Exercise 14

Atmospheric Moisture, Pressure, and Wind

By observing, recording, and analyzing weather conditions, meteorologists attempt to define the principles that control the complex interactions that occur in the atmosphere (Figure 14.1). One important element, temperature, has already been examined in Exercises 12 and 13. However, no analysis of the atmosphere is complete without an investigation of the remaining variables—humidity, precipitation, pressure, and wind.

This exercise examines the changes of state of water, how the water vapor content of the air is measured, and the sequence of events necessary to cause cloud formation. Global patterns of precipitation, pressure, and wind are also reviewed. Although the elements are presented separately, keep in mind that all are very much interrelated. A change in any one element often brings about changes in the others.

FIGURE 14.1
Developing storm clouds. (Photo by E. J. Tarbuck)

Objectives

After you have completed this exercise, you should be able to

1. Explain the processes involved when water changes state.
2. Use a psychrometer or hygrometer and appropriate tables to determine the relative humidity and dew-point temperature of air.
3. Explain the adiabatic process and its effect on cooling and warming the air.
4. Calculate the temperature and relative humidity changes that take place in air as the result of adiabatic cooling.
5. Describe the relation between pressure and wind.
6. Describe the global patterns of surface pressure and wind.

Materials

calculator

Materials Supplied by Your Instructor

psychrometer or hygrometer
beaker, ice, thermometer
barometer
atlas

Terms

water vapor
evaporation
precipitation
latent heat
dry adiabatic rate
wet adiabatic rate
atmospheric pressure
barometer
isobar
relative humidity
saturated
dew-point temperature
equatorial low
subtropical high
subpolar low
anticyclone
cyclone
wind
psychrometer/hygrometer
condensation nuclei
Coriolis effect
trade winds
westerlies
polar easterlies
monsoon

Atmospheric Moisture and Precipitation

Introduction

Water vapor, an odorless, colorless gas produced by the **evaporation** of water, comprises only a small percentage of the lower atmosphere. However, it is an important atmospheric gas because it is the source of all **precipitation**, aids in the heating of the atmosphere by absorbing radiation, and is the source of **latent heat** (hidden or stored heat).

Changes of State

The temperatures and pressures that occur at and near Earth's surface allow water to change readily from one state of matter to another. The fact that water can exist as a gas, liquid, or solid within the atmosphere makes it one of the most unique substances on Earth. Review the appropriate chapter of your text and then answer questions 1–4 using Figure 14.2

1. To help visualize the processes and heat requirements for changing the state of matter of water, write the name of the process involved (choose from the list), whether heat is absorbed or released by the process, and the amount of heat, in calories per gram, absorbed or released by the process at the indicated locations by each arrow in Figure 14.2.

Processes

Freezing	Evaporation	Deposition
Sublimation	Melting	Condensation

2. (More, Less) heat energy is required to melt a gram of ice than to evaporate a gram of water. Circle your answer.

3. The process of condensation releases (more, less) latent heat energy than freezing.

4. The energy requirement for the process of deposition is the (same as, less than) the total energy required to condense water vapor and then freeze the water. Circle your answer.

Water Vapor Capacity of Air

Any measure of water vapor in the air is referred to as *humidity*. The water vapor capacity of air is limited by, and directly related to, its temperature.

Table 14.1 presents the water vapor capacity of a kilogram of air at various temperatures. Use Table 14.1 to answer questions 5–8.

