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*Supplement of*

## **Humidity effects on the detection of soluble and insoluble nanoparticles in butanol operated condensation particle counters**

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# TSI 3776 UCPC Cut-off Measurements

Table S1: Cut-off measurements for a TSI 3776 UCPC for (+) positively and (-) negatively charged sodium chloride (NaCl) seeds under low, standard (std) and high temperature settings. In addition the experimentally determined cut-off diameter  $d_{50}$  and the deviation of the cut-off diameter  $\Delta(d_{50})$ , as well as the minimum  $\mathcal{N}_{min}$  and maximum number concentration  $\mathcal{N}_{max}$  during the cut-off measurements.

Seed	T-Setting	RH [%]	$d_{50}$ [nm]	$\Delta(d_{50})$ [nm]	$\mathcal{N}_{min}$ [ $cm^{-3}$ ]	$\mathcal{N}_{max}$ [ $cm^{-3}$ ]
NaCl(+)	low	0	2.99	0.24	500	30000
NaCl(+)	std	0	4.32	0.35	300	30000
NaCl(+)	high	0	4.76	0.39	1000	30000
NaCl(-)	low	0	3.70	0.30	300	40000
NaCl(-)	std	0	4.41	0.36	500	50000
NaCl(-)	high	0	4.72	0.39	500	12500
NaCl(+)	low	10	2.45	0.20	500	35000
NaCl(+)	std	10	3.82	0.31	300	35000
NaCl(+)	high	10	4.98	0.41	300	35000
NaCl(-)	low	10	2.82	0.23	250	30000
NaCl(-)	std	10	3.77	0.31	500	40000
NaCl(-)	high	10	4.95	0.41	200	40000
NaCl(+)	low	20	2.35	0.19	200	8000
NaCl(+)	std	20	3.14	0.26	200	12000
NaCl(+)	high	20	4.61	0.38	500	11000
NaCl(-)	low	20	2.28	0.19	100	10000
NaCl(-)	std	20	2.69	0.22	200	20000
NaCl(-)	high	20	4.11	0.34	500	15000
NaCl(+)	low	30	1.96	0.16	300	10000
NaCl(+)	std	30	2.45	0.20	500	20000
NaCl(+)	high	30	4.09	0.34	200	18000
NaCl(-)	low	30	1.50	0.12	200	15000
NaCl(-)	std	30	2.40	0.20	200	15000
NaCl(-)	high	30	4.02	0.33	250	30000
NaCl(+)	low	40	1.84	0.15	500	17500
NaCl(+)	std	40	2.04	0.17	1500	15000
NaCl(+)	high	40	3.18	0.26	800	12500
NaCl(-)	low	40	1.23	0.10	500	20000
NaCl(-)	std	40	1.84	0.15	500	25000
NaCl(-)	high	40	3.33	0.27	1000	25000

Table S2: Cut-off measurements for a TSI 3776 UCPC for (+) positively and (-) negatively charged silver (Ag) seeds under low, standard (std) and high temperature settings. In addition the experimentally determined cut-off diameter  $d_{50}$  and the deviation of the cut-off diameter  $\Delta(d_{50})$ , as well as the minimum  $\mathcal{N}_{min}$  and maximum number concentration  $\mathcal{N}_{max}$  during the cut-off measurements.

