temperatures, the enormously high absolute values of χ with these salts, which may occasionally be more than three times that of *water*, must be considered as very remarkable. In connection with the data given above, we can moreover generally conclude:

1. *The temperature-coefficient b of the specific surface-energy decreases continually in the case of the four halogenides of the same alcali-metal, with increasing atomic weight of the halogen-atom.* This rule holds evidently quite accurately in all the cases here considered.

As to the absolute values of χ of these salts, attention can moreover be drawn to the following general rules:

2. *At the same temperature t, the values* χ_t *for the same halogenide of all alcali-metals, will decrease gradually with increasing atomic weight of the alcali-metal.*

3. *At the same temperature t the values* χ_t *will gradually decrease in the case of the four halogenides of the same alcali-metal, with increasing atomic weight of the halogen-atom.*

These relations however do not possess a simple *additive* character.

Generally speaking, the *Li*-compounds appear to deviate more from those of the other alcali-metals, than these from each other; the *K*-, *Rb*-, and *Cs*-compounds approach each other more, than each of these elements do the corresponding *Na*-compounds, while in the series of the first mentioned three alcalimetals, the compounds of *K* and *Rb* appear to have the nearest analogies to each other. Probably the liquid lithium-salts may possess a higher degree of molecular complexity, than the salts of the other alcali-metals.

Groningen, Augustus 1914. *Laboratory for Inorganic and Physical Chemistry of the University.*

Chemistry. — "*Researches on the Temperature-coefficients of the free Surface-energy of Liquids at Temperatures between* — 80° *and* 1650° *C.* **VIII.** *The Specific Surface-energy of some Salts of the Alcali-metals.*" By Prof. Dr. F. M. JAEGER. (Communicated by Prof. H. HAGA).

§ 1. As a sequel to the data published in the foregoing communication, which related to the *halogenides* of the alcali-metals, the results of the measurements made with a number of salts of the alcali-metals, which belong to some other series, are communicated in the following pages. These measurements include the following objects:

The *Sulphates* of *Lithium*, *Sodium*, *Potassium*, *Rubidium* and *Caesium*; the *Nitrates* of *Lithium*, *Sodium*, *Potassium*, *Rubidium* and *Caesium*; the *Metaborates* of *Lithium*, *Sodium* and *Potassium*; and the *Molybdates*, *Tungstates* and *Metaphosphates* of *Sodium* and *Potassium*.

With the exception of rubidiumsulfate, which evidently contained some potassiumsulfate, all salts were chemically pure; the sulfates, molybdates and tungstates were those commonly used in this laboratory for the calibration of the thermoelements, and just the same was the case with lithiummetaborate. For the method and practice of the measurements etc., we can refer to the foregoing communication.

§ 2.

I.

Lithiumsulphate: Li_2SO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm². :
	in mm. mercury of 0° C.	in Dynes	
860°	6.361	8481	223.8
873.5	6.342	8455	223.1
897	6.303	8403	221.8
923	6.256	8341	220.2
962.5	6.169	8224	217.4
976.8	6.146	8194	216.4
1001.2	6.099	8132	214.8
1038.5	6.027	8035	212.3
1057	5.987	7982	211.0
1074	5.953	7936	209.8
1089.5	5.923	7897	208.8
1112	5.879	7838	207.3
1156.5	5.791	7720	204.2
1167.5	5.766	7687	203.4
1183.5	5.737	7649	202.4
1192.2	5.718	7624	201.8
1214	5.675	7566	200.3

Molecular weight: **109.94.** Radius of the Capillary tube 0.05240 cm. at 16° C.
Depth: 0.1 mm.

The meltingpoint is 852° C.; the salt appears to be stable up to rather high temperatures.

II.

Sodiumsulphate: Na_2SO_4.			
Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
900°	6.285	8379	194.8
945	6.247	8329	189.3
990	6.209	8278	188.2
1032	6.149	8198	186.5
1077	6.088	8116	184.7

Molecular weight: **142.07.** Radius of the Capillary tube: 0.04512 cm. at 16° C.
Depth: 0.1 mm.

The salt melted at 884° C. The molten mass, if brought into water, shows an alkaline reaction, if the temperature of the molten salt has been above 1100° C.

III.

