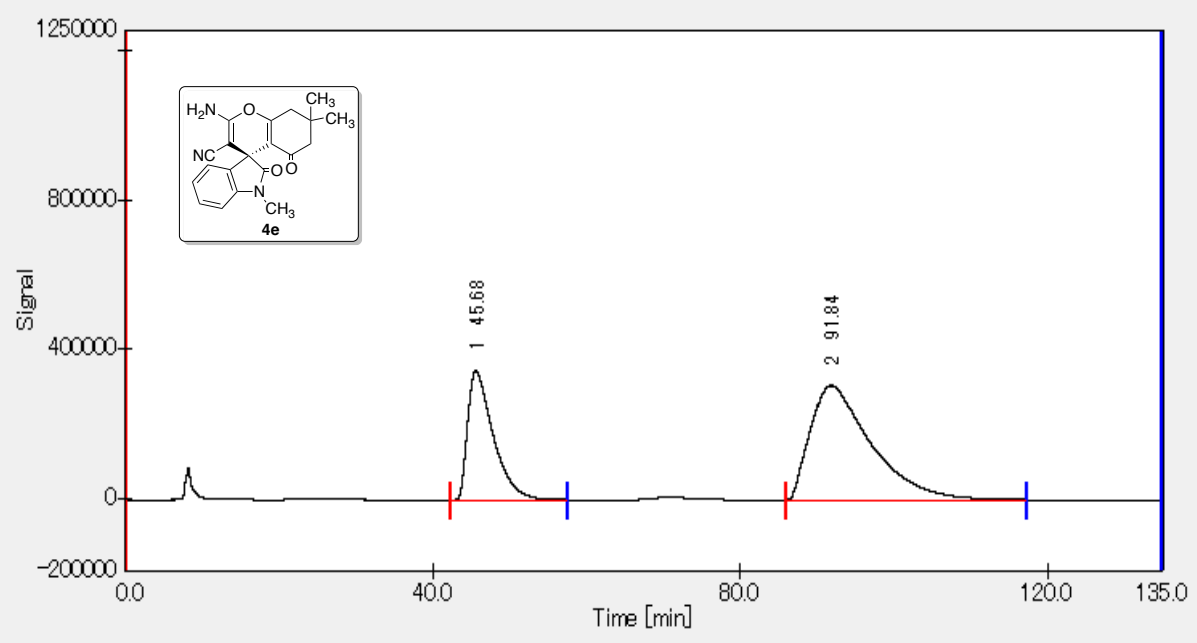
1e 1.0 gr, 4.78 mmol

2a 0.670 gr, 4.78mmol

(3*S*)-4e 1.60 g, 96% yield, 35% ee

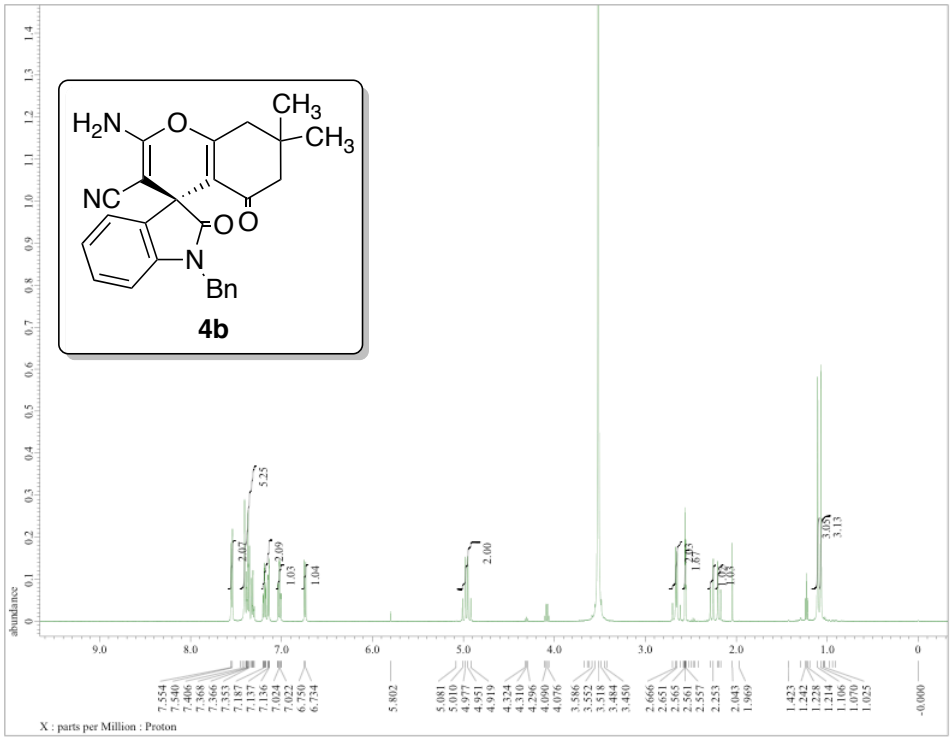
To a solution of **2a** (0.670 gr, 4.78mmol) in 100 mL round bottom-flask containing in dry THF (20 mL) was added catalyst **3a** (0.144 gr, 5 mol %). The reaction mixture was allowed to stir at 0 °C for 1h, followed by added *N*-methyl-3-dicyano-oxoindoline **1e** (1.0 gr, 4.78mmol) at 0 °C. The reaction mixture was allowed to stir at the same temperature for 48 h. After 48h the starting materials were completely consumed indicated by TLC and the reaction mixture suspension was simply filtered using Buchman filter paper to afford product **4e** in pure form.

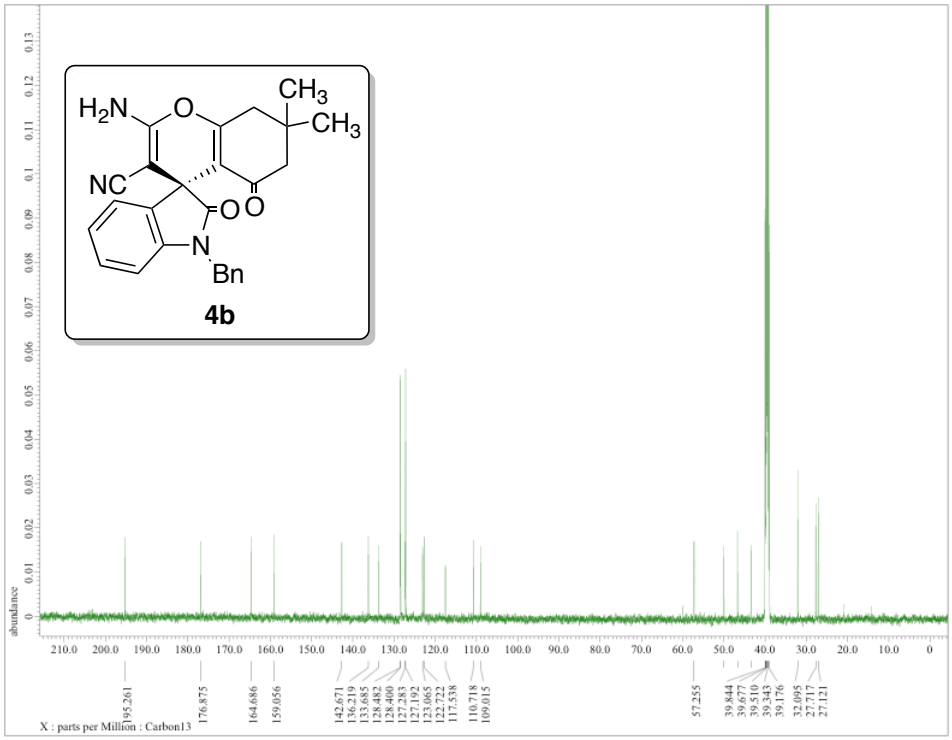
For racemic **4e** HPLC chart (see page no: S5) in this supporting information file.

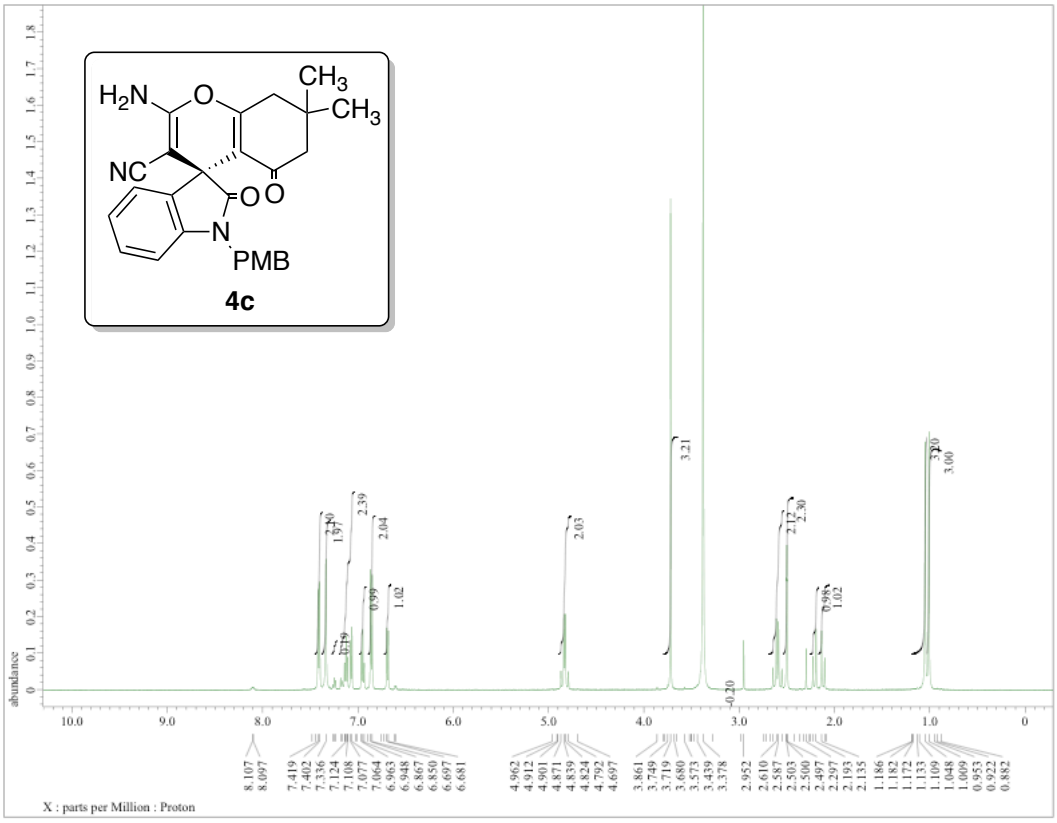


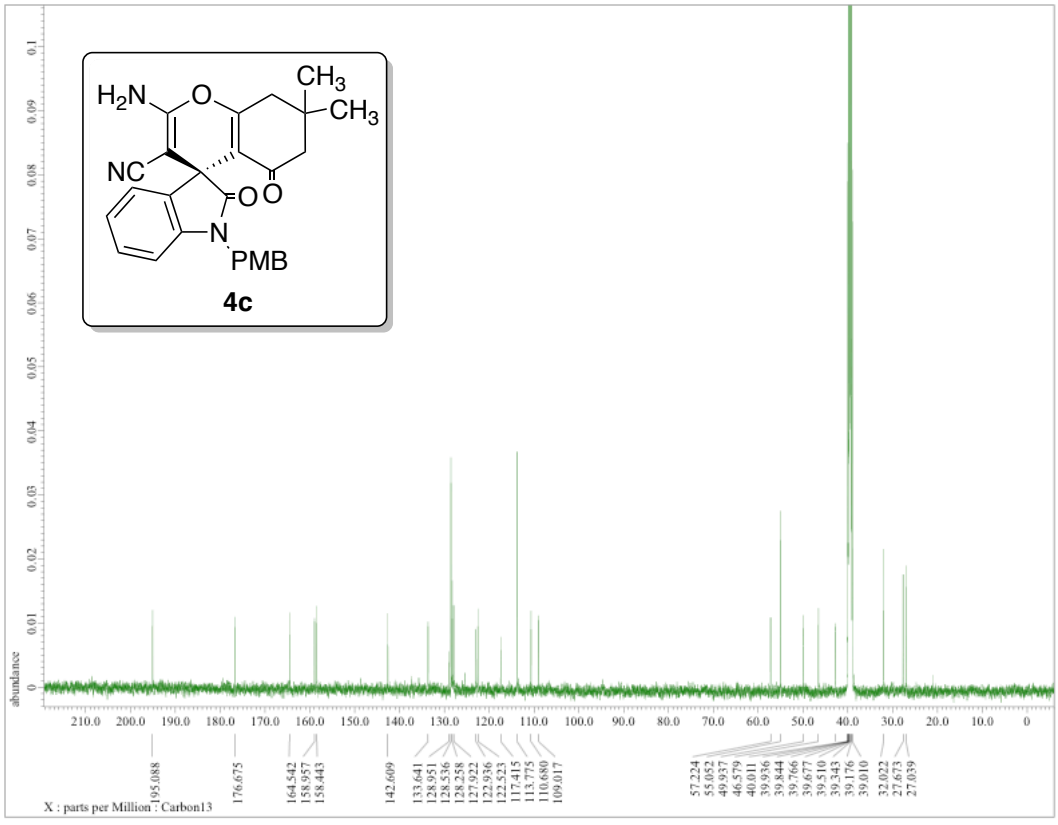
No	Rt(min)	Area	Areea(%)	Height	NTP	Symmetry	Resolution
1	45.68	79894736	32.1297	347994	813.8	1.908	4.223
2	91.84	1.69E+08	67.8703	308554	565.1	1.935	*****
		2.49E+08	100	656548			

