

Latent Heat of Vaporization of Liquid Nitrogen (General Physics)

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In this experiment, we present an intuitive setup to measure the latent heat of vaporization of liquid nitrogen. We will learn about the thermal properties of materials, and explore connections between thermodynamics and electricity. Furthermore, we will be exposed to the safe handling of cryogenics that are routinely used in physics. This experiment is inspired from previously published articles [1, 2, 3] on the subject.

KEYWORDS Latent Heat of Vaporization · Cryogenics · Wire wound resistors · Ammeter · Voltmeter · Measurement of mass ·

1 Conceptual Objectives

In this experiment, we will,

1. understand the concept of latent heat of vaporization,
2. understand the transfer of heat in calorimetric experiments, and
3. learn how to get meaningful data from experimental graphs.

2 Experimental Objectives

The experimental objectives attainable from this experiment are,

1. getting familiar with the safe use of cryogenics,
2. setup of simple circuits for heating and measurement of current and voltage,
3. data processing, and
4. data acquisition.

2.1 Latent Heat of Vaporization

The amount of energy released or absorbed by any substance during a *phase transition* is called the *latent heat*. If we add heat continuously as in Figure 1, a change of phase from solid to liquid and then from liquid to vapor occurs. In physics, these changes are examples of phase transitions. The latent heat absorbed during the liquid-vapor transition is called the *latent heat of vaporization*. This energy overcomes the inter-molecular forces inside the liquid. Figure 1 illustrates this phenomenon, whereby temperature remains constant as heat is supplied during the phase transition.

The latent heat of vaporization can be mathematically expressed as,

$$L_v = \frac{\Delta Q}{m}, \quad (1)$$

where ΔQ is the heat supplied during phase transition and m is the mass of the liquid vaporized.

In our experiment we will use electrical energy to supply energy to a boiling mass of liquid nitrogen. Current is made to flow through a heater placed inside liquid nitrogen. The heat supplied then becomes, $\Delta Q = VI\Delta t$, where V is the voltage from the source having units in volts, I is the current flowing in amperes and Δt is time interval for which heating remains on.

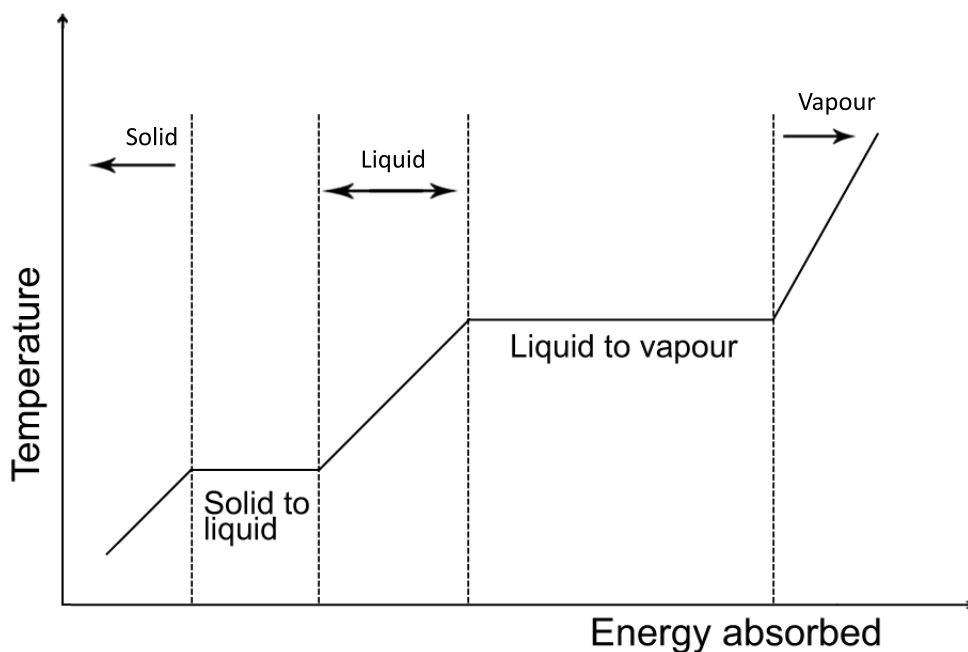


Figure 1: Phase change when heat is added at a constant rate. The temperature remains constant during the phase transition and the heat supplied at these points is called a latent heat.

