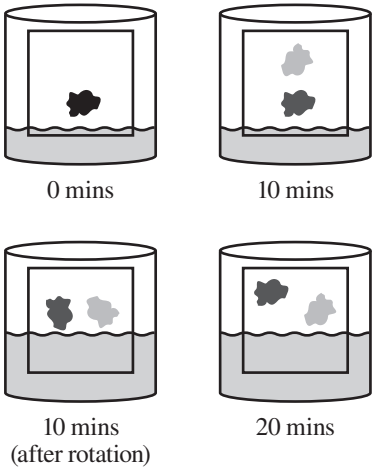
DRILL 1

Passage II

A scientist mixed three drops each of Red #3 and Blue #1, dyes commonly used to color food, together to form a purple spot at the base of a square of filter paper and placed the filter paper in a beaker. Next, 15 mL of *acetone* (AC), a slightly polar solvent, was added to the beaker, and the solvent was allowed to migrate up the filter paper for ten minutes. Next, the filter paper was rotated 90 degrees and placed in a new beaker. A second solvent was made by dissolving 19 grams of *magnesium chlorate* (MC) in 100 mL of water, and 30 mL of this solution was added to the beaker. The solvent was allowed to migrate up the filter paper for another ten minutes, resulting in the filter paper having a total of 20 minutes of soaking in solvents. The dyes on the filter paper migrated to the pattern shown in the figure below.



Note: the darkest colored spot represents purple, the dark gray spot represents blue, and the light gray spot represents red.

The scientist asked each of 4 students to explain what occurred on the filter paper over the 20 min period.

Student 1

Over the 20 min, the mixture of food dyes separated because Red #3 is more polar than Blue #1 and was more attracted to the filter paper. Blue #1 migrated further in AC, and Red #3 migrated further in MC. Red #3 dissolved more in the MC, because MC is a covalent solid and forms a nonpolar solution when dissolved in water. Blue #1 is less polar, so it was more soluble in the slightly polar AC.

Student 2

Over the 20 min, the mixture of food dyes separated because Blue #1 is more polar than Red #3 and was more attracted to the filter paper. Red #3 migrated further in AC, and Blue #1 migrated further in MC. Blue #1 dissolved more in the MC, because MC is a covalent solid and forms a nonpolar solution when dissolved in water. Red #3 is less polar, so it was more soluble in the slightly polar AC.

Student 3

Over the 20 min, the mixture of food dyes separated because Blue #1 was more soluble in the AC, causing the blue dye to migrate further up the filter paper. Red #3 is more polar than Blue #1. Red #3 dissolved more in the MC, because MC is an ionic solid and forms a polar solution when dissolved in water. Blue #1 is less polar, so it was more soluble in the slightly polar AC.

Student 4

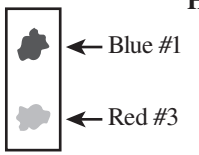
Over the 20 min, the mixture of food dyes separated because Blue #1 was more soluble in the MC, causing the blue dye to migrate further up the filter paper. Blue #1 is more polar than Red #3. Blue #1 dissolved more in the MC, because MC is an ionic solid and forms a polar solution when dissolved in water. Red #3 is less polar, so it was more soluble in the slightly polar AC.

7. Which of Students 1 and 2, if either, claimed that Red #3 is more polar than Blue #1 ?

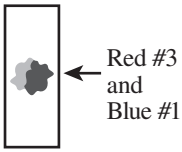
A. Student 1 only
B. Student 2 only
C. Both Student 1 and Student 2
D. Neither Student 1 nor Student 2

8. Suppose that 3 drops of Red #3 and 3 drops of Blue #1 are mixed together, placed at the base of a strip of filter paper, and placed in a beaker with 15 mL of MC. Based on Student 2's explanation, the resulting filter paper would best be represented by which of the following diagrams?

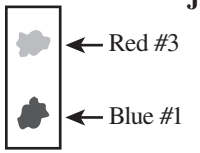
F.



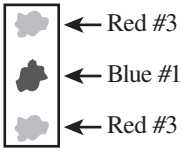
H.



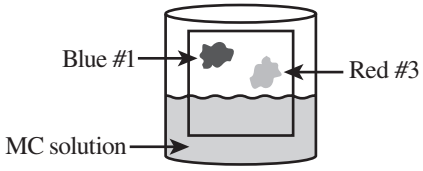
G.



