

日本酒を飲むときは、「やわらぎ水」
(チェイサー) を飲むと、非常に健康によ
い！消化器官でのエタノール濃度が下がっ
て、吸収が減少するからであるう。

エタノールと水は完全混合する。水の水
素結合ネットワーク内にエタノールも参加
できるので引力的な相互作用が働くため
であるう。

ではこの引力的な相互作用をどのように確認したらいいのでしょうか？

一番簡単なのはその体積の変化であろう。100 mLずつ混合すれば、引力的であれば体積は200 mLより減少し、斥力的であれば増加する。

これらを定量的にあらわす指標が部分モル体積である。溶液内のある成分を1 mol増加させると溶液の体積がどれだけ増加するのかという量である。

溶液の密度と部分モル体積

実際に部分モル体積を求めるには、ある温度 T での溶液の濃度を変えて、密度をピクノメーター（比重瓶）等で正確に測定すればよい。

化学便覧等にも、濃度 c (w/w%) と密度 ρ (g cm⁻³) の表が掲載されている。

表 6.23 エタノール/水の密度 ρ (25°C)

質量%	$\rho / \text{g cm}^{-3}$	質量%	$\rho / \text{g cm}^{-3}$	質量%	$\rho / \text{g cm}^{-3}$	質量%	$\rho / \text{g cm}^{-3}$	質量%	$\rho / \text{g cm}^{-3}$	質量%	$\rho / \text{g cm}^{-3}$
1	0.9952	18	0.9692	36	0.9395	54	0.9008	72	0.8586	90	0.8136
2	0.9934	20	0.9664	38	0.9356	56	0.8962	74	0.8538	92	0.8082
4	0.9898	22	0.9635	40	0.9315	58	0.8916	76	0.8489	94	0.8027
6	0.9866	24	0.9605	42	0.9273	60	0.8870	78	0.8440	96	0.7971
8	0.9835	26	0.9574	44	0.9230	62	0.8823	80	0.8391	98	0.7912
10	0.9804	28	0.9541	46	0.9187	64	0.8776	82	0.8342		
12	0.9775	30	0.9507	48	0.9143	66	0.8729	84	0.8291		
14	0.9747	32	0.9471	50	0.9099	68	0.8682	86	0.8241		
16	0.9720	34	0.9434	52	0.9053	70	0.8634	88	0.8189		

[“International Critical Table, vol. III”, McGraw-Hill (1928), p.116]

化学便覧データ

25°C NaCl水溶液

c (w/w%) は 1–26 w/w% の範囲

$$\rho/\text{g cm}^{-3} = \alpha c^4 + \beta c^3 + \gamma c^2 + \delta c + \epsilon$$

$$\frac{d\rho}{dc} = 4\alpha c^3 + 3\beta c^2 + 2\gamma c + \delta$$

$$\alpha = 0.0, \quad \beta = 0.339931 \times 10^{-6}, \quad \gamma = 1.39329 \times 10^{-5}$$

$$\delta = 0.699864 \times 10^{-2}, \quad \epsilon = 0.997062$$

14点測定

化学便覧データ

2成分の溶液を考え、成分1を溶媒に、成分2を溶質にする。

溶液内の成分1, 2の物質量(mol)を n_1, n_2 とし、それぞれのモル質量(g mol^{-1}) (分子量) を M_1, M_2 とする。

成分2の濃度は質量パーセント濃度 c_2 (w/w%)で与えられており、 c_2 の関数として溶液の密度 $\rho(c_2)$ が測定されたとしよう。

$$c_2 = \frac{100n_2M_2}{n_1M_1 + n_2M_2}$$

この時、成分1および2の部分モル体積はどのように求めたらいいのであろうか？

$$c_2 = \frac{100n_2M_2}{n_1M_1 + n_2M_2}, \quad c_1 = \frac{100n_1M_1}{n_1M_1 + n_2M_2}, \quad c_1 + c_2 = 100$$

$$\rho(c_2)V = n_1M_1 + n_2M_2, \quad V = \frac{n_1M_1 + n_2M_2}{\rho(c_2)}$$

$$\bar{V}_1 = \left(\frac{\partial V}{\partial n_1} \right)_{n_2} = \frac{M_1}{\rho} - \frac{n_1M_1 + n_2M_2}{\rho^2} \left[\frac{\partial \rho(c_2)}{\partial n_1} \right]_{n_2}$$

$$\left[\frac{\partial \rho(c_2)}{\partial n_1} \right]_{n_2} = \left[\frac{d\rho(c_2)}{dc_2} \right] \left(\frac{\partial c_2}{\partial n_1} \right)_{n_2} = \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{-100n_2M_2}{(n_1M_1 + n_2M_2)^2} M_1$$

$$= \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{-c_2M_1}{n_1M_1 + n_2M_2}$$

$$\bar{V}_1 = \frac{M_1}{\rho} - \frac{n_1M_1 + n_2M_2}{\rho^2} \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{-c_2M_1}{n_1M_1 + n_2M_2}$$

$$= \frac{M_1}{\rho(c_2)} \left[1 + \frac{c_2}{\rho(c_2)} \frac{d\rho(c_2)}{dc_2} \right]$$

$$\begin{aligned}
\bar{V}_2 &= \left(\frac{\partial V}{\partial n_2} \right)_{n_1} = \frac{M_2}{\rho} - \frac{n_1 M_1 + n_2 M_2}{\rho^2} \left[\frac{\partial \rho(c_2)}{\partial n_2} \right]_{n_1} \\
\left[\frac{\partial \rho(c_2)}{\partial n_2} \right]_{n_1} &= \left[\frac{d\rho(c_2)}{dc_2} \right] \left(\frac{\partial c_2}{\partial n_2} \right)_{n_1} = \left[\frac{d\rho(c_2)}{dc_2} \right] \left[\frac{100M_2}{n_1 M_1 + n_2 M_2} - \frac{100n_2 M_2}{(n_1 M_1 + n_2 M_2)^2} M_2 \right] \\
&= \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{100M_2 n_1 M_1 + 100M_2 n_2 M_2 - 100n_2 M_2^2}{(n_1 M_1 + n_2 M_2)^2} \\
&= \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{100M_2 n_1 M_1}{(n_1 M_1 + n_2 M_2)^2} \\
\bar{V}_2 &= \frac{M_2}{\rho} - \frac{n_1 M_1 + n_2 M_2}{\rho^2} \left[\frac{d\rho(c_2)}{dc_2} \right] \frac{100M_2 n_1 M_1}{(n_1 M_1 + n_2 M_2)^2} \\
&= \frac{M_2}{\rho(c_2)} \left[1 - \frac{c_1}{\rho(c_2)} \frac{d\rho(c_2)}{dc_2} \right] \\
&= \frac{M_2}{\rho(c_2)} \left[1 + \frac{c_2 - 100}{\rho(c_2)} \frac{d\rho(c_2)}{dc_2} \right]
\end{aligned}$$

