Solutions to End-of-Chapter Questions

Chapter 1: About Science

1. An experiment.

2. Experiments are not very good at proving ideas right. They can be very useful, however, for proving ideas wrong.

3. Scientific research usually begins with the asking of a very broad question.

4. Powerful lasers.

5. There are 60 carbon atoms in the original buckyball identified by Kroto, Smalley, and Curl. Interestingly, they also discovered larger and smaller buckyballs, but C-60 was the most stable.

6. The research team led by Don Huffman of the University of Arizona and Wolfgang Kratschmer of the Max Planck Institute in Germany.

7. Technology is the application of knowledge of the natural world (usually gained through science) to practical purposes.

8.. The greatest obstacle to solving today's problems lies more with social inertia than with a lack of technology.

9. No, medical X rays are used because the benefits of their diagnostic powers are judged to be greater than the risks of causing cancer.

10. Yes, when competent observers agree that it should.

11. A hypothesis.

12. A scientific theory.

13. Chemistry is often called the central science because it touches all of the sciences.

14. Basic research leads to a greater understanding of how the natural world works. Applied research focuses on developing applications of knowledge gained through basic research.

15. Members of the American Chemistry Council have pledged to manufacture their products without causing environmental damage.

16. The two major unit systems are the United States Customary System and the Système International.

17. A prefix is used in the metric system to designate a unit that is larger or smaller than a particular base unit by one or more powers of 10.

18. A milligram is equal to one thousandth of a gram.

19. As noted by Lavoisier, air has mass, which means that it also has weight. The weight of this air pushes against us in all directions. The force of this push at sea level is about 14 pounds for every square inch. So how does the card hold up the water in the bottle? Answer: It doesn't. The downward push from the weight of the water in the bottle is less than a pound. The upward (and sideways) push against the outer side of the card from the weight of the air, however, is about 14 pounds. The air wins! Although invisible, air is real stuff. Because of this, birds and airplanes are able to fly. When turned sideways, the water flows out of the cup.

20. As you hold up the can, the water flows out through the hole because of gravity, which is a force that pulls things downward. When you release the can, gravity continues to do the same thing—it pulls the water downward, only this time it pulls the can down with it too. Because the can and the water are falling together, there is no reason for the water to flow out of the can.

For your further consideration: Does the same hold true when the hole is made not at the bottom of the can, but along the lower side? Try it and see.

21. A large risk/benefit ratio, such as 100, can be indicated as follows:

RISK/benefit = 100

This is a risky activity that you might choose to avoid. A small risk benefit ratio, such as 0.01, can be indicated as follows:

risk/BENEFIT = 0.01

This activity offers much benefit for only little risk and so may be worthwhile. Regarding the purchase of a lottery ticket, the chances of losing a small amount of money (the risk) far exceeds the chances of gaining a large amount of money (the benefit). The risk/benefit ratio, therefore, is quite large. However, if you ignore the probabilities, as many people do, then the risk benefit ratio appears deceptively small.

22. (25 ~~years~~)(12 ~~months~~/1 year) = 300 months

(25 ~~years~~)(365 days/1 ~~year~~) = 9,125 days

Or in a single equation form:

(25 ~~years~~)(12 ~~months~~/1 ~~year~~)(25 ~~years~~)(365 ~~days~~/1 ~~year~~) = 9,125 days

23. (2000 ~~years~~)(365 ~~days~~/1 ~~year~~)(24 ~~hours~~/1 ~~day~~)(60 ~~min~~/1 ~~hour~~)(60 sec/1 ~~min~~) = 63,072,000,000 seconds

24. b < c < a (The hypothesis may not be testable, which may make it less believable than a scientific hypothesis. The scientific hypothesis, however, may have yet to be tested, which would make it less believable than the scientific theory.)

25. a < c < b (Traveling by plane is generally much safer than traveling by car, especially over long distances. A teenager driving and talking on a cell phone is very dangerous.)

26. b < a < c (This assumes the quality of the generic medicine is equal to that of the brand name medicine and also that the herbal remedy does little to alleviate the sickness aside from a placebo effect.)

27. The explanations given by science are testable explanations of the natural world.

28. The idea of the Earth revolving around the Sun is the simplest explanation of what we observe. It helps to explain the seasons. It also helps to explain why we see different constellations of stars at different times of the year. We can chart the progress of other planets around the Sun and infer that perhaps we are like them and thus also revolve around the Sun. From these and other observations, we conclude that the Earth revolves around the Sun. Alternatively, we can trust others to make these observations and reach these conclusions for us. But do we trust their observations and conclusions? If these can be verified repeatedly by many different people working in many different laboratories, then the answer is “Yes, most likely.”

29. The older, well-seasoned scientist tends to spend more time pondering broad questions and communicating with others. The younger, less-seasoned scientist tends to spend more time on the tedious detailed work, which includes a lot of time in the library learning about what has been published and in the laboratory working late at night trying to perform successful experiments.

30. The performing of experiments is typically, but not necessarily, the most involved and time-consuming, as well as money-consuming, activity.

31. A scientist can develop a hypothesis at any time no matter what she may be doing. She could be cooking at a barbeque when suddenly the idea pops into her head. Again, for emphasis, there is no one prescribed path to follow in order to hold to the scientific method.

32. Because of the great potential for error in a procedure, an experiment can only be considered valid if other scientists can reproduce it.

33. It is a sign of strength for a scientist to change his or her view when faced with evidence inconsistent with that view. Holding to hypotheses and theories that are either not testable or have been shown to be wrong is contrary to the spirit of science.

34. Any false claims are eventually uncovered. Scientists, therefore, stand to gain most from reporting their results truthfully.

35. Kroto, Curl, and Smalley were the initial discovers of this molecule and for this they received the Nobel Prize. Huffman and Kratschmer's work merely helped to confirm this discovery.

