Appendix B

Solutions to *Check for Understanding* Problems

Chapter 1

Check for Understanding 1.1

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.

Answer: B

Solution

You can reject A because it lacks the experimentation that is central to the scientific method. Also, a law is not formulated until numerous observations have been made.

You can reject C because the steps taken between a tentative explanation (hypothesis) and a well established explanation (theory) require numerous experiments.

You can reject D because a hypothesis is always developed before a theory.

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.

Answers: a) theory c) observation

b) none of these d) law

Solutions

a) This represents an explanation for the composition and observable properties of water. Scientists cannot observe molecules directly so this is not a simple observation or a summary of repeated observations (a law).

b) This cannot be a theory because it does not provide an explanation for flammability. A single example of a flammable material that does not contain oxygen will invalidate this as an observation that is always made and a law. Hydrogen is the simplest example of a flammable substance that does not contain oxygen. Others include fuels like natural gas and propane. This leaves *none of these* as the correct choice.

c) This is a simple observation. It is not a scientific law because it is not always observed; a can of soda may be flat or not highly carbonated so no fizzing is heard. It does not provide any explanation so it cannot be a theory.

d) No explanation is provided so it cannot be a theory. It is an observation that is repeatedly made (there are no known exceptions) so it represents a scientific law.

Check for Understanding 1.2

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

Answers: volume is the independent variable

pressure is the dependent variable

Solution

In the absence of additional information you should assume that the independent variable is plotted on the *x*-axis and the dependent variable is plotted on the *y*-axis. So volume is the independent variable and pressure is the dependent variable.

Check for Understanding 1.3

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.

Answer: 260 K

Solution

The equation for the straight line in Figure 1.5 can be expressed as:

$$pressure\ (\text{atm}) = 0.0038(temp\ (\text{K})) - 0.047$$

Substituting 0.94 atm for the pressure and solving for temperature yields:

$$temp\,(\text{K}) = \frac{0.94 + 0.047}{0.0038} = 260$$

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?

Answer: g/min

Solution

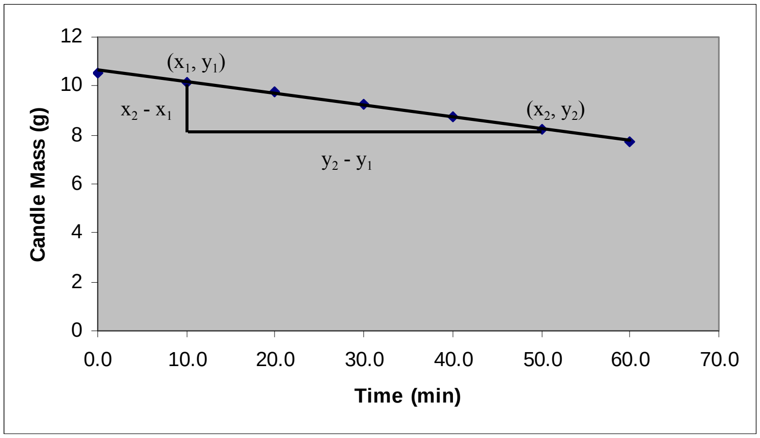
The slope of a straight-line graph is given by $\frac{y_2 - y_1}{x_2 - x_1}$ so the units of the slope are the units of the *y*-axis variable (g) divided by the units of the *x*-axis variable (min). In this case the ratio of units is g/min.

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

Answer: negative

Solution

Think about how this graph might look. As the candle burns its mass decreases so a plot of candle mass versus time might look like that below. Since it slopes downward from left to right, the slope is negative. You can also see this by noting that $(y_2 - y_1)$ is positive but $(x_2 - x_1)$ is negative so the ratio of these quantities is negative.



12
10
8
6
4
2
0
Candle Mass (g)
(x1, y1)
x2 - x1
(x2, y2)
y2 - y1
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Time (min)

Chapter 2

Check for Understanding 2.1

1. Write the solution map for the conversion of *pm* to *km*. Indicate the numerical ratio that is the conversion factor in each step.

