



*Supplement of*

## **Atmospheric impact of 2-methylpentanal emissions: kinetics, photochemistry, and formation of secondary pollutants**

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# SUPPLEMENT

## I. CHEMICALS

Gases were used as supplied: Synthetic air (99.999 %, Air Liquide), Cl<sub>2</sub> (Sigma Aldrich, 99.8%), propene (Sigma Aldrich, 99%), and He (Nippon Gases, 99.999%). Liquids from  
5 Sigma Aldrich, with purities in brackets, were used after freeze-pump-thaw cycles: 2-methylpentanal (97%), ethanol (99.8%), isoprene (99%), 2-pentanone (94.2%), acetaldehyde (99.5%), acetic acid (99.7%), and cyclohexane (99.9%). The aqueous solution of H<sub>2</sub>O<sub>2</sub> (Sharlab, >50% v/v) was preconcentrated as previously described (Albaladejo et al., 2002).

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## II. ADDITIONAL INFORMATION ON MATERIALS AND METHODS

### II.A. Gas-phase UV spectroscopy (220-360 nm)

To obtain reliable values of the UV absorption cross section ( $\sigma_\lambda$  in cm<sup>2</sup> molecule<sup>-1</sup>) several  
15 UV spectra were recorded in a cylindrical jacketed gas cell (optical path length,  $l = 107.15$  cm) using different concentrations of 2MP (1.02 – 9.65 Torr). The temperature inside the cell was maintained at  $(298 \pm 1)$  K by flowing water from a thermostatic bath (Huber, Polystat cc1) through the jacket. According to the Beer-Lambert's law (Eq. S1)  $\sigma_\lambda$  was obtained from the slope of the measured absorbance ( $A_\lambda$ ) versus [2MP] plots.

$$A_\lambda = \sigma_\lambda l [2MP] \quad (\text{S1})$$

20 Some of these plots at several wavelengths are depicted in **Fig. S1**, including the absorption maximum at 296 nm.

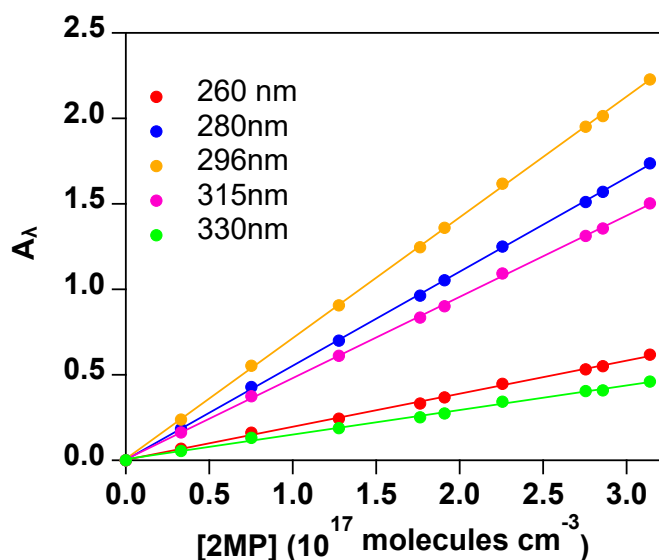


Figure S1. Examples of plots of Beer-Lambert's law for 2MP at room temperature.

## II.B. Smog chamber kinetic experiments. Preliminary experiments

25 Preliminary experiments on the loss processes of 2MP and reference compounds in the absence of Cl atoms were done as described in previous studies (Antiñolo et al., 2019; Antiñolo et al., 2020):

- *Wall losses*: in the absence of Cl<sub>2</sub> and UV light ( $k_w$ )
- *Reaction with Cl<sub>2</sub>*: in the absence of UV light ( $k'_{Cl_2}$ )
- 30 • *UV photolysis*: irradiating the sample in the absence of Cl<sub>2</sub> ( $k_{hv}$ )

As shown in **Table S1**, all species exhibited wall losses and no photolysis at the emission wavelengths of the actinic lamps ( $\lambda = 340\text{-}400$  nm). The latter observations are in agreement with the very low UV absorption of 2MP in that range observed in the present work and for the reference alkenes.

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**Table S1.** Average loss rate coefficients due to different processes observed for the 2MP and the reference compounds.

Compound	$k_w$ ( $10^{-5} \text{ s}^{-1}$ )	$k_{hv}$ ( $10^{-5} \text{ s}^{-1}$ )	$k'_{Cl_2}$ ( $10^{-5} \text{ s}^{-1}$ )	$k_{Total\_loss}$ ( $10^{-5} \text{ s}^{-1}$ )
2MP	1.2±0.2	-	-	<b>1.2±0.2</b>
Propene	1.2±0.3	-	-	<b>1.2±0.3</b>
Isoprene	0.6±0.2	-	0.8±0.3	<b>1.4±0.4</b>

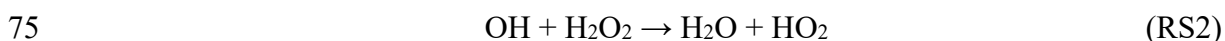
## 40 II.C. Pulsed Laser Photolysis-Laser Induced Fluorescence (PLP-LIF) technique

The temperature of the reactor was measured by a type K (chromel-alumel) thermocouple inserted a few millimeters above the reaction zone. The temperature was controlled ( $\pm 0.2$  K) by flowing water (for  $T \geq 278$  K) or water/ethanol mixture (for  $T \leq 268$  K) through the double wall of the reactor. The total pressure was controlled by means  
45 a needle valve placed between the exit of the reactor and the pump, and it was measured by a pressure transducer (Oerlikon Leybold Vacuum, model CERAVAC CTR 100, Full scales of 0–100 Torr and 0–1000 Torr). The total incoming gas flow ( $F_{Total}$ ) consisted of a mixture of bath gas ( $F_{He} = 269.8\text{--}468.1$  standard cubic centimeters per minute (sccm)), OH radical precursor ( $F_{H_2O_2/He} = 1.31\text{--}26.49$  sccm) and different concentrations of  
50 diluted 2MP ( $F_{2MP} = 0.44\text{--}14.38$  sccm), all of them controlled by calibrated mass flow controllers. The 2MP diluted mixtures were prepared in a 10 L storage bulb by introducing a specific pressure of pure 2MP and diluting it with He up to around 770 Torr. The dilution factor ( $f$ ), calculated as the ratio of the pure 2MP pressure and total pressure in the storage bulb, was in the  $(1.37\text{--}6.65) \times 10^{-3}$  range. In **Table S3** are shown the  
55 experimental conditions employed.