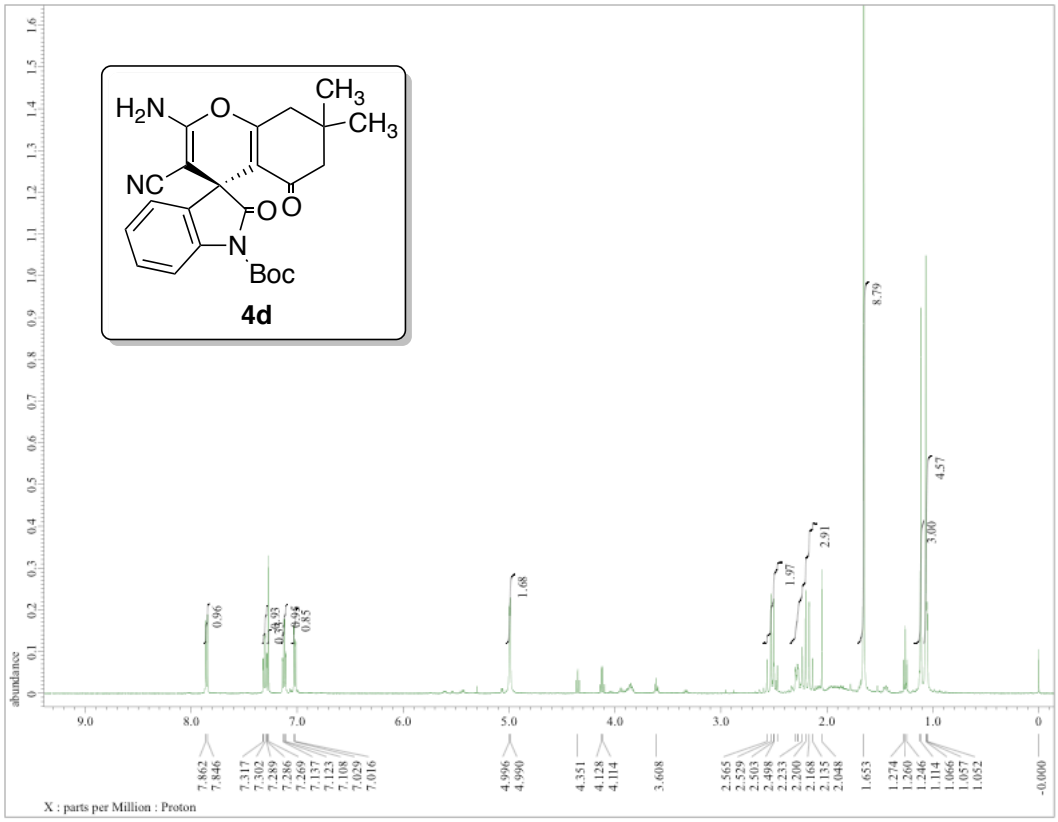
3. Copies of ^{1}HNMR and ^{13}CNMR of **4b-r**

