ENTHALPY OF SEVERAL GRADES OF QUARTZ GLASS WITHIN THE 1300-2400°K TEMPERATURE RANGE*

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UDC 536.7

Results are shown of an experiment in which the enthalpy of grades KI, KV, and KSSh quartz glass was measured at temperatures from 1300 to 2400°K.

Quartz glass represents one of the many modifications of silica, and in this study its enthalpy was measured at temperatures from 1300 to 2400°K. So far the enthalpy of quartz glass had been measured at temperatures up to 1600°K [1-7] and only in one published study [8] was the temperature as high as 1775°K. The upper limit on the test temperature is dictated by the tremendous difficulties in measuring the enthalpy of oxides in the liquid state. Meanwhile, measuring the enthalpy of quartz glass at elevated temperatures is very worthwhile not only in terms of accumulating more test data for a better knowledge of the physical phenomena, but also in terms of thermodynamic reference data needed for heat calculations.

In this study the enthalpy was measured in an apparatus consisting of a high-temperature oven with a tungsten heater and a calorimeter, the latter made up of a massive copper block with an isothermal shell inside a water thermostat. The block temperature was measured with a copper-type resistance thermometer. The shell temperature was maintained constant with the aid of a model KMT-1 thermistor probe inside the thermostat and a thyratron amplifier. Details of the apparatus, including its components and circuits, as well as the test procedure have already been described in [9-11].

The enthalpy of quartz glass was measured on specimens of three different grades: KV and KI made of Volynian raw material, and skimmed KSSh material. A spectral semiquantitative analysis of the specimens is given in Table 1. It is evident here that all impurities in these grades of quartz glass did not exceed 0.02%. The test specimens, shaped as hollow cylinders 17 mm in diameter and 35-40 mm high, were put inside molybdenum or tungsten bulbs. For measurements at temperatures up to 2000°K these bulbs were made of foil 0.5-0.1 mm thick. For measurements above 2000°K we used double bulbs: an inner one of molybdenum or tungsten 0.05 mm thick and an outer one bored out of molybdenum rod stock to a wall thickness of approximately 0.5 mm. The use of double bulbs was dictated by the different thermal expansivities of the cast specimen and the bulb material, which would cause the destruction of a bulb upon cooling of the specimen inside the calorimeter. A double bulb made it feasible to perform several tests with a single specimen. The amount of heat per bulb of metal foil represented approximately 3% of the total heat input to the calorimeter. In the case of compound bulbs, the amount of heat per bulb had risen to 25%. The energy spent on heating a bulb was calculated from the data in [12, 13].

The specimen temperature was measured with a model ÉOP-51 optical pyrometer, the latter having been calibrated against a set of model SI-10-300 heater lamps which, in turn, had been checked against operative standards on a model SPK-4 spectrometer stand at the D. I. Mendeleev All-Union Scientific-Research Institute of Metrology. The temperature of a specimen was measured with a black-body standard

*The temperature here is referred to the MPTSh-48 scale.

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 25, No. 2, pp. 341-344, August, 1973. Original article submitted March 27, 1973.

TABLE 1. Spectral Semiquantitative Analysis of Grades KV, KI, and KSSh Quartz Glass Specimens

Grade of quartz glass	Impurities (% weight)													
	Fe	Al	Mg	Ti	Ca	Cu	Mn	Cr	Ni	Pb	Sn	Ag	Ga	total
KV	$3\cdot10^{-5}$	$9{,}3\cdot10^{-3}$	$1{,}4\cdot10^{-5}$	$4{,}8\cdot10^{-3}$	$1{,}2\cdot10^{-4}$	$3\cdot10^{-6}$	$3\cdot10^{-6}$	$3\cdot10^{-6}$	$3\cdot10^{-6}$	$3\cdot10^{-4}$	$5\cdot10^{-6}$	$3\cdot10^{-6}$	$5\cdot10^{-6}$	0,015
KI	$2{,}2\cdot10^{-5}$	$1\cdot10^{-2}$	$2{,}5\cdot10^{-5}$	$1{,}1\cdot10^{-3}$	$3{,}3\cdot10^{-3}$	$3\cdot10^{-6}$	$3\cdot10^{-6}$	$3\cdot10^{-6}$	$5\cdot10^{-6}$	$3\cdot10^{-5}$	$3\cdot10^{-4}$	—	—	0,014
KSSh	$7\cdot10^{-3}$	$4\cdot10^{-2}$	$3\cdot10^{-4}$	$7\cdot10^{-4}$	$2\cdot10^{-3}$	$2\cdot10^{-4}$	$1\cdot10^{-4}$	$1\cdot10^{-4}$	$2\cdot10^{-4}$	$1{,}2\cdot10^{-4}$	$1\cdot10^{-4}$	—	—	0,015