The OH radicals were generated *in situ* from the PLP of H<sub>2</sub>O<sub>2</sub> at 248 nm. This radiation was emitted by a KrF excimer laser (Coherent, Excistar 200), with a laser fluence of 23 mJ pulse<sup>-1</sup> cm<sup>-2</sup> at 10 Hz. The OH radicals generated in electronic ground state were excited at *ca.* 282 nm to the first excited electronic state (laser energy 0.8–1.2 mJ pulse<sup>-1</sup> at 10 Hz) by the second harmonic of a Rhodamine-6G dye laser (LiopTech, LiopStar).  
 60 The dye laser was pumped by the second harmonic of a Nd-YAG laser (InnoLas, SpitLight 1200). At 90 degrees from photolysis and excitation lasers, the laser induced fluorescence (LIF) at *ca.* 310 nm was collected by a filtered phototube (Thorn EMI, 9813B). The LIF signal ( $I_{LIF}$ ) was integrated by a boxcar unit and treated by computer  
 65 software (Stanford Research Systems, SR270). By varying the delay between excitation and photolysis lasers, the time evolution of  $I_{LIF}$  was obtained. Under *pseudo*-first order conditions, *i.e.* when initial concentration of 2MP is in large excess with respect to that of OH radicals, the time evolution of  $I_{LIF}$  follows a single exponential decay:

$$I_{LIF} = I_{LIF,0} \exp(-k't) \quad (S2)$$

70 where  $I_{LIF,0}$  is the LIF intensity at time 0 and  $k'$  is the *pseudo*-first order rate coefficient for a given 2MP concentration, temperature, and pressure. Some examples of temporal evolution of  $I_{LIF}$  are shown in **Figure S2**.  $k'$  includes all OH-loss processes: reaction with 2MP and H<sub>2</sub>O<sub>2</sub>, and diffusion out from the detection zone mainly.



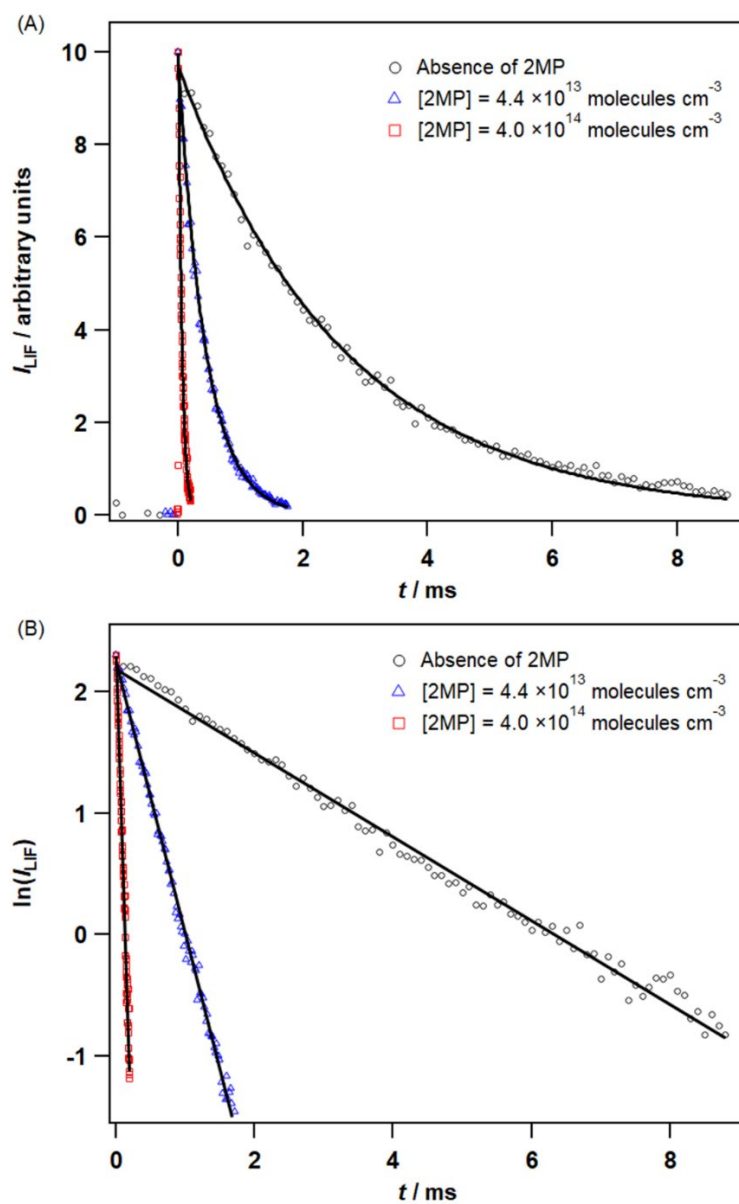
From the analysis of  $k'$  in presence and absence ( $k'_0$ ) of 2MP, the second-order rate coefficient  $k_{OH}(T)$  at a given temperature is obtained.

$$k' - k'_0 = k_{OH}(T)[2\text{MP}]_0 \quad (S3)$$

80 The concentration of 2MP in the reactor was calculated as follows:

$$[2\text{MP}]_0 = 3.24 \times 10^{16} \text{ molecules cm}^{-3} \text{ Torr}^{-1} \frac{F_{2\text{MP}}}{F_T} f P_T(\text{Torr}) \frac{298 \text{ K}}{T(\text{K})} \quad (S4)$$

From the slope of  $k' - k'_0$  versus  $[2\text{MP}]_0$ ,  $k_{OH}(T)$  was determined at each temperature and pressure.



