GC-MS半揮発性有機化合物分析：微量分析の限界に挑む

低濃度SVOC分析におけるGC-MSの感度とピーク形状の課題

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- 次世代TriMax不活性化処理により、より低い検出限界でも品質基準を満たすデータが取得可能に
- 高い不活性度により、分析が難しい成分を含む多様なSVOCにおいてシャープで対称性の高いピーク形状を実現
- 高感度分析（SIM）と汎用的なスクリーニング（scan）の両方に適したGC-MS分析条件を確立

SVOCのGC-MS分析で検出限界の改善が求められる背景

半揮発性有機化合物の分析を実施するラボでは、顧客要求や溶媒削減（規制対応・コスト削減）のため、検出限界の引き下げが常に求められています。MSベースのメソッド（例：EPA 8270）は一般的なアプローチであり、MSを活用することでより低い検出限界を実現できます。

EPA Method 8270に代表されるMSを用いたSVOCの分析手法は広く活用されており、ラボは目的に応じてベストな検出限界を達成できる装置を柔軟に選択できます。例えば、GC-MS/MSのような高感度な装置を採用する場合もある一方で、GC-MSを用いてSIMによる感度向上を図る運用や、より汎用的なscanモードによる分析を選択する場合もあります。

SVOC分析におけるGC-MSのscan法とSIM法の使い分け

SIMとscanはどちらもGC-MSで実施可能ですが、scanが幅広い質量範囲の信号をまとめて取得するシンプルで汎用的な手法であるのに対し、SIMは特定イオンを特定の保持時間に絞って測定することができるため、より高い感度が得られます。SIMはメソッドの設定や維持が煩雑になる傾向がありますが、検出限界の引き下げを検討する場合、新たな装置投資を行わずに感度を高める選択肢として、GC-MSのSIM運用が有力候補になります。

低濃度SVOC分析を想定したGC-MS測定ワークフロー

本研究では、シンプルで堅牢な scanと、GC-MS/MSに代わり得る高感度なSIMという二つのワークフローを目的に応じて選択できるよう、scanとSIMの両モードにおけるGC-MS半揮発性有機化合物分析の条件を確立しました（**Figure 1 & Figure 2**）。

RMX-5Sil MSカラムによるSVOC分析のクロマトグラフィー性能評価

いずれのメソッドもRMX-5Sil MSカラムを採用しました。このカラムは標準的な5silの選択性を備えながらも、次世代のTriMax不活性化処理により、極めて高い不活性度を実現することが示されています[1,2]。**Figure 2**に示すように、ベンジジン、ペンタクロロフェノール、2,4-ジニトロフェノールといった主要化合物において、ピーク対称性は一貫して品質目標（≤2）を満たしました。さらに、分離が難しいPAH類については、EPA 8270のシステム適合性で求められるvalley% 基準（>50%）に対し、benzo[b]fluoranthenebenzo[k]fluoranthenのピーク間valley%は94%、indeno[1,2,3-cd]pyreneとdibenz[a,h]anthraceneのvalley%は95%と、極めて良好な結果が得られました。

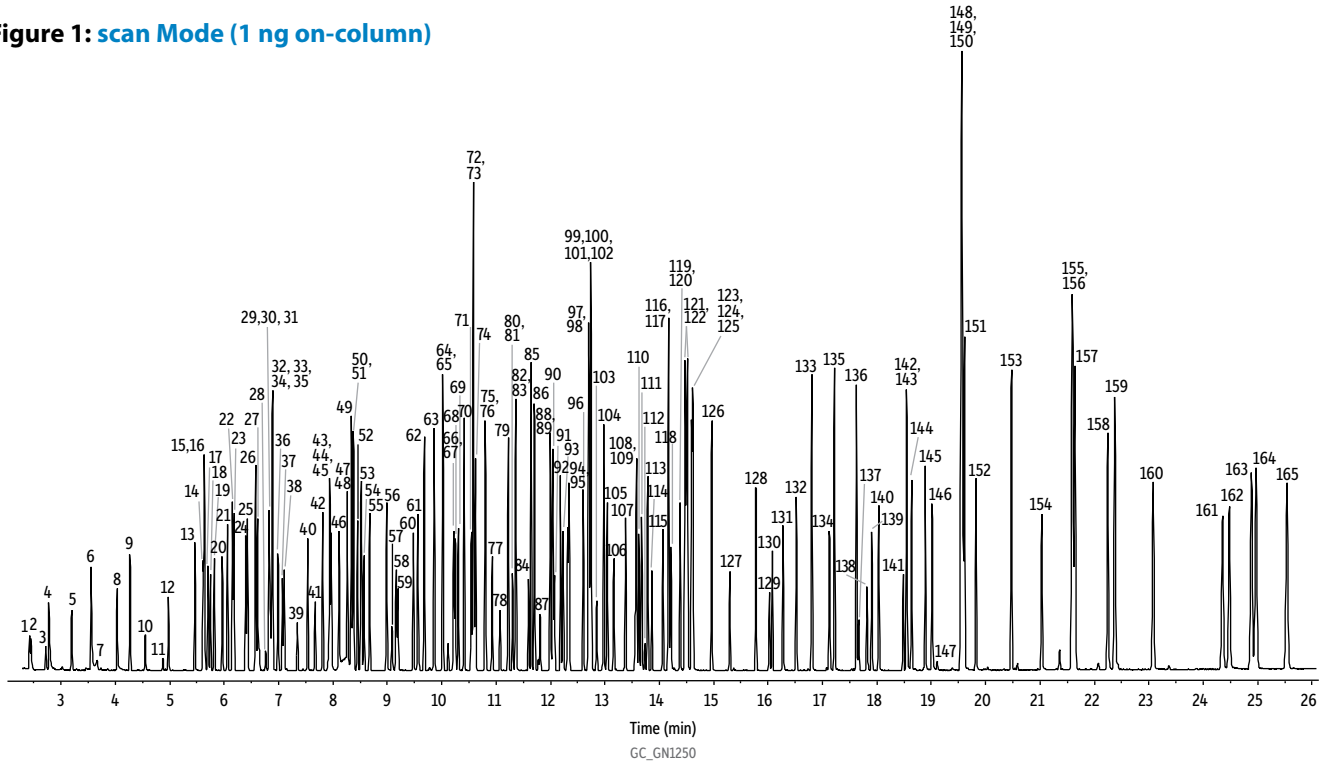
pgレベルにおけるSVOCの感度とピーク形状の評価結果

また、本稿で示した条件下で RMX-5Sil MS カラムを使用したところ、scanモードでは1 ng on-column、SIMモードでは200 pg on-columnという極めて低いオンカラム量においても、幅広い半揮発性有機化合物に対して良好なピーク形状と十分な分離性能が維持され、MSの検出限界近傍においても感度およびクロマトグラフィー性能の両立が可能であることが示されました。

