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with the aim of achieving a doctoral degree

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Department of Earth System Sciences
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submitted by

Sheldon Cooper

Hamburg, YYYY

Department of Earth System Sciences

Date of Oral Defence:	DD.MM.YYYY
Reviewers:	Prof. Dr. [First Name Last Name] Dr. [First Name Last Name]
Panel Chair:	Prof. Dr. [First Name Last Name]
Members of the examination commission:	Prof. Dr. [First Name Last Name] Dr. [First Name Last Name] Prof. Dr. [First Name Last Name] Prof. Dr. [First Name Last Name] Dr. [First Name Last Name]
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Abstract

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Zusammenfassung

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Nomenclature

Abbreviations

Abbreviation	Definition
AI	Artificial intelligence
GPS	Global positioning system
LED	Light-emitting diode
RMS	Root mean square

Variable Names

Symbol	Definition	Unit
A	Area	$[m^2]$
c	Concentration	$[mol\,L^{-1}]$
E	Energy	[J]
F	Force	[N]
m	Mass	[kg]
P	Power	[W]
T	Temperature	[K]
t	Time	[s]
v	Velocity	$[m\,s^{-1}]$
ρ	Density	$[kg\,m^{-3}]$
θ	Angle	[°]

List of Publications

Cooper, Sheldon (2016). "A Reconsideration of Symmetry Breaking in the String Landscape". In: *Reviews in Fundamental Physics* 33.1. (Chapter 4 of dissertation), pp. 1–19.

Cooper, Sheldon and Fowler, Amy Farrah (2015). "Supersymmetric Boundary Conditions and Their Implications for String Cosmology". In: *Foundations of Theoretical Physics* 61.2. (Chapter 3 of dissertation), pp. 88–104.

Cooper, Sheldon and Hofstadter, Leonard (2012). "Higher-Dimensional Symmetries in String Theory Compactification". In: *Journal of Theoretical Physics* 42.3. (Chapter 2 of dissertation), pp. 211–228.

— (2018). "Emergent Gauge Symmetries from Discrete Space-Time Structures". In: *Journal of Mathematical and Theoretical Physics* 54.5, pp. 601–619.

Cooper, Sheldon, Hofstadter, Leonard, and Wolowitz, Howard (2017). "Asymptotic Properties of Quantum Fields in Eleven-Dimensional Space-Time". In: *Physical Theory Letters* 76.12, pp. 1201–1214.

Cooper, Sheldon, Koothrappali, Rajesh, and Hofstadter, Leonard (2013). "Quantum Vacuum Fluctuations in Higher-Dimensional Space-Time". In: *International Journal of Advanced Theoretical Physics* 18.7, pp. 445–459.

Cooper, Sheldon, Koothrappali, Rajesh, Hofstadter, Leonard, and Wolowitz, Howard (2019). "Toward a Unified Framework for Quantum Gravity and String Dynamics". In: *Advances in Fundamental Physics*. Manuscript under review.

Fowler, Amy Farrah **and Cooper, Sheldon** (2017). "Neural Correlates of Pattern Recognition during Abstract Mathematical Reasoning". In: *Journal of Computational Neuroscience and Cognition* 9.6, pp. 355–369.

Hofstadter, Leonard**, Cooper, Sheldon**, and Koothrappali, Rajesh (2014). "Entanglement Effects in High-Energy Particle Interactions". In: *Annals of Quantum Physics* 27.4, pp. 301–317.

Koothrappali, Rajesh**, Cooper, Sheldon**, and Hofstadter, Leonard (2015). "Constraints on Dark Matter Models from Early-Universe Cosmology". In: *Journal of Cosmological Studies* 15.9, pp. 512–529.

Manuscripts in Preparation

Cooper, Sheldon and Hofstadter, Leonard (n.d.). "String Dynamics under Modified Boundary Conditions". Manuscript in preparation (Chapter 5 of dissertation).

Cooper, Sheldon, Hofstadter, Leonard, and Koothrappali, Rajesh (2020). "A Symmetry-Based Approach to Quantum Gravity in Higher-Dimensional Space-Time". In: *Journal of Theoretical Physics*. Manuscript under review (Chapter 4 of dissertation).

Fowler, Amy Farrah **and Cooper, Sheldon** (n.d.). "Pattern Recognition and Decision Making in Complex Quantum Systems". Manuscript in preparation.

Author contributions

Introduction

Sheldon Cooper: Writing — original draft.

