An overview of the biphasic dehydration of sugars to 5-hydroxymethylfurfural and furfural: a rational selection of solvents using COSMO-RS and selection guides.

Jesús Esteban [a], Andreas J. Vorholt [a] and Walter Leitner [a,b]

[a] Max-Planck-Institut für Chemische Energiekonversion, Stiftstraße 34-36, 45470 Mülheim an der Ruhr, Germany

[b] Institut für Technische und Makromolekulare Chemie, RWTH Aachen University, Worringerweg 2, 52074 Aachen, Germany

*Corresponding author e-mail address: andreas-j.vorholt@cec.mpg.de

Supplementary Information

Table of contents:

S1. Experimental procedure for the measurement of the distribution of 5-hydroxymethylfurfural and furfural

Materials

The following chemicals were used for the partition experiments: 5-hydroxymethylfurfural (Fluorochem, 98%), furfural (Sigma Aldrich, 99%), methyl propionate (Abcr GmbH, 99%), ethyl acetate (Carl Roth, ≥99.5%). In addition, milliQ water was used as filtered by Merck Millipak 0.22 µm (resistivity of 18.2 MΩ.cm).

Partition experiments

The partition of 5-HMF and furfural in aqueous biphasic media was performed putting in contact an aqueous phase containing the furan with ethyl acetate or methyl propionate as organic extracting phases. The experiments were performed in 10 mL magnetically stirred vials for microwave reactions, with reinforced glass walls to withstand higher pressures than conventional glassware.

Four different chemical compositions of the loads were tested for partition. As aqueous phases, 1.25 mL of MilliQ water solutions containing 0.7% wt. and 7% wt. of 5-HMF (corresponding to the theoretical maximum 5-HMF that could be obtained from 1% wt. and 10 % wt. of fructose) were prepared. In the case of furfural, 0.64% wt. and 6.4% wt. were added to 1.5 mL of MilliQ water (likewise, corresponding to the theoretical maximum furfural obtained from 1% wt. and 10% wt. solutions of xylose). As organic phases, 4.09 mL of methyl propionate and 4.16 mL of ethyl acetate were used (3.75 g of each), which were put in contact with the two different aqueous solutions of 5-HMF and the two of furfural.

The distribution of 5-HMF and furfural from the described four batches was performed at the temperatures of 25 °C and 150 °C. For the experiments at 25 °C, the tubes containing the biphasic systems were placed into an oil bath on a heating plate (IKA RCT basic, accuracy ±0.05 °C) magnetically stirred at 1200 rpm during 4 hours. After stirring stopped, the batches were allowed to settle at least 12 h. In the case of the experiments at 150 °C, owing to the operation exceeding the boiling points of both water and the organic solvents, the experiments were conducted in an Anton Paar Monowave 450 microwave reactor. The pressures reached during these experiments ranged between 9 and 10 bar. On this occasion, owing to the potential sensitivity to thermal degradation of the furans[1], the partition experiment was performed only for 15 min.[2,3] at 150 °C under stirred conditions, then was allowed to settle another 15 min. at this temperature without stirring and subsequently allowed to settle further 12 h at room conditions out of the microwave reactor.

Finally, samples were withdrawn from the organic-rich (top) and aqueous (bottom) phases with needles and taken for analysis.

Analytical methods

The organic-rich phase was analyzed using a Shimadzu GC-2030 GC device equipped with a flame ionization detector (FID). Resolution of the peaks was achieved with a Restek Rtx-1701 column (30 m x 0.25 mm x 0.25 µm) using He as carrier gas with an injector temperature of 260 °C and FID temperature at 260 °C. The temperature program followed started holding during 6 minutes at 140 °C, followed by a ramp of 25 °C/min up to 250 °C and finally this temperature was held during 5 minutes.

For its part, the aqueous phase was analyzed using HPLC employing a Shimadzu LC-20AD device equipped with a diode array detector (SPD-M20A). Separation was made using an Organic-Acid Resin

column (300 m x 8 mm) supplied by Chromatographie-Service GmbH employing acidic water as mobile phase (2 mM trifluoroacetic acid solution in MilliQ water) pumping at 1 mL/min through the column, which was kept at 40°C for separation in a CTO-10AS oven. Detection of 5-HMF was made at 277 nm and furfural at 282 nm.

References

1. C. H. J. T. Dietz, M. Verra, S. Verberkt, F. Gallucci, M. C. Kroon, M. F. N. D'Angelo, M. Papaioannou and M. V. Annaland, *Ind. Eng. Chem. Res.*, 2019, **58**, 16116-16125.
2. I. Dalmolin, R. R. Pinto, L. H. de Oliveira, L. A. Follegatti-Romero, A. C. Costa and M. Aznar, *J. Chem. Thermodyn.*, 2017, **111**, 80-87.
3. O. Ershova, J.-P. Pokki, A. Zaitseva, V. Alopaeus and H. Sixta, *Chem. Eng. Sci.*, 2018, **176**, 19-34.

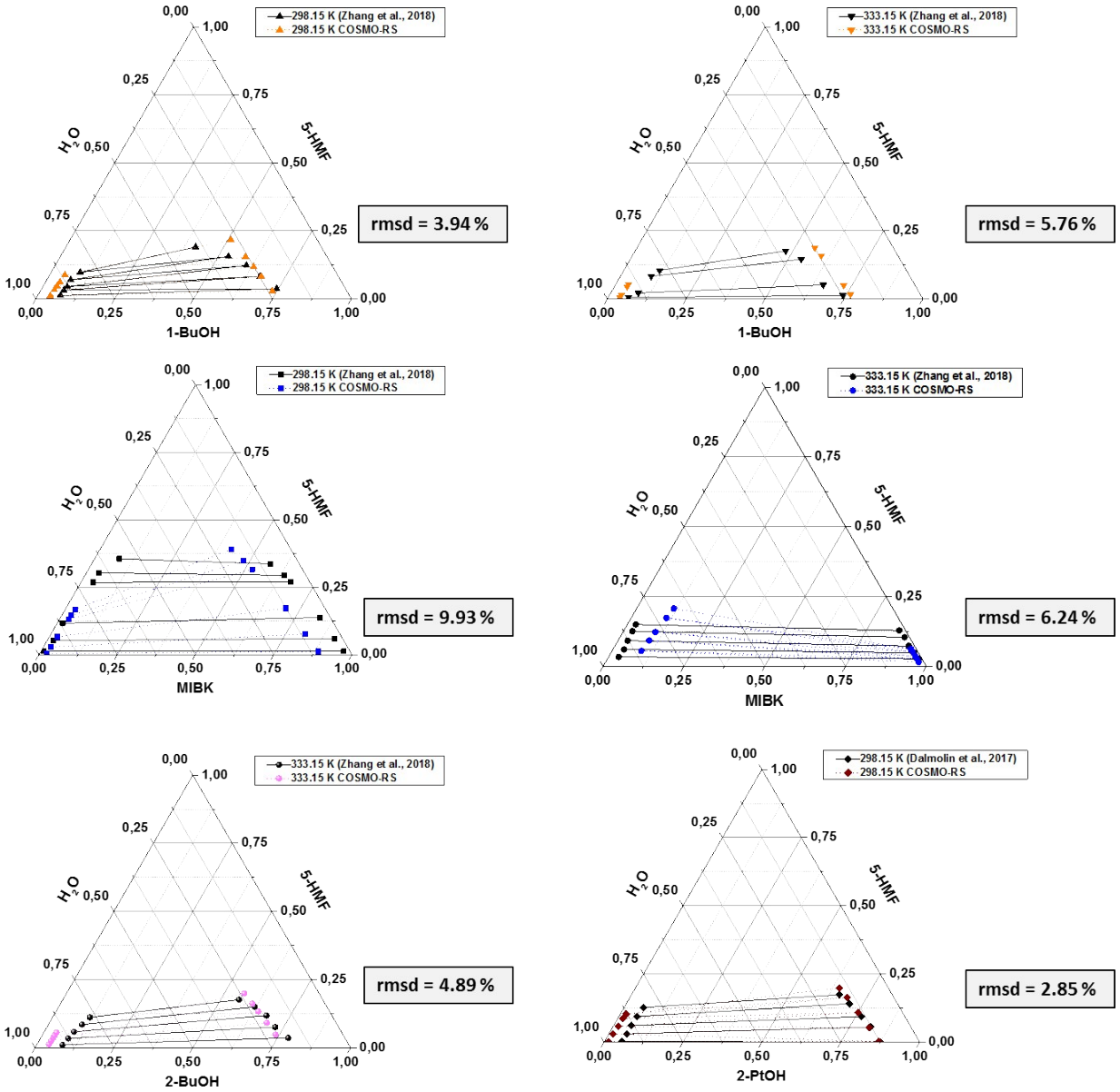

Figure S1. Experimental and COSMO-RS predictions of the liquid-liquid equilibria of different {H_2O + 5-HMF + solvent} systems at different temperatures.

