

Supporting Information

Global Warming Potentials for the C₁-C₃ Hydrochlorofluorocarbons (HCFCs) Included in the Kigali Amendment to the Montreal Protocol

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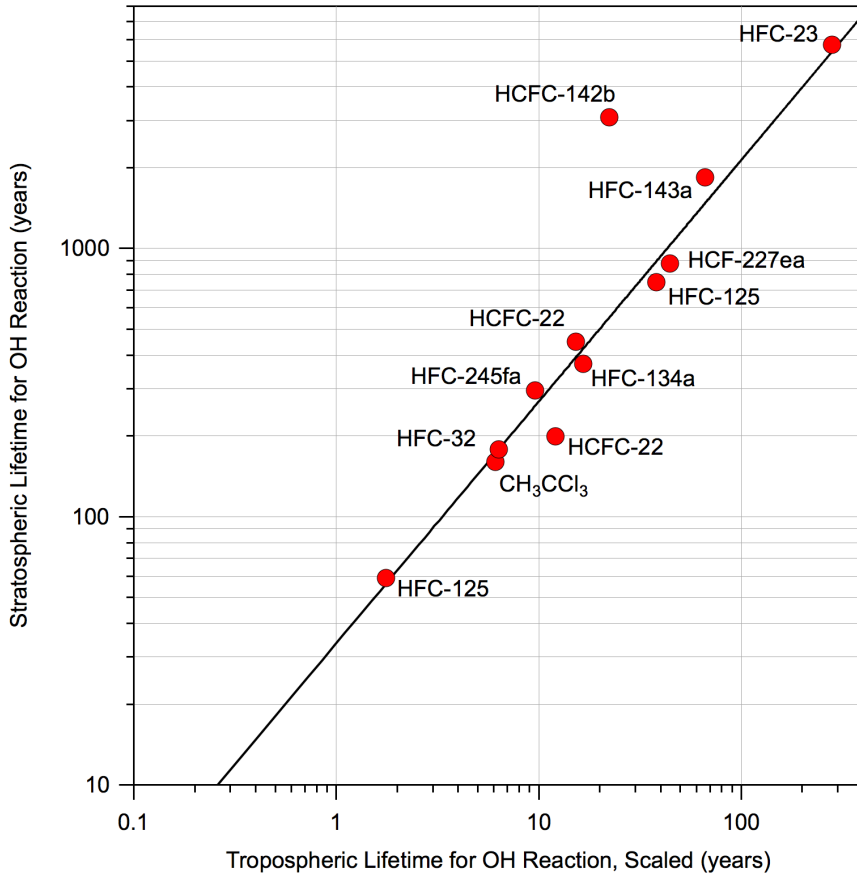


Figure S1. Correlation between the tropospheric and stratospheric lifetimes for OH reactive loss calculated using the 2-D atmospheric model results for the HCFCs and HFCs reported in the SPARC (Ko et al., 2013) lifetime report. The stratospheric lifetime has been corrected for O(¹D) reactive loss using reactive rate coefficients reported in Burkholder et al. (Burkholder et al., 2015) and estimated lifetimes as described in the text. The line is a fit to the data, $\text{Log}_{10}(\tau_{Strat}^{OH}) = 1.528 + 0.901 \text{Log}_{10}(\tau_{Trop}^{OH})$. HCFC-142b was not included in the fit. The 2-D model calculated tropospheric lifetimes were scaled to the recommended CH₃CCl₃ tropospheric lifetime of 6.1 years.

