ChE-101
H-4: Quality Tables and Plots

(Last updated May 02, 2005 by GGB)

This handout contains important information for the development of quality tables and Plots. These are general rules for making tables and plots, the specific details on how to use Matlab and Excel to make tables and plots are discussed in tutorials V and IX, respectively.

Introduction

Graphs and tables are two of the classic ways in which engineers communicate. Properly prepared, they convey a great deal of information in a short time. A graph is typically preferable, especially when a good deal of information is to be presented. It conveys trends not always evident in a table.

Unfortunately, far too many graphs are poorly prepared, thereby minimizing or misrepresenting the information that is meant to be conveyed. Following the conventions presented below will make your graphs and tables more reader friendly and informative.

REMEMBER, a quality presentation cannot save poor work, but a shoddy presentation will detract from quality work.

Guidelines for making Quality Plots

1. Each graph should have a Figure number, that way you can refer to it in the text where you use the information provided by the figure. Use Arabic numbers for the figures. The figures should be numbered in chronological order as they are cited in the text of a manuscript. DO NOT present a figure in your work unless you use it in the text of your manuscript. If you don't use it (refer to it) in the text of your manuscript that means that you don't need that figure. **Example:** Figure 1 (notice that the first letter in the word Figure is capitalized).
2. Each graph should have a figure title and caption. The figure title should be meaningful and related to the information presented in the graph. Most times it is convenient to show a caption of the figure. A caption summarizes important information that can be learned from the graph. This is really useful for the reader of your document. Examples of figure titles:

Proper figure title:

Figure 1. Pressure Drop for Water in a 2 Straight Inch Pipe as a Function of Flowrate

Each main word in the title starts with a capital letter

A dot is used to separate the figure number from the figure title

Incorrect figure title:

Figure 1. Pressure Drop vs. Flowrate

Avoid using vs. It is not meaningful. Notice that this title does not say anything about the figure

Title

Example using caption:

Figure 1. Pressure Drop for Water in a 2 Straight Inch Pipe as a Function of Flowrate. The pressure drop in the pipeline is a strong function of the flowrate, particularly at high flowrates.

Caption. Notice that the caption is separated from the figure title by a "." To write a figure caption you actually need to see the data. You don't need to capitalize each word in the caption. Think of the caption as a short explanation or conclusion of what is shown in the graph.

3. Each axis must be labeled including the units. Write the units in parenthesis. See examples:

   Proper label for axis:
   Temperature in the Tank (^{o}C)

   Notice that each main word is capitalized

   Incorrect label for axis:
   ~~T (^{o}C)~~ ← You can't do this. The reader does not know what is T

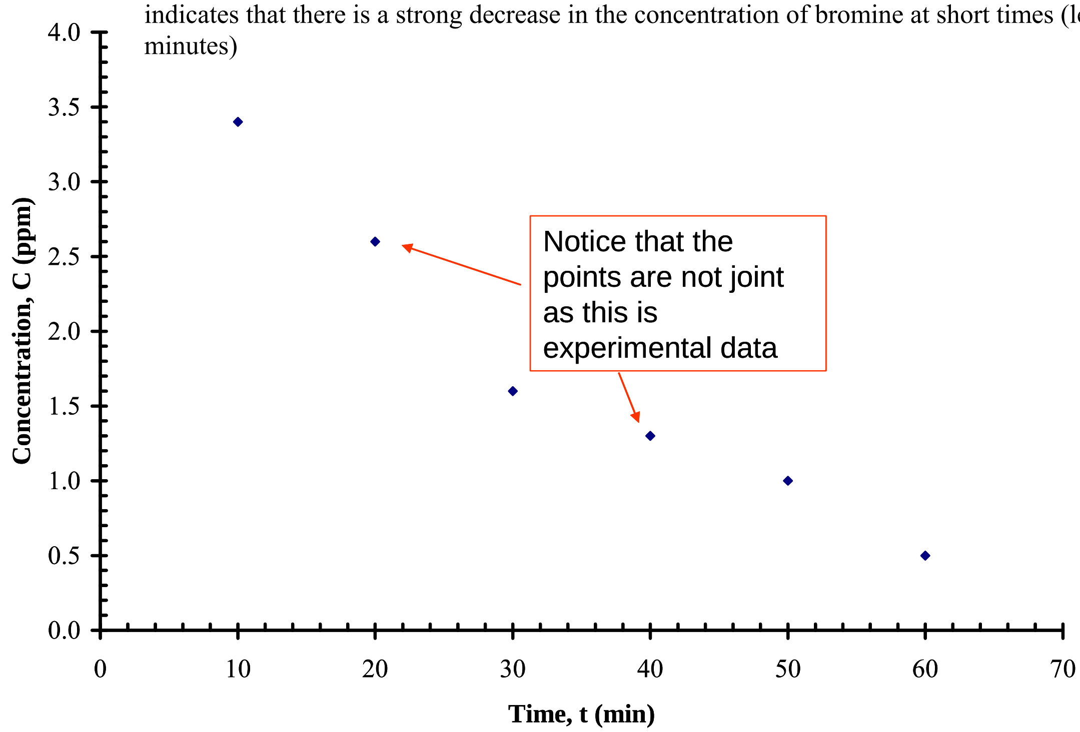
   Most of the time the information plotted in a graph is coming from an equation. In that case, it is very useful to include the symbol that is used in the equation. This should not be a stand alone symbol; the symbol should follow the axis label. See example below:

   Example using label and symbol simultaneously:
   Temperature in the Tank, T (^{o}C)

