ACT Science Practice Paper 9
SET-1

Directions: Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

There are four planets in our solar system called gas giants: Jupiter, Saturn, Uranus, and Neptune. They are so named because they are composed largely of gases rather than solids. Figure 1 shows how temperatures of the atmospheres of Jupiter, Neptune, and Saturn vary with altitude above the cloud tops. Table 1 gives the composition of the planets in both relative abundance of gases and the altitude at which those gases are most abundant. Table 2 gives what the temperature at the cloud tops would be without greenhouse warming.

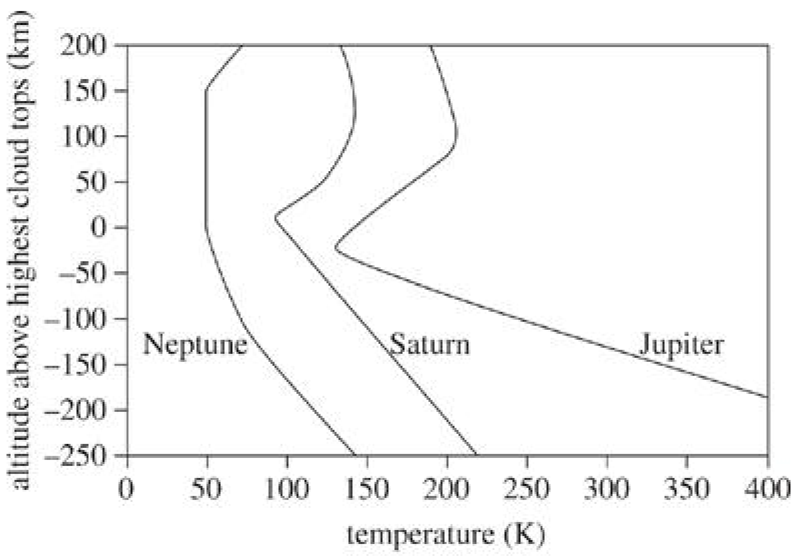


Figure 1

Table 1						
	Relative abundance (%)			Altitude above cloud tops where most abundant (km)		
Gas	Jupiter	Neptune	Saturn	Jupiter	Neptune	Saturn
H	86.1	79.0	96.1	–1,000 to –70,000	–10,000 to –23,000	–1,000 to –60,000
He	13.6	18.0	3.3	–500 to –1,000	–500 to –10,000	–500 to –900
CH_3	0.2	3.0	0.4	0 to 300	–100 to 0	0 to 200
NH_3	0.0045	0	0.0035	0 to –100	–	–50 to –200
H_2O vapor	0.0055	0	0.0065	–50 to –100	–	–200 to –300

Table 2	
Planet	Temperature at cloud tops without greenhouse warming (K)
Jupiter	100
Neptune	50
Saturn	25

1. According to Figure 1, the temperature of Neptune remains the same as altitude above the highest cloud tops increases from:

F. -250 km to -200 km.

G. -150 km to -50 km.

H. 0 km to 100 km.

J. 150 km to 200 km.

2. According to Figure 1, the temperature of Jupiter changes the most between:

A. -150 km and -50 km.

B. -50 km and 50 km.

C. 50 km and 100 km.

D. 100 km and 200 km.

3. Considering only the gases listed in **Table 1**, which gas is more abundant in the atmosphere of Jupiter than in the atmosphere of either Neptune or Saturn?

F. H

G. CH_3

H. NH_3

J. He

4. Based on **Table 2**, the average temperature at Saturn's cloud tops *without* greenhouse warming is how many degrees cooler than the temperature given in Figure 1?

A. 5 K

B. 25 K

C. 75 K

D. 150 K

5. Which of the following statements about H and He in the atmospheres of the 3 planets is supported by the data in **Table 1**?

F. Both Saturn and Neptune have a higher relative abundance of He than of H.

G. Both Saturn and Jupiter have a higher relative abundance of He than of H.

H. Both Jupiter and Neptune have an equivalent relative abundance of He and H.

J. Both Saturn and Neptune have a lower relative abundance of He than of H.

Nuclear fission occurs when the *nucleus* (central core) of an atom splits into multiple parts. This splitting is accompanied by the release of a large amount of energy, as in nuclear weapons and nuclear power plants.