Higher-Dimensional Symmetries in String Theory Compactification

Sheldon Cooper: Writing — original draft, Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization. **Leonard Hofstadter:** Methodology, Validation, Visualization, Writing — review & editing.

Supersymmetric Boundary Conditions and Their Implications for String Cosmology

Sheldon Cooper: Writing — original draft, Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization. **Amy Farrah Fowler:** Formal analysis, Methodology, Validation, Writing — review & editing.

A Symmetry-Based Approach to Quantum Gravity in Higher-Dimensional Space-Time

Sheldon Cooper: Writing — original draft, Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization. **Leonard Hofstadter:** Investigation, Methodology, Validation, Writing — review & editing. **Rajesh Koothrappali:** Formal analysis, Investigation, Visualization, Writing — review & editing.

String Dynamics under Modified Boundary Conditions

Sheldon Cooper: Writing — original draft, Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization. **Leonard Hofstadter:** Formal analysis, Methodology, Validation, Writing — review & editing.

Synthesis

Sheldon Cooper: Writing — original draft.

1 Introduction

1.1. Motivation

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1.2. Research Objectives

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- **Chapter 2** investigates ...
- **Chapter 3** analyzes ...
- **Chapter 4** examines ...

2

Paper 1 Title

Abstract

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Graphical Abstract

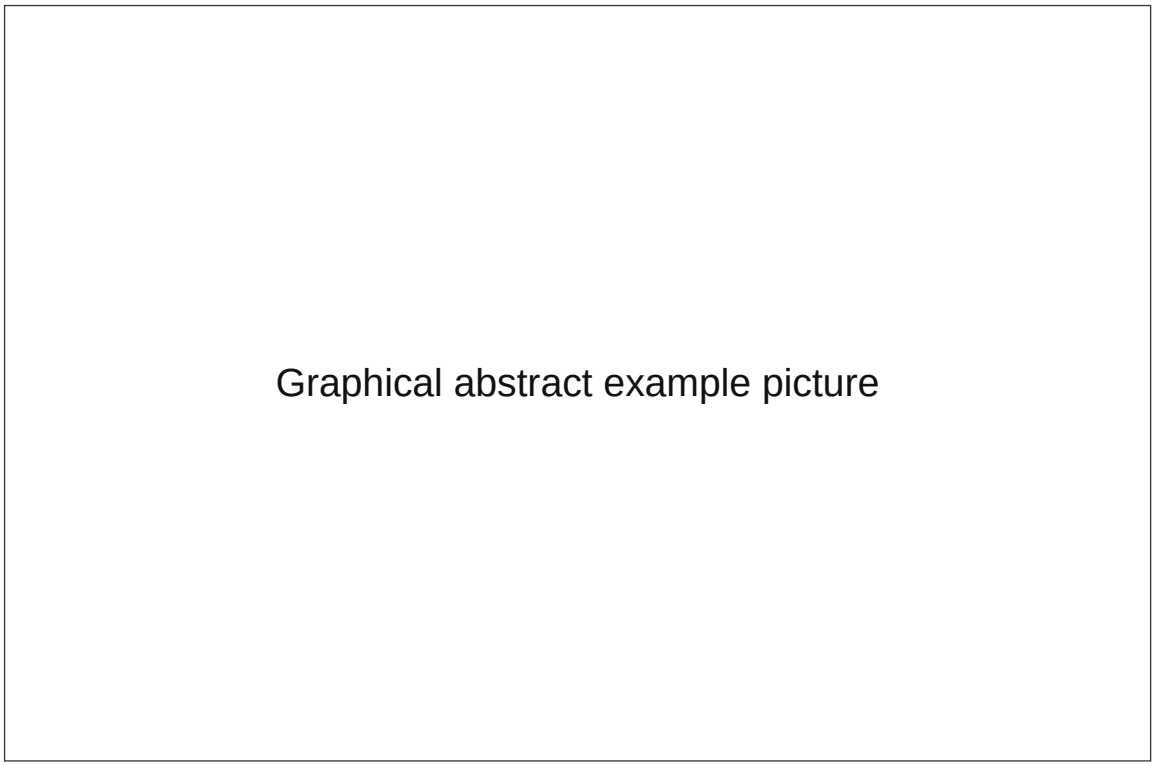


Figure 2.1: Conceptual overview of the rock weathering experiments and associated alkalinity generation

2.1. Introduction

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2.1.1. Showcase: Chemical Equations

The following examples demonstrate how to typeset chemical reactions using the `mhchem` package within the `equation` environment. Equations are automatically numbered and can be referenced throughout the document using `\label{}` and `\ref{}`.

$$\text{Silicate weathering} \quad \mathrm{CaSiO_3 + 2\,CO_2 + H_2O \longrightarrow Ca^{2+} + 2\,HCO_3^- + SiO_2} \tag{2.1}$$

$$\text{Carbonate precipitation} \quad \mathrm{Ca^{2+} + 2\,HCO_3^- \longrightarrow CaCO_3 + CO_2 + H_2O} \tag{2.2}$$

For example, Equation 2.1 illustrates silicate weathering, while Equation 2.2 shows carbonate precipitation.