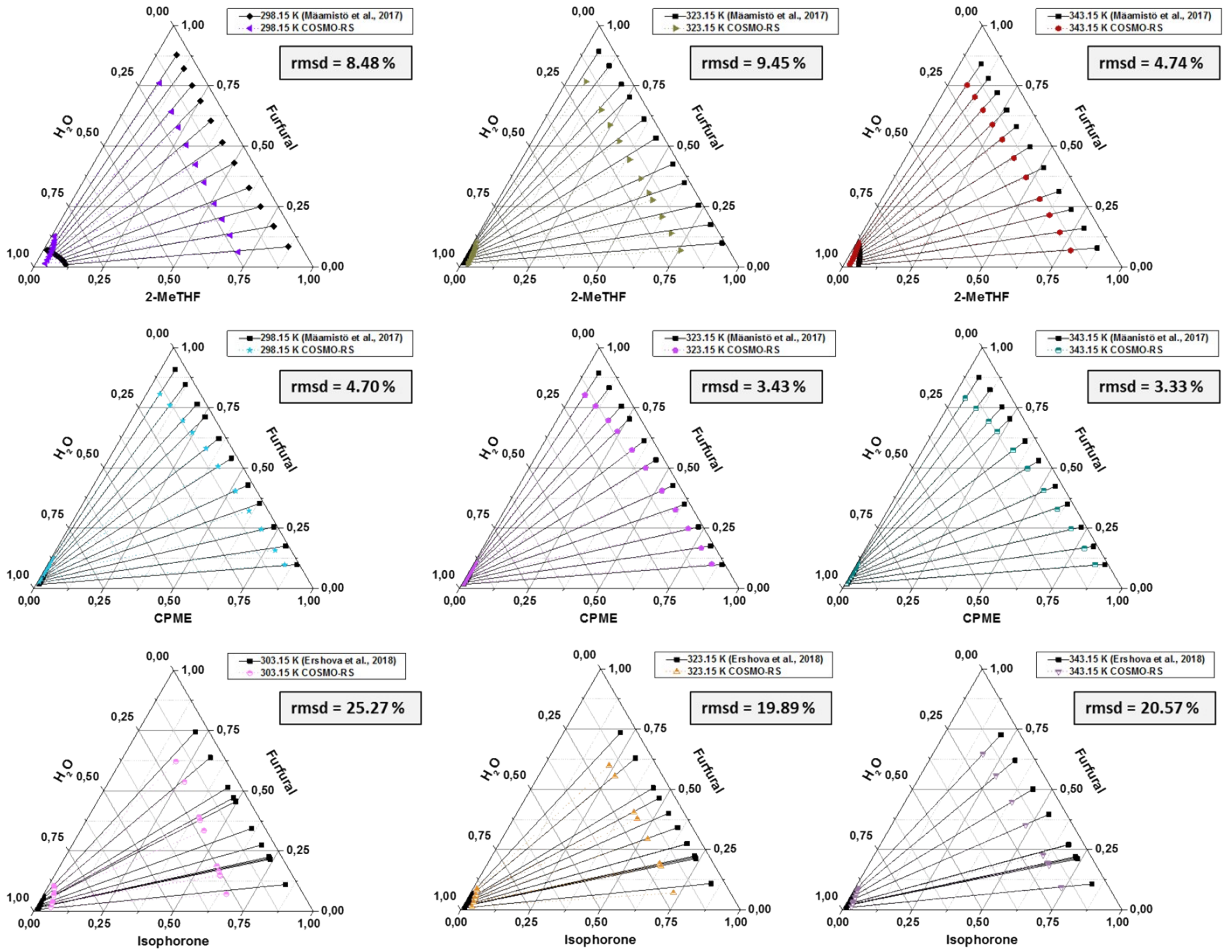

Figure S2.Experimental and COSMO-RS predictions of the liquid-liquid equilibria of different {H_2O + furfural + solvent} systems at different temperatures.

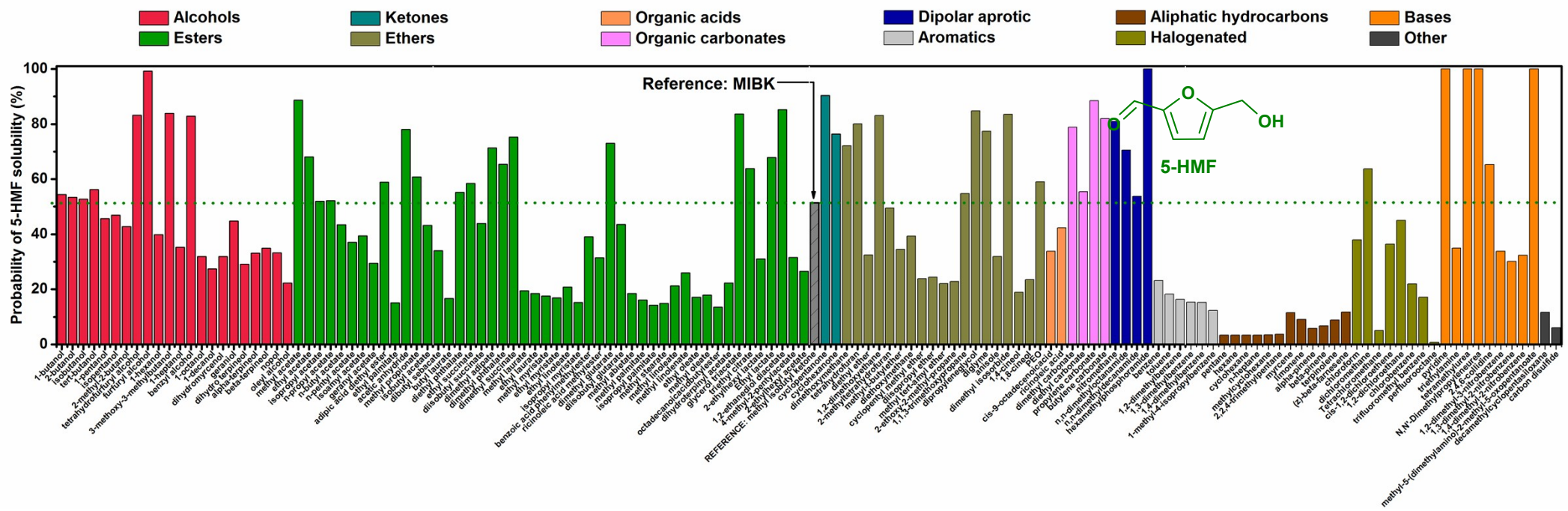

Figure S3. Probability of solubility of 5-HMF in the entire set of solvents showing miscibility gap with water at 150 °C as predicted from the relative solvent screening by COSMO-RS

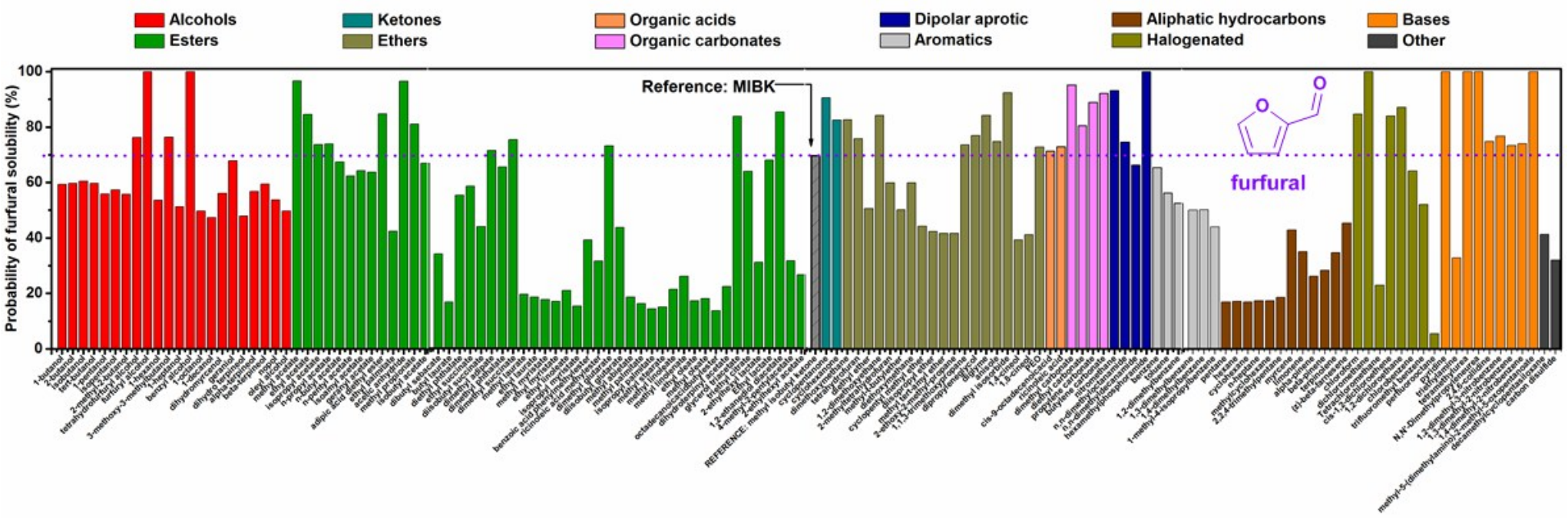

Figure S4. Probability of solubility of furfural in the entire set of different solvents showing miscibility gap with water solvents at 150 °C as predicted from the relative solvent screening by COSMO-RS

Table S1. List of candidates for the biphasic dehydration of sugars to furans from different solvent guides in literature and COSMO-RS predictions of miscibility with water at 298.15, 373.15 and 423.15 K