J.



9. Consider the diagram below.



The locations of the Blue #1 dot, Red #3 dot, and MC solution shown in the diagram are consistent with the explanation(s) given by which student(s)?

A. Student 1 only
B. Student 2 only
C. Student 1 and Student 3 only
D. Student 2 and Student 4 only

10. Based on the figure, when the filter paper was first placed in the container with the AC, would the mixture of dyes spotted on the filter paper be more appropriately categorized as a homogeneous or heterogeneous mixture?

F. Homogeneous, because the distribution of the dyes differed from one part of the spot to another.
G. Homogeneous, because the dyes were evenly distributed throughout the spot.
H. Heterogeneous, because the distribution of the dyes differed from one part of the spot to another.
J. Heterogeneous, because the dyes were evenly distributed throughout the spot.

11. Which students, if any, would be likely to agree that the AC and MC solvents both interacted more strongly with the same dye?

A. Students 1 and 3 only
B. Students 2 and 4 only
C. Students 1, 3, and 4 only
D. None of the students

12. The statement "A solute will be more soluble and migrate further when mixed with a solvent of similar polarity" is consistent with the explanation(s) given by which of Students 1 and 3, if either?

F. Student 1 only
G. Student 3 only
H. Both Student 1 and Student 3
J. Neither Student 1 nor Student 3

13. The formula of MC is $Mg(ClO_3)_2$. Based on Student 4's explanation, which of the following chemical equations best represents a process that occurred in the water when the scientist made the MC solution?

A. $Mg(ClO_3)_2 \rightarrow Mg + 2ClO_3$
B. $Mg(ClO_3)_2 \rightarrow Mg^{2+} + 2ClO_3^-$
C. $Mg(ClO_3)_2 \rightarrow 2MgClO_3$
D. $Mg(ClO_3)_2 \rightarrow 2MgClO_3^{2-}$

DRILL 2

Passage III

A baseball team's general manager tested the performance of 3 brands of pitching machines under differing conditions.

Experiment 1

Each brand of pitching machine (Brand A, Brand B, and Brand C) was loaded with game-used baseballs and set to throw 30 pitches, 15 at the "fastball" setting and 15 at the "changeup" setting. During each pitch, the following procedure was followed:

1. The manager set the pitching machine to the appropriate setting and activated the machine by pressing a button.

2. A ball was placed into the machine, and a radar gun set up next to the machine recorded the *initial velocity, V*, of the pitch.

3. The point at which the ball hit the ground was recorded, and the *horizontal displacement, d*, to the pitching machine was measured. It was found that the horizontal displacement of each pitch from the pitching machine could be estimated as a function of initial velocity of the pitch by the equation

$$d = \frac{0.2\,V^2}{32 \text{ ft/sec}^2}$$

The results of each set of 15 pitches were averaged to get average values of V (in ft/sec) and d (in ft) for each pitch setting, fastball and changeup, on each brand of pitching machine. The results of the experiment are shown in Table 1.

Table 1

Pitching machine	Pitch setting	Average V (ft/sec)	Average d (ft)
Brand A	fastball	126.6	100.3
	changeup	101.3	64.0
Brand B	fastball	120.4	90.7
	changeup	98.3	60.4
Brand C	fastball	128.8	103.9
	changeup	102.7	65.2

Experiment 2

The three pitching machines were tested with new baseballs using the procedure for Experiment 1. The results were recorded and are shown in Table 2.

Table 2

Pitching machine	Pitch setting	Average V (ft/sec)	Average d (ft)
Brand A	fastball	123.3	95.0
	changeup	99.2	61.8
Brand B	fastball	118.5	87.1
	changeup	97.1	58.9
Brand C	fastball	125.5	98.2
	changeup	101.9	64.3

Experiment 3

The pitching machine produced by Brand A was tested with a teeball, a softball, a youth baseball, and a major league baseball that were each previously used in a game. The procedure used in Experiment 1 was repeated for each type of ball using both the fastball and changeup settings. The results are shown in Figure 1.