How do we calculate the mass of the nitrogen vaporized *due to the electrical heating alone*? In fact, the mass of liquid nitrogen, for example, when it is measured on a weighing balance, gradually decreases because the room temperature provides a sufficiently high temperature for the nitrogen to boil off. So, one has to separate out the quantifiable loss in mass due to electrical heating from the loss in mass due to ambient heating, in order to make use of Equation 2. This is done by establishing a background rate of loss of nitrogen *before* the

electrical heating is switched on. The heater is then switched on for a fixed duration of time Δt and the differential reduction in mass calculated. In this experiment, you will be required to understand your data and calculate m by comparing against the background loss. This is something for you to figure out on your own.

With electrical heating, Equation (1) becomes,

$$L_v = \frac{V/\Delta t}{m}. \quad (2)$$

3 Experimental preparation and safety measures

3.1 Using Liquid Nitrogen

Liquid nitrogen is a colorless, odorless and tasteless fluid which boils at 77 K (-196°C), and is formed by cooling and increasing pressure on air which is predominantly N_2 . On evaporation, it generates enormous pressure and direct contact with liquid nitrogen can cause cold burns or frost bites. Liquid nitrogen should never be mixed with water and you **must wear goggles** when making solutions. Never ever dip your finger in a container of liquid nitrogen. Some solvents when mixed with dry ice are flammable but most of them are not. Students must not mix any solvent without prior knowledge.

The container of liquid nitrogen, also called a *dewar*, should be handled with care and covered properly after taking out liquid nitrogen. The cylindrical tubes used to take out nitrogen are delicate and no extra pressure should be exerted on them. The container must be refilled when the level of LN_2 is below a certain value.

3.2 Mass Balance Setup

A digital mass balance Kern 440-47N is connected to the serial port COM1 on the computer using an RS-232 interface connection. The balance will send mass (g) readings to the computer where a LabView code will be used to collect data into an output file. The balance needs to be set up on **AU PC** mode before it can transmit data to the computer. For this purpose one needs to follow the steps given in Table 1.

Setting of Data Transfer Mode	Balance Display
1. Keep the Print key pressed until Unit is displayed.	Unit
2. Press Mode key till Pr appears.	Pr
3. Press the Set key to change the settings of the balance.	
4. Keep pressing the Mode key until the balance displays AU PC .	Au PC
5. Press the Set key to confirm this change in settings.	
6. The balance returns to the weighing mode.	0.0 g

Table 1: Steps to setup the mass balance for data transfer mode.

You are also required to turn off the **Dosing and Zero-tracking** function of the mass balance. This function, if active, is used to tare small variations in weight automatically which can cause improper weighing results. So, it is advisable to switch this function off. Follow the steps given in Table 2.

Activate/deactivate Zero-Tracking	Balance Display
1. Keep the Print key pressed until Unit is displayed.	Unit
2. Press the Mode key several times until tr is displayed.	tr
3. Press the Set key to activate the function.	tr on
4. By pressing once more the Mode key, the function is deactivated.	tr off
5. The changed setting takes over by pressing the Set key.	
6. The balance returns to the weighing mode.	0.0 g

Table 2: Steps to activate/deactivate Zero-Tracking.

3.3 Using the LabView Application

To collect the data of mass (g) and time (t) you will be using a **LabView** code which is available for download from the experiment's website. Two files "**Charts.vi**" and "**Mass Record.vi**" have to be placed on the desktop. Run the file named "**Mass Record.vi**" and give an output path to your data collection. The different functions in the code should be configured to the values given in Table 3.

Functional Title	Value
Visa Resource Name	COM1
Baud Rate	9600
Bits	8
Parity	None
Stop bit	1
Flow Control	None

Table 3: LabView application setting.

4 The Experiment: Latent Heat of Vaporization of Liquid Nitrogen

A resistor (e.g., a 10 watts wire wound resistor ¹ or a disassembled 30 watts soldering rod) is connected to the variac (*Space Power Electronics, Karachi*) through a digital ammeter in series as shown in the Figure 2. The variac is an AC transformer that can provide variable voltage. The variac voltage must lie between 22-23V. **Note: Do not turn on the variac unless the**

¹Wire wound resistors consist of a cylindrical core which is wrapped with a wire. This core is typically made up of a ceramic material and the wire is a type of resistance wire.

resistor is immersed in liquid nitrogen and Do not operate it above 25 V. The balance is connected to the computer using an RS-232 interface connection. Note that this is a special cable made for you that puts the appropriate voltages on the correct wire.

