

**Metropolitan Museum of Art**  
**Gas Chromatography- Mass Spectrometry (GC-MS) Results from Material Analysis**

This document includes (1) a mass spectrum and (2) the volatile organic compounds (VOCs) emitted from samples using GC-MS analysis. The data is not interpreted; however, several classes of chemicals are highlighted because they are potential risks for artwork in an enclosed environment. A basic key, provided below, indicates those classes. The amount of each chemical identified has not been determined; similarly, it is not known how much of each chemical is necessary to do damage to art. Finally, peaks may be present that are the result of the sample adsorbing chemicals from the air and reemitting them during testing rather than being inherent to the sample. Research is ongoing to determine specifically which chemicals and amounts are required to negatively affect artifacts.

**Highlighted data:**

Pink – chemicals currently known to be hazardous to art

Green – amines; can raise the pH, are suspected to react with acids and may form crystals in an enclosed environment

Yellow – chemicals of the following type, which *may* be hazardous to art:

*Acids* – lower the pH, corrosive to metals, degrade organic materials

*Aldehydes* – can convert to acids with heat or exposure to UV light

*Esters* – can hydrolyze into acids with heat and humidity

*Sulfur-containing compounds* – known to tarnish and corrode some metals

*Halogenated compounds* – can become reactive with exposure to heat and UV light

*Nitrogen-containing, not amine* – can react with other off-gassed chemicals

*Alkynes* – can become reactive when exposed to heat or UV light

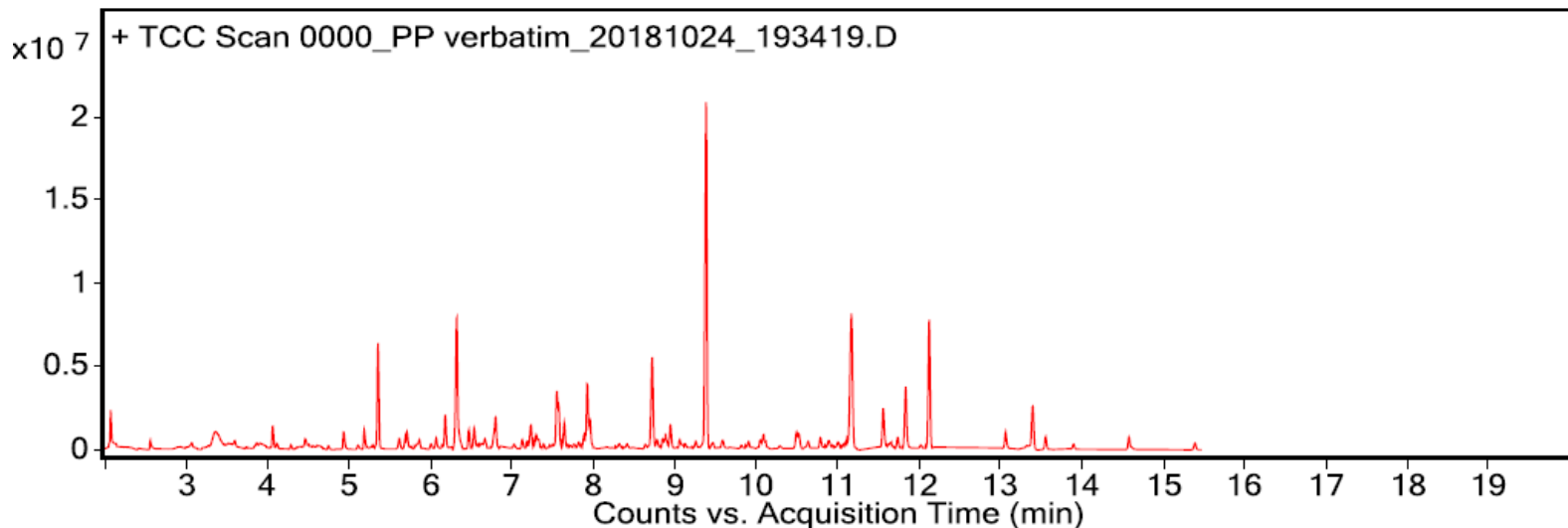
Sample: Verbatim 3D printed polypropylene

Oddy test result: Permanent

Date collected: 10/24/2018

Technique used: SPME with a PDMS/DVB fiber; Agilent 7890B GC and 5977B MS fitted with a GL Sciences OPTIC-4 multimode inlet and LEAP PAL RTC autosampler; Pre-heated at 60°C for 20 minutes; fiber exposure at 60°C for 20 minutes; sample injected into 220°C inlet and crotrapped for 2 min at -15°C; GC ramped from 40°C to 225 °C at 10°C/min. Data analyzed in masshunter Qualitative. Samples > 80% match with a NIST library are reported.