			T= 298.15 K				T= 423.15 K			
			Solvent-rich phase		Water-rich phase		Solvent-rich phase		Water-rich phase	
Solvent	CAS	Miscibility gap predicted?	w_{H2O}	$w_{solvent}$	w_{H2O}	$w_{solvent}$	w_{H2O}	$w_{solvent}$	w_{H2O}	$w_{solvent}$
Alcohols										
methanol	67-56-1	No								
ethanol	64-17-5	No								
propanol	71-23-8	No								
2-propanol	67-63-0	No								
ethylene glycol	107-21-1	No								
propylene glycol	57-55-6	No								
1,3-propanediol	504-63-2	No								
glycerol	56-81-5	No								
1-butanol	71-36-3	Yes	0.2315	0.7685	0.9608	0.0392	0.2802	0.7198	0.9401	0.0599
2-butanol	78-92-2	Yes	0.2262	0.7738	0.9593	0.0407	0.2591	0.7409	0.9428	0.0572
isobutanol	78-83-1	Yes	0.1998	0.8002	0.9622	0.0378	0.2650	0.7350	0.9383	0.0617
tert-butanol	75-65-0	Yes	0.2580	0.7420	0.9476	0.0524	0.2893	0.7107	0.9278	0.0722
glycerol formal	5464-28-8	No								
3-methoxy-1,2-propanediol	623-39-2	No								
1-pentanol	71-41-0	Yes	0.1404	0.8596	0.9869	0.0131	0.1800	0.8200	0.9768	0.0232
isopentanol	123-51-3	Yes	0.1416	0.8584	0.9836	0.0164	0.1897	0.8103	0.9703	0.0297
2-methyl-2-butanol	75-85-4	Yes	0.1274	0.8726	0.9843	0.0157	0.1612	0.8388	0.9735	0.0265
tetrahydrofurfuryl alcohol	97-99-4	Not at all temperatures					0.4723	0.5277	0.7586	0.2414
furfuryl alcohol	98-00-0	Yes	0.1824	0.8176	0.9226	0.0774	0.4144	0.5856	0.7708	0.2292
1,3-dimethoxy-2-propanol	623-69-8	No								
1-hexanol	111-27-3	Yes	0.0953	0.9047	0.9955	0.0045	0.1300	0.8700	0.9901	0.0099
3-methoxy-3-methylbutanol	56539-66-3	Yes	0.4129	0.5871	0.9119	0.0881	0.2215	0.7785	0.9559	0.0441
solketal	100-79-8	No								
1-heptanol	111-70-6	Yes	0.0688	0.9312	0.9985	0.0015	0.0985	0.9015	0.9958	0.0042
benzyl alcohol	100-51-6	Yes	0.1022	0.8978	0.9741	0.0259	0.2021	0.7979	0.9353	0.0647

1-octanol	111-87-5	Yes	0.0520	0.9480	0.9995	0.0005	0.0783	0.9217	0.9982	0.0018
1-decanol	112-30-1	Yes	0.0336	0.9664	0.9999	0.0001	0.0552	0.9448	0.9997	0.0003
dihydromyrcenol	53219-21-9	Yes	0.0330	0.9670	0.9998	0.0002	0.0550	0.9450	0.9990	0.0010
geraniol	106-24-1	Yes	0.0469	0.9531	0.9994	0.0006	0.0744	0.9256	0.9978	0.0022
dihydro terpineol	58985-02-7	Yes	0.0422	0.9578	0.9993	0.0007	0.0598	0.9402	0.9977	0.0023
□-terpineol	98-55-5	Yes	0.0341	0.9659	0.9992	0.0008	0.0593	0.9407	0.9971	0.0029
β-terpineol	138-87-4	Yes	0.0319	0.9681	0.9992	0.0008	0.0607	0.9393	0.9969	0.0031
nopol	128-50-7	Yes	0.0414	0.9586	0.9992	0.0008	0.0588	0.9412	0.9973	0.0027
oleyl alcohol	143-28-2	Yes	0.0109	0.9891	1.0000	0.0000	0.0248	0.9752	1.0000	0.0000
Esters										
methyl formate	107-31-3	No								
methyl acetate	79-20-9	Yes	0.2399	0.7701	0.9115	0.0885	0.4388	0.5612	0.7476	0.2524
ethyl acetate	141-78-6	Yes	0.1423	0.8577	0.9095	0.0905	0.1977	0.8023	0.9369	0.0631
isopropyl acetate	108-21-4	Yes	0.0631	0.9369	0.9778	0.0222	0.1206	0.8794	0.9769	0.0231
n-propyl acetate	109-60-4	Yes	0.0604	0.9396	0.9800	0.0200	0.1190	0.8810	0.9792	0.0208
n-butyl acetate	123-86-4	Yes	0.0367	0.9633	0.9937	0.0063	0.0860	0.9140	0.9913	0.0087
n-pentyl acetate	628-63-7	Yes	0.0242	0.9758	0.9981	0.0019	0.0657	0.9343	0.9965	0.0035
isoamyl acetate	123-92-2	Yes	0.0284	0.9716	0.9969	0.0031	0.0711	0.9289	0.9951	0.0049
geranyl acetate	105-87-3	Yes	0.0057	0.9943	1.0000	0.0000	0.0302	0.9698	0.9999	0.0001
adipic acid diethyl ester	141-28-6	Yes	0.0242	0.9758	0.9975	0.0025	0.0685	0.9315	0.9973	0.0027
ethyl palmitate	628-97-7	Yes	0.0023	0.9977	1.0000	0.0000	0.0150	0.9850	1.0000	0.0000
acetic anhydride	108-24-7	Yes	0.0363	0.9637	0.9392	0.0608	0.2502	0.7498	0.8541	0.1459
methyl propionate	554-12-1	Yes	0.0812	0.9188	0.9431	0.0569	0.1716	0.8284	0.9454	0.0546
isobutyl acetate	110-19-0	Yes	0.0394	0.9606	0.9921	0.0079	0.0884	0.9116	0.9897	0.0103
dibutyl sebacate	109-43-3	Yes	0.0067	0.9933	1.0000	0.0000	0.0264	0.9736	1.0000	0.0000
butyl laurate	106-18-3	Yes	0.0035	0.9965	1.0000	0.0000	0.0182	0.9818	1.0000	0.0000
diethyl phthalate	84-66-2	Yes	0.0092	0.9908	0.9993	0.0007	0.0519	0.9481	0.9972	0.0028
ethyl succinate	123-25-1	Yes	0.0189	0.9811	0.9949	0.0051	0.0782	0.9218	0.9920	0.0080
diisobutyl succinate	925-06-4	Yes	0.0133	0.9867	0.9998	0.0002	0.0453	0.9547	0.9995	0.0005
dimethyl adipate	627-93-0	Yes	0.0189	0.9811	0.9949	0.0051	0.0782	0.9218	0.9920	0.0080
dimethyl phthalate	131-11-3	Yes	0.0133	0.9867	0.9998	0.0002	0.0453	0.9547	0.9995	0.0005
dimethyl succinate	106-65-0	Yes	0.0352	0.9648	0.9631	0.0369	0.1453	0.8547	0.9516	0.0484
methyl laurate	111-82-0	Yes	0.0043	0.9957	1.0000	0.0000	0.0234	0.9766	1.0000	0.0000
ethyl laurate	106-33-2	Yes	0.0041	0.9959	1.0000	0.0000	0.0213	0.9787	1.0000	0.0000
methyl myristate	124-10-7	Yes	0.0032	0.9968	1.0000	0.0000	0.0193	0.9807	1.0000	0.0000
ethyl myristate	124-06-1	Yes	0.0032	0.9968	1.0000	0.0000	0.0181	0.9819	1.0000	0.0000

ethyl linoleate	544-35-4	Yes	0.0023	0.9977	1.0000	0.0000	0.0163	0.9837	1.0000	0.0000
isopropyl myristate	110-27-0	Yes	0.0296	0.9704	0.9808	0.0192	0.1103	0.8897	0.9786	0.0214
benzoic acid phenylmethylester	118-58-1	Yes	0.0034	0.9966	1.0000	0.0000	0.0320	0.9680	0.9992	0.0008
ricinoleic acid methylester	141-24-2	Yes	0.0110	0.9890	1.0000	0.0000	0.0257	0.9743	1.0000	0.0000
dimethyl glutarate	1119-40-0	Yes	0.0379	0.9621	0.9724	0.0276	0.1202	0.8798	0.9748	0.0252
diisobutyl glutarate	71195-64-7	Yes	0.0092	0.9908	0.9993	0.0007	0.0519	0.9481	0.9972	0.0028
methyl abietate	127-25-3	Yes	0.0027	0.9973	1.0000	0.0000	0.0160	0.9840	1.0000	0.0000
methyl palmitate	112-39-0	Yes	0.0024	0.9976	1.0000	0.0000	0.0163	0.9837	1.0000	0.0000
isopropyl palmitate	142-91-6	Yes	0.0021	0.9979	1.0000	0.0000	0.0139	0.9861	1.0000	0.0000
methyl stearate	112-61-8	Yes	0.0019	0.9981	1.0000	0.0000	0.0140	0.9860	1.0000	0.0000
methyl linoleate	112-63-0	Yes	0.0016	0.9984	1.0000	0.0000	0.0148	0.9852	1.0000	0.0000
methyl linolenate	301-00-8	Yes	0.0026	0.9974	1.0000	0.0000	0.0192	0.9808	1.0000	0.0000
ethyl oleate	111-62-6	Yes	0.0021	0.9979	1.0000	0.0000	0.0146	0.9854	1.0000	0.0000
methyl oleate	112-62-9	Yes	0.0021	0.9979	1.0000	0.0000	0.0156	0.9844	1.0000	0.0000
octadecanoicacidbutylester	123-95-5	Yes	0.0017	0.9983	1.0000	0.0000	0.0119	0.9881	1.0000	0.0000
dihydroterpinyl acetate	58985-18-5	Yes	0.0088	0.9912	0.9999	0.0001	0.0299	0.9701	0.9996	0.0004
glycerol triacetate	102-76-1	Yes	0.0032	0.9968	1.0000	0.0000	0.0181	0.9819	1.0000	0.0000
triethyl citrate	77-93-0	Yes	0.0127	0.9873	0.9990	0.0010	0.0552	0.9448	0.9977	0.0023
γ-Valerolactone	108-29-2	No								
2-ethylhexyl lactate	6283-86-9	Yes	0.0180	0.9820	0.9999	0.0001	0.0389	0.9611	0.9996	0.0004
Ethyl lactate	97-64-3	Yes	0.1304	0.8696	0.9484	0.0516	0.1638	0.8362	0.9553	0.0447
1,2-ethanediol diacetate	111-55-7	Yes	0.0680	0.9320	0.9123	0.0877	0.1813	0.8187	0.9362	0.0638
4-methyl-2-pentylacetate	108-84-9	Yes	0.0177	0.9823	0.9991	0.0009	0.0530	0.9470	0.9978	0.0022
2-ethylhexyl acetate	103-09-3	Yes	0.0117	0.9883	0.9999	0.0001	0.0381	0.9619	0.9996	0.0004
Ketones										
acetone	67-64-1	No								
butanone	78-93-3	No								
methyl isobutyl ketone	108-10-1	Yes	0.2315	0.7685	0.9608	0.0392	0.4046	0.5954	0.8391	0.1609
cyclopentanone	120-92-3	Yes	0.1275	0.8725	0.8876	0.1124	0.4088	0.5912	0.8025	0.1975
cyclohexanone	108-94-1	Yes	0.1098	0.8902	0.8515	0.1485	0.2477	0.7523	0.9135	0.0865
Organic acids										
formic acid	64-18-6	No								
acetic acid	64-19-7	No								
propionic acid	79-09-4	No								
hydracrylic acid	503-66-2	No								