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**Figure S2.** Temporal profiles of  $I_{LIF}$  from OH radicals in the absence and presence of 2MP at 263 K and 50 Torr.

**Table S2.** Experimental conditions employed and *pseudo*-first order coefficient (corrected with  $k_0'$ ) obtained in the kinetic study of the OH + 2MP reaction.

$T / \text{K}$	$P_T / \text{Torr}$	$f / 10^{-3}$	$F_{2\text{MP}} / \text{sccm}$	$F_{\text{H}_2\text{O}_2/\text{He}} / \text{sccm}$	$F_{\text{He}} / \text{sccm}$	$[\text{2MP}]_0 / 10^{14} \text{ molecules cm}^{-3}$	$k'-k_0' / 10^3 \text{ s}^{-1}$
263	50	6.646	0.92 – 8.61	4.03	275.3 – 283.6	0.44 – 3.56	1.75 – 15.58
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.44 – 3.96	1.88 – 16.97
	250	2.771	0.92 – 6.69	26.49	254.1 – 260.5	0.95 – 5.91	3.51 – 24.95
	250	2.771	0.92 – 6.69	26.49	254.1 – 260.5	0.95 – 5.91	3.52 – 24.93
	500	2.771	0.44 – 3.81	26.49	349.1 – 352.8	0.82 – 5.19	2.88 – 22.59
	500	2.771	0.44 – 3.81	26.49	349.1 – 352.8	0.82 – 5.19	2.60 – 21.72
268	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.43 – 3.88	1.66 – 16.09
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.43 – 3.88	1.42 – 16.02
278	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.42 – 3.74	1.33 – 14.53
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.42 – 3.74	1.53 – 14.54
288	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.40 – 3.61	1.34 – 13.13
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.40 – 3.61	1.02 – 13.02
298	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.39 – 3.49	0.73 – 11.70
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.39 – 3.49	1.16 – 11.92
	250	1.372	0.92 – 9.57	8.56	269.8 – 279.0	0.42 – 3.72	1.03 – 11.92
	250	2.771	0.92 – 7.65	8.56	456.1 – 463.5	0.51 – 3.62	1.19 – 11.94
	500	1.372	0.92 – 9.57	1.31	458.9 – 468.1	0.51 – 4.55	1.97 – 14.39
	500	2.771	0.44 – 3.81	26.49	349.1 – 352.8	0.72 – 4.58	1.92 – 14.82
309	50	2.771	1.88 – 14.38	4.03	269.8 – 283.6	0.30 – 2.13	0.92 – 6.83
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.37 – 3.37	0.90 – 10.53
323	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.36 – 3.22	0.98 – 9.82
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.36 – 3.22	0.85 – 9.46
338	50	6.646	0.92 – 9.57	4.03	274.4 – 286.6	0.34 – 3.08	0.93 – 8.62
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.34 – 3.08	0.84 – 8.56
353	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.33 – 2.95	0.87 – 8.05
	50	6.646	0.92 – 9.57	4.03	274.4 – 283.6	0.33 – 2.95	0.88 – 8.22
	250	2.771	0.92 – 9.57	8.56	362.0 – 371.2	0.54 – 4.72	1.53 – 12.80
	250	2.771	0.92 – 9.57	8.56	362.0 – 371.2	0.54 – 4.72	1.33 – 12.62
	500	2.771	0.44 – 4.77	26.49	348.2 – 352.8	0.61 – 4.80	1.50 – 12.94
	500	2.771	0.44 – 4.77	26.49	348.2 – 352.8	0.61 – 4.80	1.66 – 12.95

90 **II.D. Determination of the error in the rate coefficients**

The reported errors in the rate coefficients ( $\Delta k_{2MP}$  and  $J$ ) were obtained considering both the statistical uncertainties (*stat*) and systematic errors coming from instruments, (*syst*). For the Cl-reaction experiments  $\Delta k_{2MP}(\text{stat})$  also includes the error propagation considering the uncertainties of  $k_{\text{ref}}$ .

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$$\Delta k_{2MP} = \sqrt{\Delta k_{2MP}(\text{stat})^2 + \Delta k_{2MP}(\text{syst})^2} \quad (\text{S5})$$

$$\Delta J = \sqrt{\Delta J(\text{stat})^2 + \Delta J(\text{syst})^2} \quad (\text{S6})$$

Instrumental uncertainties ( $\Delta k_{2MP}(\text{syst})$  and  $\Delta J(\text{syst})$ ) do not exceed  $\pm 10\%$  of the determined parameter. Thus,

