1. Vapor Pressure

Objective

In this experiment, the vapor pressure of several volatile liquids will be demonstrated.

Introduction

When a volatile liquid evaporates into a vacuum in a closed container, evaporation continues only until the space above the liquid becomes *saturated* with the vapor of the liquid. Beyond this point, an *equilibrium* exists between the vapor and any remaining liquid. The maximum number of molecules of the vapor of a volatile liquid that can exist above the liquid in a container of a fixed volume is a *constant number* at a given temperature. The pressure of vapor that exists in a closed container above such a liquid is called the **saturation vapor pressure** of the liquid, and is also constant at a given temperature.

To a macroscopic observer of this situation, it would appear that the liquid had stopped evaporating once the space above the liquid had been saturated with the vapor of the liquid. On a microscopic level, however, evaporation is still taking place. Evaporation *appears* to have stopped because the vapor of the liquid is *condensing* at the same rate at which evaporation is occurring. Evaporation and condensation are opposing processes, and in a system in which a liquid and its vapor have come to equilibrium, every time a molecule of liquid enters the vapor phase, somewhere else in the system a molecule of vapor enters the liquid phase. Studies using radioactive tracers have shown unequivocally that there is a constant interchange between liquid and vapor molecules in such a system.

For the situation in which a liquid evaporates into a container that already contains some other gas (air, for example), the total pressure in the container will be the sum of the partial pressures of all the components, that is

$$P_{\text{total}} = P_1 + P_2 + \dots P_n \text{ where } n \text{ is the number of components.}$$

If the container of vapor is equilibrated with the atmosphere (see Figure 1-1, in which the bottom of the tubes containing vapor are open to the atmosphere), then the total pressure in the container is equal to the barometric pressure of the laboratory.

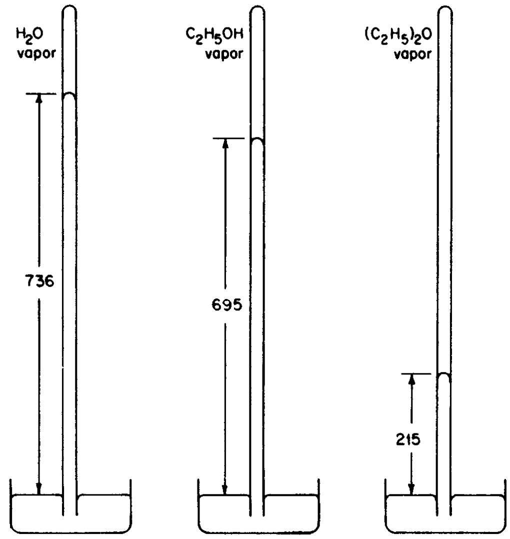


FIGURE 1-1
The vapor pressure of a liquid can be easily demonstrated using an inverted buret. The three liquids shown—water, ethanol, and diethyl ether—have quite different vapor pressures. Ether is by far the most volatile of the three, causing the largest depression of the mercury level.

SAFETY PRECAUTIONS

- **Wear safety glasses at all times while in the laboratory.**
- **The liquids used for vapor pressure determination are highly volatile and extremely flammable. For this reason, the apparatus should be set up in the *exhaust hood* to minimize the build-up of fumes. *Absolutely no flames are permitted in the laboratory under any circumstances.***
- **The liquids used in the vapor pressure determination should be assumed to be toxic. Do not spill them on the skin, and confine the transfer of the liquids to the exhaust hood.**
- **Dispose of the liquid samples as directed by the instructor.**

Apparatus/Reagents Required

Buret, funnel, rubber tubing, large beaker or basin, samples of volatile liquids, medicine dropper or Pasteur pipet

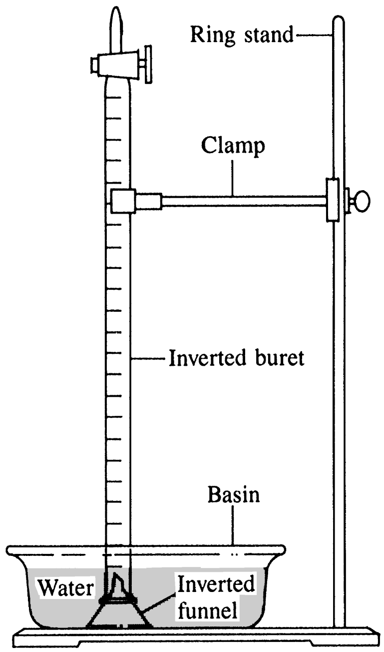
Procedure

Record all data and observations directly in your notebook in ink.

