

# Determination of Latent Heats of Vaporization and Fusion

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## Abstract

Water is the most abundant liquid on the surface of the earth. It is a liquid whose properties are quite surprising, both as a pure liquid and as a solvent. Water is a very cohesive liquid: its melting and vaporization temperatures are very high for a liquid that is neither ionic nor metallic, and whose molar mass is low. Thus, water remains liquid at atmospheric pressure up to 100°C while similar molecules such as H<sub>2</sub>S, H<sub>2</sub>Se, H<sub>2</sub>Te for example would give a vaporization temperature close to -80°C. This cohesion is in fact ensured by hydrogen bonds between water molecules. This type of bonds between neighboring molecules, hydrogen bonds, is quite often found in chemistry [1] [2]. Any change in the state of aggregation of a substance occurs with the absorption or release of a certain amount of latent heat of transformation. Latent heat of fusion, vaporization or sublimation is the ratio of the energy supplied as heat to the mass of the substance that is melted, vaporized or sublimated. As a result of the reversibility of the processes, the fusion heat is equal to the heat released in the reverse process: crystallization and solidification heat. And likewise the heat of vaporization is equal to the heat of condensation. This equality of heat is often used to determine experimentally either of these quantities. There are two main measurement methods: 1) Direct measurement using the calorimeter, 2) Indirect measure based on the use of the Vant'Hoff relationship. The objective of this work is to measure the latent

heat of water vaporization and verify the compatibility of the experimental values with the values given by the tables using the indirect method.

## Keywords

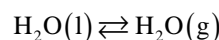
Latent Heat of Vaporization, Latent Heat of Fusion, Calorimetry, Relationship of Vant'Hoff

## 1. Introduction

Under constant pressure, any change of state occurs at constant  $T^\circ$ . This involves a certain amount of heat corresponding to the energy required for the modification of the body at the molecular level.

Water vaporization enthalpy, also known as vaporization heat, is the amount of energy required to vaporize a given amount of water at a given pressure and temperature. At normal atmospheric pressure (1 atm) and a temperature of  $100^\circ\text{C}$ , the water vaporization enthalpy is about 40.7 kJ/mol. This means providing 40.7 kJ of energy to spray a mole of water at this temperature.

When heating water, the following balance is established:



The knowledge of the water vapor pressure in equilibrium, at each temperature allows to draw the curve  $P_{(\text{H}_2\text{O})g} = f(1/T)$ , it is very easy to determine the heat of vaporization since it is directly proportional to  $dP_{(\text{H}_2\text{O})g}/dT$ , *i.e.*, the slope of the tangent to this curve, for the temperature under consideration.

Indeed the equilibrium constant  $K_p$  depends on the temperature according to the Vant'Hoff relation [3] [4] [5] [6] [7]:

$$\frac{d \ln(K_p)}{dT} = \frac{\Delta H_T^\circ}{RT^2} \quad (1)$$

$\Delta H_T$ : is the latent heat of water vaporization;  $T$ : temperature and  $R$ : the perfect gas constant.

For the water balance studied  $K_p = P_{(\text{H}_2\text{O})g}$  (partial pressure of water in the steam state).

Assuming that  $\Delta H_T$  does not depend on temperature, Equation (1) is obtained:

$$\ln(P_{(\text{H}_2\text{O})g}) = A - \frac{\Delta H_T^\circ}{RT} \quad (2)$$

The graphic representation  $\ln[P_{(\text{H}_2\text{O})g}]$  as a function of  $1/T$  must therefore provide a line, whose angular coefficient is:

$$\frac{\Delta \ln(P_{(\text{H}_2\text{O})g})}{\Delta(1/T)} = -\frac{\Delta H_T^\circ}{R} \quad (3)$$

Hence

$$\Delta H_T^\circ = -R \frac{\Delta \ln(P_{(H_2O)g})}{\Delta(1/T)}$$

Calorimetry is the part of thermodynamics that involves measuring heat exchange. The experiments are carried out under constant external pressure (equal to atmospheric pressure). The heat transfer received by the system during the transformations performed in this experiment is therefore equal to the enthalpy variation of this system [3] [8] [9] [10] [11]. The heat capacities of the bodies studied are assumed to be constant over the temperature range considered. The heat transfer to be measured, heats up a given quantity of water.