Seed	T-Setting	RH [%]	$d_{50}$ [nm]	$\Delta(d_{50})$ [nm]	$\mathcal{N}_{min}$ [ $cm^{-3}$ ]	$\mathcal{N}_{max}$ [ $cm^{-3}$ ]
Ag(+)	low	0	2.57	0.21	200	30000
Ag(+)	std	0	3.03	0.25	500	20000
Ag(+)	high	0	3.47	0.28	200	18000
Ag(-)	low	0	2.12	0.17	200	25000
Ag(-)	std	0	2.54	0.21	200	7000
Ag(-)	high	0	3.00	0.25	200	3000
Ag(+)	low	10	2.29	0.19	1000	25000
Ag(+)	std	10	2.77	0.23	2000	25000
Ag(+)	high	10	3.23	0.26	1000	12000
Ag(-)	low	10	2.15	0.18	2000	25000
Ag(-)	std	10	2.69	0.22	200	6000
Ag(-)	high	10	3.18	0.26	2000	15000
Ag(+)	low	20	2.37	0.19	100	6000
Ag(+)	std	20	2.89	0.24	1000	70000
Ag(+)	high	20	3.11	0.25	200	80000
Ag(-)	low	20	2.11	0.17	500	8000
Ag(-)	std	20	2.66	0.22	250	5000
Ag(-)	high	20	3.11	0.25	200	3000
Ag(+)	low	30	2.26	0.19	200	6000
Ag(+)	std	30	2.60	0.21	200	3000
Ag(+)	high	30	2.99	0.25	100	3000
Ag(-)	low	30	2.12	0.17	500	6000
Ag(-)	std	30	2.54	0.21	400	4000
Ag(-)	high	30	3.00	0.25	250	4000
Ag(+)	low	40	2.49	0.20	500	6000
Ag(+)	std	40	2.95	0.24	500	6000
Ag(+)	high	40	3.08	0.25	500	6000
Ag(-)	low	40	2.41	0.20	600	6000
Ag(-)	std	40	2.42	0.20	400	6000
Ag(-)	high	40	2.99	0.25	1000	18000

Table S3: Cut-off measurements for a TSI 3776 UCPC for (0+) positively and (0-) negatively neutralized sodium chloride (NaCl) seeds under low, standard (std) and high temperature settings. In addition the experimentally determined cut-off diameter  $d_{50}$  and the deviation of the cut-off diameter  $\Delta(d_{50})$ , as well as the minimum  $\mathcal{N}_{min}$  and maximum number concentration  $\mathcal{N}_{max}$  during the cut-off measurements.

Seed	T-Setting	RH [%]	$d_{50}$ [nm]	$\Delta(d_{50})$ [nm]	$\mathcal{N}_{min}$ [ $cm^{-3}$ ]	$\mathcal{N}_{max}$ [ $cm^{-3}$ ]
NaCl(0+)	low	0	3.20	0.26	500	15000
NaCl(0+)	std	0	3.78	0.31	500	15000
NaCl(0+)	high	0	4.57	0.38	500	15000
NaCl(0-)	low	0	3.14	0.26	250	70000
NaCl(0-)	std	0	3.96	0.32	250	60000
NaCl(0-)	high	0	4.59	0.38	400	30000
NaCl(0+)	low	10	2.41	0.20	200	8000
NaCl(0+)	std	10	3.31	0.27	200	7500
NaCl(0+)	high	10	4.30	0.35	400	6000
NaCl(0-)	low	10	2.14	0.18	500	30000
NaCl(0-)	std	10	3.20	0.26	500	30000
NaCl(0-)	high	10	4.26	0.35	500	25000
NaCl(0+)	low	20	2.36	0.19	400	10000
NaCl(0+)	std	20	2.81	0.23	500	7500
NaCl(0+)	high	20	4.10	0.34	500	7000
NaCl(0-)	low	20	1.92	0.16	800	25000
NaCl(0-)	std	20	2.60	0.21	800	20000
NaCl(0-)	high	20	4.04	0.33	600	20000
NaCl(0+)	low	30	2.04	0.17	100	10000
NaCl(0+)	std	30	2.32	0.19	100	10000
NaCl(0+)	high	30	3.00	0.25	1000	11000
NaCl(0-)	low	30	1.54	0.13	500	25000
NaCl(0-)	std	30	1.80	0.15	500	25000
NaCl(0-)	high	30	2.86	0.23	100	15000
NaCl(0+)	low	40	1.95	0.16	100	12000
NaCl(0+)	std	40	2.20	0.18	800	13500
NaCl(0+)	high	40	2.68	0.22	100	14000
NaCl(0-)	low	40	1.63	0.13	500	15000
NaCl(0-)	std	40	1.76	0.14	500	15000
NaCl(0-)	high	40	2.49	0.20	1000	20000

Table S4: Cut-off measurements for a TSI 3776 UCPC for (0+) positively and (0-) negatively neutralized silver (Ag) seeds under low, standard (std) and high temperature settings. In addition the experimentally determined cut-off diameter  $d_{50}$  and the deviation of the cut-off diameter  $\Delta(d_{50})$ , as well as the minimum  $\mathcal{N}_{min}$  and maximum number concentration  $\mathcal{N}_{max}$  during the cut-off measurements.