2.1.2. Showcase: Chemical Formulas in Text

The `mhchem` package can also be used to display chemical formulas and ions directly within running text using the `\ch{}` command. This ensures consistent formatting of chemical symbols, subscripts, superscripts, and charges.

For example, Equation 2.1 illustrates the weathering of calcium silicate ($CaSiO_3$) in the presence of carbon dioxide (CO_2) and water (H_2O). During this reaction, calcium ions (Ca^{2+}) and bicarbonate ions (HCO_3^-) are released into the solution.

The `\ch{}` command can also be used for more complex chemical formulas, such as sulfuric acid (H_2SO_4) or calcium carbonate ($CaCO_3$).

2.1.3. Showcase: Different citations

Overall Arrhenius (1896) calculated that cutting CO_2 in half would suffice to produce an ice age. He further calculated that a doubling of atmospheric CO2 would give a total warming of 5–6 degrees Celsius.

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Overall, Arrhenius calculated that cutting CO_2 in half would suffice to produce an ice age. He further calculated that a doubling of atmospheric CO_2 would give a total warming of 5 to 6 °C (Arrhenius, 1896).

2.2. Methods

2.2.1. Example Figure

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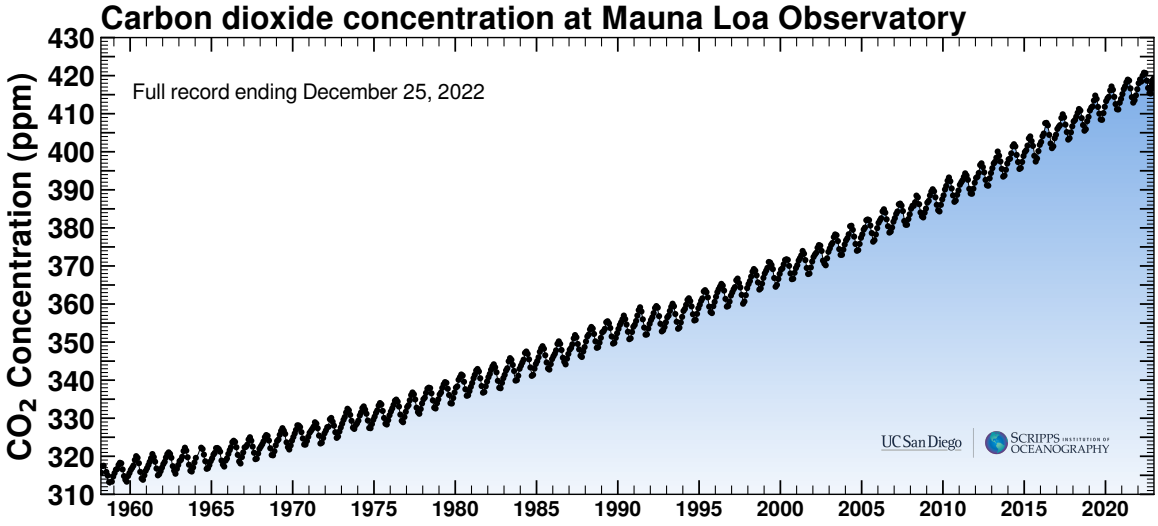


Figure 2.2: Mauna Loa observatory CO_2 measurement (R. F. Keeling and C. D. Keeling, 2017)

2.2.2. Showcase: Tables

The following example demonstrates how to create a scientific table using the `table` and `tabular` environments. The `booktabs` package provides horizontal rules, while `siunitx` allows consistent formatting and alignment of numerical values. The data shown below are fictional and serve only as an example.

Table 2.1: Example measurements for four experimental sample groups. Values represent the mean and standard deviation of fictional measurements. All values are provided for demonstration purposes only.