A chemical element is said to be *radioactive* if it is prone to fission. Fission is often the result of the nucleus of a radioactive atom absorbing a *free neutron* (an uncharged nuclear particle). When a *fission event* occurs, the nucleus often splits into two new nuclei and produces free neutrons. This process generates the possibility of a chain reaction. If, on average, a fission event produces one neutron and that neutron causes another nucleus to fission, the reaction is said to be *critical*; that is, it will sustain itself, but not increase in magnitude. If one fission event releases more free neutrons than are required to initiate another fission event, the reaction is said to be *supercritical*; that is, it will sustain and increase in magnitude. If more neutrons are required to initiate a fission event than are released in fission, the reaction is said to be *subcritical*: the reaction will not sustain itself.

Many factors affect how many neutrons from each fission event will trigger another fission event. The most important factor is the mass (*m*) of the substance. The criticality of a substance also depends on the substance's purity, shape, density, temperature, and whether or not it is surrounded by a material that reflects neutrons.

In a nuclear weapon, a radioactive substance is made highly supercritical. One of the primary challenges in building a nuclear weapon is keeping the radioactive material subcritical prior to detonation, then upon detonation, keeping it supercritical for a long enough period of time for all of the material to fission before it is blown apart by the energy of the blast. A *fizzle* occurs when a nuclear weapon achieves supercriticality but is blown apart before all of the radioactive material fissions.

The first nuclear weapons were made of enriched uranium, or U-235. The density (ρ) of U-235 under normal conditions is 19.1 g/cm^3. For U-235 to attain a supercritical state, the product of its mass and density must exceed 10^6 g^2/cm^3. If it is assembled over too long a time (*t*), it will achieve slight supercriticality and then fizzle. Therefore, the speed of assembly (measured as *t* divided by ρ), must be less than 10^{-5} sec × cm^3/g (*Michelson's Criterion*).

Two schemes for the assembly of a supercritical amount of U-235 that avoid fizzle are discussed below.

Gun-Type Weapon

At one end of a tube, similar to a gun barrel, is a hollow, subcritical cylinder of U-235 with a mass of 48 kg; on the other end is a subcritical pellet of U-235 with a mass of 12 kg. The pellet is propelled by a small explosion down the tube and into the cylinder of U-235. The combined mass of the two pieces of U-235 is great enough to induce a supercritical state. Since the combined cylinder of U-235 is at or near normal density, the assembly process must be completed in less than 2 × 10^{-4}sec to meet Michelson's Criterion.

Implosion-Type Weapon

A 15-kg sphere of U-235 is surrounded by explosives. When the explosives are simultaneously detonated, the U-235 is compressed in order to achieve supercriticality. The explosives are designed to compress the U-235 to a density of approximately 70 g/cm^3 in less than 10^{-7} sec.

6. For both types of weapon, avoiding fizzle is difficult because:

A. the mass of U-235 must be large.

B. 2 separate pieces of U-235 must be brought together.

C. U-235 is highly unstable.

D. of the speed with which the U-235 must be assembled.

7. Comparing the mass of uranium used in the two types of weapons reveals that:

F. the mass of U-235 used in the implosion-type weapon is less than the mass of U-235 used in the gun type weapon.

G. the mass of U-235 used in the implosion-type weapon is greater than the mass of U-235 used in the gun type weapon.

H. the mass of U-235 used in the implosion-type weapon is greater in some cases and less in some cases than the mass used in the gun-type weapon.

J. the mass of U-235 used in both weapons is approximately the same.

8. Both types of weapons use explosives in order to:

A. increase the heat of the U-235.

B. release the nuclear energy of the weapon from the confinement of the bomb's casing.

C. achieve supercriticality of U-235.

D. generate neutrons to start the chain reaction.

9. For an implosion-type weapon, when U-235 has reached supercriticality, to which of the following is the value of ρ closest?

F. 10^{-3} g/cm^3

G. 0.1 g/cm^3

H. 100 g/cm^3

J. 10^6 g/cm^3

10. In the implosion-type weapon, the explosives are used to:

A. trigger the first fission events.

B. heat the U-235 so it will become supercritical.

C. increase the density of U-235.

D. produce additional damage.

11. In order to achieve a supercritical state just before detonation, both methods:

F. increase the product of the mass and density of the U-235.

G. decrease the product of the mass and density of the U-235.

H. increase the amount of U-235 in the weapon.

J. decrease the time necessary for all the U-235 to fission.

12. Scientists are trying to build a bomb using only 8 kg of U-235. Presently they can achieve a ρ of 150 g/cm^3 with $t = 10^{-2}$ sec. Which of the following changes would be the most likely to get the weapon to meet Michelson's Criterion?