$$\Delta k_{2MP}(\text{syst}) = 0.1 \times k_{2MP}$$

$$\Delta J(\text{syst}) = 0.1 \times J$$

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### III. ADDITIONAL RESULTS

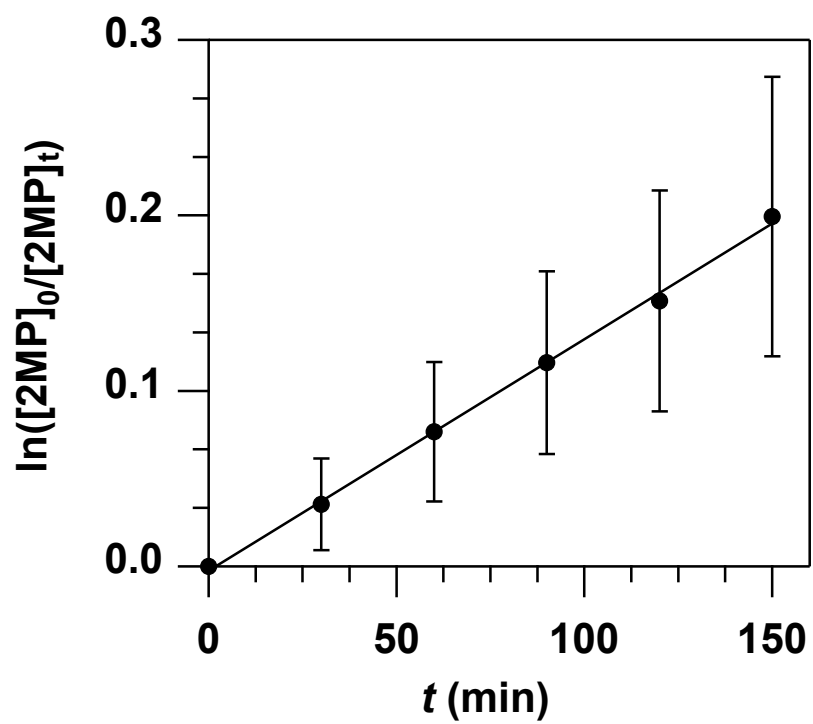
#### III.A. UV photochemistry of 2MP

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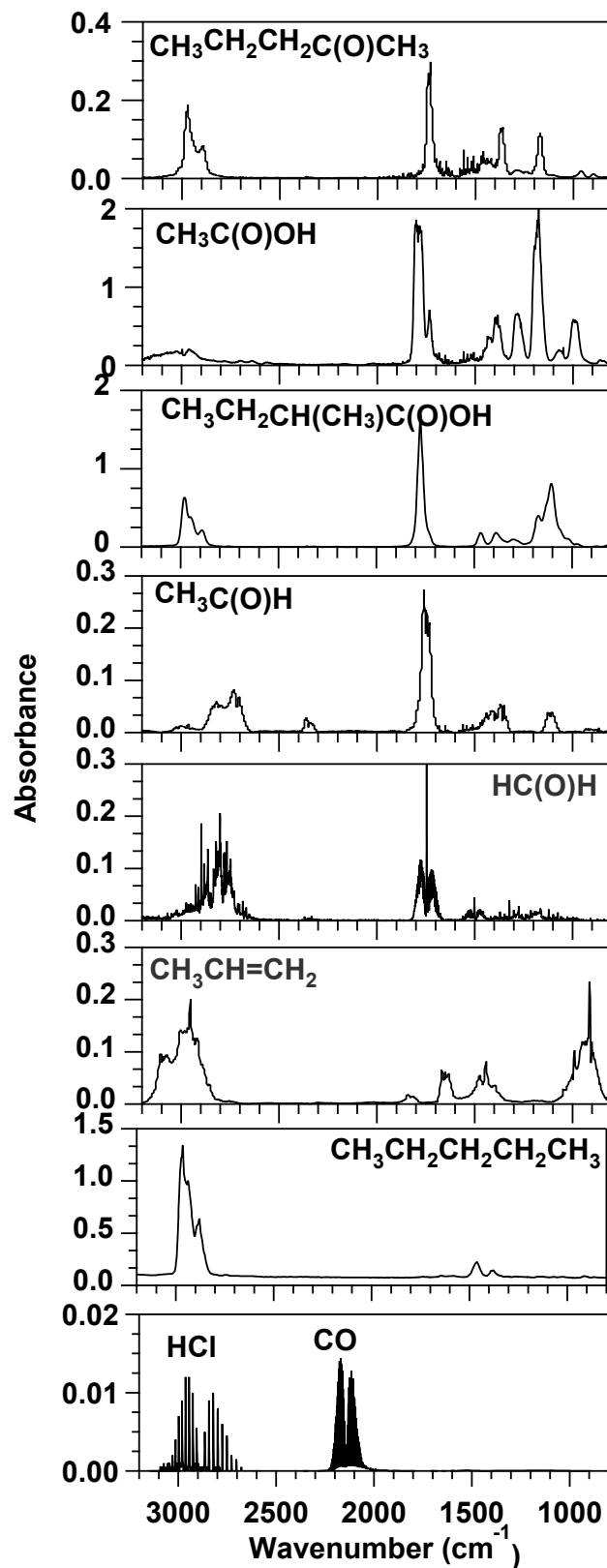
**Table S3.** Average UV absorption cross sections of 2MP (in base  $e$ ) in the range of 220-360 nm at 1 nm intervals. Uncertainties are  $\pm 2\sigma$  of the average.