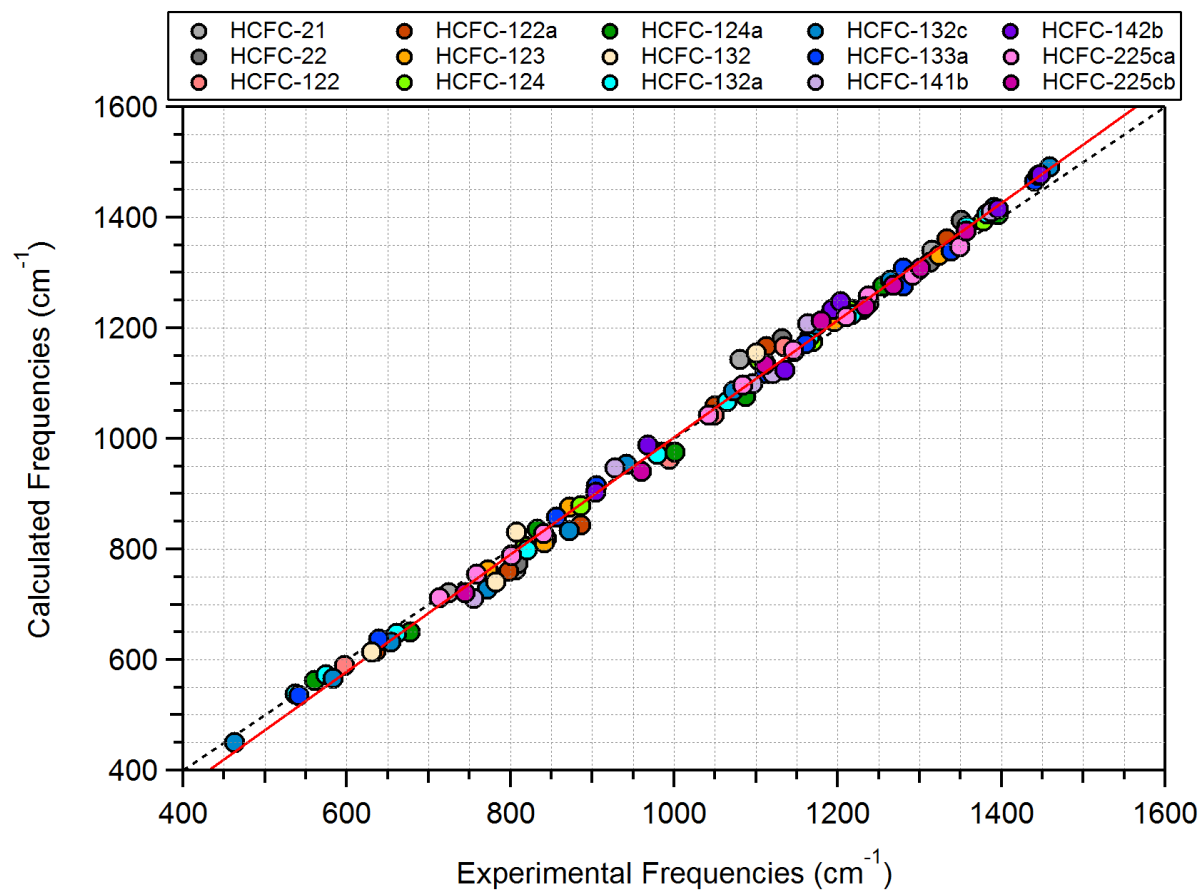


Figure S2. Comparison of experimentally measured and calculated infrared absorption spectrum frequencies for the HCFCs listed in the legend. The dashed line represents a 1:1 correlation. The correlation was used to derive a linear frequency correction (red line) for the calculated HCFC spectra in this study.