VOCs not highlighted are because they were also observed in blanks: (1) 4.75 min: methoxy-phenyl-oxime; (2) 11.6 min: 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl) propyl ester propanoic acid; (3) 11.8 min: 2-methyl-, 3-hydroxy-2,4,4-trimethylpentyl ester propanoic acid



Library results

RT	Score	Formula	MW	Area	CAS #	Name
1.470	90.9	C3H4O3	88.0	943169	2258-42-6	Acetic acid, anhydride with formic acid
2.070	81.7	C2H8O2Si	92.0	3244852	1066-42-8	Silanediol, dimethyl-
2.410	90.6	C5H5N	79.0	370880	110-86-1	Pyridine
2.560	94.6	C3H8O2	76.1	719125	57-55-6	1,2-Propanediol
2.930	82.9	C7H14O	114.1	828769	27944-79-2	Pentanal, 2,4-dimethyl-
3.070	81.6	C7H12O2	128.1	442102	53657-15-1	(S)-(-)-2-ISOPROPYL-.GAMMA.-BUTYROLACTONE
3.270	82.9	C11H19DO	169.2	381373	68687-86-5	(1S,2R,3R,6S)-3-Methyl-6-tert-butyl(2-2H1)cyclohexanol
3.360	91.7	C9H18	126.1	6886213	19549-87-2	2,4-Dimethyl-1-heptene
3.600	92.5	C6H18O3Si3	222.1	562676	541-05-9	Cyclotrisiloxane, hexamethyl-
3.860	86.9	C9H18	126.1	568454	19549-87-2	2,4-Dimethyl-1-heptene
3.930	87.4	C8H10	106.1	880828	0-00-0	unidentified C2-benzene
4.060	92.6	C5H6O2	98.0	924923	98-00-0	2-Furanmethanol
4.750	86.7	C8H9NO2	151.1	357546	1000222-86-6	Oxime-, methoxy-phenyl-
4.930	85.8	C5H10O	86.1	1629832	107-87-9	2-Pentanone
5.190	92.5	C6H10O2	114.1	1637926	110-13-4	2,5-Hexanedione
5.360	95.2	C8H16O	128.1	6611091	6137-06-0	2-Heptanone, 4-methyl-
5.840	91.4	C9H12	120.1	347185	0-00-0	unidentified C3-benzene
5.860	93.6	C10H22	142.2	848793	5911-04-6	Nonane, 3-methyl-
6.070	84.8	C10H20	140.2	946959	1678-93-9	Cyclohexane, butyl-
6.180	94.6	C9H18O	142.1	3078949	19549-80-5	2-Heptanone, 4,6-dimethyl-
6.310	96.1	C8H24O4Si4	296.1	1986064	556-67-2	Cyclotetrasiloxane, octamethyl-
6.320	96.7	C10H22	142.2	11231619	124-18-5	Decane
6.470	91.9	C11H24	156.2	1603307	17302-28-2	Nonane, 2,6-dimethyl-
6.540	87.3	C10H22	142.2	2039836	17302-01-1	3-Ethyl-3-methylheptane
6.670	86.0	C11H22	154.2	744376	33933-75-4	2-Octene, 2,3,7-trimethyl-
6.780	88.9	C8H18O	130.1	1072944	104-76-7	1-Hexanol, 2-ethyl-
6.800	96.5	C10H16	136.1	2674363	138-86-3	dl-Limonene
7.030	83.2	C11H22	154.2	397378	55499-08-6	Nonane, 2-methyl-3-methylene-