$$\begin{aligned}
n_1 \bar{V}_1 + n_2 \bar{V}_2 &= \frac{n_1 M_1}{\rho(c_2)} \left[1 + \frac{c_2}{\rho(c_2)} \frac{d\rho(c_2)}{dc_2} \right] \\
&+ \frac{n_2 M_2}{\rho(c_2)} \left[1 + \frac{c_2 - 100}{\rho(c_2)} \frac{d\rho(c_2)}{dc_2} \right] \\
&= \frac{n_1 M_1 + n_2 M_2}{\rho(c_2)} + \frac{1}{\rho^2} \frac{d\rho}{dc_2} (n_1 M_1 c_2 - n_2 M_2 c_1) \\
&= \frac{n_1 M_1 + n_2 M_2}{\rho(c_2)} + \frac{1}{\rho^2} \frac{d\rho}{dc_2} 100 \frac{n_1 M_1 n_2 M_2 - n_2 M_2 n_1 M_1}{n_1 M_1 + n_2 M_2} \\
&= \frac{n_1 M_1 + n_2 M_2}{\rho(c_2)} = \frac{n_1 M_1 + n_2 M_2}{(n_1 M_1 + n_2 M_2)/V} = V
\end{aligned}$$

$$V = n_1 \bar{V}_1 + n_2 \bar{V}_2$$

ある濃度の時の成分 1, 2 の物質質量と部分モル体積がわかれば溶液の体積が求められる。

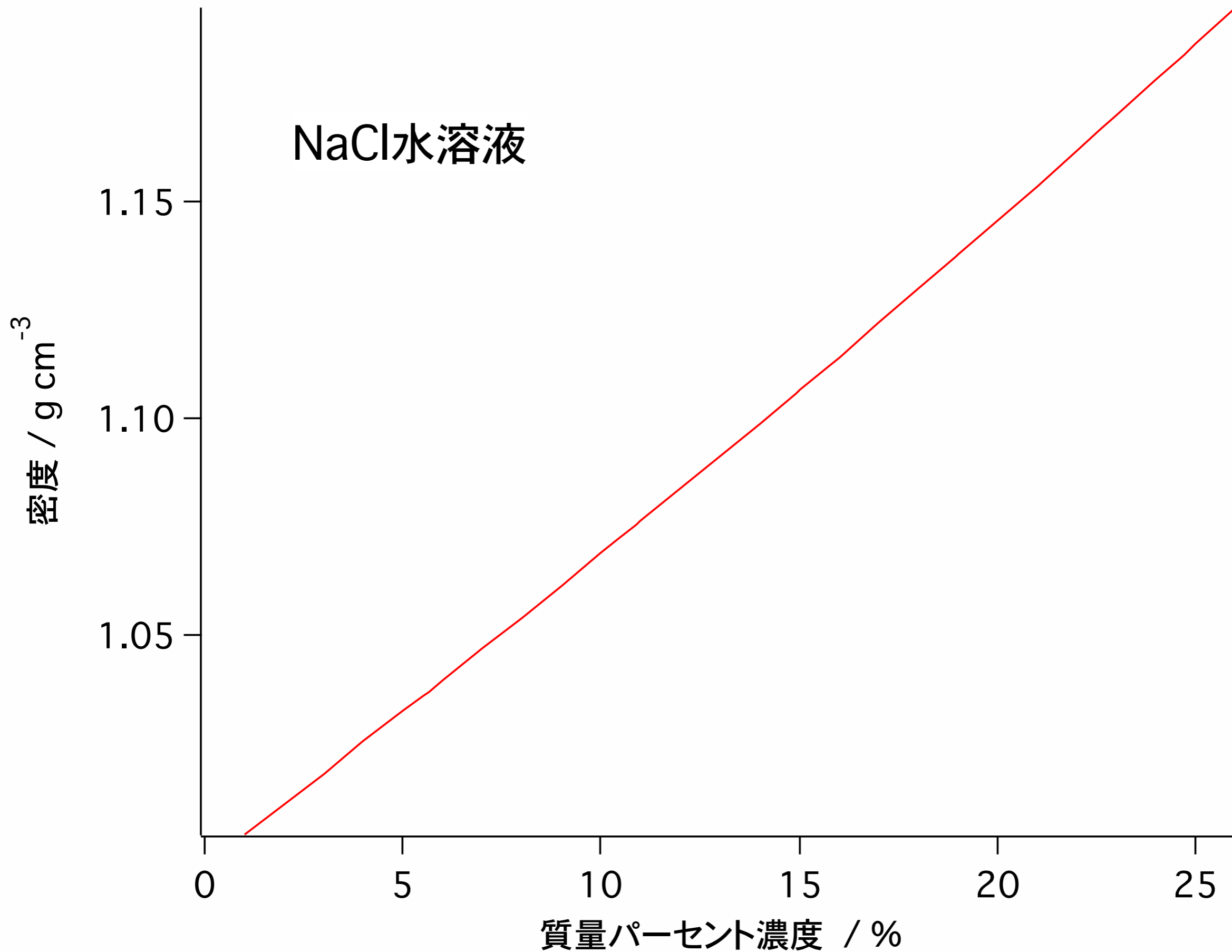
NaCl水溶液数値データ

water-NaCl	M_Na=22.990	M_Cl=35.45	M_H=1.008	M_O=15.999	25°C	水密度 =0.997047 g cm ⁻³	NaCl密度(0°C) =2.168 g cm ⁻³												
c w/w%	$\rho / \text{g cm}^{-3}$	$d\rho / dc$	bar_V_1	bar_V_2	溶液 1000 gは => 何cm ³	NaCl g / 溶液 1000 g	NaCl / mol	NaCl / mol dm ⁻³	溶液1000 cm ³ => 何g?	NaCl g / dm ³	NaCl mol	溶液1000cm ³ に水 何グラ ム?	水 mol	n_1 bar_V_1+n_2 bar_V_2	純水体积cm ³	質量モル濃度 mol kg ⁻¹	NaCl体積 cm ³	純水+NaCl体 積	
1	1.004074913	0.007027526	18.06774456	17.87400015	995.9416247	10	0.171115674	0.171812956	1004.074913	10.04074913	0.171812956	994.0341637	55.17813842	1000.015495	996.9782404	0.172844115	4.631341849	1001.609582	
2	1.011117731	0.007058451	18.06595118	18.25691798	989.0045138	20	0.342231348	0.346036184	1011.117731	20.22235462	0.346036184	990.8953764	55.00390655	1000.015444	993.8301569	0.349215662	9.327654345	1003.157811	
3	1.018192494	0.007091416	18.06308111	18.62053327	982.1325591	30	0.513347023	0.522686085	1018.192494	30.54577483	0.522686085	987.6467194	54.82357588	1000.015391	990.5718782	0.529223735	14.08937953	1004.661258	
4	1.025301242	0.00712642	18.05922448	18.96582004	975.3231139	40	0.684462697	0.701780453	1025.301242	41.01204968	0.701780453	984.2891923	54.6372019	1000.015336	987.2044069	0.712981976	18.91699708	1006.121404	
5	1.032446014	0.007163464	18.05446546	19.29370746	968.573646	50	0.855578371	0.883338479	1032.446014	51.62230069	0.883338479	980.8237132	54.44483559	1000.015278	983.7286639	0.900608812	23.81102431	1007.539688	
5.52	1.036176209	0.007183533	18.05166043	19.45762863	965.0868175	55.2	0.944558522	0.978729068	1036.176209	57.19692674	0.978729068	978.9792823	54.34245253	1000.015247	981.8787703	0.999744413	26.38234628	1008.261117	
5.64	1.037038515	0.007188242	18.0509826	19.49483535	964.2843397	56.4	0.965092402	1.000837992	1037.038515	58.48897226	1.000837992	978.549543	54.318598	1000.015239	981.4477583	1.022777027	26.97830824	1008.426066	
6	1.039628849	0.007202547	18.04888257	19.60508206	961.8817335	60	1.026694045	1.067380749	1039.628849	62.37773097	1.067380749	977.2511185	54.24652337	1000.015217	980.1454882	1.092227708	28.77201613	1008.917504	
7	1.046851788	0.00724367	18.04254895	19.90078986	955.2450605	70	1.197809719	1.253929247	1046.851788	73.27962519	1.253929247	973.5721632	54.04230715	1000.015155	976.4556367	1.28796744	33.80056512	1010.256202	
8	1.05411687	0.007286833	18.03553262	20.18163832	948.6614134	80	1.368925394	1.443007352	1054.11687	84.32934962	1.443007352	969.7875207	53.83222429	1000.01509	972.659785	1.487962384	38.89730149	1011.557086	
9	1.061426135	0.007332035	18.02789672	20.44839819	942.1286771	90	1.540041068	1.634639838	1061.426135	95.52835211	1.634639838	965.8977825	53.61630766	1000.015023	968.7585264	1.692352822	44.06289304	1012.821419	
10	1.068781621	0.007379277	18.01969971	20.7018052	935.6448318	100	1.711156742	1.828852876	1068.781621	106.8781621	1.828852876	961.9034589	53.39458556	1000.014954	964.7523727	1.901285269	49.29804525	1014.050418	
10.47	1.072255247	0.007402186	18.01566883	20.81649473	932.6137621	104.7	1.791581109	1.921032245	1072.255247	112.2651244	1.921032245	959.9901228	53.28837762	1000.014921	962.8333697	2.001095844	51.78280645	1014.616176	