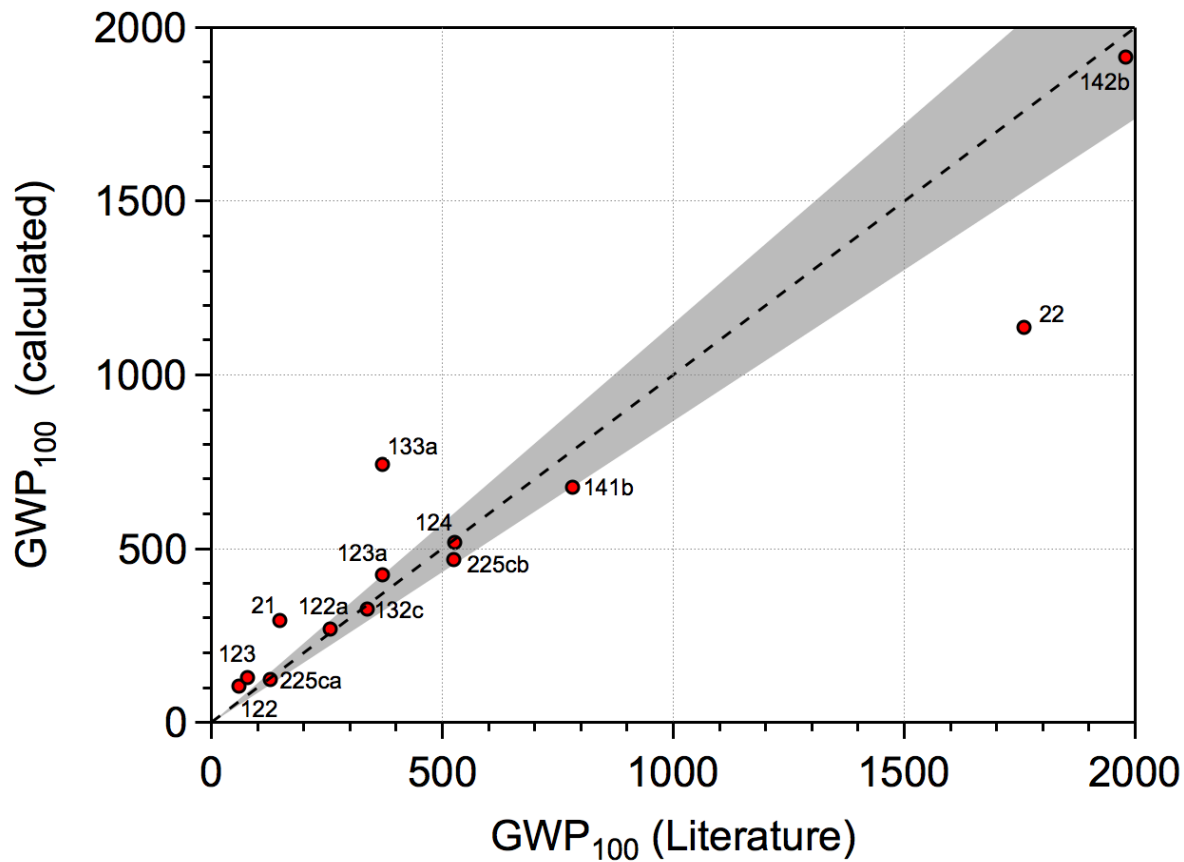


Figure S3. Comparison of 100-year time horizon GWP values reported in the WMO assessment (WMO, 2014) and McGillen et al. (2015) for 133a (with lifetime-adjustment and stratospheric temperature correction applied) and the values calculated in this study. The dashed line represents the 1:1 correlation and the shaded area is a 15% spread around the 1:1 line.