in the form of a hollow molybdenum or tungsten cylinder. This cavity, 25 mm deep and 3 mm in diameter, was placed axially inside a specimen along a specially predrilled hole. The error of temperature measurements due to imperfection of the black-body standard did not exceed 1% under the most unfavorable conditions and was, therefore, disregarded. The specimen temperature was measured through a prism with total reflection. The correction for errors in temperature readings due to absorption of radiation in the prism was determined in special tests. The pressure in SiO_2 vapor is 1 atm already at a temperature of 1900°K [14], which may cuase contamination of the viewing channel with products of specimen sublimation and evaporation. In order to reduce the effect of evaporation, the tests were performed in an argon atmosphere under a pressure of 1.05 atm and with the apparatus evacuated down to 10^{-4} mm Hg. In order to remove the evaporation products from the viewing channel, through which the pyrometer was focused on a specimen, it had been purged with a mild stream of argon [15] prior to measurements.

Heat losses incurred during the transfer of a specimen from the oven into the calorimeter were accounted for on the assumption that, during this transfer, heat was transmitted from the specimen to the ambient medium by radiation only. The emissivity of the bulb material, which had to be known for calculating the radiative heat losses, was taken from [16].

Spectral semiquantitative analyses of specimens before and after a test revealed an increase of tungsten and molybdenum impurity at the specimen surface. Thus, while at the surface of grade KV quartz glass there was $1\cdot10^{-3}$% tungsten and $1.6\cdot10^{-3}$% molybdenum before a test, their amounts after a test were $5\cdot10^{-3}$% and $16\cdot10^{-2}$% respectively (a surface layer of approximately 0.2 mm was sampled for analysis), with $1\cdot10^{-3}$% and $3\cdot10^{-4}$% respectively deeper in the bulk. No substantial quantitative changes in the content levels of other impurities were detected.

This experiment, covering the 1300-2400°K temperature range, yielded 25 test values: 15 for grade KV, 6 for grade KI, and 4 for grade KSSh specimens. The results are shown in Table 2. The temperature 298.15°K was adopted as reference for the enthalpy readings. The enthalpy correction for the departure of the final temperature of a specimen from 298.15°K was calculated on the basis of the data in [2]. The likely systematic error in enthalpy measurements over the entire range was estimated at 0.7-1.3%.

As was to be expected, the study of various glasses with a 0.02% content of diverse impurities did not yield, within test accuracy, different values for the enthalpy.

TABLE 2. Results of Enthalpy Measurements on Specimens of Grades KV, KI, and KSSh Quartz Glass over the 1300-2400°K Temperature Range

T, °K	$H_T - H_{298.15}$, J/mole	Grade of quartz glass	T, °K	$H_T - H_{298.15}$, J/mole	Grade of quartz glass
1318	659_{90}	KSSh	1856	1084_{90}	KSSh
1318	675_{70}	KI	1869	1093_{30}	KV
1356	684_{10}	KI	1958	1153_{10}	KV
1374	697_{50}	KV	2043	1231_{80}	KI
1384	707_{95}	KV	2076	1257_{70}	KV
1432	744_{80}	KV	2105	1280_{40}	KV
1486	787_{00}	KV	2175	1352_{70}	KV
1538	826_{40}	KV	2210	1384_{10}	KSSh
1560	861_{50}	KI	2210	1402_{50}	KV
1560	844_{80}	KSSh	2328	1474_{90}	KI
1661	915_{10}	KV	2355	1494_{10}	KI
1729	973_{20}	KV	2356	1507_{10}	KV
1757	1006_{30}	KV			

Note. The molecular weight of quartz glass was taken as 60.08.

NOTATION

T	is the temperature of a specimen, °K;
$H_T - H_{298.15}$	is the enthalpy of a specimen through the temperature interval (298.15—T), J/mole.

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