1 Reading, Writing and Doing Science

Learning Objectives

As you work through this chapter you will learn how to:

- identify and apply the elements of the scientific method.
- distinguish between science and pseudoscience.
- plan a scientific experiment.
- identify quantitative relationships between two quantities.
- graph quantitative data on an x-y scatter plot.
- interpret straight line graphs.

1.1 The Language of Science

Have you or a friend, when thinking about or discussing some situation, ever said "My theory is ..." ? In science sometimes commonly used words like theory have a very different meaning than what is usually associated with the term. In addition, there is often an extensive vocabulary of specialized terms used by scientists in various fields. Part of learning about science, and chemistry, involves learning a new language, just as if you were studying Greek or Chinese. In this text such new keywords will generally be introduced in **boldface**. It is essential that you learn these terms, including the proper spelling and any symbol or shorthand abbreviation used. You should also be able to explain the significance or meaning of each of these terms.

Scientists, like everyone else, sometimes get very casual in their speech and say one thing when, in fact, they mean another. For example, they may refer to the weight of an object when they really mean mass[3]. Often the context is understood by the reader so no confusion results. Sometimes the inappropriate use of a term is even acknowledged by the writer. However, science is usually discussed in very specific terms and such casual mistakes need to be avoided. Throughout this text and in your classroom you will be encouraged to be precise in your use of the scientific language of chemistry.

In science, the term theory means something very different than a guess or an opinion. The term **scientific theory** refers to an explanation of some phenomenon that has been extensively tested and is widely (if not universally) accepted by scientists. The idea that all matter is composed of atoms is an example of a well established theory and it provides explanations for a range of phenomena. However, a theory can be proved false at any time by new evidence. Scientists are constantly expanding, refining and questioning scientific theories.

The knowledge of science can be visualized by the set of concentric circles in Figure 1.1. The **core ideas of science** make up the inner circle. These are well established and do not change much. Ideas such as the theory of gravitational attraction or the theory of evolution are in the inner circle. Next come the **frontiers of science** where new ideas, often revolutionary, are being explored. The study of the nature and causes of autism or the design of lightweight, efficient batteries for automobiles fall into the science frontiers circle. Finally, the outermost ring refers to **fringe ideas**. Here there is much speculation and little science. The denial of global climate change and its man-made causes belongs in the fringe area.

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[3]**Mass** is a measure of the amount of matter in an object. In common experience the mass of an object does not change. **Weight** is a force caused by gravitational attraction and depends on location. The relationship between mass (m) and weight (w) is given by $w = mg$ where g is the acceleration due to gravitational attraction.

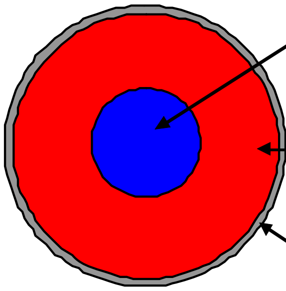


Figure 1.1 Representation of Science Knowledge[4]

1.2 Doing Science

How does a theory develop? It is the product of the scientific method being applied over and over again. The **scientific method** is a process used by scientists to develop a reliable and accurate representation of the natural world. It is based on **observations** rather than belief. The scientific method starts when you ask a question about something you observe. As Isaac Asimov (1920-1992), the prolific American author and biochemist best known for his science fiction stories, once observed, "The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' but 'That's funny...' ". In response to observations a hypothesis is proposed. A **hypothesis** is a tentative explanation of the possible cause of what was observed. It has the important characteristic that a scientific test can prove the hypothesis untrue. This tentative explanation allows one to make **predictions** about what should happen under certain circumstances. These predictions are then tested by **experimentation**. If the results are inconsistent with the predictions, and thus do not support the hypothesis, then it is rigorously questioned, and either rejected or modified to be consistent with the new

[4]Adapted from E. Scott, Science News, August 1, 2009, p. 32.

observations. If the predicted results are obtained, then they add support to the hypothesis, but they do not prove that the hypothesis is correct. Generally, a hypothesis can never be proven correct, only disproved. As more and more results from experiments lend support to a hypothesis, it becomes so well established it is recognized as a theory. These steps in the scientific method are outlined in Figure 1.2.