10.87	1.075220081	0.007422037	18.01215407	20.9119548	930.0421541	108.7	1.860027379	1.999938788	1075.220081	116.8764228	1.999938788	958.3436579	53.19698351	1000.014893	961.1820285	2.086870165	53.9097891	1015.091818	
11	1.076185369	0.007428559	18.01099567	20.9425617	929.2079494	110	1.882272416	2.025674035	1076.185369	118.3803906	2.025674035	957.8049785	53.16708179	1000.014883	960.6417536	2.114912827	54.6035012	1015.245255	
12	1.083639418	0.00747988	18.0018344	21.17133818	922.8161906	120	2.05338809	2.225132276	1083.639418	130.0367302	2.225132276	953.6026882	52.93381561	1000.01481	956.4270171	2.333395557	59.98004161	1016.407059	
13	1.091145809	0.00753324	17.99226168	21.38877465	916.4678013	130	2.224503765	2.427257959	1091.145809	141.8489551	2.427257959	949.2968534	52.69480174	1000.014736	952.1084296	2.556900879	65.42848483	1017.536914	
14	1.098706579	0.007588641	17.98231945	21.59548202	910.1611104	140	2.395619439	2.632082838	1098.706579	153.8189211	2.632082838	944.887658	52.4500504	1000.014659	947.6861753	2.785603999	70.94968684	1018.635862	
14.92	1.10571227	0.00764141	17.97287918	21.77667853	904.3944135	149.2	2.553045859	2.822934132	1105.71227	164.9722707	2.822934132	940.7399994	52.21981679	1000.014587	943.5262324	3.00075912	76.0942208	1019.620453	
15	1.10632377	0.00764608	17.97204595	21.79204333	903.8945266	150	2.566735113	2.839640066	1106.32377	165.9485654	2.839640066	940.3752042	52.19956726	1000.014581	943.1603567	3.019688368	76.54454126	1019.704898	
15.76	1.112151823	0.007691099	17.96403804	21.93498752	899.1578121	157.6	2.696783025	2.999232158	1112.151823	175.2751273	2.999232158	936.8766958	52.00536751	1000.01452	939.6514866	3.201309384	80.84646094	1020.497948	
16	1.11399942	0.00770556	17.96147592	21.97901494	897.6665358	160	2.737850787	3.049964188	1113.99942	178.2399072	3.049964188	935.7595126	51.94335346	1000.014501	938.5309946	3.259346175	82.21397932	1020.744974	
17	1.121735569	0.007767079	17.95064072	22.15692765	891.4756985	170	2.908966461	3.263091149	1121.735569	190.6950467	3.263091149	931.0405224	51.68140563	1000.014419	933.7980279	3.504778869	87.9589699	1021.756998	
18	1.129534257	0.007830637	17.93956854	22.32628771	885.3206475	180	3.080082136	3.479058287	1129.534257	203.3161663	3.479058287	926.2180909	51.41371584	1000.014335	928.9613137	3.756197726	93.78051951	1022.741833	
18.95	1.137002795	0.007892907	17.92885335	22.47969784	879.5053137	189.5	3.242642026	3.686893047	1137.002795	215.4620297	3.686893047	921.5407654	51.15408079	1000.014254	924.2701351	4.000792136	99.38285501	1023.65299	
19	1.137397524	0.007896235	17.92828447	22.48757789	879.2000855	190	3.25119781	3.697904338	1137.397524	216.1055295	3.697904338	921.2919941	51.14027167	1000.01425	924.0206271	4.013824456	99.67967227	1023.700299	
20	1.145327408	0.007963873	17.9168107	22.64125833	873.1127824	200	3.422313484	3.919669432	1145.327408	229.0654816	3.919669432	916.2619264	50.86105614	1000.014163	918.9756615	4.277891855	105.65751	1024.633171	
20.36	1.148198867	0.007988722	17.91263753	22.69480552	870.9292689	203.6	3.483915127	4.000227402	1148.198867	233.7732894	4.000227402	914.4255779	50.75912172	1000.014132	917.1338742	4.374579516	107.829008	1024.962882	
21	1.15332595	0.008033551	17.90516663	22.78776751	867.0575739	210	3.593429158	4.144395097	1153.32595	242.1984495	4.144395097	911.1275004	50.57604776	1000.014075	913.8260287	4.548644504	111.715152	1025.541181	
22	1.161395189	0.008105267	17.89336899	22.92752302	861.0333585	220	3.764544832	4.372124257	1161.395189	255.5069416	4.372124257	905.8882473	50.2852205	1000.013985	908.5712583	4.826339529	117.8537553	1026.425014	
22.61	1.166353012	0.008150016	17.88610317	23.00962814	857.3733594	226.1	3.868925394	4.512532785	1166.353012	263.712416	4.512532785	902.6405959	50.10494565	1000.013929	905.3139881	4.999257518	121.6385683	1026.952556	
23	1.169537165	0.008179024	17.88143196	23.06092241	855.0390961	230	3.935660507	4.60290123	1169.537165	268.9935479	4.60290123	900.5436167	49.98854381	1000.013893	903.2107982	5.111247411	124.0745147	1027.285313	