Parameter	Sample A Mean ± SD	Sample B Mean ± SD	Sample C Mean ± SD	Sample D Mean ± SD
Parameter 1	12.45 ± 0.23	14.87 ± 0.55	13.44 ± 0.27	15.93 ± 0.73
Parameter 2	2.02 ± 0.11	2.15 ± 0.06	2.58 ± 0.33	2.77 ± 0.09
Parameter 3	7.78 ± 0.21	8.13 ± 0.18	9.79 ± 0.25	8.83 ± 0.13
Parameter 4	5.26 ± 0.30	6.66 ± 0.18	6.19 ± 0.26	7.31 ± 0.13
Parameter 5	0.89 ± 0.05	0.97 ± 0.04	1.17 ± 0.01	1.14 ± 0.01
Total	28.40 ± 0.90	32.78 ± 1.01	33.17 ± 1.12	35.98 ± 1.09

2.3. Results

2.3.1. Showcase: The siunitx Package

The `siunitx` package provides a consistent way to format numbers, physical quantities, and units in scientific documents. The `\SI{}{}` command combines numerical values with their units, while `\si{}` displays units without numerical values.

For example, a sample was heated to 80 °C for 30 min under a pressure of 1.5 bar. The experiment was conducted using a solution with a concentration of 25 mmol L^{-1} and a volume

of 250 mL.

The package also supports percentages (15 %), scientific notation ($1.23 \cdot 10^{-5}$), and standalone units such as $\mathrm{kg\,m^{-3}}$.

The `siunitx` package can also be used to report measurement uncertainties, such as the standard deviation (SD). For example, the mean temperature of five measurements was 25.4 ± 1.2 °C (mean ± SD). Using the `+-` notation within the `\SI{}{}` command ensures that both the mean and its standard deviation are formatted consistently with the same unit.

2.3.2. Showcase: The siunitx Package with custom Units

The `siunitx` package also allows users to define custom units that are not included by default. These units must be declared in the document preamble using the `\DeclareSIUnit{}{}` command.

For example, to define parts per million (ppm), add the following line to your preamble:

```
\DeclareSIUnit{\ppm}{ppm}
```

Once defined, the custom unit can be used just like any other unit supported by `siunitx`.

For example, a sample contains a concentration of 250 ppm, while another sample contains only 15 ppm. The unit can also be displayed independently using ppm.

2.4. Discussion

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2.5. Conclusion

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut

augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetuer.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

3

Paper 2 Title

Abstract

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetuer at, consectetuer sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetuer a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetuer. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Graphical Abstract

