A LaTeX Template for a Master's or PhD Thesis: Because Microsoft Word is terrible for scientific writing

Submitted in partial fulfillment of the requirements for

the degree of

Some Degree

in

Blahblah Engineering

Student Name

B.S., Basic Engineering, Whatever University.
M.S., Next-level Engineering, Random University

Name of Curent University
City, State

Month Year

Dedicated to dogs

Acknowledgements

I would like to thank my advisor, my friends, my family, my funding sources, etc.

Abstract

LaTeX is an extremely powerful and efficient tool for scientific writing. However, as with all software, there is a bit of a learning curve involved. With LaTeX, the biggest (and perhaps only) learning curve is that it does not have graphical user interface. All formatting commands such as **boldfacing**, *italicizing*, changing font size on the fly, $\text{text}_{\text{subscripting}}$, $m = a_h^t$, etc. have to be entered as plain-text code: `\textbf{boldfacing}`, `\textit{italicizing}`, `{\tiny changing font size on the fly}`, `text\textsubscript{subscripting}`, `$m=a^t_h$`. Seems cumbersome, right? Why type the extra commands, when you can instead select the text you wish to modify, and just click a button in your writing software?

The thing is, scientific documents such as manuscripts, dissertations, and books are often "complex". What I mean by that is they are not just text documents. They have plenty of figures, tables, equations, chapters, sections, subsections, literature references etc. In theory, typical writing software like MS Word and Libre Writer have the capability to handle this. But in practice, as the complexity of a document increases, these software are prone to several issues:

1. Crashing without auto-saving, because of too much memory/processor load
2. Messing up numbering of figures, tables, sections, equations, etc. when document is opened.
3. Compatibility issues with citation software like Mendeley.
4. Complex equations written in companion software like MathType (for MS Word) and

Math Formula (for Libre Writer) just don't look aesthetic. The fonts look different, the subscripting and superscripting is all off, and ... well it just doesn't look pretty.

5. Inter-computer compatibility issues i.e., the document looks a certain way on your computer, but when you send it to someone else, it looks different on their computer for a variety of reasons such as you have a Mac, but they have Windows.

6. Updating in-text references to figures, tables, etc. is cumbersome and requires user to manually double-check every one of them even though Word is supposed to do it automatically.

Instead, LaTeX simplifies things incredibly. Here's a point-by-point list of how LaTeX is a solution to these issues:

1. The reason Word crashes is that it is not only trying to keep the text of the document on memory (while you are editing the file), but it is also trying to keep all formatting, figures, references, equations, captions, etc. preserved while letting you edit them in real time. Instead, LaTeX separates these two processes. The user only enters the text and the commands for formatting, importing figures, etc. are entered as plain text. All of this knitted together only when the LaTeX code is compiled, and the output is a clean PDF. The few seconds it takes for LaTeX to compile a code is the only time during which your machine's processing power is used by LaTeX.

2. The reason Word messes up numbering is that it refreshes all numbering when the file is first opened. Instead, LaTeX generates a PDF wherein all numbering is "locked in", and not refreshed when the PDF file is opened.

3. LaTeX has no need to "talk" to your citation manager.

4. LaTeX uses the same font for its text, as it does for its math. And LaTeX is built to accept math commands of a wide range of complexities.

5. LaTeX generates a PDF, which by definition is a "portable document format" and thus it looks exactly the same on all computers, irrespective of what OS they are using (Mac, Linux, Windows, etc.), what PDF reader they are using, etc.

6. LaTeX only processes cross-references at the time of compiling, and thus relieves the user of the task of double-checking the referencing (as long as there were no typos in the referencing commands in the first place).

Contents

List of Figures

List of Tables

Chapter 1

A Chapter

1.1 A section on math

To activate in-line math mode, enclose math within dollar signs. So, if your code has `$\alpha^2 = 10\beta_{s}^{0.8}$`, LaTeX will interpret it as $\alpha^2 = 10\beta_s^{0.8}$.

