Density of liquids

Related topics

Hydrogen bond, H_2O anomaly, volume expansion, melting, evaporation, Mohr balance.

Principle and task

The density of water and glycerol is determined as a function of temperature using the Mohr balance.

Equipment

Mohr density balance		45017.00	1
Immersion thermostat A100		46994.93	1
Accessory set for A100		46994.02	1
Bath for thermostat, Makrolon		08487.02	1
Glycerol	250 ml	30084.25	2
Water, distilled	5 l	31246.81	1
Sodium chloride	500 g	30155.50	1

Problems

The density of water and glycerol is measured in 1 to 2° steps over a temperature range from 0 to 20°C, then in larger steps up to 50°C.

Set-up and procedure

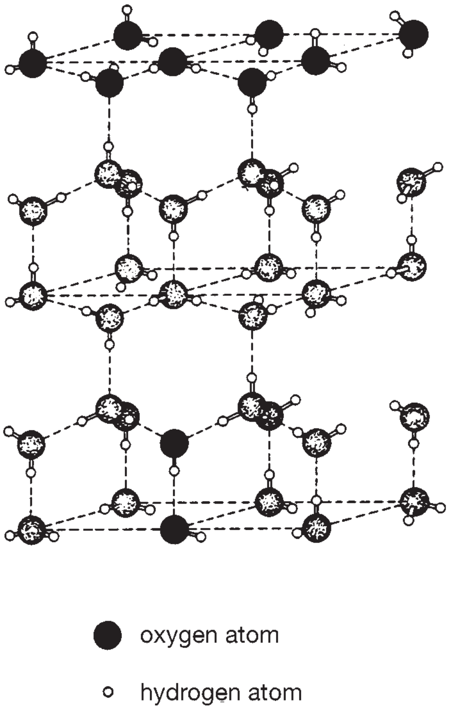
The liquid studied is placed in a glass beaker and its temperature adjusted by the water bath. The circulating pump of the thermostat ensures rapid temperature equilibrium. By addition of NaCl a temperature close to 0°C can be achieved.

The temperature in the glass beaker is measured with a thermometer. The experiment begins with iced water. The temperature of the water bath is raised gradually by switching the heating on for a short time (approx. 30 seconds). From 20°C the desired temperature can be set on the thermostat, and this is kept constant by a controller.

The density of the liquid is measured by the buoyancy method using the Mohr balance (the operating instructions describe how this works and how to adjust it). The density of the liquid can be accurately measured at 4 points ($\rho < 2$ g/cm^3) by means of weights in the ratio 1 :10 : 100 : 1000 and ten marked points on the balance beam at which the weights are attached in order to compensate for the buoyancy. This degree of accuracy is required in order to demonstrate the H_20 anomaly.

Fig. 1: Experimental set-up for determining density with the Mohr balance.

Fig. 2: Crystal lattice of ice.



Theory and evaluation

The mutual forces between the molecules of a liquid decrease rapidly with the distance between them. There are, therefore, only small regions with a crystal-like structure (close array) but no long range order.

In ice, every atom of oxygen is surrounded by 4 hydrogen atoms in a tetrahedral arrangement (Fig. 2).

Two hydrogen atoms are bound by valency forces and are thus closer (10 nm) to the oxygen atom than the two hydrogen atoms bound by the hydrogen bond (17 nm).

The arrangement of the water molecules in ice is not the dense packed. On transition to the liquid state a part of the hydrogen bond is broken and the molecules move closer together, which explains the fact that the density of water increases initially as the temperature rises. Chains and rings of molecules also exist in the liquid state.

Glycerol is one of the glass-like substances: it has no sharp melting point, but softens gradually on heating.

The density of liquids generally decreases as the temperature increases, so long as there. are no other effects at work as in the case of water.

The coefficient of expansion α can be calculated from the relationship measured between density and temperature, the loss on evaporation being disregarded (boiling point at normal pressure: water 100°C, glycerol 290.5°C).

$$\alpha = \frac{1}{V} \cdot \frac{\partial V}{\partial T}$$

$$= -\frac{1}{\rho} \cdot \frac{\partial \rho}{\partial T}$$

In the case of glycerol, α is virtually independent of temperature over the range measured.

$$\alpha = 0.49 \cdot 10^{-3}/\mathrm{K}^{-1}$$

The value obtained for water at 20°C is:

$$\alpha = 0.19 \cdot 10^{-3}/\mathrm{K}^{-1}.$$

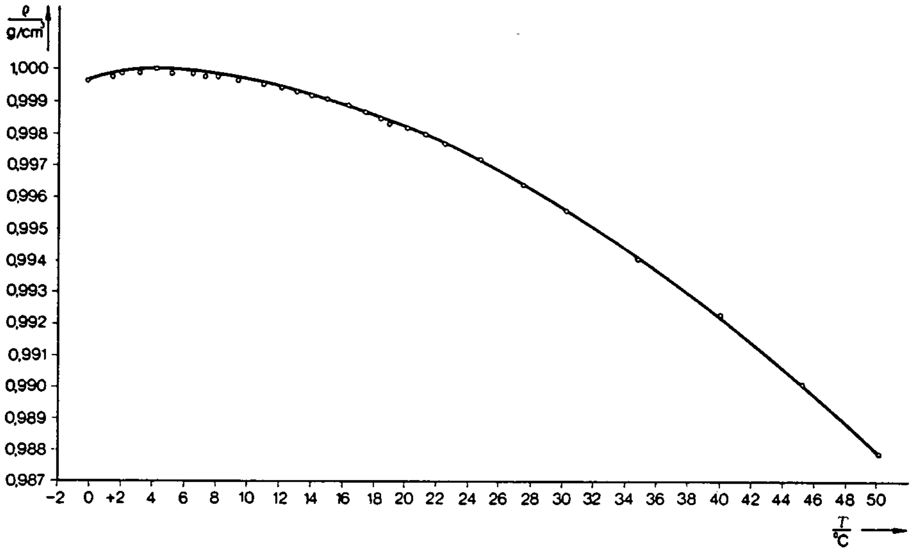


Fig. 3: Density of water as a function of temperature.

Fig. 4: Density of glycerol as a function of temperature.