   Notice that the symbol follows the axis label and it is separated from it by a ","

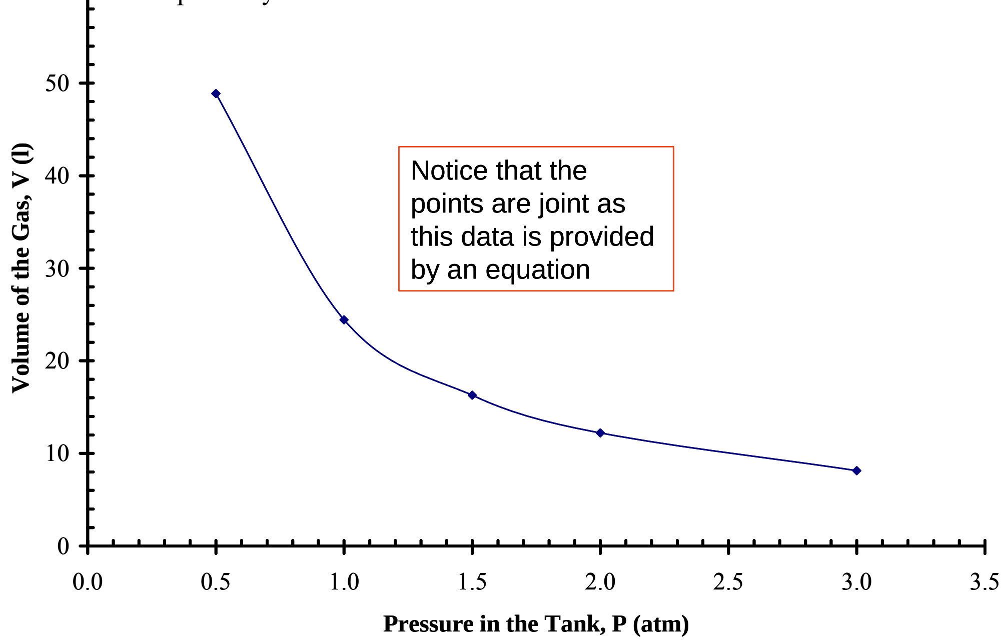
4. Scale. Choose an appropriate scale (e.g., linear, logarithmic, etc) depending on the data that you are going to plot. It is not necessary to start an axis at ZERO. If an intercept is an important piece of information, then show the ZERO in the scale.
5. Experimental data should be plotted as discrete points (do not join the points). See example below:

Figure 2**.** Variation of the Concentration of Aqueous Bromine as a Function of Time. The data indicates that there is a strong decrease in the concentration of bromine at short times (less than 30 minutes)



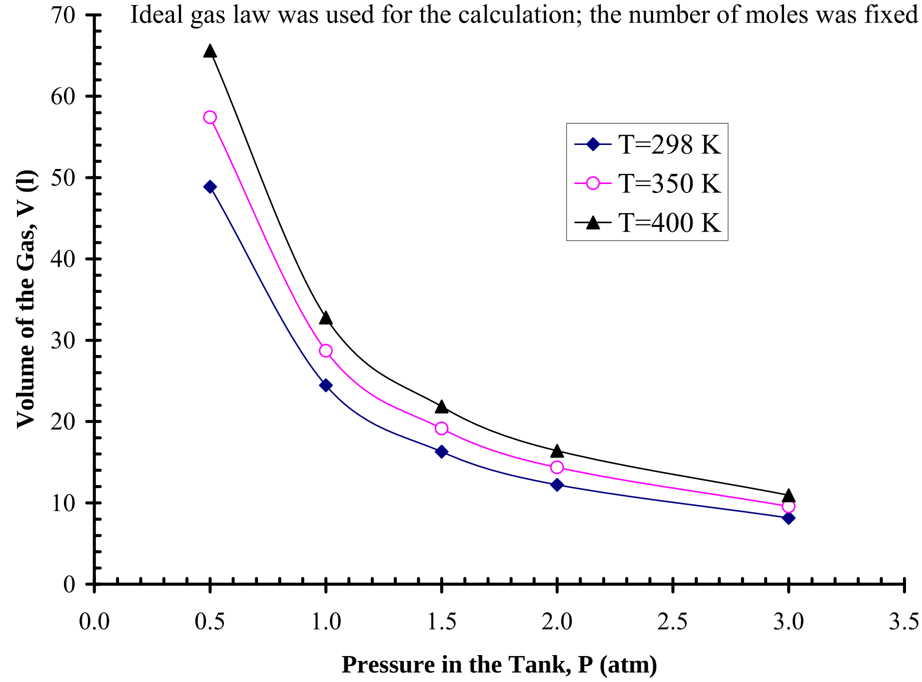
6. Functions should be plotted as a smooth curve (that is, in this case you MUST join the points). In the example given below the ideal gas law is used to predict the volume of a gas as function of pressure. Notice that in this case the caption of the figure indicates the values that were fixed in the calculation (number of moles and temperature). Anytime, this is the case, you MUST provide that information in the graph (OTHERWISE the reader won't understand how you did your calculation)

Figure 3**.** Volume of the Gas as a Function of the Pressure in the Tank. Ideal gas law was used for the calculation; the number of moles and the temperature were fixed at 1 mol and 298 K, respectively.