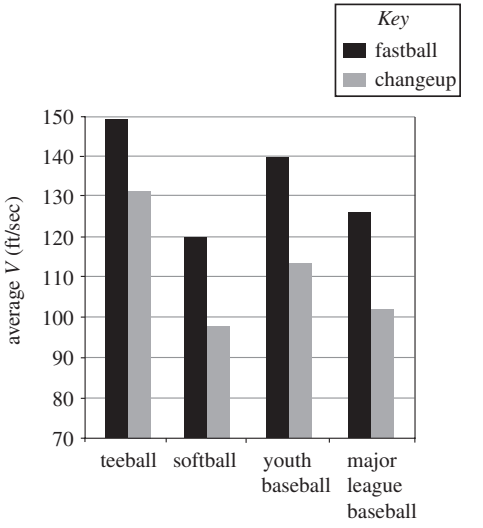


Figure 1

14. Which of the following statements about the design of the 3 experiments is consistent with their descriptions?

F. Experiment 1 was the only experiment in which more than 3 types of ball were involved.
G. Experiment 3 was the only experiment in which the pitching machines were tested with game-used balls.
H. Experiments 1 and 2 were the only experiments in which more than one brand of pitching machine was tested.
J. Experiments 2 and 3 were the only experiments in which the pitching machines were tested on more than one pitch setting.

15. Any pitching machine that produced an average d less than 60.5 ft would not be able to reach home plate and was designated as "unsatisfactory" by the general manager. Based on the results of Experiments 1 and 2, which machine(s) was(were) most likely designated as "unsatisfactory" under at least 1 setting?

A. Brand B only
B. Brands A and B only
C. Brands B and C only
D. Brands A, B, and C

16. The table below gives the mass of each of the balls used in Experiment 3.

Ball type	Mass (oz)
Teeball	4.178
Softball	6.230
Youth baseball	4.499
Major league baseball	5.125

For a given pitch setting, as mass increased, the average V:

F. increased only.
G. decreased only.
H. did not vary.
J. varied, but with no general trend.

17. Consider the 15 pitches in Experiment 2 in which the pitching machine produced by Brand B was set to throw fastballs. Which of the following statements about the 15 pitches' initial velocities is most likely correct?

A. All 15 velocities were less than 118.5 ft/sec.
B. All 15 velocities were greater than 118.5 ft/sec.
C. Some of the velocities were less than 118.5 ft/sec, and some of the velocities were greater than 118.5 ft/sec.
D. All 15 velocities were equal to 118.5 ft/sec.

18. Suppose that in Experiment 3, a fifth ball had been tested on the fastball setting, and its average d was determined to be 90.7 ft. Based on the results of Experiment 1, the average V for this ball on the fastball setting would most likely have been closest to the average V in Experiment 3 for which other type of ball on the fastball setting?

F. Teeball
G. Softball
H. Youth baseball
J. Major league baseball

19. According to the results of Experiments 1 and 2, compared to the pitches on the fastball setting, the pitches on the changeup setting resulted in:

A. greater average initial velocities and greater average distances.
B. greater average initial velocities and lesser average distances.
C. lesser average initial velocities and greater average distances.
D. lesser average initial velocities and lesser average distances.

20. In a new trial of 15 pitches using the fastball setting, the pitching machine produced by Brand C was tested with game-used baseballs in a high-altitude environment with lower air resistance. To estimate d, the following equation was used:

$$d = \frac{0.23\,V^2}{32\ \text{ft/sec}^2}$$

The average V for this set of trials was 128.8 ft/sec. Was the average d more likely less than 103.9 ft or more than 103.9 ft ?

F. Less; a pitch at the same initial velocity encountering less air resistance will not travel as far.
G. Less; a pitch at the same initial velocity encountering more air resistance will not travel as far.
H. Greater; a pitch at the same initial velocity encountering less air resistance will travel farther.
J. Greater; a pitch at the same initial velocity encountering more air resistance will travel farther.

DRILL 3

Passage IV

A team of volcanologists studied ash deposits in the wake of a volcanic eruption. They measured the thickness and composition of the ash at four different points along the slope of the volcano (see diagram). At each point, cores of ash were cut away at several locations 0.5 m apart in order to measure the thickness of the ash layer using a ruler.