A. Decrease both *t* and ρ.

B. Decrease *t* and leave ρ the same.

C. Increase *t* and decrease ρ.

D. Increase *t* and leave ρ the same.

SET -2

A scientist studying hemoglobin investigated the impact of temperature and carbon dioxide (CO_2) concentrations on the binding capacity of oxygen (O_2). The scientist observed the binding of oxygen to hemoglobin molecules as the pressure of oxygen was increased. The temperature and CO_2 were varied to identify their direct impact on the binding capacity of O_2.

Figure 1 displays the impact of changes in temperature on the binding (percent of hemoglobin saturated) of oxygen. Figure 2 displays the impact of varying carbon dioxide concentrations on oxygen binding. Under normal conditions, the core body temperature is 37°C and has carbon dioxide and oxygen concentrations of 40 mmHg and 100 mmHg respectively.

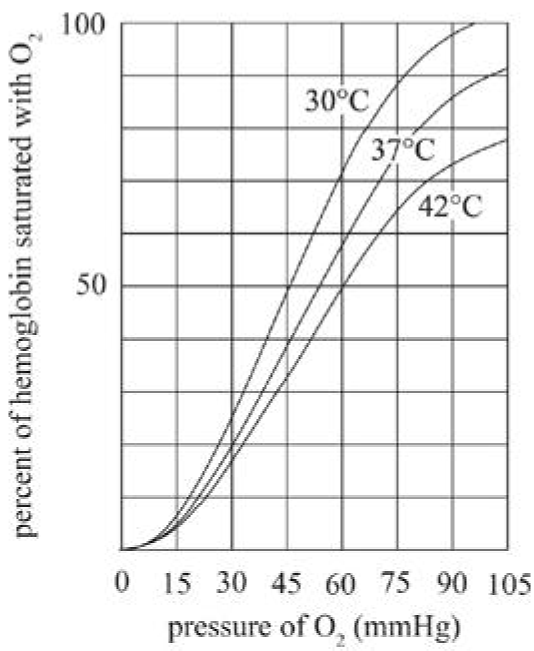


Figure 1

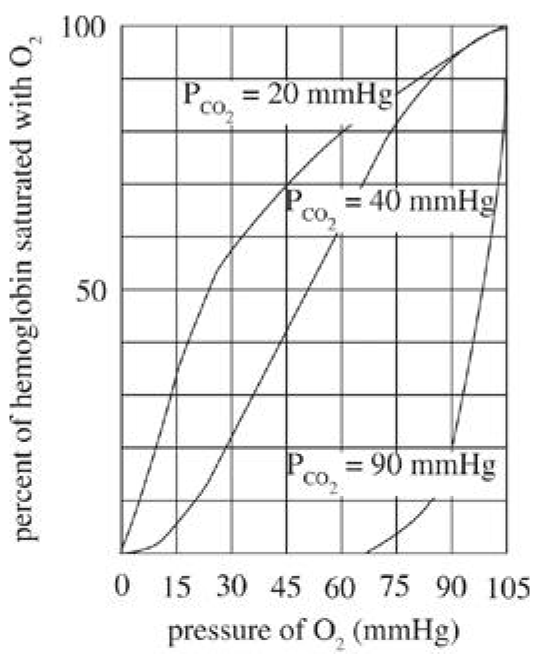


Figure 2

1. According to Figure 1, if the temperature is 42°C, which of the following changes in pressure of oxygen will cause the least increase in the percent of hemoglobin saturated with O_2?

F. 0-15 mmHg

G. 15-30 mmHg

H. 30-45 mmHg

J. 45-60 mmHg

2. According to Figure 1, which of the following sets of temperature and pressure of oxygen results in the lowest hemoglobin saturation with oxygen?

Temperature (°C)

A. 37

B. 37

C. 42

D. 42

3. According to Figure 1, if the pressure of oxygen is 100 mmHg and 65% of hemoglobin molecules are saturated with oxygen then the core body temperature is most likely within which of the following ranges?