GC-MSによる低濃度SVOC 165成分分析の実測データ

GC-MSによる低濃度SVOC 165成分分析におけるRMX-5Sil MSカラムのクロマトグラフィー性能評価のクロマトグラムを以下に示します。

Figure 1: scan Mode (1 ng on-column)



Column	RMX-5Sil MS, 30 m, 0.25 mm ID, 0.25 µm (cat.# 17323)
Standard/Sample	
	Methapyrilene (cat.# 32460)
	Appendix IX mix #1, revised (cat.# 32459)
	SVOC additions (cat.# 31909)
	Benzoic acid (cat.# 31879)
	8270 MegaMix (cat.# 31850)
	Appendix IX mix #2 (cat.# 31806)
	Acid surrogate mix (4/89 SOW) (cat.# 31025)
	Base neutral surrogate mix (4/89 SOW) (cat.# 31024)
	Revised SV internal standard mix (cat.# 31886)
Diluent:	Methylene chloride
Conc.:	1 µg/mL
Injection	
Inj. Vol.:	1 µL split (split ratio 10:1)
Liner:	Topaz 4.0 mm ID single taper liner w/wool (cat.# 23303)
Inj. Temp.:	250 °C
Split Vent Flow Rate:	12 mL/min
Oven	
Oven Temp.:	40 °C (hold 1 min) to 280 °C at 12.4 °C/min to 330 °C at 3.3 °C/min (hold 3.65 min)
Carrier Gas	He, constant flow
Flow Rate:	1.2 mL/min
Linear Velocity:	39.7 cm/sec
Detector	MS
Mode:	Scan
Scan Program:	

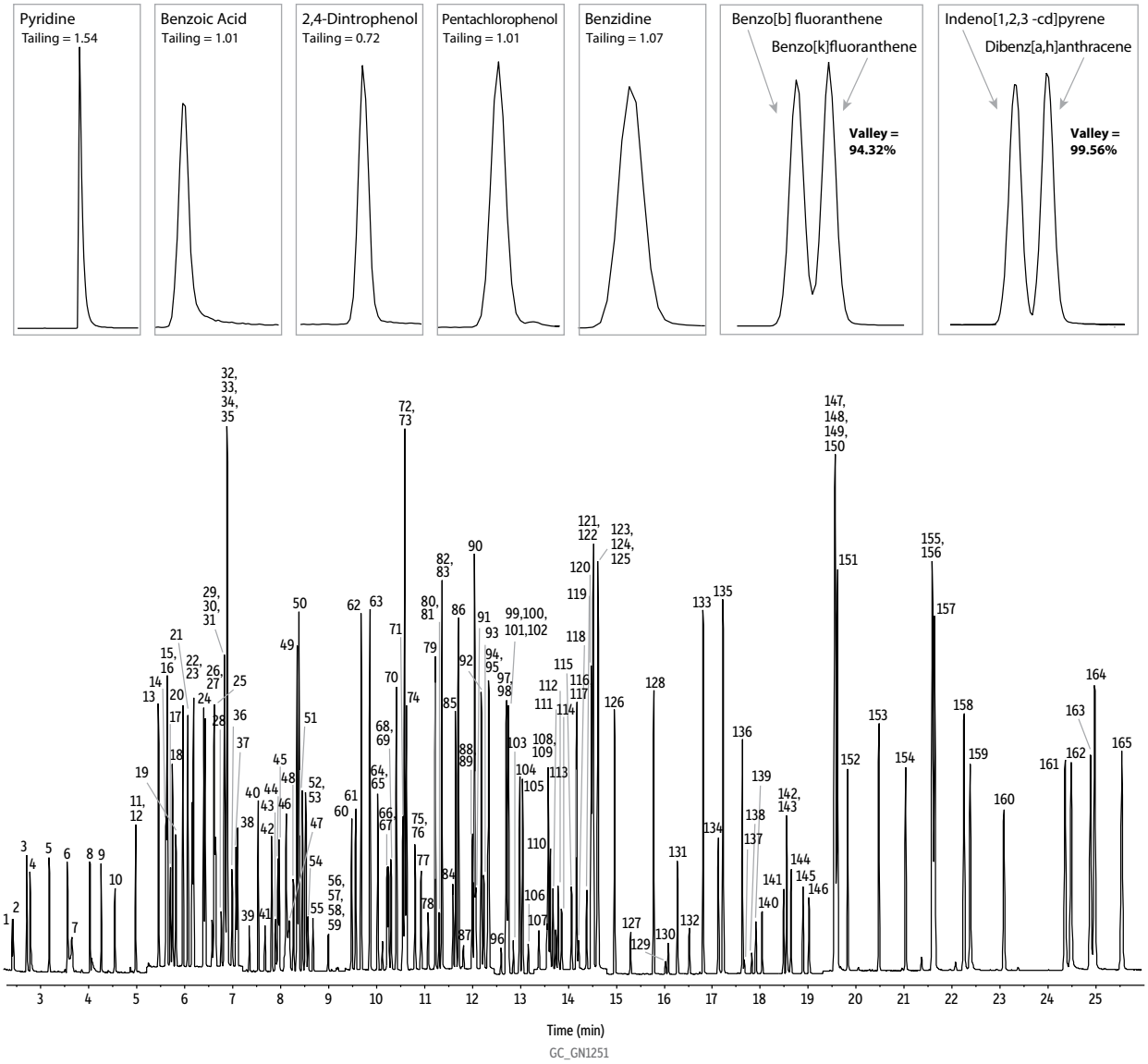
Group	Start Time (min)	Scan Range (amu)	Scan Rate (scans/sec)
1	2	35-550	5