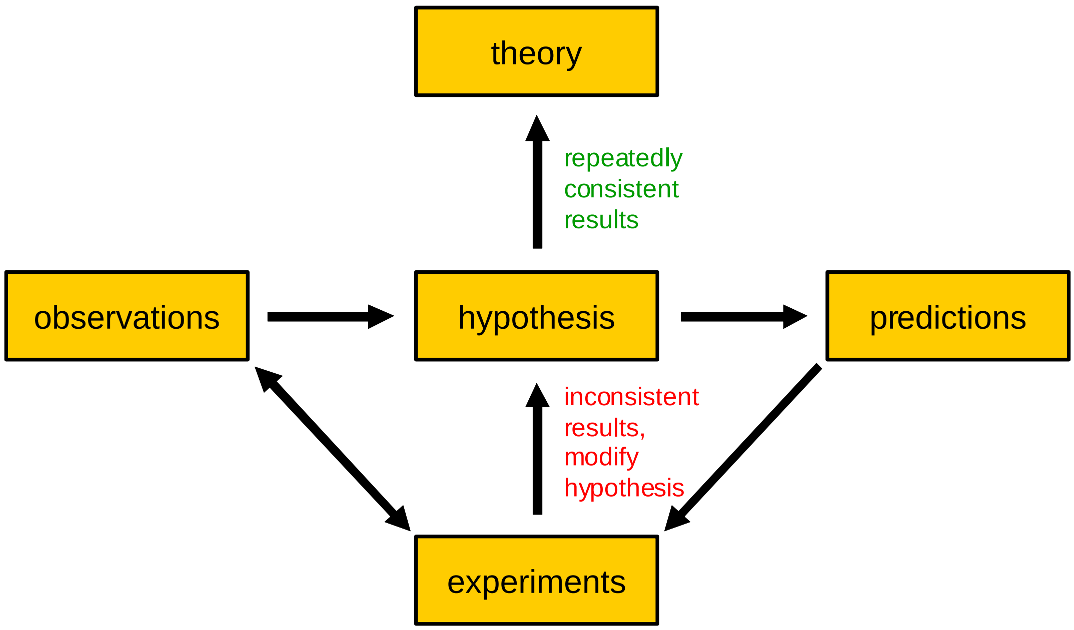


Figure 1.2 Elements of the scientific method

The scientific method is quite commonly used by non-scientists in everyday problem solving. Suppose, for example, you come home late at night and when you flick the wall switch your light does not come on as expected. In order to get to the bottom of this dilemma you think about the possible causes for this problem and check out each one in turn. This process is equivalent to making an observation, constructing various hypotheses and doing experiments to test your hypotheses. Your list of possible explanations, along with an appropriate test for each, might look like the following.

Observation: Table light does not come on when the wall switch is flipped.	
Possible explanation	Method of testing
Light is unplugged.	Check wire and plug from lamp.
Light bulb is loose.	Tighten bulb.
Light bulb is burned out.	Replace light bulb.
Circuit breaker is tripped.	Test electrical outlet with other items.
There is a general power outage.	Check if other electrical items work.
Wiring from lamp is defective.	Check continuity of circuit with ohmmeter.
Gremlins in the electrical circuit are unhappy with you because you continually leave the light on and waste energy so they have disabled the light.	Not testable.

You may quickly determine there is no general power outage and start to test the other possible explanations. If you find that the light works when you replace the bulb, it is this explanation that becomes accepted. Given that the last explanation in the table above cannot be tested (Can you think of any test that would support this explanation?), it is, consequently, not a valid scientific hypothesis. This does not mean it is incorrect, it simply means that it cannot be supported using the scientific method and hence does not represent science.

Scientific research is cumulative and progressive. A scientist often does not simply rely on his or her own observations to propose a hypothesis or to design experiments to test a hypothesis. The extraordinary English physicist and mathematician Sir Isaac Newton (1643-1727) once wrote, “If I have seen further it is only by standing on the shoulders of giants.” It is very important to learn what other research has been done and the results of those experiments. Scientific research results are disseminated through publications and public presentations. In order to publish one’s results a scientist usually submits a manuscript that is reviewed by other scientists to ensure that the research is sound. This peer review checks to see that there were proper controls for the experiment, that the research took into account related work in designing the experiments and interpreting the results, that the results were reproducible and any bias was minimized. If a quantitative (numerical) result is obtained, then its uncertainty must be properly estimated.

Published results and conclusions serve as invitations to further testing by the scientific community. Only after many repeated confirmations, usually over a significant period of time, are such ideas adopted by most scientists. In this way the scientific method is unprejudiced. However, remember that these ideas can be brought into question at any time if some inconsistent results are observed. The chemistry explanations presented in this text are widely accepted by scientists because there have been no observations that run counter to these theories. In this course you will be studying science knowledge in the innermost circle (Fig. 1.1).

In some cases it is not possible to test a hypothesis directly with experiments, so the hypothesis is evaluated by analyzing existing information. For example, in trying to identify when and explain how woolly mammoths and other large animals died out in the Americas, paleoecologists and zooarchaeologists study fossil samples, do carbon dating and analyze mitochrondrial DNA recovered from permafrost to find clues in support of a possible explanation.[5] Astronomers and physicists studying the very beginning of our universe face similar limitations. In some situations more than one logical explanation is consistent with all that has been observed. In this case, there is much debate as scientists continue to seek more evidence and refine their explanations.

[5]Note that these methods of analysis, such as using fossils and carbon dating, have been developed through rigorous scientific testing.