lactic acid	50-21-5	No								
cis-9-octadecenoicacid	112-80-1	Yes	0.0204	0.9796	1.0000	0.0000	0.0324	0.9676	1.0000	0.0000
ricinoleic acid	141-22-0	Yes	0.0254	0.9746	1.0000	0.0000	0.0400	0.9600	1.0000	0.0000
methanesulfonic acid	75-75-2	No								
Ethers										
dimethyl ether	111109-77-4	No								
2-methoxyethanol	109-86-4	No								
dioxolane	646-06-0	No								
dimethoxymethane	109-87-5	Not at all temperatures					0.2883	0.7117	0.8782	0.1218
tetrahydrofuran	109-99-9	Yes	0.3861	0.6139	0.7770	0.2230	0.3022	0.6978	0.9019	0.0981
diethyl ether	60-29-7	Yes	0.1196	0.8804	0.9867	0.0133	0.1076	0.8924	0.9861	0.0139
dioxane	123-91-1	No								
1,2-dimethoxyethane	110-71-4	Not at all temperatures					0.2880	0.7120	0.9117	0.0883
2-methyltetrahydrofuran	96-47-9	Yes	0.2428	0.7572	0.9649	0.0351	0.1489	0.8511	0.9723	0.0277
methyl-t-butylether	1634-04-4	Yes	0.1493	0.8507	0.9880	0.0120	0.1038	0.8962	0.9872	0.0128
diethoxymethane	462-95-3	Yes	0.0839	0.9161	0.9847	0.0153	0.0951	0.9049	0.9880	0.0120
cyclopentyl methyl ether	5614-37-9	Yes	0.0482	0.9518	0.9953	0.0047	0.0636	0.9364	0.9927	0.0073
diisopropyl ether	108-20-3	Yes	0.0754	0.9246	0.9979	0.0021	0.0646	0.9354	0.9965	0.0035
methyl tert-amyl ether	994-05-8	Yes	0.0572	0.9428	0.9970	0.0030	0.0596	0.9404	0.9952	0.0048
2-ethoxy-2-methyl-propane	637-92-3	Yes	0.0661	0.9339	0.9975	0.0025	0.0615	0.9385	0.9962	0.0038
1,1,3-trimethoxypropane	14315-97-0	Yes	0.1124	0.8876	0.9593	0.0407	0.1089	0.8911	0.9827	0.0173
dipropyleneglycol	25265-71-8	Not at all temperatures					0.2976	0.7024	0.9137	0.0863
diglyme	111-96-6	Not at all temperatures					0.1735	0.8265	0.9680	0.0320
anisole	100-66-3	Yes	0.0029	0.9971	0.9984	0.0016	0.0502	0.9498	0.9892	0.0108
dimethyl isosorbide	5306-85-4	Not at all temperatures					0.1750	0.8250	0.9258	0.0742
1,4-cineol	470-67-7	Yes	0.0267	0.9733	0.9995	0.0005	0.0366	0.9634	0.9988	0.0012
1,8-cineol	470-82-6	Yes	0.0554	0.9446	0.9990	0.0010	0.0456	0.9544	0.9979	0.0021
PEO	25322-68-3	Yes	0.1870	0.8130	0.8906	0.1094	0.1448	0.8552	0.9379	0.0621
Organic carbonates										
dimethyl carbonate	616-38-6	Yes	0.0626	0.9374	0.8895	0.1105	0.2869	0.7131	0.8249	0.1751
diethyl carbonate	105-58-8	Yes	0.0274	0.9726	0.9834	0.0166	0.1079	0.8921	0.9774	0.0226
propylene carbonate	108-32-7	Not at all temperatures	0.1142	0.8858	0.7734	0.2266				

butylene carbonate	4437-85-8	Yes	0.0612	0.9388	0.9176	0.0824	0.2940	0.7060	0.8116	0.1884
glycerol carbonate	931-40-8	No								
Dipolar aprotic										
nitromethane	75-52-5	Not at all temperatures	0.0368	0.9632	0.9485	0.0515				
acetonitrile	75-05-8	No								
dimethylformamide	68-12-2	No								
n,n-dimethylacetamide	127-19-5	No								
n,n-dimethyloctanamide	1118-92-9	Yes	0.1842	0.8158	0.9976	0.0024	0.1003	0.8997	0.9982	0.0018
n,n-dimethyldecanamide	14433-76-2	Yes	0.1102	0.8898	0.9998	0.0002	0.0670	0.9330	0.9997	0.0003
dimethylsulfoxide	67-68-5	No								
sulfolane	126-33-0	No								
hexamethylphosphoramide	680-31-9	Not at all temperatures					0.2423	0.7577	0.9694	0.0306
Aromatics										
benzene	71-43-2	Yes	0.0013	0.9987	0.9978	0.0022	0.0480	0.9520	0.9857	0.0143
toluene	108-88-3	Yes	0.0011	0.9989	0.9985	0.0015	0.0455	0.9545	0.9901	0.0099
1,2-dimethylbenzene	95-47-6	Yes	0.0009	0.9991	0.9993	0.0007	0.0347	0.9653	0.9942	0.0058
1,3-dimethylbenzene	108-38-3	Yes	0.0007	0.9993	0.9997	0.0003	0.0285	0.9715	0.9969	0.0031
1,4-dimethylbenzene	106-42-3	Yes	0.0007	0.9993	0.9998	0.0002	0.0271	0.9729	0.9975	0.0025
1-methyl-4-isopropylbenzene	99-87-6	Yes	0.0007	0.9993	0.9997	0.0003	0.0270	0.9730	0.9975	0.0025
Hydrocarbons										
pentane	109-66-0	Yes	0.0002	0.9998	0.9999	0.0001	0.0168	0.9832	0.9991	0.0009
hexane	110-54-3	Yes	0.0002	0.9998	1.0000	0.0000	0.0144	0.9856	0.9996	0.0004
cyclohexane	110-82-7	Yes	0.0002	0.9998	0.9998	0.0002	0.0154	0.9846	0.9982	0.0018
n-heptane	142-82-5	Yes	0.0002	0.9998	1.0000	0.0000	0.0128	0.9872	0.9998	0.0002
methylcyclohexane	108-87-2	Yes	0.0002	0.9998	0.9999	0.0001	0.0137	0.9863	0.9992	0.0008
2,2,4-trimethylpentane	540-84-1	Yes	0.0002	0.9998	1.0000	0.0000	0.0123	0.9877	0.9998	0.0002
myrcene	123-35-3	Yes	0.0004	0.9996	1.0000	0.0000	0.0183	0.9817	0.9997	0.0003
limonene	138-86-3	Yes	0.0004	0.9996	1.0000	0.0000	0.0166	0.9834	0.9996	0.0004
□-pinene	80-56-8	Yes	0.0002	0.9998	1.0000	0.0000	0.0130	0.9870	0.9996	0.0004
β-pinene	127-91-3	Yes	0.0003	0.9997	1.0000	0.0000	0.0145	0.9855	0.9995	0.0005
terpinolene	586-62-9	Yes	0.0004	0.9996	1.0000	0.0000	0.0161	0.9839	0.9997	0.0003
(z)-beta-farnesene	28973-99-1	Yes	0.0003	0.9997	1.0000	0.0000	0.0128	0.9872	1.0000	0.0000
Halogenated										
chloroform	67-66-3	Yes	0.0056	0.9944	0.9932	0.0068	0.0497	0.9503	0.9705	0.0295