You can also insert complicated math using the `align` environment like below:

$$\iiint_V (\nabla \cdot \mathbf{F}) dV = \oiint_{S(V)} \mathbf{F} \cdot \hat{\mathbf{n}} dS$$
$$\iiint_V (\nabla \times \mathbf{F}) dV = \oiint_{S(V)} \hat{\mathbf{n}} \times \mathbf{F} dS$$
$$\iiint_V (\nabla f) dV = \oiint_{S(V)} \hat{\mathbf{n}} f dS$$

If you want the equations to be numbered, use the `\begin{align}` command instead of `\begin{align*}`. The `\label` command declares the unique key to be used for referring to this equation, as shown in Equations 1.1 and 1.2.

$$S(\omega) = \frac{\alpha g^2}{\omega^5} e^{[-0.74\left\{\frac{\omega U_\omega 19.5}{g}\right\}^{-4}]} \tag{1.1}$$

$$= \frac{\alpha g^2}{\omega^5} \exp\left[-0.74\left\{\frac{\omega U_\omega 19.5}{g}\right\}^{-4}\right] \tag{1.2}$$

1.2 A section on citing literature

1.2.1 Preparing your .bib file

To include citations, first add them to the `ch01_REFS.bib` file in a specific format called "BibTeX" format. The easiest way to do this is from a citation managing software (e.g., in Mendeley, right-click on any paper and select "Copy As > Bibtex entry". Next, open the `ch01_REFS.bib` file in your TeX editor, and paste the BibTeX entry at the end. It should look something like this:

```
@article{Shah2020,
  Author = {Shah, Rishabh U. and Coggon, Matthew M. and Gkatzelis, Georgios I. and McDonald, Brian C. and Tasoglou, Antonios and Huber, Heinz and Gilman, Jessica and Warneke, Carsten and Robinson, Allen L. and Presto, Albert A.},
  Doi = {10.1021/acs.est.9b06531},
  Journal = {Environmental Science and Technology},
  Number = {2},
  Pages = {714--725},
  Title = {{Urban Oxidation Flow Reactor Measurements Reveal Significant Secondary Organic Aerosol Contributions from Volatile Emissions of Emerging Importance}},
  Volume = {54},
  Year = {2020},
  Url = {https://doi.org/10.1021/acs.est.9b06531}}
```

The `Shah2020` that appears at the top of the BibTeX record is called a "cite key". **Warning:** No two records in the `ch01_REFS.bib` can have the same cite key!

1.2.2 Get citing

To cite the study shown in Section 1.2.1, you should type the command `\citep{Shah2020}`. Sometimes you may want to cite a paper at the end of a sentence (Shah et al., 2020). But

sometimes, you might also insert a citation as part of sentence, such as Shah et al. (2020). Sometimes, you might want to cite multiple references altogether inside one set of parantheses (Shah et al., 2018, 2020; Robinson et al., 2019). LaTeX identifies papers by the same author, and compresses them together i.e., instead of (Shah et al. 2018, Shah et al. 2020), it writes (Shah et al., 2018, 2020). Sometimes, you may want to cite a study in text that is already in parantheses (e.g., the study by (Shah et al., 2018) was about air pollution). If you want, you can avoid double parantheses as follows: (e.g., the study by Shah et al., 2018, was about air pollution).

1.3 A section on embedding figures

As shown in Figures 1.1 and 1.2, data visualization is an art. The code for importing figures is fairly self-explanatory.

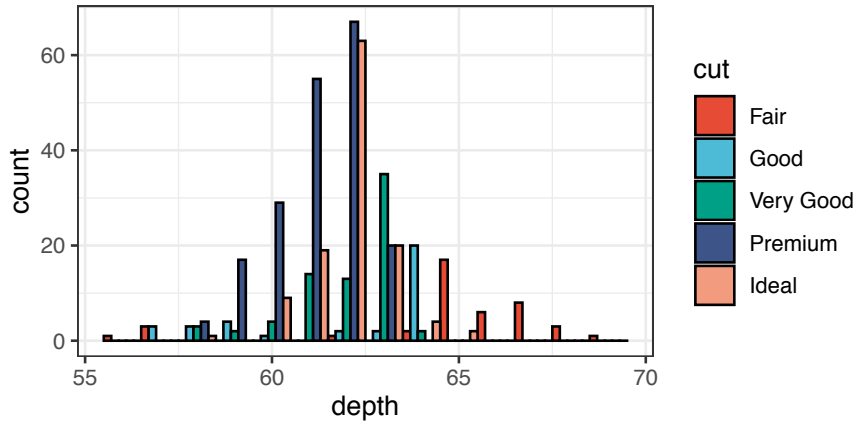

Fig. 1.1: This is a detailed figure caption, describing what the figure shows. A general good practice: a figure and its caption, together, should be self-sufficient in conveying the message. The reader should not have to look for further explanation of the figure in the text.

