Understanding and Interpreting Graphs and Tables

The ability to interpret graphs and tables is a necessary skill in science but also finds use in everyday life. In articles or textbooks you are likely to find graphs and tables. Understanding the article's message depends heavily on being able to interpret many different types of graphs and tables.

In science tables are used to provide information. Frequently one quantity in a table depends upon or is related to another. Data from tables can be graphed to aid interpretation. Graphs give a visual representation of the data that helps to reveal regularities and patterns.

INTRODUCTORY GRAPHING ACTIVITY

The data table in Figure 7 shows the relationship between the month of the year and the average water temperatures and average dissolved oxygen levels in the Snake River at Riverwood.

Month	Water Temperature (°C)	Dissolved Oxygen (ppm)
January	2	12.7
February	3	12.5
March	7	11.0
April	8	10.6
May	9	10.4
June	11	9.8
July	19	9.2
August	20	9.2
September	19	9.2
October	11	10.6
November	7	11.0
December	7	11.0

Figure 7 *Snake River Data*

Activity

1. Each member of your group will prepare a graph of these data, so you need to make independent decisions about the type of graph you wish to prepare. Be sure to label your axes clearly and to give your graph an informative title. Use only one side of a piece of graph paper.
2. Compare and discuss each group member's graph. List the advantages and disadvantages of the way each graph presents the information provided in the table.
3. Select the graph that the group feels conveys the information in the table most successfully. List the factors that the group used in making this choice.
4. What conclusions about the data can you draw from the graph?
5. As a group, make a list of rules that should be followed in the making of a good graph.

BASIC GRAPHING RULES

1. First decide where the information will be graphed. The horizontal axis (x-axis) is used for the quantity that can be controlled or adjusted. This is called the **independent variable**. The vertical axis (y-axis) is used for the quantity that responds to the changes in the quantity on the x-axis. This is called the **dependent variable**.
2. Choose the scale so the graph becomes large enough to fill most of the available space on the paper.
3. Each regularly spaced division on the graph paper should equal some convenient, constant value. In general, each interval should have a value that can be easily divided visually such as 1, 2, 5, or 10, rather than a value such as 3, 6, 7, or 9.
4. An axis does not need to start at zero, particularly if the plotted values cluster in a narrow range not near zero.
5. Label each axis with the quantity and unit being graphed. For example an axis might be labeled "Temperature, °C."
6. Plot each point. If you plot more than one curve on the same graph, use a different color or geometric shape to distinguish each set of data.
7. For an XY graph, draw a smooth line that lies as close as possible to most of the points. Think of this drawing as a line that is averaging your data. Do not draw a line that connects one point to the next one as in a dot-to-dot drawing. If the curve appears to be straight, draw one continuous line with a ruler.
8. Title your graph with an informative title.

TYPES OF GRAPHS

Graphs are of four basic types: pie charts, bar graphs, line graphs, and XY-plots. The type chosen depends on the characteristics of the data displayed.

Pie Charts

Pie charts show the relationship of parts to a whole. The pie chart in Figure 8 displays the distribution of the world's petroleum reserves. This presentation helps the reader to visualize the magnitude of the differences between various parts of the world. Pie charts are not used as frequently as other types.

