LABORATORY ACTIVITY: Water Vapor Investigation

I. Background: Water vapor is found in varying amounts in the atmosphere ranging from near zero to about 4% by volume depending upon both temperature and the availability of water. The highest water vapor content is found above hot, wet surfaces (tropical forests). The lowest is where temperatures are the lowest (polar regions) and in desert areas. In reality, the total mass of water in the atmosphere at any time is only enough, if it all precipitated, to cover the globe with a layer of water 2.5 cm, or about 1 inch deep.

The higher the temperature, the more water vapor a volume of air is capable of holding. Therefore, any change in temperature alters the volume's water vapor capacity. As air warms, its capacity for holding water vapor increases; as it cools, the capacity decreases.

The maximum water vapor capacity of a volume increase at an increasing rate as temperature increases. For the range of temperatures normally found near the Earth's surface, this capacity doubles for every ten degree Celsius warming. Conversely, a ten-degree cooling nearly cuts the capacity of a volume of air to hold water vapor in half.

Humidity is the measurement of the water vapor content of the air. The term humidity is a general term and can be given as either absolute or relative, or even as a temperature reflecting moisture content, such as dew point. It is measured with a variety of instruments including psychrometers, hygrometers, and dew cells.

A commonly used measurement of atmospheric water vapor content is relative humidity. Relative humidity is expressed in percent and is the amount of water vapor actually present in air as compared to its maximum capacity at that temperature. Relative humidity is temperature dependent since the maximum amount of water vapor contained in a volume of air is related to temperature. Consequently, relative humidity values decrease during the day, as temperatures rise, and increase at night, as temperatures lower.

The dew point, or dew-point temperature, is another common humidity measure. It is the temperature to which the air has to be cooled at constant pressure (without changing the water vapor content) so that the actual amount of water vapor in the air is equal to the maximum amount that could be in the air at that temperature. High dew points indicate high atmospheric water content; low dew points indicate low content. Adding water vapor to the air increases the dew point; removing water vapor lowers it.

Water vapor is extremely important to weather. It condenses to form cloud particles, which can lead to precipitation. It releases large amounts of latent heat when changing from a vapor to liquid or ice, serving as a major energy source for storms ranging in size from local thunderstorms to hurricanes. In addition, water vapor strongly absorbs and re-radiates Earth's long wave infrared (heat) radiation, making it the major greenhouse gas in the planet's heat and energy balance.

II. Objectives:

- To simulate the capacity of air to hold water vapor varies with temperature;
- To create a model to explain the relationship between the "capacity" of air to hold water and the actual amount of water vapor in the air;

III. Materials:

Four 12-ounce clear or translucent drinking sups for every two students, enough Styrofoam "peanut" packing or popped popcorn to fill one cup, scissors, permanent marking pen, paper/pencil;

IV. Teacher Preparation:

Preparing a set of cups for use in this activity:

1. Fill a twelve-ounce cup to the brim with water.
2. Pour the water from that cup into another cup until the water levels in both are the same.
3. Trace the water line on the outside of both cups with a permanent marker.
4. Empty the water from one of these cups. Cut along the traced line to make a 6 ounce cup.
5. Pour the water remaining in the 12 ounce cup into the third cup until their water levels are the same.
6. Trace their water levels with the marker. Cut the third cup down to the water line to make a cup that holds 3 ounces.
7. You should now have one 3-ounce cup, one 6-ounce cup with a line marking the 3 ounce level, and one 12 ounce cup with lines marking the 6 and 3 ounce levels.
8. Write a large zero (0) on the side of the smallest cup, 10 on the middle size, and 20 on the largest cup to indicate 0, 10 and 20 degrees Celsius.
9. Use these cups as guides for preparing other sets. The fourth and unmarked cup will be used to hold the Styrofoam "peanuts" or popped corn.

V. Procedure:

(Note: Cups of different sizes are used in this activity to represent the "capacity of the air to hold water at different temperatures. Packing "peanuts" or popcorn are used to represent the water vapor actually in the air.)

1. Fill the large unmarked cup approximately level with Styrofoam packing "peanuts" or popped corn.
   - Tap the cup gently on the desk or table top to help settle the material. This is the total supply of packing peanuts you will use in this activity.