Seed	T-Setting	RH [%]	$d_{50}$ [nm]	$\Delta(d_{50})$ [nm]	$\mathcal{N}_{min}$ [ $cm^{-3}$ ]	$\mathcal{N}_{max}$ [ $cm^{-3}$ ]
Ag(0+)	low	0	2.22	0.18	300	80000
Ag(0+)	std	0	3.02	0.25	300	70000
Ag(0+)	high	0	3.93	0.32	1500	35000
Ag(0-)	low	0	2.32	0.19	250	70000
Ag(0-)	std	0	2.96	0.24	250	60000
Ag(0-)	high	0	3.81	0.31	400	30000
Ag(0+)	low	10	2.52	0.21	250	35000
Ag(0+)	std	10	3.06	0.25	250	35000
Ag(0+)	high	10	3.80	0.31	300	20000
Ag(0-)	low	10	2.40	0.20	500	30000
Ag(0-)	std	10	2.98	0.24	500	30000
Ag(0-)	high	10	3.69	0.30	500	25000
Ag(0+)	low	20	2.51	0.21	250	20000
Ag(0+)	std	20	3.31	0.27	250	20000
Ag(0+)	high	20	3.73	0.31	250	20000
Ag(0-)	low	20	2.33	0.19	800	25000
Ag(0-)	std	20	3.06	0.25	800	20000
Ag(0-)	high	20	4.06	0.33	600	20000
Ag(0+)	low	30	2.46	0.20	250	12000
Ag(0+)	std	30	2.82	0.23	250	12000
Ag(0+)	high	30	3.98	0.33	100	20000
Ag(0-)	low	30	2.28	0.19	500	25000
Ag(0-)	std	30	2.74	0.22	500	25000
Ag(0-)	high	30	3.98	0.33	100	15000
Ag(0+)	low	40	2.48	0.20	250	12000
Ag(0+)	std	40	2.77	0.23	200	10000
Ag(0+)	high	40	3.37	0.28	500	15000
Ag(0-)	low	40	2.33	0.19	500	15000
Ag(0-)	std	40	2.70	0.22	500	15000
Ag(0-)	high	40	3.37	0.28	1000	20000



## Size Analyzing Nuclei Counter (SANC) Measurements

Table S5: A summary of experimentally inferred onset saturation ratio  $S_0$ , nucleation temperature  $T_{nuc}$  and number of molecules in the critical cluster  $n^*$  values, as well as the selected mobility equivalent diameter  $d_p$  for neutralized silver seeds (0-/ +). All measurements were conducted with a maximal relative humidity at room temperature (RH) below 2.5% or 10%.