Potassiumsulphate: K_2SO_4.			
Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
1070°.2	4.080	5439	143.7
1103	4.048	5397	142.6
1145	3.989	5318	140.6
1199	3.878	5171	136.7
1247	3.762	5016	132.7
1305.5	3.651	4868	128.8
1347	3.578	4770	126.2
1371.5	3.529	4705	124.6
1400	3.468	4623	122.4
1439.5	3.393	4523	119.8
1462.5	3.344	4458	118.1
1490.4	3.286	4381	116.1
1530.3	3.228	4304	114.1
1586	3.130	4173	110.7
1656	3.020	4026	106.8

Molecular weight: **174.27.** Radius of the Capillary tube: 0.05240 cm. at 19° C.
Depth: 0.1 mm.

The salt melts at 1074° C., and does not dissociate appreciably up to 1550° C.

IV.

Rubidiumsulphate: Rb_2SO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
1086°	3.760	5013	132.5
1112	3.681	4907	129.7
1144.7	3.611	4814	127.3
1195	3.520	4693	124.2
1234.5	3.452	4602	121.8
1289	3.368	4490	118.9
1343.8	3.286	4381	116.0
1396.8	3.223	4297	113.8
1414.6	3.200	4267	113.1
1482	3.138	4183	110.9
1545	3.079	4105	108.9

Molecular weight: **266.97.** Radius of the Capillary tube: 0.0524 cm. at 18° C.
Depht: 0.1 mm.

The salt melts at 1055° C. At about 1400° C. it begins to evaporate somewhat faster, and sublimes against the colder parts of the apparatus. It appears to contain some K_2SO_4; analysis gave: 37,45 % SO_4 and 62,56 % Rb, instead of 36 % SO_4 and 64 % Rb.

V.

Caesiumsulphate: Cs_2SO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
1036°	3.170	4226	111.3
1063	3.080	4106	108.2
1105	2.988	3984	105.0
1165	2.869	3825	100.8
1221	2.764	3685	97.3
1274.5	2.691	3588	94.7
1331.4	2.607	3476	91.7
1372	2.552	3402	89.8
1423	2.482	3309	87.4
1470	2.427	3236	85.5
1530	2.354	3138	83.0

Molecular weight: **361.69.** Radius of the Capillary tube: 0.05223 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at ca. 1015° C. At 1325° C. it begins to evaporate in an appreciable degree; at 1440° C. very rapidly, and at higher temperatures it sublimes in a rather troublesome way.

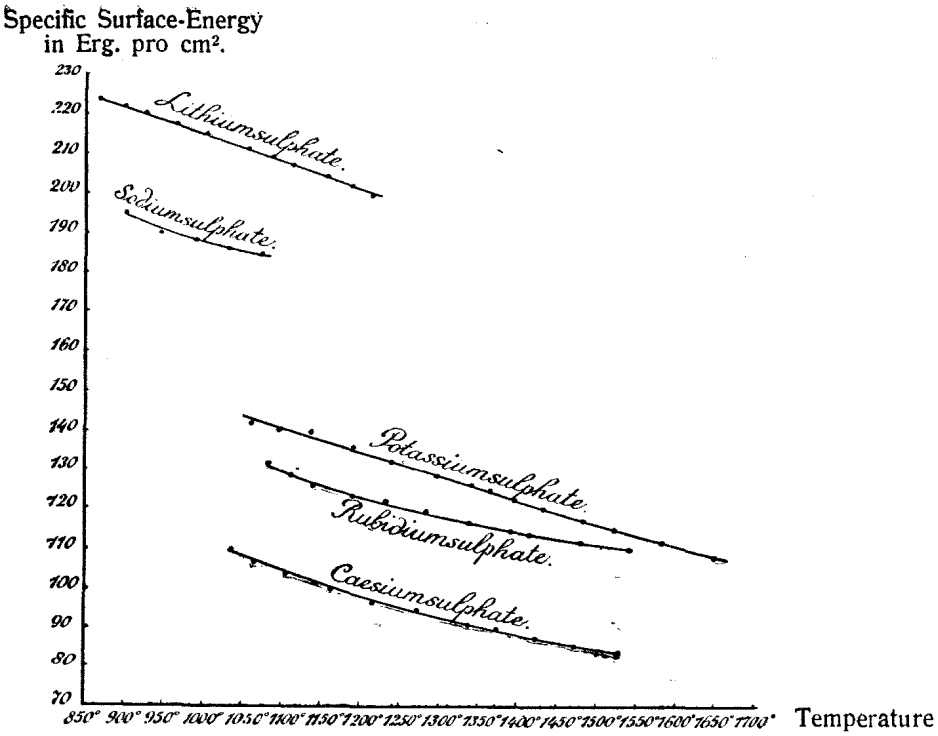

Fig. 1.