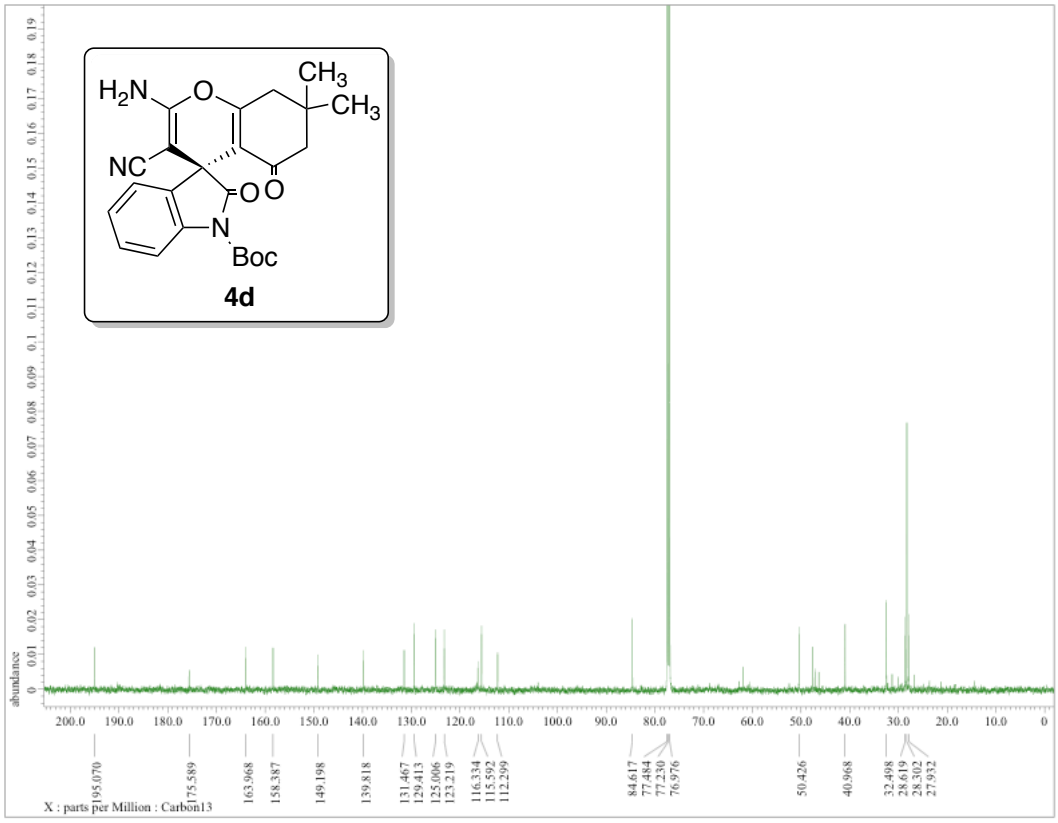


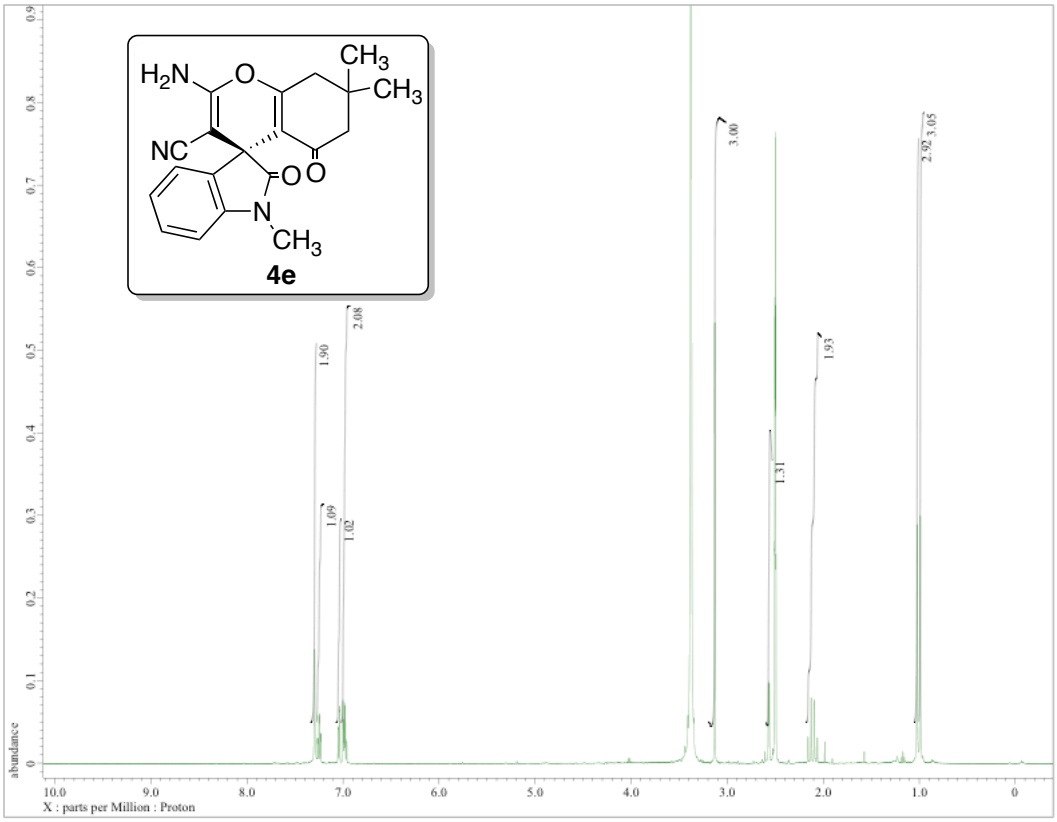


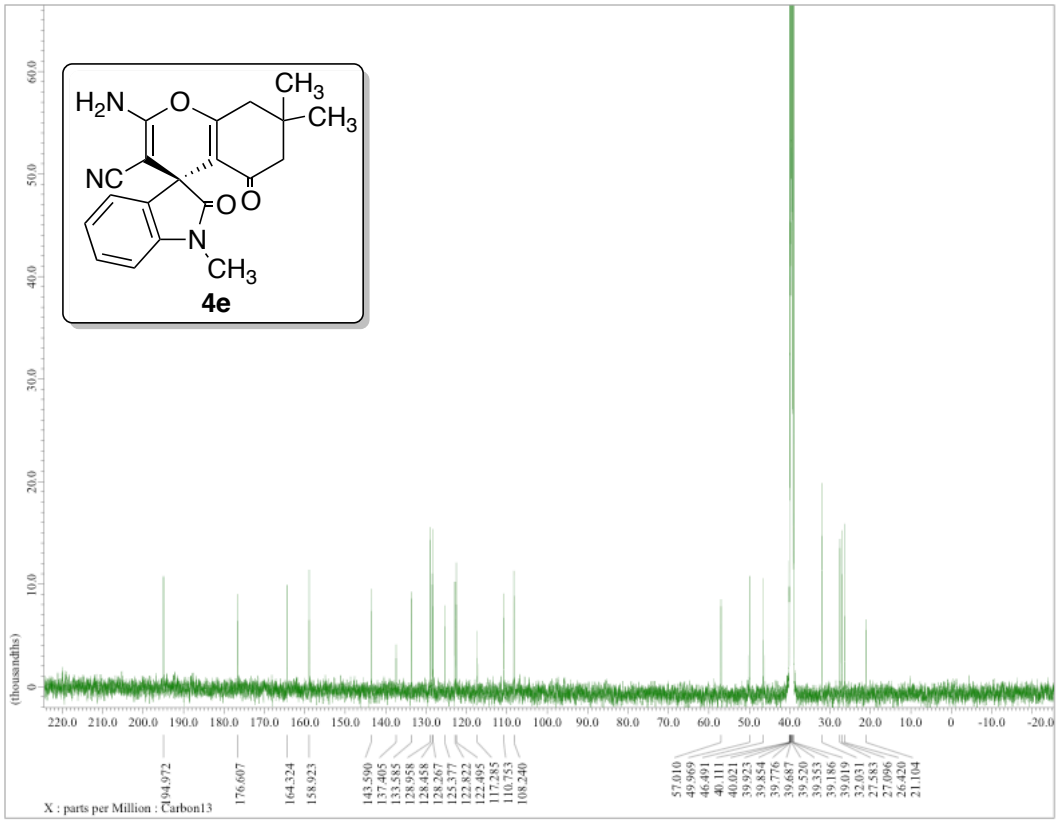

4c
X : parts per Million : Proton

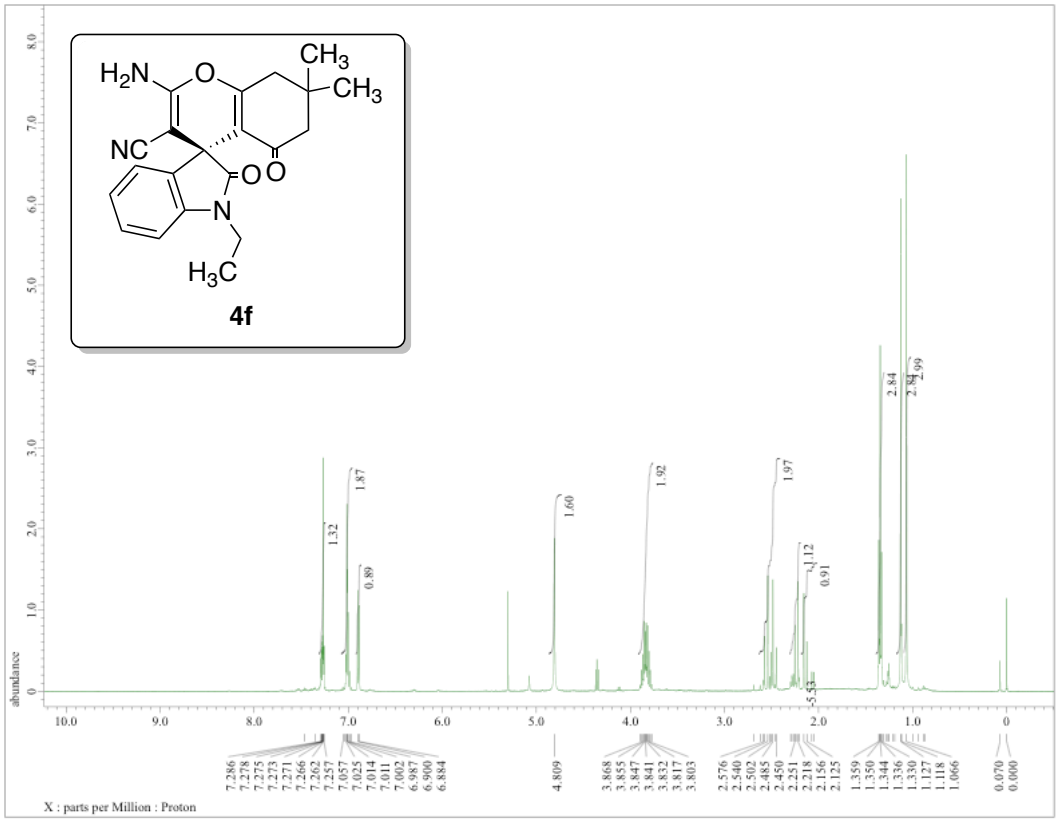

4c
X : parts per Million : Carbon13

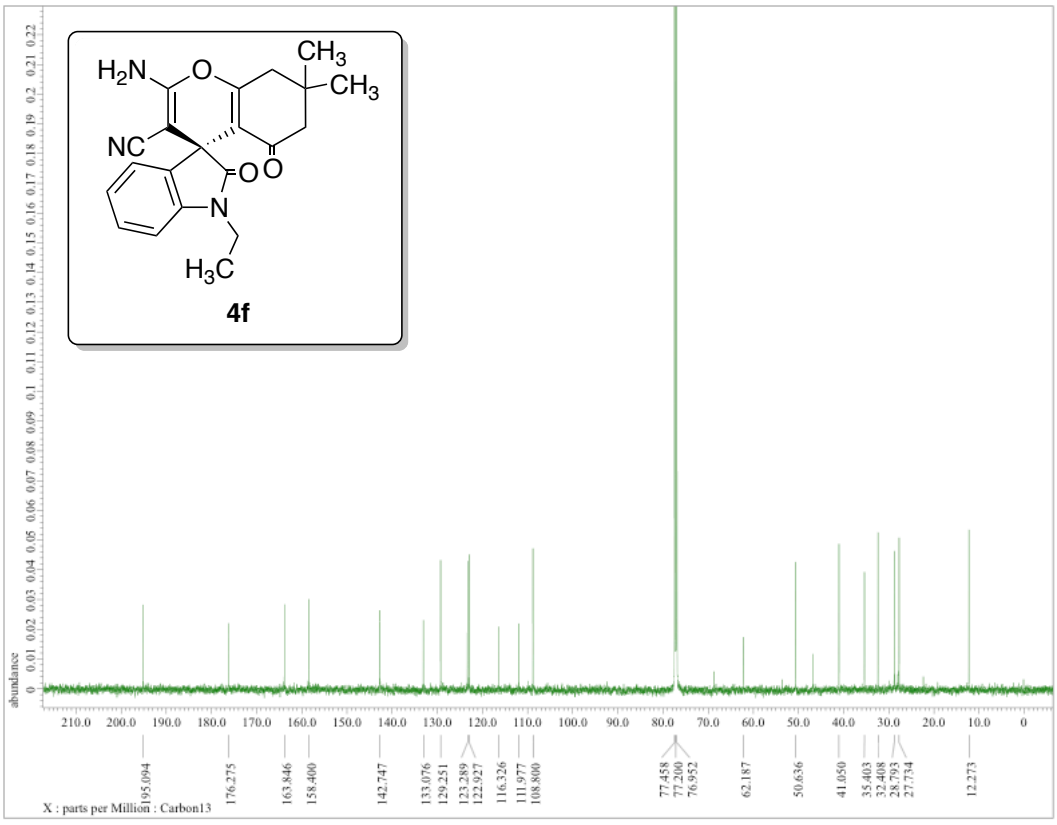

4d
X : parts per Million : Proton

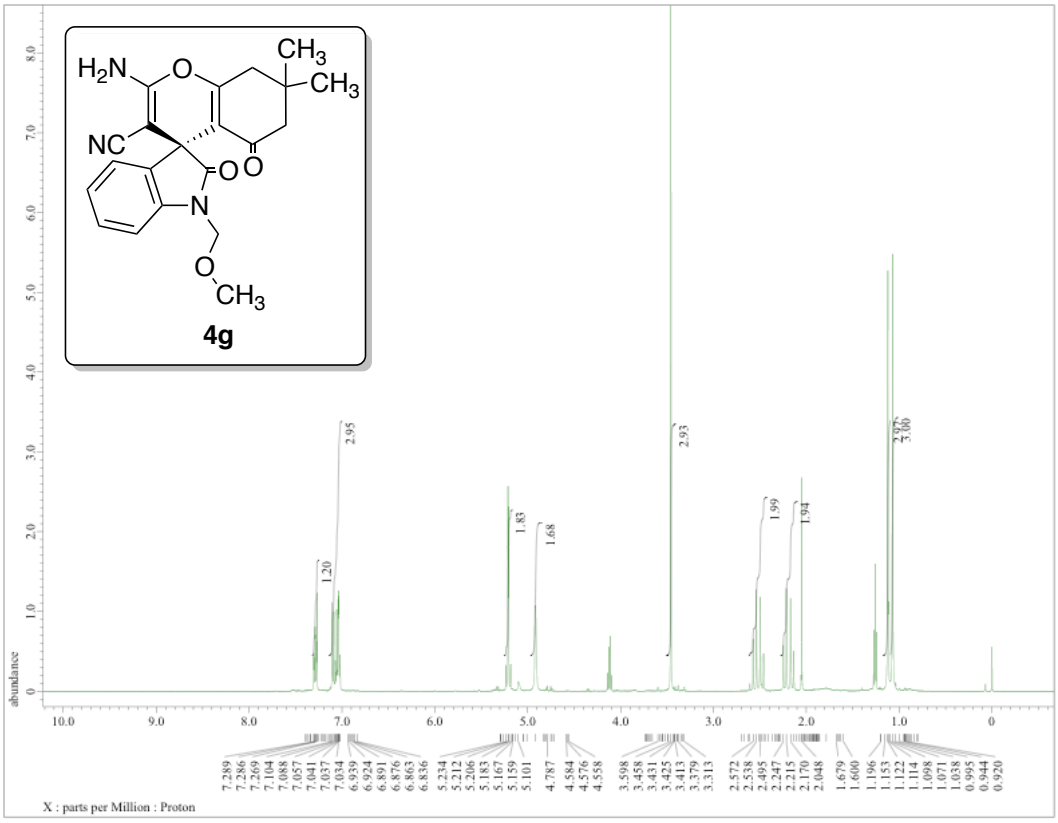

4d
X : parts per Million : Carbon13

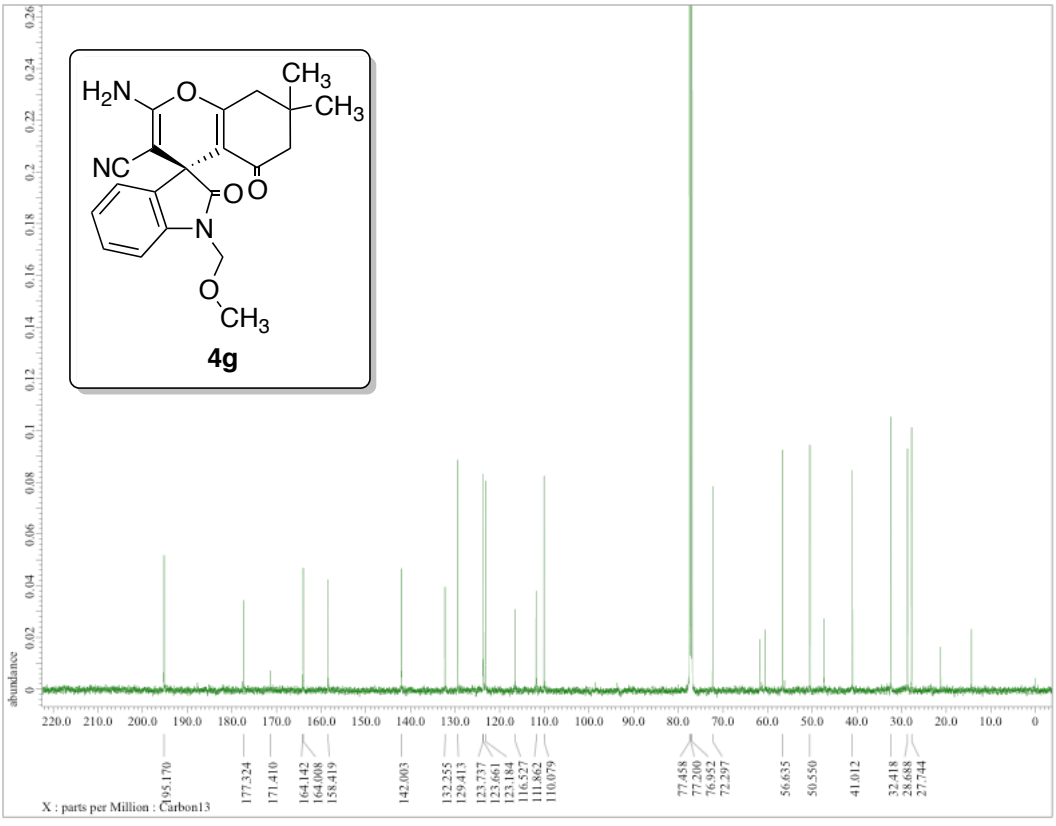

H2N
O
CH3
CH3
NC
O
O
N
CH3
4e
3.00
2.92
3.05
2.08
1.90
1.93
1.31
1.09
1.02
abundance
X : parts per Million : Proton