Seed	$d_p$ [nm]	RH [%]	$S_0$ [ ]	$T_{nuc}$ [ $^{\circ}C$ ]	$n^*$
Ag(0-)	2.5	< 10.0	3.16	-4.0	13.64
Ag(0-)	2.5	< 10.0	3.13	-3.0	10.70
Ag(0-)	2.5	< 10.0	3.06	0.0	16.16
Ag(0-)	2.5	< 10.0	3.07	1.0	9.55
Ag(0-)	2.5	< 10.0	2.90	4.0	11.78
Ag(0-)	2.5	< 10.0	2.92	5.0	12.75
Ag(0-)	3.0	< 2.5	2.59	-4.0	15.58
Ag(0-)	3.0	< 2.5	2.61	0.0	11.58
Ag(0-)	3.0	< 2.5	2.45	5.0	11.74
Ag(0-)	3.0	< 2.5	2.43	6.0	11.58
Ag(0-)	3.0	< 2.5	2.44	10.0	11.24
Ag(0+)	3.5	< 2.5	2.36	3.0	15.69
Ag(0+)	3.5	< 2.5	2.33	10.0	10.98
Ag(0-)	5.0	< 2.5	1.83	0.0	25.57
Ag(0-)	5.0	< 10.0	1.72	4.0	25.53
Ag(0-)	5.0	< 10.0	1.70	5.0	25.52
Ag(0-)	5.0	< 10.0	1.67	8.0	27.68
Ag(0-)	5.0	< 10.0	1.67	12.0	27.56
Ag(0-)	5.0	< 10.0	1.67	13.0	29.00
Ag(0-)	6.5	< 10.0	1.56	2.0	45.90
Ag(0-)	6.5	< 10.0	1.57	5.0	50.41
Ag(0-)	6.5	< 10.0	1.46	10.0	49.18
Ag(0-)	6.5	< 10.0	1.49	15.0	53.93
Ag(0-)	9.0	< 10.0	1.36	4.0	62.43
Ag(0-)	9.0	< 10.0	1.29	7.0	70.79
Ag(0-)	9.0	< 10.0	1.30	8.0	47.39
Ag(0-)	9.0	< 10.0	1.30	12.0	75.85
Ag(0-)	9.0	< 10.0	1.29	15.0	74.18
Ag(0-)	9.0	< 10.0	1.29	16.0	81.21

Table S6: A summary of experimentally inferred onset saturation ratio  $S_0$ , nucleation temperature  $T_{nuc}$  and number of molecules in the critical cluster  $n^*$  values, as well as the selected mobility equivalent diameter  $d_p$  for neutralized NaCl seeds (0-/ +). All measurements were conducted with a maximal relative humidity at room temperature (RH) below 10%.

Seed	$d_p$ [nm]	RH [%]	$S_0$ [ ]	$T_{nuc}$ [ $^{\circ}C$ ]	$n^*$
NaCl(0-)	2.5	< 10.0	3.28	-4.0	12.51
NaCl(0-)	2.5	< 10.0	3.18	-1.0	15.61
NaCl(0-)	2.5	< 10.0	3.14	1.0	19.71
NaCl(0-)	2.5	< 10.0	3.15	3.0	13.13
NaCl(0-)	2.5	< 10.0	3.13	4.0	11.25
NaCl(0-)	2.5	< 10.0	3.11	6.0	14.99
NaCl(0-)	3.0	< 10.0	2.79	-1.0	10.87
NaCl(0-)	3.0	< 10.0	2.79	1.0	10.40
NaCl(0-)	3.0	< 10.0	2.86	5.0	10.13
NaCl(0-)	3.0	< 10.0	2.89	7.0	13.51
NaCl(0-)	3.0	< 10.0	2.89	8.0	13.49
NaCl(0-)	5.5	< 10.0	1.92	-1.0	20.33
NaCl(0-)	5.5	< 10.0	1.97	0.0	18.34
NaCl(0-)	5.5	< 10.0	1.99	1.0	12.84
NaCl(0-)	5.5	< 10.0	2.02	2.0	12.74
NaCl(0-)	5.5	< 10.0	2.11	5.0	8.12
NaCl(0-)	5.5	< 10.0	2.12	6.0	9.80
NaCl(0-)	5.5	< 10.0	2.16	10.0	6.9
NaCl(0-)	7.5	< 10.0	1.64	1.0	16.22
NaCl(0-)	7.5	< 10.0	1.69	3.0	11.57
NaCl(0-)	7.5	< 10.0	1.68	4.0	13.63
NaCl(0-)	7.5	< 10.0	1.72	8.0	10.61
NaCl(0-)	7.5	< 10.0	1.72	9.0	9.09
NaCl(0-)	7.5	< 10.0	1.81	12.0	9.08
NaCl(0-)	7.5	< 10.0	1.83	13.0	9.34
NaCl(0-)	10.5	< 10.0	1.40	2.0	23.89
NaCl(0-)	10.5	< 10.0	1.49	6.0	23.06
NaCl(0-)	10.5	< 10.0	1.51	7.0	21.47
NaCl(0-)	10.5	< 10.0	1.52	11.0	14.80
NaCl(0-)	10.5	< 10.0	1.53	12.0	12.22
NaCl(0-)	10.5	< 10.0	1.52	14.0	17.13

Table S7: A summary of experimentally inferred onset saturation ratio  $S_0$ , nucleation temperature  $T_{nuc}$  and number of molecules in the critical cluster  $n^*$  values, as well as the selected mobility equivalent diameter  $d_p$  for neutralized NaCl seeds (0-/ +). All measurements were conducted with a maximal relative humidity at room temperature (RH) below 2.5%.