VI.

Lithiumnitrate: $LiNO_3$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
358°.5	3.334	4445	111.5
403	3.260	4347	109.1
418.2	3.240	4320	108.4
445.3	3.169	4225	106.0
492.5	3.069	4092	102.3
555.3	2.956	3941	99.0
609.4	2.872	3829	96.2

Molecular weight: **68.95.** Radius of the Capillary tube: 0.05002 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 254° C. to a very thin liquid. The values of χ are evidently *smaller* than in the case of the sodium nitrate. At 600° C. already a decomposition, with oxygen and nitrous vapours setting free, can be stated.

VII.

Sodiumnitrate: $NaNO_3$.			
Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
321.5°	3.580	4773	119.7
355	3.534	4711	118.1
396.5	3.466	4621	115.9
426.5	3.412	4549	114.2
465.7	3.341	4454	111.8
513.1	3.253	4337	108.9
559	3.162	4216	105.9
601.6	3.086	4114	103.4
656.3	2.966	3954	99.4
693	2.889	3852	96.8
738.2	2.793	3723	93.7

Molecular weight: **85.01.** Radius of the Capillary tube: 0 05002 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 312° C. At 700° C. already it distinctly gives off nitrous vapours and oxygen; the solidified mass gives in water a strong alkaline reaction.

VIII.

Potassiumnitrate: KNO_3.			
Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes	
380°	3.300	4400	110.4
436	3.168	4223	106.0
480.1	3.073	4097	102.8
534.3	2.942	3923	98.5
578	2.841	3788	95.2
628	2.735	3646	91.6
675.4	2.623	3497	87.9
721.7	2.506	3341	84.0
771.6	2.391	3188	80.2

Molecular weight: **101.11.** Radius of the Capillary tube 0.05002 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 339° C. At 760° C. already a decomposition, analogous to that observed in the case of the sodiumsalt, can be stated.

IX.

Rubidiumnitrate: $RbNO_3$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
326°.5	3.215	4286	107.5
376	3.110	4146	104.0
428	2.982	3976	99.8
480	2.871	3828	96.1
527	2.763	3684	92.5
578	2.653	3537	88.9
625	2.556	3408	85.6
676.2	2.429	3238	81.4
726.2	2.316	3088	77.7

Molecular weight: **147.46**. Radius of the Capillary tube: 0.05002 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 304° C. At 650° C. it begins to decompose, setting free oxygen and nitrous vapours.

X.

Caesiumnitrate: $CsNO_3$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
425°.5	2.743	3657	91.8
459.7	2.636	3514	88.2
511	2.500	3333	83.7
576.5	2.366	3154	79.2
602	2.277	3036	76.3
686.4	2.162	2882	72.5

Molecular weight: **194.82**. Radius of the Capillary tube: 0.05002 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 414° C.; just as in the case of the solubilities, also in the situation of the meltingpoints of *K*-. *Rb*-, and *Cs*-nitrates an evident irregularity can be stated. At 600° C. already the molten salt begins to decompose.

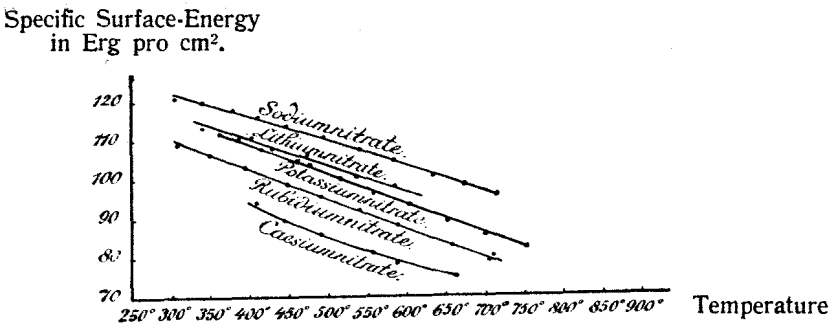

Fig. 2.

XI.

Lithium-Metaborate : $LiBO_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
879.2°	7.442	9922	261.8
922	7.379	9838	259.7
967.5	7.279	9704	256.2
1011.5	7.190	9586	253.1
1054.5	7.108	9476	250.3
1097.3	7.034	9378	247.7
1149.7	6.912	9215	243.6
1198	6.800	9066	239.7
1249	6.638	8850	234.2
1309.3	6.399	8531	225.8
1355	6.252	8335	220.7
1408	6.022	8029	212.7
1457	5.750	7666	203.1
1520	5.445	7260	192.4

Molecular weight: **49.99.** Radius of the Capillary tube: 0.05240 cm. at 19° C.
Depth: 0.1 mm.