The `[!h]` flag after the `\begin{figure}` command forces LaTeX to place the Figure exactly where it appears in the code. If this flag is not included, LaTeX will try to place the Figure where it "fits" best. Other options instead of `!h` include `!b` (bottom of page), `!t` (top of page), etc.

The `\caption` command takes two arguments: the first one (in square brackets) is a short caption, while the second one (in curly brackets) is a detailed caption. The short caption appears in the List of Figures. The detailed caption appears directly beneath the Figure.

As always, the `\label` command declares the unique key to be used for referring to this Figure.

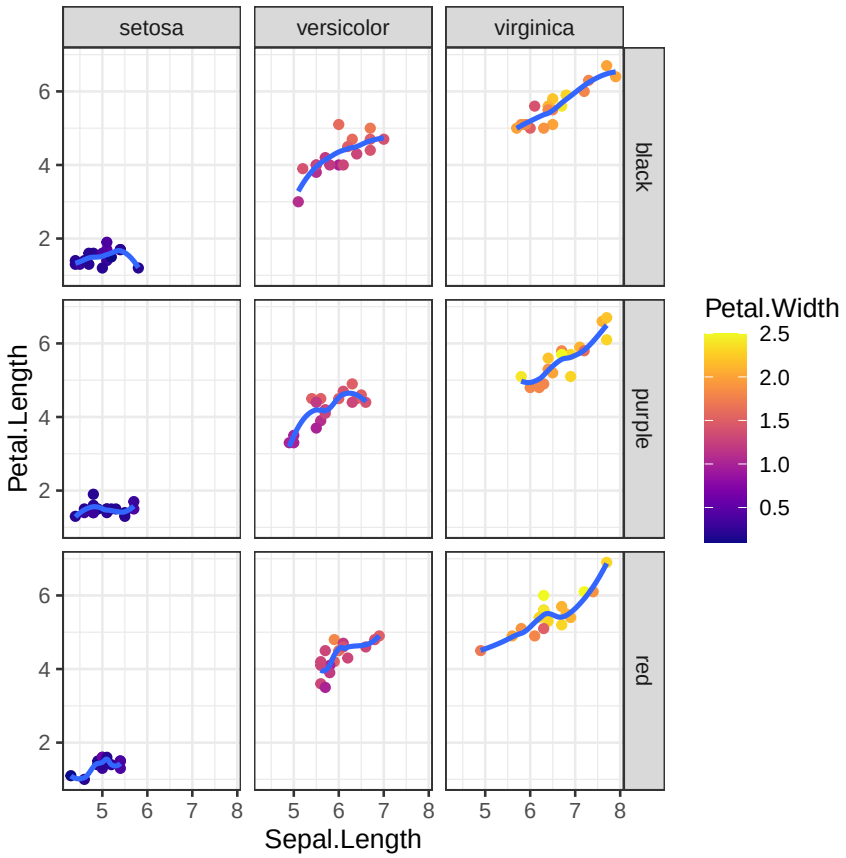

Fig. 1.2: This is a detailed figure caption for another figure, describing what the figure shows. Fun fact: this figure was prepared in RStudio open-source software, just like Figure 1.1 (yes, you can have a reference to another Figure inside a Figure caption; try doing that in Word!).

1.4 A section on tables

A table can be created pretty easily in LaTeX, as shown in Table 1.1. The number of times `| c |` is entered after the `\begin\{tabular\}` command declares the number of columns to be used. The `c` stands for "center" justification. Other options can be `l` for left, and `r` for

right.

As with Figure captioning, there is a short caption (in square brackets; this shows up in List of Tables), and a long caption (in curly brackets; this shows up at the top of the Table). While Figure captions are typically placed below the figure, the convention for Table captions is to place them on top of Tables. This can be achieved by simply moving the `\caption` command as shown in the code for Table 1.2.

1	2	3
4	5	6
7	8	9

Table 1.1: A table of alphabets. Though this caption is supposed to be detailed, I cannot think of a way to put more text here.

While Table 1.1 was fairly simple, a more complicated table with varying column widths can also be created, as shown in Table 1.2.

