Converting electrical energy into heat energy - Measuring with a voltmeter and an ammeter

Objects of the experiment

- The aim of the experiment is to establish the equivalence of electrical and heat energy.

Theory

Water will be heated up and from the temperature difference we will calculate the heat energy. The electrical power will be measured with two multimeters and with the duration we can calculate the electrical energy.

We will use a Dewar vessel to minimize the losses of heat during the experiment. It must additionally be taken into account that the vessel itself possesse a certain heat capacity c_D (dependent on the liquid height). In order to determine c_D water with a mass m_2 is poured into the calorimeter and the initial temperature ϑ_2 is measured after heat compensation.

A quantity of water m_1 with higher temperature ϑ_1 is then added. The mixture temperature ϑ_m is again obtained after heat compensation. The quantity of heat given off is described by

$$\Delta Q_1 = c_1 m_1 (\upsilon_1 - \upsilon_m), \qquad \text{(I)}$$

while the absorbed heat quantity is

$$\Delta Q_2 = (c_D + c_2 m_2)(\upsilon_m - \upsilon_2). \qquad \text{(II)}$$

Where $c_1 = c_2 = c_W$ (specific heat capacity of water), we obtain the following :

$$K = \frac{c_D}{c_W} = \frac{m_1(\upsilon_1 - \upsilon_m) - m_2(\upsilon_m - \upsilon_2)}{(\upsilon_m - \upsilon_2)} \qquad \text{(III)}$$

The quotient K can be seen as the mass of the water quantity which has the same heat capacity as the calorimeter.

The electrical energy can be calculated by

$$E = UI \cdot \Delta t \qquad \text{(IV)}$$

with the voltage U the current I and the time difference.

If the temperature increases from ϑ_1 to ϑ_2, we can set :

$$E = UI \cdot \Delta t = c_W (K + m_W)(\upsilon_2 - \upsilon_1) \qquad \text{(V)}$$

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Apparatus

1 Electric calorimeter attachement 384 20
1 Dewar vessel 386 48

Version (a)

1 Thermometer, -10 to 110 C 382 34

or - Version (b)

1 Digital thermometer with 1 input 666 190
1 Temperature sensor NiCr-Ni................... 666 193

or - Version (c)

1 Mobile-CASSY....................................... 524 009
1 Ni Cr-Ni Adapter S................................. 524 0673
1 NiCr-Ni temperature sensor 1.5 mm....... 529 676

1 Stopclock... 313 07
1 Beaker, 250 ml squat............................. 664 103
1 Graduated cylinder, 250 ml..................... 665 755
1 Multimeter LDanalog20 .... 531 120
1 Multimeter LDanalog 30.......................... 531 130
1 Variable extra low-voltage transformer ... 521 35
3 Connecting lead 50 cm black.................. 501 28
1 Pair cables 50 cm red/blue 501 45

Measuring example

In a mixing experiment we can measure the water equivalent of the calorimeter. We will get a value of around 9.5 g. Please note that this value is a function of the filling of the calorimeter. Use always the same filling level or make a measurement as a function of the level.

Mass of the water	m_W	= 170 g
Initial temperature	ϑ_1	= 20.05 °C
Final temperature	ϑ_2	= 25.10 °C
Time difference	t	= 300 s
Current	I	= 2.72 A
Voltage	U	= 4.7 V

Evaluation and results

We can calculte the electrical energy E_{elec} = U I t = 3835 Ws = 3835 J. With a literature value of c_W = 4.2 J/gK for the specific heat of water we get the heat energy E_{heat} = 3807 J.

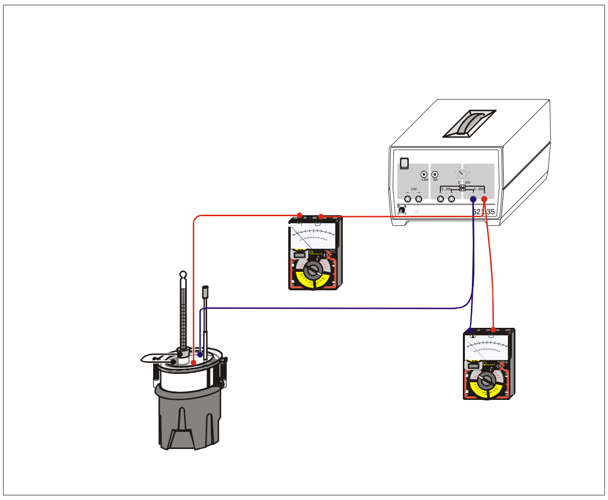

Fig. 1: Experimental setup for measuring with the thermometer 382 34 (Version (a))

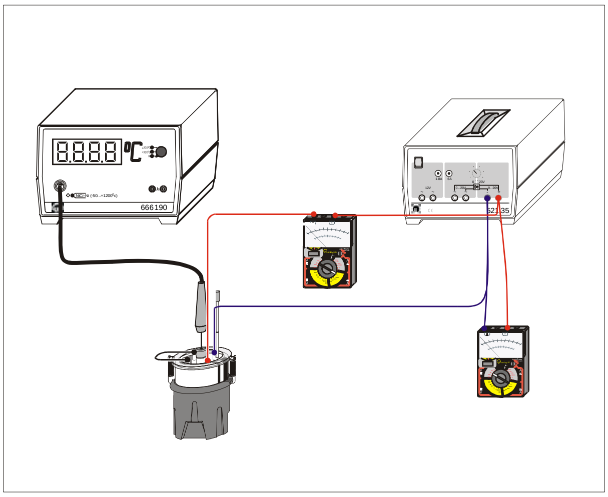

Fig. 2: Experimental setup for measuring with the digital thermometer 666 190 (Version (b))

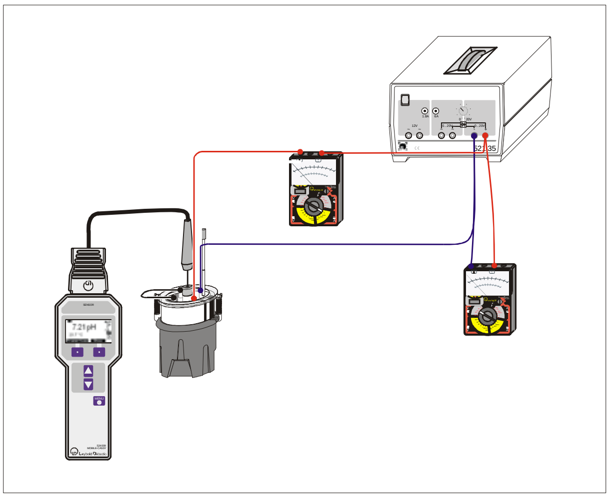

Fig. 3: Experimental setup for measuring with Mobile CASSY 524 009 (Version (c))

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