The salt melts at 845° C. At 1200° C. it begins to evaporate appreciably; the vapours show alkaline reaction (Li_2O). At 1300° C. the volatilisation of the Li_2O occurs already rather rapidly; the χ-t-curve descends by this dissociation far more rapidly, than in the beginning.

XII.

Sodiummetaborate: $NaBO_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
1015°.6	5.762	7682	193.7
1051.9	5.599	7465	188.3
1096.5	5.378	7170	180.9
1140	5.190	6919	174.7
1192.2	4.933	6577	166.1
1234	4.700	6266	159.7
1276.5	4.476	5967	150.8
1323.3	4.239	5651	142.9
1372	4.006	5341	135.1
1441	3.740	4986	126.2

Molecular weight: **66.0.** Radius of the Capillary tube: 0.05002 cm. at 18° C.
Depth: 0.01 mm.

The salt melts at ca. 965° C. At 1230° C. it begins to evaporate distinctly; at 1350° the evaporation goes on rapidly.

XIII.

Potassiummetaborate: KBO_2.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
992°	3.676	4901	123.5
1036	3.341	4454	112.3
1091	3.062	4083	103.0
1142	2.872	3829	96.6

Molecular weight: **82.1.** Radius of the Capillary tube: 0.05002 cm. at 18° C.
Depth: 0.1—0.3 mm.

The salt melts at about 946° C. The measurements were difficult by the great volatility and high viscosity of the substance. The obtained values cannot be considered therefore as being highly accurate.

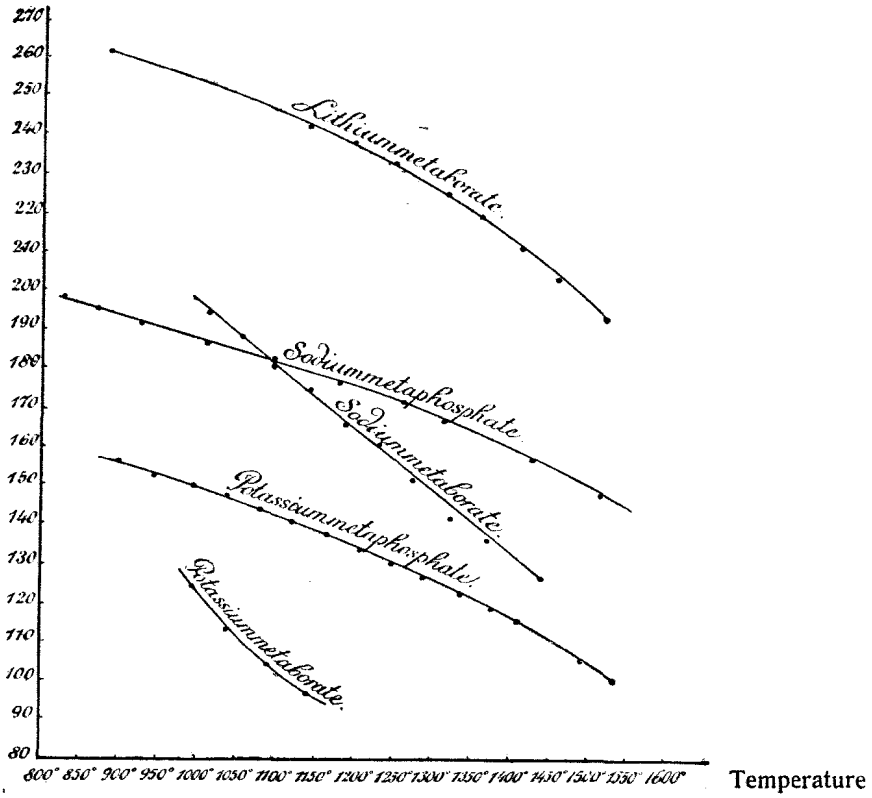

Fig. 3.

XIV.

Sodiummolybdate: Na_2MoO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
698.5°	6.091	8122	214.0
728.5	5.975	7967	210.0
751	5.921	7893	208.1
777	5.828	7770	204.9
818.8	5.757	7675	202.4
858.5	5.657	7542	199.0
903.8	5.552	7401	195.4
948	5.436	7247	191.4
989.5	5.330	7106	187.7
1035	5.224	6966	184.1
1078.5	5.141	6854	181.2
1121.5	5.070	6760	178.8
1171.5	4.998	6654	176.1
1212	4.947	6595	174.6

Molecular weight: **206**. Radius of the Capillary tube; 0.05240 cm. Depth: 0.1 mm.