The experiments take place in an enclosure that is sufficiently insulated to prevent heat exchange with the outside world (for a reasonable period of time). This enclosure is called a calorimeter. The inner chamber and the calorimeter accessories (stirrer and thermometer) are involved in heat exchange, since their temperature varies from the initial to the final value.

## 2. Experimental Procedure

### 2.1. Determining the Heat of Vaporization from the Steam Pressure Curve

To determine the value of the latent heat of water vaporization, the following assembly is performed (Figure 1).

A volume of 1500 ml of distilled water is introduced into the large beaker (2 l) and placed on the heating magnetic stirrer.

We squeeze on the base of the test tube (10 ml) a clamp, then we introduce into this test tube 8 ml of distilled water, then we mouth it with the thumb, we spill it and we immerse it in the large beaker.

The clamp, in the vertical position, in the axis of the specimen, is fixed at its other end, by another clamp to the gantry support.

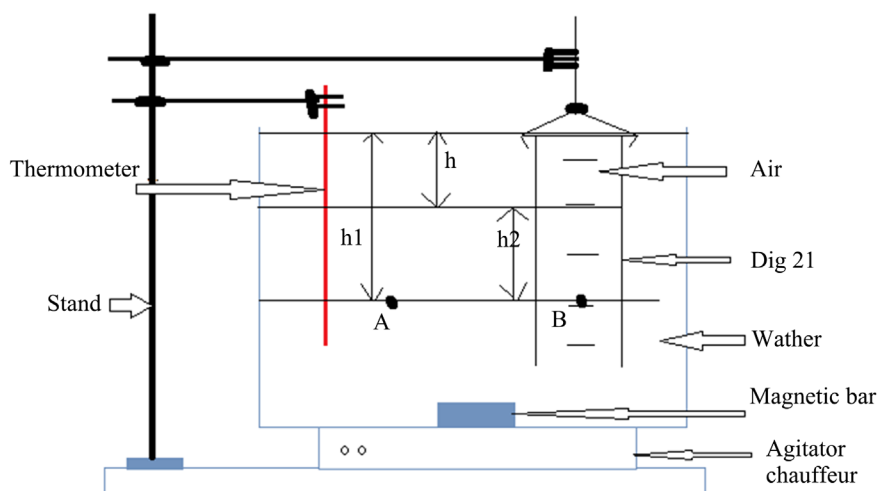


Figure 1. Diagram of experimental set-up.

Also insert the magnet bar and thermometer into the large beaker holding the thermometer with a clamp at the gantry stand and turn on the magnetic stirrer. Then measure the height  $h$ , between the bottom of the meniscus of the bubble, and the surface of the water in contact with the atmosphere.

To remedy the problem of measuring the height  $h$ , it is necessary to fix a ruler of 30 cm, in vertical position, with a clamp outside of large beaker (2 l).

## 2.2. Determining the Heat of Fusion Using the Calorimetric Mixture Method

Experiments take place in an enclosure that is sufficiently insulated to prevent heat exchange with the outside world. This enclosure is called a calorimeter. The inner chamber and the calorimeter accessories (stirrer and thermometer) are involved in heat exchange, as their temperature varies from the initial to the final value (Figure 2).

To measure the calorimeter's heat capacity  $K_{cab}$  the following procedure is used: Weigh the empty calorimeter (m calorimeter), then add a quantity of cold water, noting the initial temperature  $T_{fr}$  of the cold water, and weigh the calorimeter again with the cold water when the temperature stabilizes to determine the mass of cold water introduced and the equilibrium temperature of the calorimeter and cold water  $T_{m1}$ . Heat water in a Pyrex® beaker (wait for boiling). Then pour in a mass of hot water of known initial temperature  $T_{ch}$  and take the mass of (calorimeter + cold water + hot water) and the mixing temperature  $T_{m2}$  when equilibrium is established between cold and hot water.