$\lambda$ (nm)	$\sigma_{\lambda}$ ( $10^{-20}$ cm <sup>2</sup> molecule <sup>-1</sup> )	$\lambda$ (nm)	$\sigma_{\lambda}$ ( $10^{-20}$ cm <sup>2</sup> molecule <sup>-1</sup> )	$\lambda$ (nm)	$\sigma_{\lambda}$ ( $10^{-20}$ cm <sup>2</sup> molecule <sup>-1</sup> )
220	0.31 ± 0.10	267	2.85 ± 0.07	314	4.64 ± 0.10
221	0.30 ± 0.10	268	3.02 ± 0.08	315	4.46 ± 0.11
222	0.28 ± 0.10	269	3.20 ± 0.10	316	4.25 ± 0.11
223	0.27 ± 0.10	270	3.38 ± 0.11	317	3.99 ± 0.10
224	0.26 ± 0.11	271	3.56 ± 0.10	318	3.71 ± 0.11
225	0.24 ± 0.10	272	3.73 ± 0.09	319	3.45 ± 0.14
226	0.21 ± 0.09	273	3.91 ± 0.09	320	3.23 ± 0.14
227	0.19 ± 0.07	274	4.07 ± 0.06	321	3.02 ± 0.11
228	0.18 ± 0.06	275	4.24 ± 0.05	322	2.83 ± 0.08
229	0.18 ± 0.10	276	4.42 ± 0.05	323	2.65 ± 0.11
230	0.18 ± 0.12	277	4.61 ± 0.06	324	2.47 ± 0.10
231	0.18 ± 0.09	278	4.80 ± 0.07	325	2.30 ± 0.11
232	0.19 ± 0.09	279	4.97 ± 0.07	326	2.13 ± 0.12
233	0.20 ± 0.11	280	5.14 ± 0.06	327	1.97 ± 0.11
234	0.21 ± 0.10	281	5.30 ± 0.09	328	1.79 ± 0.12
235	0.22 ± 0.09	282	5.44 ± 0.09	329	1.58 ± 0.11
236	0.24 ± 0.10	283	5.57 ± 0.07	330	1.39 ± 0.13
237	0.26 ± 0.11	284	5.71 ± 0.06	331	1.20 ± 0.15
238	0.28 ± 0.09	285	5.85 ± 0.06	332	1.05 ± 0.15
239	0.30 ± 0.08	286	5.99 ± 0.08	333	0.93 ± 0.16
240	0.34 ± 0.10	287	6.12 ± 0.10	334	0.82 ± 0.16
241	0.37 ± 0.10	288	6.23 ± 0.11	335	0.72 ± 0.15
242	0.40 ± 0.10	289	6.34 ± 0.12	336	0.63 ± 0.13
243	0.43 ± 0.09	290	6.41 ± 0.11	337	0.55 ± 0.13
244	0.47 ± 0.08	291	6.47 ± 0.09	338	0.49 ± 0.17
245	0.52 ± 0.08	292	6.51 ± 0.07	339	0.42 ± 0.14
246	0.57 ± 0.09	293	6.57 ± 0.07	340	0.36 ± 0.11
247	0.62 ± 0.09	294	6.62 ± 0.11	341	0.30 ± 0.11
248	0.68 ± 0.08	295	6.64 ± 0.11	342	0.26 ± 0.11
249	0.74 ± 0.09	296	6.64 ± 0.11	343	0.22 ± 0.13
250	0.81 ± 0.08	297	6.62 ± 0.08	344	0.17 ± 0.11
251	0.88 ± 0.08	298	6.59 ± 0.08	345	0.14 ± 0.10
252	0.97 ± 0.09	299	6.56 ± 0.09	346	0.12 ± 0.12
253	1.05 ± 0.09	300	6.52 ± 0.09	347	0.11 ± 0.14
254	1.14 ± 0.09	301	6.47 ± 0.07	348	0.10 ± 0.11
255	1.23 ± 0.08	302	6.40 ± 0.07	349	0.09 ± 0.10
256	1.33 ± 0.05	303	6.32 ± 0.11	350	0.09 ± 0.12
257	1.44 ± 0.05	304	6.24 ± 0.12	351	0.08 ± 0.11
258	1.56 ± 0.06	305	6.14 ± 0.12	352	0.08 ± 0.14
259	1.69 ± 0.09	306	5.98 ± 0.10	353	0.09 ± 0.17
260	1.81 ± 0.09	307	5.79 ± 0.09	354	0.07 ± 0.08
261	1.95 ± 0.08	308	5.60 ± 0.10	355	0.07 ± 0.06
262	2.09 ± 0.08	309	5.44 ± 0.09	356	0.06 ± 0.07
263	2.23 ± 0.08	310	5.29 ± 0.08	357	0.06 ± 0.07
264	2.38 ± 0.08	311	5.13 ± 0.08	358	0.08 ± 0.11
265	2.54 ± 0.09	312	4.98 ± 0.09	359	0.07 ± 0.10
266	2.69 ± 0.08	313	4.82 ± 0.10	360	0.07 ± 0.08





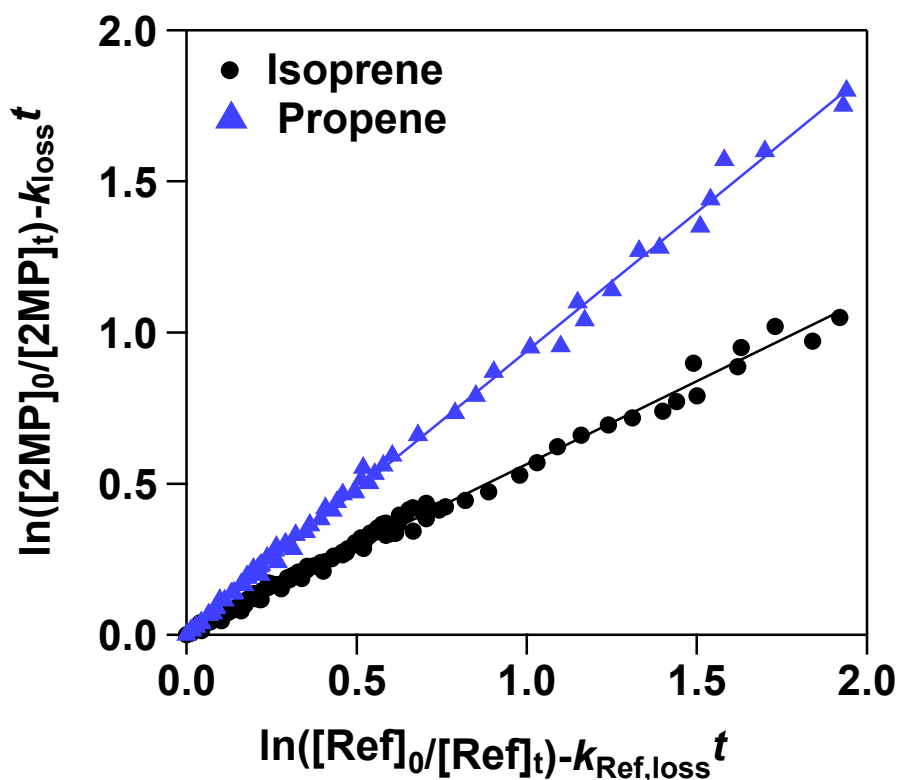
**Figure S3.** Plot of the 2MP loss after absorption of radiation at  $\lambda \geq 290$  nm as a function of time.



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**Figure S4.** Reference infrared spectrum of 2-pentanone, acetic acid, acetaldehyde, formaldehyde, HCl and CO recorded in our lab. Pentane, 2-methylbutanoic acid, and propene spectra were taken from the NIST FTIR database.