2. This activity involves the use of four cups:
    - The large, unmarked cup is used to store the "peanuts".
    - The largest marked cup is twice the capacity of the mid-size cup.
    - The mid-size cup is twice as big as the small cup.
    - The marked cups represent the capacity of the air to hold water at 0, 10 and 20 degrees C. Each cup is labeled by the temperature related to its capacity.

3. Fill the small 0-degree cup with its packing peanuts/popped corn until the contents are level with the top of the container.
    - Pour the contents into the mid-size 10-degree cup until the 10-degree cup is level full.
    - Pour filled 10-degree cups into the 20-degree cup until it is full.
    - Answer the question in **Part VI: Observations/Analysis** relating to this part of the procedure.

4. Starting with the filled 20-degree cup, pour its contents into the 10-degree cup until it is level full.
    - Pour the contents of the 10-degree cup into the 0-degree cup until it is filled to the brim.
    - Answer the appropriate questions in **Part VI: Observation/Analysis**.

5. Empty the 20-degree cup and pour the filled 0-degree cups into the large cup until it is full.

6. Complete the remaining questions/statements in **Part VI: Observation/Analysis.**

Lab Activity: Water Vapor Investigation

PART VI. Observation / Analysis:

1. The capacity of air to hold water vapor approximately ________________ when the temperature increases 10 degrees Celsius.

2. The capacity of the air to hold water vapor or approximately ______________________ when the temperature lowers 10 degrees Celsius.

3. The capacity of air to hold water vapor approximately ________________________ when the temperature rise 20 degrees Celsius.

4. According to the same observations that you used to complete #3, what happens to the capacity of air to hold water vapor as the temperature falls 20 degrees Celsius?

5. When air cools, its capacity to hold water vapor decreases, and any excess water vapor must condense. This can be demonstrated by attempting to pour all the packing peanuts from a filled 20-degree cup into a 10-degree cup. Level the top of the 10 degree cup. The overflow represents the water vapor that condensed out.
   In this example of the 10-degree cooling, how much of the water vapor condensed to liquid as the temperature dropped 10 degrees?

6. Air filled to capacity with water vapor is called saturated air. If saturated air at 20 degrees is cooled 20 degrees, how much of its water vapor must condense?

7. Saturated air has a relative humidity of 100%.
   - Pour a full 0-degree cup into a 10-degree cup to determine the relative humidity if air saturated at 0-degrees is warmed 10-degrees with no addition of water vapor.
   - What is the relative humidity? What would it be if that same air were warmed another 10 degrees to 20 degrees?

8. Explain in your own words why in cold weather the relative humidities in heated buildings (without humidifiers) are quite low?

9. Dew point is another common humidity measure.
   - Fill the 20-degree cup half full; pour it into the 10-degree cup.
   - What is the approximate dew point of air at 20 degrees with a relative humidity of 50%?

10. Pour a filled 0-degree cup into a 10-degree cup.
    - Would the dew point change?
    - What would the dew point of air saturated at 0-degrees be if the temperature is raised 10 degrees without the addition of additional water vapor?

Lab Activity: Water Vapor Investigation

11. Attempt to pour a filled 20-degree cup into a 10-degree cup.
    - How much water vapor is the 10-degree cup holding compared to its capacity?
    - What is its final dew point?

12. In general, when saturated air is cooled, what happens to its capacity to hold water vapor, its dew point and it relative humidity? (Refer to the observations you made above.)

13. Describe the water vapor and temperature relationships that must exist for cloud, dew and frost formation.

14. Water vapor is very important as a greenhouse gas because of its ability to absorb IR (heat) radiation
    - If the Earth's average temperature increases due to global warming, how could the water vapor content of the atmosphere be affected?
    - If the water vapor content of the atmosphere increases, what would the effect be on the ability of the atmosphere to absorb heat?
    - If the atmosphere's heat absorbing capacity increased, what would the effect be on the Earth's average temperature?
    - What effect would increased atmospheric water vapor and higher temperatures have on cloud formation?

15. Which of the scenarios outlined above would be a positive feedback mechanism? Why?

16. Which of the scenarios above would be considered a negative feedback mechanism? Why?