Millions and millions of scientific observations have been made. Generally the more important ones get published in some form and are known to other scientists and non-scientists. When a consistent pattern of results is observed over time it is often expressed as a law. A **scientific law** is a general summary of observations (facts). Unlike a scientific theory, it simply states what is likely to happen, not why. Scientific laws are usually integral components of a scientific theory. **Scientific principle** and **rule** are terms that are often used interchangeably with law. In most cases the choice of term appears to depend on historical convention.

Check for Understanding 1.1

Solutions

1. Which of the following represents the fundamental steps of the scientific method?

   A. observation → law → hypothesis → theory.

   B. observation → hypothesis → experiment → theory.

   C. hypothesis → theory → experiment → law.

   D. observation → theory → experiment → hypothesis.

2. Characterize each of the following as an example of a scientific law, scientific theory, observation, or none of these.

   a) The liquid in a glass of water is composed of molecules.

   b) Flammable materials always contain oxygen.

   c) When a can of soda pop is opened, a fizzing sound is heard.

   d) The force of gravity between two objects increases as they get closer.

As in all areas where not only inquiry, discovery and explanation, but also competition, are involved, one concern about the scientific method is the issue of fraud. Scientists who are seeking recognition or financial gain may fake results or distort data. There are many known examples of this in science. However, since important ideas gain acceptance only after a given result has been obtained many times by many different people, the disciplines in science are self-correcting. Fraud may persist for some time, especially in medical science where the potential financial gains are very significant. However, as a rule, eventually such deception is uncovered.

Another concern is that science is done by an exclusive club of like-minded individuals and that anyone challenging the prevailing or mainstream explanations - the "status quo" - is marginalized. It is, in fact, often very difficult to get a new and important scientific idea accepted. When new ideas are proposed, the scientists proposing them use their evidence to make the strongest case possible. Their colleagues, in turn, challenge that evidence and reasoning because that's the scientific method. While sometimes unpleasant, the rigor of this process in science is what distinguishes it from a debate you may have with your friends about something like lowering the drinking age. The most reasoned and widely explanatory ideas win out because scientists are very demanding in their review of each other's work. For example, the suggestion that chelation therapy[6] is an effective way to treat autism has been met with widespread skepticism because most of the support is anecdotal (based on causal observations) rather than based on rigorous and reproducible scientific studies involving controlled testing. Until such supporting evidence is provided, it is unlikely that this idea will gain much acceptance in the medical or wider scientific community.

Nonetheless, science is open to new ideas even if they are initially challenged or ignored by the scientific community. Take, for example, the work done by Barbara McClintock (Fig. 1.3). Her research on corn in the 1940s and 1950s showed that sequences of DNA can change positions within a chromosome (transposition) resulting in mutations. This discovery went against the accepted view that DNA was stable and unchanging. Initially her research was met with such skepticism that, after several years, she stopped publishing detailed reports of her work. As new technology was developed and other scientists verified her revolutionary ideas, Barbara McClintock's work was

[6]Chelation therapy is the use of chemicals to scavenge metals from the body. It is used, for example, to treat acute lead poisoning.

validated and she was the recipient of many prestigious science awards, including the 1983 Nobel Prize for Physiology or Medicine.

Figure 1.3 Barbara McClintock in the lab at Cold Spring Harbor in 1947
Courtesy of the Barbara McClintock Papers, American Philosophical Society.

Other scientists whose revolutionary ideas initially met significant resistance in the science community before ultimately being validated include Alfred Wegener (continental drift), Lynn Margulis (endosymbiosis and evolution), Barry Marshall (bacterial origin of ulcers), Stanley Prusiner (protein replication without DNA and RNA), Jacobus H. van't Hoff (stereochemistry) and Hannes Alfvén (magnetohydrodynamic waves), all of whom were eventually awarded a Nobel Prize.[7]

All of this indicates that science does not advance in the tidy way suggested by Figure 1.2. There may be many twists and turns until a well supported scientific theory is developed. In fact, many accomplished scientists have subscribed to ideas that were later shown to be in error. However, given the process of the scientific method, all this in no way suggests that just because there is some measure of uncertainty in a scientific theory

[7]See B. Barber, *Science* **134**, 596 (1961) for a discussion of various reasons why scientists might resist new discoveries.

any belief is equally meritorious. Science still insists on confirmed predictions to support legitimate scientific hypotheses and theories.

1.3 Pseudoscience - If it looks like a duck...

Perhaps you have heard the expression, “If it looks like a duck, swims like a duck and quacks like a duck, then it probably is a duck.” Well, this is not always the case. Several years ago the first-place winning project in a local elementary school science fair attempted to answer the question of whether the color of a milkshake influences one’s preference for the shake. The details of the project were nicely presented in a three-panel display with all of the items colorfully labeled and neatly printed (see Fig. 1.4).