Table 1.2: A table of numbers and things. Though this caption is supposed to be detailed, I cannot think of a way to put more text here.

City	**Neighborhood**	**Time period**	**Results**			
			α	β	χ^2	μ [m]
Oakland	Full domain	All day	1.83	-0.21	0.89	218
	Downtown	All day	1.24	-0.04	0.03	36
	Urban residential	All day	2.09	-0.23	0.67	234
Pittsburgh	Full domain	All day	2.18	-0.27	0.52	268
		Morning	6.42	-0.39	0.42	398
		Midday	0.55	-0.14	0.05	148
		Afternoon	4.08	-0.42	0.54	419

1.5 A section on footnotes

I say, "Footnotes are so easy!"*

*And you say, "How easy are they?!"

1.6 A section on bulleting and numbering

Bulleted lists are very simple to prepare in LaTeX, using the `itemize` environment.

- An item
- Another item
- And so forth

The only difference between numbered and bulleted lists is the `enumerate` environment instead of `\itemize`. LaTeX takes care of the numbering during code compilation.

1. An item
2. Another item
3. And so forth

If you need the numbering reversed, use the `\etaremune` environment[†].

3. An item
2. Another item
1. And so forth

1.7 A section on chemical reactions

You can write chemical reactions using the `\chemfig` package:

$$\mathrm{H_2O} \xrightarrow{\lambda = 185\ \mathrm{nm}} \mathrm{OH + H}$$

$$\mathrm{O_2} \xrightarrow{\lambda = 185\ \mathrm{nm}} \mathrm{2\ O(^3P)} \xrightarrow{\mathrm{O_2}} \mathrm{2\ O_3} \xrightarrow{\lambda = 254\ \mathrm{nm}} \mathrm{2\ O(^1D)} \xrightarrow{\mathrm{H_2O}} n\mathrm{OH}$$

[†]see the brilliance of it? "etaremune" is "enumerate" spelled backwards.

You can also write chemical reactions using the `\chemmacros` package, which follows a slightly different syntax. Unfortunately, neither of them will check your reactions for stoichiometric balancing, so that part's on you.

$$\mathrm{Na_2SO_4} \xrightarrow{\mathrm{H_2O}} 2\,\mathrm{Na^+} + \mathrm{SO_4^{2-}}$$

$$(2\,\mathrm{Na^+}{,}\mathrm{SO_4^{2-}}) + (\mathrm{Ba^{2+}}{,}2\,\mathrm{Cl^-}) \longrightarrow \mathrm{BaSO_4}\downarrow + 2\,\mathrm{NaCl}$$

You can also include chemical reactions (and organic structures) as a Figure, as shown in Figure 1.3. *Note:* drawing organic structures can be time-consuming if you have too many of these. If you are writing a hard-core chemical engineering/chemistry document, you might be better off drawing the reactions in other specific software and then import them as figures into your LaTeX document.

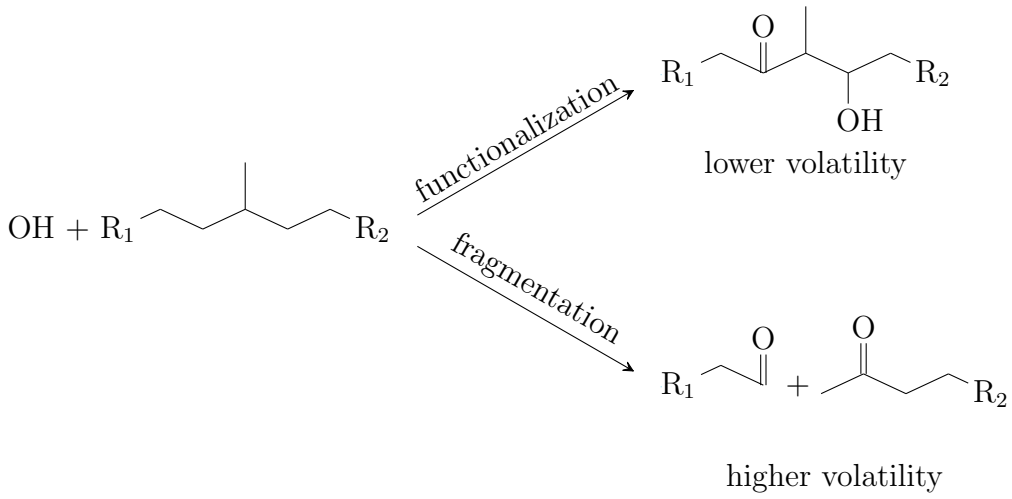

Fig. 1.3: Caption describing what is going on in this chemical reaction.