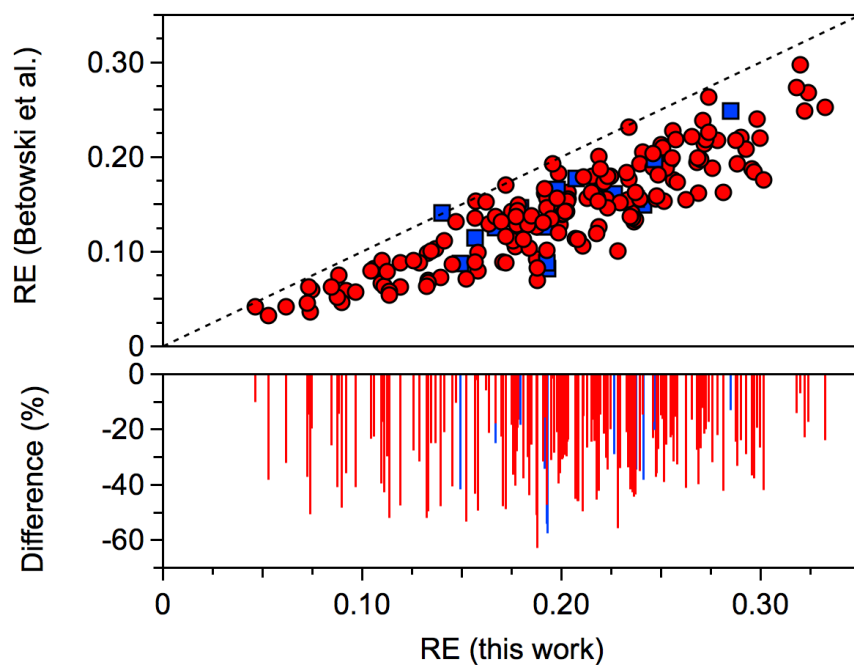


Figure S4. Comparison of radiative efficiencies (RE) ($\text{W m}^{-2} \text{ppbv}^{-1}$) calculated in this work and reported in Betowski et al. (2015). The HCFCs that have experimentally derived RE values are shown in blue (rectangles and lines). The bottom panel shows the percent difference between this work and that of Betowski et al. for each of the HCFCs.

Table S1. Data used to derive the empirical correlation of fractional release factor (FRF) versus stratospheric lifetime, τ_{Strat} . Stratospheric lifetimes were taken from the 2-D model results given in the SPARC (Ko et al., 2013) lifetime report. The FRFs were taken from WMO assessment (WMO, 2014).

Molecule	Fractional Release Factor (FRF)	Stratospheric Lifetime (τ_{Strat}) (years)
CFC-11	0.47	55
CFC-12	0.23	95.5
CFC-113	0.29	88.4
CFC-114	0.12	191
CFC-115	0.04	664
Halon-1202	0.62	36
Halon-1211	0.62	41
Halon-1301	0.28	73.5
Halon-2402	0.65	41
CH ₃ Cl	0.44	30.4
CCl ₄	0.56	44
CH ₃ CCl ₃	0.67	38
HCFC-22	0.13	161
HCFC-141b	0.34	72.3
HCFC-142b	0.17	212
CH ₃ Br	0.60	26.3

Table S2. Summary of estimated lifetimes, ozone depletion potentials (ODP), radiative efficiencies (REs), global warming potentials (GWPs), and global temperature potentials (GTPs) for the C₁-C₃ hydrochlorofluorocarbons (HCFCs) included in this work. The GWP and GTP values are consistent with the CO₂ radiative forcing used in the IPCC (2013) and WMO (2014) assessments.