Transfer Line Temp.:	280 °C
Analyzer Type:	Quadrupole
Source Temp.:	330 °C
Quad Temp.:	180 °C
Solvent Delay Time:	2 min
Tune Type:	PFTBA
Ionization Mode:	EI
Instrument	Agilent 7890B GC & 5977B MSD
Notes	To simplify ordering, the SVOC MegaMix 150 kit (cat.# 31907) contains one ampul each of the following standards that were used in this experiment.
	• 8270 MegaMix (cat.# 31850)
	• SVOC Additions standard (cat.# 31909)
	• Appendix IX mix #1, revised (cat.# 32459)
	• Methapyrilene (cat.# 32460)
	• Appendix IX mix #2 (cat.# 31806)
	• Benzoic acid (cat.# 31879)

Figure 1: (続き)

	Peaks	t_R (min)	Conc. (µg/mL)
1.	1,4-Dioxane-d8	2.400	1
2.	1,4-Dioxane	2.428	1
3.	N-Nitrosodimethylamine	2.702	1
4.	Pyridine	2.774	1
5.	Ethyl methacrylate	3.175	1
6.	2-Picoline	3.554	1
7.	N-Nitrosomethylethylamine	3.648	1
8.	Methyl methanesulfonate	4.021	1
9.	2-Fluorophenol	4.258	1
10.	Acrylamide	4.543	1
11.	N-Nitrosodiethylamine	4.875	1
12.	Ethyl methanesulfonate	4.977	1
13.	Benzaldehyde	5.454	1
14.	Phenol-d6	5.612	1
15.	Phenol	5.629	1
16.	Aniline	5.638	1
17.	Pentachloroethane	5.705	1
18.	Bis(2-chloroethyl)ether	5.743	1
19.	2-Chlorophenol	5.814	1
20.	n-Decane (C10)	5.962	1
21.	1,3-Dichlorobenzene	6.066	1
22.	1,4-Dichlorobenzene-d4	6.153	1
23.	1,4-Dichlorobenzene	6.180	1
24.	Benzyl alcohol	6.393	1
25.	1,2-Dichlorobenzene	6.426	1
26.	2-Methylphenol (o-cresol)	6.612	1
27.	2,2'-Oxybis(1-chloropropane)	6.634	1
28.	N-Nitrosopyrrolidine	6.765	1
29.	Acetophenone	6.825	1
30.	N-Nitrosomorpholine	6.836	1
31.	N-Nitroso-di-n-propylamine	6.847	1
32.	3-Methylphenol (m-cresol)	6.885	1
33.	4-Methylphenol (p-cresol)	6.885	1
34.	Indene	6.885	1
35.	o-Toluidine	6.890	1
36.	Hexachloroethane	6.989	1
37.	Nitrobenzene-d5	7.067	1
38.	Nitrobenzene	7.101	1
39.	N-Nitrosopiperidine	7.347	1
40.	Isophorone	7.536	1
41.	2-Nitrophenol	7.673	1
42.	2,4-Dimethylphenol	7.816	1
43.	Benzoic acid	7.943	1
44.	O,O,O-Triethyl phosphorothioate	7.943	1
45.	Bis(2-chloroethoxy)methane	7.970	1
46.	2,4-Dichlorophenol	8.113	1
47.	α,α-Dimethylphenethylamine (phentermine)	8.268	1
48.	1,2,4-Trichlorobenzene	8.268	1
49.	Naphthalene-d8	8.342	1
50.	Naphthalene	8.376	1
51.	α-Terpineol	8.451	1
52.	4-Chloroaniline	8.519	1
53.	2,6-Dichlorophenol	8.519	1
54.	Hexachloropropene	8.571	1
55.	Hexachlorobutadiene	8.674	1
56.	Quinoline	8.988	1
57.	ε-Caprolactam	9.085	1
58.	1,4-Phenylenediamine	9.160	1
59.	N-Nitrosodibutylamine	9.195	1
60.	4-Chloro-3-methylphenol	9.480	1
61.	Isosafrole isomer 2	9.560	1
62.	2-Methylnaphthalene	9.680	1
63.	1-Methylnaphthalene	9.857	1
64.	1,2,4,5-Tetrachlorobenzene	10.023	1
65.	Hexachlorocyclopentadiene	10.023	1
66.	2,3-Dichloroaniline	10.217	1
67.	Isosafrole isomer 1	10.217	1
68.	2,4,6-Trichlorophenol	10.248	1
69.	2,4,5-Trichlorophenol	10.303	1
70.	2-Fluorobiphenyl	10.412	1
71.	Safrole	10.547	1
72.	Biphenyl	10.585	1
73.	2-Chloronaphthalene	10.585	1
74.	1-Chloronaphthalene	10.623	1
75.	2-Nitroaniline	10.801	1
76.	Diphenyl ether	10.801	1
77.	1,4-Naphthoquinone	10.926	1
78.	1,4-Dinitrobenzene	11.075	1
79.	Dimethylphthalate	11.224	1
80.	1,3-Dinitrobenzene	11.304	1
81.	2,6-Dinitrotoluene	11.304	1
82.	1,2-Dinitrobenzene	11.361	1
83.	Acenaphthylene	11.361	1
84.	3-Nitroaniline	11.595	1
85.	Acenaphthene-d10	11.647	1
86.	Acenaphthene	11.704	1
87.	2,4-Dinitrophenol	11.809	1
88.	4-Nitrophenol	11.996	1
89.	Pentachlorobenzene	11.996	1
90.	Dibenzofuran	12.040	1
91.	2,4-Dinitrotoluene	12.070	1
92.	1-Naphthylamine (1-aminonaphthalene)	12.184	1
93.	2,3,5,6-Tetrachlorophenol	12.236	1
94.	2,3,4,6-Tetrachlorophenol	12.319	1
95.	2-Naphthylamine (2-aminonaphthalene)	12.341	1
96.	Diethylphthalate	12.602	1
97.	n-Hexadecane (C16)	12.699	1
98.	Fluorene	12.699	1
99.	Zalophus (thionazine)	12.745	1
100.	4-Chlorophenyl phenyl ether	12.745	1
101.	4-Nitroaniline	12.745	1
102.	5-Nitro-o-toluidine	12.745	1
103.	4,6-Dinitro-2-methylphenol (Dinitro-o-cresol)	12.853	1
104.	Diphenylamine†	12.979	1
105.	Azobenzene*	13.042	1
106.	2,4,6-Tribromophenol	13.162	1
107.	Sulfotepp	13.379	1
108.	1,3,5-Trinitrobenzene	13.579	1
109.	Phorate	13.579	1
110.	Phenacetin	13.625	1
111.	4-Bromophenyl phenyl ether	13.677	1
112.	Diallate	13.734	1
113.	Hexachlorobenzene	13.785	1
114.	Dimethoate	13.865	1
115.	Atrazine	14.071	1
116.	4-Aminobiphenyl	14.168	1
117.	Pentachlorophenol	14.170	1
118.	Pentachloronitrobenzene (Quintozene)	14.214	1
119.	Propyzamide	14.380	1
120.	Phenanthrene-d10	14.477	1
121.	n-Octadecane (C18)	14.517	1
122.	Phenanthrene	14.517	1
123.	Dinoseb	14.599	1
124.	Disulfoton	14.599	1
125.	Anthracene	14.614	1
126.	Carbazole	14.963	1
127.	Methyl parathion	15.295	1
128.	Di-n-butyl phthalate	15.775	1
129.	4-Nitroquinoline-N-oxide	16.027	1
130.	Parathion (ethyl parathion)	16.078	1
131.	Methapyrilene hydrochloride	16.273	1
132.	Isodrin	16.518	1
133.	Fluoranthene	16.804	1
134.	Benzidine	17.127	1
135.	Pyrene	17.222	1
136.	p-Terphenyl-d14	17.622	1
137.	Aramite isomer 2	17.668	1
138.	Aramite isomer 1	17.822	1
139.	p-Dimethylaminoazobenzene	17.908	1
140.	Chlorobenzilate	18.034	1
141.	Famphur	18.485	1
142.	3,3'-Dimethylbenzidine (o-tolidine)	18.548	1
143.	Kepone	18.548	1
144.	Benzyl butyl phthalate	18.640	1
145.	Bis(2-ethylhexyl)adipate	18.891	1
146.	2-Acetylaminofluorene	19.017	1
147.	4,4'-Methylene-bis(2-chloroaniline)	19.108	1
148.	3,3'-Dichlorobenzidine	19.560	1
149.	Benz[a]anthracene	19.560	1
150.	Chrysene-d12	19.560	1
151.	Chrysene	19.612	1
152.	Bis(2-ethylhexyl)phthalate	19.823	1
153.	6-Methylchrysene	20.475	1
154.	Di-n-octyl phthalate	21.030	1
155.	Benzo[b]fluoranthene	21.590	1
156.	7,12-Dimethylbenz[a]anthracene	21.590	1
157.	Benzo[k]fluoranthene	21.641	1
158.	Benzo[a]pyrene	22.248	1
159.	Perylene-d12	22.379	1
160.	3-Methylcholanthrene	23.082	1
161.	Dibenz(a,h)acridine	24.357	1
162.	Dibenz[a,j]acridine	24.483	1
163.	Indeno[1,2,3-cd]pyrene	24.883	1
164.	Dibenz[a,h]anthracene	24.969	1
165.	Benzo[g,h,i]perylene	25.541	1