References

Robinson, E. S., Shah, R. U., Messier, K., Gu, P., Li, H. Z., Apte, J. S., Robinson, A. L., and Presto, A. A. (2019). Land-Use Regression Modeling of Source-Resolved Fine Particulate Matter Components from Mobile Sampling. *Environmental Science & Technology*, 53(15):8925–8937.

Shah, R. U., Coggon, M. M., Gkatzelis, G. I., McDonald, B. C., Tasoglou, A., Huber, H., Gilman, J., Warneke, C., Robinson, A. L., and Presto, A. A. (2020). Urban Oxidation Flow Reactor Measurements Reveal Significant Secondary Organic Aerosol Contributions from Volatile Emissions of Emerging Importance. *Environmental Science and Technology*, 54(2):714–725.

Shah, R. U., Robinson, E. S., Gu, P., Robinson, A., Apte, J. S., and Presto, A. A. (2018). High-spatial-resolution mapping and source apportionment of aerosol composition in Oakland, California using mobile aerosol mass spectrometry. *Atmospheric Chemistry and Physics*, 18(22):16325–16344.

Chapter 2

Another Chapter

2.1 What's different about this chapter?

The only new items in this chapter is a demonstration that you can refer to items from other chapters as well, as long as the same exact label is not assigned to something else in a different chapter. Here's a reference to Figure 1.1, Equation 1.2, Section 1.7, and Table 2.2 from the Chapter 1.

Also, the references in this chapter are treated differently from the references in other chapters i.e., irrespective of whether a paper was cited in another chapter or not, if it is cited in this chapter, it will be included in the references section of this chapter. And of course, any new papers cited in this chapter will only appear in this chapter's reference section. For e.g., here's a paper that was not cited in the previous chapter: (Robinson et al., 2018).

2.2 A section on math

To activate in-line math mode, enclose math within dollar signs. So, if your code has `$\alpha^2 = 10\beta_{s}^{0.8}$`, LaTeX will interpret it as $\alpha^2 = 10\beta_s^{0.8}$.

You can also insert complicated math using the `align` environment like below:

$$\iiint_V (\nabla \cdot \mathbf{F}) dV = \oiint_{S(V)} \mathbf{F} \cdot \hat{\mathbf{n}} dS$$
$$\iiint_V (\nabla \times \mathbf{F}) dV = \oiint_{S(V)} \hat{\mathbf{n}} \times \mathbf{F} dS$$
$$\iiint_V (\nabla f) dV = \oiint_{S(V)} \hat{\mathbf{n}} f dS$$

If you want the equations to be numbered, use the `\begin{align}` command instead of `\begin{align*}`. The `\label` command declares the unique key to be used for referring to this equation, as shown in Equations 2.1 and 2.2.

$$S(\omega) = \frac{\alpha g^2}{\omega^5} e^{[-0.74\left\{\frac{\omega U_\omega 19.5}{g}\right\}^{-4}]} \tag{2.1}$$
$$= \frac{\alpha g^2}{\omega^5} \exp\Big[-0.74\Big\{\frac{\omega U_\omega 19.5}{g}\Big\}^{-4}\Big] \tag{2.2}$$

2.3 A section on citing literature

2.3.1 Preparing your .bib file

To include citations, first add them to the `ch01_REFS.bib` file in a specific format called "BibTeX" format. The easiest way to do this is from a citation managing software (e.g., in Mendeley, right-click on any paper and select "Copy As > Bibtex entry". Next, open the `ch01_REFS.bib` file in your TeX editor, and paste the BibTeX entry at the end. It should look something like this:

```
@article{Shah2020,
  Author = {Shah, Rishabh U. and Coggon, Matthew M. and Gkatzelis, Georgios I. and McDonald, Brian C.
and Tasoglou, Antonios and Huber, Heinz and Gilman, Jessica and Warneke, Carsten and Robinson, Allen L.
and Presto, Albert A.},
  Doi = {10.1021/acs.est.9b06531},
  Journal = {Environmental Science and Technology},
  Number = {2},
  Pages = {714--725},
  Title = {{Urban Oxidation Flow Reactor Measurements Reveal Significant Secondary Organic Aerosol
Contributions from Volatile Emissions of Emerging Importance}},
  Volume = {54},
  Year = {2020},
  Url = {https://doi.org/10.1021/acs.est.9b06531}}
```

The `Shah2020` that appears at the top of the BibTeX record is called a "cite key". **Warning:** No two records in the `ch01_REFS.bib` can have the same cite key!