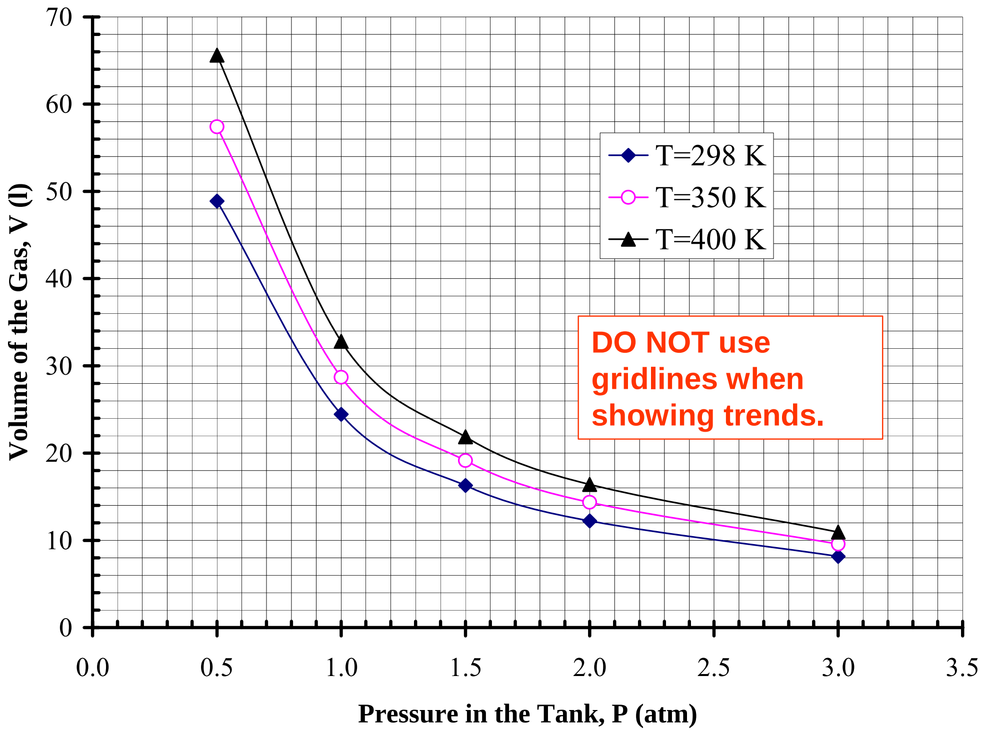
7. Plot multiple data sets together when comparison is important. Use clear symbols to each data set to increase readability. For a written presentation use various shapes or line types. Only use multiple colors on oral presentations, or if it is in addition to different shapes and line types. When plotting multiple data it is necessary to have a legend which identifies each curve. In the example given below ideal gas law is used to predict the volume of the gas as a function of pressure at different temperatures.

Figure 4**.** Volume of the Gas as a Function of the Pressure in the Tank at Different Temperatures. Ideal gas law was used for the calculation; the number of moles was fixed at 1 mol.



8. Gridlines. Do NOT use gridlines in your graphs. Gridlines are used ONLY when the goal of the graph is to read values (this is how books are written). Most of the time, the only purpose of the graph is to show trends, therefore, gridlines only make your presentation of the graph crowed and the graph is not really useful to show trends. See how crowded the graph looks in the example given below:

Figure 5**.** Volume of the Gas as a Function of the Pressure in the Tank at Different Temperatures. Ideal gas law was used for the calculation; the number of moles was fixed at 1 mol.



9. Use error bars to indicate the uncertainty of experimental data. You will learn how to calculate this when you take ChE-408: Engineering Experimental Design.
10. Digits and other numbers. Use a few number of digits as possible in your axis. The precision of the reading depends on the graph divisions (ticks), not on the number of significant figures labeling the tick marks on the axis. See example given below:

Figure 6**.** Variation of the Concentration of Aqueous Bromine as a Function of Time.