### III.B. Kinetics and products of Cl + 2MP reaction studied in smog chambers.

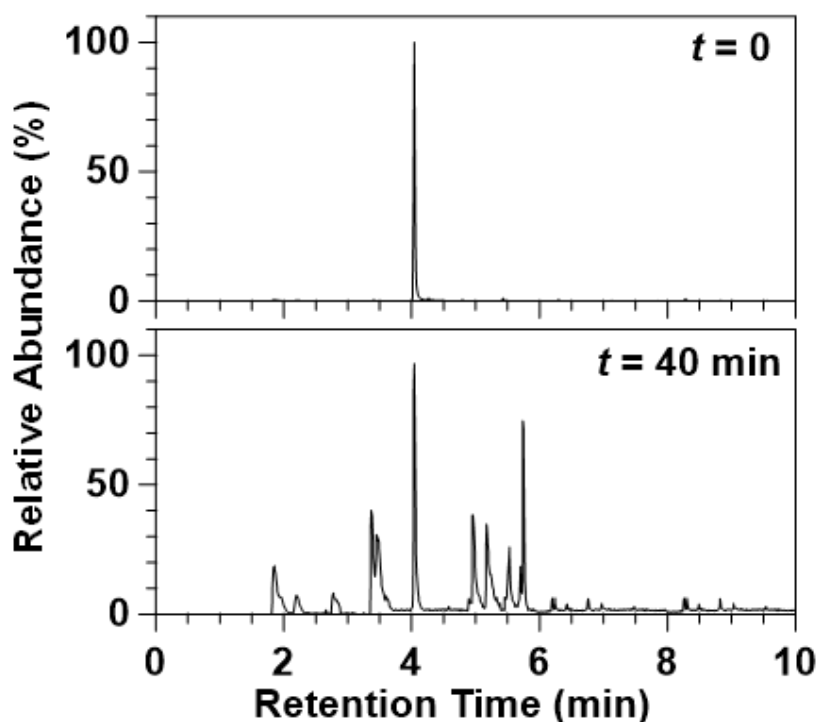


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**Figure S5.** Plot of Equation (E2) for the Cl-reaction of 2MP using two reference compounds.

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*Detection by SPME/GC-MS:* Gas chromatography coupled to mass spectrometry was also used in the product study of reactions R2 as an identification technique. In **Figure S6**, the recorded chromatograms before starting the Cl + 2MP reaction (a) and after 40 min (b) are shown.



**Figure S6.** Chromatograms obtained for a 2MP and Cl<sub>2</sub> mixture (a) before irradiation and (b) after 40 min of irradiation.

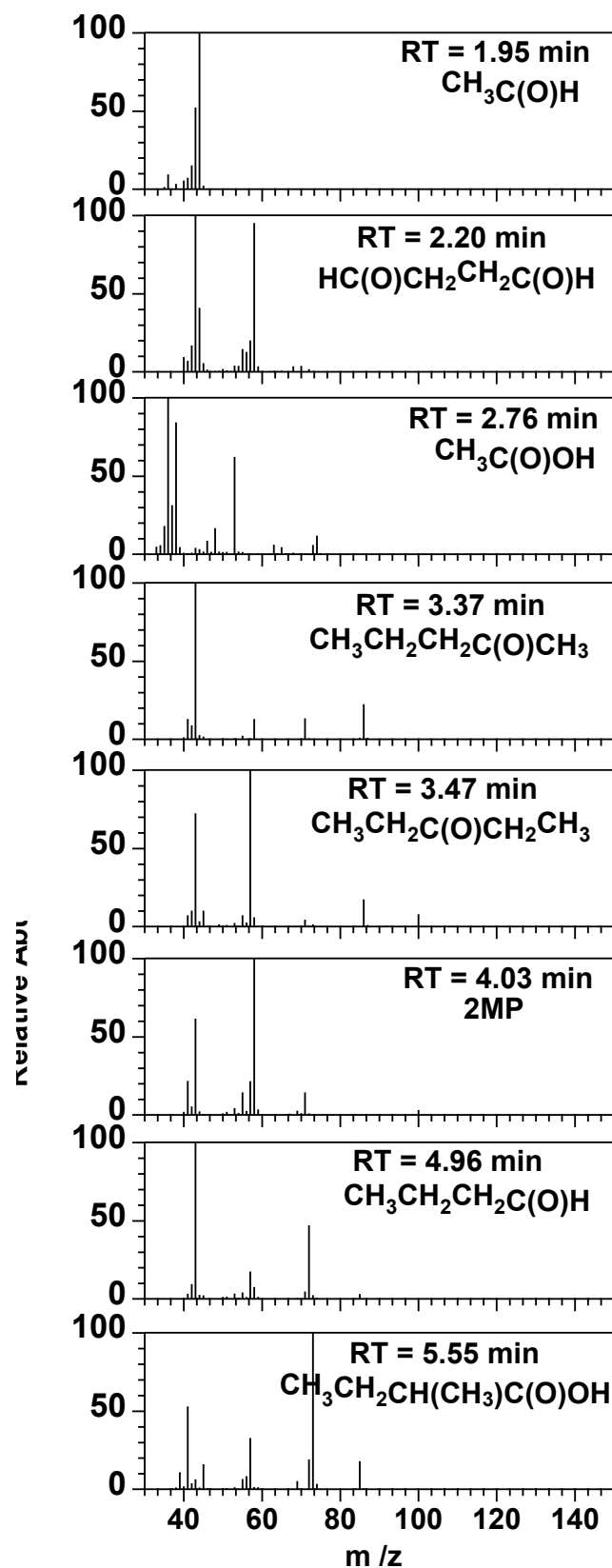
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At a retention time (RT) of 4.03 min, a strong peak can be observed corresponding to 2MP according to its mass spectrum. The rest of the peaks that appeared in the chromatogram were assigned to the following products using their mass spectra:

135 acetaldehyde (RT = 1.95 min), butanedial (RT = 2.20 min), acetic acid (RT = 2.76 min), 2-pentanone (RT = 3.37 min), 3-pentanone (RT = 3.47 min), butanal (RT = 4.96 min), 2-methylbutanoic acid (RT = 5.55 min).

