Measurements for a Rainy Day

Making observations and taking careful, quantitative measurements are important skills for chemistry students. In this Activity, students collect data on a rainy day and use the information to calculate the rate of rainfall.

Integrating the Activity into Your Curriculum

This Activity reinforces ideas about density, mass, volume, area, length, and units. It gives practice in making measurements and doing simple mathematical calculations. The terms *precision* and *accuracy* could be introduced and discussed, as well as the problem of selecting appropriate samples for measurements that are representative of a large quantity of material or a complex phenomenon (such as chemical reaction rates, which vary in a more predictable way than rainfall rates). The use of significant digits in measurements and calculations can be emphasized.

About the Activity

It must be raining for this Activity to be performed. Students will get wet and may need towels, protective rain gear, or dry clothing. It is recommended that students work in groups of three. Inexpensive polystyrene plates, available at most grocery and discount stores, are used to collect rainwater for rate and density determinations. The plates are nonabsorbent and provide some insulation to keep the temperature of the collected rainwater constant. Paper towels placed in the plates for the rate determination absorb water and allow the plates to be moved with less danger of spilling the sample. Rainwater for the density determination is collected in a plate with no paper towels and transferred to a cup to prevent spilling before bringing it into the lab. (It could be collected in a cup, but the plate's larger surface area reduces the time required to collect an appropriate volume.) Students in each group should collect three samples at the same time and as close together as possible. Different groups can be spread out over a larger area so that multiple measurements made at different locations can be compared. After collecting rainwater for a known length of time, rates of rainfall are calculated and compared.

If the wind is strong enough to blow the paper towels off the plates or flip the plates over, instructors may wish to have students set a small anchoring rock or similar item on top of the paper towel and plates or use paper clips or staples to attach the towels to the plates. Students should be reminded to take the additional mass into account.

The time intervals required to collect a sample of rainwater depend on the rate of rainfall. Instructors may wish to assign specific time intervals. If time permits, students can dry the plates and cups and add new paper towels to make a second set of measurements at the same location. Student measurements and calculations can also be compared to rainfall data measured with a rain gauge or reported by the weather bureau.

Don L. Lewis, a retired teacher from Texas, contributed the idea for this Activity, along with portions of the text.

Answers to Calculations and Questions

Sample answers to questions to questions 1–5 are based on the following data:

exposure time:	$t = 2.0 \times 10^1$ s	mass of rainwater in cup:	$m_{cup} = 3.09$ g
plate diameter:	$D = 23.4$ cm	mass of plate and dry towel:	$m_i = 16.88$ g
volume of rain in cup:	$V_{cup} = 3.15$ mL (or cm^3)	mass of plate, towel, and rainwater:	$m_f = 31.08$ g

1. $A = \pi r^2 = \pi D^2/4 = (3.142)(23.4\text{ cm})^2/4 = 4.30 \times 10^2$ cm^2.
2. $\rho = m_{cup}/V_{cup} = 3.09$ g/3.15 mL $= 0.981$ g/mL $= 0.981$ g/cm^3. Students should average their three density values. The density of water in the temperature range 13–18 °C is 0.999 g/cm^3 (*CRC;* 61st ed.), so the error is 1.80%.
3. $V = m/\rho = (m_f - m_i)/\rho = (31.08\text{ g} - 16.88\text{ g})/0.981\text{ g/cm}^3 = 14.5$ cm^3.
4. h (calculated depth of water over exposed area) $= V/A = 14.5\text{ cm}^3/4.30 \times 10^2\text{ cm}^2 = 0.0337$ cm.
5. r (rate of rainfall) $= h/t = 0.0337\text{ cm}/2.0 \times 10^1\text{ s} = 1.7 \times 10^{-3}$ cm/s $= 6.1$ cm/hr $= 2.4$ in/hr. There is likely to be some variation in the data collected. Collecting multiple samples allows one to determine the precision or reproducibility of the measurement.
6. Answers will vary. The greater the distance between measurement sites, and the time between measurements, the more likely the values are to differ. In testing, even plates that were close together occasionally had significant differences in mass of rainwater collected, possibly because of the small plate area and short collection time.
7. Answers will vary. This method gives a rate for a very short period of time. A rain gauge gives an average rate for a longer period of time. To report volumes, one would have to specify the area onto which the rain fell. It is much easier to measure the depth at several locations within the area of interest and report an average depth. The rate of rainfall is likely to change in unpredictable ways. A rate observed at a particular time might not be representative of the overall rainfall. The average rate for the entire time during which rain was falling could also be misleading if the rate was not constant—if there were brief periods of very heavy rainfall, for example.
8. This method of measurement probably would not work well with snowfall, because snow does not have a definite density at a particular temperature. Also, snow would not be collected as reliably as rainwater by the paper towel and plate. Melting or substantial change in the temperature of the snow sample could occur while making measurements in the laboratory.