HCFC	Formula	Lifetimes (years)								Ozone Depletion Potential (ODP)	Radiative Efficiency (RE) W m ⁻² ppb ⁻¹	Global Warming Potential (Time Horizon, years)		Global Temperature Potential (Time Horizon, years)		
		Global	Total Trop	Total Strat	Total OH Reactive Loss	Trop OH Reactive Loss	Strat OH Reactive Loss	O(1D) Reactive Loss	UV Photolysis Loss			20	100	20	50	100
21	CHFCI ₂	2.66	2.87	36.4	2.780	2.87	87.2	285	80	0.053	0.185	1078	292	438	53	41
22	CHF ₂ Cl	8.09	8.67	119.8	8.365	8.67	236.2	529	450	0.032	0.2	3847	1138	2661	344	162
31	CH ₂ FCI	0.897	0.927	27.7	0.901	0.927	31.5	463	450	0.015	0.0587	173	47	55	8	7
121	CHCl ₂ CCl ₂ F	1.11	1.17	20.0	1.137	1.17	38.9	185	50	0.030	0.183	244	66	80	11	9
121a	CHClFCCl ₂	2.67	2.96	27.3	2.863	2.96	89.6	185	50	0.066	0.18	582	158	237	29	22
122	CHCl ₂ CClF ₂	1.39	1.47	24.5	1.430	1.47	47.8	195	67.9	0.030	0.211	389	105	133	18	15
122a	CHClFCCl ₂ F	3.2	3.54	34.1	3.422	3.54	105.3	195	67.9	0.060	0.232	988	268	434	50	37
122b	CHF ₂ CCl ₃	9.31	12.6	35.5	12.154	12.6	331.1	195	50	0.170	0.213	2326	713	1702	253	102
123	CHCl ₂ CF ₃	1.81	1.92	30.8	1.861	1.92	60.7	285	80	0.026	0.181	480	130	173	23	18
123a	CHClFCClF ₂	4.16	4.45	63.8	4.304	4.45	129.5	285	225	0.038	0.256	1558	425	778	84	60
123b	CHF ₂ CCl ₂ F	11.8	15.1	53.8	14.525	15.1	389.0	285	80	0.124	0.24	3394	1125	2694	528	167
124	CHClFCF ₃	5.47	5.8	98.0	5.600	5.8	164.3	529	450	0.018	0.211	1860	517	1070	114	73
124a	CHF ₂ CClF ₂	17	19	161.2	18.266	19	478.6	529	450	0.026	0.241	4677	1826	4088	1258	327
131	CHCl ₂ CHClF	0.752	0.786	20.0	0.764	0.786	27.1	185	67.9	0.019	0.101	113	31	36	5	4
131a	CH ₂ CICCl ₂ F	2.57	2.8	31.4	2.711	2.8	85.3	185	67.9	0.056	0.169	647	175	259	32	24
131b	CH ₂ FCCl ₂	2.33	2.55	26.2	2.473	2.55	78.5	185	50	0.054	0.132	456	123	176	22	17
132	CHClFCHClF	1.73	1.81	39.1	1.759	1.81	57.7	264	225	0.025	0.152	438	119	156	21	17
132a	CHCl ₂ CHF ₂	1.12	1.18	23.9	1.144	1.18	39.1	264	80	0.020	0.131	246	67	81	12	9
132b	CH ₂ CICClF ₂	4.84	5.21	67.0	5.039	5.21	149.4	264	225	0.048	0.202	1602	441	864	92	62
132c	CH ₂ FCCl ₂ F	3.76	4.14	40.8	4.005	4.14	121.4	264	80	0.054	0.191	1194	325	566	63	45
133	CHClFCHF ₂	3.07	3.21	67.8	3.109	3.21	96.5	463	450	0.017	0.173	1008	273	434	51	38
