Experiment 3: Latent Heat of Vaporization

EQUIPMENT NEEDED:

— Calorimeter
— Steam Generator *
— Tubing
— Thermometer
— Water Trap
— Balance

* If a steam generator is not available, a distillation flask and Bunsen burner is adequate. A second flask can be used as a water trap.

Introduction

When a substance changes phase, the arrangement of its molecules changes. If the new arrangement has a higher internal energy, the substance must absorb heat in order to make the phase transition. Conversely, if the new arrangement has a lower internal energy, heat will be released as the transition occurs.

In this experiment you will determine how much more energy is contained in one gram of steam at 100°C, than in one gram of water at the same temperature. This value is called the Latent Heat of Vaporization of water.

Procedure

➤ **CAUTION:** This experiment requires the use of live steam. Work carefully.

① Measure T_{rm}, the room temperature.

② Set up a steam generator with a water trap as shown in Figure 3.1. The tube lengths should be approximately as shown in the figure.

③ Weigh a calorimeter to determine M_{cal}, the mass of the empty, dry calorimeter.

④ Fill the calorimeter approximately 1/2 full of cool water (about 10°C below room temperature).

⑤ Turn on the steam generator and wait for the steam to flow freely for at least a minute.

⑥ Measure Tinitial and $M_{cal + H_2O}$, the temperature of the cool water and the mass of the water plus calorimeter.

⑦ Immediately immerse the free end of the short tube into the cool water in the calorimeter. Stir the water continuously with the thermometer.

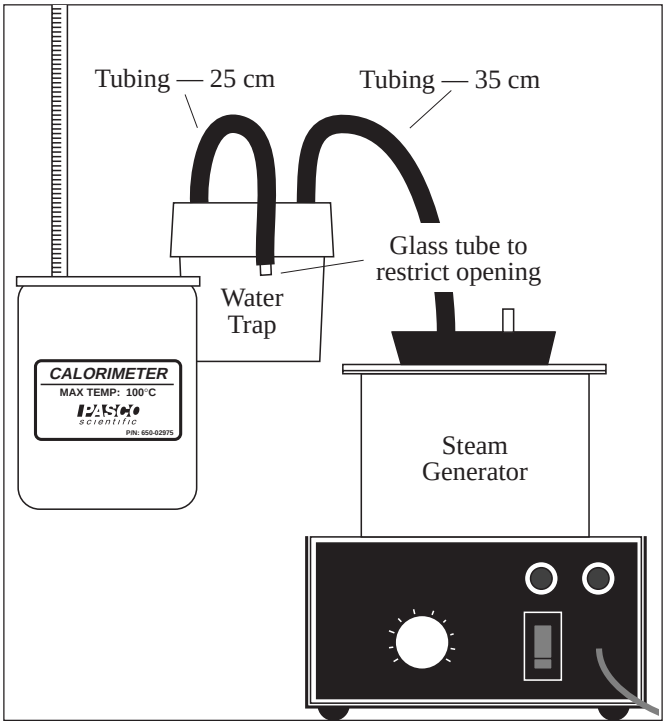

Figure 3.1 Equipment Setup

➤ **IMPORTANT:** The bottom of the water trap should be kept HIGHER than the water level in the calorimeter to avoid water being pulled from the calorimeter back into the water trap.

⑧ When the water temperature, T, gets as far above room temperature as it was initially below room temperature (i.e. $T_{rm} - T_{initial} = T - T_{initial}$), remove the steam tube. Continue stirring the water and record the highest stable temperature attained by the water (T_{final}).

➤ **IMPORTANT:** Always remove the steam tube from the water before turning off the steam generator heat. (Can you explain why?)

⑨ Immediately weigh the water to determine M_{final}, the total mass of calorimeter plus water plus (condensed) steam.

Data

T_{rm} = _____

M_{cal} = _____

$T_{initial}$ = _____

$M_{cal + H_2O}$ = _____

T_{final} = _____

M_{final} = _____

Calculations

When steam condenses in cool water, heat energy is released into the water in two ways. One, the latent heat of vaporization is released. With this release of heat, the steam is converted into water, but the newly converted water is still at boiling temperature, 100 °C. Second, the newly converted water releases heat as it comes into thermal equilibrium with the cooler water, at a final equilibrium temperature, T_{final}.

According to the principle of the conservation of energy, the total heat released by the steam equals the total heat absorbed by the cooler water. Stated mathematically:

$$(\mathbf{M}_{steam})(\mathbf{H}_v) + (\mathbf{M}_{steam})(\mathbf{1\ cal/gm°C})(\mathbf{T}_{steam} - \mathbf{T}_{final}) = (\mathbf{M}_{H_2O})(\mathbf{1\ cal/gm°C})(\mathbf{T}_{final} - \mathbf{T}_{initial});$$

where,

$M_{steam} = M_{final} - M_{cal + H_2O}$ = _____

$M_{H_2O} = M_{cal + H_2O} - M_{cal}$ = _____

T_{steam} = 100 °C

H_v = the Latent Heat of Vaporization per gram of water

Use your data and the above information to determine H_v, the latent heat of vaporization per gram of water.

➤ **NOTE:** The thermometer also absorbs a certain amount of heat during the experiment. As a good approximation, assume that the heat capacity of the thermometer is equivalent to that of approximately 1 gram of water (i.e., add one gram to M_{H_2O} in the above equation).

H_v = _____

Questions

① Why would a burn produced by 1 gram of steam at 100°C do more damage than a burn caused by 1 gram of water at 100°C?

② Speculate on how the heat of vaporization might influence climate and weather systems.

③ In what way does water used to cook food serve as a refrigerant?
(Hint: What happens when the water all boils away?)