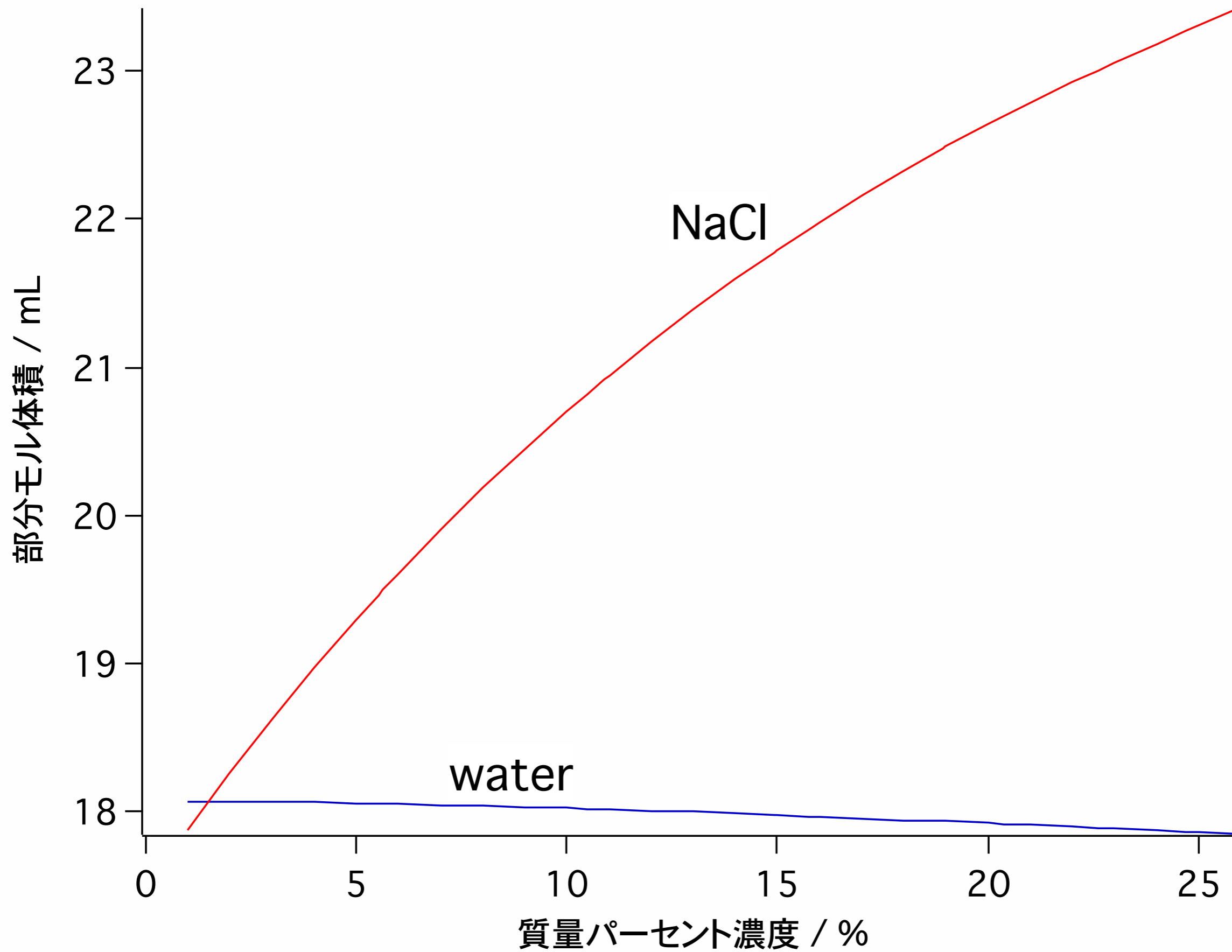
数値では見にくいのでグラフにしよう

NaCl水溶液：密度

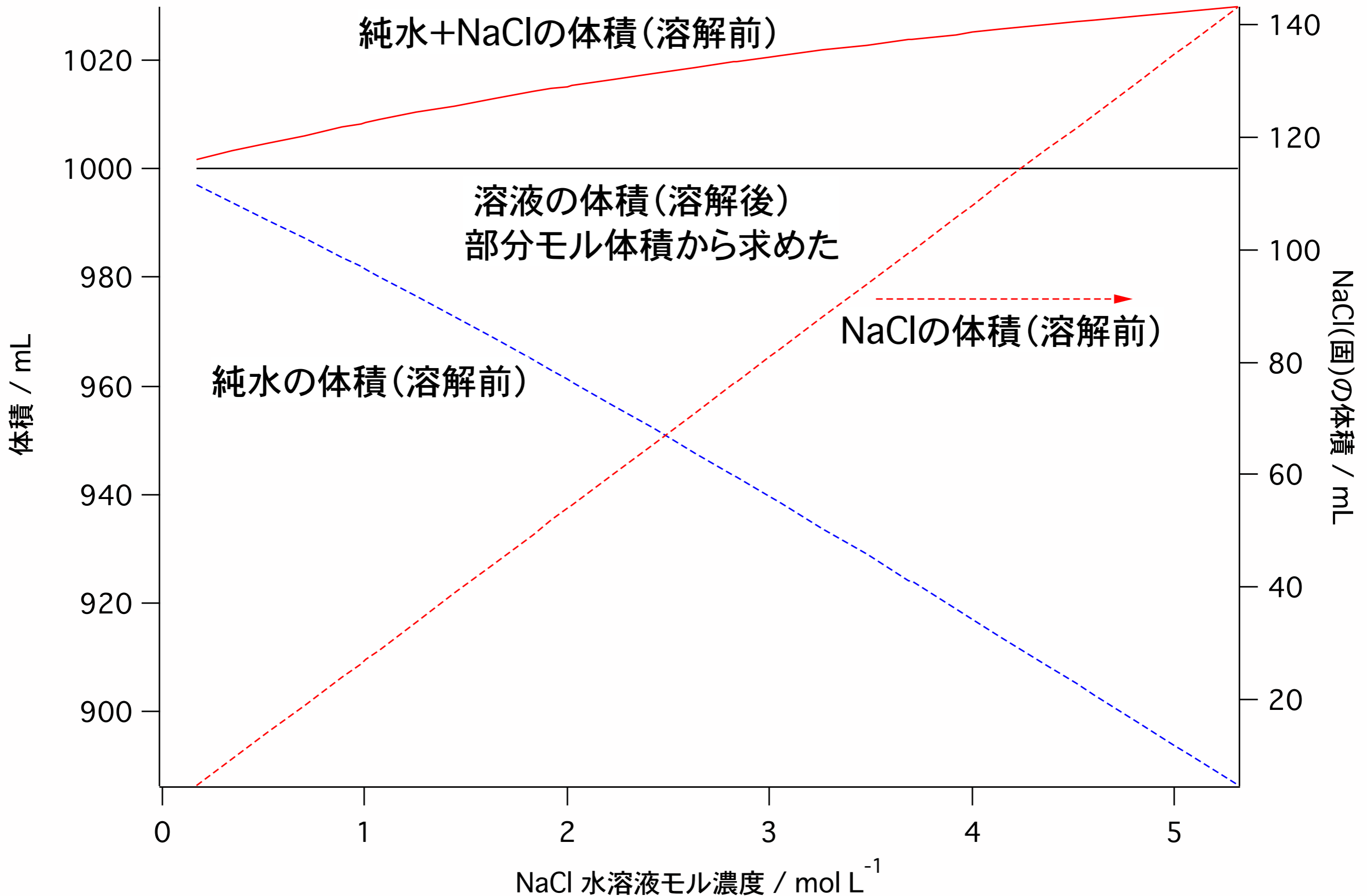
NaCl水溶液



NaCl水溶液：部分モル体積



NaCl水溶液：溶解による体積変化



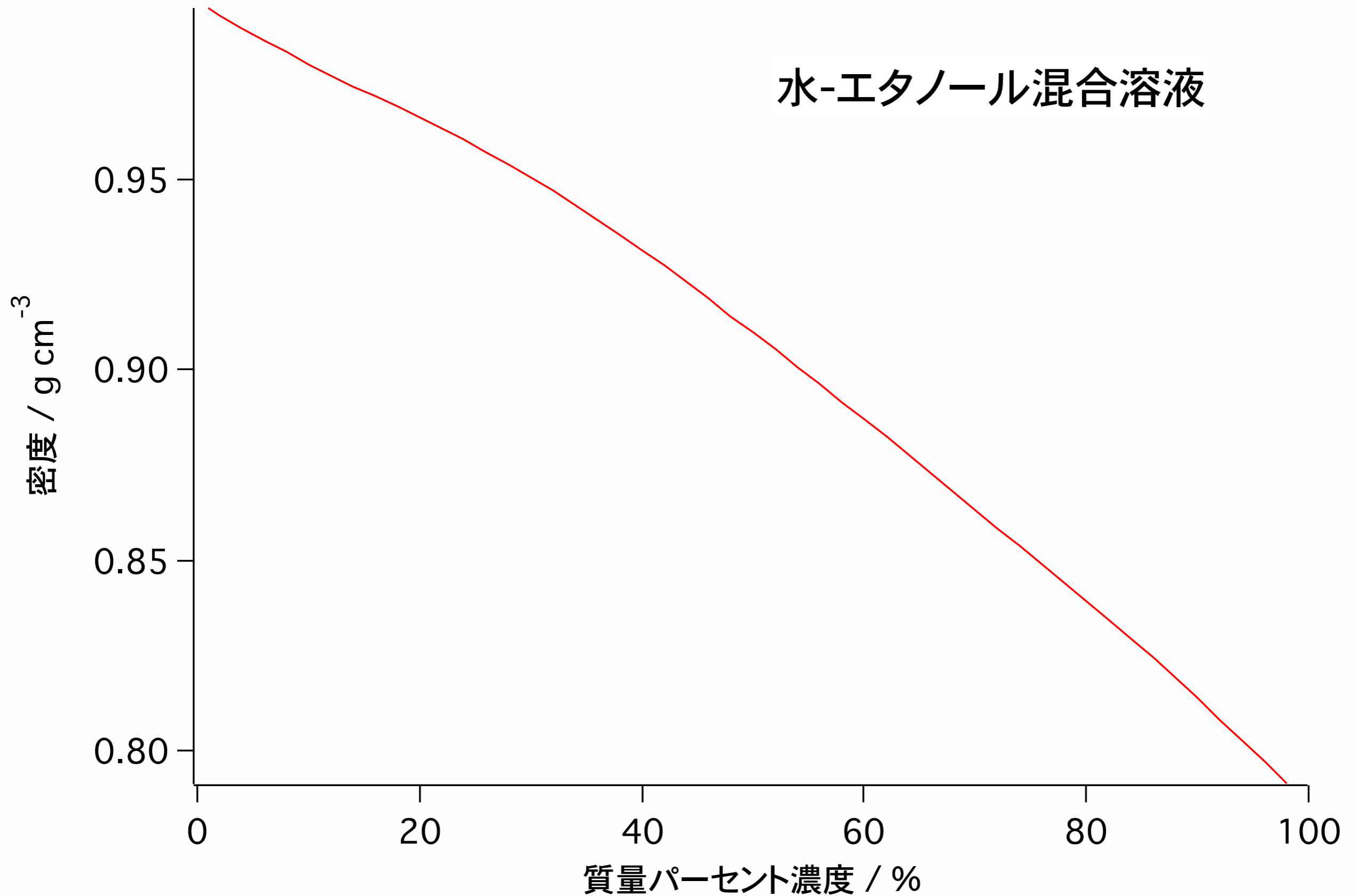
NaCl(固体) は Na^+ と Cl^- に電離する。

それぞれのイオンは水分子をイオンの近くに引きつける（水和する）ため、引力的な相互作用が働き、体積は減少する。

水-エタノール混合溶液数値データ

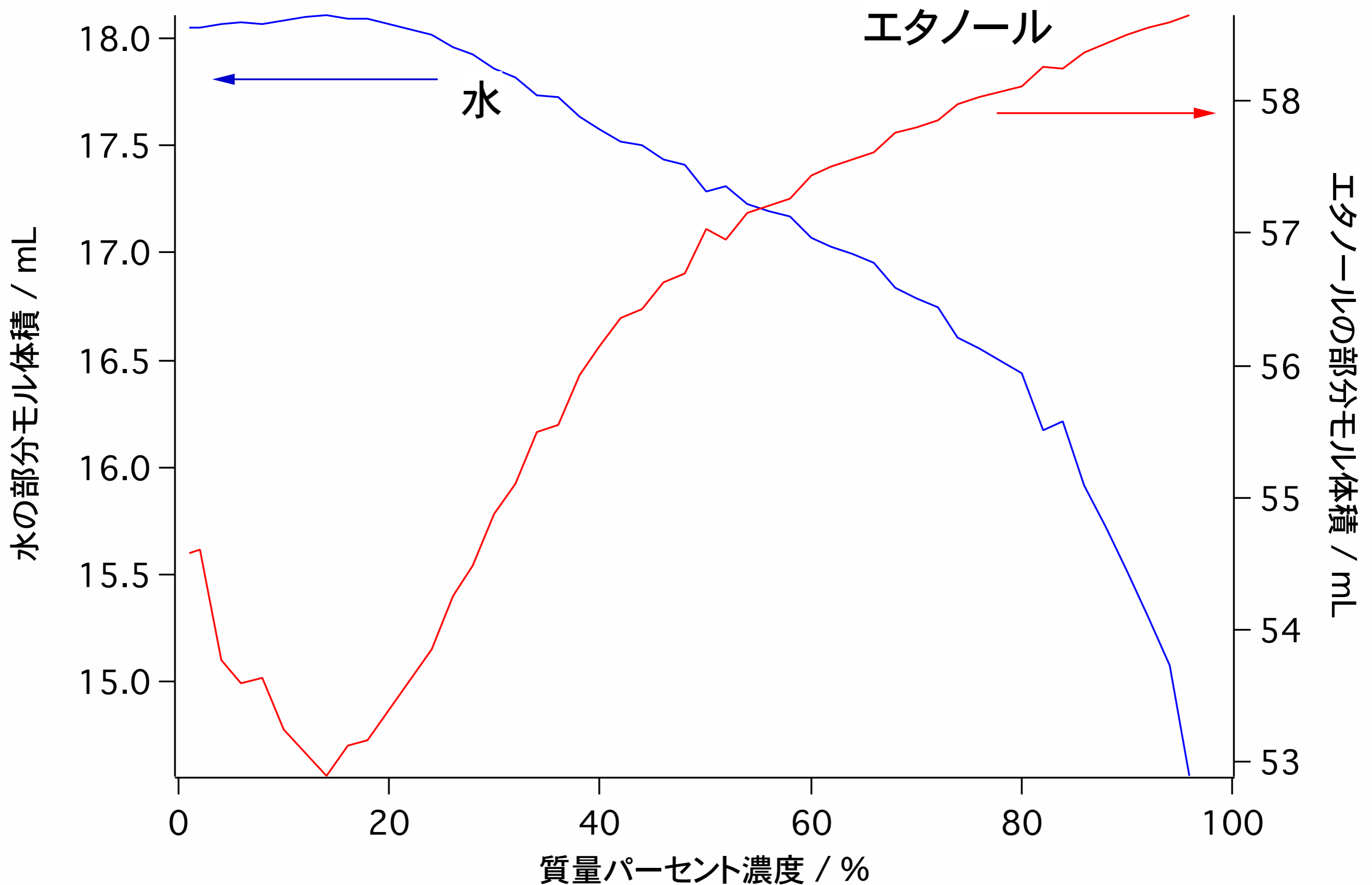
water ethanol	M.EtOH=46.06 844 g mol ⁻¹	M.H ₂ O=18.015 28 g mol ⁻¹			ρ 98%EtOH =0.7912 g cm ⁻³																
c w/w%	ρ / g cm ⁻³	d ρ / dc	bar_V_1	bar_V_2	溶液 1000 gは => 何cm ³	EtOH g / 溶 液 1000 g	EtOH / mol dm ⁻³	EtOH / mol dm ⁻³	溶液1000 cm ³ => 何g?	EtOH g / dm ³	EtOH mol	溶液1000cm ³ に水 何グラ ム?	水 mol	n_1 bar_V_1+n_2 bar_V_2	純水体积 c m ³	質量モル濃度 mol kg ⁻¹	純EtOH 体積	純水+純 EtOH			
1	0.9952	-0.0018	18.05410343	54.57941234	1004.823151	10	0.217068344	0.216026416	995.2	9.952	0.216026416	985.248	54.68957463	999.1618315	988.1660544	0.219260954	12.57836198	1000.744416			
2	0.9934	-0.0018	18.05392539	54.60932543	1006.643849	20	0.434136689	0.431271387	993.4	19.868	0.431271387	973.532	54.0392378	999.1718067	976.4153545	0.442996621	25.11122346	1001.526578			
4	0.9898	-0.0016	18.06790549	53.76588454	1010.305112	40	0.868273378	0.859416989	989.8	39.592	0.859416989	950.208	52.74455906	999.1910227	953.0222748	0.904451435	50.04044489	1003.06272			
6	0.9866	-0.00155	18.07249784	53.58988082	1013.581999	60	1.302410066	1.284957772	986.6	59.196	1.284957772	927.404	51.47874471	999.2102366	930.1507351	1.385542624	74.8179798	1004.968733			
8	0.9835	-0.00155	18.07123072	53.63295627	1016.776817	80	1.736546755	1.707893734	983.5	78.68	1.707893734	904.82	50.22514221	999.2295229	907.499847	1.887550821	99.44388271	1006.94373			
10	0.9804	-0.00145	18.08831307	53.24414626	1019.99184	100	2.170683444	2.128138049	980.4	98.04	2.128138049	882.36	48.97842276	999.2479379	884.9733262	2.411870493	123.9130435	1008.88637			
12	0.9775	-0.0014	18.0978408	53.06876005	1023.017903	120	2.604820133	2.54621168	977.5	117.3	2.54621168	860.2	47.74835584	999.2664393	862.7476939	2.960022878	148.255814	1011.003508			
14	0.9747	-0.00135	18.10913053	52.89403561	1025.956705	140	3.038956822	2.962071214	974.7	136.458	2.962071214	838.242	46.52950162	999.2847187	840.7246599	3.533670723	172.4696663	1013.194326			