Seed	$d_p$ [nm]	RH [%]	$S_0$ [ ]	$T_{nuc}$ [ $^{\circ}C$ ]	$n^*$
NaCl(0+)	2.5	< 2.5	3.19	0.0	10.71
NaCl(0-)	2.5	< 2.5	3.18	4.0	16.38
NaCl(0+)	3.0	< 2.5	2.83	1.0	9.26
NaCl(0+)	3.0	< 2.5	2.80	2.3	10.65
NaCl(0+)	3.0	< 2.5	2.82	7.5	21.22
NaCl(0+)	3.5	< 2.5	2.65	1.6	10.43
NaCl(0+)	3.5	< 2.5	2.60	8.0	16.57
NaCl(0+)	5.5	< 2.5	2.15	5.0	16.45
NaCl(0+)	5.5	< 2.5	2.21	11.8	11.59
NaCl(0+)	10.5	< 2.5	1.63	16.3	9.19
NaCl(0-)	10.5	< 2.5	1.66	17.2	12.12

Table S8: A summary of experimentally inferred onset saturation ratio  $S_0$ , nucleation temperature  $T_{nuc}$  and number of molecules in the critical cluster  $n^*$  values, as well as the selected mobility equivalent diameter  $d_p$  for positively (+) and negatively (-) charged silver seeds. All measurements were conducted with a maximal relative humidity at room temperature (RH) below 2.5% or 10%.

Seed	$d_p$ [nm]	RH [%]	$S_0$ [ ]	$T_{nuc}$ [ $^{\circ}C$ ]	$n^*$
Ag(+)	2.5	< 2.5	3.07	0.0	17.48
Ag(+)	2.5	< 2.5	3.03	6.0	14.10
Ag(+)	3.0	< 2.5	2.68	2.0	13.67
Ag(+)	3.0	< 2.5	2.48	8.0	11.65
Ag(+)	3.5	< 2.5	2.32	3.0	18.15
Ag(+)	3.5	< 2.5	2.33	10.0	11.74
Ag(-)	5.0	< 2.5	1.83	6.0	24.99
Ag(+)	5.0	< 2.5	1.85	7.0	20.55
Ag(+)	5.0	< 2.5	1.83	14.0	22.24
Ag(+)	9.0	< 2.5	1.36	11.0	33.67
Ag(+)	9.0	< 2.5	1.32	19.0	44.22

Table S9: A summary of experimentally inferred onset saturation ratio  $S_0$ , nucleation temperature  $T_{nuc}$  and number of molecules in the critical cluster  $n^*$  values, as well as the selected mobility equivalent diameter  $d_p$  for positively (+) and negatively (-) charged sodium chloride seeds. All measurements were conducted with a maximal relative humidity at room temperature (RH) below 2.5% or 10%.