Answers: The solution map is pm ➔ m ➔ km

The conversion factor for the first step is $\frac{10^{-12}\ \text{m}}{1\,\text{pm}}$.

The conversion factor for the second step is $\frac{1\,\text{km}}{10^{3}\ \text{m}}$.

Solutions

Each step of the solution map requires a conversion factor.

For pm ➔ m, we need a conversion factor with units of $\frac{\text{m}}{\text{pm}}$ which will cancel *pm* and introduce *m* into the numerator.

Since 1 pm = 10^{-12} m we use $\frac{10^{-12}\ \text{m}}{1\,\text{pm}}$.

For m ➔ km, we need a conversion factor with units of $\frac{\text{km}}{\text{m}}$ to cancel *m*.

Since 1 km = 10^{3} m we use $\frac{1\,\text{km}}{10^{3}\ \text{m}}$.

2. Convert 233 kg to an equivalent number of micrograms.

Answer: 2.33×10^{11} μg

Solution

First create the appropriate solution map.

kg → g → μg

Each step requires a conversion factor.

For kg → g, we need a conversion factor with units of $\frac{\text{g}}{\text{kg}}$ which will cancel *kg* and introduce *g* into the numerator.

Since 1 kg = 10^3 g we use $\frac{10^3\ \text{g}}{1\,\text{kg}}$.

For g → μg, we need a conversion factor with units of $\frac{\mu\text{g}}{\text{g}}$ to cancel *g*.

Since 1 μg = 10^{-6} g we use $\frac{1\,\mu\text{g}}{10^{-6}\ \text{g}}$.

Now multiply 233 kg by both unit ratios and cancel common terms in both numerator and denominator.

$$233\,\cancel{\text{kg}} \times \frac{10^3\ \cancel{\text{g}}}{1\,\cancel{\text{kg}}} \times \frac{1\,\mu\text{g}}{10^{-6}\ \cancel{\text{g}}} = 2.33 \times 10^{11}\ \mu\text{g}$$

3. Find the correct numerical value of *x*. $\frac{9.15 \times 10^7\ \text{cycles}}{\text{s}} = \frac{x\,\text{cycles}}{\text{ms}}$

Answer: $9.15 \times 10^4\ \frac{\text{cycles}}{\text{ms}}$

Solution

First create the appropriate solution map.

$\frac{\text{cycles}}{\text{s}} \rightarrow \frac{\text{cycles}}{\text{ms}}$

We need a conversion factor with units of $\frac{s}{ms}$ which will cancel *s* and introduce *ms* into the denominator.

Since 1 ms = 10^{-3} g we use $\frac{10^{-3}\ s}{1\,ms}$.

Now multiply $\frac{9.15 \times 10^{7}\ cycles}{s}$ by this unit ratio and cancel common terms in both numerator and denominator.

$$\frac{9.17 \times 10^{7}\ cycles}{\cancel{s}} \times \frac{10^{-3}\ \cancel{s}}{1\,ms} = 9.15 \times 10^{4}\ \frac{cycles}{ms}$$

Note that you would expect to have fewer cycles in the shorter time interval.

4. Write each of the following in proper scientific notation.

a) 0.000000203 b) 12,918

Answers: a) 2.03×10^{-7}

b) 1.2918×10^{4}

<u>Solutions</u>

a) First express the original quantity as a number between 1 and 10.

0.000000203 → 2.03

Then multiply by the appropriate power of ten. This is determined by noting how many places, and in which direction, the decimal point was moved in the first step. Notice that we moved the decimal point 7 places to the right. This means that the power of ten to use is 7. However, since the decimal point was moved to the right, thereby making the number larger, the power of ten must be negative so that you are multiplying by a value smaller than 1; that is, 10^{-7}.

0.000000203 → 2.03×10^{-7}

b) First express the original quantity as a number between 1 and 10.

12,918 ➔ 1.2918

Then multiply by the appropriate power of ten. This is determined by noting how many places, and in which direction, the decimal point was moved in the first step. Notice that we moved the decimal point 4 places to the left. In doing so, the original quantity has been reduced by 4 powers of ten (12,918 ➔ 1.2918). In order to restore the quantity to its original value you must multiply by 4 powers of ten; that is, 10^4.