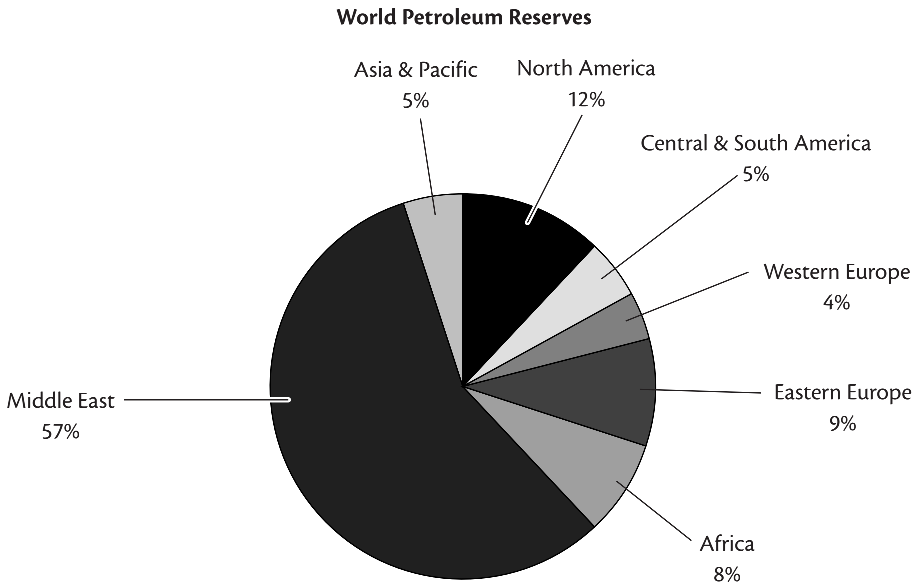

Figure 8 *Sample Pie Chart*

Bar Graphs

Bar graphs and line graphs compare values in a category or between categories. The bar graph in Figure 9 makes a visual comparison of the fat content of types of cheese. This chart might help the viewer choose a cheese snack with a low fat content.

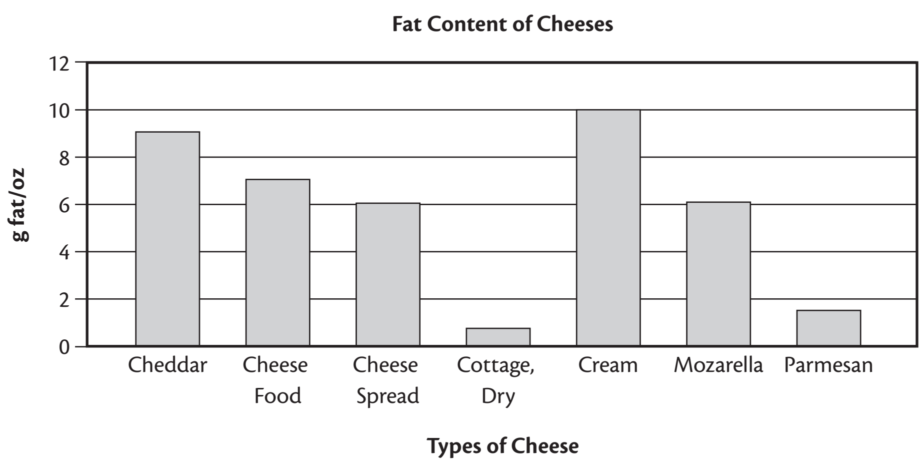

Figure 9 *Comparison of Fat Content in Selected Cheeses*

Bar graphs also can be useful to study trends over time, as in Figure 10. It quickly shows the reader that generally lower temperatures occur in the early morning hours and higher temperatures occur in the late afternoon.

Temperatures also can be predicted for times when a reading was not taken. However, a mathematical relationship between time and temperature is not expected and is not demonstrated. We cannot make any general assumptions for daily temperature graphs that might be constructed at a different location or a different season.