16	0.972	-0.0014	18.09175431	53.12978652	1028.806584	160	3.47309351	3.375846892	972	155.52	3.375846892	816.48	45.32152706	999.303957	818.8982064	4.134635131	196.562184	1015.46039			
18	0.9692	-0.0014	18.08913036	53.1625712	1031.778787	180	3.907230199	3.786887509	969.2	174.456	3.786887509	794.744	44.11499571	999.322585	797.0978299	4.764914877	220.4954499	1017.59328			
20	0.9664	-0.00145	18.06689879	53.39215464	1034.768212	200	4.341366888	4.195496961	966.4	193.28	4.195496961	773.12	42.91468131	999.3418266	775.4097851	5.42670861	244.2871587	1019.696944			
22	0.9635	-0.0015	18.04203183	53.61975674	1037.882719	220	4.775503577	4.601197696	963.5	211.97	4.601197696	751.53	41.7162542	999.3610872	753.755841	6.122440483	267.9095046	1021.665346			
24	0.9605	-0.00155	18.0144332	53.84537091	1041.124414	240	5.209640266	5.003859475	960.5	230.52	5.003859475	729.98	40.52004743	999.3803572	732.1420154	6.854789823	291.3549039	1023.496919			
26	0.9574	-0.00165	17.95847145	54.25494237	1044.495509	260	5.643776954	5.403352056	957.4	248.924	5.403352056	708.476	39.32639404	999.4004791	710.574326	7.626725614	314.6157735	1025.190099			
28	0.9541	-0.0017	17.92472584	54.47907795	1048.108165	280	6.077913643	5.798937407	954.1	267.148	5.798937407	686.952	38.13163048	999.4197853	688.9865774	8.441546727	337.6491405	1026.635718			
30	0.9507	-0.0018	17.85799459	54.87963716	1051.856527	300	6.512050332	6.191006251	950.7	285.21	6.191006251	665.49	36.94030845	999.4400051	667.4610124	9.302929046	360.4777553	1027.938768			
32	0.9471	-0.00185	17.81742289	55.10247145	1055.854714	320	6.946187021	6.578733727	947.1	303.072	6.578733727	644.028	35.74898642	999.4592961	645.9354474	10.21498091	383.0535895	1028.989037			
34	0.9434	-0.00195	17.73903017	55.49413142	1059.99576	340	7.38032371	6.962597388	943.4	320.756	6.962597388	622.644	34.56199404	999.4795494	624.4881134	11.18230865	405.4044489	1029.892562			
36	0.9395	-0.00195	17.72754579	55.54871276	1064.395955	360	7.814460398	7.341685544	939.5	338.22	7.341685544	601.28	33.37611183	999.4977324	603.0608387	12.21009437	427.4772497	1030.538088			
38	0.9356	-0.00205	17.63711265	55.92857581	1068.832835	380	8.248597087	7.717387435	935.6	355.528	7.717387435	580.072	32.19888894	999.5179199	581.7900259	13.30418885	449.3528817	1031.142908			
