Measurement of the Hypersonic Velocity in the Molten Salts NaCl and KCl

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The hypersonic velocity of molten sodium and potassium chlorides has been measured over a temperature range of about 100 °C above the melting points. The measurements were carried out at scattering angles 90° and 140°, corresponding to a 6–10 GHz frequency range. No deviation from previous ultrasonic values of velocity was observed at these frequencies, indicating that the measurements were performed at frequencies lower than any relaxation frequency.

As part of a continuing study of the Brillouin spectra of ionic liquids in this laboratory [1], a high temperature thermostat has been constructed [2] to be used for measurements around 1000 °C in molten chlorides. This work on the molten sodium and potassium chlorides was a natural continuation of our previous study on molten nitrates. Molten alkali halides have a simpler structure than the nitrates, and for comparison with theories of liquids it is preferable to study halide melts. The experimental difficulties are, however, much larger, due to the higher melting points and the more corrosive nature of halide melts.

The salts used in these experiments were of the highest quality that could be obtained commercially, Merck suprapur quality. To get rid of excess water the salt was kept in a vacuum furnace at a temperature of 240 °C for 24 hours. Then the salt was loaded into the quartz salt reservoir situated above the scattering cell in the central part of the furnace, where it was kept at a temperature of 300 °C for another 24 hours before melting into the sample cell. The cylindrical scattering cell, diameter 4 cm, was constructed to protect the furnace from halide vapors [2]. The exciting source was an Ar-ion laser operating in single mode at a wavelength of 4880 Å. Radiation scattered at 90°03′ ± 20′ and 139°56′ ± 20′ was collected and analyzed with a pressure-scanned Fabry-Perot interferometer. The free spectral range was 29.59 GHz, and during an experiment the interferometer was pressure-scanned over five orders.

Spectra were recorded in the temperature range (800–916) °C for molten NaCl and (776–907) °C for molten KCl. From the Brillouin frequency shift the sound velocity, v, was calculated according to the formula

$$v = \frac{\Delta\nu\, c}{2 n \nu_0 \sin\theta/2},$$

where $c/\nu_0 = \lambda_0$ = wavelength of the light source, $\Delta\nu$ = frequency shift of the Brillouin line, n = index of refraction of the scattering medium, θ = scattering angle.

The index of refraction [3], the measured value of the frequency shift and the calculated hypersonic velocity are listed in Table 1. The velocity as a function of temperature is shown in Fig. 1, where solid lines represent the present results and broken lines the ultrasonic results reported by Cerisier et al. [4]. With an experimental error of 1% the hypersonic result is in good agreement with the ultrasonic data which can be seen in the figure.

Table 1. Experimental data of hypersonic velocity.

Salt	Temperature (°C)	Refractive index	Frequency (GHz)	Velocity (ms^{-1})	Frequency (GHz)	Velocity (ms^{-1})
			$\theta = 90.1°$		$\theta = 139.9°$	
NaCl	800.4	1.426	7.17	1734	9.57	1743
	814.7	1.430	7.14	1722	9.52	1730
	829.2	1.423	7.09	1718	9.43	1722
	843.4	1.421	7.01	1701	9.35	1710
	857.7	1.419	6.98	1695	9.30	1702
	872.7	1.417	6.88	1674	9.21	1688
	887.0	1.416	6.86	1670	9.10	1669
	901.5	1.414	6.80	1658	9.06	1664
	916.7	1.412	6.72	1641	8.96	1648
KCl	776.2	1.395	6.40	1582	8.57	1595
	790.7	1.393	6.33	1567	8.46	1577
	805.2	1.391	6.28	1556	8.37	1563
	819.0	1.390	6.20	1540	8.30	1551
	833.4	1.388	6.16	1532	8.22	1538
	847.5	1.386	6.11	1520	8.14	1525
	862.5	1.384	6.03	1504	8.06	1513
	876.8	1.382	6.00	1497	7.97	1498
	891.6	1.380	5.93	1483	7.93	1493
	905.7	1.378	5.89	1475	7.84	1476

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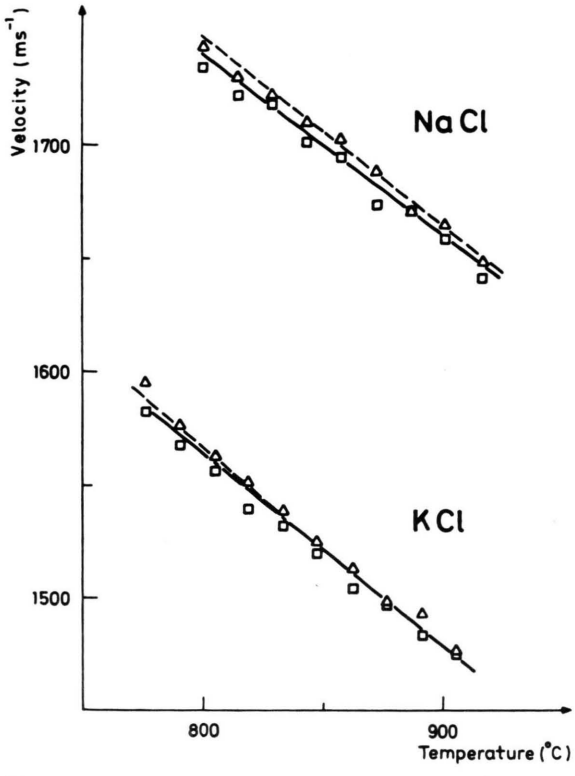

Fig. 1. Graph of velocity versus temperature for molten KCl and NaCl. Present hypersonic measurements are labeled □ at 90° scattering angle △ at 140°. Solid lines represent the best fit to the present results at both the scattering angles; broken lines represent the ultrasonic measurements of [4].

Table 2. Velocity data as a function of temperature (ms^{-1}).

Hypersonic velocity Present research	Hypersonic velocity Martin et al. [5]	Ultrasonic velocity Cerisier et al. [4]
NaCl Salt		
$2367 - 0.789\,T$ (90°)	$2419 - 0.834\,T$	$2707.7 - 1.5155\,T + 0.39527 \cdot 10^{-3}\,T^2$
$2389 - 0.806\,T$ (140°)		
KCl Salt		
$2222 - 0.828\,T$ (90°)	$3032 - 2.691\,T + 0.10847 \cdot 10^{-2}\,T^2$	$2477.9 - 1.3760\,T + 0.29561 \cdot 10^{-3}\,T^2$
$2278 - 0.886\,T$ (140°)		

The temperature dependence of the velocity from the present and recently reported [5] hypersonic data are summarized in Table 2 together with ultrasonic data [4]. All the tabulated values of the hypersonic velocity and its temperature dependence agree well with the corresponding ultrasonic results; accordingly no dispersion was found for frequencies lower than 10 GHz. The measurements were thus performed below any relaxation frequency for both liquids.

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