dichloromethane	75-09-2	Yes	0.0068	0.9932	0.9716	0.0284	0.1193	0.8807	0.8741	0.1259
Tetrachloromethane	56-23-5	Yes	0.0002	0.9998	0.9996	0.0004	0.0104	0.9896	0.9966	0.0034
cis-1,2-dichloroethene	156-59-2	Yes	0.0027	0.9973	0.9921	0.0079	0.0565	0.9435	0.9609	0.0391
1,2-dichloroethane	107-06-2	Yes	0.0031	0.9969	0.9898	0.0102	0.0821	0.9179	0.9317	0.0683
chlorobenzene	108-90-7	Yes	0.0009	0.9991	0.9990	0.0010	0.0321	0.9679	0.9915	0.0085
trifluoroacetic acid	76-05-1	No								
trifluoromethyl benzene	98-08-8	Yes	0.0006	0.9994	0.9993	0.0007	0.0231	0.9769	0.9944	0.0056
perfluorooctane	307-34-6	Yes	0.0000	1.0000	1.0000	0.0000	0.0025	0.9975	1.0000	0.0000
Bases										
2-pyrrolidone	616-45-5	No								
pyridine	110-86-1	Yes	0.3555	0.6445	0.8866	0.1134	0.3246	0.6754	0.8645	0.1355
n-methyl-2-pyrrolidinone	872-50-4	No								
1,3-dimethyl-2-imidazolidinone	80-73-9	No								
triethylamine	121-44-8	Yes	0.0725	0.9275	0.9997	0.0003	0.0618	0.9382	0.9985	0.0015
tetramethylurea	632-22-4	Not at all temperatures					0.4066	0.5934	0.9031	0.0969
N,N′-Dimethylpropyleneurea	7226-23-5	Not at all temperatures					0.4101	0.5899	0.8690	0.1310
2,4,6-collidine	108-75-8	Yes	0.1197	0.8803	0.9963	0.0037	0.0928	0.9072	0.9935	0.0065
1,2-dimethyl-3-nitrobenzene	83-41-0	Yes	0.0023	0.9977	0.9996	0.0004	0.0406	0.9594	0.9949	0.0051
1,3-dimethyl-2-nitrobenzene	81-20-9	Yes	0.0016	0.9984	0.9997	0.0003	0.0360	0.9640	0.9955	0.0045
1,4-dimethyl-2-nitrobenzene	89-58-7	Yes	0.0025	0.9975	0.9996	0.0004	0.0392	0.9608	0.9958	0.0042
methyl-5-(dimethylamino)-2-methyl-5-oxopentanoate	1174627-68-9	Not at all temperatures					0.1923	0.8077	0.9676	0.0324
Other										
decamethylcyclopentasiloxane	541-02-6	Yes	0.0007	0.9993	1.0000	0.0000	0.0091	0.9909	1.0000	0.0000
carbon disulfide	75-15-0	Yes	0.0002	0.9998	0.9993	0.0007	0.0169	0.9831	0.9939	0.0061

Table S2. COSMO-RS: relative solubility ($log_{10}(w_{solub})$) predictions and probability of solubility of 5-HMF and furfural at 298.15 and 423.15 K in solvents showing miscibility gap with water.

		5-HMF				furfural			
		T= 298.15 K		T= 423.15 K		T= 298.15 K		T= 423.15 K	
Solvent	CAS	$log_{10}(w_{solub})$	Probability	$log_{10}(w_{solub})$	Probability	$log_{10}(w_{solub})$	Probability	$log_{10}(w_{solub})$	Probability
Alcohols									
1-butanol	71-36-3	-0.4731	0.3364	-0.2646	0.5437	-0.581	0.2624	-0.2269	0.593
2-butanol	78-92-2	-0.4322	0.3697	-0.2723	0.5342	-0.553	0.2799	-0.2238	0.5973
isobutanol	78-83-1	-0.4852	0.3272	-0.2778	0.5274	-0.5416	0.2873	-0.2181	0.6052
tert-butanol	75-65-0	-0.3636	0.4329	-0.25	0.5624	-0.5554	0.2783	-0.2241	0.5968
1-pentanol	71-41-0	-0.5714	0.2683	-0.3403	0.4567	-0.6146	0.2429	-0.2524	0.5592
isopentanol	123-51-3	-0.555	0.2786	-0.3284	0.4695	-0.5921	0.2558	-0.2415	0.5735
2-methyl-2-butanol	75-85-4	-0.5464	0.2842	-0.3685	0.4281	-0.5843	0.2604	-0.2539	0.5573
tetrahydrofurfuryl alcohol	97-99-4	0.0	1.0	-0.0799	0.832	-0.2784	0.5267	-0.1179	0.7623
furfuryl alcohol	98-00-0	0.0	1.0	-0.0033	0.9924	0.0	1.0	0.0	1.0
1-hexanol	111-27-3	-0.658	0.2198	-0.3992	0.3988	-0.6437	0.2271	-0.2708	0.5361
3-methoxy-3-methylbutanol	56539-66-3	0.0	1.0	-0.0762	0.8392	-0.221	0.6011	-0.1173	0.7633
1-heptanol	111-70-6	-0.7271	0.1875	-0.452	0.3532	-0.669	0.2143	-0.2896	0.5134
benzyl alcohol	100-51-6	-0.0952	0.8031	-0.0816	0.8287	-0.0285	0.9365	0.0	1.0
1-octanol	111-87-5	-0.793	0.1611	-0.4967	0.3187	-0.6912	0.2036	-0.3038	0.4968
1-decanol	112-30-1	-0.896	0.1271	-0.5623	0.274	-0.7269	0.1876	-0.3247	0.4734
dihydromyrcenol	53219-21-9	-0.69	0.2042	-0.4961	0.3191	-0.5477	0.2833	-0.2514	0.5605
geraniol	106-24-1	-0.4896	0.3239	-0.3487	0.4481	-0.4226	0.3779	-0.1682	0.6789
dihydro terpineol	58985-02-7	-0.7547	0.1759	-0.5351	0.2917	-0.6977	0.2006	-0.3198	0.4788
□-terpineol	98-55-5	-0.6765	0.2106	-0.4794	0.3316	-0.5263	0.2976	-0.2456	0.568
β-terpineol	138-87-4	-0.6502	0.2238	-0.4573	0.3489	-0.4814	0.3301	-0.226	0.5943
nopol	128-50-7	-0.6721	0.2127	-0.4789	0.332	-0.5841	0.2606	-0.2694	0.5378
oleyl alcohol	143-28-2	-1.0488	0.0894	-0.6512	0.2233	-0.6763	0.2107	-0.3032	0.4975
Esters									
methyl acetate	79-20-9	-0.0774	0.8367	-0.0522	0.8868	-0.0002	0.9996	-0.015	0.966
ethyl acetate	141-78-6	-0.2058	0.6225	-0.1667	0.6812	-0.086	0.8203	-0.073	0.8452
isopropyl acetate	108-21-4	-0.3807	0.4162	-0.2842	0.5198	-0.1915	0.6435	-0.1328	0.7365
n-propyl acetate	109-60-4	-0.3867	0.4105	-0.2828	0.5214	-0.1883	0.6482	-0.1315	0.7387

n-butyl acetate	123-86-4	-0.5161	0.3047	-0.3624	0.4341	-0.2645	0.5439	-0.1716	0.6735
n-pentyl acetate	628-63-7	-0.6367	0.2308	-0.4312	0.3705	-0.331	0.4666	-0.2052	0.6234
isoamyl acetate	123-92-2	-0.5858	0.2596	-0.4043	0.3942	-0.3057	0.4947	-0.1917	0.6432
geranyl acetate	105-87-3	-0.9308	0.1173	-0.5313	0.2943	-0.383	0.414	-0.1959	0.6369
adipic acid diethyl ester	141-28-6	-0.3738	0.4228	-0.2299	0.5889	-0.1343	0.734	-0.0716	0.8479
ethyl palmitate	628-97-7	-1.4339	0.0368	-0.819	0.1517	-0.7317	0.1855	-0.3727	0.4239
acetic anhydride	108-24-7	-0.4143	0.3852	-0.1075	0.7807	-0.0387	0.9148	-0.0155	0.9649
methyl propionate	554-12-1	-0.3412	0.4558	-0.216	0.6082	-0.1308	0.74	-0.0913	0.8105
isobutyl acetate	110-19-0	-0.5187	0.3029	-0.3643	0.4323	-0.2674	0.5403	-0.1745	0.6691
dibutyl sebacate	109-43-3	-0.7914	0.1617	-0.4682	0.3402	-0.3731	0.4236	-0.1805	0.6599
diethyl phthalate	84-66-2	-0.5796	0.2633	-0.2584	0.5516	-0.111	0.7745	-0.0349	0.9229
ethyl succinate	123-25-1	-0.48	0.3311	-0.233	0.5848	-0.1334	0.7356	-0.0658	0.8594
diisobutyl succinate	925-06-4	-0.5946	0.2543	-0.3571	0.4394	-0.2603	0.5492	-0.1341	0.7344
dimethyl adipate	627-93-0	-0.2816	0.5228	-0.1467	0.7133	-0.069	0.8531	-0.0336	0.9255
dimethyl phthalate	131-11-3	-0.4882	0.3249	-0.1846	0.6538	-0.0487	0.8939	-0.003	0.9931
dimethyl succinate	106-65-0	-0.3305	0.4672	-0.1236	0.7524	-0.0573	0.8763	-0.0219	0.9508
methyl laurate	111-82-0	-1.2205	0.0602	-0.7101	0.1949	-0.6122	0.2442	-0.3265	0.4715
ethyl laurate	106-33-2	-1.2401	0.0575	-0.7343	0.1844	-0.6419	0.2281	-0.3418	0.4552
butyl laurate	106-18-3	-1.3149	0.0484	-0.7785	0.1665	-0.6989	0.2	-0.3645	0.432
methyl myristate	124-10-7	-1.3228	0.0476	-0.7563	0.1753	-0.6631	0.2172	-0.3455	0.4513
ethyl myristate	124-06-1	-1.3199	0.0479	-0.771	0.1694	-0.6863	0.2059	-0.3565	0.44
ethyl linoleate	544-35-4	-1.2614	0.0548	-0.6825	0.2077	-0.5688	0.2699	-0.2652	0.543
isopropyl myristate	110-27-0	-1.4063	0.0392	-0.8161	0.1527	-0.7374	0.1831	-0.3789	0.418
benzoic acid phenylmethylester	118-58-1	-0.912	0.1225	-0.408	0.3909	-0.1858	0.6519	-0.066	0.859
ricinoleic acid methylester	141-24-2	-0.6902	0.2041	-0.5025	0.3144	-0.4295	0.372	-0.2052	0.6235
dimethyl glutarate	1119-40-0	-0.287	0.5164	-0.1368	0.7298	-0.0565	0.8781	-0.0271	0.9394
diisobutyl glutarate	71195-64-7	-0.6111	0.2449	-0.3609	0.4356	-0.2601	0.5495	-0.131	0.7396
methyl abietate	127-25-3	-1.414	0.0386	-0.7334	0.1847	-0.6153	0.2425	-0.2884	0.5148
methyl palmitate	112-39-0	-1.4097	0.0389	-0.7933	0.161	-0.7031	0.1981	-0.3578	0.4387
isopropyl palmitate	142-91-6	-1.4914	0.0323	-0.8473	0.1421	-0.7726	0.1688	-0.389	0.4083
methyl stearate	112-61-8	-1.4994	0.0317	-0.8284	0.1485	-0.7425	0.1809	-0.371	0.4256
methyl linoleate	112-63-0	-1.2524	0.0559	-0.672	0.2128	-0.5465	0.2841	-0.2573	0.5529
methyl linolenate	301-00-8	-1.1295	0.0742	-0.5863	0.2592	-0.4418	0.3616	-0.1953	0.6378
ethyl oleate	111-62-6	-1.3775	0.0419	-0.7664	0.1713	-0.669	0.2143	-0.3255	0.4726
methyl oleate	112-62-9	-1.3705	0.0426	-0.746	0.1795	-0.6382	0.23	-0.3118	0.4878