Seed	$d_p$ [nm]	RH [%]	$S_0$ [ ]	$T_{nuc}$ [ $^{\circ}C$ ]	$n^*$
NaCl(+)	2.5	< 2.5	3.20	0.0	15.20
NaCl(-)	2.5	< 2.5	3.04	0.0	15.11
NaCl(-)	2.5	< 2.5	3.08	7.0	26.46
NaCl(+)	2.5	< 2.5	3.14	7.0	11.86
NaCl(-)	3.0	< 2.5	2.81	1.0	25.91
NaCl(+)	3.0	< 2.5	2.87	1.0	18.86
NaCl(-)	3.0	< 2.5	2.64	8.0	6.87
NaCl(+)	3.0	< 2.5	2.72	8.0	12.57
NaCl(+)	3.5	< 2.5	2.73	2.0	16.96
NaCl(-)	3.5	< 2.5	2.64	2.0	13.14
NaCl(-)	3.5	< 2.5	2.48	9.0	12.91
NaCl(+)	3.5	< 2.5	2.54	9.0	16.31
NaCl(+)	5.5	< 2.5	2.22	4.0	15.40
NaCl(-)	5.5	< 2.5	2.17	4.0	14.25
NaCl(+)	5.5	< 2.5	2.12	11.0	22.31
NaCl(+)	10.5	< 2.5	1.66	9.0	10.57
NaCl(-)	10.5	< 2.5	1.63	9.0	7.07
NaCl(+)	10.5	< 2.5	1.64	17.0	10.07
NaCl(-)	10.5	< 2.5	1.63	14.0	10.59

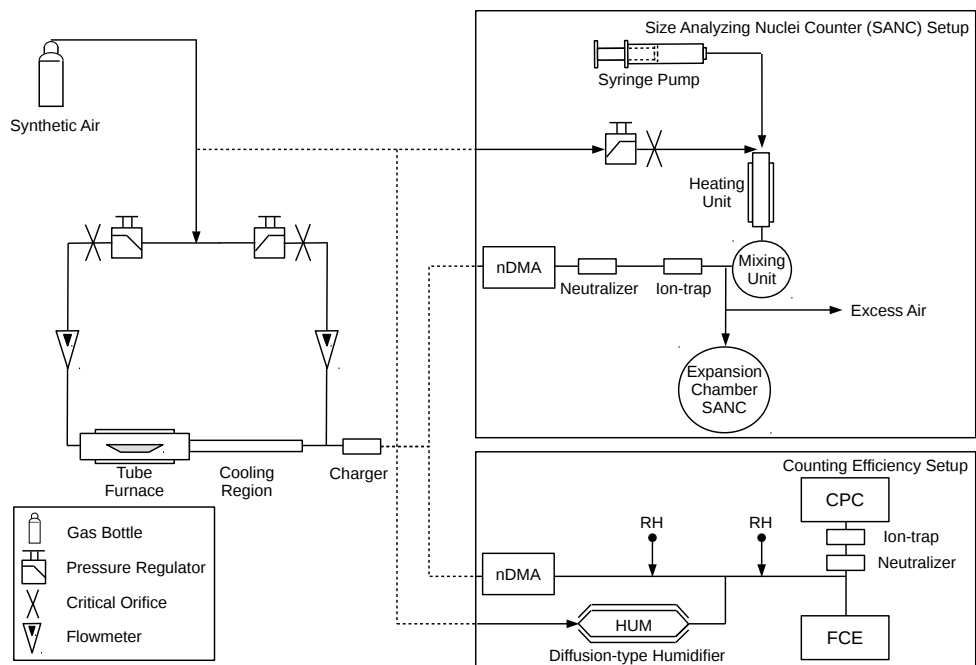


Figure S1: The experimental setup for evaluating the supersaturation and nucleation temperature with the SANC and the relative humidity dependent counting efficiency measurements of a continuous flow type CPC (TSI 3776 UCPC), which was measured by operating a Faraday Cup Electrometer (FCE) in parallel.