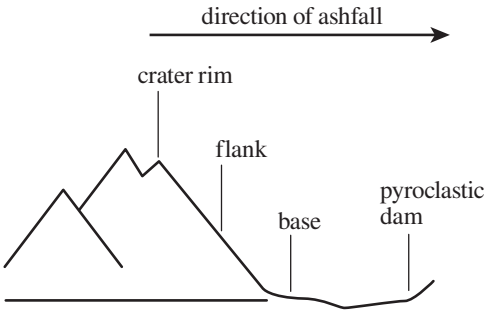


diagram of measurement points

Study

The ash layer at each of the four points was measured on the day of the eruption using a coring device to remove the ash layer and a centimeter ruler to determine its thickness. On subsequent days, the volcanologists returned to measure the ash thickness at each point. To account for the uneven distribution of the ash layer, several cores were taken at each of the four points. Each measurement was converted to a *relative ash thickness* (the average measured thickness of the ash layer at a point divided by the average value of the ash thickness at the same point on the day of the eruption). The results are shown in Figure 1.

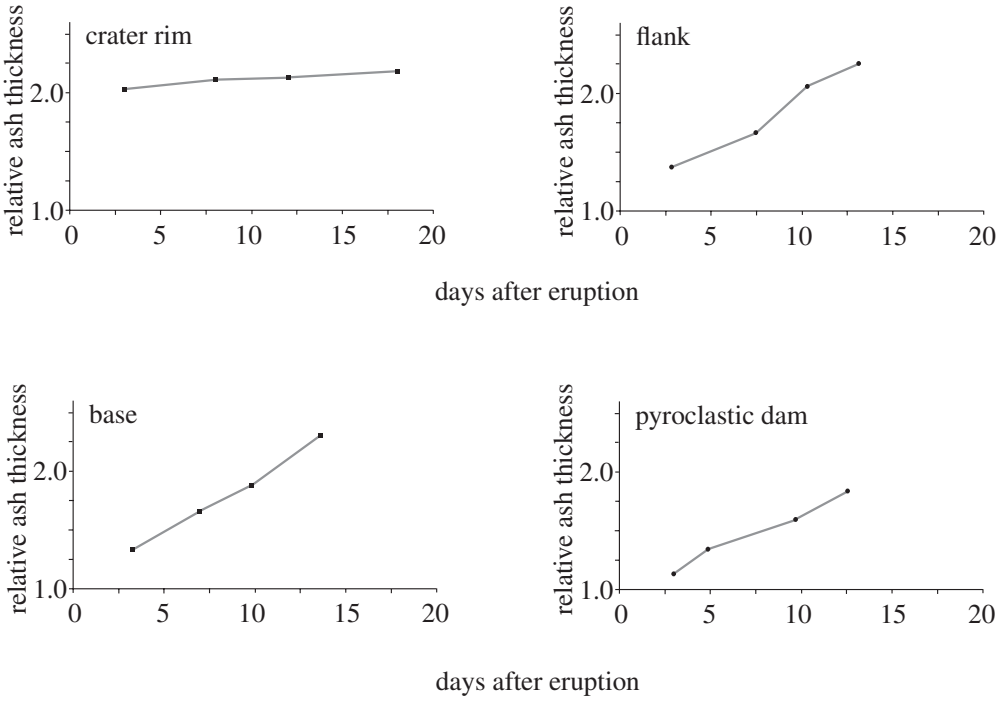


Figure 1

On the day of the eruption, air samples of known volume were collected at each of the 4 measurement points and a special filter was used to remove all particles smaller than 12 μm in diameter, which are known to be particularly hazardous to human health. The total mass of the particles was obtained. The particles were further passed through a series of 11 filters to sort them by size and assigned a value on the *PM scale* (a measure of the diameter of small particles), where PM1 was used to denote all particles smaller than 1 μm in diameter, PM2 all particles smaller than 2 μm but larger than 1 μm, and so on. Each of the 12 groups of particles corresponding to the 12 PM scale values was separately weighed, followed by dividing each group's total mass by the volume of the air sample to obtain the concentration of each type of particle in the air (see Figure 2).