To calculate the enthalpy of fusion of ice  $L_f$  we'll carry out the following experimental protocol:



Figure 2. Dewar calorimeter.

Weigh the empty calorimeter ( $m$  calorimeter), then add a quantity of distilled water ( $1/3 V_{cal}$ ), noting the initial temperature  $T_{dit}$  of the distilled water, and weigh the calorimeter again with the distilled water when the temperature stabilizes to determine the mass of distilled water introduced and the equilibrium temperature of the calorimeter and distilled water  $T_{m3}$ . Prepare an ice cube set at  $-23^{\circ}\text{C}$  (of mass heat capacity  $C$  water(s)) and immerse it immediately in the calorimeter water, quickly closing the lid. When the ice cube melts completely in the calorimeter, which has a total heat capacity of  $K_{cal}$  and contains a mass  $m$  of distilled water, or when the temperature seems to stabilize (15 to 20 min), note  $T_{m4}$ . Weigh the calorimeter again and deduce the mass of ice  $m$  ice.

### 3. Results and Discussion

#### 3.1. The Enthalpy of Vaporization of Water $L_v$

The total pressure,  $P_{tot}(B)$ , at point  $B$  in **Figure 1** is equal to the sum of the partial pressures of air,  $P_{air}$ , and water vapour,  $P_{(H_2O)g}$  :

$$P_{tot}(B) = P_{air} + P_{(H_2O)g} + P_{h2} \quad (4)$$

On the other hand, the total pressure,  $P_{tot}(A)$ , at point  $A$  on **Figure 1** is equal to the sum of the atmospheric pressure,  $P_{atm}$  and the overpressure,  $P_h$ , corresponding to the height  $h$  between the bottom of the meniscus and the level where the water is in contact with the atmosphere:

$$P_{tot}(A) = P_{atm} + P_{h1} \quad (5)$$

Pascal's principle [12] [13] [14] [15] implies that the pressures measured at points  $A$  and  $B$  in **Figure 1** are equal:

In equation, this amounts to writing that:

$$P_{tot}(A) = P_{tot}(B)$$

$$P_{tot}(A) = P(A) + P_{surface\ area}(A)$$

with

$$P(A) = \rho_{water} g h_1 \quad \text{and} \quad P_{surface\ area}(A) = P_{atmospheric}$$

and

$$P_{tot}(B) = P(B) + P_{surface\ area}(B)$$

with

$$P(B) = \rho_{water} g h_2 \quad \text{and} \quad P_{surface\ area}(B) = P_{air} + P_{(H_2O)g}$$

After simplification:

$$\rho_{water} g h_1 + P_{atmospheric} = \rho_{water} g h_2 + P_{air} + P_{(H_2O)g}$$

This gives:

$$P_{air} + P_{(H_2O)g} = \rho_{water} g h + P_{atmospheric} \quad (6)$$

with  $h = h_1 - h_2$ .

At  $T_0 < 5^\circ\text{C}$ , the partial pressure of water vapor is negligible, so  $P_{(\text{H}_2\text{O})\text{g}}$  tend around 0.

Hence, the relationship (6) becomes:

$$\begin{aligned} P_{\text{air}} &= \rho_{\text{eau}} g (h_1 - h_2) + P_{\text{atmospheric}} \\ P_{\text{air}} &= \rho_{\text{water}} g h_0 + P_{\text{atmospheric}} \end{aligned} \quad (7)$$

with  $h_1 - h_2 = h$  at  $T_0 < 5^\circ\text{C}$ .

At  $T_0 > 5^\circ\text{C}$ , the partial pressure of water vapor is not negligible, so  $P_{(\text{H}_2\text{O})\text{g}}$  is given from (6)-(7), we deduce that:

$$P_{(\text{H}_2\text{O})\text{g}} = \rho_{\text{water}} g (h_i - h_0) \quad (8)$$

Knowing that the density of water is equal to  $10^3 \text{ kg/m}^3$ ; and the acceleration of gravity is equal to  $9.81 \text{ m/s}^2$ . Hence, the pressure exerted by a column of 1 cm of water is equivalent to 98 Pa.

$$\begin{aligned} P(1 \text{ cm water column}) &= \rho_{\text{water}} g h = 10^3 \times 9.81 \times 1 \times 10^{-2} \\ &= 0.98 \text{ kg/cm} \cdot \text{s}^2 = 0.98 \text{ Pa (avec } h(\text{cm})) \end{aligned}$$

And therefore the relation (8) becomes:

$$P_{(\text{H}_2\text{O})\text{g}} = 0.98 \times (h_i - h_0) \text{ Pa} \quad (9)$$

With the unit of  $h_i$  and  $h_0$  is on cm.