The salt melts at 687° C. to a colourless liquid.

XV.

Potassium-Molybdate: K_2MoO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
930°.6	4.310	5746	150.5
977	4.218	5626	147.3
1021	4.158	5543	145.2
1105	4.021	5360	140.7
1143	3.960	5280	138.6
1189.3	3.868	5156	135.5
1273	3.714	4950	130.0
1286	3.676	4900	128.8
1356	3.529	4712	123.6
1438	3.364	4483	118.0
1452.8	3.330	4440	116.9
1522.3	3.205	4273	112.5

Molecular weight: **238.2.** Radius of the Capillary tube: 0.05240 cm. at 18° C.
Depth: 0.1 mm.

The salt melts at 919° C.; at 1400° C. it begins to decompose very slowly.

XVI.

Sodiumtungstate: Na_2WoO_4.

Temperature in ° C. (corr. on G. Th.).	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
710°	5.932	7909	203.3
719.5	5.909	7878	202.6
741	5.863	7817	201.0
788	5.778	7703	198.2
834	5.686	7580	195.2
879	5.579	7438	191.5
932	5.517	7355	189.5
985.3	5.364	7151	184.2
1038.5	5.280	7040	181.4
1080.5	5.186	6913	178.3
1133	5.073	6762	174.6
1181.4	5.010	6679	172.4
1231.5	4.880	6506	168.0
1281.8	4.755	6339	163.8
1331.5	4.663	6217	160.6
1390.5	4.494	5991	155.0
1450	4.405	5872	152.0
1516.5	4.265	5686	147.3
1559	4.171	5560	144.0
1595	4.129	5508	142.6

Molecular weight: . Radius of the Capillary tube: 0.05113 cm. at 16° C.
Depth: 0.1 mm.

The colourless, perfectly anhydrous salt melts at 694° C to a very clear, somewhat viscous liquid, which however at higher temperatures soon becomes much thinner.

XVII.

Potassiumtungstate: K_2WO_4.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
925°	4.611	6147	161.0
969	4.410	5879	154.1
1012.5	4.305	5739	150.2
1051.5	4.173	5563	145.9
1097	4.056	5409	141.9
1138.8	3.943	5257	138.0
1183.2	3.832	5109	134.1
1230	3.720	4960	130.3
1284	3.558	4744	124.6
1322.4	3.449	4598	120.9
1366.5	3.379	4505	118.4
1408.5	3.259	4345	114.3
1458.2	3.135	4180	110.0
1489	3.076	4101	107.9
1520.3	3.010	4013	105.6

Molecular weight: 326.2. Radius of the Capillary tube: 0.05201 cm. at 17° C.
Depth: 0.1—0.2 mm.

The meltingpoint of the salt is 921° C.; even at 1500° C. the compound does not sublime appreciably.

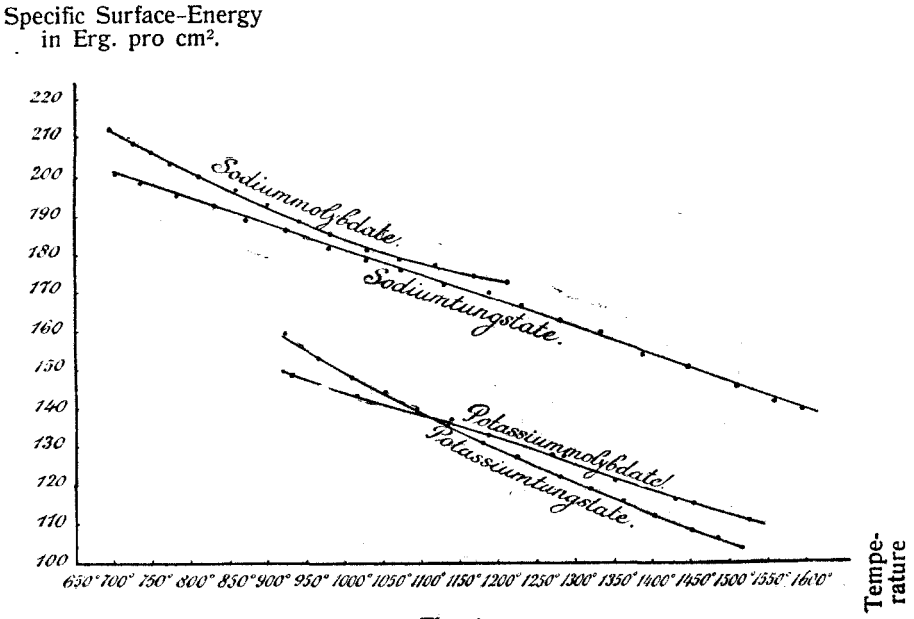

Fig. 4.