Figure 2: SIM Mode (200 pg on-column)



Column	RMX-5Sil MS, 30 m, 0.25 mm ID, 0.25 µm (cat.# 17323)
Standard/Sample	
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	SVOC additions (cat.# 31909)
	Benzoic acid (cat.# 31879)
	8270 MegaMix (cat.# 31850)
	Appendix IX mix #2 (cat.# 31806)
	Acid surrogate mix (4/89 SOW) (cat.# 31025)
	Base neutral surrogate mix (4/89 SOW) (cat.# 31024)
	Revised SV internal standard mix (cat.# 31886)
Diluent:	Methylene chloride
Conc.:	200 ng/mL
Injection	
Inj. Vol.:	1 µL split (split ratio 10:1)
Liner:	Topaz 4.0 mm ID single taper liner w/wool (cat.# 23303)
Inj. Temp.:	250 °C
Split Vent Flow Rate:	12 mL/min
Oven	
Oven Temp.:	40 °C (hold 1 min) to 280 °C at 12.4 °C/min to 330 °C at 3.3 °C/min (hold 3.65 min)
Carrier Gas	He, constant flow
Flow Rate:	1.2 mL/min
Linear Velocity:	39.7 cm/sec
Detector	MS
Mode:	SIM

SIM Program:

Group	Start Time (min)	Ion(s) (m/z)	Dwell (ms)
1	2	see peak list	300
2	5.2	see peak list	286
3	7.2	see peak list	289
4	9.35	see peak list	285
5	10.7	see peak list	273
6	12.45	see peak list	290
7	13.29	see peak list	280
8	14.8	see peak list	300
9	17.4	see peak list	297
10	19.3	see peak list	285

Transfer Line Temp.:	280 °C
Analyzer Type:	Quadrupole
Source Temp.:	330 °C
Quad Temp.:	180 °C
Solvent Delay Time:	2 min
Tune Type:	PFTBA
Ionization Mode:	EI
Instrument	Agilent 7890B GC & 5977B MSD
Notes	To simplify ordering, the SVOC MegaMix 150 kit (cat.# 31907) contains one ampul each of the following standards that were used in this experiment. • 8270 MegaMix (cat.# 31850) • SVOC Additions standard (cat.# 31909) • Appendix IX mix #1, revised (cat.# 32459) • Methapyrilene (cat.# 32460) • Appendix IX mix #2 (cat.# 31806) • Benzoic acid (cat.# 31879)

Figure 2: (続き)