Generally speaking, the water vapor pressure  $P_{(\text{H}_2\text{O})\text{g}}$  exerted by an incompressible liquid depends only on:

- The height (or depth)  $h$ ;
- The density of the liquid  $\rho$ ;
- The acceleration of gravity  $g$ .

Water vapor pressure does not depend on the cross-section of the container.

The water vapor pressure  $P_{(\text{H}_2\text{O})\text{g}}$  exerted by the liquid at a depth  $h$  is:

$$P_{(\text{H}_2\text{O})\text{g}} = \rho \times g \times (h_i - h_0)$$

From relationship (2):

$$\ln(P_{(\text{H}_2\text{O})\text{g}}) = A - \frac{\Delta H_T^\circ}{RT} \quad (2)$$

We conclude that:

$$\ln(\rho \times g \times (h_i - h_0)) = A - \frac{\Delta H_T^\circ}{RT}$$

Consequently, we deduce that the latent heat of vaporization  $L_v$  for an incompressible liquid depends only on:

- The height (or depth)  $h$ ;
- The density of the liquid  $\rho$ ;
- The acceleration of gravity  $g$ .

The latent heat of vaporization  $L_v$  does not depend on the cross-section of the container.

**Table 1** gives the values of:  $T_i$ ;  $1/T_i$ ;  $h_0$ ;  $h_i$ ;  $P_{(H_2O)g}$  et  $\ln[P_{(H_2O)g}]$ .

The Vant'Hoff equation is a consequence of the second fundamental law of thermodynamics and the Clausius-Clapeyron formula [13] [14] [15] [16]. It is valid for any system of the described type, so also for the phenomena of fusion and sublimation. When the water vapor pressure curve is known,

$$P_{(H_2O)g} = 0.98(h_i - h_0)$$

It is very simple to determine the vaporization heat  $\Delta H_T$  since it is directly proportional to  $dP_{(H_2O)g}/dT$ , in other words to the slope of the tangent to this curve, for the temperature under consideration. The practical determination of  $\Delta H_T$  will be as follows:

The graphic representation of  $P_{(H_2O)g}$  in function of  $1/T$  must therefore provide a line, whose angular coefficient is:

$$\frac{\Delta \ln(P_{(H_2O)g})}{\Delta(1/T)} = -\frac{\Delta H_T^\circ}{R}$$

Hence

$$\Delta H_T^\circ = -R \frac{\Delta \ln(P_{(H_2O)g})}{\Delta(1/T)}$$

with  $R = 8.3145 \times 10^{-3}$  kJ/(mol.K).

The curve  $\ln(P_{(H_2O)g})$  as a function of  $1/T$  is shown in **Figure 3**.

From the curve of  $\ln(P_{(H_2O)g})$  in function of  $1/T$  one can deduce the latent heat of water vaporization which is worth:

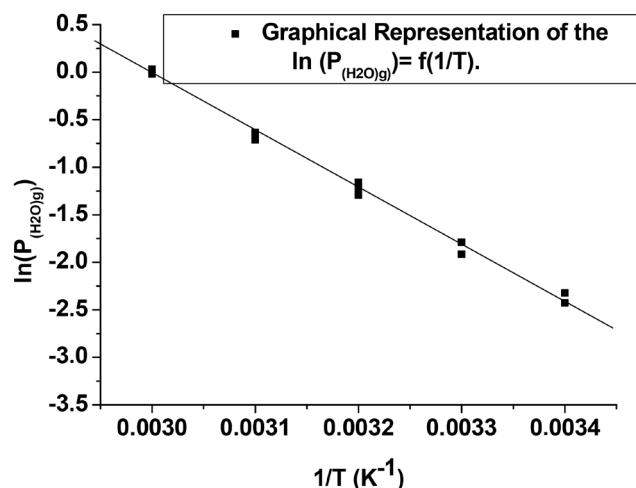
$$\Delta H_T^\circ = -R \frac{\Delta \ln(P_{(H_2O)g})}{\Delta(1/T)}$$