133a	CH ₂ CICF ₃	9.82	10.6	126.5	10.262	10.6	284.1	463	450	0.026	0.147	2386	743	1782	280	107
133b	CH ₂ FCClF ₂	7.21	7.71	110.0	7.443	7.71	212.5	463	450	0.024	0.206	2640	762	1736	206	108
141	CH ₂ CiCHClF	1.14	1.19	29.5	1.153	1.19	39.4	247	225	0.022	0.0772	170	46	56	8	6
141a	CH ₂ FCHCl ₂	0.494	0.51	20.0	0.498	0.51	20.0	247	80	0.011	0.0594	56	15	17	3	2
141b	CH ₂ CCl ₂ F	8.33	10	49.3	9.666	10	269.2	247	80	0.122	0.156	2269	676	1589	211	96
142	CH ₂ CiCHF ₂	2.61	2.73	60.1	2.643	2.73	83.4	411	450	0.019	0.11	643	174	259	32	24
142a	CH ₂ FCHClF	1.58	1.64	42.3	1.591	1.64	52.7	411	450	0.015	0.113	399	108	139	19	15
142b	CH ₂ CClF ₂	16.6	18.7	147.6	17.958	18.7	471.3	411	450	0.041	0.191	4969	1916	4319	1291	336
151	CH ₂ CiCH ₂ F	0.487	0.5	20.0	0.488	0.5	20.0	370	450	0.008	0.0306	41	11	12	2	2
151a	CH ₂ CHClF	1.16	1.2	33.2	1.165	1.2	39.7	370	450	0.015	0.0629	199	54	66	9	7
221aa	CHCl ₂ CCl ₂ CCl ₂ F	0.929	0.979	20.0	0.951	0.979	33.1	185	50	0.027	0.183	142	38	46	7	5
221ab	CHClFCCl ₂ CCl ₂	2.67	2.96	27.3	2.863	2.96	89.6	185	50	0.069	0.181	404	109	164	20	15
221ba	CHCl ₂ CClFCCl ₂	1.11	1.17	20.0	1.137	1.17	38.9	185	50	0.032	0.174	161	44	53	8	6
221da	CCl ₂ CHClCCl ₂ F	3.29	3.71	29.0	3.592	3.71	110.0	185	50	0.083	0.243	668	181	297	34	25
221ea	CCl ₂ CHFCCl ₂	3.51	3.99	29.5	3.859	3.99	117.3	185	50	0.088	0.219	644	175	295	33	24
222aa	CHCl ₂ CCl ₂ CClF ₂	1.11	1.17	20.0	1.137	1.17	38.9	185	50	0.028	0.224	221	60	73	10	8
222ab	CHClFCCl ₂ CCl ₂ F	2.67	2.96	27.3	2.863	2.96	89.6	185	50	0.061	0.234	557	151	226	28	21
222ac	CHF ₂ CCl ₂ CCl ₃	9.29	12.6	35.2	12.154	12.6	331.1	185	50	0.191	0.221	1616	495	1182	175	71
222ba	CHCl ₂ CClFCCl ₂ F	1.11	1.17	20.0	1.137	1.17	38.9	185	50	0.028	0.21	207	56	68	10	8
222bb	CHClFCClFCCl ₃	3.15	3.54	28.6	3.422	3.54	105.3	185	50	0.071	0.199	557	151	243	28	21
222ca	CHCl ₂ CF ₂ CCl ₃	1.38	1.47	21.6	1.430	1.47	47.8	185	50	0.034	0.205	253	68	86	12	10
222da	CCl ₂ FCHClCCl ₂ F	4.48	5.23	31.2	5.055	5.23	149.8	185	50	0.097	0.283	1118	306	580	62	43
222db	CCl ₂ CHClCClF ₂	4.62	5.42	31.4	5.236	5.42	154.6	185	50	0.100	0.265	1077	296	568	61	41
222ea	CCl ₂ CHFCCl ₂ F	4.68	5.49	31.5	5.306	5.49	156.5	185	50	0.101	0.245	1007	276	534	57	39