octadecanoicacidbutylester	123-95-5	-1.545	0.0285	-0.8682	0.1355	-0.7966	0.1597	-0.3917	0.4058
dihydroterpinyl acetate	58985-18-5	-0.9868	0.1031	-0.6519	0.2229	-0.5647	0.2725	-0.3148	0.4844
glycerol triacetate	102-76-1	-0.2264	0.5937	-0.0776	0.8364	-0.0023	0.9947	0.0	1.0
triethyl citrate	77-93-0	-0.4219	0.3785	-0.1951	0.6381	-0.0886	0.8155	-0.0183	0.9588
2-ethylhexyl lactate	6283-86-9	-0.6624	0.2176	-0.5078	0.3106	-0.4351	0.3672	-0.236	0.5808
Ethyl lactate	97-64-3	-0.1275	0.7456	-0.1682	0.679	-0.1543	0.7009	-0.083	0.8261
1,2-ethanediol diacetate	111-55-7	-0.1622	0.6883	-0.0697	0.8518	-0.0101	0.9769	-0.0045	0.9896
4-methyl-2-pentylacetate	108-84-9	-0.7512	0.1773	-0.5006	0.3158	-0.3976	0.4003	-0.2379	0.5782
2-ethylhexyl acetate	103-09-3	-0.8762	0.133	-0.5756	0.2657	-0.4743	0.3355	-0.2743	0.5317
Ketones									
methyl isobutyl ketone	108-10-1	-0.2979	0.5037	-0.2895	0.5135	-0.2285	0.5909	-0.157	0.6967
cyclopentanone	120-92-3	0.0	1.0	-0.0442	0.9033	-0.0166	0.9624	-0.0429	0.9059
cyclohexanone	108-94-1	0.0	1.0	-0.1172	0.7635	-0.0795	0.8327	-0.0832	0.8256
Organic acids									
cis-9-octadecenoicacid	112-80-1	-0.5847	0.2602	-0.471	0.3381	-0.1483	0.7107	-0.147	0.7128
ricinoleic acid	141-22-0	-0.6711	0.2133	-0.3735	0.4231	-0.3812	0.4158	-0.1373	0.729
Ethers									
dimethoxymethane	109-87-5	-0.0185	0.9582	-0.1421	0.7209	-0.0885	0.8157	-0.0828	0.8264
tetrahydrofuran	109-99-9	0.0	1.0	-0.0967	0.8004	-0.0795	0.8328	-0.1205	0.7577
diethyl ether	60-29-7	-0.3843	0.4128	-0.4881	0.325	-0.4311	0.3706	-0.2961	0.5057
1,2-dimethoxyethane	110-71-4	0.0	1.0	-0.0806	0.8306	-0.0391	0.9139	-0.0749	0.8416
2-methyltetrahydrofuran	96-47-9	0.0	1.0	-0.3053	0.4951	-0.2714	0.5354	-0.2229	0.5986
methyl-tert-butylether	1634-04-4	-0.1856	0.6522	-0.4622	0.345	-0.4146	0.385	-0.2996	0.5017
diethoxymethane	462-95-3	-0.4001	0.398	-0.405	0.3935	-0.3336	0.4639	-0.2224	0.5992
cyclopentyl methyl ether	5614-37-9	-0.6602	0.2187	-0.623	0.2382	-0.5673	0.2708	-0.3538	0.4428
diisopropyl ether	108-20-3	-0.4097	0.3893	-0.6117	0.2445	-0.5699	0.2692	-0.3736	0.423
methyl tert-amyl ether	994-05-8	-0.5773	0.2647	-0.6564	0.2206	-0.5954	0.2539	-0.3806	0.4163
2-ethoxy-2-methyl-propane	637-92-3	-0.5074	0.3109	-0.6411	0.2285	-0.5892	0.2575	-0.3809	0.416
1,1,3-trimethoxypropane	14315-97-0	-0.1968	0.6356	-0.2615	0.5476	-0.199	0.6323	-0.133	0.7362
dipropyleneglycol	25265-71-8	0.0	1.0	-0.0719	0.8474	-0.3037	0.4969	-0.1138	0.7694
diglyme	111-96-6	0.0	1.0	-0.1113	0.774	-0.0489	0.8935	-0.0749	0.8416
anisole	100-66-3	-1.2154	0.0609	-0.4966	0.3187	-0.2701	0.5369	-0.1259	0.7483
dimethyl isosorbide	5306-85-4	0.0	1.0	-0.078	0.8356	-0.0515	0.8882	-0.0345	0.9237
1,4-cineol	470-67-7	-0.7561	0.1753	-0.7227	0.1894	-0.6797	0.2091	-0.4058	0.3928
1,8-cineol	470-82-6	-0.4035	0.3949	-0.6287	0.2351	-0.6111	0.2448	-0.3852	0.4119

PEO	25322-68-3	-0.1322	0.7376	-0.2292	0.59	-0.1906	0.6448	-0.1379	0.7279
Organic carbonates									
dimethyl carbonate	616-38-6	-0.3325	0.465	-0.1033	0.7882	-0.0465	0.8984	-0.0216	0.9514
diethyl carbonate	105-58-8	-0.5135	0.3066	-0.256	0.5546	-0.1595	0.6926	-0.0944	0.8047
propylene carbonate	108-32-7	-0.2537	0.5576	-0.0534	0.8842	-0.0925	0.8082	-0.0513	0.8886
butylene carbonate	4437-85-8	-0.2913	0.5114	-0.0861	0.8201	-0.0784	0.8349	-0.0353	0.9219
Dipolar aprotic									
nitromethane	75-52-5	-0.6006	0.2509	-0.0918	0.8095	-0.0941	0.8052	-0.0309	0.9314
n,n-dimethyloctanamide	1118-92-9	0.0	1.0	-0.1513	0.7059	-0.1295	0.7422	-0.1276	0.7455
n,n-dimethyldecanamide	14433-76-2	0.0	1.0	-0.2693	0.5379	-0.2432	0.5713	-0.1785	0.663
hexamethylphosphoramide	680-31-9	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Aromatics									
benzene	71-43-2	-1.6821	0.0208	-0.6352	0.2316	-0.3875	0.4097	-0.1847	0.6536
toluene	108-88-3	-1.8617	0.0138	-0.7377	0.1829	-0.5083	0.3103	-0.25	0.5624
1,2-dimethylbenzene	95-47-6	-1.948	0.0113	-0.7859	0.1637	-0.5663	0.2715	-0.2793	0.5257
1,3-dimethylbenzene	108-38-3	-2.0029	0.0099	-0.8154	0.153	-0.605	0.2483	-0.3002	0.501
1,4-dimethylbenzene	106-42-3	-2.0038	0.0099	-0.8162	0.1527	-0.6044	0.2487	-0.3	0.5011
1-methyl-4-isopropylbenzene	99-87-6	-2.1808	0.0066	-0.9107	0.1228	-0.7206	0.1903	-0.3568	0.4397
Hydrocarbons									
pentane	109-66-0	-3.2061	0.0006	-1.4794	0.0332	-1.4491	0.0356	-0.7709	0.1695
hexane	110-54-3	-3.2048	0.0006	-1.4773	0.0333	-1.4481	0.0356	-0.7668	0.1711
cyclohexane	110-82-7	-3.2057	0.0006	-1.4669	0.0341	-1.4644	0.0343	-0.7713	0.1693
n-heptane	142-82-5	-3.2	0.0006	-1.4719	0.0337	-1.4431	0.036	-0.7596	0.1739
methylcyclohexane	108-87-2	-3.1903	0.0006	-1.4587	0.0348	-1.4496	0.0355	-0.7605	0.1736
2,2,4-trimethylpentane	540-84-1	-3.1423	0.0007	-1.4383	0.0364	-1.3983	0.04	-0.7318	0.1854
myrcene	123-35-3	-2.2055	0.0062	-0.9381	0.1153	-0.7319	0.1854	-0.3681	0.4284
limonene	138-86-3	-2.4049	0.0039	-1.0439	0.0904	-0.8961	0.127	-0.4549	0.3508
□-pinene	80-56-8	-2.77	0.0017	-1.2339	0.0584	-1.1348	0.0733	-0.5821	0.2618
β-pinene	127-91-3	-2.6274	0.0024	-1.1704	0.0675	-1.0645	0.0862	-0.5475	0.2835
terpinolene	586-62-9	-2.4266	0.0037	-1.0542	0.0883	-0.9074	0.1238	-0.4589	0.3476
(z)-beta-farnesene	28973-99-1	-2.2256	0.0059	-0.929	0.1178	-0.7285	0.1868	-0.3438	0.4531
Halogenated									
chloroform	67-66-3	-0.4951	0.3198	-0.421	0.3793	0.0	1.0	-0.0722	0.8469
dichloromethane	75-09-2	-0.548	0.2831	-0.1957	0.6372	0.0	1.0	0.0	1.0