$$\Delta H_{T \text{ exp}}^\circ = 41.067 \text{ kJ/mol.}$$

The value of the latent heat of vaporization of the water found experimentally is slightly different from their tabulated value ( $\Delta H_T^\circ$  theorique = 40,657 kJ/mol)

**Table 1.** Values of  $T_i$ ;  $1/T_i$ ;  $h_0$ ;  $h_i$ ;  $P_{(H_2O)g}$  et  $\ln[P_{(H_2O)g}]$ .

$T_i$ (K)	275	295	299	303	307	311	315	319	323	327	331	335
$1/T_i$ (K <sup>-1</sup> )	0.0036	0.0034	0.0033	0.0033	0.0033	0.0032	0.0032	0.0031	0.0031	0.0031	0.0030	0.0030
$h_i$ (cm)	6	6.09	6.1	6.15	6.17	6.28	6.3	6.32	6.5	6.54	7	7.05
$h_i - h_0$ (cm)		0.09	0.1	0.15	0.17	0.28	0.3	0.32	0.5	0.54	1	1.05
$P_{(H_2O)g}$ (Pa)		0.09	0.10	0.15	0.17	0.27	0.29	0.31	0.49	0.53	0.98	1.03
$\ln(P_{(H_2O)g})$		-2.43	-2.32	-1.92	-1.79	-1.29	-1.22	-1.16	-0.71	-0.64	-0.02	0.03



**Figure 3.** Graphical representation of  $\ln(P_{(H_2O)g})$  as a function of  $1/T$ .

because of the measurement errors of the manipulator during the measurements of the height between the bottom of the meniscus of the bubble, and the surface of the water in contact with the atmosphere at different temperatures [16].

The relationship used to determine the relative difference in latent heat of vaporization is:

$$\begin{aligned} \text{Relative deviation}(L_v) &= \frac{|L_{v \text{ experimental}} - L_{v \text{ theorique}}|}{L_{v \text{ theorique}}} \times 100 \\ &= \frac{|41.067 - 40.657|}{40.657} \times 100 = 1.008\% \end{aligned}$$

The value of the relative deviation of the latent heat of vaporization  $L_V$  is about 1.008%. A very plausible deviation, given the many possible sources of error.

Sources of error when determining the latent heat of vaporization  $L_V$  are:

- The accuracy of measurements of the height (or depth)  $h$  and therefore the accuracy of the corresponding heights;
- Heat exchanges between the system (water + large beaker, test tube, thermometer, stirrer) and the external environment (resulting in heat loss);
- Exchanges of matter (water in its gaseous state) between the system (water + large beaker. Test tube, thermometer, stirrer) and the external environment (resulting in a loss of water in its gaseous state);
- Exchanges of matter (water in gaseous state) within the system between the large beaker and the test tube (are they total or partial);
- Temperature reading on the thermometer (temperature stabilization);
- Height reading  $h$ , on the ruler (ruler is better secured by a clamp on the stand support).

### 3.2. Chaleur Latente De Fusion De La Glace $L_f$

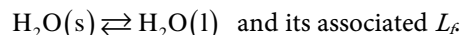
The mass latent heat of a substance's change of state is the quantity of heat  $L$  re-



quired to effect, at constant temperature, the change of state of the body's unit mass, with the pressure remaining constant and equal to the equilibrium pressure between the two states [3] [4] [10] [11].

$$Q = mL \quad L \text{ in J/kg}$$

In this work, we will study a particular physical reaction corresponding to the following change of state of water:



We have seen in thermodynamics that an equilibrium between two phases of a pure body occurs at a given  $P$  and  $T$ , *i.e.* fixed. The reaction is isobaric and isothermal. In this case, the enthalpy of fusion by mass  $\Delta_{fus}H$  represents the amount of heat  $Q$  per unit mass (J/kg) absorbed by the solid water to transform it into liquid water. If the atmospheric pressure  $P_{atm}$  under which we're working is equal to the standard pressure  $P_0 = 1 \text{ bar}$ , we speak of the standard enthalpy of fusion by mass,  $\Delta_{fus}H^\circ$ .