2.3.2 Get citing

To cite the study shown in Section 2.3.1, you should type the command `\citep{Shah2020}`. Sometimes you may want to cite a paper at the end of a sentence (Shah et al., 2020). But sometimes, you might also insert a citation as part of sentence, such as Shah et al. (2020). Sometimes, you might want to cite multiple references altogether inside one set of parantheses (Shah et al., 2018, 2020; Robinson et al., 2019). LaTeX identifies papers by the same author, and compresses them together i.e., instead of (Shah et al. 2018, Shah et al. 2020), it writes (Shah et al., 2018, 2020). Sometimes, you may want to cite a study in text that is already in parantheses (e.g., the study by (Shah et al., 2018) was about air pollution). If you want, you can avoid double parantheses as follows: (e.g., the study by Shah et al., 2018, was about air pollution).

2.4 A section on embedding figures

As shown in Figures 2.1 and 2.2, data visualization is an art. The code for importing figures is fairly self-explanatory.

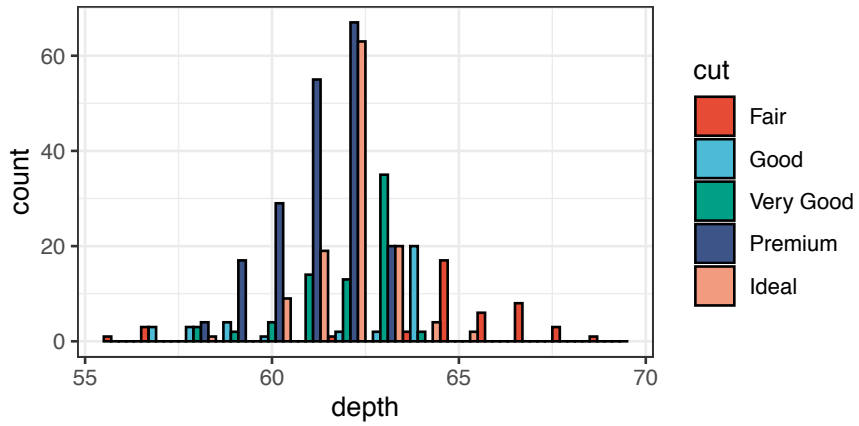

Fig. 2.1: This is a detailed figure caption, describing what the figure shows. A general good practice: a figure and its caption, together, should be self-sufficient in conveying the message. The reader should not have to look for further explanation of the figure in the text.

The `[!h]` flag after the `\begin{figure}` command forces LaTeX to place the Figure exactly where it appears in the code. If this flag is not included, LaTeX will try to place the Figure where it "fits" best. Other options instead of `!h` include `!b` (bottom of page), `!t` (top of page), etc.

The `\caption` command takes two arguments: the first one (in square brackets) is a short caption, while the second one (in curly brackets) is a detailed caption. The short caption appears in the List of Figures. The detailed caption appears directly beneath the Figure.

As always, the `\label` command declares the unique key to be used for referring to this Figure.

2.5 A section on tables

A table can be created pretty easily in LaTeX, as shown in Table 1.1. The number of times `| c |` is entered after the `\begin\{tabular}` command declares the number of columns to be used. The `c` stands for "center" justification. Other options can be `l` for left, and `r` for right.

As with Figure captioning, there is a short caption (in square brackets; this shows up in List of Tables), and a long caption (in curly brackets; this shows up at the top of the Table).