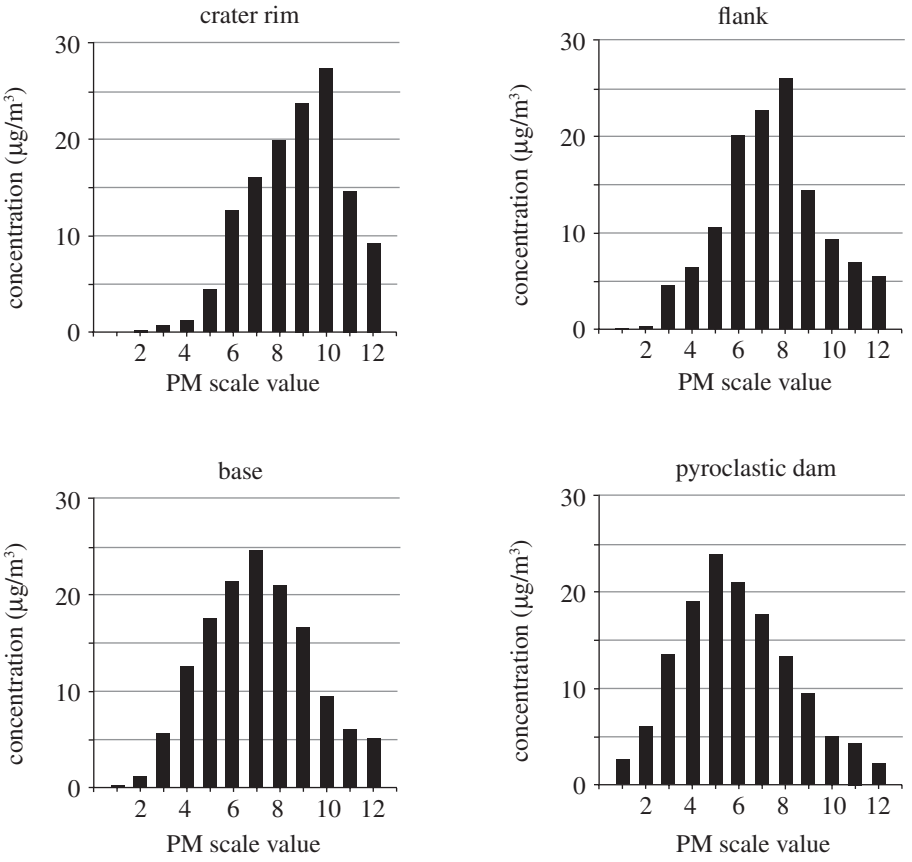


Figure 2

21. According to Figure 1, at the base site, as the number of days after eruption increased, the relative ash thickness:

A. decreased only.
B. increased only.
C. decreased, then increased
D. increased, then decreased.

22. According to Figure 2, at the crater rim, ash particles corresponding to which 2 adjacent PM scale values both had a concentration greater than 20 $\mu g/m^3$?

F. PM6 and PM7
G. PM7 and PM8
H. PM8 and PM9
J. PM9 and PM10

23. If in the study the volcanologists had returned to the crater rim on Day 21 after the eruption, the relative ash thickness at that time would most likely have been closest to which of the following?

A. 1.4
B. 1.8
C. 2.3
D. 2.7

24. The ash particles with the highest *fall speed* in the study were the particles with the largest median in terms of diameter. Based on Figure 2, the collected ash particles from which measurement point had the highest fall speed?

F. Crater rim
G. Flank
H. Base
J. Pyroclastic dam

25. What was the average ash thickness measured on the day of the eruption at the crater rim?

A. 1.0 cm
B. 2.0 cm
C. 5.0 cm
D. Cannot be determined from the given information

26. Suppose that the air sample taken at the pyroclastic dam had a total volume of 20 m^3. Based on Figure 2, the ash particles making up the PM10 category would have a mass closest to which of the following?

F. 100 μg
G. 200 μg
H. 300 μg
J. 400 μg

27. Ash particles in categories PM1-PM3 are classified as *fine inhalable particles*, and ash particles in categories PM10-PM12 are classified as *non-inhalable particles*. According to Figure 2, from site to site in the direction of ashflow, how did the concentration of fine inhalable particles change, and how did the concentration of non-inhalable particles change?

	fine inhalable particles	non-inhalable particles
A.	decreased	increased
B.	increased	decreased
C.	increased	increased
D.	decreased	decreased