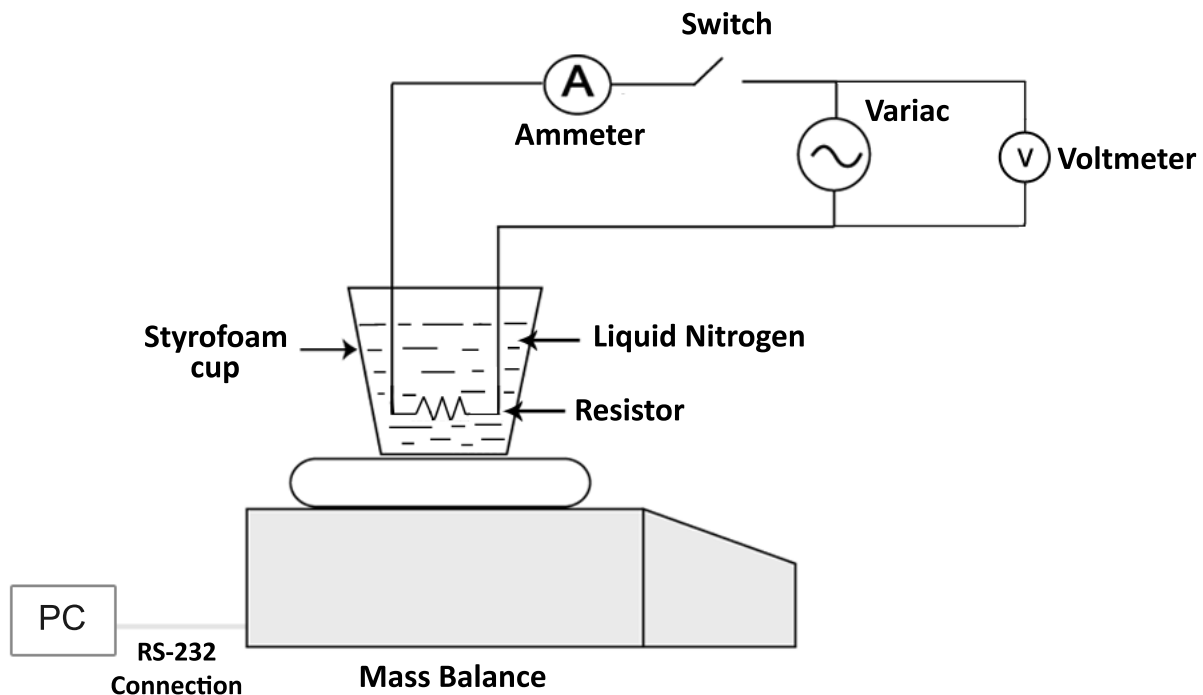


Figure 2: Set up of the Experiment.

Q 1. Set up the apparatus as shown in Figure (2).

Q 2. Place the styrofoam cup on the mass balance with resistor inside and pour safely liquid nitrogen from the cryogenic container into the provided styrofoam cup. The mass balance will record the loss in the mass of liquid nitrogen. Wait for a few seconds until the system establishes a state of thermal equilibrium and the sizzling sound of nitrogen settles. **Note: Do not put the liquid nitrogen filled styrofoam cup for more than 3 min on the mass balance.**

Q 3. Give a path name for your data output and run the LabView program to record the decrease in mass of the liquid nitrogen against time. Press the **Run** button in the LabView file and press **Print** on the mass balance.

Q 4. After having the background loss for ≈ 30 seconds, the switch is closed to turn on the heater. Now the rate of mass loss will be faster and is again recorded as a function of time for ≈ 30 seconds. The heater is then switched off to reestablish the background loss rate and take data for an additional ≈ 30 seconds once again.

Q 5. Why does the mass of the liquid nitrogen decrease and at what rate? Can this rate be controlled?

Q 6. Plot the data points using Matlab.

Q 7. From the data, find the change in mass m **only** due to electrical heating.

Q 8. Calculate the latent heat of vaporization of liquid nitrogen L_v , also find the uncertainty.

Q 9. What would happen if we repeat the experiment varying the heating time (to say 40, 50s) and calculate the latent heat?

References

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