36. Technologies whose risks and benefits differ for different people tend to be hotly debated. An example would include the placement of a large, obtrusive, and noisy wind energy turbine within a neighbor's backyard—the neighbor gets the benefit of cheap electricity while you gain an eyesore. Also, should people be allowed to use cell phones while driving? While the cell phone user gains the benefit of a convenient phone call, others share the risk of a potential traffic accident.

37. During the 1950s nuclear arms race, there was great fear that "the other side" with its different ideological views would attack. The benefit of the nuclear bombs was their ability to deter either side from being eager to use them. The very real risk was obscured of placing a lot of radioactivity into the atmosphere. This radiation made its way into the food chain. The supply of milk, for example, was soon found to be tainted with radioactive strontium. Of course, hindsight is 20/20. It's easy for us to look back on this history and shake our heads. At the time, coming out of the tragedy of World War II, however, the perspective was quite different. Actual risk and our perceptions of that risk are difficult to gauge.

38. The urge to protect oneself or one's immediate family and friends is strong. Thus, the perception of risk gets amplified when that risk is striking close to home. A greater focus on the benefits should help to offset the skewed perceived risk. Sadly, as in the case of vaccinations, this focus is often not realized until after the many children who didn't receive the vaccine become sick. Also helpful would be to foster a trust between the developers of a technology (the vaccination) and the users of that technology (the general public).

39. Vaccinations prevent sickness and this is their benefit. While not sick, however, people tend to move on with their lives often taking their good health for granted. In such a case, the benefit of the vaccination becomes invisible and thus difficult to perceive. A vaccination program, however, must continue until the disease has been totally eradicated across the entire population. This is especially true in our modern society where people travel between different parts of the world so frequently.

40. A hypothesis must be testable, at least in principle, in order to be deemed scientific. The tests may suggest that the hypothesis is correct or incorrect. Either way, so long as some definitive tests can be designed, then the hypothesis is scientific: a, c, d, f

41. Science is unable to answer non-testable questions, such as those that are philosophical or religious in nature. Science can, however, generate ideas that have philosophical or religious implications.

42. If all the material that makes a tree comes from the surrounding soil, then one would expect the mass of that surrounding soil to get smaller as the tree grows larger. For an experiment, therefore, you could grow a tree within a pot adding only water to keep the growing tree alive. The dry mass of the soil before the tree grows is then compared to the dry mass of the soil after the tree has grown, as well as to the mass of the tree itself. The results will show that the dry mass before and after has not changed sufficiently to account for the much greater mass of the tree. Interestingly, through photosynthesis, the bulk of a tree's mass comes from the absorption atmospheric carbon dioxide and water vapor plus water also coming up from the roots. This explains why large trees are not generally found growing within sunken depressions.

43. A scientific theory that *can* be modified to account for new experimental evidence is a theory that is stronger than it was prior to that modification. However, if such modifications to a scientific theory are not possible, then that theory is taken to be wrong and is scrapped.

44. You exhale carbon dioxide, some of which is absorbed by trees and transformed (via photosynthesis) into wood, which is used to make paper.

45. Physics is the most fundamental science as it lays the foundation for chemistry, which is the study of the physics of the atom. Chemistry, in turn, lays the foundation for the most complex science, which is biology.

46. Biology is the study of life. A living organism is an example of the most complicated chemical system in the universe. In learning biology, you need to have a solid understanding of the many chemicals that are used to create life. One important topic is DNA, – which holds the genetic code for a living organism, which consumes and generates all sorts of biomolecules, such as carbohydrates, lipids, and proteins. Learn your chemistry first before the biology. Then you will be much better equipped to understand the supremely complicated details of biology.

47. For the United States, the major advantage of using the United States Customary system is that this system is already in use and familiar to everyone. Instituting a different measurement system would involve considerable disruption in many areas of life, including science, commerce, and industry.

48. The number of zeros in the decimal equivalent is equal to the numeral given in the superscript of the exponential form. For example, there are two zeros in 100, which can be expressed as 10^2. Note also that there are zero zeros in 1, which has the exponential form 10^0. 49. Making observations is an activity that occurs on a continual basis, even during the course of other activities. Remember, we humans are very good at observing. We do it all the time.

50. Many medicines are flushed down drains or toilets directly or after already having passed through the human body and into the urine. These drugs then end up in downstream water supplies. By the time they reach the downstream consumer their concentration is at a relatively low level. But this level is easily measured. Perhaps of greatest concern is the effect these low doses might have over the long term. Drinking a single glass of drug tainted water might not have a noticeable effect. But what if this water is consumed by an individual over his or her lifetime? Once released into the environment, these drug molecules are difficult to remove because they are so dilute. A solution would be a media campaign to discourage people from flushing pharmaceuticals. But would the cost of such a campaign be worth it? First, scientists might assess the degree to which harm is being caused. But is there enough preliminary evidence to support such a research endeavor? Might the money be better spent on other more immediately pressing environmental issues, such as the global climate? Where we place our money for research can be a very difficult decision.

Chapter 2: Particles of Matter

1. It would take you 31,800 years to count to a trillion. Do this 125 million times and you would have counted to about the number of atoms there are in a single grain of sand.

2. A biological cell is microscopic, which means it is best viewed through a microscope.

3. The term atom was derived from the Greek phrase *a tomos*, which means “not cut” or “that which is indivisible.”

4. Antoine Lavoisier

5. Mendeleev predicted the existence of elements that had not yet been discovered.

6. Mass is a measure of inertia. Inertia is the resistance an object has to a change in motion.

7. Weight can change from one location to the next because it is dependent on gravity.

8. Mass is the measure of how much matter an object contains. Volume is the amount of space that the material occupies.