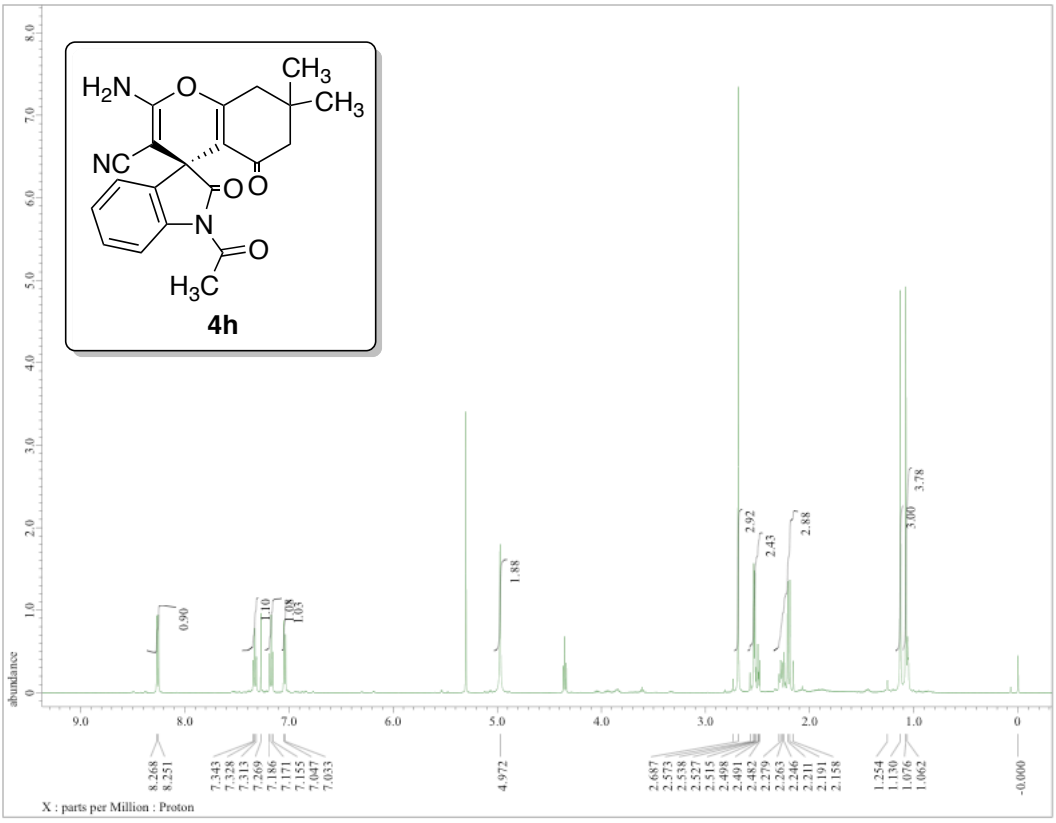

H2N
O
CH3
CH3
NC
O
O
N
CH3
4e
(thousandths)
X : parts per Million : Carbon13

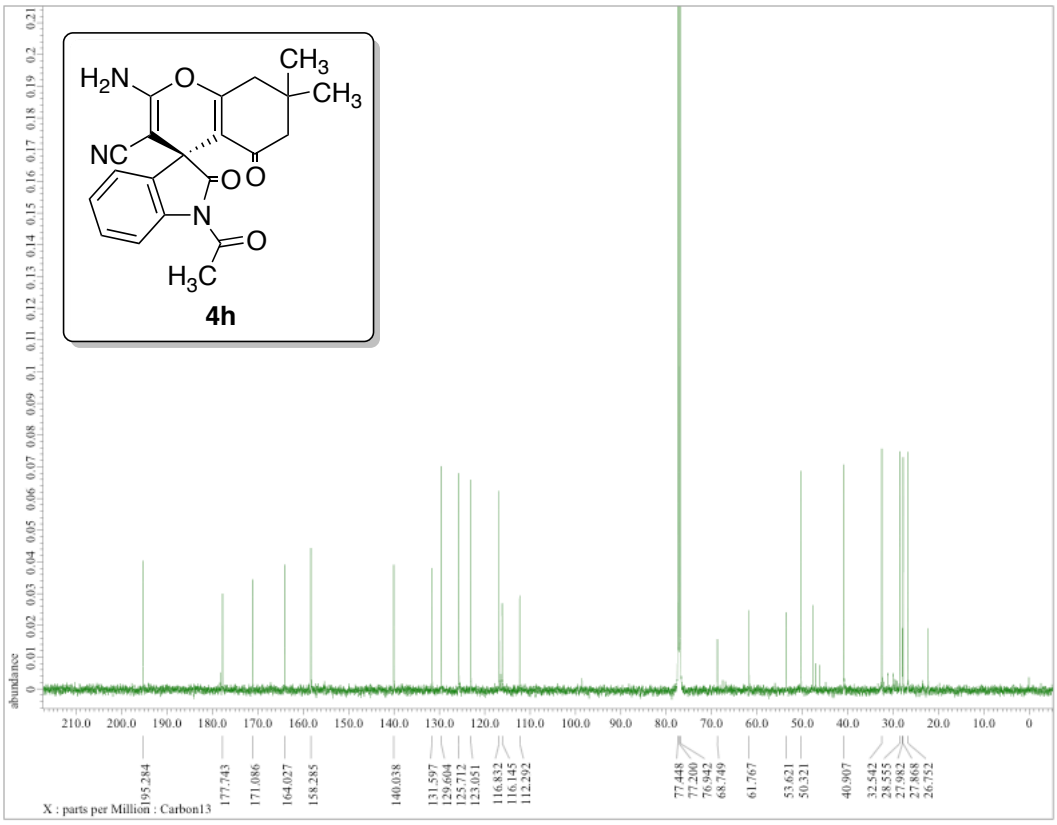

4f
abundance
X : parts per Million : Proton

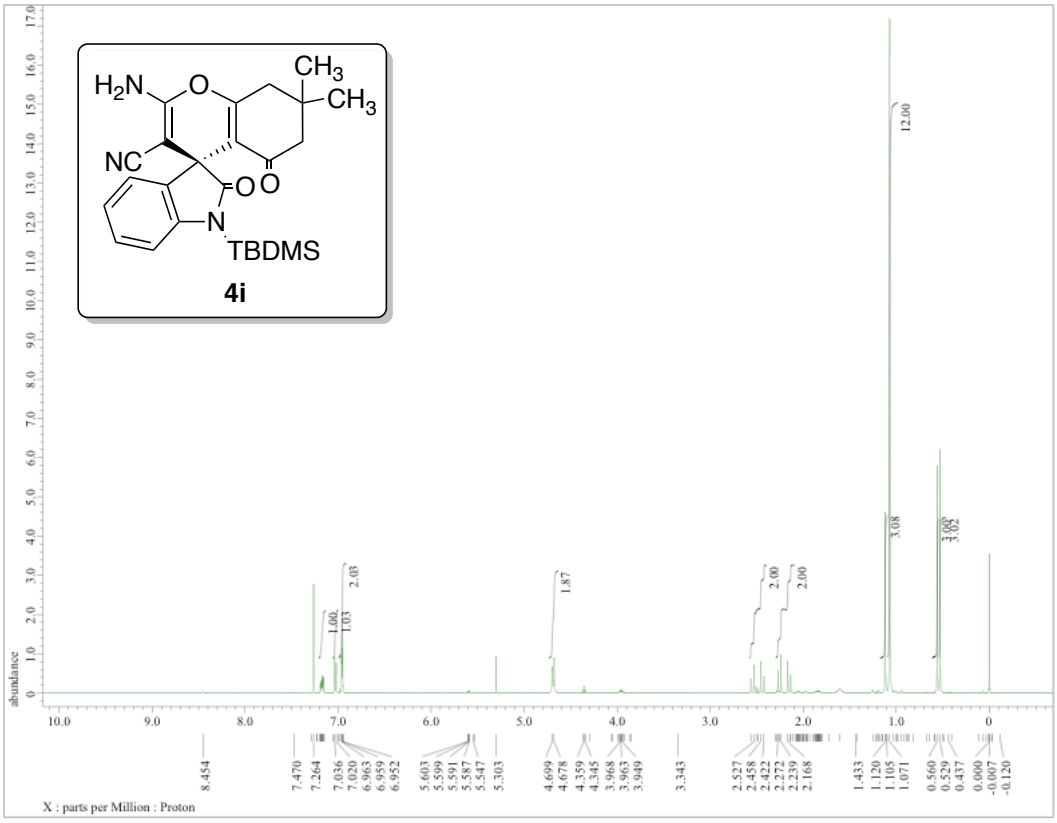

4f
abundance
X : parts per Million : Carbon13

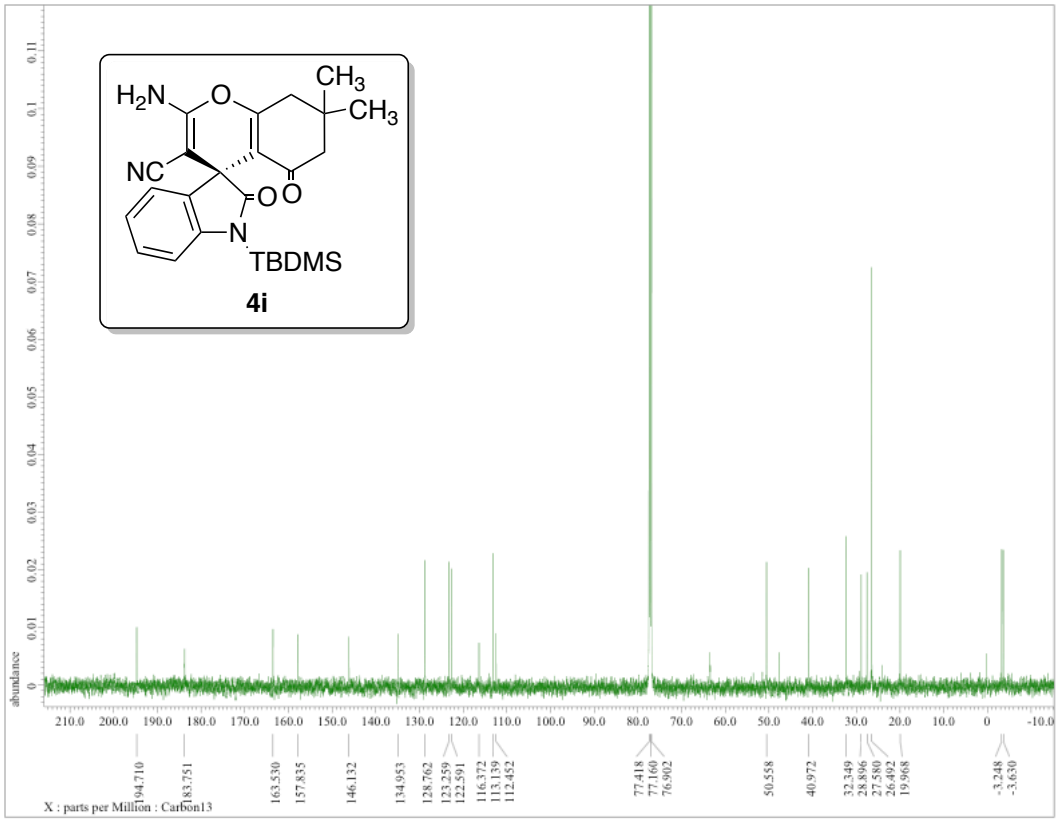

4g
abundance
X : parts per Million : Proton

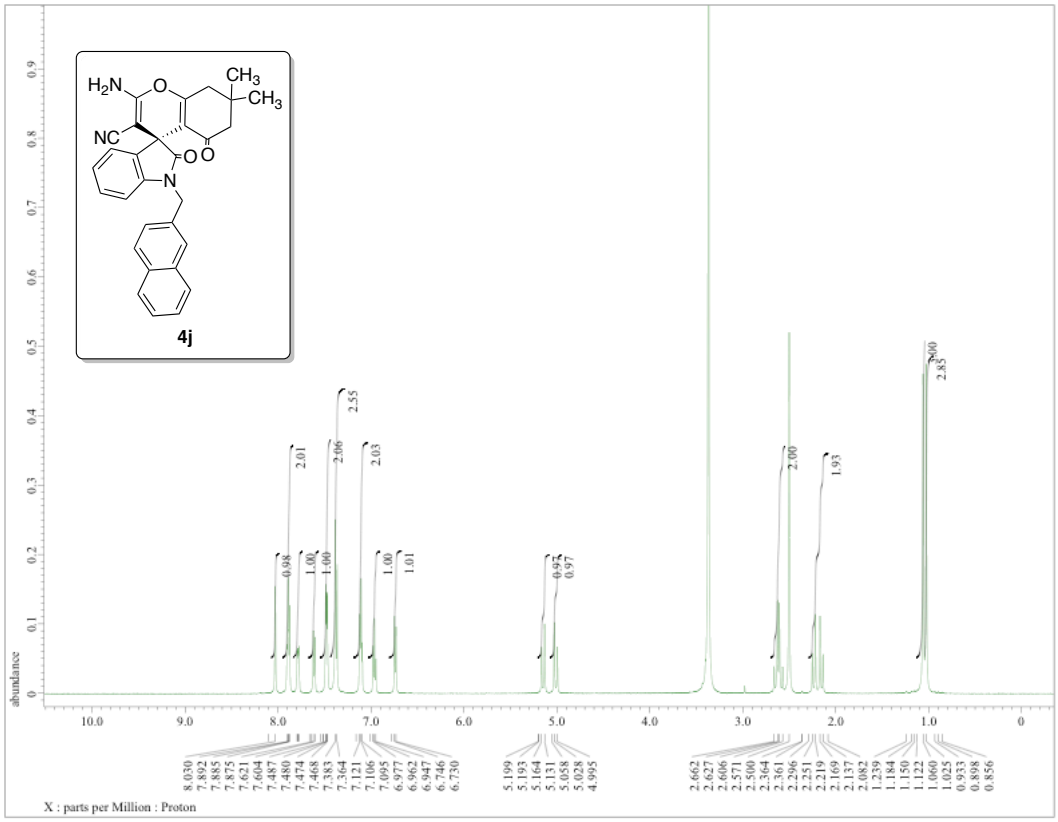

4g
abundance
X : parts per Million : Carbon13

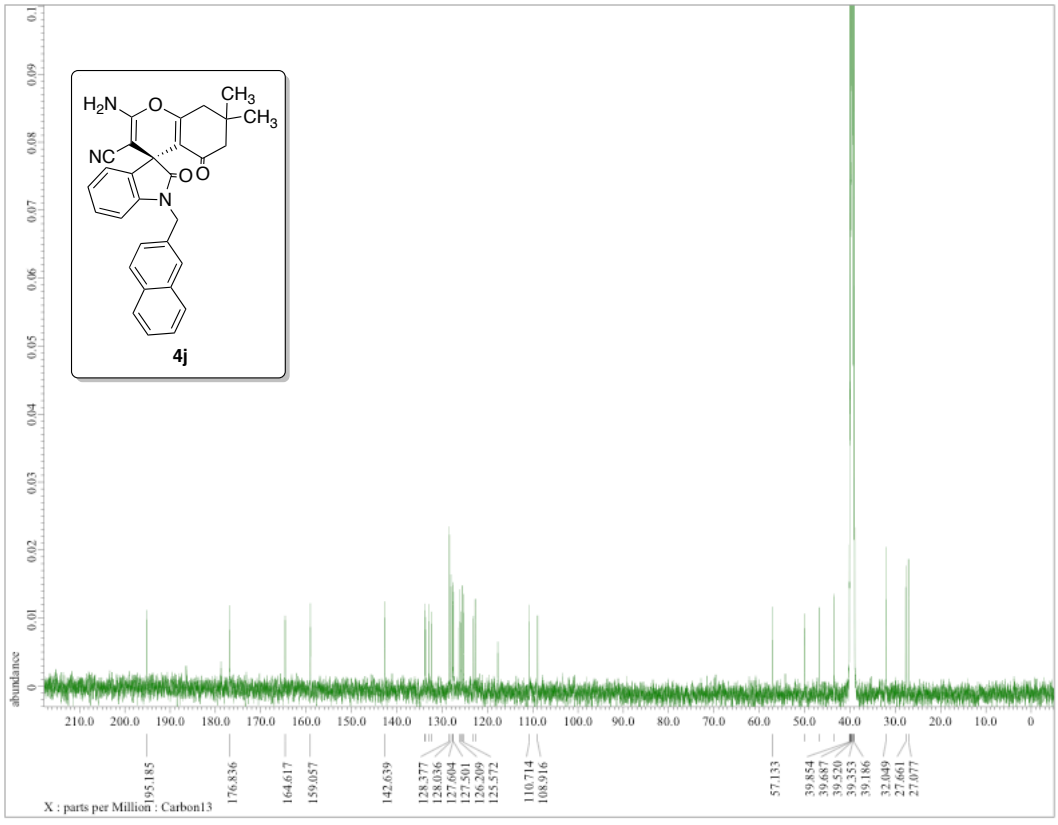

H2N
O
CH3
CH3
NC
O
O
N
O
H3C
4h
abundance
X : parts per Million : Proton

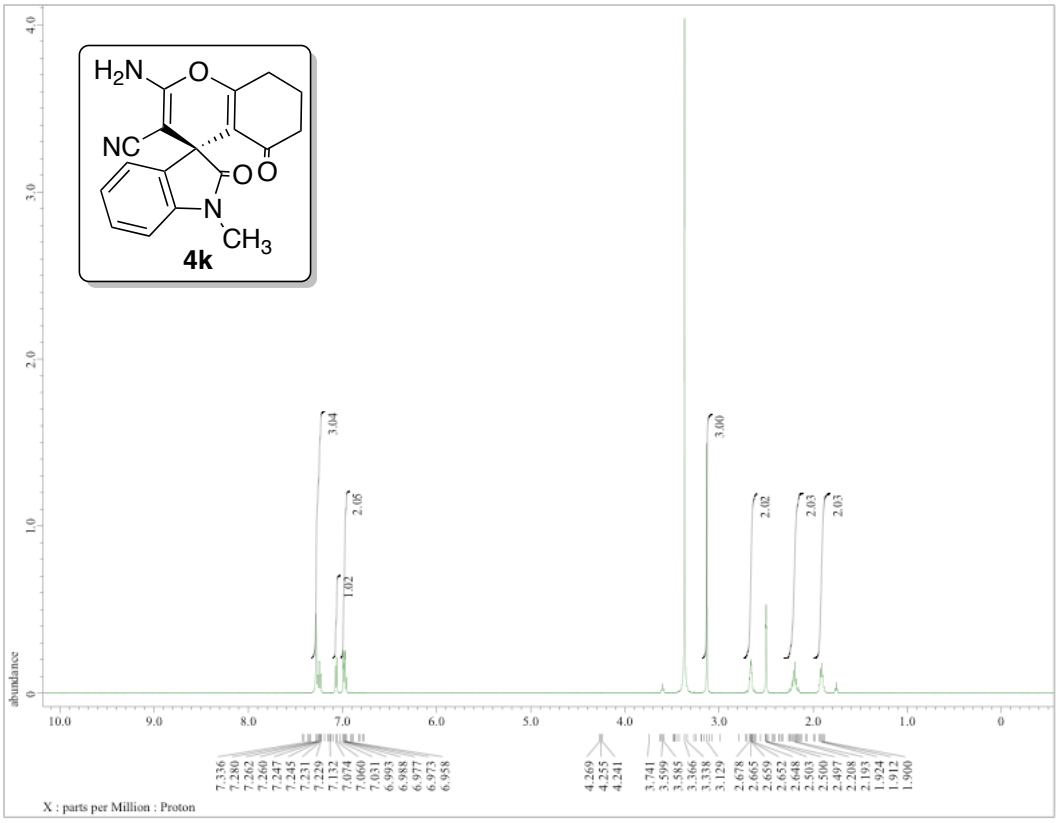

H2N
O
CH3
CH3
NC
O
O
N
O
H3C
4h
abundance
X : parts per Million : Carbon13

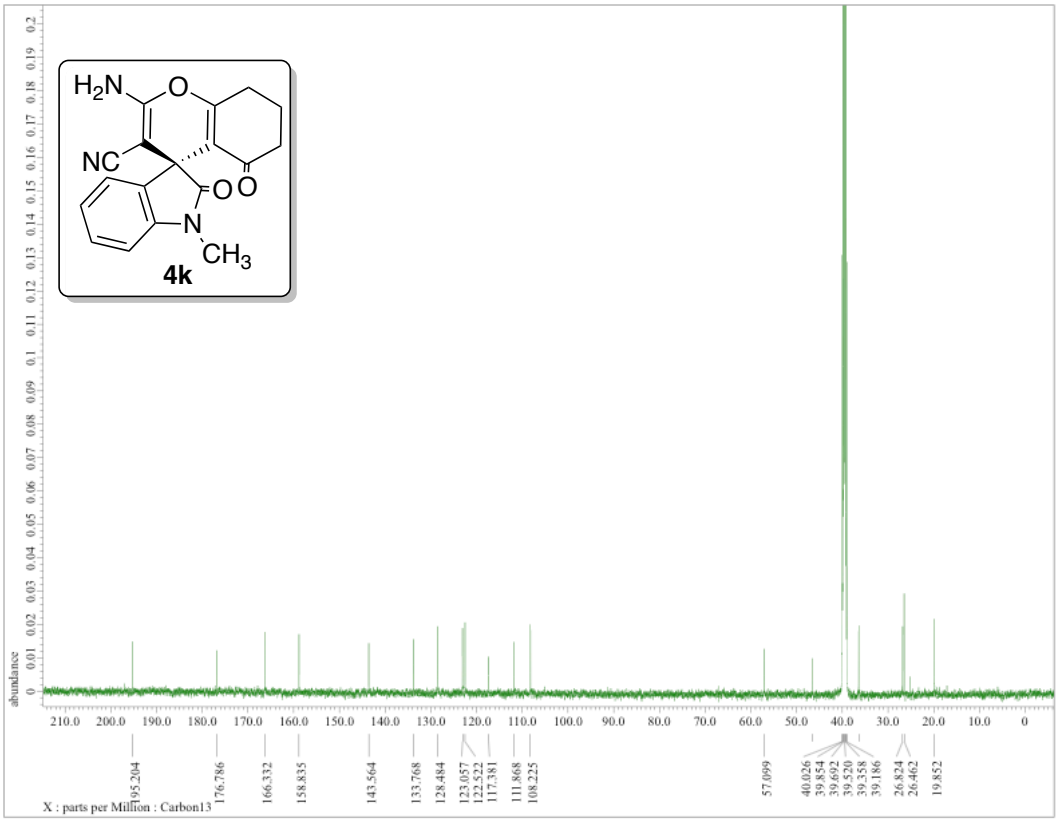

H2N
O
CH3
CH3
NC
O
O
N
TBDMS
4i
abundance
X : parts per Million : Proton

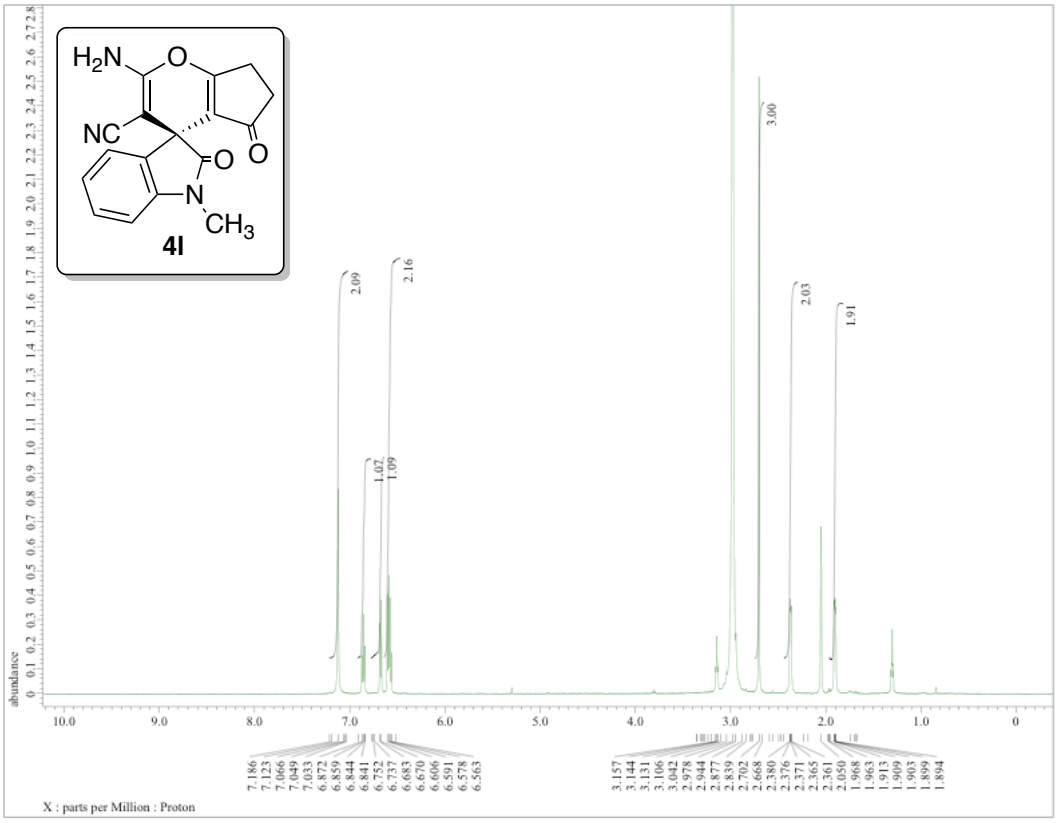

H2N
O
CH3
CH3
NC
O
O
N
TBDMS
4i
abundance
X : parts per Million : Carbon13

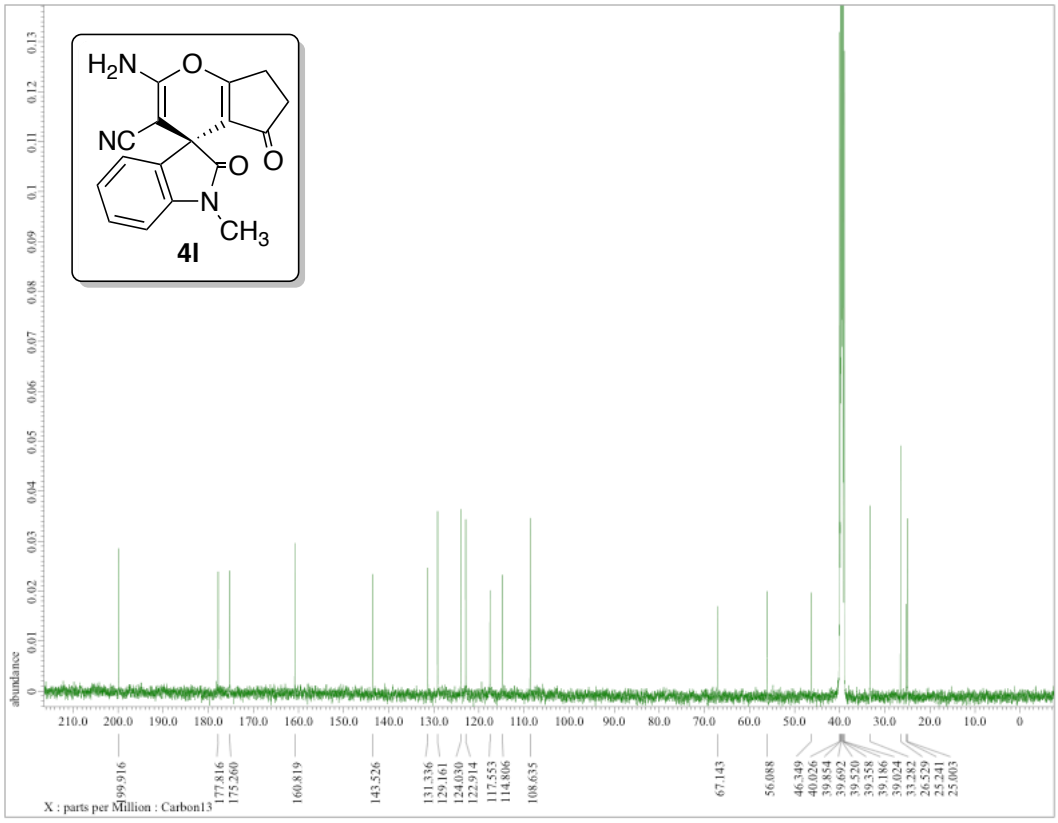

4j
abundance
X : parts per Million : Proton

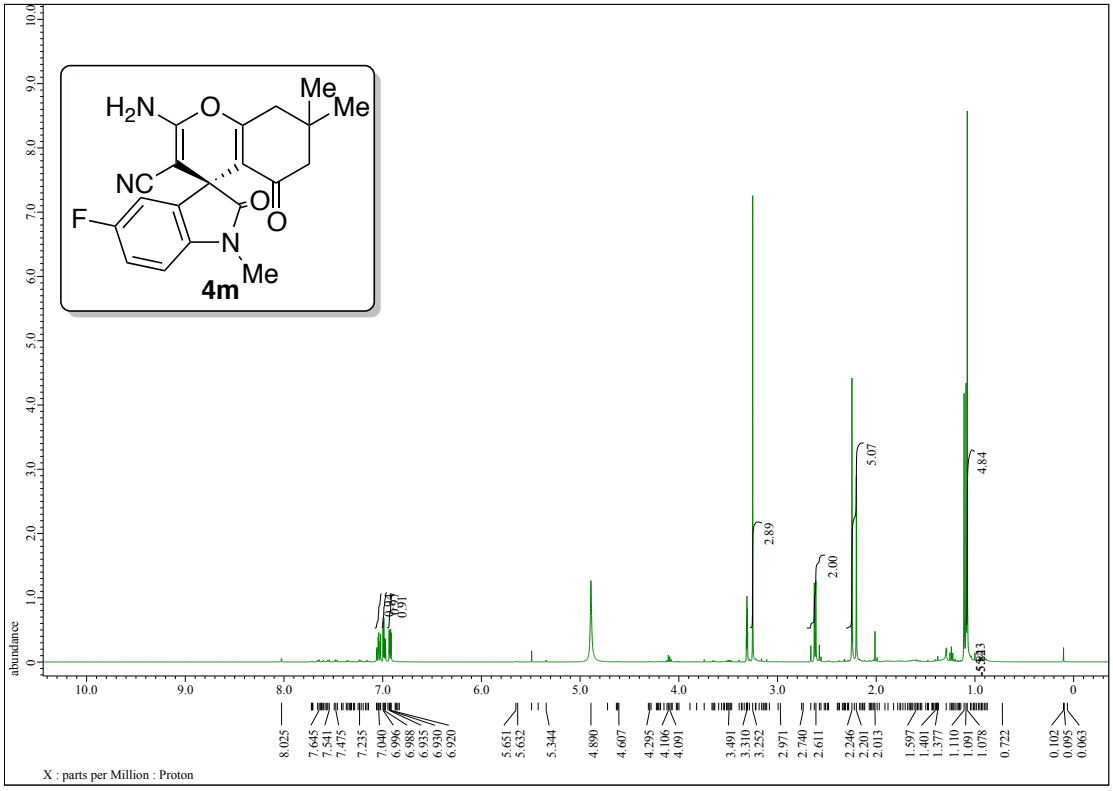

4j
abundance
X : parts per Million : Carbon13

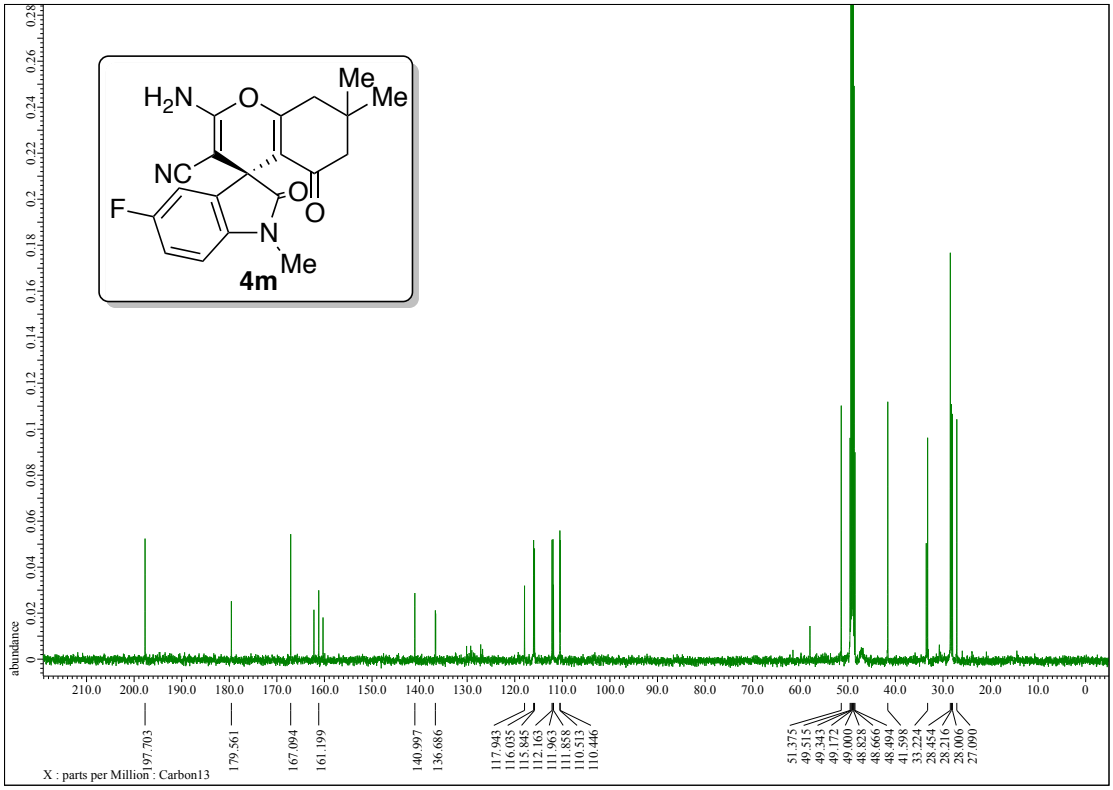

4k
abundance
X : parts per Million : Proton

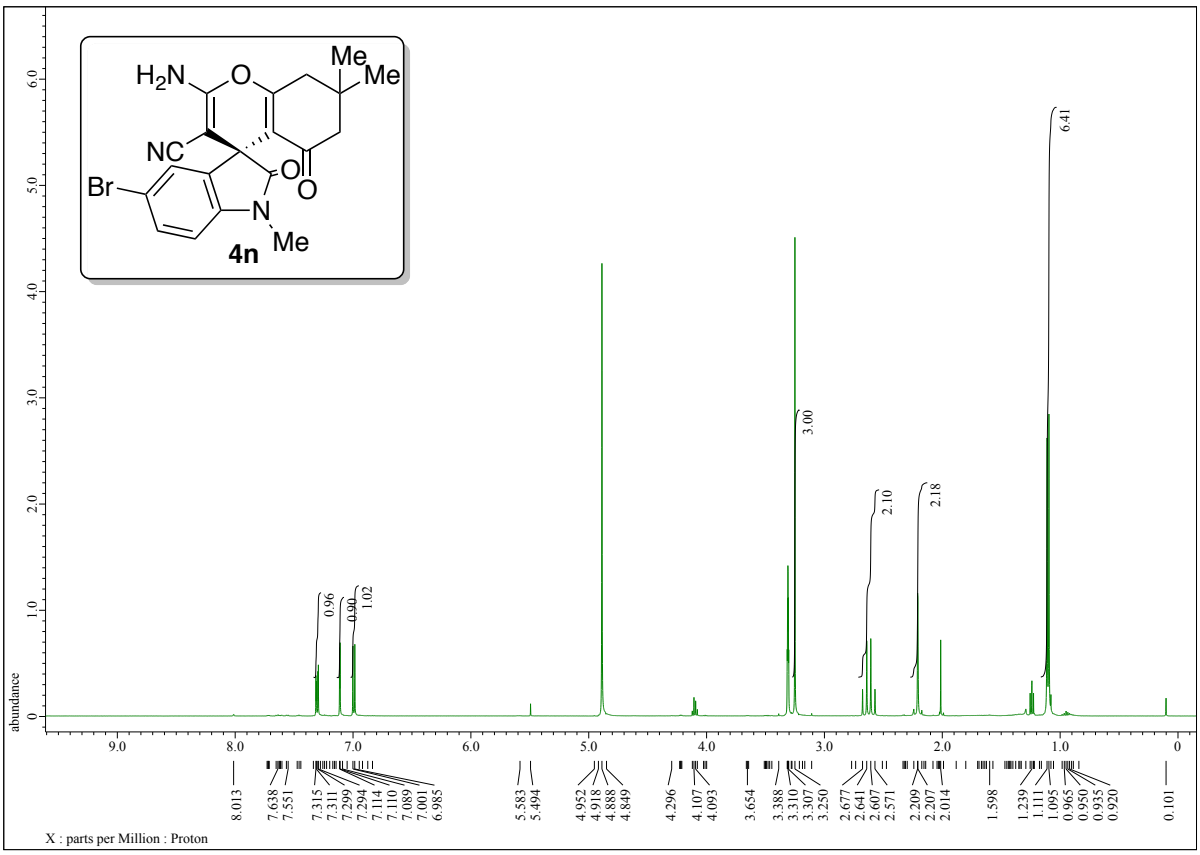

4k
abundance
X : parts per Million : Carbon13

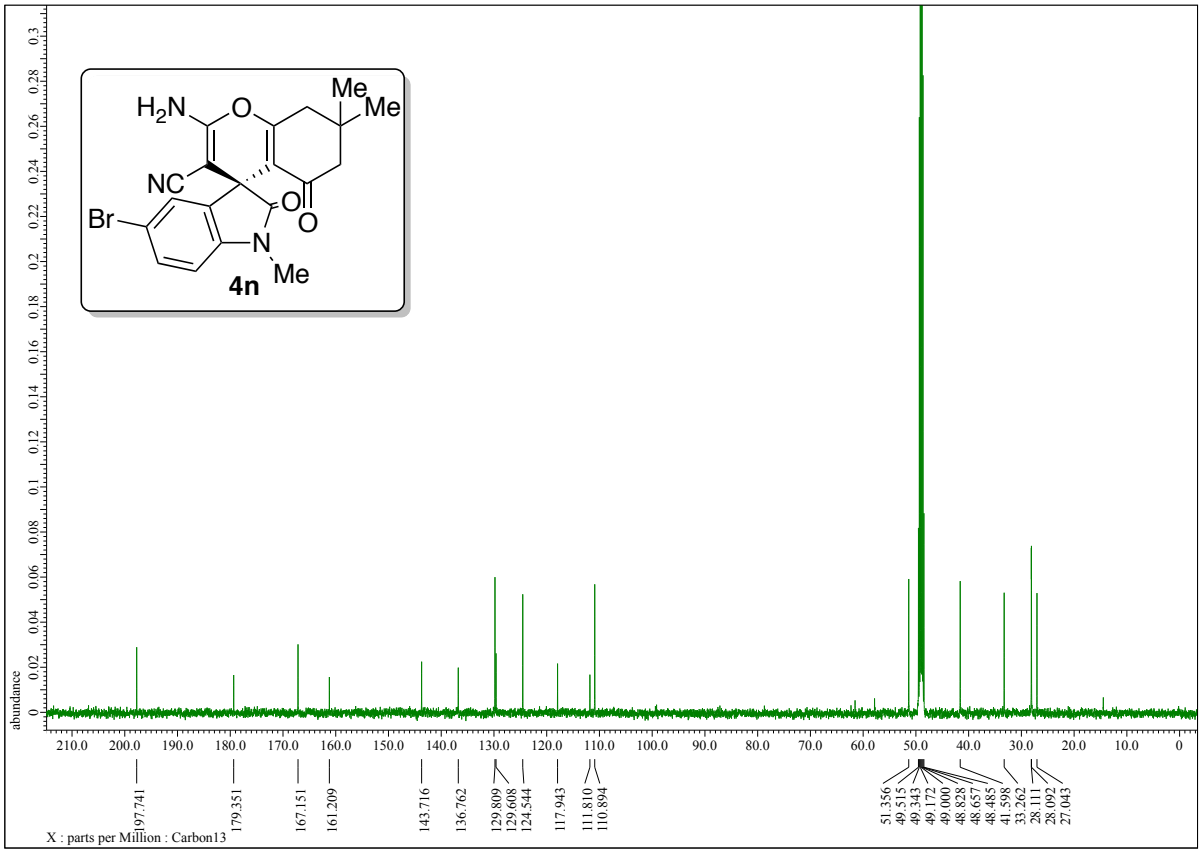

4l
X : parts per Million : Proton

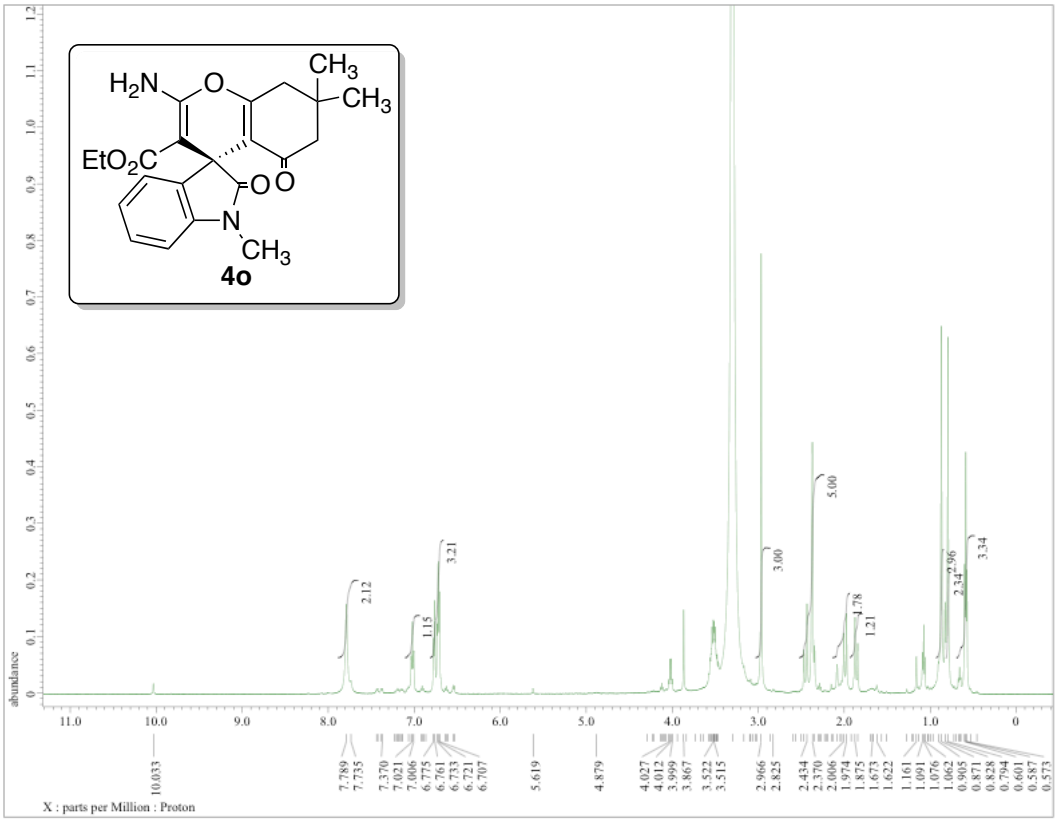

4l
X : parts per Million : Carbon13

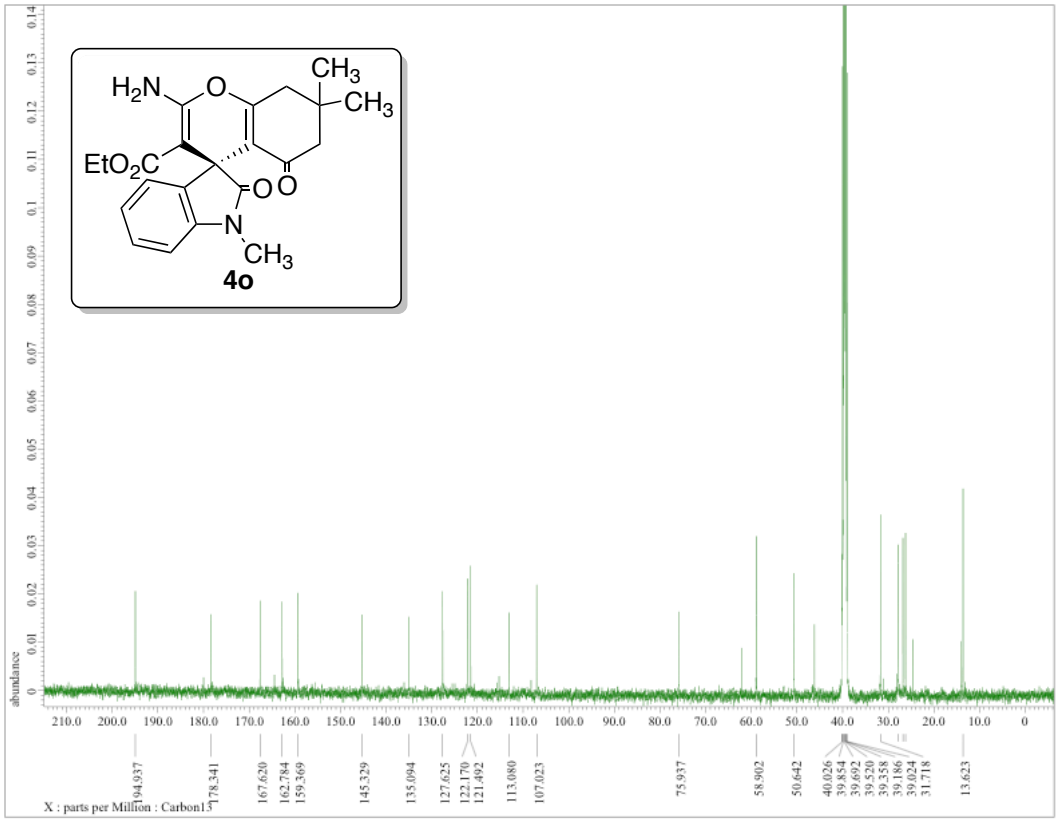

4m
X : parts per Million : Proton
abundance

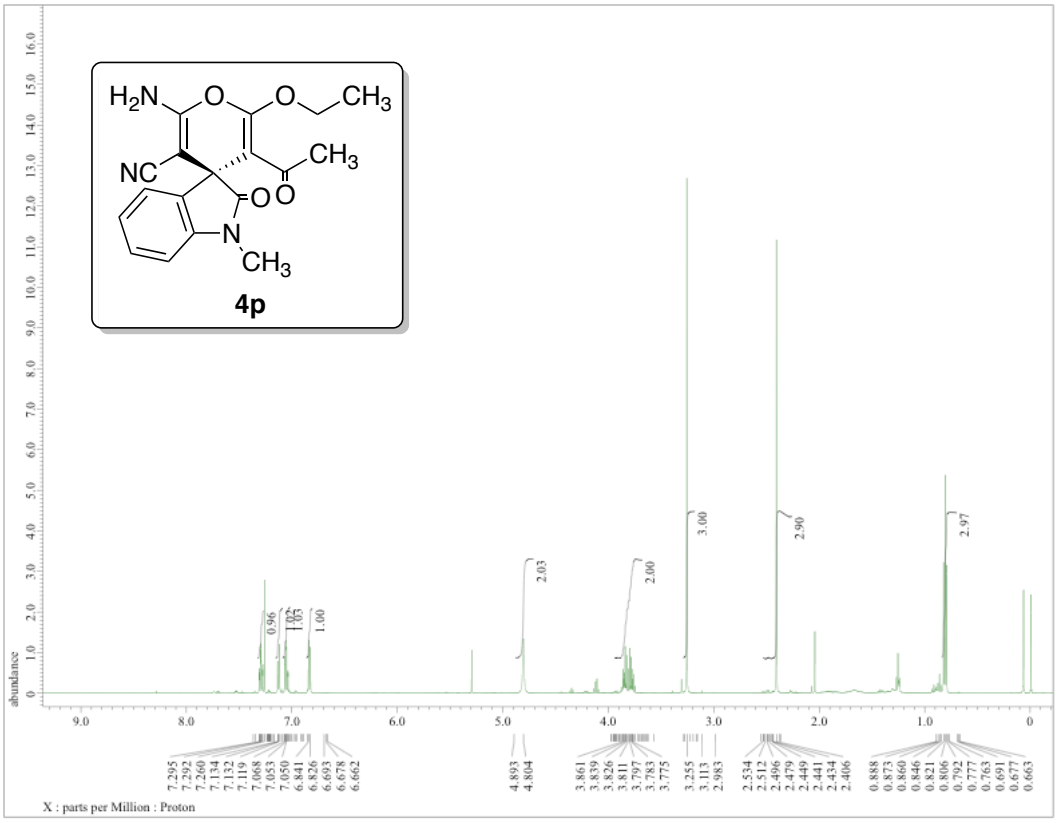

4m
X : parts per Million : Carbon13
abundance

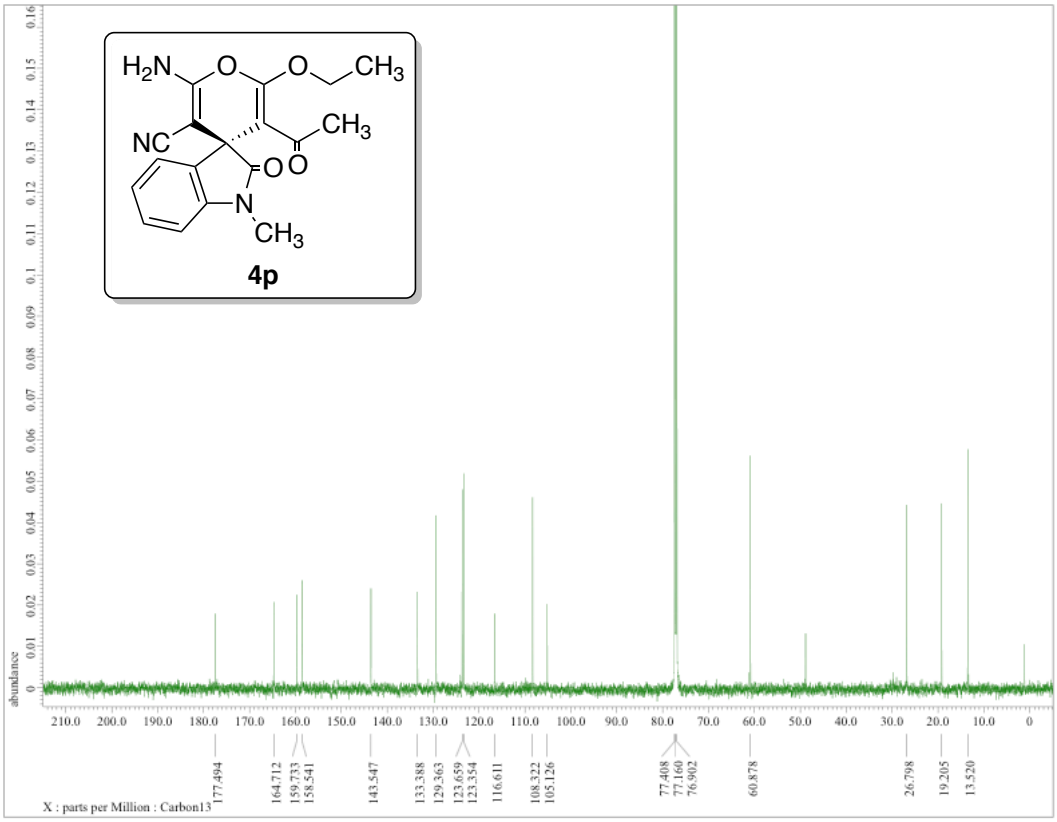