Tetrachloromethane	56-23-5	-2.901	0.0013	-1.2997	0.0502	-1.2291	0.059	-0.6395	0.2294
cis-1,2-dichloroethene	156-59-2	-1.0092	0.0979	-0.4395	0.3635	0.0	1.0	-0.0758	0.8398
1,2-dichloroethane	107-06-2	-1.0658	0.086	-0.3468	0.45	-0.0976	0.7987	-0.0599	0.8712
chlorobenzene	108-90-7	-1.6908	0.0204	-0.6587	0.2194	-0.385	0.4121	-0.1928	0.6416
trifluoromethyl benzene	98-08-8	-1.8484	0.0142	-0.7654	0.1716	-0.5311	0.2944	-0.283	0.5212
perfluorooctane	307-34-6	-4.3214	0.0	-2.0985	0.008	-2.3649	0.0043	-1.2579	0.0552
Base									
pyridine	110-86-1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
triethylamine	121-44-8	0.0	1.0	-0.4571	0.349	-0.6226	0.2384	-0.4847	0.3276
tetramethylurea	632-22-4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
N,N′-Dimethylpropyleneurea	7226-23-5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
2,4,6-collidine	108-75-8	0.0	1.0	-0.1855	0.6524	-0.144	0.7177	-0.1262	0.7479
1,2-dimethyl-3-nitrobenzene	83-41-0	-1.2084	0.0619	-0.4711	0.338	-0.2587	0.5512	-0.115	0.7673
1,3-dimethyl-2-nitrobenzene	81-20-9	-1.3562	0.044	-0.5206	0.3016	-0.2977	0.5039	-0.1347	0.7333
1,4-dimethyl-2-nitrobenzene	89-58-7	-1.2111	0.0615	-0.49	0.3236	-0.2842	0.5197	-0.1304	0.7407
methyl-5-(dimethylamino)-2-methyl-5-oxopentanoate	1174627-68-9	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Other									
decamethylcyclopentasiloxane	541-02-6	-1.816	0.0153	-0.9354	0.116	-0.7998	0.1586	-0.3841	0.4129
carbon disulfide	75-15-0	-2.8726	0.0013	-1.2191	0.0604	-1.0347	0.0923	-0.4941	0.3205

Table S3. Distribution coefficients calculated from COSMO-RS predictions of the LLE {H_2O + 5-HMF +solvent} at 298.15 K and 423.15 K for feed compositions simulated from different initial substrate concentrations. Note: the results for a feed composition corresponding to an initial concentration of fructose of 1% wt. at 423.15 K are marked in green italic font for reference for the raking of solvents. The results for MIBK are highlighted due this solvent being the most commonly applied in experimental studies. – denotes non-existing LLE-

		T=298.15 K					T=423.15 K				
Solvent	**CAS**	**$C_{fruc,0}$ =1% wt.**	**$C_{fruc,0}$ =5% wt.**	**$C_{fruc,0}$ =10% wt.**	**$C_{fruc,0}$ =25% wt.**	**$C_{fruc,0}$ =50% wt.**	**$C_{fruc,0}$ =1% wt.**	**$C_{fruc,0}$ =5% wt.**	**$C_{fruc,0}$ =10% wt.**	**$C_{fruc,0}$ =25% wt.**	**$C_{fruc,0}$ =50% wt.**
Alcohols											
1-butanol	71-36-3	2.48	2.49	2.49	2.49	2.49	*3.45*	3.43	3.40	3.32	3.12
2-butanol	78-92-2	2.53	2.53	2.54	2.54	2.53	*3.45*	3.44	3.41	3.34	3.15
isobutanol	78-83-1	2.52	2.52	2.52	2.53	2.54	*3.42*	3.40	3.38	3.30	3.11
tert-butanol	75-65-0	2.56	2.56	2.56	2.54	2.50	*3.31*	3.29	3.27	3.17	2.96
tetrahydrofurfuryl alcohol	97-99-4	-	-	-	-	-	*1.76*	1.73	1.69	-	-
furfuryl alcohol	98-00-0	4.80	4.75	4.69	4.49	4.10	*2.20*	2.17	2.13	1.95	1.63
3-methoxy-3-methylbutanol	56539-66-3	2.22	2.21	2.20	2.17	2.07	*3.24*	3.22	3.19	3.11	2.92
benzyl alcohol	100-51-6	4.05	4.04	4.02	3.95	3.80	*3.83*	3.80	3.77	3.65	3.40
Ester											
methyl acetate	79-20-9	-	-	-	-	-	*2.06*	2.02	1.97	1.79	-
ethyl acetate	141-78-6	3.61	3.59	3.55	3.43	3.19	*3.84*	3.82	3.78	3.68	3.44
isopropyl acetate	108-21-4	2.52	2.51	2.51	2.50	2.49	*3.02*	3.02	3.01	3.00	2.95
n-propyl acetate	109-60-4	2.50	2.50	2.49	2.49	2.48	*3.04*	3.03	3.03	3.01	2.96
adipic acid diethyl ester	141-28-6	1.18	1.19	1.19	1.20	1.23	*1.73*	1.73	1.73	1.73	1.72
acetic anhydride	108-24-7	2.22	2.25	2.29	2.40	2.58	*3.05*	3.02	2.99	2.85	2.55
methyl propionate	554-12-1	3.11	3.10	3.10	3.09	3.04	*3.68*	3.67	3.65	3.58	3.40
diethyl phthalate	84-66-2	0.60	0.61	0.61	0.63	0.67	*1.47*	1.48	1.48	1.51	1.54
ethyl succinate	123-25-1	1.08	1.09	1.11	1.15	1.25	*2.07*	2.08	2.08	2.09	2.11
dimethyl adipate	627-93-0	1.83	1.84	1.85	1.89	1.96	*2.57*	2.57	2.57	2.53	2.51
dimethyl phthalate	131-11-3	0.92	0.93	0.95	1.02	1.16	*2.14*	2.14	2.15	2.18	2.21
dimethyl succinate	106-65-0	1.93	1.94	1.97	2.03	2.15	*3.06*	3.05	3.04	2.99	2.86
dimethyl glutarate	1119-40-0	1.97	1.98	1.99	2.04	2.13	*2.84*	2.83	2.83	2.80	2.74
glycerol triacetate	102-76-1	1.61	1.62	1.64	1.69	1.79	*2.49*	2.49	2.49	2.48	2.43
triethyl citrate	77-93-0	0.69	0.70	0.70	0.72	0.73	*1.40*	1.41	1.41	1.43	1.45
ethyl lactate	97-64-3	3.02	3.01	2.99	2.94	2.81	*3.24*	3.23	3.21	3.15	3.02
1,2-ethanediol diacetate	111-55-7	2.65	2.65	2.64	2.63	2.58	*3.23*	3.21	3.19	3.10	2.91
Ketones											

methyl isobutyl ketone	108-10-1	2.85	2.83	2.80	2.73	2.62	***3.01***	3.00	2.99	2.97	2.90
cyclopentanone	120-92-3	-	-	-	-	-	***2.41***	2.38	2.33	2.18	1.86
cyclohexanone	108-94-1	2.59	2.54	2.51	2.48	2.45	***3.40***	3.38	3.34	3.22	2.95
Ethers											
dimethoxymethane	109-87-5	-	-	-	-	-	***3.40***	3.37	3.32	3.17	2.85
tetrahydrofuran	109-99-9	-	-	-	-	-	***3.51***	3.48	3.44	3.30	3.00
1,2-dimethoxyethane	110-71-4	-	-	-	-	-	***3.63***	3.60	3.56	3.41	3.10
1,1,3-trimethoxypropane	14315-97-0	2.67	2.66	2.64	2.58	2.47	***2.52***	2.52	2.52	2.52	2.50
dipropyleneglycol	25265-71-8	-	-	-	-	-	***2.82***	2.80	2.72	2.68	2.47
diglyme	111-96-6	-	-	-	-	-	***3.34***	3.33	3.30	3.23	3.06
dimethyl isosorbide	5306-85-4	-	-	-	-	-	***2.76***	2.75	2.73	2.67	2.52
PEO	25322-68-3	2.43	2.42	2.40	2.33	2.21	***2.60***	2.60	2.59	2.57	2.49
Organic carbonates											
dimethyl carbonate	616-38-6	2.20	2.19	2.16	2.11	2.05	***3.30***	3.26	3.21	3.17	3.12
diethyl carbonate	105-58-8	2.01	2.00	1.97	1.92	1.85	***2.93***	2.92	2.87	2.82	2.77
propylene carbonate	108-32-7	1.86	1.84	1.79	1.73	1.65	***2.55***	2.51	2.43	2.34	2.19
butylene carbonate	4437-85-8	1.78	1.76	1.72	1.67	1.58	***2.51***	2.49	2.40	2.28	2.11
Dipolar aprotic											
nitromethane	75-52-5	2.54	2.60	2.68	2.91	3.28	-	-	-	-	-
n,n-dimethyloctanamide	1118-92-9	2.34	2.33	2.31	2.25	2.12	***2.07***	2.05	2.03	1.97	1.84
n,n-dimethyldecanamide	14433-76-2	1.71	1.69	1.66	1.57	1.38	***1.32***	1.31	1.29	1.23	1.09
hexamethylphosphoramide	680-31-9	-	-	-	-	-	***3.12***	3.09	3.06	2.96	2.76
Halogenated											
dichloromethane	75-09-2	2.07	2.33	2.67	3.59	4.62	***3.69***	3.69	3.69	3.65	3.44
Bases											
pyridine	110-86-1	-	-	4.08	3.93	3.61	***3.55***	3.51	3.46	3.28	2.92
tetramethylurea	632-22-4	-	-	-	-	-	-	-	3.03	2.91	2.66
N,N′-Dimethylpropyleneurea	7226-23-5	-	-	-	-	-	***2.69***	2.67	2.63	2.52	-
2,4,6-collidine	108-75-8	3.31	3.28	3.24	3.10	2.80	***2.51***	2.50	2.49	2.44	2.37
methyl-5-(dimethylamino)-2-methyl-5-oxopentanoate	1174627-68-9	1.02	-	-	-	-	***3.23***	3.21	3.18	3.08	2.88