40	0.9315	-0.0021	17.58111819	56.14591498	1073.537305	400	8.682733776	8.087966512	931.5	372.6	8.087966512	558.9	31.02366436	999.5369899	560.5553199	14.47122296	470.9302326	1031.485552			
42	0.9273	-0.00215	17.52094166	56.36100471	1078.399655	420	9.116870465	8.454073982	927.3	389.466	8.454073982	537.834	29.85432366	999.5559667	539.4269277	15.71874218	492.2472194	1031.674147			
44	0.923	-0.00215	17.50286702	56.42231958	1083.423619	440	9.551007154	8.815579603	923	406.12	8.815579603	516.88	28.69119991	999.5737065	518.4108673	17.05536992	513.2962588	1031.707126			
46	0.9187	-0.0022	17.43463396	56.62968929	1088.494612	460	9.985143843	9.173351648	918.7	422.602	9.173351648	496.098	27.53762362	999.5924413	497.5673163	18.49100712	534.127907	1031.695223			
48	0.9143	-0.0022	17.4133572	56.69108989	1093.73291	480	10.41928053	9.52634819	914.3	438.864	9.52634819	475.436	26.39070833	999.6098924	476.8441207	20.03707794	554.6814965	1031.525617			
50	0.9099	-0.0023	17.28214609	57.02925119	1099.021871	500	10.85341722	9.875524329	909.9	454.95	9.875524329	454.95	25.25356253	999.6295145	456.2974464	21.70683444	575.012639	1031.310085			
52	0.9053	-0.00225	17.31326558	56.95823303	1104.606208	520	11.28755391	10.21862255	905.3	470.756	10.21862255	434.544	24.12085741	999.6454948	435.831009	23.51573731	594.9898888	1030.820898			
54	0.9008	-0.0023	17.22713814	57.14834754	1110.124334	540	11.7216906	10.55889889	900.8	486.432	10.55889889	414.368	23.00091922	999.6636363	415.5952528	25.48193608	614.8028311	1030.398084			
56	0.8962	-0.0023	17.19825646	57.20882011	1115.822361	560	12.15582729	10.89405241	896.2	501.872	10.89405241	394.328	21.88853018	999.6804404	395.4958994	27.6268802	634.3174924	1029.813392			
58	0.8916	-0.0023	17.1678601	57.26750153	1121.579183	580	12.58996398	11.22521188	891.6	517.128	11.22521188	374.472	20.78635469	999.6970679	375.581091	29.9761047	653.5995956	1029.180687			
60	0.887	-0.00235	17.06727133	57.44143407	1127.395716	600	13.02410066	11.55237729	887	532.2	11.55237729	354.8	19.69439276	999.7146634	355.8508275	32.56025166	672.6491405	1028.499968			
62	0.8823	-0.00235	17.03223581	57.49875667	1133.401337	620	13.45823735	11.87420282	882.3	547.026	11.87420282	335.274	18.61053506	999.73092	336.2669964	35.41641409	691.3877654	1027.654762			