4n
abundance
X : parts per Million : Proton

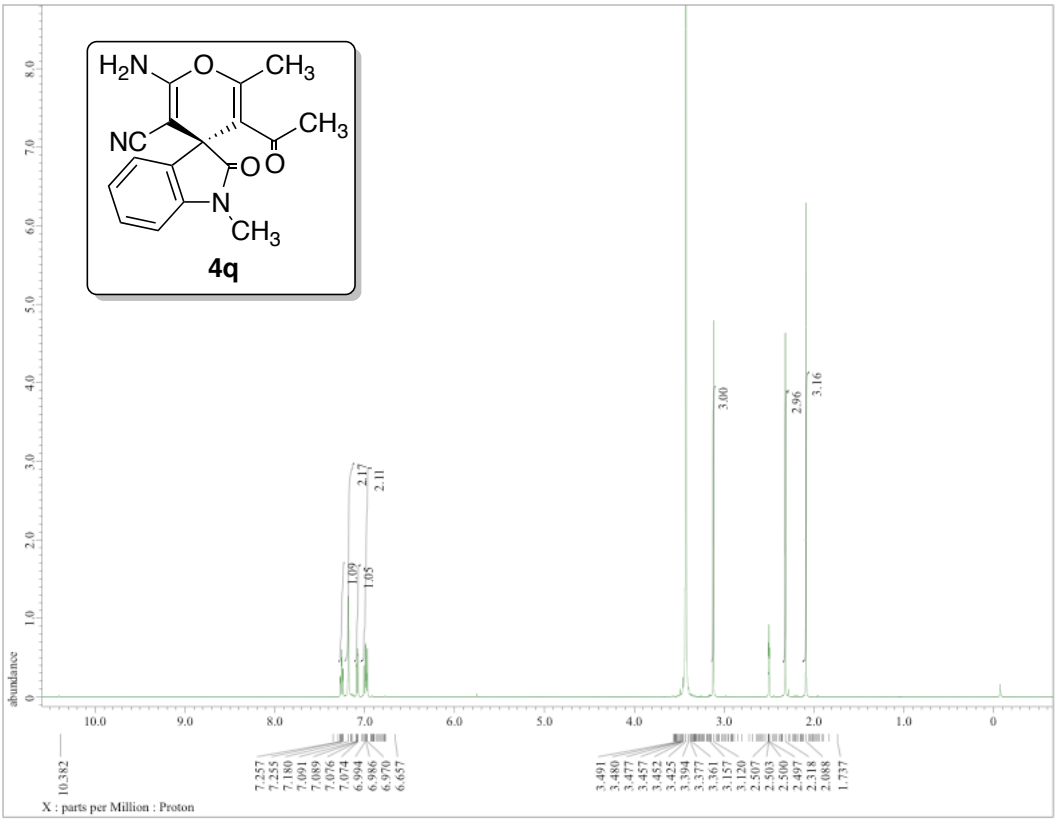

4n
abundance
X : parts per Million : Carbon13

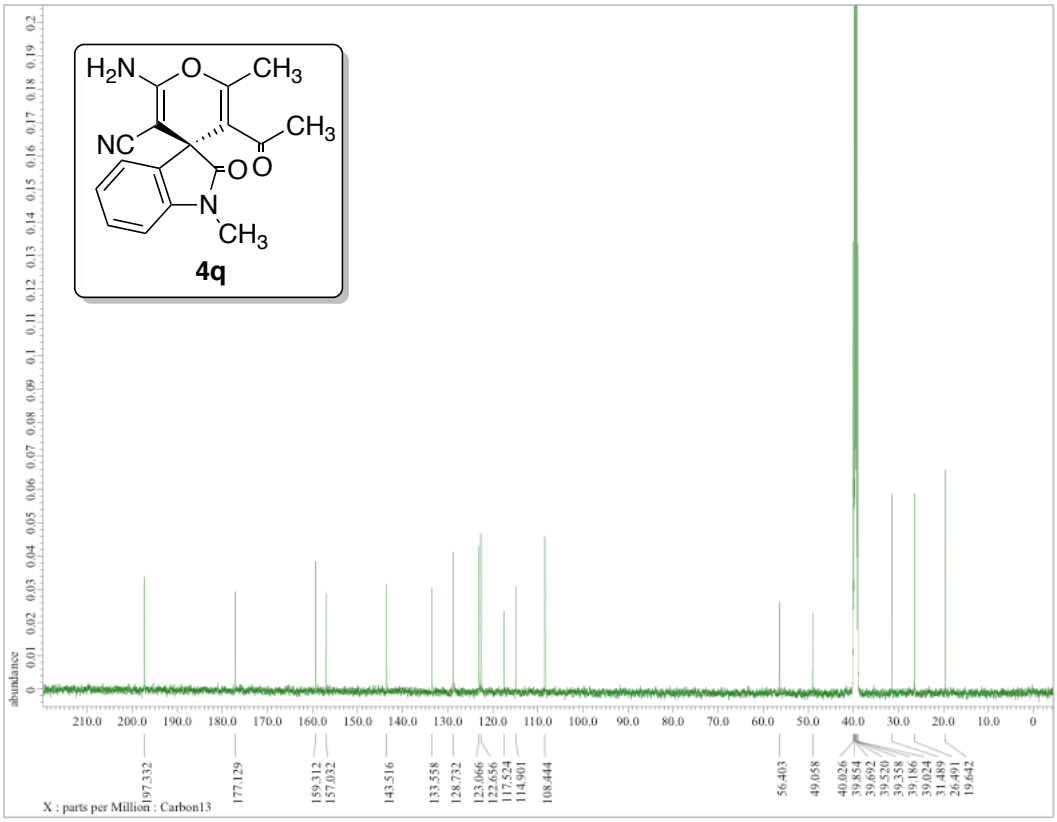

4o
abundance
X : parts per Million : Proton

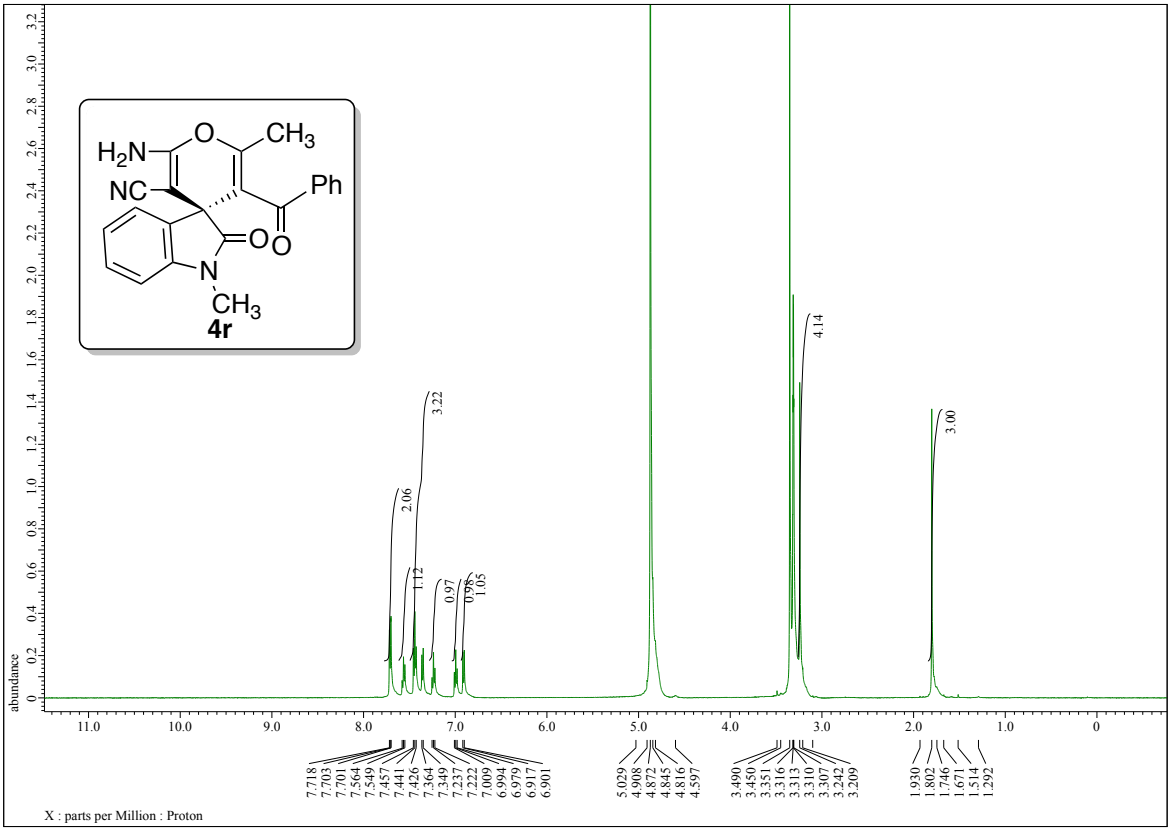

4o
abundance
X : parts per Million : Carbon13

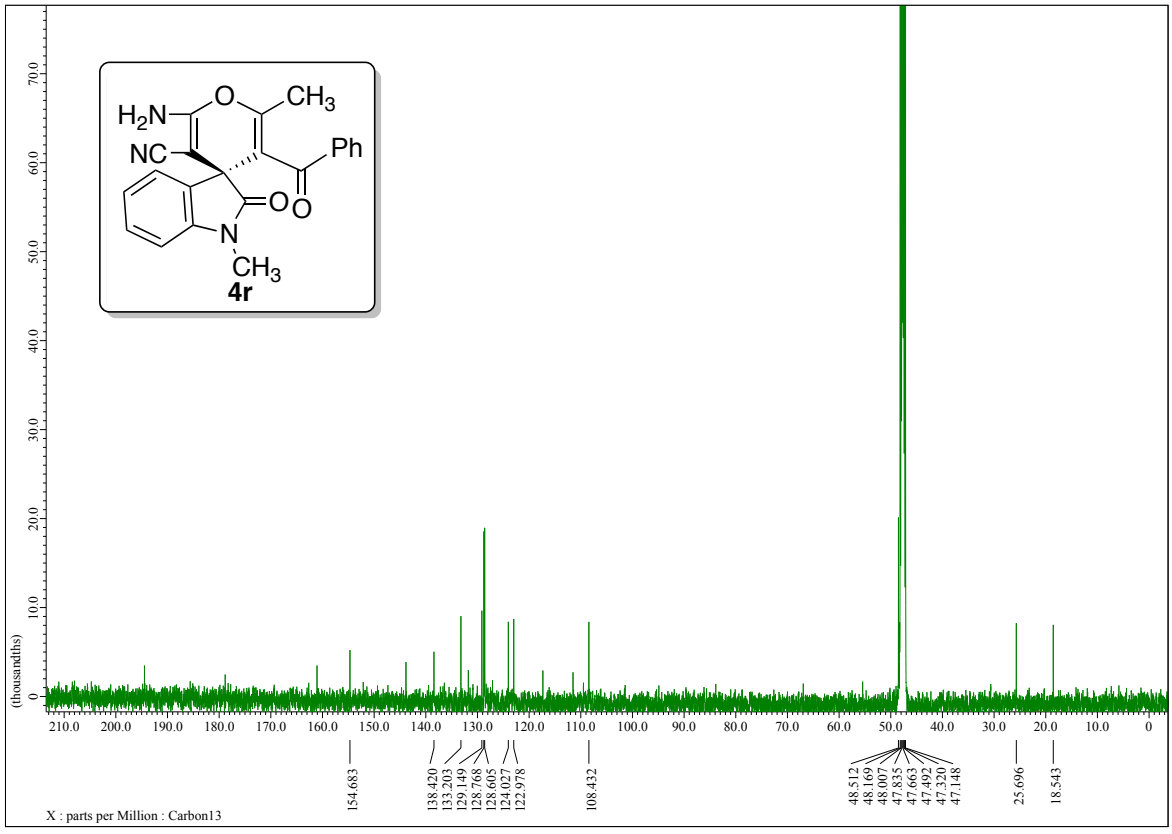

4p
abundance
X : parts per Million : Proton


4p
abundance
X : parts per Million : Carbon13


4q
abundance
X : parts per Million : Proton


4q
abundance
X : parts per Million : Carbon13


4r
abundance
X : parts per Million : Proton


4r
(thousandths)
X : parts per Million : Carbon13

4. X-ray Crystallographic Analysis of **4e**

X-ray diffraction data were collected at 93 K on a Rigaku R-AXIS RAPID diffractometer using multi-layer mirror monochromated Cu-Kα radiation. The structure was solved by direct methods[1] and expanded using Fourier techniques. The non-hydrogen atoms were refined anisotropically. Hydrogen atoms were refined using the riding model. The final cycle of full-matrix least-squares refinement[2] on F^2 was based on 2997 observed reflections and 236 variable parameters and converged (largest parameter shift was 0.00 times its esd) with unweighted and weighted agreement factors of:

$$R_1 = \Sigma \; | \; |F_o| - |F_c| \; | \; / \; \Sigma \; |F_o| = 0.0409$$
$$wR_2 = [\; \Sigma \; (\; w \; (F_o^2 - F_c^2)^2 \;) \; / \; \Sigma \; w(F_o^2)^2]^{1/2} = 0.1092$$