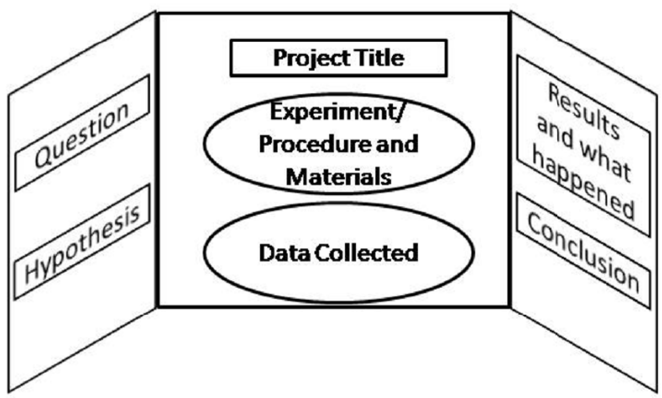


Figure 1.4 Typical display board for a science project

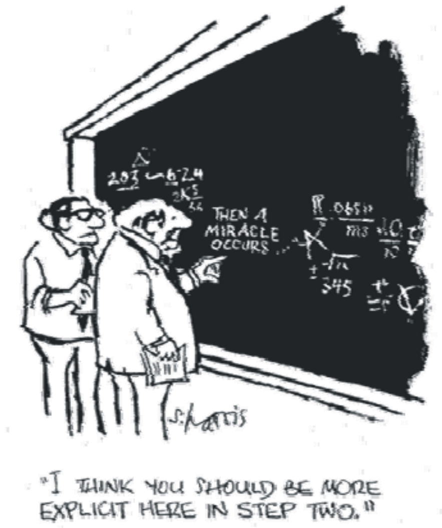
Keywords like Question, Procedure, Data and Conclusions prominently identified the various sections. Its neat and organized appearance certainly caused it to stand out among the other projects. However, there was one fault with the project - it had nothing to do with science! It was essentially an opinion poll about color preferences. There were no control experiments and no careful monitoring of experimental variables.

The purpose of a **control experiment** is to provide a reference point against which you can compare your results. For example, if you wish to investigate the effect that classical music has on plant growth, you will have to grow some plants in the absence of that music. This experimental piece would be “the control”. You must ensure that all other conditions such as the type of plants, the soil, the temperature, watering schedule and so on are the same for the control experiment and the other experiments so that any effects you observe can be traced to the music.

Experimental variables are aspects of the experiment that you change from trial to trial. For example, if you were studying how fast a chemical reaction occurs, you might vary the concentration of the reagents or the temperature of the reaction. The effect that a particular variable has on the experimental results may be found by changing one variable at a time while the other variables remain the same.

Certainly deception was not the intent of the student who did the milkshake project, nor were the teachers who judged the project trying to mislead anyone. They were all just insufficiently aware of the scientific method and were fooled into believing this was a “science” project because it looked so much like one. This is a rather harmless example of pseudoscience.

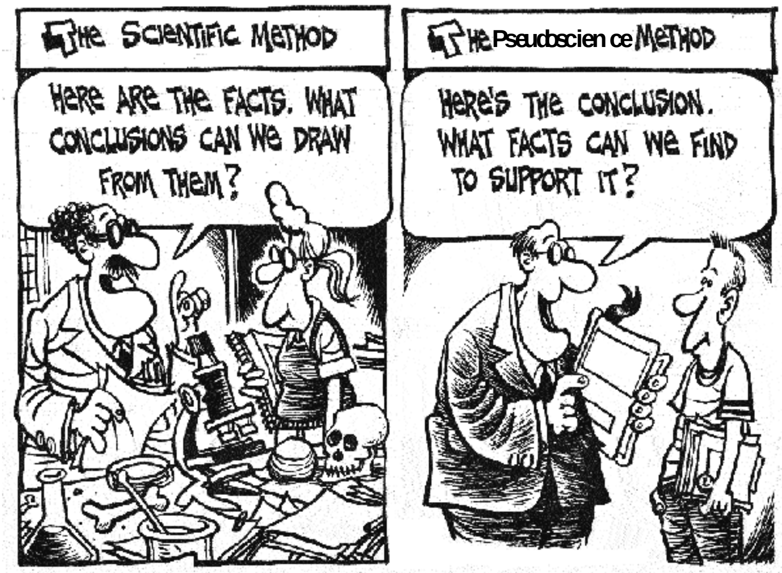
Pseudoscience is an idea or process which masquerades as science. It is often known as **alternative science**. Because pseudoscience uses many of the same terms as those used by scientists, and makes statements that may be scientifically true, many people have difficulty recognizing pseudoscience for what it is, a sham. Pseudoscience lacks carefully controlled experiments and widespread testing of its claims and explanations. This examination and analysis is at the heart of true scientific inquiry. The idea of a perpetual motion machine, phrenology, and “intelligent design” to explain natural phenomena are examples of pseudoscience.