7.130	82.3	C7H12O2	128.1	838860	13505-34-5	2,6-Heptadione
7.230	90.2	C13H28	184.2	2556007	17301-32-5	Undecane, 4,7-dimethyl-
7.300	83.8	C12H24	168.2	1141217	74421-03-7	2-Decene, 2,4-dimethyl-
7.330	88.7	C15H32	212.3	887330	31295-56-4	Dodecane, 2,6,11-trimethyl-
7.390	91.8	C8H8O	120.1	484003	98-86-2	Ethanone, 1-phenyl-
7.580	80.7	C11H22	154.2	2691380	19780-74-6	5-Ethyl-1-nonene
7.640	88.7	C10H22O	158.2	2427203	106-21-8	1-Octanol, 3,7-dimethyl-
7.820	90.3	C12H26	170.2	677812	17312-44-6	2,3-Dimethyldecane
7.880	91.8	C14H30	198.2	1231861	629-59-4	Tetradecane
7.930	93.6	C13H28	184.2	5113453	17301-32-5	Undecane, 4,7-dimethyl-
8.320	80.8	C12H24	168.2	528718	74630-40-3	1-Undecene, 8-methyl-
8.410	81.4	C11H24O	172.2	471225	91337-07-4	2-Isopropyl-5-methyl-1-heptanol
8.640	90.7	C12H26	170.2	482628	1636-44-8	Decane, 4-ethyl-
8.720	94.1	C10H30O5Si5	370.1	9842361	541-02-6	Cyclopentasiloxane, decamethyl-
8.780	89.9	C12H26	170.2	647281	2980-69-0	Undecane, 4-methyl-
8.850	83.9	C12H26	170.2	431297	7045-71-8	Undecane, 2-methyl-
8.880	83.6	C13H28	184.2	550698	17312-77-5	Undecane, 2,3-dimethyl-
8.950	94.5	C12H26	170.2	2336377	1002-43-3	Undecane, 3-methyl-
9.260	93.2	C12H26O	186.2	669551	112-53-8	1-Dodecanol
9.390	95.4	C12H26	170.2	34328652	112-40-3	Dodecane
9.470	90.9	C10H20O	156.2	740626	112-31-2	Decanal
9.590	89.2	C13H28	184.2	908088	17312-82-2	Undecane, 4,6-dimethyl-
10.090	91.0	C13H28	184.2	1007260	17301-30-3	Undecane, 3,8-dimethyl-
10.530	89.4	C13H28	184.2	1362246	629-50-5	Tridecane
10.640	90.6	C13H28	184.2	853488	17301-32-5	Undecane, 4,7-dimethyl-
10.790	95.5	C13H28	184.2	1199450	629-50-5	Tridecane
10.890	85.4	C14H23F5O2	318.2	1010761	999502-65-8	Pentafluoropropionic acid, undecyl ester
11.010	88.3	C11H24O	172.2	808847	91337-07-4	2-Isopropyl-5-methyl-1-heptanol
11.080	82.9	C12H25Br	248.1	536084	13187-99-0	2-Bromo dodecane
11.150	90.9	C14H30	198.2	4219295	61141-72-8	Dodecane, 4,6-dimethyl-
11.170	95.8	C12H36O6Si6	444.1	13667388	540-97-6	Cyclohexasiloxane, dodecamethyl-
11.560	92.3	C12H24O3	216.2	4308271	74367-33-2	Propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl)propyl ester
11.670	85.1	C21H44	296.3	516213	54833-23-7	Eicosane, 10-methyl-
11.740	91.9	C14H30	198.2	1121651	6418-41-3	Tridecane, 3-methyl-
11.840	91.8	C12H24O3	216.2	6468334	74367-34-3	Propanoic acid, 2-methyl-, 3-hydroxy-2,4,4-trimethylpentyl ester
12.020	89.4	C14H28	196.2	362060	1120-36-1	1-Tetradecene
12.130	94.6	C14H30	198.2	12710277	629-59-4	Tetradecane
13.060	93.9	C14H20O2	220.1	1649542	719-22-2	2,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)-
13.560	90.7	C14H22O	206.2	1225402	96-76-4	Phenol, 2,4-bis(1,1-dimethylethyl)-
13.900	88.4	C15H32	212.3	538098	31295-56-4	Dodecane, 2,6,11-trimethyl-
14.580	93.5	C16H34	226.3	1317123	544-76-3	Hexadecane
15.390	90.3	C16H48O8Si8	592.2	747820	556-68-3	Cyclooctasiloxane, hexadecamethyl-