***JCE Classroom Activities* are edited by Nancy S. Gettys and Erica K. Jacobsen**

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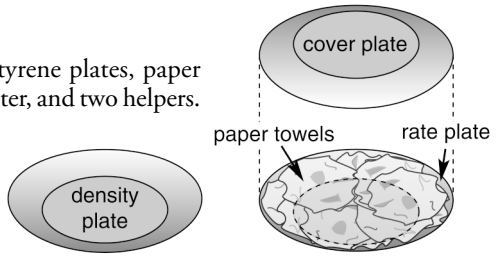
An important part of a scientist's work is to collect data. Data can include both *qualitative* and *quantitative* observations. Qualitative observations describe something with words. Quantitative observations use numbers and are obtained by measurement. For example, a qualitative observation might be that a water sample is clear and colorless, while a quantitative observation might report the volume and mass of the sample. In this Activity, you will practice making quantitative measurements on a rainy day that will allow you to calculate the rate of rainfall in a localized area.

Try This



You will need: rainy day, waterproof marker, 3 polystyrene cups, 9 polystyrene plates, paper towels, ruler, stopwatch or watch, balance, 10-mL graduated cylinder, thermometer, and two helpers. **Perform steps 8 and 9 quickly so the temperature of the rainwater remains constant. Wear protective clothing so you don't get wet.**

__1. Use a ruler to measure the diameter of a polystyrene plate. Record the diameter. Label the plate "rate 1" with a waterproof marker. Label a second plate and a polystyrene cup "1". The first plate will be used to collect rainwater for a rainfall rate determination (rate plate), the second for a density determination (density plate).

__2. Place several paper towels on the rate plate. The towels should fit within the plate boundaries and cover as much of its surface as possible. Crumple the towels if necessary.

__3. Weigh the towels and rate plate. Record the mass.

__4. Cover the towels and rate plate with a third inverted polystyrene plate (cover plate) to form a stack.

__5. Repeat steps 1–4 with two more sets of plates and cups. Label them "2" and "3".

__6. Take the stacks, density plates, and cups into the rain. Place the stacks and density plates on the ground as close as possible to each other without overlapping and away from any objects that obstruct the rain. You and your helpers should remove the cover plate from each stack (keep the cover dry) simultaneously. Start a stopwatch or note the time on a watch. Do not block the rain from falling on the plates.

__7. Leave the rate plates uncovered for an amount of time you determine. Record the time. It should be long enough for the rain to wet the paper towels thoroughly, but not long enough to allow a large amount of standing water to collect in the rate plate. When the time is up, cover the towels and rate plates with the cover plates. Leave the density plates in the rain until each contains a few mL of rainwater. Pour the rain from each density plate into its labeled polystyrene cup. Take the plate stacks and cups into the laboratory.

__8. Remove the cover plates and dry the bottom of each rate plate. Weigh the rate plates and wet towels from each stack and record the masses. Determine the mass of rainwater collected with each stack.

__9. With a thermometer, measure and record the temperature of the rain in the three cups. Weigh a 10-mL graduated cylinder and record the mass. Pour the rainwater from the cup labeled "1" into the cylinder. Record the new mass. Determine the mass and volume of the collected rainwater. Repeat for the cups labeled "2" and "3".

Calculations and Questions

__1. Calculate the area of each rate plate using the diameter you found in step 1.

__2. Calculate the density of the rainwater using the mass and volume data from step 9. Average the three density values. Look up the density of water at the recorded temperature and calculate the percent error for your average.

__3. Calculate the volume of the rain that fell on each rate plate using the mass of rainwater from step 8 and the average density calculated in question 2.

__4. For each rate plate, divide the volume of rainwater collected (question 3) by the area of the rate plate (question 1). This will yield the depth of water that would have covered the rate plate had the paper towels not been present.

__5. The rate of rainfall is the depth of rain that fell during a certain amount of time. Calculate the rate of rainfall in cm/s and in/hr for each rate plate. Are the rates calculated for all three stacks the same? Why is it important to collect data from more than one trial during an experiment? Average the three rates.

__6. Compare your average rate to that calculated by other students at the same time but at different locations.

__7. Do you think this method of determining rate of rainfall is more or less accurate than using a rain gauge that collects rain in a container with measuring increments on the side? Explain your reasoning. Why do you think rainfall is usually reported as a total depth rather than as a rate or a volume?

__8. Would this method work for finding the rate of snowfall? Why or why not?

Information from the World Wide Web *(accessed July 2002)*

1. SI Base Units; *http://physics.nist.gov/cuu/Units/units.html*
2. Resources: Weather Measurements; *http://www.usatoday.com/weather/basics/measurements.htm*
3. National Weather Service; *http://www.nws.noaa.gov/*