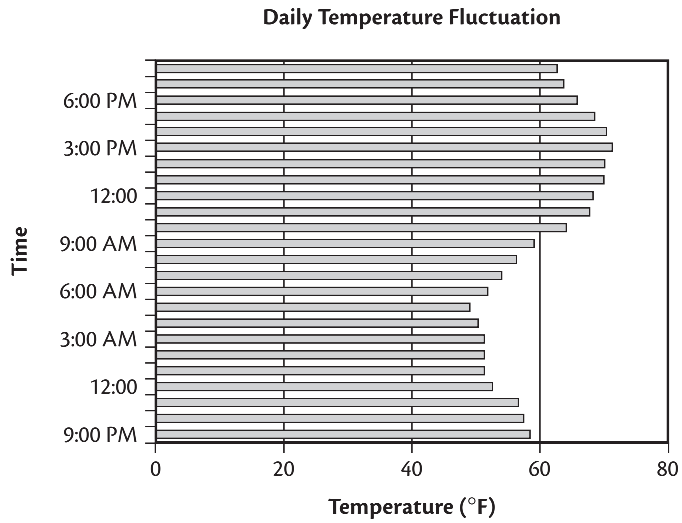

Figure 10 *Temperature Fluctuation Graph*

Multiple Bar Graphs

Multiple bar graphs compare relationships of closely related data sets. Atomic radii plotted against atomic number (Figure 11) show a pattern, but additional interpretation is possible if the elements are divided into periodic table groups as is shown in Figure 12. Some relationships are more easily seen in this format.

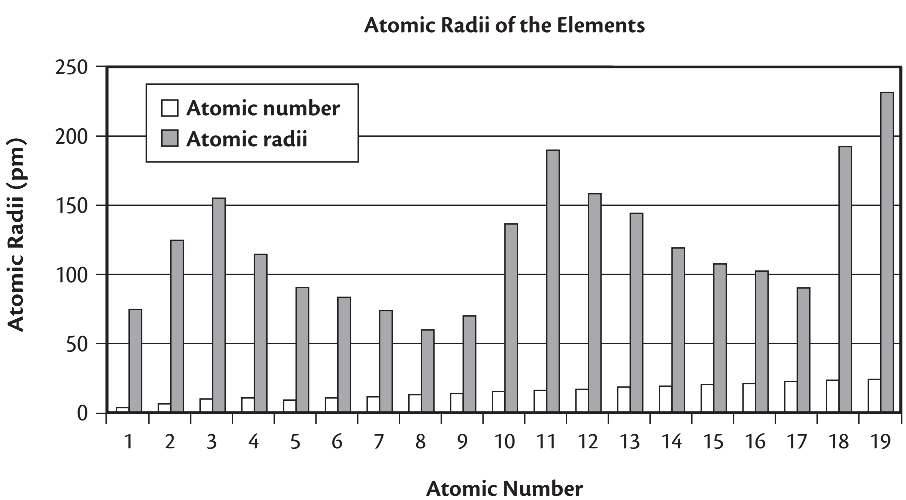

Figure 11 *Atomic Radii*

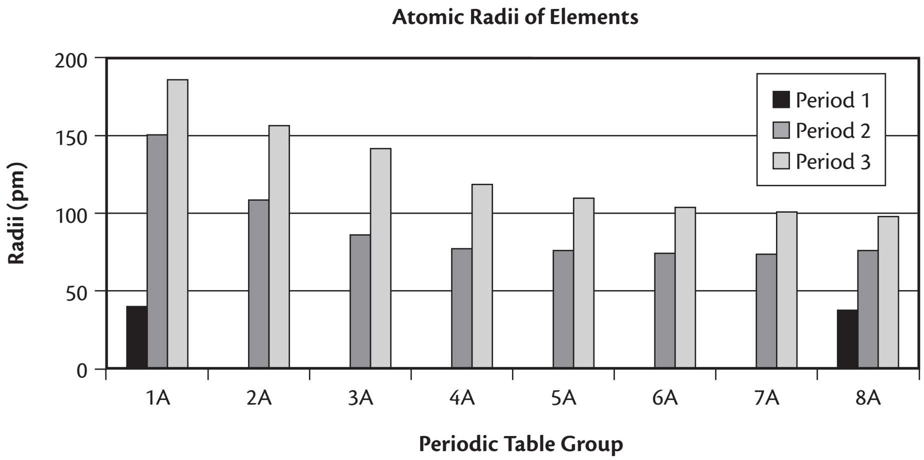

Figure 12 *Periodic Table Group Comparison*

Activity

Answer the following questions based on the graphs in Figures 11 and 12.