- Global system  $S$  {hot water + cold water + calorimeter}

The cold system  $S_{fr}$ : {cold water introduced + calorimeter} will exchange a quantity of heat  $Q_{fr}$  with the calorimeter (cold water is initially introduced into the calorimeter).

- Hot system  $S_{ch}$ : {hot water}. Hot water will give off a quantity of heat  $Q_{ch}$ .

- The system studied is an isolated system (no exchange with the outside environment). The calorimeter is an adiabatic chamber.

The expression for the quantity of heat released or absorbed by each of these objects is:

- Quantity of heat received by the cold water:  $m_{fr} = 76 \text{ g}$ ; the temperature of the cold-water increases from  $T_{fr} = 23^\circ\text{C}$  to  $T_{m1} = 22^\circ\text{C}$ . Therefore:

$$Q_{fr} = [m_{fr} \times C_{water}(l) + K_{cal}] \times (T_{m2} - T_{m1})$$

- Quantity of heat released by hot water:  $m_{ch} = 85.5 \text{ g}$ . Initial temperature of hot water:  $T_{ch} = 52^\circ\text{C}$ ; Final temperature when equilibrium is reached:  $T_{m2} = 35^\circ\text{C}$ . Taking into account the calorimeter:

$$Q_{ch} = m_{ch} \times C_{water}(l) \times (T_{m2} - T_{ch})$$

- As the calorimeter is an adiabatic enclosure, everything inside is thermally insulated; the sum of heat quantities exchanged inside the calorimeter is zero:

$$\Delta U = Q_1 + Q_2 = 0$$

The internal energy of a macroscopic system results from microscopic contributions:

$$U = E_c(\text{microscopic}) + E_p(\text{microscopic}).$$

In this case, there is no exchange of energy with the external environment (neither in the form of work  $W$ , nor in the form of heat  $Q$ ), so we can write:

$$\Delta U = W + Q = 0$$

If the system is isolated (*i.e.* there is no exchange with the external environ-

ment), the internal energy remains constant, and the change in internal energy is zero, so  $\Delta U = 0$ .

When the final state of equilibrium is reached:

$$\Delta U = 0 \quad \text{i.e.} \quad Q_1 + Q_2 = 0;$$

The calorimetric equation is therefore:

$$\left[ K_{cal} + m_{fr} C_{water}(l) \right] (T_{m2} - T_{m1}) + m_{ch} C_{water}(l) (T_{m2} - T_{ch}) = 0$$

From the calorimetric equation, we derive the expression for the calorimeter's heat capacity  $K_{cal}$  in J/K, given that  $C_{water}(l) = 4.18 \text{ J/(g}\cdot\text{K)}$  is given by the following equation:

$$K_{cal} = \frac{m_{water}(l) \left[ -m_{fr} + m_{ch} (T_{m2} - T_{ch}) \right]}{T_{m1} - T_{m2}}$$

A.N:  $K_{cal} = 150 \text{ J/K}$ .

We often talk about the water value of the calorimeter. From a thermal point of view, this means equating the calorimeter with a fictitious mass  $\mu$  of liquid water, and writing  $K_{cal} = \mu C_{water}(l)$ . We deduce the calorimeter's water value  $\mu$ .

$$\mu = \frac{K_{cal}}{C_{water}(l)}$$

A.N:  $\mu = 35.81 \text{ g}$ .