12,918 ➔ 1.2918×10^4

Check for Understanding 2.2

1. How many significant figures are in each of the following measurements?

a) 588.0 kg b) 12,000 miles c) 0.00700100 s

Answers: a) 4 sig. fig.

b) 2 sig. fig.

c) 6 sig. fig.

Solutions

Recall that all digits in a measurement are significant except trailing zeros in numbers without a decimal point and all leading zeros.

a) Because of the decimal point, the trailing zero is significant so there are 4 significant figures.

b) Because there is no decimal point, the trailing zeros are not significant so there are just 2 significant figures.

c) The leading zeros are not significant, but because of the decimal point the trailing zeros are significant, so there are 6 significant figures.

2. Write each of the quantities in question 1 in proper scientific notation.

Answers: a) 5.880×10^{2} kg

b) 1.2×10^{4} miles

c) 7.00100×10^{-3} s

Solutions

Recall that when measurements are written in proper scientific notation all significant digits are shown.

a) First express the original quantity as a number between 1 and 10.

588.0 ➔ 5.880 The trailing zero is included because it is significant.

Then multiply by the appropriate power of ten. This is determined by noting how many places, and in which direction, the decimal point was moved in the first step. Notice that we moved the decimal point 2 places to the left. In doing so, the original quantity has been reduced by 2 powers of ten (588.0 ➔ 5.880). In order to restore the quantity to its original value you must multiply by 2 powers of ten; that is, 10^{2}.

588.0 kg ➔ 5.880×10^{2} kg Note that 4 significant figures are shown.

b) First express the original quantity as a number between 1 and 10.

12,000 ➔ 1.2 The trailing zeros are not included because they are not significant.

Then multiply by the appropriate power of ten. This is determined by noting how many places, and in which direction, the decimal point was moved in the first step. Notice that we moved the decimal point 4 places to the left. In doing so, the original quantity has been reduced by 4 powers of ten (12,000 ➔ 1.2). In order to restore the quantity to its original value you must multiply by 4 powers of ten; that is, 10^{4}.

12,000 miles ➔ 1.2×10^{4} miles Note that 2 significant figures are shown.

c) First express the original quantity as a number between 1 and 10.

0.00700100 ➔ 7.00100 The trailing zeros are included because they are significant.

Then multiply by the appropriate power of ten. This is determined by noting how many places, and in which direction, the decimal point was moved in the first step. Notice that we moved the decimal point 3 places to the right. This means that the power of ten to use is 3. However, since the decimal point was moved to the right, thereby making the number larger, the power of ten must be negative so that you are multiplying by a value smaller than 1; that is, 10^{-3}.

0.00700100 s ➔ 7.00100×10^{-3} s Note that 6 significant figures are shown.

Check for Understanding 2.3

1. For each of the following, calculate the result and round it off to the proper number of significant figures. Units have been omitted for clarity.

a) $28.4 \div 0.0091$ b) $63.2 - 61.04$

Answers: a) 3.1×10^3

b) 2.2

Solutions

a) The calculated result is: $\dfrac{28.4}{0.0091} = 3120.8...$

Note the number of significant figures in each measurement in this calculation.

28.4 (3 sig. fig.) 0.0091 (2 sig. fig.)

Since 2 significant figures is the fewest number in any measurement, the result is rounded off to 2 significant figures. Since the first digit to be dropped is less than 5, the preceding digit stays the same.

3120.8... ➔ 3100 or 3.1×10^3

b) The calculated result is

$$\begin{array}{r} 63.2 \\ -\ \underline{61.04} \\ 2.16 \end{array} \rightarrow 2.2$$

Note that the uncertain digit (in blue) in the first measurement is in the tenths place while the uncertain digit in the second measurement is in the hundredths place. Thus, the sum is rounded off to the (larger) tenths place. Since the first digit to be dropped is greater than 5, the preceding digit is increased by 1.