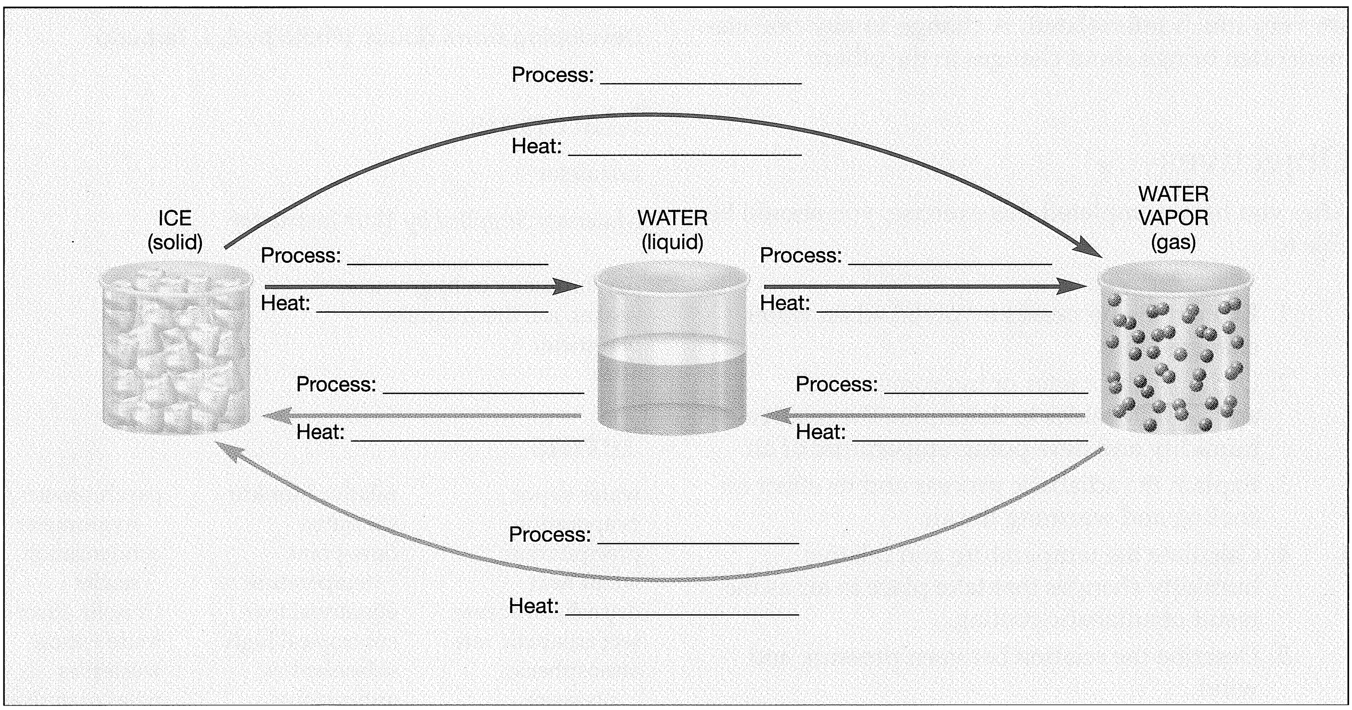

FIGURE 14.2
Changes of state of water.

Table 14.1 Water vapor capacity of a kilogram of air (at average sea level pressure)

Temperature (°C)	Temperature (°F)	Grams of water vapor per kg of air (g/kg)
−40	−40	0.1
−30	−22	0.3
−20	−4	0.75
−10	14	2
0	32	3.5
5	41	5
10	50	7
15	59	10
20	68	14
25	77	20
30	86	26.5
35	95	35
40	104	47

5. To illustrate the relation between water vapor capacity and air temperature, prepare a graph by plotting the data from Table 14.1 on Figure 14.3.

6. From Table 14.1 and/or Figure 14.3, what is the water vapor capacity of a kilogram of air at each of the following temperatures?

   40°C: ________ grams/kilogram

   68°F: ________ grams/kilogram

   0°C: ________ grams/kilogram

   −20°C: ________ grams/kilogram

7. Raising the air temperature of a kilogram of air 5°C, from 10°C to 15°C, (increases, decreases) its water vapor capacity by (3, 6) grams. However, raising the temperature from 35°C to 40°C (increases, decreases) the capacity by (8, 12) grams. Circle your answers.

8. Using Table 14.1 and/or Figure 14.3, write a statement that relates the water vapor capacity of air to the temperature of the air.