1. How does the atomic radius of an element change within a group as the atomic number increases? Is this generalization consistent for all groups illustrated?
2. How does the atomic radius of an element change within a period as atomic number increases? Is this generalization true for all groups illustrated?

Line Graphs

Constructing a **line graph** is another way to show the relationship between two variables. The time and temperature data shown in Figure 10 is probably more easily visualized as a line graph (Figure 13). The same type of information is conveyed.

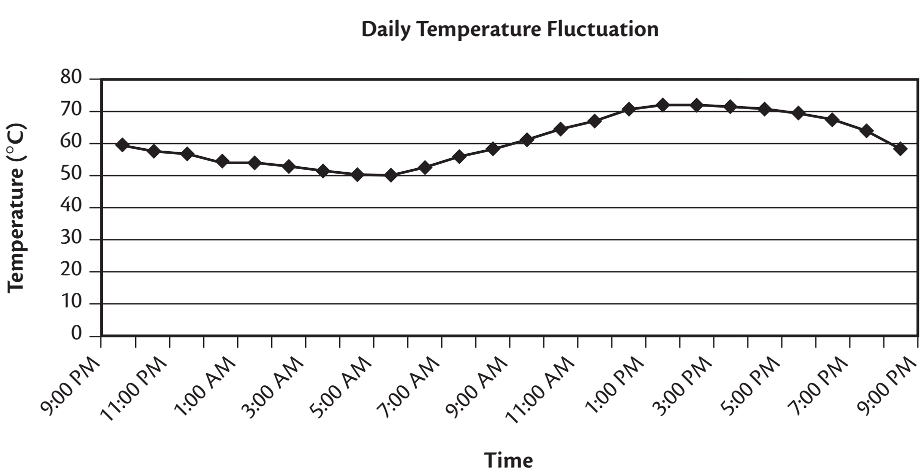

Figure 13 *Daily Temperature Fluctuation*

Activity

Alkanes are compounds of carbon and hydrogen with the general formula, C_nH_{2n+2}. Suppose that you did an experiment to determine the heat of combustion of several alkanes and noticed that the heat of combustion/mole increased as the number of carbons in the alkane increased. The data taken are shown in Figure 14. In your group plot a graph to help interpret the data.

Alkane	Number of carbon atoms	Heat of combustion, kJ/mole
Methane, CH_4	1	891
Ethane, C_2H_6	2	1561
Propane, C_3H_8	3	2219
n-Butane, C_4H_{10}	4	2879
n-Pentane, C_5H_{12}	5	3509

Figure 14 *Increase in Heat of Combustion in Alkanes*

Answer the following questions using your graph.

1. Describe the type of relationship that the graph depicts between carbon atoms and the heat of combustion.
2. Predict the value for the heat of combustion for the alkane with six carbon atoms.
3. Predict the value for the heat of combustion for a substance with no carbon atoms. Why is the value not 0? (*Hint:* Consider what remains in the formula when there are no carbon atoms.)
4. Could you use this same graph to predict the heat of combustion for other kinds of hydrocarbons? Why or why not?

XY-Plots

An **XY-plot** (also called a scatterplot) demonstrates a mathematical relationship between two variables. This type of plot is especially useful in scientific work. Sometimes it is difficult to decide if a graph is a line graph or an XY-plot. One difference is that in an XY-plot it is possible to determine a mathematical relationship between the variables. Sometimes the relationship is the equation for a straight line ($y = mx + b$), but other times it is more complex and requires manipulation of the data. To clarify, we will first look at a straight line, or direct relationship, then proceed to more complex situations.

Example

An entrepreneur was considering investing in a mine that was said to produce gold. Several very small irregular nuggets were given to a chemist for analysis. The chemist, who was instructed to use nondestructive methods, decided to determine the density of the small samples. A micro-buret was used to determine the volume of each nugget, and the mass was determined on an analytical balance. The data collected are shown in Figure 15.