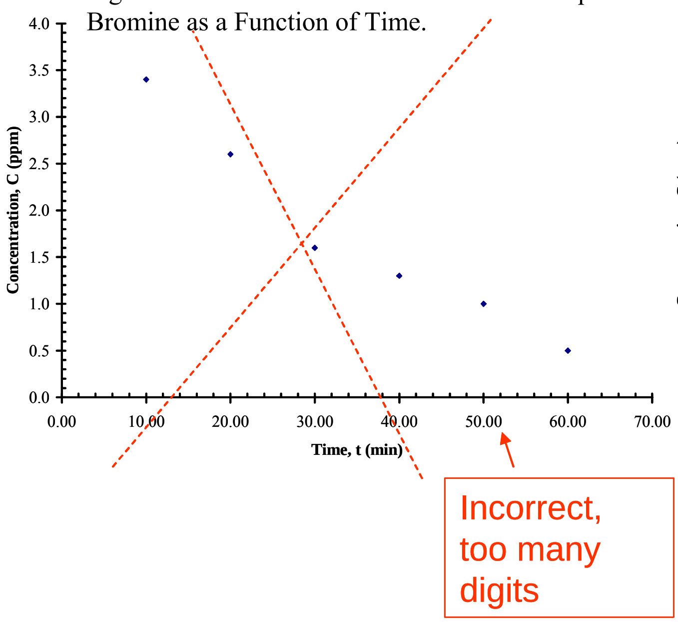
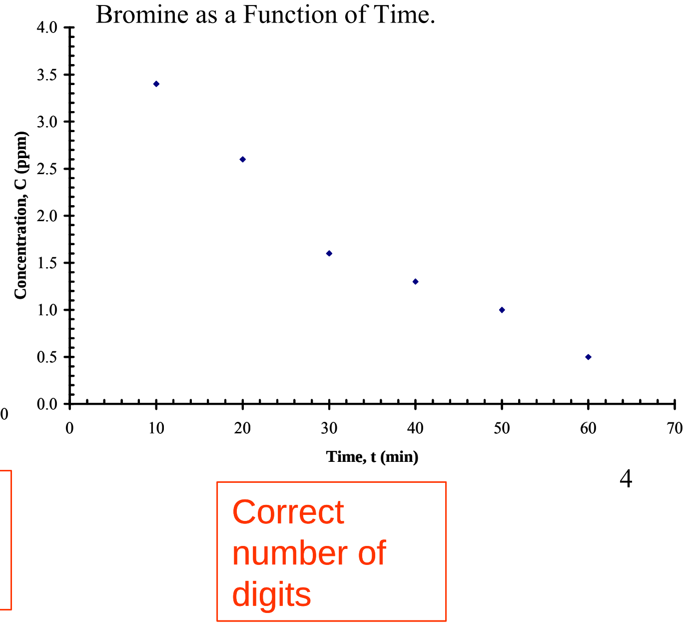
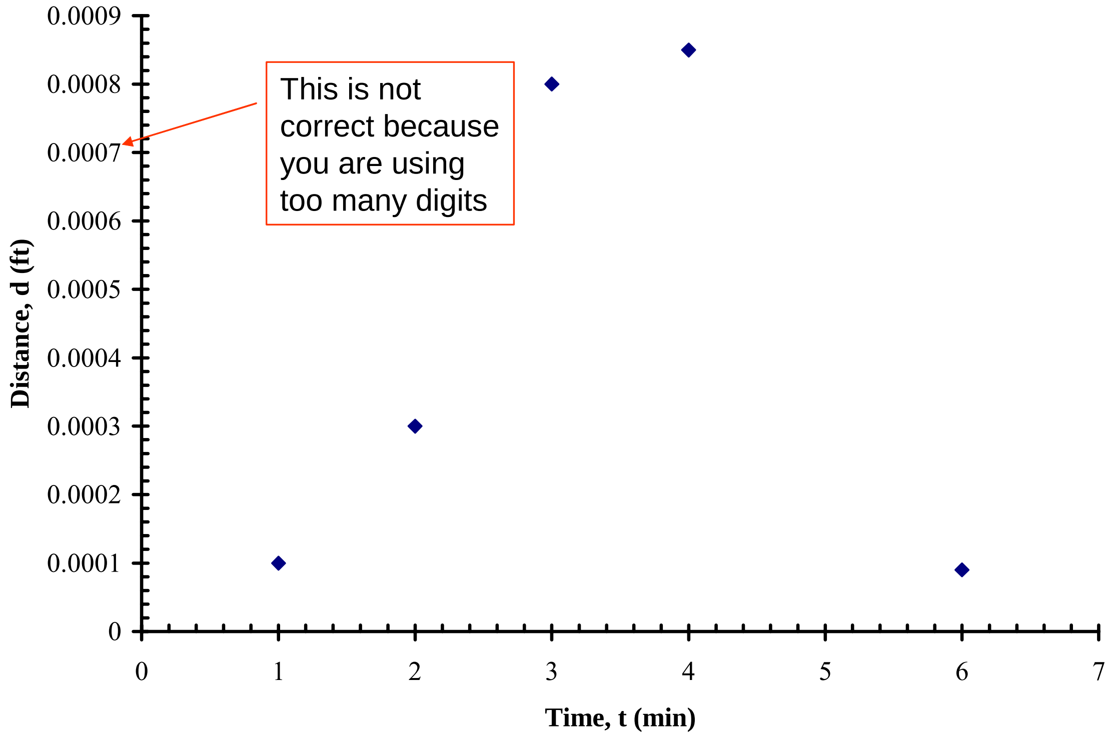


Figure 7**.** Variation of the Concentration of Aqueous Bromine as a Function of Time.