F. Less than 30°C

G. 30°C-37°C

H. 37°C-42°C

J. Greater than 42°C

4. Based on Figure 2, if an individual has 70% of his hemoglobin molecules saturated at a pressure of 75 mmHg of oxygen, then the individual's carbon dioxide pressure is most likely closest to which of the following?

A. 30 mmHg

B. 50 mmHg

C. 70 mmHg

D. 90 mmHg

5. According to Figure 2, at a CO_2 pressure of 90 mmHg, as the pressure of O_2 is increased from 45 mmHg to 90 mmHg, the percent of hemoglobin saturated with oxygen:

F. remains constant, then increases.

G. remains constant, then decreases.

H. increases, then decreases.

J. decreases, then increases.

The magnitude of seismic energy released from an earthquake is often described using the logarithmic and unit-less Richter scale. Originating at the *epicenter*, seismic energy travels through the earth via waves such as L-waves, S-waves, and P-waves. Earthquakes with a Richter scale magnitude of 5.0 or greater can typically be detected throughout the world. Figure 1 depicts the layers of the earth and typical travel patterns of seismic waves. Table 1 lists characteristics of those seismic waves. Figure 2 shows the number of earthquakes (by magnitude) detected at a particular seismic activity monitoring station in the past 30 years, as well as the percentage probability of future earthquakes (by magnitude) in that same region in the next 30 years.

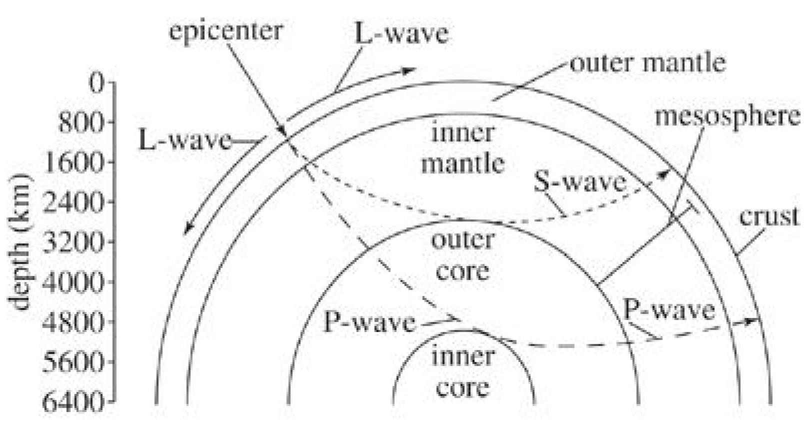
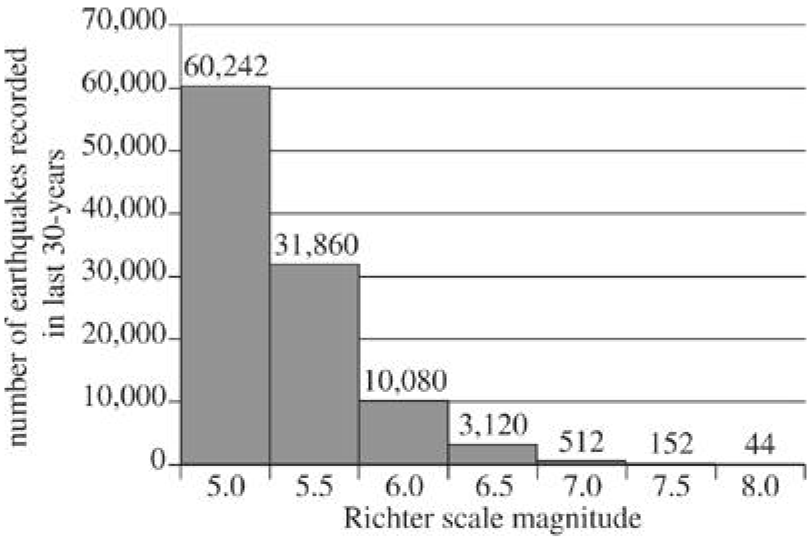


Figure 1

Table 1

Seismic wave	Depth range (km)	Crust velocity (m/s)
L-wave	0-10	2.0-4.5
S-wave	0-2921	3.0-4.0
P-wave	0-5180	5.0-7.0