Table S4 Distribution coefficients calculated from COSMO-RS predictions of the LLE {H_2O + 5-HMF +solvent} at 298.15 K and 423.15 K for feed compositions simulated from different initial substrate concentrations. Note: the results for a feed composition corresponding to an initial concentration of xylose of 1% wt. at 423.15 K are marked in purple italic font for reference for the raking of solvents. The results for MIBK are highlighted due this solvent being the most commonly applied in experimental studies. – denotes non-existing LLE-

		T=298.15 K					T=423.15 K				
Solvent	**CAS**	**$C_{fruc,0}$ =1% wt.**	**$C_{fruc,0}$ =5% wt.**	**$C_{fruc,0}$ =10% wt.**	**$C_{fruc,0}$ =25% wt.**	**$C_{fruc,0}$ =50% wt.**	**$C_{fruc,0}$ =1% wt.**	**$C_{fruc,0}$ =5% wt.**	**$C_{fruc,0}$ =10% wt.**	**$C_{fruc,0}$ =25% wt.**	**$C_{fruc,0}$ =50% wt.**
Alcohols											
tetrahydrofurfuryl alcohol	97-99-4	-	-	-	-	-	***1.92***	1.91	1.90	-	1.80
furfuryl alcohol	98-00-0	8.37	8.32	8.27	8.09	7.79	***2.53***	2.53	2.53	2.53	2.52
3-methoxy-3-methylbutanol	56539-66-3	2.68	2.69	2.70	2.73	2.81	***4.39***	4.38	4.37	4.33	4.25
benzyl alcohol	100-51-6	9.60	9.55	9.48	9.27	8.91	***5.76***	5.73	5.69	5.57	5.32
Esters											
methyl acetate	79-20-9	-	-	-	-	-	***2.31***	2.31	2.31	2.30	2.29
ethyl acetate	141-78-6	6.64	6.63	6.63	6.60	6.56	***5.71***	5.69	5.65	5.55	5.33
isopropyl acetate	108-21-4	6.51	6.52	6.53	6.58	6.66	***5.52***	5.51	5.50	5.46	5.37
n-propyl acetate	109-60-4	6.61	6.62	6.63	6.67	6.75	***5.57***	5.56	5.55	5.51	5.42
adipic acid diethyl ester	141-28-6	4.09	4.12	4.15	4.27	4.50	***3.60***	3.61	3.62	3.65	3.70
acetic anhydride	108-24-7	8.02	8.01	8.00	7.98	7.90	***4.07***	4.05	4.03	3.96	3.81
methyl propionate	554-12-1	7.40	7.39	7.39	7.37	7.33	***5.85***	5.83	5.80	5.71	5.50
diethyl phthalate	84-66-2	3.74	3.78	3.83	3.98	4.30	***3.51***	3.52	3.53	3.57	3.65
ethyl succinate	123-25-1	4.63	4.66	4.70	4.83	5.08	***4.18***	4.18	4.19	4.20	4.22
diisobutyl succinate	925-06-4	2.61	2.64	2.67	2.79	3.06	***2.64***	2.65	2.66	2.71	2.80
dimethyl adipate	627-93-0	5.37	5.39	5.42	5.50	5.66	***4.49***	4.49	4.49	4.48	4.44
dimethyl phthalate	131-11-3	4.99	5.02	5.06	5.18	5.43	***4.33***	4.33	4.33	4.34	4.33
dimethyl succinate	106-65-0	6.12	6.14	6.16	6.22	6.33	***4.80***	4.79	4.78	4.72	4.61
benzoic acid phenylmethylester	118-58-1	3.15	3.19	3.24	3.42	3.79	***3.19***	3.20	3.22	3.27	3.37
dimethyl glutarate	1119-40-0	5.81	5.83	5.85	5.92	6.04	***4.76***	4.76	4.75	4.72	4.64
diisobutyl glutarate	71195-64-7	2.45	2.47	2.50	2.61	2.85	***2.48***	2.48	2.49	2.53	2.61
glycerol triacetate	102-76-1	5.02	5.05	5.08	5.18	5.37	***4.15***	4.15	4.15	4.14	4.11
triethyl citrate	77-93-0	3.25	3.29	3.33	3.48	3.79	***3.05***	3.06	3.08	3.13	3.23
Ethyl lactate	97-64-3	5.55	5.56	5.58	5.63	5.72	***5.02***	5.01	4.99	4.94	4.82
1,2-ethanediol diacetate	111-55-7	5.93	5.93	5.94	5.97	6.01	***4.65***	4.63	4.61	4.55	4.41
Ketones											
methyl isobutyl ketone	108-10-1	5.92	5.93	5.94	5.98	6.07	***5.36***	5.35	5.34	5.30	5.22
cyclopentanone	120-92-3	-	-	-	-	-	***2.74***	2.74	2.73	2.70	2.65
cyclohexanone	108-94-1	3.43	3.41	3.38	3.33	3.27	***4.51***	4.49	4.47	4.40	4.25

Organic acids											
cis-9-octadecenoicacid	112-80-1	2.67	2.64	2.60	2.52	2.43	***1.90***	1.89	1.89	1.87	1.84
ricinoleic acid	141-22-0	1.72	1.73	1.75	1.82	1.99	***2.03***	2.04	2.04	2.06	2.10
Ethers											
dimethoxymethane	109-87-5	-	-	-	-	-	***4.43***	4.41	4.38	4.29	4.11
tetrahydrofuran	109-99-9	-	-	-	-	-	***4.45***	4.43	4.41	4.33	4.17
1,2-dimethoxyethane	110-71-4	-	-	-	-	-	***4.61***	4.59	4.57	4.48	4.31
1,1,3-trimethoxypropane	14315-97-0	4.83	4.84	4.86	4.94	5.08	***4.54***	4.54	4.54	4.54	4.53
dipropyleneglycol	25265-71-8	-	-	-	-	-	***3.47***	3.46	3.45	3.41	3.33
diglyme	111-96-6	-	-	-	-	-	***4.85***	4.84	4.83	4.78	4.67
anisole	100-66-3	5.06	5.12	5.19	5.44	5.91	***5.39***	5.40	5.41	5.43	5.44
dimethyl isosorbide	5306-85-4	-	-	-	-	-	***3.85***	3.85	3.84	3.81	3.74
PEO	25322-68-3	3.64	3.66	3.69	3.79	3.99	***4.00***	4.00	4.00	4.00	3.97
Organic carbonates											
dimethyl carbonate	616-38-6	5.32	5.33	5.36	5.41	5.49	***4.44***	4.44	4.42	4.36	4.26.
diethyl carbonate	105-58-8	4.91	4.93	4.98	5.05	5.15	***4.22***	4.21	4.17	4.11	4.03
propylene carbonate	108-32-7	4.77	4.79	4.82	4.86	4.93	***4.14***	4.13	4.11	4.08	4.05
butylene carbonate	4437-85-8	4.68	4.70	4.74	4.80	4.89	***4.05***	4.05	4.03	4.00	3.97
Dipolar aprotic											
nitromethane	75-52-5	11.19	11.15	11.11	10.96	10.68	***-***	-	-	-	-
n,n-dimethyloctanamide	1118-92-9	3.30	3.33	3.42	3.63	3.62	***3.62***	3.62	3.62	3.63	3.30
hexamethylphosphoramide	680-31-9	2.08	2.08	-	-	-	***3.81***	3.81	3.81	3.79	3.75
Halogenated											
chloroform	67-66-3	18.16	17.30	16.30	13.73	10.68	***5.24***	5.22	5.19	5.12	5.02
dichloromethane	75-09-2	20.39	20.03	19.59	18.30	16.14	***6.52***	6.47	6.41	6.20	5.81
cis-1,2-dichloroethene	156-59-2	10.77	10.71	10.64	10.44	10.11	***6.23***	6.22	6.21	6.16	6.04
1,2-dichloroethane	107-06-2	8.17	8.20	8.24	8.36	8.55	***5.89***	5.87	5.85	5.79	5.63
Bases											
pyridine	110-86-1	5.05	5.05	5.05	5.05	5.06	***4.40***	4.38	4.36	4.27	4.10
tetramethylurea	632-22-4	-	-	-	-	-	***3.44***	3.43	3.42	3.38	3.31
N,N′-Dimethylpropyleneurea	7226-23-5	-	-	-	-	-	***2.95***	2.95	2.94	2.92	2.87
2,4,6-collidine	108-75-8	4.83	4.86	4.90	5.05	5.34	***4.89***	4.89	4.89	4.88	4.87
1,2-dimethyl-3-nitrobenzene	83-41-0	3.71	3.76	3.83	4.05	4.49	***4.05***	4.07	4.08	4.14	4.24
1,3-dimethyl-2-nitrobenzene	81-20-9	3.36	3.42	3.49	3.72	4.19	***3.85***	3.86	3.88	3.95	4.07
1,4-dimethyl-2-nitrobenzene	89-58-7	3.50	3.55	3.62	3.84	4.28	***3.90***	3.92	3.94	3.99	4.10
methyl-5-(dimethylamino)-2-methyl-5-oxopentanoate	1174627-68-9	-	-	1.53	1.72	1.94	***4.35***	4.34	4.33	4.28	4.19