The expression of the energy given up by the water initially present in the calorimeter, between the start of the experiment and the moment when the temperature of the mixture takes the value  $T_{m4}$  is:

$$Q_{dis} = m_{dis} C_{water}(l) (T_{m4} - T_{m3})$$

A.N:  $Q_{dis} = 108.6 \times 4.18 \times (6.5 - 20)$

$$Q_{dis} = -6128.30 \text{ J}$$

The energy released by the calorimeter during the same time interval is expressed as follows:

$$Q_{cal} = K_{cal} (T_{m4} - T_{m3})$$

A.N:  $Q_{dis} = 150 \times (6.5 - 20)$

$$Q_{dis} = -2025 \text{ J}$$

The expression for the energy received by the ice cubes during the change of state where the temperature remains constant is given by:

$$Q_{ice} = m_{ice} \left[ C_{water}(s) (T_f - T_{ice}) + C_{water}(l) (T_{m4} - T_f) \right].$$

A.N:  $Q_{ice} = 20 \left[ 2.09(0 - (-23)) + 2.18(6.5 - 0) \right]$

$$Q_{ice} = 1504.8 \text{ J}$$

The expression for the energy received by the water in the ice cubes when it has reached the final temperature of the mixture is as follows.

$$Q_{melting} = m_{ice} L_f$$

Since the calorimeter is thermally insulated, we can assume that the energy received by the ice cubes is equal to the energy supplied by the calorimeter and the water it contains.

The first principle gives:

$$\Delta U = Q_{dis} + Q_{cal} + Q_{melting} + Q_{ice} = 0$$

$$m_{ice} \left[ L_f + C_{water}(s)(T_f - T_{ice}) + C_{water}(l)(T_{m4} - T_f) \right] + \left[ m_{dis} C_{water}(l) + K_{cal} \right] (T_{m4} - T_{m3}) = 0$$

The literal expression for the latent heat of fusion of ice given the heat capacity of ice is  $C_{water}(s) = 2.09 \text{ J/(K}\cdot\text{g)}$  which is written as:

$$L_f = C_{water}(s)(T_{ice} - T_f) + C_{water}(l)(T_f - T_{m4}) + \frac{\left[ m_{dis} C_{water}(l) + K_{cal} \right] (T_{m3} - T_{m4})}{m_{ice}}$$

A.N:  $L_f = 332.43 \text{ kJ/kg}$ .

The value found is almost equal to the tabulated enthalpy of fusion of water  $L_f$ :  $L_f = 6 \text{ kJ/mol}$  or  $334 \text{ kJ/kg}$ , measured at room temperature.

The relationship used to determine the relative difference in latent heat of fusion is:

$$\text{Relative deviation}(L_f) = \frac{|L_{f \text{ experimental}} - L_{f \text{ theorique}}|}{L_{f \text{ theorique}}} \times 100$$

$$= \frac{|332.43 - 334|}{334} \times 100 = 0.5\%$$

The value of the relative deviation of the latent heat of fusion LV is about 0.5%. A very small change, given the many possible sources of error.

Sources of error when determining the latent heat of fusion  $L_f$  are:

- The imperfect calorimeter (not completely adiabatic enclosure);
- The accuracy of the volumes of water taken from the graduated cylinder, and therefore the accuracy of the corresponding masses;
- Heat exchanges between the ice cube and the ambient air: the time required to transport the ice cube and place it in the calorimeter (resulting in heat loss);
- Temperature reading on the thermometer (temperature stabilization);
- Measuring the mass of the empty calorimeter, cold water and ice cube at equilibrium with the balance may not be accurate.
- If the mass of the ice cube is much greater than the mass of the cold water, it may increase the time taken to reach equilibrium  $\text{H}_2\text{O}(s) \rightleftharpoons \text{H}_2\text{O}(l)$ . Consequently, the increase in time to equilibrium results in heat loss.

#### 4. Conclusions

Measurements of the latent enthalpy of vaporization were made using the indirect method based on the Clausius-Clapeyron formula. The results found show that there is no big difference between the experimental values and the tabulated values of the latent heat of vaporization. This implies that it is an interesting

method to determine not only the latent heat of vaporization but also the latent heat of fusion and sublimation of a body.

The values of the relative deviation of the latent heat of vaporization and melting are very plausible deviation, given the many possible sources of error. These relative differences in the latent heats of vaporization and melting can be explained by errors that are not perfectly avoided.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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