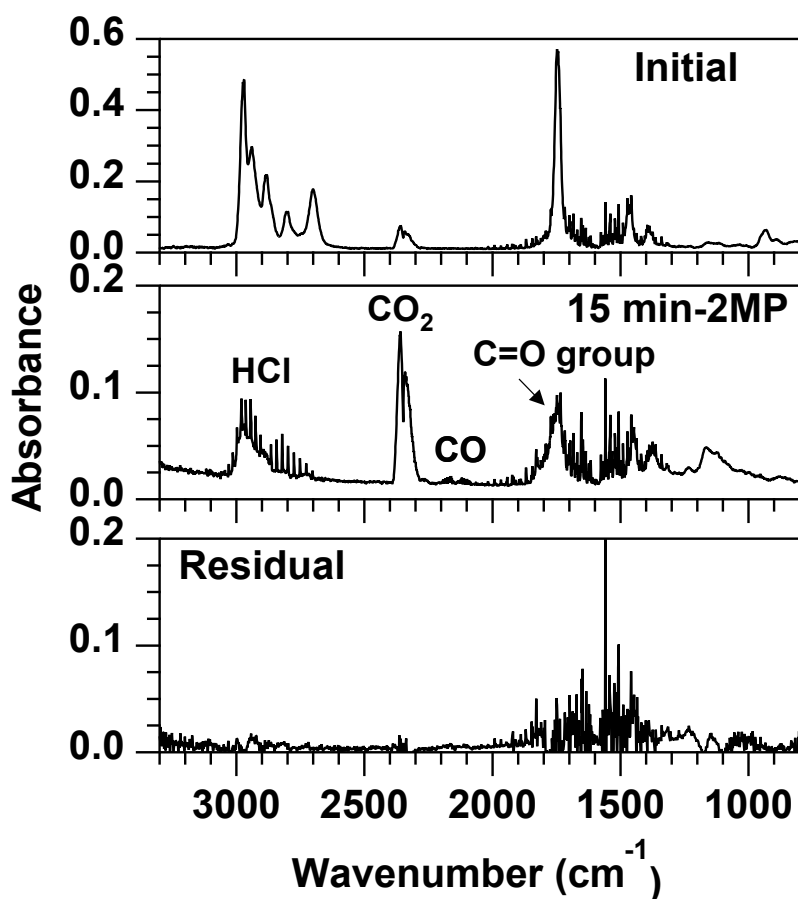
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Other small peaks in the chromatogram were due to the degradation of the SPME fibre and the chromatographic column. Mass spectra of 2MP and the identified products are shown in **Figure S7**.



**Figure S7.** Mass spectra detected for the peaks of the chromatogram shown in Figure S6.

145 *Detection by FTIR:* In **Figure S8**, the FTIR spectra of a mixture of 2MP and Cl<sub>2</sub> in synthetic air before (initial) and after 15 min of the photolysis (with the features of 2MP subtracted) are shown. By comparison with the reference spectra (Figure S4), the major products were found to be CO, HCl, 2-pentanone, and acetaldehyde.



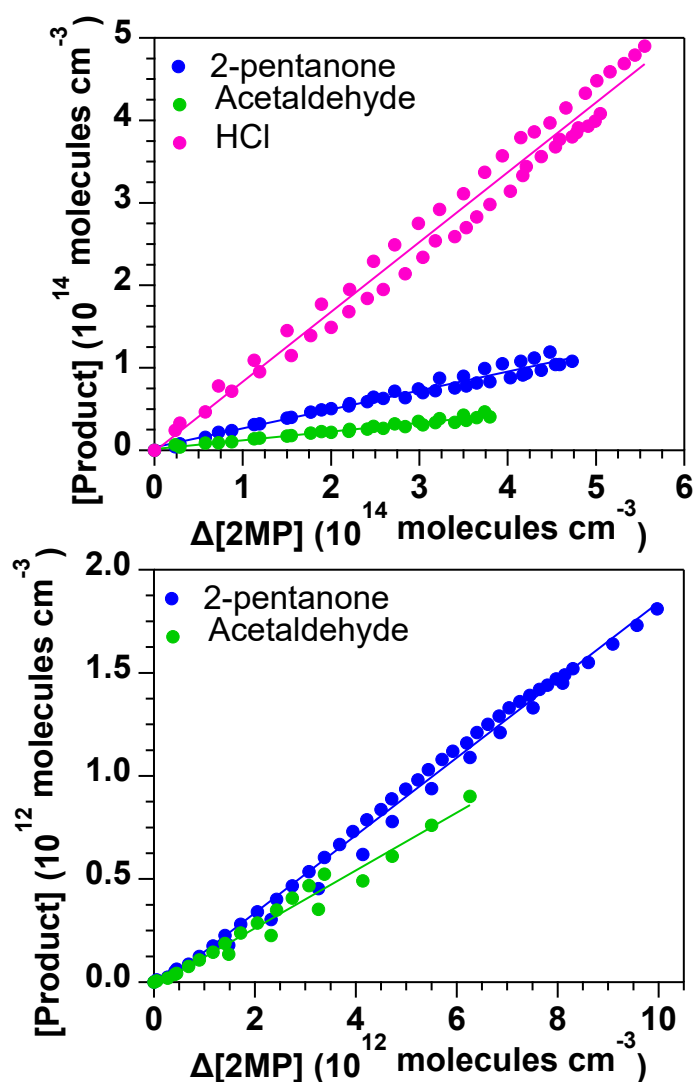
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**Figure S8.** IR spectrum before irradiation (top), after 15 min of the Cl+2MP reaction with the 2MP features subtracted (middle) and the residual spectrum after subtraction of the IR features of the identified products (bottom).

155 The molar yield of a product,  $Y_{\text{Product}}$ , is defined as:

$$Y_{\text{Product}} = \frac{[\text{Product}]}{\Delta[2\text{MP}]} \quad (\text{S7})$$

160 The concentration of a product, [Product], was corrected considering its loss by Cl reaction. Product concentrations were corrected to account for their Cl-reaction loss as explained by Ceacero-Vega *et al.* (2012). Plots of [Product] versus  $\Delta[2\text{MP}]$  showed a linear behaviour for all these products, indicating that they are primary products (see Figure S9).