Nugget	Volume (mL)	Mass (g)
1	0.006	0.116
2	0.012	0.251
3	0.015	0.290
4	0.018	0.347
5	0.021	0.386

Figure 15 *Gold Nugget Data*

Because a mathematical relationship is expected between the mass and volume of an element, the chemist constructed an XY-plot.

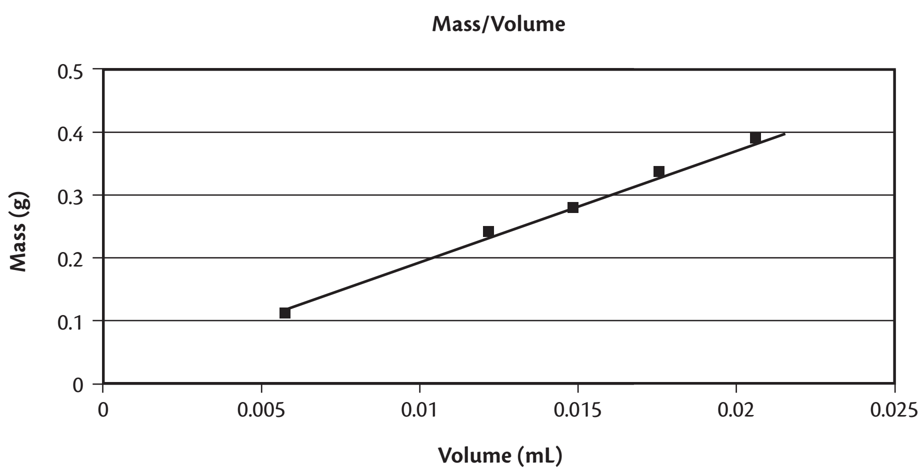

Figure 16 *Gold Nugget Graph*

To connect the plotted points, the best smooth curve, which appears to be a straight line, is drawn.

Activity

1. Find the slope of the line drawn on the Mass/Volume graph. To find the slope, choose two points on the line. These points do not need to be ones you plotted. Determine the *x* and *y* coordinates of each point.

   Calculate the slope using the formula $slope = \frac{y^2 - y^1}{x^2 - x^1}$
2. What units are appropriate for the slope?
3. The density of a gold sample is 18.88. Is the sample likely to be pure gold? Explain your answer.

Next we will consider a graph where the initial plot is not a straight line. Figure 17 (page 21) provides the data for the graph in Figure 18. It plots the volume of one mole of NH_3 gas at various pressures.

Pressure (atm)	Volume (mL)
0.1000	244.5
0.2000	122.2
0.4000	61.02
0.8000	30.44
2.000	12.17
4.000	5.975
8.000	2.925

Figure 17 *Data for the Effect of Pressure on Volume*

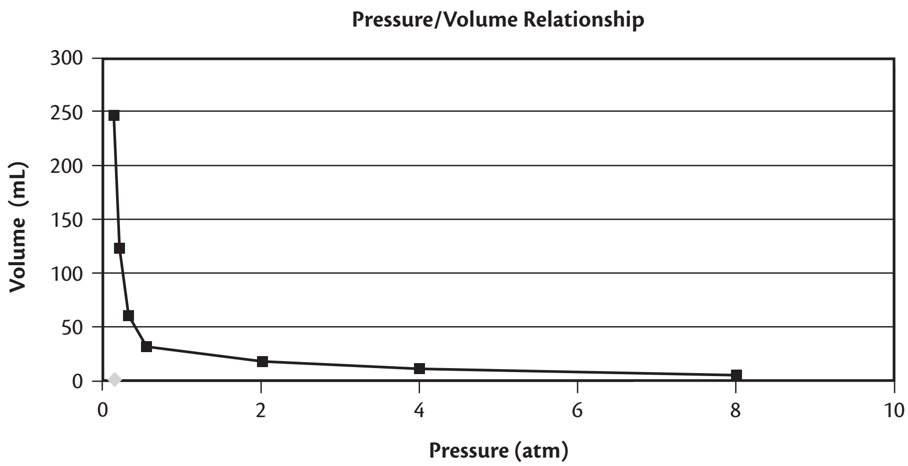

Figure 18 *Graph of Pressure-Volume Relationship*

When the best smooth curve is not a straight line, the data can be manipulated to see if another mathematical relationship is possible. In this case it appears that as the pressure increases the volume decreases. So we can calculate the value of 1/V, add another column to the table (Figure 19), and plot that data (Figure 20).