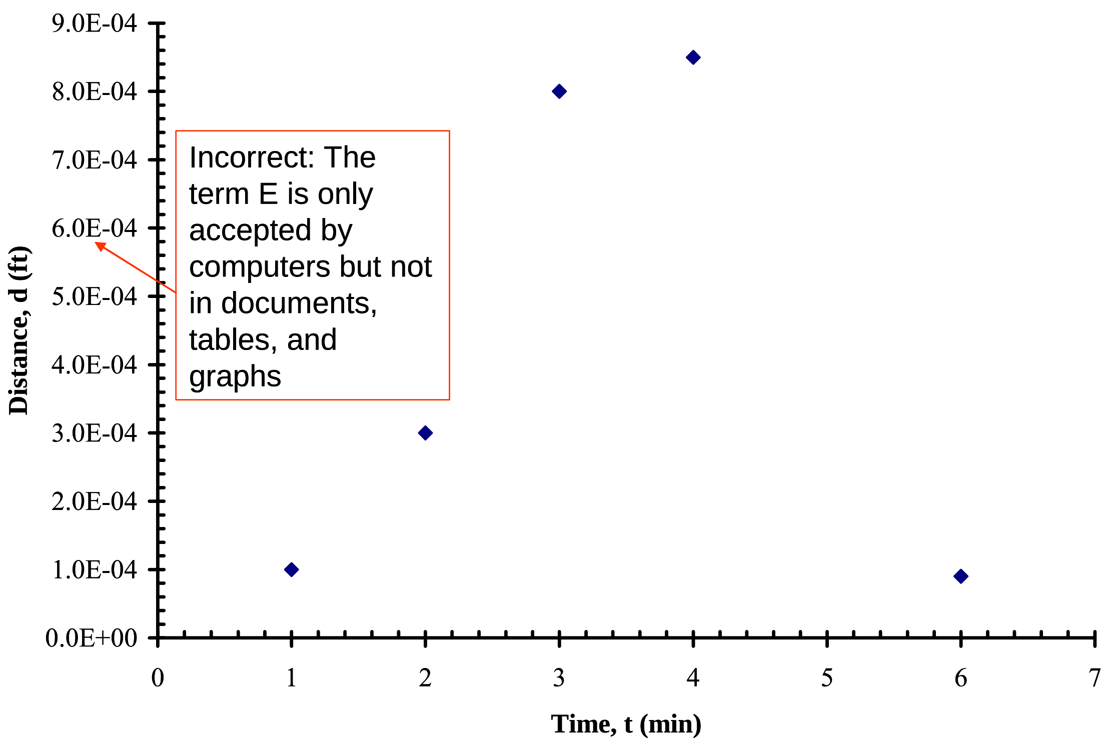


Use scientific notation with the units when appropriate. Be careful about the sign of the exponent. See the examples given below for correct use of scientific notation in graphs:

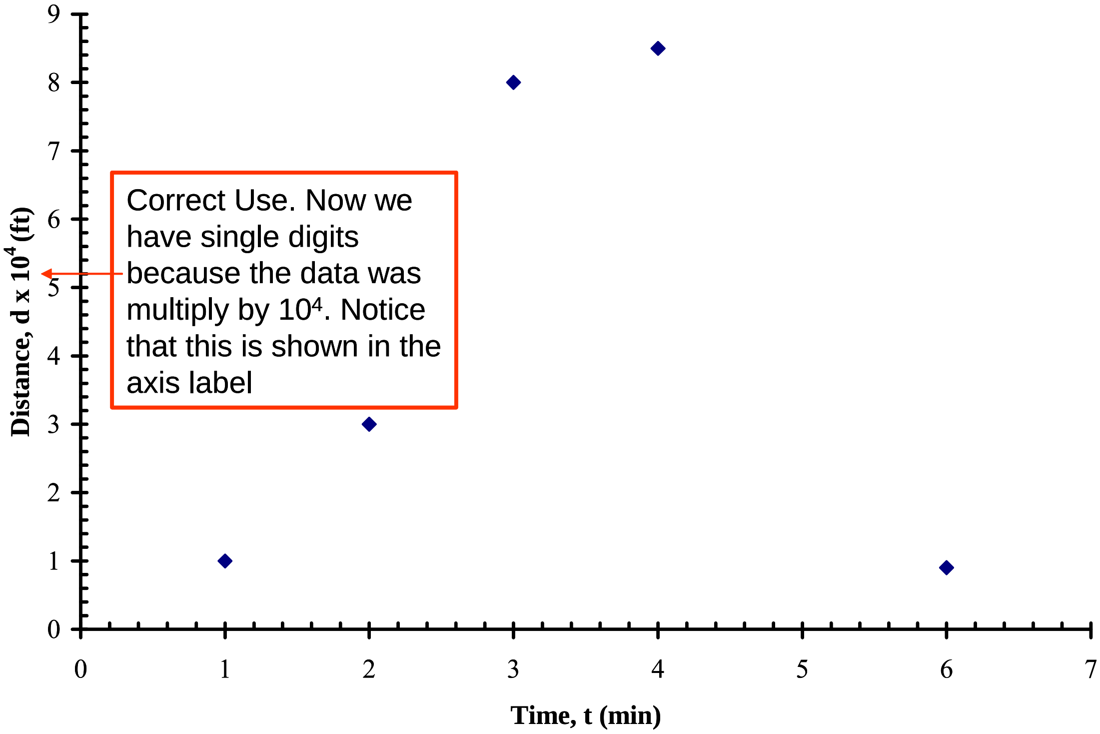
Incorrect use: Too many digits. Need to use scientific notation



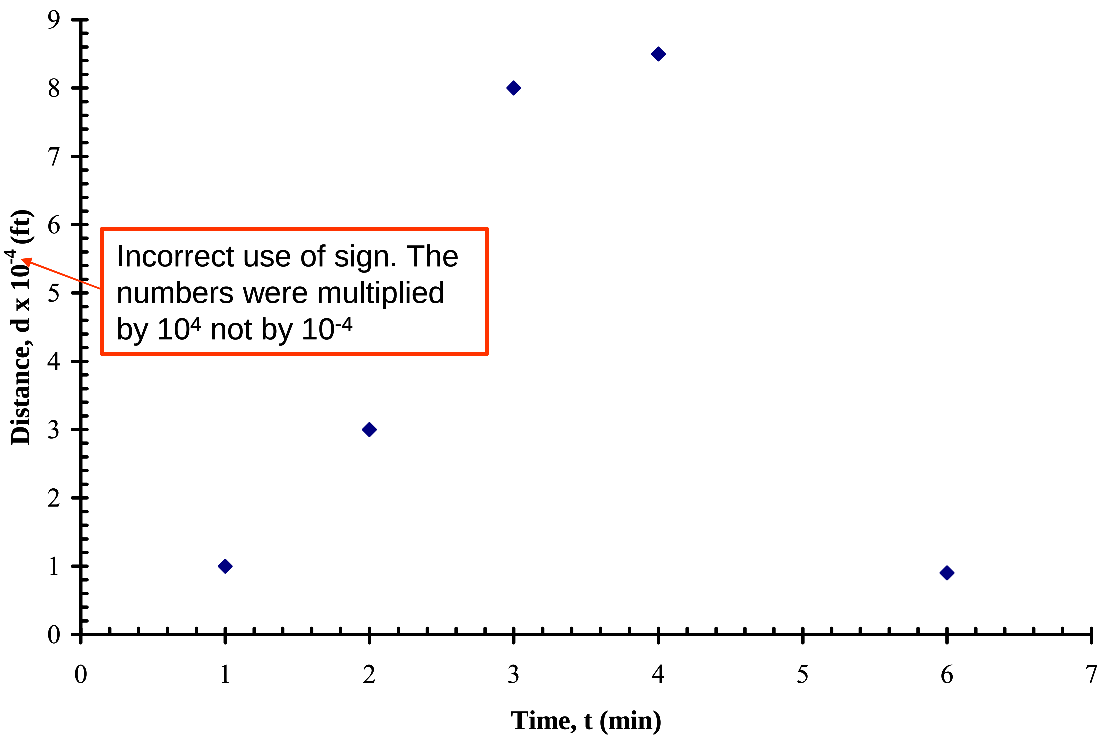
Incorrect use: Even though scientific notation is used the term "E" is only recognized by computers. Remember that the right way to write down scientific notation in documents is by $1\text{x}10^{+/-4}$