It is not always easy to distinguish pseudoscience from science. It usually takes much more information than one obtains from unreviewed Internet postings or TV news stories. It is challenging to identify a logically sounding claim that is not based on fact. However, it is very important for individuals in today's society to be able to make this distinction. Many far-reaching political decisions require a minimum appreciation for the difference in order to avoid costly errors in policy. Individuals must recognize pseudoscience to avoid making harmful medical decisions or wasting money on quack products. The following characteristics are some things to look for in making the distinction between sound scientific studies and pseudoscience claims.[8]

- Pseudoscience is more likely to be driven by ideological, cultural, or commercial goals than a desire for a complete, logical and predictive understanding.
- There is little research associated with pseudoscience and hence limited expansion of knowledge in this area. Any work that is done is generally carried out to justify a belief rather than to develop an understanding.
- In pseudoscience, workers in the field do not seek out counterexamples or challenge the prevailing belief.

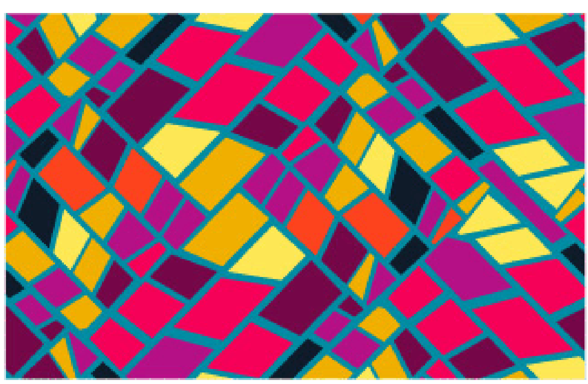
[8]See also **http://www.quackwatch.com/01QuackeryRelatedTopics/pseudo.html**.



Adapted from cartoon by John Trever, Albuquerque Journal. ©1998. Used with permission of author.

1.4 Pattern Recognition

If you study the picture below, you may discover that this mosaic is constructed from the repeated use of a specific arrangement of colored figures.[9] Behind all of the complexity lies a relatively simple pattern. In a similar fashion, scientific laws are statements about patterns that appear in nature. You will encounter many patterns or trends as you study chemistry.



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[9]How might you go about finding the pattern? How would you test your idea? Try this before going to **http://www.csun.edu/~hcchm003/100/mosaic.jpg** to see an outline of the repeating element.

Because chemistry is efficiently organized, it is better understood and remembered if you take careful note of the patterns, or trends, that are mentioned in each chapter. For example, we will see that the periodic table of the elements is organized so that many regular trends and relationships exist among the arranged elements. By knowing these patterns, you will be able to make predictions about the properties of an element without even knowing specific details about that element.

1.5 Representing Quantitative Scientific Information - Equations and Graphs

A scientific law can often be expressed as a mathematical equation, especially in areas like chemistry and physics. This shorthand notation allows scientists to make quantitative[10] predictions about the outcome of a particular experiment quite readily. For example, consider a balloon full of air as it significantly changes temperature (imagine putting the air balloon in the freezer). You will quickly see that there is a connection between the temperature of the balloon and its volume. The kinetic theory of gases, and countless observations, indicate that a substance in the gas phase will generally behave according to the following equation:

$$PV = nRT \qquad \text{(ideal gas[11] equation)} \qquad (1.1)$$

where P is the pressure of the gas, V is the volume occupied by the gas sample, T is the temperature of the gas, n is a measure of how much gas is present and R is a numerical constant. Although we will not discuss the behavior of ideal gases in this class, we will use this equation to illustrate a few examples of quantitative relationships.

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[10]**Quantitative results** are associated with quantities that are measured and have a numerical value (for example, this milk contains 1% fat). **Qualitative results** do not have a numerical value and may be subjective (for example, this milk tastes sour).

[11]An **ideal gas** is a substance in which the particles that make up the material are assumed to be moving randomly and independently of each other. This is a reasonable assumption for many gases at room temperature and pressure conditions.

The mathematical statement in equation 1.1 enables one to predict, for example, how the pressure of a fixed amount of gas in a fixed volume will change as the temperature is altered. To see this more clearly, a little algebra can be used to relate *P* and *T*. First divide both sides of the ideal gas equation by *V* to give:

$$\frac{PV}{V} = \frac{nRT}{V} \qquad (1.2)$$

On the left side of the equation the volume term in the numerator cancels the volume term in the denominator. On the right side of the equation, since *n*, *R* and *V* are all fixed in value, their ratio (*nR*/*V*) can be replaced by a number (a constant value). Thus, equation 1.2 becomes:

$$P = (\text{constant}) \times T \qquad (\text{when } n \text{ and } V \text{ are fixed}) \qquad (1.3)$$

The relationship in equation 1.3 means that *P* is **directly proportional** to *T*; the pressure will change by the same factor as a change in temperature. For example, if the value of *T* doubles then the pressure will double, or, if the temperature is reduced by 15% then the pressure is reduced by 15%. This relationship between pressure and temperature explains the reasoning behind warnings on aerosol cans to avoid subjecting the can to high temperatures. Such cans contain a gas under pressure. If the temperature increases enough, the pressure of the gas inside may become so high that the can explodes.