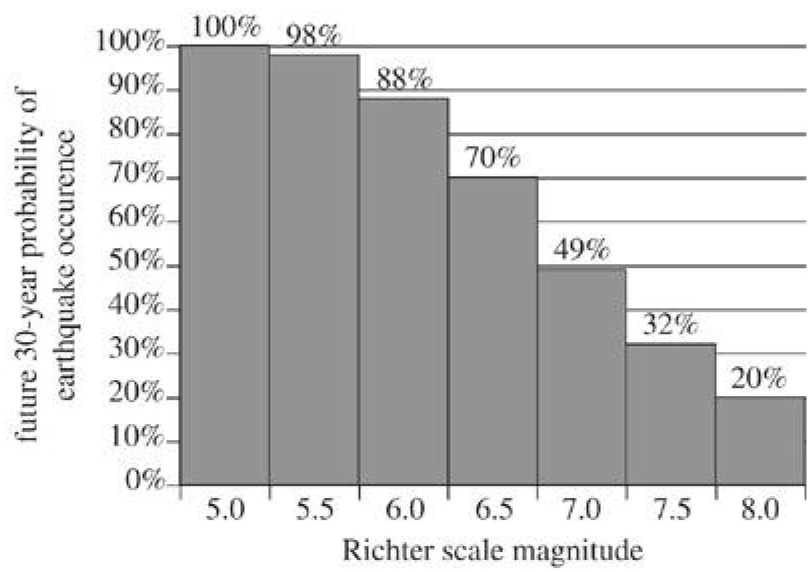


Figure 2

6. Figure 1 defines the mesosphere as a region of the Earth that overlaps which of the following atmospheric layers?

I. Outer core

II. Inner mantle

III. Outer mantle

A. II only

B. I and II only

C. II and III only

D. I, II, and III

7. A series of seismic waves was observed from an observation station. The average crust velocity of these waves was 3 m/s, and their maximum depth occurred in the inner mantle. Based on Figure 1 and **Table 1**, the seismic waves observed were most likely:

F. L-waves.

G. S-waves.

H. P-waves.

J. K-waves.

8. Given the data in Figure 2, the future probability of an earthquake occurrence decreases by more than half when comparing which of the following 2 Richter scale magnitudes?

A. 5.0 and 6.0

B. 6.0 and 6.5

C. 6.5 and 7.5

D. 7.5 and 8.0

9. According to Figure 2, the probability of a future earthquake occurrence is lowest for which of the following ranges of Richter scale magnitude?

F. 5.5 to 6.0

G. 6.0 to 6.5

H. 6.5 to 7.0

J. 7.0 to 7.5

10. Based on Figure 2, the ratio of Richter scale 5.5 earthquakes to Richter scale 5.0 earthquakes in the last 30 years can be expressed approximately by which of the following fractions?

A. $\frac{1}{3}$

B. $\frac{1}{2}$

C. $\frac{2}{3}$

D. $\frac{3}{2}$

SET 3

In agriculture, soils can be classified based on *mineral content* (the amount of various metals present in the soil), and *organic content* (the percent of soil volume occupied by material made by living organisms). Ideal concentrations of various minerals are given in parts per million (*ppm*) in Table 1. If the levels of different minerals of a soil are all similar, relative to the optimal levels, the soil is said to be *well defined*. If the levels of different minerals in a soil vary widely relative to the optimal levels, the soil is said to be *poorly defined*.

Table 1

Mineral	Ideal concentration (ppm)
Nitrogen	22
Phosphorus	14
Potassium	129
Chloride	12
Sulfur	88
Iron	6.9
Manganese	2.7

Study 1

Soil was taken from 5 different farms to a laboratory. The soils were *desiccated* (all water was removed), and a 1 L sample of each soil was prepared. In order to make sure that no minerals were trapped within the organic matter of a soil, the organic matter of each soil was burned by heating the soil to 500°C for 20 minutes. The ash of the organic matter was removed and the remaining soil analyzed for the concentration of various minerals. The results are shown, as percent of ideal concentration, in Table 2.

Table 2					
Mineral	Concentration of minerals (% of ideal concentration)				
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Nitrogen	89	112	160	78	210
Phosphorus	76	19	212	94	34
Chloride	124	106	64	87	65
Sulfur	290	97	189	102	112
Iron	57	26	73	91	165
Manganese	86	45	89	97	109

Study 2

To determine the percentage of the mass of each soil composed of organic matter, the above procedure was repeated, with the soil weighed before being heated to 500°C and after having the ash removed. The number of live cells (bacteria, fungi, etc.) in a cubic millimeter of each soil was determined by microscopic analysis. The results are presented in Table 3.