Pressure (atm)	Volume (mL)	1/Volume, 1/mL
0.1000	244.5	0.00409
0.2000	122.2	0.00816
0.4000	61.02	0.0164
0.8000	30.44	0.0329
2.000	12.17	0.0822
4.000	5.975	0.167
8.000	2.925	0.3419

Figure 19 *Data for Inverse Relationship Between Pressure and Volume*

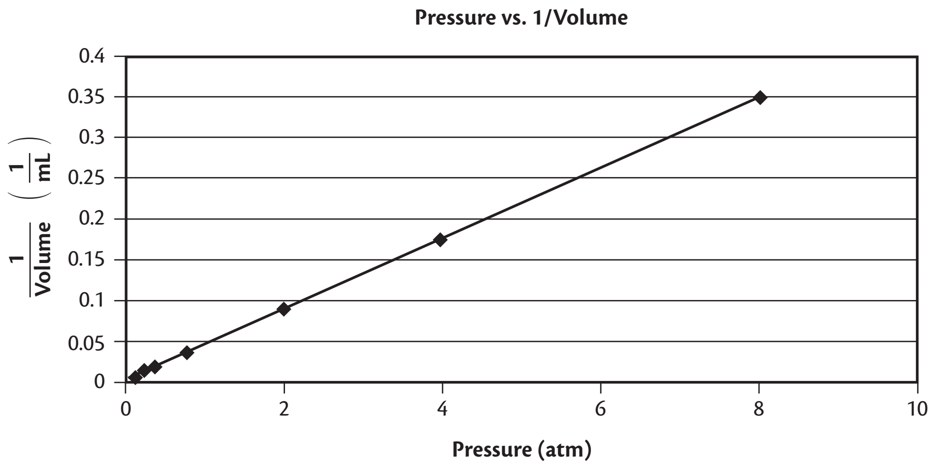

Figure 20 *Graph Showing Inverse Relationship Between Pressure and Volume*

This time the graph exhibits a straight line so we know that pressure and volume are inversely related. If this mathematical manipulation did not result in a straight line, other mathematical changes or analysis might be considered.

INTERPRETING TABLES

Tables can be as simple as listing the value for a single property of a substance or as complex as the one in Figure 21. The unshaded portion lists the melting points for several substances. The shaded portion of the chart suggests some additional information to aid in interpretation. You may be asked to look for relationships in the data.

Substance	Formula	Melting Point (°C)	*Molar Mass*	*Structure*	*Polarity of Molecule*
Water	H_2O	0	*18*	*Molecular*	*Polar—H bonds*
Benzene	C_6H_6	5	*78*	*Molecular*	*Nonpolar*
Naphthalene	$C_{10}H_8$	80	*128*	*Molecular*	*Nonpolar*
Sodium chloride	NaCl	800	*58.5*	*Ionic*	*Not Applicable*
Methane	CH_4	−183	*16*	*Molecular*	*Nonpolar*
Magnesium fluoride	MgF_2	1248	*62*	*Ionic*	*Not Applicable*
Methanol	CH_3OH	−97.8	*32*	*Molecular*	*Polar—H bonds*

Figure 21 *Complex Table Showing Selected Properties of Substances*

Activity

1. Find two compounds in the table with similar molar masses. Compare their melting points. Which of the characteristics listed appears to correlate with the differences in melting point?
2. Compare the molecular compounds with the ionic compounds and make a generalization about structure and melting point.
3. Compare the characteristics of methane, benzene, and naphthalene. What factor seems to be responsible for differences in melting point?
4. The previous three questions use only some of the information available in the table. Write two more questions that might be asked about the table.
5. It is important to use all of the information available in a table. However, you should not make sweeping generalizations that are supported by only a small number of facts. Look at your answer to Question 1 and state what other information you might wish to look up to support your statement.