HCFC	Formula	Lifetimes (years)								Ozone Depletion Potential (ODP)	Radiative Efficiency (RE) $W m^{-2} ppb^{-1}$	Global Warming Potential (Time Horizon, years)		Global Temperature Potential (Time Horizon, years)		
		Global	Total Trop	Total Strat	Total OH Reactive Loss	Trop OH Reactive Loss	Strat OH Reactive Loss	O(¹ D) Reactive Loss	UV Photolysis Loss			20	100	20	50	100
253fb	CH ₂ CICH ₂ CF ₂	1.05	1.09	30.8	1.054	1.09	36.3	370	450	0.009	0.121	216	58	70	10	8
253fc	CH ₂ FCH ₂ CCIF ₂	1.48	1.54	39.9	1.489	1.54	49.6	370	450	0.011	0.194	487	132	168	23	18
261aa	CH ₂ CCl ₂ CH ₂ F	1.06	1.11	22.7	1.080	1.11	37.1	218	80	0.020	0.0727	132	36	43	6	5
261ba	CH ₂ CCIFCH ₂ Cl	2.19	2.31	43.5	2.237	2.31	71.7	218	225	0.031	0.0827	312	84	118	15	12
261da	CH ₂ CICHClCH ₂ F	0.45	0.462	20.0	0.452	0.462	20.0	218	225	0.009	0.0338	26	7	8	1	1
261db	CH ₂ CHClCHClF	0.465	0.478	20.0	0.467	0.478	20.0	218	225	0.009	0.0625	50	14	15	2	2
261ea	CH ₂ CICHFCH ₂ Cl	0.536	0.554	20.0	0.539	0.554	20.0	218	225	0.010	0.0493	45	12	14	2	2
261eb	CH ₂ CHFCHCl ₂	0.309	0.315	20.0	0.310	0.315	20.0	218	80	0.006	0.0618	33	9	10	2	1
261fa	CH ₂ CICH ₂ CHClF	0.572	0.591	20.0	0.575	0.591	21.0	218	225	0.011	0.0746	73	20	23	3	3
261fb	CH ₂ FCH ₂ CHCl ₂	0.332	0.339	20.0	0.333	0.339	20.0	218	80	0.006	0.0557	32	9	10	1	1
261fc	CH ₂ CH ₂ CCl ₂ F	0.614	0.638	20.0	0.621	0.638	22.5	218	80	0.012	0.137	145	39	45	7	5
262ba	CH ₂ CClFCH ₂ F	3.41	3.59	68.6	3.469	3.59	106.6	336	450	0.020	0.125	837	227	378	43	32
262ca	CH ₂ CF ₂ CH ₂ Cl	3.17	3.33	65.6	3.219	3.33	99.6	336	450	0.019	0.117	724	196	316	37	27
262da	CH ₂ FCHClCH ₂ F	0.924	0.956	27.7	0.929	0.956	32.4	336	450	0.009	0.0587	107	29	34	5	4
262db	CH ₂ CHClCH ₂ F	0.642	0.662	20.8	0.644	0.662	23.3	336	450	0.007	0.0813	103	28	32	5	4
262ea	CH ₂ FCH ₂ CHCl ₂	0.828	0.856	25.4	0.831	0.856	29.3	336	450	0.009	0.0657	107	29	34	5	4
262eb	CH ₂ CHFCHCl ₂	0.663	0.685	21.3	0.666	0.685	24.0	336	450	0.007	0.0982	128	35	40	6	5
262fa	CH ₂ CICH ₂ CHF ₂	0.801	0.828	24.8	0.804	0.828	28.4	336	450	0.008	0.0858	135	37	43	6	5
262fb	CH ₂ FCH ₂ CHCl ₂	0.873	0.902	26.5	0.877	0.902	30.7	336	450	0.009	0.0991	170	46	54	8	6
262fc	CH ₂ CH ₂ CF ₂ Cl	1.19	1.24	33.7	1.202	1.24	40.9	336	450	0.011	0.168	394	107	131	18	15
271ba	CH ₂ CClFCH ₃	5.05	5.37	83.4	5.190	5.37	153.4	308	450	0.028	0.106	1224	338	675	72	47
271da	CH ₂ CHClCH ₂ F	0.273	0.278	20.0	0.274	0.278	20.0	308	450	0.004	0.0261	17	5	5	1	1
271ea	CH ₂ CHFCH ₂ Cl	0.297	0.302	20.0	0.298	0.302	20.0	308	450	0.004	0.033	23	6	7	1	1
271fa	CH ₂ CICH ₂ CH ₂ F	0.339	0.345	20.0	0.339	0.345	20.0	308	450	0.004	0.0284	22	6	7	1	1
271fb	CH ₂ CH ₂ CHClF	0.492	0.506	20.0	0.494	0.506	20.0	308	450	0.007	0.0652	75	20	23	3	3

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