	Peaks	t_R (min)	Conc. (ng/mL)	SIM Ion	Dwell Time (ms)	Ion Group
1.	1,4-Dioxane-d8	2.401	200	96	25	1
2.	1,4-Dioxane	2.427	200	88	25	1
3.	N-Nitrosodimethylamine	2.702	200	74	25	1
4.	Pyridine	2.774	200	79	25	1
5.	Ethyl methacrylate	3.175	200	69	25	1
6.	2-Picoline	3.554	200	93	25	1
7.	N-Nitrosomethylethylamine	3.648	200	42	25	1
8.	Methyl methanesulfonate	4.021	200	80	25	1
9.	2-Fluorophenol	4.258	200	112	25	1
10.	Acrylamide	4.543	200	71	25	1
11.	N-Nitrosodiethylamine	4.977	200	102	25	1
12.	Ethyl methanesulfonate	4.977	200	109	25	1
13.	Benzaldehyde	5.454	200	77	11	2
14.	Phenol-d6	5.612	200	99	11	2
15.	Phenol	5.633	200	94	11	2
16.	Aniline	5.633	200	93	11	2
17.	Pentachloroethane	5.7	200	167	11	2
18.	Bis(2-chloroethyl)ether	5.743	200	63	11	2
19.	2-Chlorophenol	5.814	200	128	11	2
20.	n-Decane (C10)	5.962	200	57	11	2
21.	1,3-Dichlorobenzene	6.066	200	146	11	2
22.	1,4-Dichlorobenzene-d4	6.154	200	150	11	2
23.	1,4-Dichlorobenzene	6.18	200	148	11	2
24.	Benzyl alcohol	6.393	200	79	11	2
25.	1,2-Dichlorobenzene	6.426	200	111	11	2
26.	2-Methylphenol (o-cresol)	6.611	200	108	11	2
27.	2,2'-Oxybis(1-chloropropane)	6.634	200	45	11	2
28.	N-Nitrosopyrrolidine	6.765	200	100	11	2
29.	Acetophenone	6.825	200	105	11	2
30.	N-Nitrosomorpholine	6.825	200	56	11	2
31.	N-Nitroso-di-n-propylamine	6.825	200	43	11	2
32.	3-Methylphenol (m-cresol)	6.885	200	80	11	2
33.	4-Methylphenol (p-cresol)	6.885	200	107	11	2
34.	Indene	6.885	200	117	11	2
35.	o-Toluidine	6.885	200	106	11	2
36.	Hexachloroethane	6.989	200	119	11	2
37.	Nitrobenzene-d5	7.068	200	82	11	2
38.	Nitrobenzene	7.1	200	123	11	2
39.	N-Nitrosopiperidine	7.347	200	114	17	3
40.	Isophorone	7.531	200	82	17	3
41.	2-Nitrophenol	7.671	200	139	17	3
42.	2,4-Dimethylphenol	7.811	200	122	17	3
43.	Benzoic acid	7.898	200	105	17	3
44.	O,O,O-Triethyl phosphorothioate	7.942	200	121	17	3
45.	Bis(2-chloroethoxy)methane	7.969	200	93	17	3
46.	2,4-Dichlorophenol	8.113	200	162	17	3
47.	α,α-Dimethylphenethylamine (phentermine)	8.178	200	58	17	3
48.	1,2,4-Trichlorobenzene	8.264	200	180	17	3
49.	Naphthalene-d8	8.34	200	136	17	3
50.	Naphthalene	8.378	200	128	17	3
51.	α-Terpineol	8.453	200	59	17	3
52.	4-Chloroaniline	8.518	200	127	17	3
53.	2,6-Dichlorophenol	8.518	200	164	17	3
54.	Hexachloropropene	8.572	200	213	17	3
55.	Hexachlorobutadiene	8.674	200	225	17	3
56.	Quinoline	8.993	200	129	15	4
57.	ε-Caprolactam	9.085	200	55	15	4
58.	1,4-Phenylenediamine	9.160	200	108	15	4
59.	N-Nitrosodibutylamine	9.195	200	84	15	4
60.	4-Chloro-3-methylphenol	9.477	200	107	15	4
61.	Isosafrole isomer 2	9.563	200	181	15	4
62.	2-Methylnaphthalene	9.681	200	142	15	4
63.	1-Methylnaphthalene	9.858	200	141	15	4
64.	1,2,4,5-Tetrachlorobenzene	10.024	200	216	15	4
65.	Hexachlorocyclopentadiene	10.024	200	237	15	4
66.	2,3-Dichloroaniline	10.221	200	161	15	4
67.	Isosafrole isomer 1	10.221	200	104	15	4
68.	2,4,6-Trichlorophenol	10.25	200	196	15	4
69.	2,4,5-Trichlorophenol	10.303	200	198	15	4
70.	2-Fluorobiphenyl	10.41	200	172	15	4
71.	Safrole	10.549	200	131	15	4
72.	Biphenyl	10.586	200	154	15	4
73.	2-Chloronaphthalene	10.586	200	162	15	4
74.	1-Chloronaphthalene	10.624	200	127	15	4
75.	2-Nitroaniline	10.803	200	138	13	5
76.	Diphenyl ether	10.803	200	170	15	5
77.	1,4-Naphthoquinone	10.927	200	158	13	5
78.	1,4-Dinitrobenzene	11.073	200	168	13	5
79.	Dimethylphthalate	11.223	200	163	13	5
80.	1,3-Dinitrobenzene	11.301	200	76	13	5
81.	2,6-Dinitrotoluene	11.301	200	165	13	5
82.	1,2-Dinitrobenzene	11.363	200	50	13	5
83.	Acenaphthylene	11.363	200	152	13	5
84.	3-Nitroaniline	11.591	200	65	13	5