The goodness of fit[3] was 1.04. Unit weights were used. The maximum and minimum peaks on the final difference Fourier map corresponded to 0.37 and -0.42 e-/Å^3, respectively. The final Flack parameter[4] was -0.03(5), indicating that the present absolute structure is correct.[5] A total of 9893 reflections were measured and 2997 were unique (R_{int} = 0.0361). Crystal data and refinement statistics are shown in Table **S1**. Atomic coordinates and B_{iso}/B_{eq} are listed in Table **S2**. Atomic coordinates and B_{iso} involving hydrogen atoms are listed in Table **S3**.

Crystallographic data of **4e** has been deposited with Cambridge Crystallographic Data Center, deposition no. CCDC 1823802.

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1. Sheldrick, G. M. A Short history of SHELX. *Acta Cryst*. **2008**, *A64*, 112-122.
2. Least Squares function minimized: (SHELXL 2013)
   $\Sigma w(F_o^2 - F_c^2)^2$ where w = Least Squares weights.
3. Goodness of fit is defined as:
   $[\Sigma w(F_o^2 - F_c^2)^2/(N_o - N_v)]^{1/2}$
   where: N_o = number of observations
   N_v = number of variables
4. Parsons, S.; Flack, H. Precise absolute-structure determination in light-atom crystals. *Acta Cryst*. **2004**, *A60*, s61.
5. Flack, H.D.; Bernardinelli, G. Reporting and evaluating absolute-structure and absolute-configuration determinations. *J. Appl. Cryst*. **2000**, *33*, 1143-1148.

Table S1. Crystal data and structure refinement.

A. Crystal Data	
Empirical Formula	$C_{20}H_{19}N_3O_3$
Formula Weight	349.39
Crystal Color, Habit	colorless, platelet
Crystal Dimensions	0.100 X 0.100 X 0.100 mm
Crystal System	monoclinic
Lattice Type	Primitive
Lattice Parameters	a = 6.79795(18) Å
	b = 9.9618(3) Å
	c = 12.8161(4) Å
	b = 98.897(7) o
	V = 857.46(4) Å3

Space Group	P_{21} (#4)
Z value	2
Dcalc	1.353 g/cm^3
F000	368.00