Obtain a buret and clean it with soap and water. Rinse thoroughly with tap water to remove all traces of soap. Make a final rinse of the buret with distilled water.

Pour water to a depth of 6–7 inches into a large basin. Place the basin at the base of a ringstand. Determine and record the temperature of the water. Place a glass funnel, mouth downward, into the basin of water. See Figure 1-2.

FIGURE 1-2
Apparatus for vapor pressure determination.



Fill the buret to the rim with distilled water, place your finger over the rim of the buret, and invert the buret into the basin of water, with the mouth of the buret placed *over the stem of the funnel.* Clamp the buret securely to the ring stand. If you have performed this maneuver correctly, very little (if any) water should run out of the buret. See Figure 1-2.

Carefully, and very slowly, open the stopcock of the buret until the water level drops to approximately 6 inches below the stopcock (in the inverted position). If you open the stopcock too far, or too quickly, and the water level falls by more than 6 inches, you should refill the buret completely before continuing.

Record the position of the water level in the buret (remember that the normal scale of the buret has been inverted).

Obtain a sample of one of the volatile liquids and record its identity. The liquid samples have been chosen to be highly volatile and of low density, but are relatively insoluble in water. When a sample of one of the liquids is introduced into the inverted buret, it will rise to the surface of the water in the buret and will then evaporate.

A medicine dropper or pipet will be used to transfer 1–2 mL of the volatile liquid to the buret. Lift the funnel/buret assembly about an inch from the bottom of the basin, insert the tip of the dropper/pipet containing the liquid beneath the rim of the funnel, and squeeze the bulb of the dropper/pipet.

If the transfer of the liquid has been successful, the bulk of the water in the buret will *not* fall from the buret.

As the volatile liquid rises to the surface of the water in the buret, and begins to evaporate, it will cause the water level in the buret to *change*. Allow the system to stand until the water level no longer changes, and record the position of the the water level on the scale of the buret. At this point, the air in the buret is saturated with the vapor of the volatile liquid. Record the change in the water level as an index of the vapor pressure of the volatile liquid.

Add another 1–2-mL portion of the volatile liquid to the buret through the funnel. Since the air in the buret was already saturated with the vapor of the liquid, the addition of more liquid should *not* cause any further change in the water level.

Slightly increase the temperature of the system by grasping the buret with your hand in the region of the volatile liquid for approximately 5 minutes. Does an increase in temperature result in a change in the vapor pressure of the volatile liquid?

Clean out the buret, and repeat the procedure using each of the other available volatile liquid samples. While this procedure does not easily permit a very precise determination of the vapor pressure of the liquids tested, you should be able to rank order the liquids in order of increasing vapor pressure.

Using a handbook of chemical data, compare the results of your ordering of the liquids with the actual vapor pressures of those liquids at the temperature of the water in the basin.

Vapor Pressure

Date:	....	Student name:	....
Course:	....	Team members:	....
Section:	....		....
Instructor:	....		....

Prelaboratory Questions

1. Find the specific definitions from your textbook for the following terms:

   Vapor pressure

   Evaporation

   Condensation

2. How does the vapor pressure of a pure liquid vary with *temperature*?

3. How does the presence of a solute influence the vapor pressure of a solvent, that is, how does the vapor pressure of a solution differ from that of the pure solvent used in making the solution?

4. What does it mean to say that the development of a vapor pressure above a liquid in a closed container represents a *dynamic equilibrium*?

Vapor Pressure

Date:	....	Student name:	....
Course:	....	Team members:	....
Section:	....		....
Instructor:	....		....

Results/Observations

Liquid ID	Initial water level, mL	Final water level, mL	Change in water level
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Arrange the liquids determined in order of increasing vapor pressure:

Literature value of vapor pressures:

Liquid	Vapor pressure	Temperature	Reference
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Questions

1. What effect might be introduced into the qualitative determination of vapor pressure (as in this experiment) by the saturation of the air in the buret with water vapor?

2. The liquids used in this experiment are *insoluble* in water. What effect would be seen if the liquids tested by this method were very soluble in water? For example, ethyl alcohol is fairly volatile but is also completely miscible with water in all proportions.

3. What effect on the water level in the buret would have been seen if you had cooled the samples of liquid?

4. Some solids pass directly into the vapor state (without first liquefying) and also have appreciable vapor pressures at room temperature. For example, dry ice is said to be dry because it turns directly into gaseous carbon dioxide without melting. What is the direct phase transition from solid to vapor called?