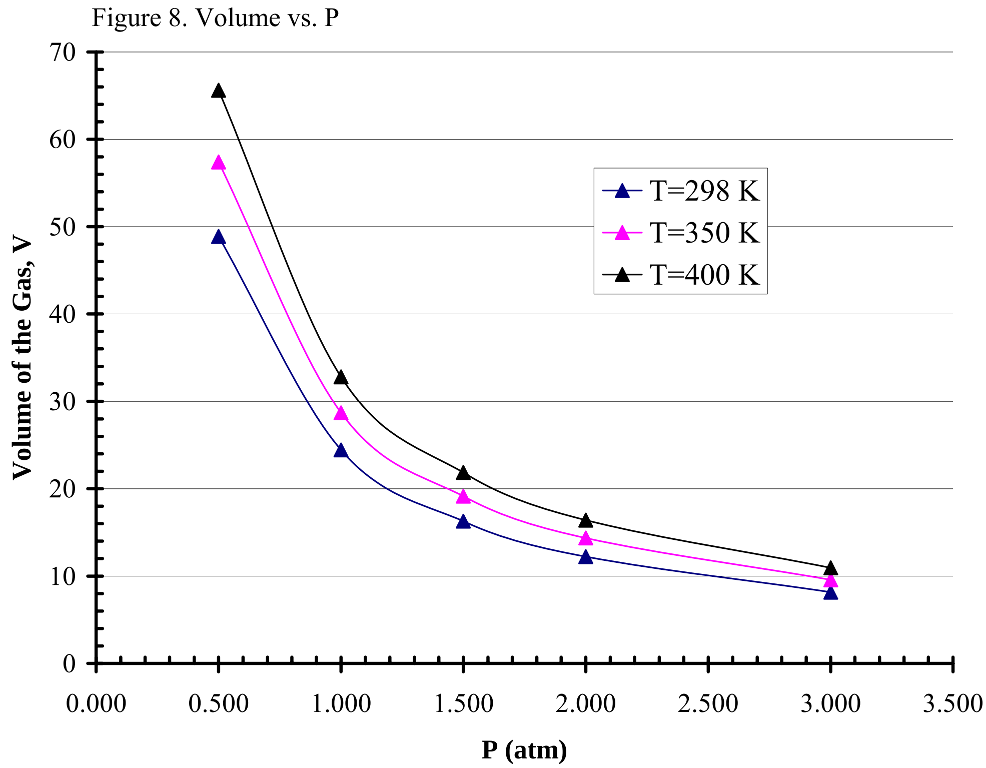
Correct use: The best thing to do in this case is to multiply the data by a number that will bring the digits to single units. For example, if we multiply the data by 10000 then the plot can be represented by (this should be indicated in the axis):

