

# Heat of Vaporization

## Introduction

When a liquid vaporizes kinetic energy must be absorbed from the surroundings to separate the molecules from each other. This energy to overcome the intermolecular forces is called the heat of vaporization. The Clausius-Clapeyron equation shows the relationship between vapor pressure, temperature and the heat of vaporization. Since boiling occurs when the vapor pressure equals the atmospheric pressure, the equation also gives us the relationship between atmospheric pressure, the boiling point, and the heat of vaporization. In the differential form of the equation

$$\frac{d \ln P}{dT} = \frac{\Delta H_v}{RT^2}$$

This gives the following integrated form

$$\ln P = \frac{-\Delta H_v}{RT} + C$$

where C is the constant of integration. Thus the graph of  $\ln P$  versus  $1/T$  results in a nearly straight line whose slope is  $-\Delta H/R$ . This provides a convenient way to determine the heat of vaporization of many liquids that are fairly volatile. This experiment provides a dramatic visual illustration of the change of BP with pressure. Our main purpose in this experiment is to determine the heat of vaporization of acetone by seeing how the boiling point changes with atmospheric pressure.

## Experimental

The apparatus consists of a long reflux column that is sealed at the top with a large rubber stopper. The end of the column is a round bottom flask that can be easily heated with a standard heating mantle. Connections through the rubber stopper at the top allow the change of inside pressure as well as the operation of the reflux condenser.

After the apparatus is set up [see instructor], add acetone to the reflux tube until the bowl is about 1/3 full. A few boiling chips will prevent bumping while under reflux. Take the atmospheric pressure reading using the room barometer. After inserting the stopper and adjusting the condenser water flow to a small but steady stream, heat the acetone with the heating mantle until the boiling point is reached and the vapor plug is above the bulb of the thermometer with liquid dripping off the thermometer. All the stopcocks should be open at this time.

Attach the open hose to the house vacuum and turn the stopcock closest to the vacuum off. Turn the house vacuum on. Then reduce the pressure inside the system using the house vacuum by gradually opening the stopcock closest to the house vacuum. The boiling temperature should have fallen to under 30°C and stabilized. Read the manometer levels on both sides and the BP with 3 students taking these readings, one student for the BP and 2 for the manometer. Close the stopcock to the house vacuum. Turn the house vacuum off and disconnect the hose from the stopcock on the vacuum side. This stopcock will be used to admit air as required during the remainder of the experiment. Measurements will need to be taken very quickly and group coordination is a must.

The 4<sup>th</sup> student in the group will increase the pressure by about 2 cm of Hg (1 cm each side) by opening the stopcock (that is open to the atmosphere) quickly to allow air to enter the system. This may cause the air 'piston' to push the liquid vapor all the way to the bottom of the tube. As the liquid warms the upper edge of the liquid vapor will gradually push the air back up the tube. As this boundary passes over the thermometer the student reading the temp will notice a jump in the temperature. When the reflux boundary reaches the condenser and equilibrium is reestablished, obtain another set of readings with the student reading the thermometer calling "read" and recording the BP while the 2 students reading the manometer record the mercury levels on each side.

The 4<sup>th</sup> student readmits more air and the entire process is repeated quickly several times until the system is back at room pressure. The entire process should have resulted in at least 10 sets of readings. Read the room barometer again. If it has changed use an average value for your calculations. Leave the equipment set up and leave the liquid in the bowl but lift the stopper out and place it on the lip of the tube.

### Calculations (Examples of Data Tables)

#### Raw Data

Identity of substance \_\_\_\_\_

Patm (cm Hg)	Manometer left reading (cm)	Manometer right reading (cm)	Temperature (°C)

#### Calculated Data

Net pressure	ln P	Temp (K)	1/T (1/K)

1. Graph ln P versus 1/T and get a least squares (linear regression) fit.
2. The slope equals  $-\Delta H/R$
3. Calculate  $\Delta H$ .
4. Use *Excel* and linear regression from the Data Analysis Pak to get the error in slope. Use it to determine the propagated error in  $\Delta H$ .
5. Compare to the true value obtained from the Handbook of Chemistry and Physics or other reference work. Compute a % error. Be sure and reference this value.