XVIII.

Sodium-Metaphosphate: $NaPO_3$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
827°	5.730	7639	197.5
871.4	5.648	7538	194.8
927	5.553	7403	191.6
1014	5.406	7202	186.7
1098.5	5.254	7004	181.6
1181	5.109	6811	176.6
1264.5	4.939	6584	170.9
1317	4.814	6418	166.7
1434	4.511	6014	156.2
1516.5	4.254	5671	147.5

Molecular weight: **102.04.** Radius of the Capillary tube: 0.05140 cm. at 15° C.
Depth: 0.1 mm.

The salt melts at about 620° C. At 1200° C. it begins to evaporate considerably, and sublimes readily at higher temperatures.

XIX.

Potassium-Metaphosphate: KPO_3.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg. pro cm².
	in mm. mercury of 0° C.	in Dynes	
897°	4.506	6007	155.5
942	4.395	5860	151.8
995.7	4.346	5793	149.0
1036	4.233	5643	146.1
1082	4.137	5515	143.0
1120	4.060	5413	140.3
1167	3.957	5275	136.8
1205.2	3.859	5145	133.5
1250	3.842	5122	130.2
1288	3.650	4866	126.3
1344.5	3.538	4717	122.5
1372	3.422	4562	118.5
1412.5	3.310	4413	114.7
1496.5	3.043	4057	105.5
1536	2.894	3858	100.3

Molecular weight: **118.** Radius of the Capillary tube: 0.05140 cm.
Depth: 0.1 mm.

The salt melts at about 820° C.; it begins to evaporate readily at 1400° C., and sublimes fast at higher temperatures.

§ 3. *The Temperature-coefficients of the Specific Surface-energy*

In connection with what was said in the foregoing communication about the calculation of χ_t at any arbitrary temperature t, lying *above* the meltingpoint t_s of the salt investigated, we only need to resume here the corresponding values of t_s, a, b, and c, for each salt:

Formula of the Salt.	t_s in ° C.	a	b	c	Remarks.
Li_2SO_4	852°	224.4	0.067	0	
Na_2SO_4	884	196.3	0.140	0.00042	
K_2SO_4	1074	144.5	0.066	0	
Rb_2SO_4	1055	135.0	0.087	0.00007	
Cs_2SO_4	1015	113.1	0.087	0.00006	
$LiNO_3$	254	118.4	0.063	0	
$NaNO_3$	312	120.7	0.063	0	
KNO_3	339	112.9	0.075	0	
$RbNO_3$	304	109.4	0.075	0	
$CsNO_3$	414	92.0	0.084	0	
$LiBO_2$	845	264.8	0.082	0	Decomposes above 1320° C.
$NaBO_2$	965	201.6	0.159	0	
KBO_2	946	136.6	0.310	0.00053	
Na_2MoO_4	687	215.1	0.121	0.00009	
K_2MoO_4	919	152.5	0.066	0	
Na_2WO_4	694	204.4	0.068	0	
K_2WO_4	921	158.2	0.083	0	
$NaPO_3$	620	209.5	0.059	0	
KPO_3	820	161.2	0.069	0	Only up to 1275° C.; then the curve bends more rapidly to the temperature-axis.

In connection with the general rules, given in § 7 of the foregoing communication, we can make the following remarks with respect to the data given above.

Although in these cases also, the value of χ_t at the same temperature t appears gradually to decrease with increasing atomic weights of the alcali-metals, whose corresponding salts are investigated, we see that in the series of the nitrates, the lithiumsalt represents an exception to this rule, because its χ-t-curve lies *under* that of the sodiumnitrate. It is of interest, that just in this series of the alcali-nitrates also other deviations of the normal arrangement are found: so with respect to the solubilities and the meltingpoints. About the relative or absolute values of the temperature-coefficient b, nothing of general application can be put to the fore: evidently no simple relations will be found here, where the structure of the salts is already more complicated than in the case of the halogenides of the alcali-metals.

Groningen, August 1914.

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