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1.Theory:

The mechanical equivalent of heat states that motion and heat are mutually interchangeable and that in every case, a given amount of work would generate the same amount of heat, provided the work done is totally converted into heat energy. The mechanical equivalent of heat J is the number of Joules of electrical energy required to generate one calorie of heat. The theory for electrical energy and power was developed using the principles of mechanical energy, and the units of energy are the same for both electrical and mechanical energy. However, heat energy is typically measured in quantities that are separately defined from the laws of mechanics, electricity, and magnetism. Sir James Joule first studied the equivalence of these two forms of energy and found that there was a constant of proportionality between them, and this constant is therefore referred to as the Joule equivalent of heat and given the symbol J. The Joule equivalent of heat is the amount of mechanical or electrical energy contained in a unit of heat energy.

If V be the potential difference across a conducting coil and i ampere be the current flowing through the coil in t seconds, then electrical energy expended in the coil is Vit. Hence if this energy is converted into H calories of heat we have,

$$J = \frac{Vit}{H} \dots \dots \dots \dots \dots \dots \dots \dots (1)$$

If the heat thus developed be measured by means of a calorimeter, then the temperature of the calorimeter with its contents will rise from θ_1℃ to θ_2℃ .

Hence the heat taken up by the calorimeter and its contents is given by,

$$H = (m_1 S_1 + m_2 S_2 + m_3 S_3)\Delta\theta \dots \dots \dots \dots \dots \dots .. (2)$$

Here,

m_1 = mass of the calorimeter

m_2 = mass of the stirrer

m_3 = mass of the contents in caloriemeter

S_1 = specific heat of calorimeter

S_2 = specific heat of stirrer

S_3 = specific heat of the contents in the calorimeter

$\Delta\theta = (\theta_2 - \theta_1)$

From equation (1) and (2) we get,

$$J = \frac{Vit}{(m_1S_1 + m_2S_2 + m_3S_3)\Delta\theta}$$

2.Apparatus

The components required to conduct the experiment include: -

- Joule's calorimeter with a heating coil
- Thermometer
- Rheostat
- Switch
- Stopwatch
- A liquid of known specific heat
- Voltmeter
- Ammeter
- Weight box
- Balance
- Connecting wires

3.Observations

Mass of the calorimeter, m_1 = 78.6 gm

Mass of the stirrer, m_2 = 21 gm

Mass of the calorimeter and water, m = 21.6 gm

Mass of water, m_3 = (m – m_1) = 139 gm

Specific heat of the material of the calorimeter, S_1 = 0.0909 calgm^{-1} $^{o}C^{-1}$

Specific heat of water, S_2 = 0.089 calgm^{-1} $^{o}C^{-1}$

Specific heat of the material of the stirrer, S_3 = 1 calgm^{-1} $^{o}C^{-1}$

Table 1: Readings of current-voltage-temperature

No. of Observations	Time (min)	Current, i (amp)	Voltage V (volts)	Temperature ℃
1	0	0	0	23
2	1	1.29	6	23
3	2	1.29	6	23
4	3	1.29	6	23.5
5	4	1.29	6	23.5
6	5	1.30	6	24
7	6	1.31	6	24.5
8	7	1.31	6	25
9	8	1.31	6	26
10	9	1.32	6	26.5
11	10	1.32	6	27
12	11	1.32	6	28
13	12	1.33	6	28.5
14	13	1.34	6	29
15	14	0	0	29.5
16	15	0	0	31
17	26	0	0	29.5

Recordings of time and temperature with radiation correction:

Initial temperature of calorimeter with its contents, θ_1= 23°C

Final temperature of calorimeter with its content, θ_2 = 31°C

Rise of temperature,$\Delta\theta'$ = θ_2- θ_1= 8°C

Temperature after falling to same length of time,$\theta_2' = 29.5$°C

Radiation correction, θ_r= ($\frac{\theta_2-\theta_2'}{2}$) = 0.75°C

Corrected rise of temperature,$\Delta\theta$ =$\Delta\theta'$ + θ_r = 8.75°C

Time during which the current is passed, t = 13 Min = 780 sec

Mean current during the interval, i = 1.309 amp

Mean voltage during the interval, V = 6 volts

The mechanical equivalent of heat,

$$J = \frac{Vit}{(m_1S_1 + m_2S_2 + m_3S_3)\Delta\theta}$$

$$\Rightarrow J = \frac{6 \times 1.309 \times 780}{(78.6 \times 0.0909 + 21 \times 0.089 + 139 \times 1) \times 8.75}$$

$$\therefore J = 4.73\, Jcal^{-1}$$

4.Result

From the experiment, the mechanical equivalent of heat **J** is calculated to be 4.73 J/cal.

Now,

% Of error =$\frac{4.73-4.2}{4.2} \times 100 = 12.61\%$

5.Discussion

(a) This experiment was conducted to determine Joule's constant **J**, which is also referred to as the mechanical equivalent of heat, via electric method.
(b) While conducting this experiment, water was stirred so that heat is evenly distributed across the system. Some heat may be lost to the surroundings due to inadequate insulation.
(c) Systematic error (zero error) of the measuring instruments such as the voltmeter, ammeter, thermometer, electronic balance and stopwatch along with human parallax error may account for inaccurate measurements.
(d) The theoretical value of J is equivalent to 4.2 J/cal and the experiment obtained a value of 4.73 J/cal which gives a percentage error of just about 12.61%, so is fairly accurate.
(e) Low voltage supply was used so it's a low-risk experiment so little danger of injury occurring. In case of spillage of water to the circuit, short-circuit can occur in which case fire-extinguishers can be kept nearby.

6.References

Resources for the:

Practical Physics (by Dr.Giasuddin Ahmed & Md. Shahabuddin): Exp. 69: To determine the value of J, the mechanical equivalent of heat by electric method(Page no-433).

- Video Link:

  https://www.youtube.com/watch?v=yjOcbjpTCFA

  https://www.youtube.com/watch?v=aZ0jDLNLFGc

  https://www.youtube.com/watch?v=XpSHdxGaWvs