The quantitative predictions that equation 1.3 yields are easily tested. If one is doing experiments to test how pressure varies with changes in temperature (for a fixed amount of gas in a fixed volume like the air in a car tire), temperature is referred to as the **independent variable** since you set its value when doing the experiment. Because the value of *P* depends on the value of *T*, pressure is known as the **dependent variable**. The dependent variable changes in response to a change in the independent variable.

Imagine measuring the pressure of a gas sample at constant volume as the temperature is changed. Perhaps you might collect the following data.

Temperature (K)	**Pressure (atm)**
290	1.06
295	1.08
300	1.10
305	1.12
310	1.14

As expected, the pressure increases as the temperature is raised, however, the numerical connection between the pressure and the temperature is not obvious from these measurements.

The relationship between a dependent variable and an independent variable is often represented in graphical form on an **x-y scatter plot**. An x-y scatter plot consists of two perpendicular lines or axes. The distance along the horizontal axis (***x*-axis**) represents the value of one of the experimental quantities and the distance along the vertical axis (***y*-axis**) represents the value of the other. For example, if we measure the pressure of a gas sample at various temperatures, we can represent each experimental measurement by a point whose horizontal distance is proportional to the temperature and whose vertical distance is proportional to the pressure. Unless specified otherwise, one plots the values of the independent variable in a series of measurements along the horizontal x-axis and the corresponding values of the dependent variable along the vertical y-axis. Figure 1.5 illustrates such a plot of pressure versus temperature. Note that each axis is labeled with the quantity being plotted and its units. This straight line graph is characteristic of a plot of two quantities that are directly proportional. In this case, as the temperature increases the pressure also increases and the line slopes upward as you go from left to right.

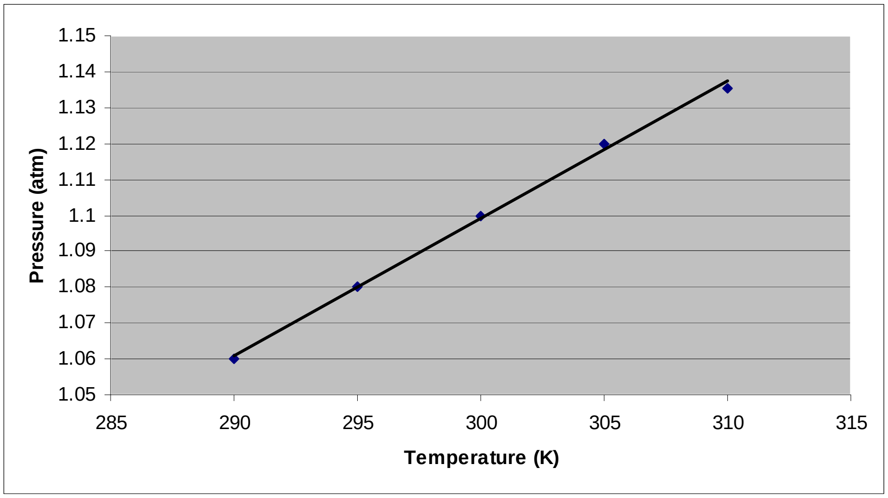

Figure 1.5 x-y scatter plot of pressure vs temperature for an ideal gas

Equation 1.1 (p. 22) also allows us to readily predict how the pressure of an ideal gas varies when the sample volume is changed for a fixed amount of gas at a constant temperature. Rearrangement of equation 1.1 yields:

$$P = \frac{nRT}{V} = \frac{\text{constant}}{V} \qquad \text{(when } n \text{ and } T \text{ are fixed)} \qquad (1.4)$$

In this case the pressure is **inversely proportional** to the volume; that is, as the volume increases by some factor the pressure decreases by the same factor, and when the volume decreases the pressure increases. Mathematically, the product of two quantities that are inversely proportional is a non-zero constant: in this case P x V is a constant. Notice that when one creates an x-y scatter plot of pressure versus volume[12] the result is not a straight line (see Fig. 1.6). The graph is not straight because neither P or V can be zero so the graph cannot cross either axis. This hyperbola curve is characteristic of plots of inversely proportional quantities.

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[12]When you are asked to make a plot of quantity *a* versus quantity *b*, this means that you plot quantity *a* on the *y*-axis and quantity *b* on the *x*-axis. This convention allows you to specify the quantity plotted on the *x*-axis even if it is not the independent variable.