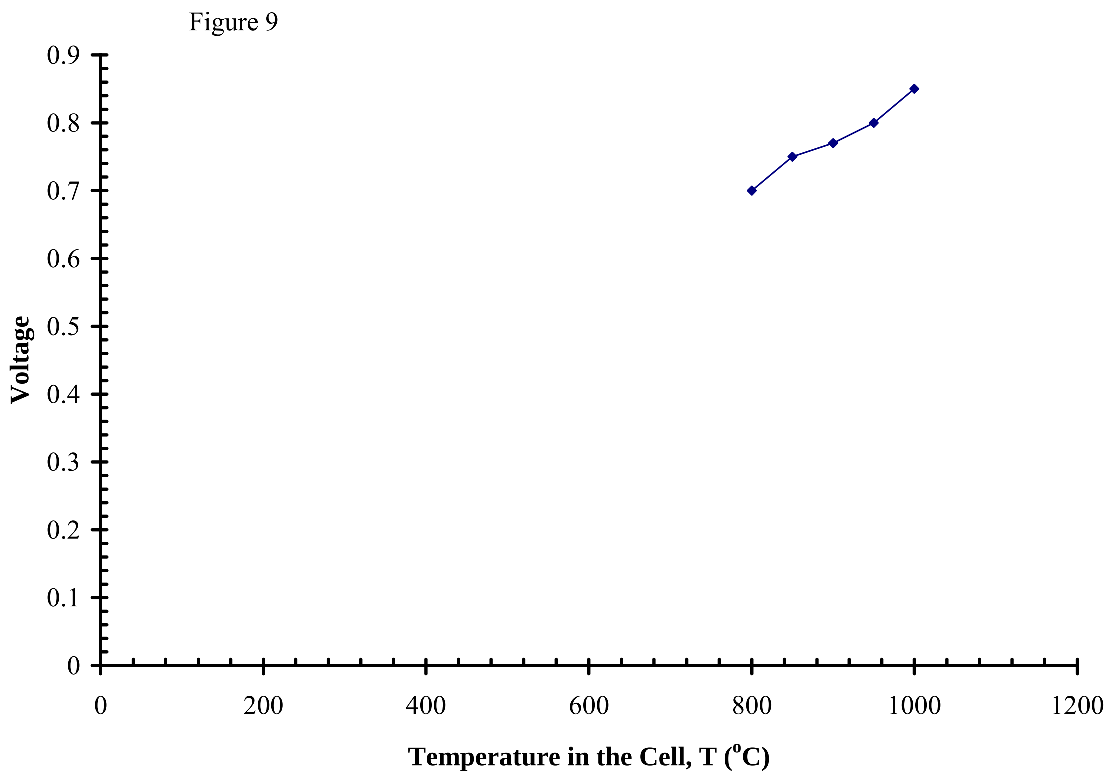


Incorrect use of sign: when using the approach explained above be careful with the sign that you use for the power. Remember that the data was multiply by 10^4 not by 10^{-4}.



Class Exercise 1: Given the graphs presented below, identify what were the mistakes made according to the guidelines for quality graphs. In all cases, indicate how you would fix the mistakes.





Guidelines for making Quality Tables

Many of the guidelines presented for graphs apply to quality table preparation as well. A few additional rules are given here.

1. Each table should have a table number, that way you can refer to it in the text where you use the information provided by the table. Use Arabic numbers for the tables. The tables should be numbered in chronological order as they are cited in the text of a manuscript. DO NOT present a table in your work unless you use it in the text of your manuscript. If you don't use it (refer to it) in the text of your manuscript that means that you don't need that table. **Example:** Table 1 (notice that the first letter in the word Table is capitalized).
2. Each table should have a table title. The table title should be meaningful and related to the information presented in the table. Captions are not commonly used in tables.

   Proper table title:

   Table 1. Properties of Saturated Liquid

   Each main word in the title starts with a capital letter

   A dot is used to separate the table number from the table title

3. Each column must be labeled including the units. This is uses the same format as for quality plots (see item #3 in Guidelines for Quality Plots, p.3).
4. Lines. Lines are used to separate columns and main rows in a table. No all the rows are separated by lines, only main rows or subdivisions are separated by lines. Do not write borders all the way around the table (only top and bottom borders are required). For a best demonstration of this item, see the examples below for correct and incorrect use of borders in tables:

   Correct use of borders in a table

Table 2. Properties of Engine Oil (unused) as Saturated Liquid

Temperature, T (^oC)	Density, ρ (kg/m^3)	Heat Capacity, c_p (kJ/kg ^oC)
0	899.12	1.796
20	888.23	1.880
40	876.05	1.964
60	864.04	2.047
80	852.02	2.131
100	840.01	2.219

Only borders allowed in a Table

Borders are also used to separated columns

Incorrect use of borders in tables

Temperature, T (°C)	Density, ρ (kg/m³)	Heat Capacity, c_p (kJ/kg °C)
0	899.12	1.796
20	888.23	1.880
40	876.05	1.964
60	864.04	2.047
80	852.02	2.131
100	840.01	2.219

Incorrect borders on side columns

Temperature, T (°C)	Density, ρ (kg/m³)	Heat Capacity, c_p (kJ/kg °C)
0	899.12	1.796
20	888.23	1.880
40	876.05	1.964
60	864.04	2.047
80	852.02	2.131
100	840.01	2.219

Incorrect borders on side columns and internal rows

Sometimes different categories or subdivisions are required in rows. In this case, the categories need to be separated by lines. See example below:

Table 3. Properties of Saturated Liquids

Fluid	Temperature, T (°C)	Density, ρ (kg/m³)	Heat Capacity, c_p (kJ/kg °C)
Engine oil (unused)	0	899.12	1.796
	20	888.23	1.880
	40	876.05	1.964
	60	864.04	2.047
	80	852.02	2.131
	100	840.01	2.219
Ethylene glycol	0	1130.75	2.294
	20	1116.65	2.382
	40	1101.43	2.474
	60	1087.66	2.562
	80	1077.56	2.650
	100	1058.5	2.742

Correct use of internal border lines. Different categories are separated

5. Use proper number of significant figures. Keep the same number of significant figures for data reported in the same column. See examples below:

Incorrect

Temperature, T (°C)	Density, ρ (kg/m³)	Heat Capacity, c_p (kJ/kg °C)
0	899.1	1.796
20	888.23	1.880
40	876.05	1.96
60	864.04	2.047
80	852	2.131
100	840.01	2.219

Correct

Temperature, T (°C)	Density, ρ (kg/m³)	Heat Capacity, c_p (kJ/kg °C)
0	899.12	1.796
20	888.23	1.880
40	876.05	1.964
60	864.04	2.047
80	852.02	2.131
100	840.01	2.219

6. Include errors in the columns to indicate the uncertainty of experimental data. You will learn how to calculate this when you take ChE-408: Engineering Experimental Design. Furthermore, the

number of significant figures used for presenting experimental data depends on the errors or uncertainties. You will learn how to do this later in the curricula.