85.	Acenaphthene-d10	11.649	200	162	13	5
86.	Acenaphthene	11.706	200	153	13	5
87.	2,4-Dinitrophenol	11.809	200	184	13	5
88.	4-Nitrophenol	11.996	200	139	13	5
89.	Pentachlorobenzene	11.996	200	250	13	5
90.	Dibenzofuran	12.043	200	84	13	5
91.	2,4-Dinitrotoluene	12.183	200	89	13	5
92.	1-Naphthylamine (1-aminonaphthalene)	12.235	200	143	13	5
93.	2,3,5,6-Tetrachlorophenol	12.339	200	232	13	5
94.	2,3,4,6-Tetrachlorophenol	12.339	200	230	13	5
95.	2-Naphthylamine (2-aminonaphthalene)	12.339	200	115	13	5
96.	Diethylphthalate	12.596	200	149	13	5
97.	n-Hexadecane (C16)	12.703	200	57	29	6
98.	Fluorene	12.703	200	166	29	6
99.	Zalophus (thionazine)	12.746	200	107	29	6
100.	4-Chlorophenyl phenyl ether	12.746	200	204	29	6
101.	4-Nitroaniline	12.746	200	65	29	6
102.	5-Nitro-o-toluidine	12.746	200	152	29	6
103.	4,6-Dinitro-2-methylphenol (Dinitro-o-cresol)	12.852	200	198	29	6
104.	Diphenylamine†	12.98	200	169	29	6
105.	Azobenzene*	13.044	200	77	29	6
106.	2,4,6-Tribromophenol	13.162	200	330	29	6
107.	Sulfotepp	13.385	200	322	14	7
108.	1,3,5-Trinitrobenzene	13.581	200	213	14	7
109.	Phenacetin	13.581	200	108	14	7
110.	Phorate	13.618	200	75	14	7
111.	4-Bromophenyl phenyl ether	13.677	200	248	14	7
112.	Diallate	13.735	200	43	14	7
113.	Hexachlorobenzene	13.788	200	284	14	7
114.	Dimethoate	13.857	200	87	14	7
115.	Atrazine	14.064	200	200	14	7
116.	4-Aminobiphenyl	14.17	200	169	14	7
117.	Pentachlorophenol	14.17	200	266	14	7
118.	Pentachloronitrobenzene (Quintozene)	14.213	200	237	14	7
119.	Propyzamide	14.377	200	173	14	7
120.	Phenanthrene-d10	14.477	200	188	14	7
121.	n-Octadecane (C18)	14.52	200	57	14	7
122.	Phenanthrene	14.52	200	178	14	7
123.	Dinoseb	14.616	200	211	14	7
124.	Disulfoton	14.616	200	88	14	7
125.	Anthracene	14.616	200	179	14	7
126.	Carbazole	14.961	200	167	30	8
127.	Methyl parathion	15.296	200	109	30	8
128.	Di-n-butyl phthalate	15.779	200	149	30	8
129.	4-Nitroquinoline-N-oxide	16.026	200	190	30	8
130.	Parathion (ethyl parathion)	16.075	200	291	30	8
131.	Methapyrilene hydrochloride	16.273	200	58	30	8
132.	Isodrin	16.52	200	193	30	8
133.	Fluoranthene	16.806	200	202	30	8
134.	Benzidine	17.124	200	184	30	8
135.	Pyrene	17.223	200	203	30	8
136.	p-Terphenyl-d14	17.627	200	244	27	9
137.	Aramite isomer 2	17.627	200	175	27	9
138.	Aramite isomer 1	17.818	200	135	27	9
139.	p-Dimethylaminoazobenzene	17.905	200	120	27	9
140.	Chlorobenzilate	18.041	200	251	27	9
141.	Famphur	18.487	200	218	27	9
142.	3,3'-Dimethylbenzidine (o-tolidine)	18.553	200	254	15	9
143.	Kepone	18.553	200	272	27	9
144.	Benzyl butyl phthalate	18.64	200	149	27	9
145.	Bis(2-ethylhexyl)adipate	18.89	200	129	27	9
146.	2-Acetylaminofluorene	19.015	200	181	27	9
147.	4,4'-Methylene-bis(2-chloroaniline)	19.561	200	231	15	9
148.	3,3'-Dichlorobenzidine	19.561	200	212	27	9
149.	Benz[a]anthracene	19.561	200	228	15	10
150.	Chrysene-d12	19.561	200	240	15	10
151.	Chrysene	19.61	200	226	15	10
152.	Bis(2-ethylhexyl)phthalate	19.824	200	167	15	10
153.	6-Methylchrysene	20.473	200	242	15	10
154.	Di-n-octyl phthalate	21.031	200	149	15	10
155.	Benzo[b]fluoranthene	21.589	200	57	15	10
156.	7,12-Dimethylbenz[a]anthracene	21.589	200	256	15	10
157.	Benzo[k]fluoranthene	21.637	200	252	15	10
158.	Benzo[a]pyrene	22.249	200	253	15	10
159.	Perylene-d12	22.377	200	264	15	10
160.	3-Methylcholanthrene	23.08	200	268	15	10
161.	Dibenz(a,h)acridine	24.357	200	279	15	10
162.	Dibenz[a,j]acridine	24.48	200	280	15	10
163.	Indeno[1,2,3-cd]pyrene	24.882	200	277	15	10
164.	Dibenz[a,h]anthracene	24.968	200	278	15	10
165.	Benzo[g,h,i]perylene	25.537	200	276	15	10