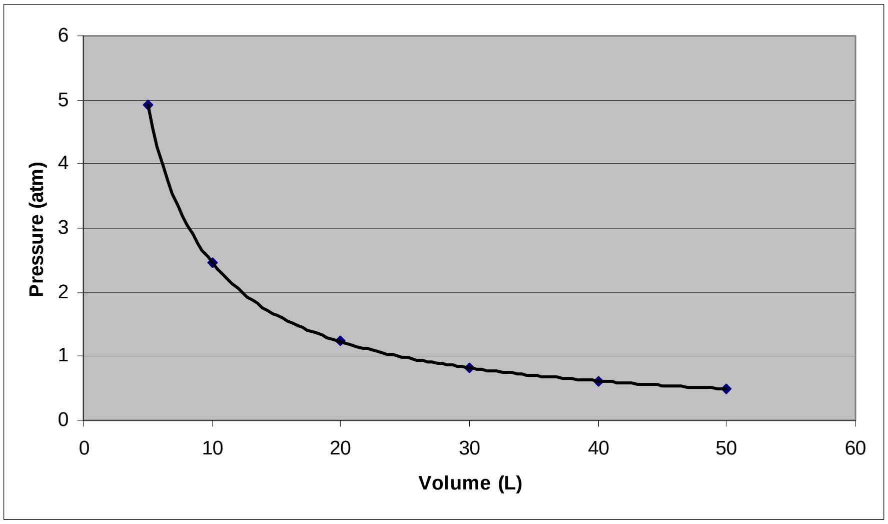


Figure 1.6 x-y scatter plot of pressure vs volume for an ideal gas

Check for Understanding 1.2 **Solution**

1. In Figure 1.6, which quantity is the independent variable and which is the dependent variable?

Straight Line Graphs

A straight line, or linear, graph such as the one in Figure 1.5 has several advantages over a curved one. A straight line graph is easier to draw, and it is easier to use to establish mathematical relationships between the variables. A straight line graph of two quantities x and y fits the equation

$$y = mx + b \tag{1.5}$$

where y is the quantity plotted on the vertical axis (also called the ordinate) and x is the quantity plotted on the horizontal axis (the abscissa). The **slope**, or steepness, of the line is m, and b is the ***y*-axis intercept** of the line, that is, the value of y when $x = 0$.

Figure 1.7 shows a straight line graph drawn between data points (x_1, y_1) and (x_2, y_2). The intercept (b) is the value of *y* at the point at which the line crosses the *y*-axis when $x = 0$.

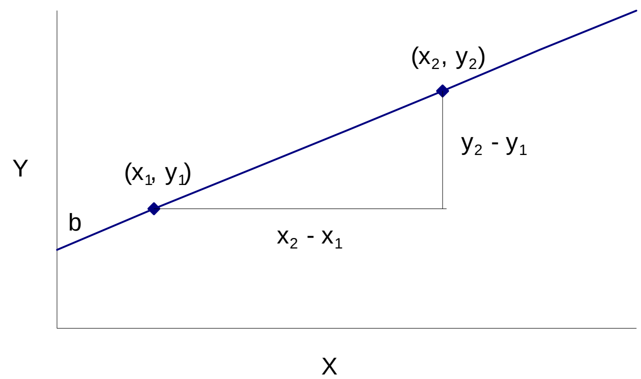


Figure 1.7 Linear x-y scatter plot

The following method can be used to determine the slope of the straight line.

1. Pick any two points lying on the line. The farther apart they are, the more precise your measurement will be. In Figure 1.7, the two points (x_1, y_1) and (x_2, y_2) are arbitrarily chosen.

2. Draw a horizontal line from (x_1, y_1) to the right and a vertical line from (x_2, y_2) downward. Combined with the graph's slanted line, these two lines form a right triangle.

3. The distance from (x_1, y_1) to the right angle is $x_2 - x_1$, and the distance from (x_2, y_2) to the right angle is $y_2 - y_1$.

4. The slope (m) is calculated by $m = \frac{y_2 - y_1}{x_2 - x_1}$ and will have units equal to the ratio of the *y*-axis and *x*-axis units.

The mathematical sign of the slope may be positive or negative. In Figure 1.7 the slope has a positive sign (because $y_2 > y_1$ and $x_2 > x_1$) and the line slopes upward as you go from left to right. The line will slope downward as you go from left to right if the slope is negative. It is quite convenient to use various computer programs to generate graphs and the lines that fit the plotted data. A spreadsheet program such as Microsoft Excel can be used to make simple x-y scatter plots.

Check for Understanding 1.3

Solutions

1. The equation for the straight-line graph in Figure 1.5 is $y = 0.0038x - 0.047$. Determine the Kelvin temperature (K) at which the pressure of this gas sample equals 0.94 atm.

2. Imagine doing an experiment in which you burn a candle and measure its diminishing mass at various times.

   a) If you plot candle mass (in grams) on the *y*-axis and time (in minutes) on the *x*-axis and fit the data with a straight line, what are the units for the slope of this line?

   b) Do you expect the slope of this straight line to be positive or negative? Explain your answer.