7. Use scientific notation where appropriate. It is recommended that when numbers are larger than the thousand ranges (that is above 9999), scientific notation should be used. Be careful about the sign of the exponent. Note that the meaning of the sign of the exponent is different when it is located in the heading, as opposed to being in the table itself. (Many tables in the literature do this incorrectly. Be careful). See examples given below for clarification:

Table A-4 Properties of Saturated Liquids† (*continued*)

T, °C	ρ, kg/m³	c_p, kJ/kg · °C	ν, m²/s	k, W/m · °C	α, m²/s	Pr	β, K⁻¹
			Dichlorodifluoromethane (Freon), CCl_2F_2				
−50	1,546.75	0.8750	0.310×10^{-6}	0.067	0.501×10^{-7}	6.2	2.63×10^{-3}
−40	1,518.71	0.8847	0.279	0.069	0.514	5.4	
−30	1,489.56	0.8956	0.253	0.069	0.526	4.8	
−20	1,460.57	0.9073	0.235	0.071	0.539	4.4	
−10	1,429.49	0.9203	0.221	0.073	0.550	4.0	
0	1,397.45	0.9345	0.214×10^{-6}	0.073	0.557×10^{-7}	3.8	
10	1,364.30	0.9496	0.203	0.073	0.560	3.6	
20	1,330.18	0.9659	0.198	0.073	0.560	3.5	
30	1,295.10	0.9835	0.194	0.071	0.560	3.5	
40	1,257.13	1.0019	0.191	0.069	0.555	3.5	
50	1,215.96	1.0216	0.190	0.067	0.545	3.5	
			Glycerin, $C_3H_5(OH)_3$				
0	1,276.03	2.261	0.00831	0.282	0.983×10^{-7}	84.7×10^3	
10	1,270.11	2.319	0.00300	0.284	0.965	31.0	
20	1,264.02	2.386	0.00118	0.286	0.947	12.5	0.50×10^{-3}
30	1,258.09	2.445	0.00050	0.286	0.929	5.38	
40	1,252.01	2.512	0.00022	0.286	0.914	2.45	
50	1,244.96	2.583	0.00015	0.287	0.893	1.63	

Values for the thermal conductivity (α) read from the table are reported as 10^{-7} , for example $0.514\text{x}10^{-7}$.

Table A-3 Properties of Nonmetals† (*continued*)

Substance	*Temperature*, °C	*k*, W/m · °C	*ρ*, kg/m³	*c*, kJ/kg · °C	*α*, m²/s × 10⁷
		Insulating material			
Asbestos:					
Loosely packed	−45	0.149			
	0	0.154	470–570	0.816	3.3–4
	100	0.161			
Asbestos-cement boards	20	0.74			
Sheets	51	0.166			
Felt, 40 laminations/in	38	0.057			
	150	0.069			
	260	0.083			
20 laminations/in	38	0.078			
	150	0.095			
	260	0.112			
Corrugated, 4 plies/in	38	0.087			
	93	0.100			
	150	0.119			
Asbestos cement	—	2.08			
Balsam wool, 2.2 lb/ft³	32	0.04	35		
Cardboard, corrugated	—	0.064			
Celotex	32	0.048			
Corkboard, 10 lb/ft³	30	0.043	160		
Cork, regranulated	32	0.045	45–120	1.88	2–5.3
Ground	32	0.043	150		
Diatomaceous earth (Sil-o-cel)	0	0.061	320		
Felt, hair	30	0.036	130–200		
Wool	30	0.052	330		
Fiber, insulating board	20	0.048	240		
Glass wool, 1.5 lb/ft³	23	0.038	24	0.7	22.6
Insulex, dry	32	0.064			
		0.144			
Kapok	30	0.035			
Magnesia, 85%	38	0.067	270		
	93	0.071			
	150	0.074			
	204	0.080			
Rock wool, 10 lb/ft³	32	0.040	160		
Loosely packed	150	0.067	64		
	260	0.087			
Sawdust	23	0.059			
Silica aerogel	32	0.024	140		
Wood shavings	23	0.059			

†Adapted to SI units from A. I. Brown and S. M. Marco, "Introduction to Heat Transfer," 3d ed., McGraw-

Same case here. However, notice that the way is presented is different. The exponential is given in the heading.

Class Exercise 2: Given the tables presented below, identify what were the mistakes made according to the guidelines for quality graphs. In all cases, indicate how you would fix the mistakes.

Table 4.

Fluid	Temperature, T (^oC)	Density, ρ (kg/m^3)	Heat Capacity, c_p ($kJ/kg\ ^oC$)
Engine oil (unused)	0	899.12	1.796
	20	888.23	1.880
	40	876	1.964
	60	864.04	2.047
	80	852.02	2.131
	100	840.01	2.219
Ethylene glycol	0	1130.75	2.294
	20	1116.65	2.382
	40	1101.43	2.474
	60	1087.66	2.562
	80	1077.56	2.650
	100	1058.5	2.742

Table 5. Properties of Engine Oil (unused) as Saturated Liquid

Temperature, T (^oC)	Density, ρ (kg/m^3)	Heat Capacity, c_p ($kJ/kg\ ^oC$)
0	8.99E+02	1.796
20	8.88E+02	1.880
40	8.76E+02	1.964
60	8.64E+02	2.047
80	8.52E+02	2.131
100	8.40E+02	2.219