64	0.8776	-0.00235	16.99546871	57.55401552	1139.471285	640	13.89237404	12.19194746	877.6	561.664	12.19194746	315.936	17.53711294	999.7469874	316.8717222	38.58992789	709.8887765	1026.760499			
66	0.8729	-0.00235	16.95692003	57.60713378	1145.606599	660	14.32651073	12.50561122	872.9	576.114	12.50561122	296.786	16.47412641	999.7628625	297.6650048	42.13679627	728.1521739	1025.817179			
68	0.8682	-0.0024	16.83534649	57.75581966	1151.808339	680	14.76064742	12.81519409	868.2	590.376	12.81519409	277.824	15.42157546	999.779605	278.6468441	46.12702319	746.1779575	1024.824802			
70	0.8634	-0.0024	16.7912529	57.80651438	1158.211721	700	15.19478411	13.1191766	863.4	604.38	13.1191766	259.02	14.37779485	999.7950602	259.7871515	50.64928036	763.8776542	1023.664806			
72	0.8586	-0.0024	16.7451182	57.85473575	1164.686699	720	15.6289208	13.4189914	858.6	618.192	13.4189914	240.408	13.34467186	999.8103089	241.1200274	55.81757427	781.3346815	1022.454709			
74	0.8538	-0.00245	16.60552049	57.98254559	1171.234481	740	16.06305749	13.71463848	853.8	631.812	13.71463848	221.988	12.32220648	999.8263032	222.6454721	61.78099033	798.5490394	1021.194512			
76	0.8489	-0.00245	16.55298832	58.02735492	1177.995052	760	16.49719417	14.00446813	848.9	645.164	14.00446813	203.736	11.30906653	999.841089	204.3394143	68.73830906	815.4246714	1019.764086			
78	0.844	-0.00245	16.49811325	58.06929915	1184.834123	780	16.93133086	14.29004325	844	658.32	14.29004325	185.68	10.30680622	999.8556525	186.229937	76.96059483	832.0525784	1018.282515			
80	0.8391	-0.00245	16.44082371	58.10826842	1191.753069	800	17.36546755	14.57136382	839.1	671.28	14.57136382	167.82	9.315425572	999.8699899	168.3170402	86.82733776	848.4327604	1016.749801			
82	0.8342	-0.00255	16.16894311	58.26331032	1198.753297	820	17.79960424	14.84842986	834.2	684.044	14.84842986	150.156	8.334924575	999.8855979	150.6007239	98.88669023	864.5652174	1015.165941			
84	0.8291	-0.0025	16.21136107	58.24510409	1206.127126	840	18.23374093	15.1175946	829.1	696.444	15.1175946	132.656	7.363526962	999.8986658	133.0488934	113.9608808	880.2376138	1013.286507			
86	0.8241	-0.0026	15.91569795	58.37065309	1213.44497	860	18.66787762	15.38419795	824.1	708.726	15.38419795	115.374	6.404230187	999.9134746	115.7157085	133.341983	895.7608696	1011.476578			
88	0.8189	-0.00265	15.72121065	58.44107509	1221.150324																