Chapter 1 Keywords

Glossary

scientific theory	experimentation	ideal gas
mass	scientific law	directly proportional
weight	scientific principle	independent variable
core ideas of science	scientific rule	dependent variable
frontiers of science	control experiment	x-y scatter plot
fringe ideas	experimental variables	*x*-axis
scientific method	pseudoscience	*y*-axis
observations	alternative science	inversely proportional
hypothesis	quantitative results	slope of the line
predictions	qualitative results	*y*-axis intercept

Supplementary Chapter 1 *Check for Understanding* questions

Chapter 1 Exercises

Answers

1. Do an Internet search for each of the items listed below. Based on this information, determine whether each is part of the core ideas, frontier ideas or fringe ideas in science.

   a) cold fusion
   b) quantum electrodynamics
   c) homeopathic treatment of flu symptoms (oscillococcinum)
   d) big bang cosmology
   e) nuclear fusion reactors
   f) link between low-level electromagnetic radiation and leukemia

2. What is the difference between a hypothesis and a scientific theory?

3. What is the difference between a scientific theory and a scientific law?

4. Outline the typical sequence of steps in the scientific method.

5. Why is it more appropriate for an elementary school student doing a science project to start the scientific process by trying to answer a question rather than by proposing and testing a hypothesis?

6. Characterize each of the following as an example of a scientific law, scientific theory, hypothesis, observation, or none of these.

a) an apple a day keeps the doctor away
b) my brother doesn't like to eat salads
c) your cell phone isn't working because the battery must be dead
d) breaking a mirror brings seven years of bad luck
e) all matter is composed of atoms

7. Which of the following is a scientific theory?

A. Beethoven's contributions to music would have been greater if he had married
B. left-handed people are more artistically inclined
C. vitamin C prevents the common cold
D. all of the above
E. none of the above

8. Indicate whether each of the following is an example of a scientific law. If an item isn't a law, identify what it represents.

a) like electric charges repel
b) particles in the gas phase exert a pressure by colliding with the container walls
c) metals tend to be good conductors of electricity
d) in a chemical reaction, matter is neither created nor destroyed
e) visible light consists of photons

9. Do you agree with the statement: "An individual scientist can not propose a theory, only a hypothesis."? Provide a short justification for your answer.

10. Five dimes and five pennies are secretly distributed between box A and box B. Then two coins are removed from each box. Two pennies are drawn from box A and two dimes are drawn from box B. Based on these observations, which of the following may be valid?

A. box A contains only pennies
B. box B contains both dimes and pennies
C. box A contains more dimes than pennies
D. all of the above
E. only A and B

11. Briefly describe how to organize an experiment to determine the effect that a particular variable has on the outcome.

12. Suppose you wish to determine the effect of ultraviolet (UV) light exposure on a particular species of fish.

a) Describe a control experiment that you would do.

b) Identify the experimental variables that you would control.

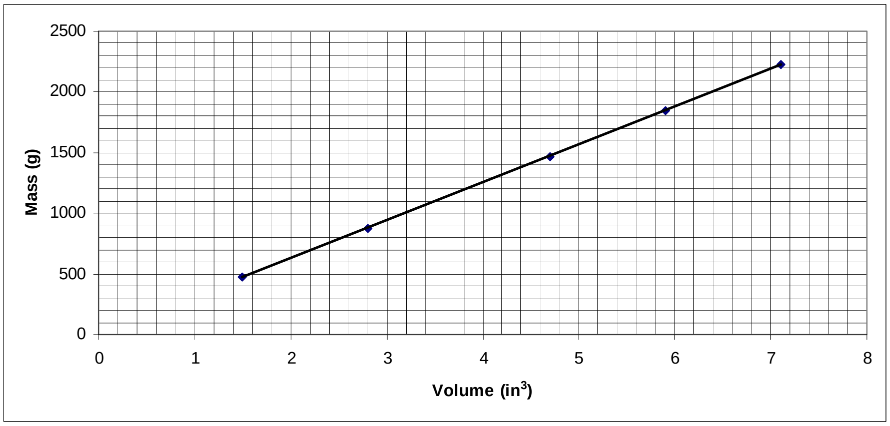
13. Using Internet resources, decide whether air ionizers really provide effective air purification or whether this is pseudoscience. Justify your conclusion with specific information.

14. Solve each of the following relationships for y.

a) $x^2 - y^2 = \mathrm{a} + \mathrm{b}$ b) $45 - \frac{1}{y} = 2x + 16$

15. You are asked to make a x-y scatter plot of your height versus your age during your lifetime. What variable do you put on the x-axis? Why?

16. Calculate the slope of the line on the x-y scatter plot below. Be sure to include the proper units.



17. Write a short paragraph in your own words summarizing the key concepts discussed in Section 1.3.