μ(CuKα)	7.573 cm^{-1}

B. Intensity Measurements

Diffractometer	R-AXIS RAPID
Radiation	CuKα (l = 1.54187 Å) multi-layer mirror monochromated
Voltage, Current	40kV, 30mA
Temperature	-183.0oC
Detector Aperture	460.0 x 256.0 mm
No. of Reflections Measured	Total: 9893 Unique: 2997 (R_{int} = 0.0361) Parsons quotients (Flack x parameter): 1351
Corrections	Lorentz-polarization Absorption (trans. factors: 0.721 - 0.927) Secondary Extinction (coefficient: 1.07500e-002)

C. Structure Solution and Refinement

Structure Solution	Direct Methods (SHELXS)
Refinement	Full-matrix least-squares on F^2
Function Minimized	Σ w (Fo^2 - Fc^2)^2
Least Squares Weights	w = 1/ [σ2(Fo^2) + (0.0773 . P)2 + 0.3462 . P] where P = (Max(Fo^2,0) + 2Fc^2)/3
2qmax cutoff	135.0o
Anomalous Dispersion	All non-hydrogen atoms
No. Observations (All reflections)	2997
No. Variables	236
Reflection/Parameter Ratio	12.70
Residuals: R_1 (I>2.00s(I))	0.0409
Residuals: R (All reflections)	0.0410
Residuals: wR_2 (All reflections)	0.1092
Goodness of Fit Indicator	1.036
Flack parameter (Parsons' quotients = 1351)	-0.03(5)
Max Shift/Error in Final Cycle	0.000
Maximum peak in Final Diff. Map	0.37 e-/Å3
Minimum peak in Final Diff. Map	-0.42 e-/Å3

Table S2. Atomic coordinates and B_{iso}/B_{eq}

atom	x	y	z	B_{eq}
O3	0.5887(3)	0.1280(2)	0.33069(15)	1.36(3)
O5	0.6485(3)	0.3916(2)	0.19882(16)	1.60(4)
O27	0.1154(3)	0.43951(19)	0.39244(14)	1.14(3)
N1	-0.0838(4)	0.2802(3)	0.44067(19)	1.35(4)
N6	0.4631(3)	0.1157(2)	0.15315(18)	1.21(4)
N12	0.0859(4)	-0.0328(3)	0.3494(2)	1.98(5)
C2	0.3834(4)	0.4002(3)	0.2967(2)	0.96(4)
C7	0.3462(4)	0.6173(3)	0.3942(2)	1.16(4)