Table 3		
Farm	% organic matter	# living cells per mm^3
1	7.1	2,964
2	8.9	3,920
3	4.8	1,642
4	6.6	2,672
5	18.9	9,467

1. Soils with more living cells per mm^3 generally consume more oxygen than soils with fewer living cells. Based on this information, the soil of which farm would be expected to consume the most oxygen?

F. Farm 1

G. Farm 2

H. Farm 3

J. Farm 5

2. If, in Study 2, before and after heating a soil sample to 500°C for 20 minutes and removing the ash, the mass of the sample was approximately the same, which of the following is the most reasonable conclusion?

A. There was little or no water in the soil.

B. There was a large quantity of water in the soil.

C. There was little or no organic matter in the soil.

D. There was little or no mineral content in the soil.

3. In Study 2, before heating the sample to 500°C, it was necessary for the scientists to desiccate the soil in order to ensure that:

F. the water was not mistaken for a mineral.

G. the water was not consumed by the living cells.

H. it was possible to count live cells by making sure the soil didn't stick together.

J. the mass of the water was not mistaken for organic matter.

4. Based on Study 2, if the scientists took a soil sample from another farm, and the number of living cells per mm^3 was determined to be 2,100, the % organic matter in that soil would most likely be:

A. less than 4.8.

B. between 4.8 and 6.6.

C. between 6.6 and 7.1.

D. greater than 7.1.

5. Beans grow fastest in soils with high nitrogen and iron levels. If all other levels were equal, then based on the results of Study 1, which of the farms would be expected to produce the fastest growing beans?

F. Farm 5

G. Farm 4

H. Farm 3

J. Farm 2

6. The soil of which of the farms would likely be considered the most well defined, based on the information in Study 1?

A. Farm 1

B. Farm 2

C. Farm 3

D. Farm 4

Rock candy was made by putting a mixture of 180°°F water and an amount of sugar (S1) into an apparatus shown in Figure 1, inserting a string through the top, and allowing the mixture to stand and cool. The internal container was a jar made of glass, and the external container was made of plastic.

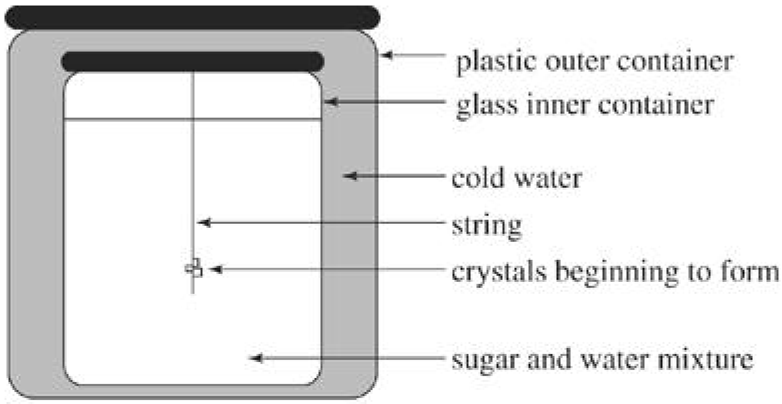


Figure 1

Figure 2 shows how the temperature of S1 and the temperature of the cold water in the outer jar varied with time as the mixture was allowed to stand.