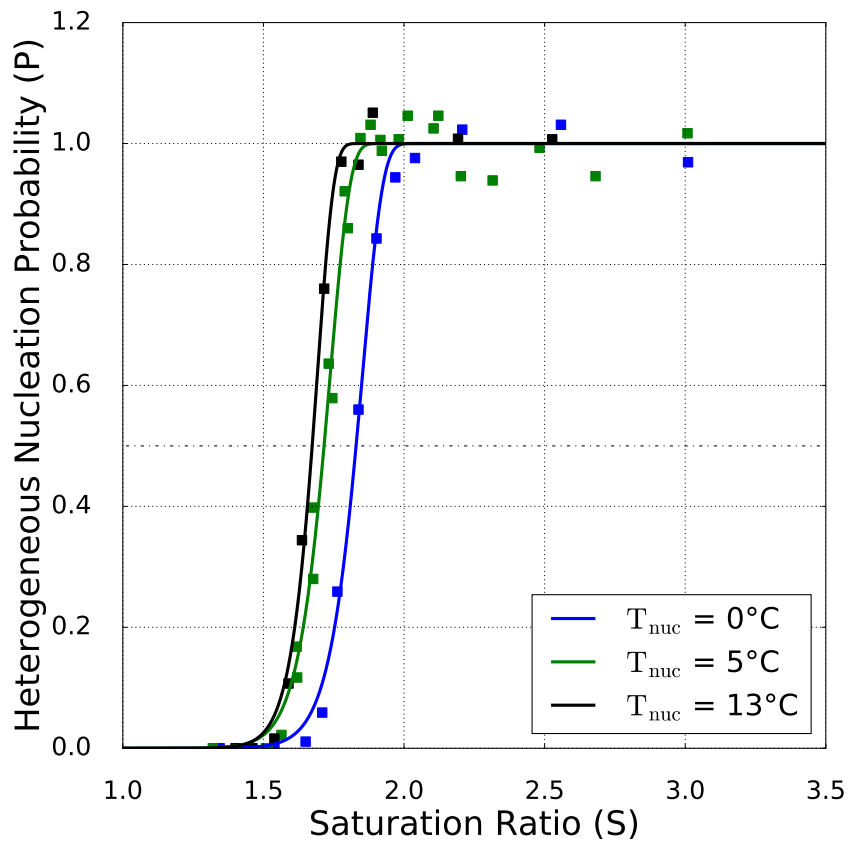


Figure S2: Heterogeneous nucleation probability measurements of n-butanol on neutral silver seeds with a mobility equivalent diameter of 5 nm at different nucleation temperatures as a function of saturation ratio. In this case lower nucleation temperature coincides with higher saturation ratios needed for particle activation. The horizontal dotted line represents the activation probability of 0.5.

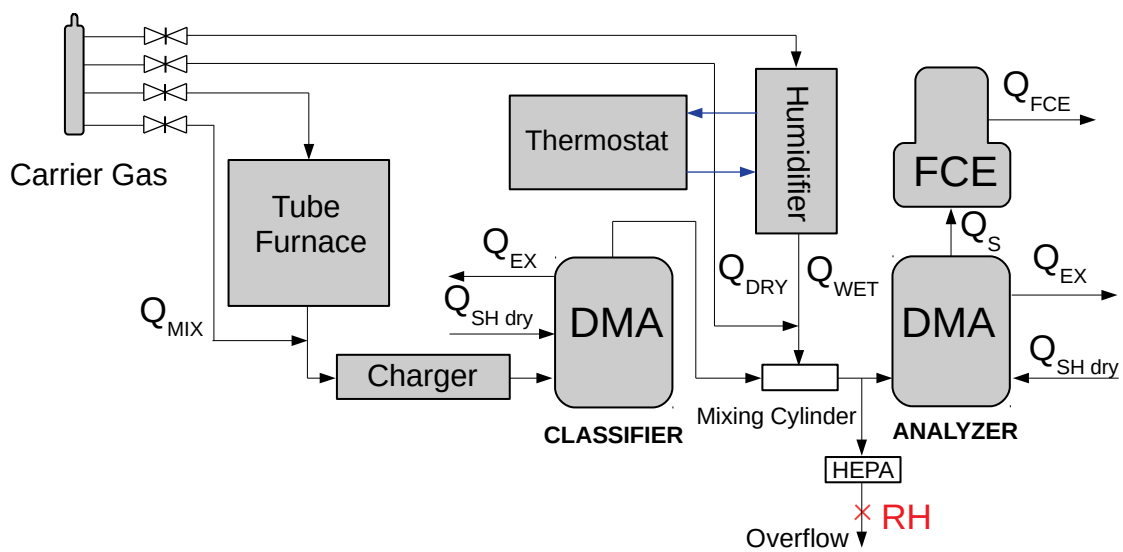


Figure S3: The experimental setup for evaluating the particle shrinkage in the presence of water vapor with a tandem nDMA setup.