C8	0.1136(4)	0.0798(3)	0.3371(2)	1.34(5)
C9	0.3890(4)	0.7272(3)	0.2224(2)	1.39(5)
C10	0.3133(4)	0.1812(3)	0.0832(2)	1.21(4)
C11	0.2643(4)	0.1629(3)	-0.0252(2)	1.42(5)
C13	0.1086(4)	0.2414(3)	-0.0771(2)	1.65(5)
C14	0.0051(4)	0.3319(3)	-0.0231(2)	1.54(5)
C15	0.6559(4)	0.5774(3)	0.3182(2)	1.23(5)
C16	0.4954(4)	0.6818(3)	0.3311(2)	1.14(4)
C17	0.2990(4)	0.2655(3)	0.2548(2)	1.07(5)
C18	0.1530(4)	0.2190(3)	0.3262(2)	1.12(4)
C19	0.6228(5)	0.0374(3)	0.1190(3)	1.70(5)
C20	0.5901(4)	0.8033(3)	0.3922(2)	1.46(5)
C21	0.2109(4)	0.2705(3)	0.1383(2)	1.10(5)
C22	0.4698(4)	0.1624(3)	0.2539(2)	1.10(4)
C23	0.2869(4)	0.4782(3)	0.3574(2)	1.05(4)
C24	0.5688(4)	0.4509(3)	0.2645(2)	1.16(4)
C25	0.0560(4)	0.3468(3)	0.0867(2)	1.37(5)
C26	0.0606(4)	0.3070(3)	0.3835(2)	1.08(4)

$B_{eq} = 8/3\ \pi^2(U_{11}(aa^*)^2 + U_{22}(bb^*)^2 + U_{33}(cc^*)^2 + 2U_{12}(aa^*bb^*)\cos\gamma + 2U_{13}(aa^*cc^*)\cos\beta + 2U_{23}(bb^*cc^*)\cos\alpha)$

Table S3. Atomic coordinates and B_{iso} involving hydrogen atoms.

atom	x	y	z	B_{iso}
H1A	-0.12861	0.19765	0.44383	1.620
H1B	-0.13378	0.34509	0.47508	1.620
H7A	0.40578	0.61390	0.46970	1.386
H7B	0.22556	0.67422	0.38811	1.386
H9A	0.48566	0.76826	0.18283	1.673
H9B	0.28576	0.79290	0.23164	1.673
H9C	0.32757	0.64935	0.18347	1.673
H11	0.33314	0.10023	-0.06218	1.698
H13	0.07255	0.23275	-0.15143	1.981
H14	-0.10022	0.38359	-0.06063	1.854
H15A	0.75176	0.61693	0.27608	1.480
H15B	0.72960	0.55416	0.38863	1.480
H19A	0.58654	0.01418	0.04423	2.045
H19B	0.64343	-0.04502	0.16108	2.045

H19C	0.74578	0.09033	0.12888	2.045
H20A	0.68536	0.84560	0.35238	1.753
H20B	0.65952	0.77407	0.46124	1.753
H20C	0.48614	0.86805	0.40229	1.753
H25	-0.01428	0.40768	0.12445	1.648