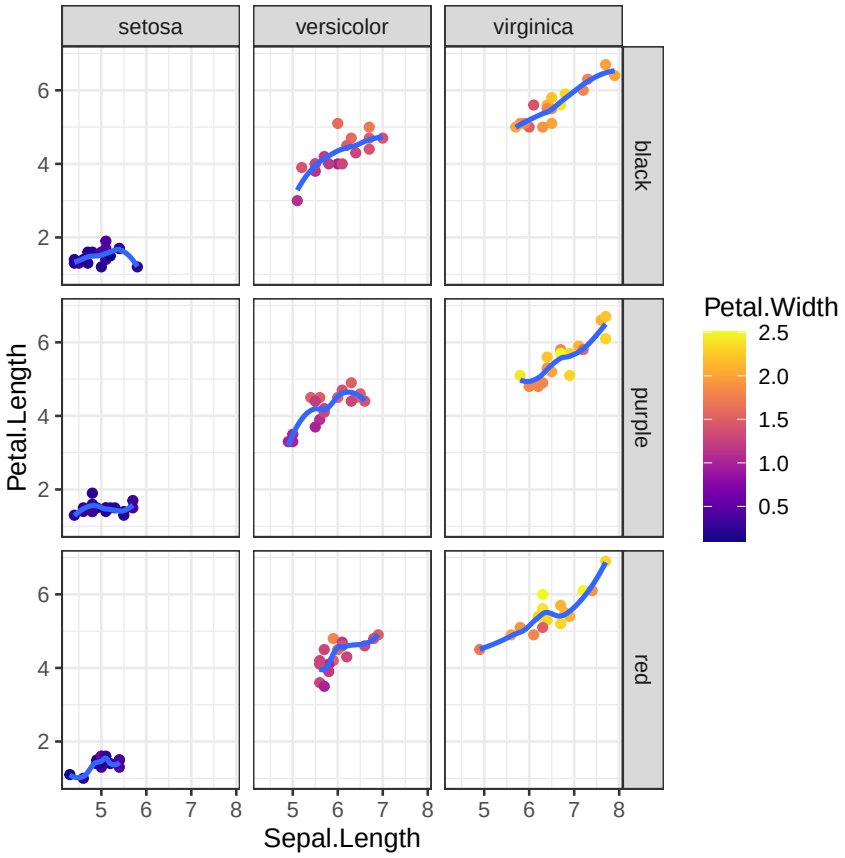

Fig. 2.2: This is a detailed figure caption for another figure, describing what the figure shows. Fun fact: this figure was prepared in RStudio open-source software, just like Figure 2.1 (yes, you can have a reference to another Figure inside a Figure caption; try doing that in Word!).

While Figure captions are typically placed below the figure, the convention for Table captions is to place them on top of Tables. This can be achieved by simply moving the `\caption` command as shown in the code for Table 2.2.

1	2	3
4	5	6
7	8	9

Table 2.1: A table of alphabets. Though this caption is supposed to be detailed, I cannot think of a way to put more text here.

While Table 2.1 was fairly simple, a more complicated table with varying column widths can also be created, as shown in Table 2.2.

Table 2.2: A table of numbers and things. Though this caption is supposed to be detailed, I cannot think of a way to put more text here.

City	**Neighborhood**	**Time period**	**Results**			
			α	β	χ^2	μ [m]
Oakland	Full domain	All day	1.83	-0.21	0.89	218
	Downtown	All day	1.24	-0.04	0.03	36
	Urban residential	All day	2.09	-0.23	0.67	234
Pittsburgh	Full domain	All day	2.18	-0.27	0.52	268
		Morning	6.42	-0.39	0.42	398
		Midday	0.55	-0.14	0.05	148
		Afternoon	4.08	-0.42	0.54	419

2.6 A section on footnotes

I say, "Footnotes are so easy!"*

2.7 A section on bulleting and numbering

Bulleted lists are very simple to prepare in LaTeX, using the `itemize` environment.

- An item
- Another item
- And so forth

The only difference between numbered and bulleted lists is the `enumerate` environment instead of `\itemize`. LaTeX takes care of the numbering during code compilation.

1. An item
2. Another item
3. And so forth

If you need the numbering reversed, use the `\etaremune` environment†.

*And you say, "How easy are they?!"

†see the brilliance of it? "etaremune" is "enumerate" spelled backwards.