水-エタノール混合溶液：密度



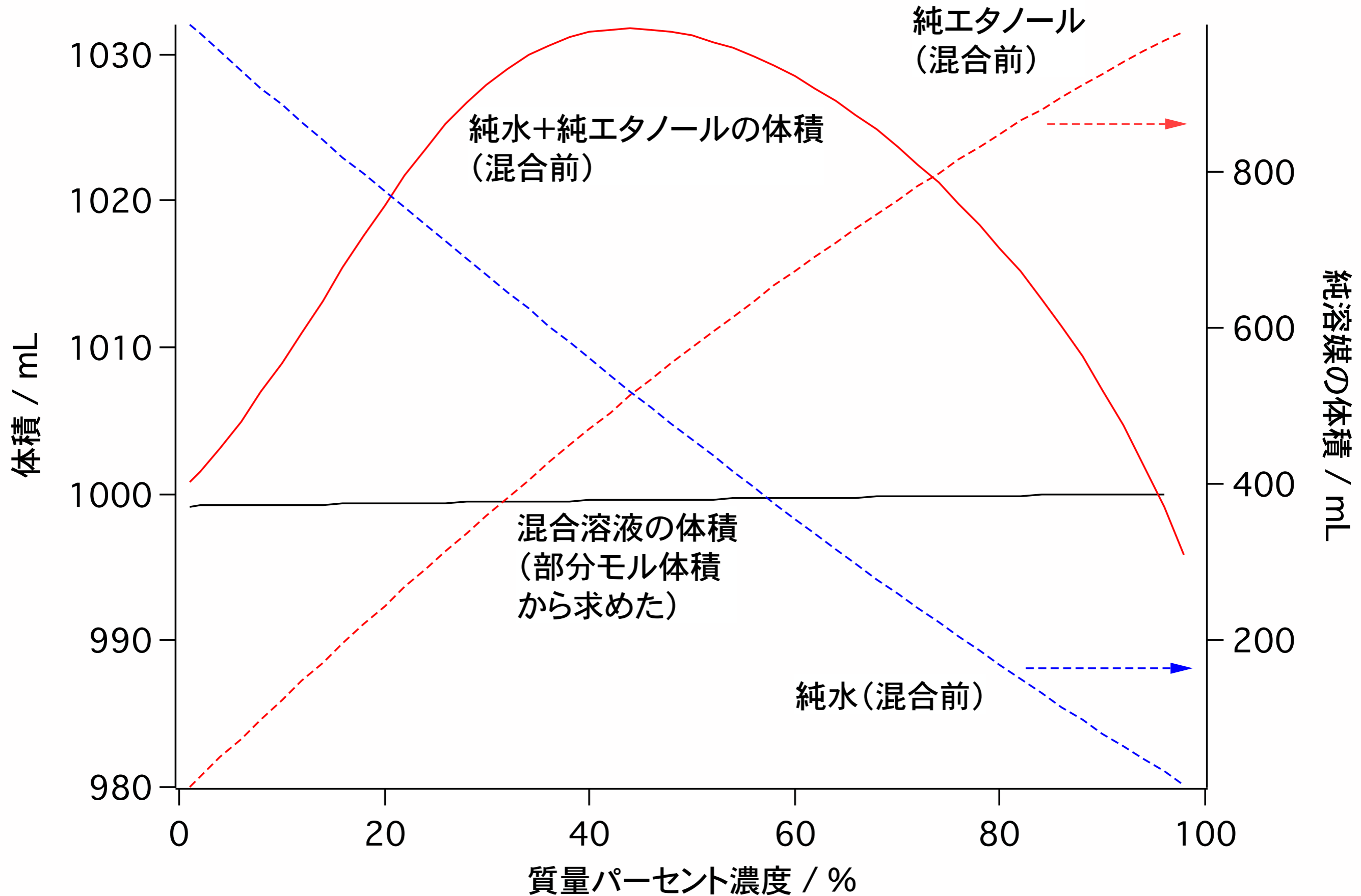
水-エタノール混合溶液

水-エタノール混合溶液：部分モル体積



データが離散的で微分が正確に求められないためグラフがスムーズではない

水-エタノール：混合による体積変化



40 w/w%の濃度で体積減少量は最大となる。

この時、純溶媒の体積はほぼ等しい。

(515 mLの水と515 mLのエタノール合わせて1030 mLが
1000 mLの混合溶媒になる)

お酒を水で割ったら体積が減少した！損したのか？

(笑)

エタノールは直線的な水素結合であるのに対して、
水は全方位的な水素結合をとるのが原因か？