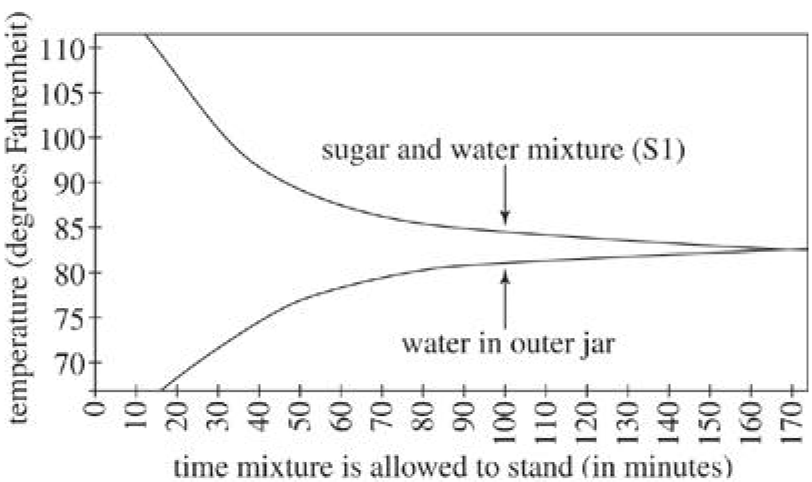


Figure 2

According to the *Second Law of Thermodynamics*, as the temperature of S1 *decreases*, the orderliness of the atoms in the solution must *increase*. This is why crystals form on the string, creating rock candy. Because of the Second Law of Thermodynamics, temperature of the sugar and water mixture can be monitored to measure orderliness of the atoms in the mixture. Two other sugar and water mixtures (S2 and S3) were monitored under standing conditions the same as those used for S1.

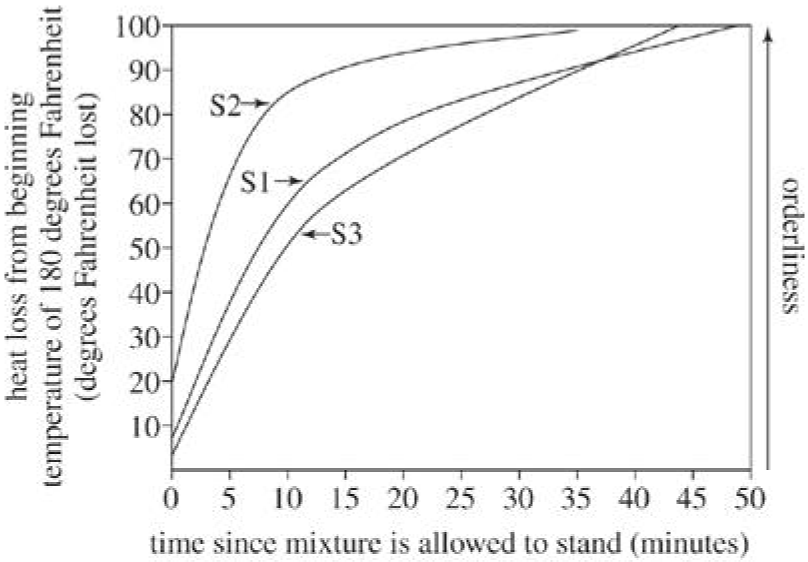


Figure 3

7. According to Figure 3, for S3, the heat lost from the beginning temperature of 180°F after being allowed to stand for 30 minutes is *closest* to which of the following?

F. 10 degrees Fahrenheit

G. 50 degrees Fahrenheit

H. 80 degrees Fahrenheit

J. 100 degrees Fahrenheit

8. According to Figures 2 and 3, as the temperature of the water in the outer jar increased, the heat loss from the beginning temperature of 180°F for S1:

A. decreased only.

B. increased only.

C. decreased, and then increased.

D. increased, and then decreased.

9. An additional sugar and water mixture (S4) was monitored under conditions identical to those used to gather the data in Figure 3. The heat lost after being allowed to stand 0 minutes was 15°F. How does the initial orderliness of the atoms in S4 compare with the orderliness of the atoms in mixtures S1, S2, and S3?

F. The orderliness of S4 was greater than the orderliness of S1, S2, and S3.

G. The orderliness of S4 was less than the orderliness of S1, S2, and S3.

H. The orderliness of S4 was greater than the orderliness of S2 and S3, but less than the orderliness of S1.

J. The orderliness of S4 was greater than the orderliness of S1 and S3, but less than the orderliness of S2.

10. Based on Figure 1, which of the following best explains the trends shown in Figure 2? In sum, as the time the mixture was allowed to stand increased, the heat was conducted by the:

A. glass jar from the sugar and water mixture to the water outside the jar.

B. glass jar from the water outside the jar to the sugar and water mixture.

C. plastic container from the string to the water outside the jar.

D. plastic container from the string to the sugar and water mixture.

11. Rock candy begins to form when the temperature of the sugar and water mixture has lost 100°F from its beginning temperature. Based on Figure 3, which mixture, if any, would begin to form rock candy first?

F. S1

G. S2

H. S3

J. All mixtures would begin to form rock candy at the same time.