まとめ：低濃度SVOCのGC-MS分析で感度とピーク形状を両立するために

低濃度の半揮発性有機化合物（SVOC）をGC-MSで分析する際には、感度低下やピーク形状の劣化が大きな課題となります。本記事で示した結果から、カラムの不活性度を含むシステム全体の最適化により、scanおよびSIMのいずれにおいても高品質な分析が可能であることが示されました。

参照文献

1. E. Pack, J. Hoisington, C. English, R. Dhandapani, and C. Myers, 微量レベル半揮発性有機化合物のGC-MS/MS一斉分析法：データ品質維持と検出下限の改善, Application note, EVAN4920-JA, Restek Corporation, 2025
2. RMX GCカラムカタログ, GNBR4923A-JA, Restek Corporation, 2026

注目製品

RMX-5Sil MS GCキャピラリーカラム

カタログ番号	製品名	入数単位
17323	RMX-5Sil MS GCキャピラリーカラム, 30 m, 0.25 mm ID, 0.25 µm	1

Topaz Single Taper注入口ライナー

カタログ番号	製品名	入数単位
23303	Topaz, Single Taper Inlet Liner, 4.0 mm x 6.5 x 78.5, for Agilent GCs, w/Quartz Wool, Premium Deactivation	5-pk.

Restekリークディテクタ

カタログ番号	製品名	入数単位
28500	Restek Electronic Leak Detector (持ち運び用ケース、ユニバーサル充電器セット[日本、米国、ヨーロッパ、英国、オーストラリア]、6-ftのUSBケーブルを含む)	1

SVOC MegaMix 150 Kit, 1 mL/ampul; 6 ampuls/kit

1アンプルあたりに含まれる内容

カタログ番号 31850: 8270 MegaMix
1000 µg/mL each in methylene chloride (3-methylphenol and 4-methylphenol at 500 µg/mL), 1 mL/ampul
Acenaphthene (83-32-9)
Acenaphthylene (208-96-8)
Aniline (62-53-3)
Anthracene (120-12-7)
Azobenzene (103-33-3)*
Benz[a]anthracene (56-55-3)
Benzo[a]pyrene (50-32-8)
Benzo[b]fluoranthene (205-99-2)
Benzo[g,h,i]perylene (191-24-2)
Benzo[k]fluoranthene (207-08-9)
Benzyl alcohol (100-51-6)
Benzyl butyl phthalate (85-68-7)
Bis(2-chloroethoxy)methane (111-91-1)
Bis(2-chloroethyl)ether (111-44-4)
Bis(2-ethylhexyl)adipate (103-23-1)
Bis(2-ethylhexyl)phthalate (117-81-7)
4-Bromophenyl phenyl ether (101-55-3)
Carbazole (86-74-8)
4-Chloroaniline (106-47-8)
4-Chloro-3-methylphenol (59-50-7)
2-Chloronaphthalene (91-58-7)
2-Chlorophenol (95-57-8)
4-Chlorophenyl phenyl ether (7005-72-3)
Chrysene (218-01-9)
Dibenz[a,h]anthracene (53-70-3)
Dibenzofuran (132-64-9)
1,2-Dichlorobenzene (95-50-1)
1,3-Dichlorobenzene (541-73-1)
1,4-Dichlorobenzene (106-46-7)
2,4-Dichlorophenol (120-83-2)
Diethylphthalate (84-66-2)
2,4-Dimethylphenol (105-67-9)
Dimethylphthalate (131-11-3)
Di-n-butyl phthalate (84-74-2)
1,2-Dinitrobenzene (528-29-0)
1,3-Dinitrobenzene (99-65-0)
1,4-Dinitrobenzene (100-25-4)
4,6-Dinitro-2-methylphenol (Dinitro-o-cresol) (534-52-1)
2,4-Dinitrophenol (51-28-5)
2,4-Dinitrotoluene (121-14-2)
2,6-Dinitrotoluene (606-20-2)
Di-n-octyl phthalate (117-84-0)
Diphenylamine (122-39-4)†
Fluoranthene (206-44-0)
Fluorene (86-73-7)
Hexachlorobenzene (118-74-1)
Hexachlorobutadiene (87-68-3)
Hexachlorocyclopentadiene (77-47-4)
Hexachloroethane (67-72-1)
Indeno[1,2,3-cd]pyrene (193-39-5)
Isophorone (78-59-1)
1-Methylnaphthalene (90-12-0)
2-Methylnaphthalene (91-57-6)
2-Methylphenol (o-cresol) (95-48-7)
3-Methylphenol (m-cresol) (108-39-4)
4-Methylphenol (p-cresol) (106-44-5)
Naphthalene (91-20-3)
2-Nitroaniline (88-74-4)
3-Nitroaniline (99-09-2)
4-Nitroaniline (100-01-6)
Nitrobenzene (98-95-3)
2-Nitrophenol (88-75-5)
4-Nitrophenol (100-02-7)
N-Nitrosodimethylamine (62-75-9)
N-Nitroso-di-*n*-propylamine (621-64-7)
2,2'-Oxybis(1-chloropropane) (108-60-1)
Pentachlorophenol (87-86-5)
Phenanthrene (85-01-8)
Phenol (108-95-2)
Pyrene (129-00-0)
Pyridine (110-86-1)
2,3,4,6-Tetrachlorophenol (58-90-2)
2,3,5,6-Tetrachlorophenol (935-95-5)
1,2,4-Trichlorobenzene (120-82-1)
2,4,5-Trichlorophenol (95-95-4)
2,4,6-Trichlorophenol (88-06-2)

カタログ番号 31909: SVOC Additions
1000 µg/mL each in methylene chloride, 1 mL/ampul
Acrylamide (79-06-1)
Benzidine (92-87-5)
n-Decane (C10) (124-18-5)
Dibenz(a,h)acridine (226-36-8)
2,3-Dichloroaniline (608-27-5)
3,3'-Dichlorobenzidine (91-94-1)
Dimethoate (60-51-5)
Dinoseb (88-85-7)
Disulfoton (298-04-4)
Famphur (52-85-7)
n-Hexadecane (C16) (544-76-3)
Indene (95-13-6)
Methyl parathion (298-00-0)
6-Methylchrysene (1705-85-7)
4,4'-Methylene-bis(2-chloroaniline) (101-14-4)
n-Octadecane (C18) (593-45-3)
Parathion (ethyl parathion) (56-38-2)
Phorate (298-02-2)
Quinoline (91-22-5)
Sulfotepp (3689-24-5)
α-Terpineol (98-55-5)
o,o,o-Triethyl phosphorothioate (126-68-1)
Zalophus (thionazine) (297-97-2)

カタログ番号 32459: Appendix IX mix #1, revised
2000 µg/mL each in methylene chloride, 1 mL/ampul
2-Acetylaminofluorene (53-96-3)
4-Aminobiphenyl (92-67-1)
p-Dimethylaminoazobenzene (60-11-7)
3,3'-Dimethylbenzidine (o-tolidine) (119-93-7)
α,α-Dimethylphenethylamine (phentermine) (122-09-8)
1-Naphthylamine (1-aminonaphthalene) (134-32-7)
2-Naphthylamine (2-aminonaphthalene) (91-59-8)
N-Nitrosodibutylamine (924-16-3)
N-Nitrosodiethylamine (55-18-5)
N-Nitrosomethylethylamine (10595-95-6)
N-Nitrosomorpholine (59-89-2)
N-Nitrosopiperidine (100-75-4)
N-Nitrosopyrrolidine (930-55-2)
5-Nitro-o-toluidine (99-55-8)
1,4-Phenylenediamine (106-50-3)
2-Picoline (109-06-8)
o-Toluidine (95-53-4)

カタログ番号 32460: Methapyrilene
2000 µg/mL in methylene chloride, 1 mL/ampul
Methapyrilene hydrochloride (135-23-9)

