612-1335 (15-125) Electric Calorimeter

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Materials Needed:

- **15-125 Electric Calorimeter**
- **Power supply or 6v battery**
  Can use 10-171 Battery Kit from **Science First**
- **Ammeter (0 to 3A)**
- **Voltmeter, 20v**
- **Connecting wires**
- **Thermometer**
- **Stopwatch or laboratory timer**
- **Laboratory balance**

Theory

Power P expended in an electrical circuit is given by:

$$\mathbf{P = VI} \qquad (1)$$

where V = voltage
I = current

By integrating (adding up) power over time t, we get work, W, done by the circuit.

$$\mathbf{W = Pt} \qquad (2)$$

or

W = VIt By Ohm's Law,

$$\mathbf{V = IR} \qquad (3)$$

we get:

$$\mathbf{W = I^2Rt = \frac{V^2t}{R}} \qquad (4)$$

where **R** is the resistance of the circuit in ohms.

The electrical energy expended is manifested as heat energy and is called **joule heat** or I^2R losses, with I^2R being the power or energy expended per time.

Equation 4 shows how the joule heat varies with resistance:

> 1. For a constant current I, the joule heat is proportional to resistance: I^2R
> 2. For a constant voltage V, the joule heat is inversely proportional to the resistance, V^2/R.

The energy expended in an electrical circuit as given by *Equation 4* is in the units of joules. The relationship (conversion factor) between joules and heat units in calories was established by James Joule from mechanical considerations - the *mechanical equivalent of heat.* In Joule's mechanical experiment, a descending weight turned a paddle wheel in a liquid. He then correlated the mechanical (gravitational) potential energy lost by the descending weight to the heat generated in the liquid. The result was **1 cal = 4.186 J.**

A similar electrical experiment may be done to determine the "electrical equivalent of heat." By the conservation of energy, the heat equivalents of mechanical and electrical energy are the same (i.e. 1 cal = 4.186 J.)

Experimentally, the amount of electrical joule heat generated in a circuit element of resistance R is measured by calorimetry methods. If a current is passed through a resistance in a calorimeter in an arrangement as shown in *Diagram 1*, by the conservation of energy, the electrical energy expended in the resistance is equal to the heat energy (joule heat) Q gained by the system:

Electrical energy expended = heat gained:

$$\mathbf{W = Q} \text{ or}$$

$$\mathbf{IVt = (m_{cal}c_{cal} + m_{coil}c_{res})\,(T_f - T_i)}$$

where the *m's* and *c's* are the masses and specific heats of the calorimeter, and resistor, respectively, as shown by the subscripts. T_f and T_i are the final and initial temperatures of the system, respectively.

Procedure

1. Weigh the small inner cup of the calorimeter to nearest 1/10 gram and record.
2. Fill the cup 3/4 of the way with cool water. Weigh the mass of the cup with water to the nearest 1/10 gram. Subtract the mass of the cup to obtain the mass of the water in the cup. Record the value. The mass of the resistor is small and can be approximated as 10 grams.
3. Place the resistor in the calorimeter and set up the circuit as shown in *Diagram 1*. ***Do not apply power yet.*** The **(A)** represents the ammeter, and the **(V)** represents the voltmeter. It is recommended that a 6v DC power supply be used, but a 6v battery (or pack) will work.
4. To reduce errors, it is desirable to have an initial water temperature about 5 degrees cooler than the ambient room temperature. Record initial temperature **(T_I)**. Then connect the power supply with connecting wires. At the same time, start the stopwatch or laboratory timer. Start at even minutes if a clock is used. Read and record the initial ammeter and voltmeter readings after 30 seconds. Record the voltage and the current at one minute intervals..
5. When the temperature of the calorimeter is 10 to 15° C above the initial temperature, simultaneously disconnect the power supply and stop the timer at the time of a particular minute interval reading. Keep recording temperature until a maximum temperature is reached and record this temperature **(T_F)**.
6. Compute the electric work energy **(W)** expended in the coil (in joules) from the electrical and time readings by using ***Table 1***.

Calculations

7. Compute the heat energy (in calories) gained by the calorimeter system using formula $Q = (T_F - T_I)\,MC$
where:
Q = Total heat added (in calories)
M = mass of calorimeter
C = specific heat of calorimeter
$(T_F - T_I)$ = temperature increase

The specific heat of the calorimeter must be calculated for the mass and specific heat of each component; the aluminum, the water, and the brass of the heating element. The mass of the brass when the calorimeter is 3/4 full of water can be considered ***10 grams***. Any lack of precision due to varying water levels will be negligible due to the small mass difference compared to the overall calorimeter.
The specific heat of materials is:

Aluminum (C_{al}) = 0.215
Brass (C_{br}) = 0.092
Water (C_w) = 1.00

We must calculate the heat added to each component of the calorimeter (**Q**):

$$Q_{al} = M_{al}C_{al}(T_F - T_I)$$
$$Q_{br} = M_{br}C_{br}(T_F - T_I)$$
$$Q_w = M_wC_w(T_F - T_I)$$

The resulting equation becomes:
$$Q = Q_{al} + Q_{br} + Q_w$$

Taking the ratio of the electrical and heat energy results, find the "electrical equivalent of heat." Compare this to the value of the mechanical equivalent of heat by computing the percent error. The accepted value of work per calorie is:

(W/Q) = 4.18 Joules/calorie, or

1 cal = 4.18 Joules

Repeat the experiment and use the average value of the experimental results in determining the percent error.

P/N 24-5125

Diagram 1

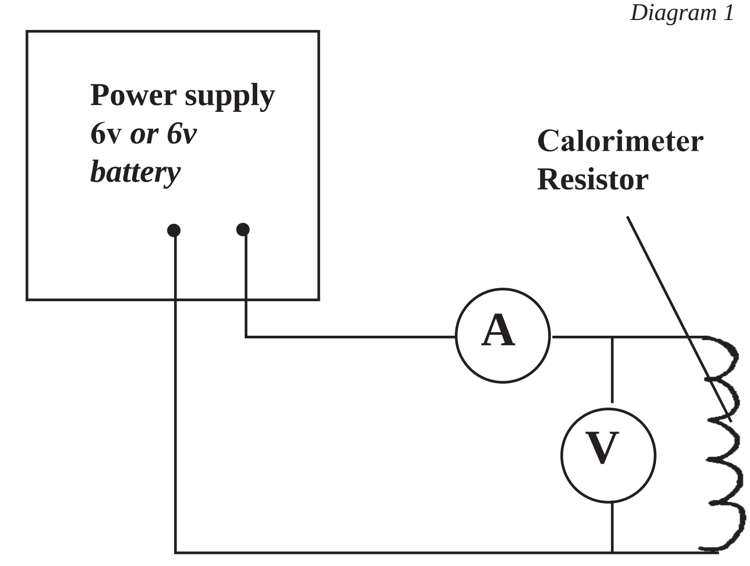

Table 1.

Minutes Interval	Voltage V	Amperage A	Joules V * A * 60(seconds)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Use additional sheets if needed		**Work (W) (Total Joules)**	