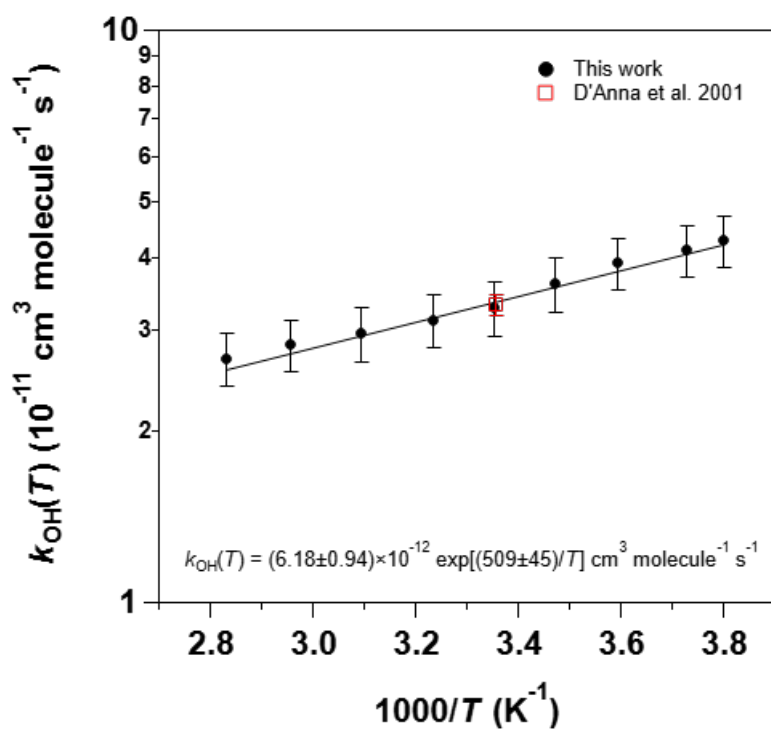
165 **Figure S9.** Plots to obtain the product yields of reaction R2 determined by a) FTIR spectroscopy and b) PTR-ToF-MS.

Note that during the test exposure to UV light of 2MP small amounts of 2-pentanone, acetaldehyde, and CO ( $<7 \times 10^{12}$  molecule  $\text{cm}^{-3}$  ( $<0.3$  ppm)) were detected and negligible compared with the observed in the Cl reaction ( $>1 \times 10^{14}$  molecule  $\text{cm}^{-3}$  ( $>4$  ppm)). The [CO] versus  $\Delta[2MP]$  plot was curved in most of its range, what indicates that CO is mostly a secondary product. For that reason, no CO yields are provided in this work.  $\text{CO}_2$  was not quantified since it is a final product of different reaction pathways. The minor products identified were 2-methylbutanoic acid, acetic acid, and formaldehyde. The yield plots for these products were curved from the beginning, so molar yields have not been calculated for these products.

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### III.C. Kinetics of the OH + 2MP reaction as a function of temperature



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**Figure S10.** Plot of the temperature dependence of rate coefficient between 2MP and OH radicals, and Arrhenius fit, together with the literature value reported by D'Anna et al. (2001). Quoted error bars correspond to  $\pm 2\sigma$  statistical error and  $\pm 10\%$  of systematic error.



**Table S4.** Individual rate coefficients and results from combing all kinetic data ( $\pm 2\sigma$ ) for the OH + 2MP reaction as a function of total pressure and temperature. Errors include  $\pm 2\sigma$  statistical and 10 % of systematic error.

$T / \text{K}$	$P_T / \text{Torr}$	$k_{\text{OH}}(T) / 10^{-11} \text{ cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$	$T / \text{K}$	$P_T / \text{Torr}$	$k_{\text{OH}}(T) / 10^{-11} \text{ cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$
263	50	$4.4 \pm 0.4$	309	50	$3.2 \pm 0.3$
	50	$4.3 \pm 0.4$		50	$3.1 \pm 0.3$
	250	$4.3 \pm 0.4$		<b>50</b>	<b><math>3.1 \pm 0.3</math></b>
	250	$4.3 \pm 0.5$	323	50	$2.9 \pm 0.3$
	500	$4.3 \pm 0.5$		50	$3.0 \pm 0.3$
	500	$4.2 \pm 0.4$		<b>50</b>	<b><math>3.0 \pm 0.3</math></b>
	<b>50-500</b>	<b><math>4.3 \pm 0.4</math></b>	338	50	$2.8 \pm 0.3$
268	50	$4.1 \pm 0.4$		50	$2.8 \pm 0.3$
	50	$4.2 \pm 0.4$		<b>50</b>	<b><math>2.8 \pm 0.3</math></b>
	<b>50</b>	<b><math>4.1 \pm 0.4</math></b>	353	50	$2.7 \pm 0.3$
278	50	$4.0 \pm 0.4$		50	$2.7 \pm 0.3$
	50	$3.9 \pm 0.4$		250	$2.7 \pm 0.3$
	<b>50</b>	<b><math>3.9 \pm 0.4</math></b>		250	$2.7 \pm 0.3$
288	50	$3.6 \pm 0.4$		500	$2.7 \pm 0.3$
	50	$3.6 \pm 0.4$		500	$2.6 \pm 0.3$
	<b>50</b>	<b><math>3.6 \pm 0.4</math></b>		<b>50-500</b>	<b><math>2.7 \pm 0.3</math></b>
298	50	$3.4 \pm 0.4$			
	50	$3.4 \pm 0.4$			
	250	$3.3 \pm 0.4$			
	250	$3.4 \pm 0.4$			
	500	$3.1 \pm 0.3$			
	500	$3.2 \pm 0.4$			
	<b>50-500</b>	<b><math>3.3 \pm 0.3</math></b>			

### III.D. Photolysis lifetime of 2MP

**Table S5.** Estimated photolysis rate coefficients for 2MP.

Scenario	Season	Time (GMT + 1)	$z / \text{km}$	$\theta / ^\circ$	$J(z, \theta) / \text{s}^{-1}$
<i>i</i>	Winter	13:00	0.6	62.27	$1.35 \times 10^{-5}$
	Summer	13:00	0.6	16.00	$3.60 \times 10^{-5}$
<i>ii</i>	Winter	08:30	0.0	88.15	$4.04 \times 10^{-7}$
	Summer	07:00	0.0	76.00	$3.77 \times 10^{-6}$

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