カタログ番号 31806: Appendix IX mix #2
1000 µg/mL each in methylene chloride, 1 mL/ampul
Acetophenone (98-86-2)
Aramite (140-57-8)
Atrazine (1912-24-9)
Benzaldehyde (100-52-7)
Biphenyl (92-52-4)
ε-Caprolactam (105-60-2)
Chlorobenzilate (510-15-6)
1-Chloronaphthalene (90-13-1)
Diallate (2303-16-4)
Dibenz[a,j]acridine (224-42-0)
2,6-Dichlorophenol (87-65-0)
7,12-Dimethylbenz[a]anthracene (57-97-6)
1,4-Dioxane (123-91-1)
Diphenyl ether (101-84-8)
Ethyl methacrylate (97-63-2)
Ethyl methanesulfonate (62-50-0)
Hexachloropropene (1888-71-7)
Isodrin (465-73-6)
Isosafrole (cis & trans) (120-58-1)
Kepone (143-50-0)
3-Methylcholanthrene (56-49-5)
Methyl methanesulfonate (66-27-3)
1,4-Naphthoquinone (130-15-4)
4-Nitroquinoline-N-oxide (56-57-5)
Pentachlorobenzene (608-93-5)
Pentachloroethane (76-01-7)
Pentachloronitrobenzene (Quintozene) (82-68-8)
Phenacetin (62-44-2)
Propyzamide (23950-58-5)
Safrole (94-59-7)
1,2,4,5-Tetrachlorobenzene (95-94-3)
1,3,5-Trinitrobenzene (99-35-4)

カタログ番号 31879: Benzoic acid
2000 µg/mL in methylene chloride, 1 mL/ampul
Benzoic acid (65-85-0)

*1,2-ジフェニルヒドラジン (8270収載分析種) は注入口内でアゾベンジン(混合成分)に分解されます。
†N-ニトロソジフェニルアミンは反応性が高く、混合物中の他成分の早期分解を誘発する可能性があります。そのため、本混合物の調整にはジフェニルアミンが使用されています。

カタログ番号	入数単位
31907	kit

GC-MS Tuning Mix

1000 µg/mL, Methylene Chloride, 1 mL/ampul

カタログ番号.	内容	入数単位
31615	Benzidine (92-87-5) 4,4'-DDT (50-29-3) DFTPP (decafluorotriphenylphosphine) (5074-71-5) Pentachlorophenol (87-86-5)	1

Acid Surrogate Mix (4/89 SOW)

2000 µg/mL, Methanol, 1 mL/ampul

カタログ番号	内容	入数単位
31025	2-Fluorophenol (367-12-4) Phenol-d6 (13127-88-3) 2,4,6-Tribromophenol (118-79-6)	1

Base Neutral Surrogate Mix (4/89 SOW)

1000 µg/mL, Methylene Chloride, 1 mL/ampul

カタログ番号	内容	入数単位
31024	2-Fluorobiphenyl (321-60-8) Nitrobenzene-d5 (4165-60-0) p-Terphenyl-d14 (1718-51-0)	1

Revised SV Internal Standard Mix

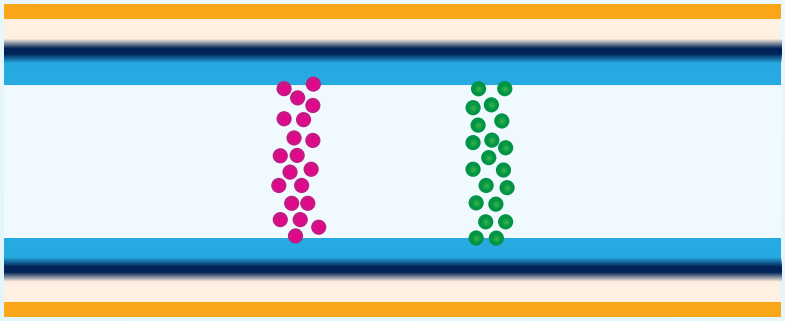
4000 µg/mL, Methylene Chloride, 1 mL/ampul

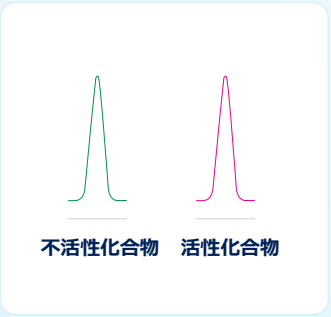
カタログ番号	内容	入数単位
31886	Acenaphthene-d10 (15067-26-2) Chrysene-d12 (1719-03-5) 1,4-Dichlorobenzene-d4 (3855-82-1) 1,4-Dioxane-d8 (17647-74-4) Naphthalene-d8 (1146-65-2) Perylene-d12 (1520-96-3) Phenanthrene-d10 (1517-22-2)	1

RMX GC COLUMNS が優れている理由とは？

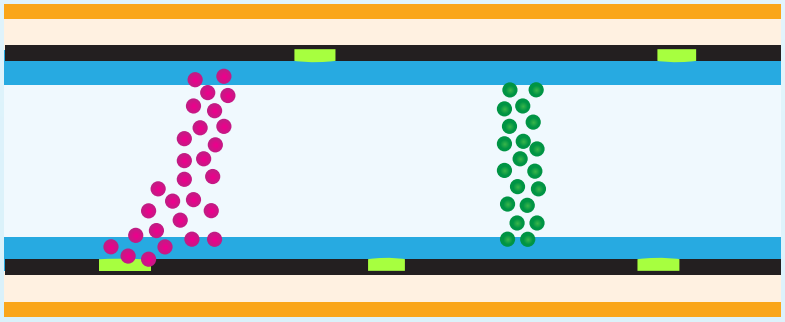
高い効果を発揮するTriMax不活性化処理が、不要な表面相互作用から化合物を保護し、幅広い化合物に対してピーク形状と感度を大きく向上させます。

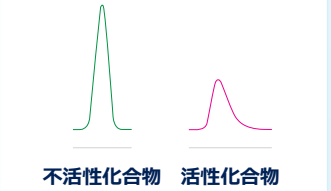
TriMax 不活性化処理あり

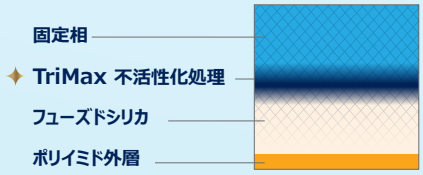




TriMax 不活性化処理なし







- **不活性化合物：** アルカン, アルケン, アルキンなど
- **活性化合物:** 酸, 塩基, アルコール, エステル, エーテルなど
- **残存活性点**

RMXカラムに関する最新情報はこちらから！

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