3. An item

2. Another item

1. And so forth

2.8 A section on chemical reactions

You can write chemical reactions using the `\chemfig` package:

$$\mathrm{H_2O} \xrightarrow{\lambda = 185\ \mathrm{nm}} \mathrm{OH + H}$$

$$\mathrm{O_2} \xrightarrow{\lambda = 185\ \mathrm{nm}} \mathrm{2\ O(^3P)} \xrightarrow{\mathrm{O_2}} \mathrm{2\ O_3} \xrightarrow{\lambda = 254\ \mathrm{nm}} \mathrm{2\ O(^1D)} \xrightarrow{\mathrm{H_2O}} n\mathrm{OH}$$

You can also write chemical reactions using the `\chemmacros` package, which follows a slightly different syntax. Unfortunately, neither of them will check your reactions for stoichiometric balancing, so that part's on you.

$$\mathrm{Na_2SO_4} \xrightarrow{\mathrm{H_2O}} \mathrm{2\,Na^+ + SO_4^{2-}}$$

$$\mathrm{(2\,Na^+,SO_4^{2-}) + (Ba^{2+},2\,Cl^-) \longrightarrow BaSO_4\downarrow + 2\,NaCl}$$

You can also include chemical reactions (and organic structures) as a Figure, as shown in Figure 2.3. *Note:* drawing organic structures can be time-consuming if you have too many of these. If you are writing a hard-core chemical engineering/chemistry document, you might be better off drawing the reactions in other specific software and then import them as figures into your LaTeX document.

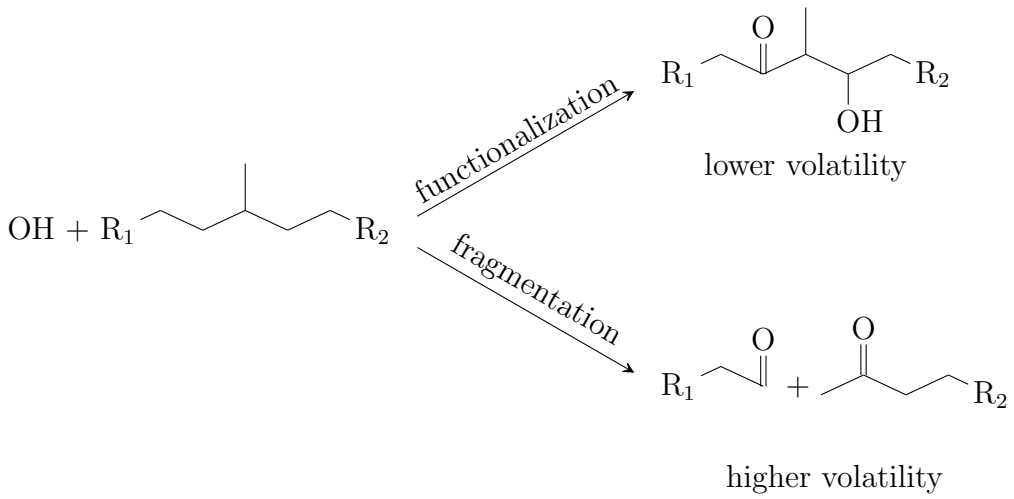

Fig. 2.3: Caption describing what is going on in this chemical reaction.

References

Robinson, E. S., Gu, P., Ye, Q., Li, H. Z., Shah, R. U., Apte, J. S., Robinson, A. L., and Presto, A. A. (2018). Restaurant Impacts on Outdoor Air Quality: Elevated Organic Aerosol Mass from Restaurant Cooking with Neighborhood-Scale Plume Extents. *Environmental Science & Technology*, 52(16):9285–9294.

Robinson, E. S., Shah, R. U., Messier, K., Gu, P., Li, H. Z., Apte, J. S., Robinson, A. L., and Presto, A. A. (2019). Land-Use Regression Modeling of Source-Resolved Fine Particulate Matter Components from Mobile Sampling. *Environmental Science & Technology*, 53(15):8925–8937.

Shah, R. U., Coggon, M. M., Gkatzelis, G. I., McDonald, B. C., Tasoglou, A., Huber, H., Gilman, J., Warneke, C., Robinson, A. L., and Presto, A. A. (2020). Urban Oxidation Flow Reactor Measurements Reveal Significant Secondary Organic Aerosol Contributions from Volatile Emissions of Emerging Importance. *Environmental Science and Technology*, 54(2):714–725.

Shah, R. U., Robinson, E. S., Gu, P., Robinson, A., Apte, J. S., and Presto, A. A. (2018). High-spatial-resolution mapping and source apportionment of aerosol composition in Oakland, California using mobile aerosol mass spectrometry. *Atmospheric Chemistry and Physics*, 18(22):16325–16344.