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   ____

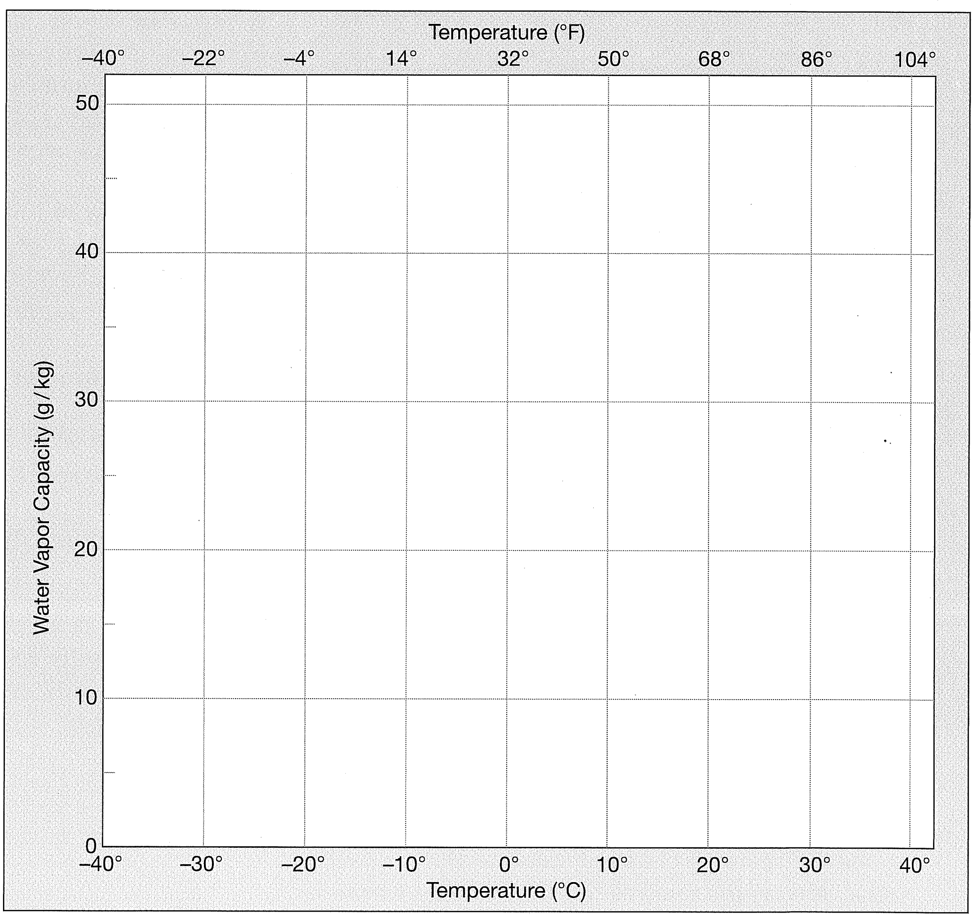

FIGURE 14.3
Graph of water vapor capacity of a kilogram of air versus temperature.

Measuring Humidity

Relative humidity is the most common measurement used to describe water vapor in the air. In general, it expresses how close the air is to reaching its water vapor capacity. Relative humidity is the *ratio* of the air's water vapor *content* (amount actually in the air) to its water vapor *capacity* at a given temperature, expressed as a percent. The general formula is

$$\text{Relative humidity(\%)} = \frac{\text{Water vapor content}}{\text{Water vapor capacity}} \times 100$$

For example, from Table 14.1, the water vapor capacity of a kilogram of air at 25°C would be 20 grams per kilogram. If the actual amount of water vapor in the air was 5 grams per kilogram (the water vapor content), the relative humidity of the air would be calculated as follows:

$$\text{Relative humidity(\%)} = \frac{5\ \text{g/kg}}{20\ \text{g/kg}} \times 100 = 25\%$$

9. Use Table 14.1 and the formula for relative humidity to determine the relative humidity for each of the following situations of identical temperature.

Air Temp.	Water Vapor Content	Water Vapor Capacity	Relative Humidity
15°C	2 g/kg	______ g/kg	______%
15°C	5 g/kg	______ g/kg	______%
15°C	7 g/kg	______ g/kg	______%

10. From question 9, if the temperature of air remains constant, adding water vapor will (raise, lower) the relative humidity, while removing water vapor will (raise, lower) the relative humidity. Circle your answers.

11. Use Table 14.1 and the formula for relative humidity to determine the relative humidity for each of the following situations of identical water vapor content.

Air Temp.	Water Vapor Content	Water Vapor Capacity	Relative Humidity
25°C	5 g/kg	______ g/kg	______%
15°C	5 g/kg	______ g/kg	______%
5°C	5 g/kg	______ g/kg	______%

12. From question 11, if the amount of water vapor in the air remains constant, cooling the air will (raise, lower) the relative humidity, while warming the air will (raise, lower) the relative humidity. Circle your answers.

13. In the winter, air is heated in homes. What effect does heating the air have on the relative humidity inside the home? What can be done to lessen this effect?

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14. Explain why a cool basement is humid (damp) in the summer.

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15. Write brief statements describing each of the two ways that the relative humidity of air can be changed.

1) ______________________________

2) ______________________________

One of the misconceptions concerning relative humidity is that it alone gives an accurate indication of the amount of water vapor in the air. For example, on a winter day if you hear on the radio that the relative humidity is 90 percent, can you conclude that the air contains more moisture than on a summer day which records a 40 percent relative humidity? Completing question 16 will help you find the answer.

16. Use Table 14.1 to determine the water vapor content for each of the following situations. As you do the calculations, keep in mind the definition of relative humidity.

Summer	Winter
Air temperature = 77°F	Air temperature = 41°F
Capacity = ______ g/kg	Capacity = ______ g/kg
Relative humidity = 40%	Relative humidity = 90%
Content = ______ g/kg	Content = ______ g/kg

17. Explain why relative humidity does *not* give an accurate indication of the amount of water vapor in the air.

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