Additional Problems

1. The graph in Figure 22 shows the approximate level of CO_2 in the atmosphere from 1900 to 1990 for available decades. Study the graph and answer these questions:
   - **a.** Predict the CO_2 levels in 1910, 1940, and 2000.
   - **b.** What other type(s) of graph might also be useful to study this data?

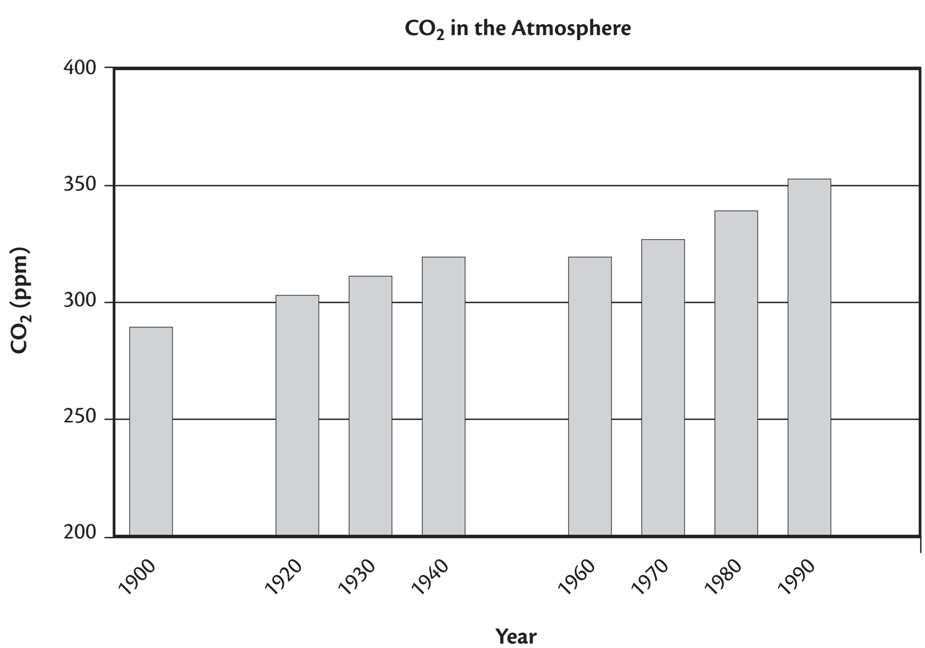

Figure 22 *Relative CO_2 Levels*

2. Graphically determine the density of ethylene glycol for the following data collected in the laboratory.

Volume (mL)	Mass (g)
10.0	11.20
15.0	16.72
20.0	22.14
25.0	17.78
30	33.42

Figure 23 *Ethylene Glycol Density Data*

3. The data below was collected when water was heated to its boiling point. Make a plot of this data. Answer the questions.

Time (sec)	Temperature (°C)
0	23
0.5	27
1.0	34.0
1.5	43.0
2.0	58.0
2.5	69.0
3.0	75.0
3.5	83.0
4.0	90.0
4.5	94.0
5.0	96.0
5.5	97.0
6.0	98.0
6.5	99.0
7.0	100.0
7.5	100.5

Figure 24 *Boiling Water Data*

4. Answer the following questions based on your graph.

a. What type of graph did you choose to plot? Explain why you chose this type.
b. Describe the change in temperature with time.
c. Predict the temperature at 4.3 minutes.
d. Predict the temperature at 8.5 minutes.
e. During what time period was there the greatest change in temperature?