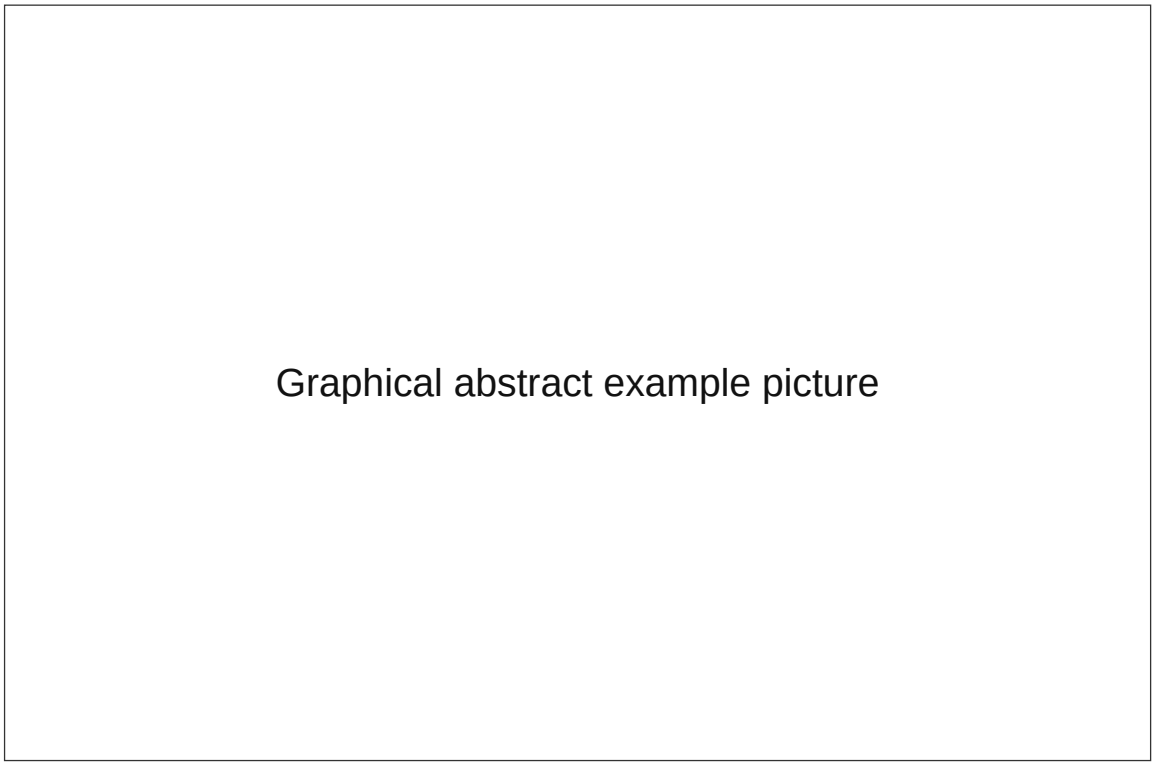


Figure 3.1: Example Caption

3.1. Introduction

3.2. Methods

3.3. Results and discussion

3.4. Conclusion

4

Paper 3 Title

Abstract

Graphical Abstract

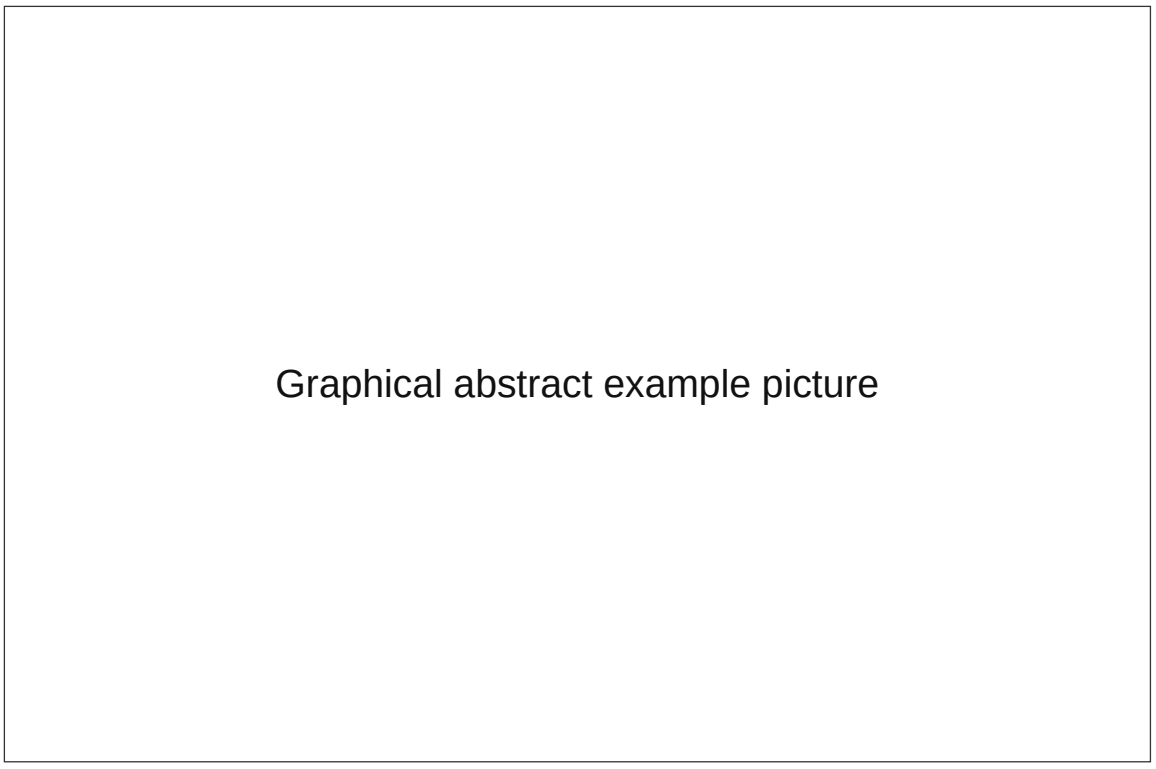


Figure 4.1: Title

4.1. Introduction

4.2. Materials and methods

4.3. Results

4.4. Discussion

4.5. Conclusion

5
Synthesis

General overarching text

Chapter 2: Title

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetuer odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetuer eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

Chapter 3: Title

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce

elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Chapter 4: Title

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu pretium enim. Nunc purus neque, placerat id, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero. Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus. Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

Concluding Remarks

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

A

Appendix for Chapter 2

B

Appendix for Chapter 3

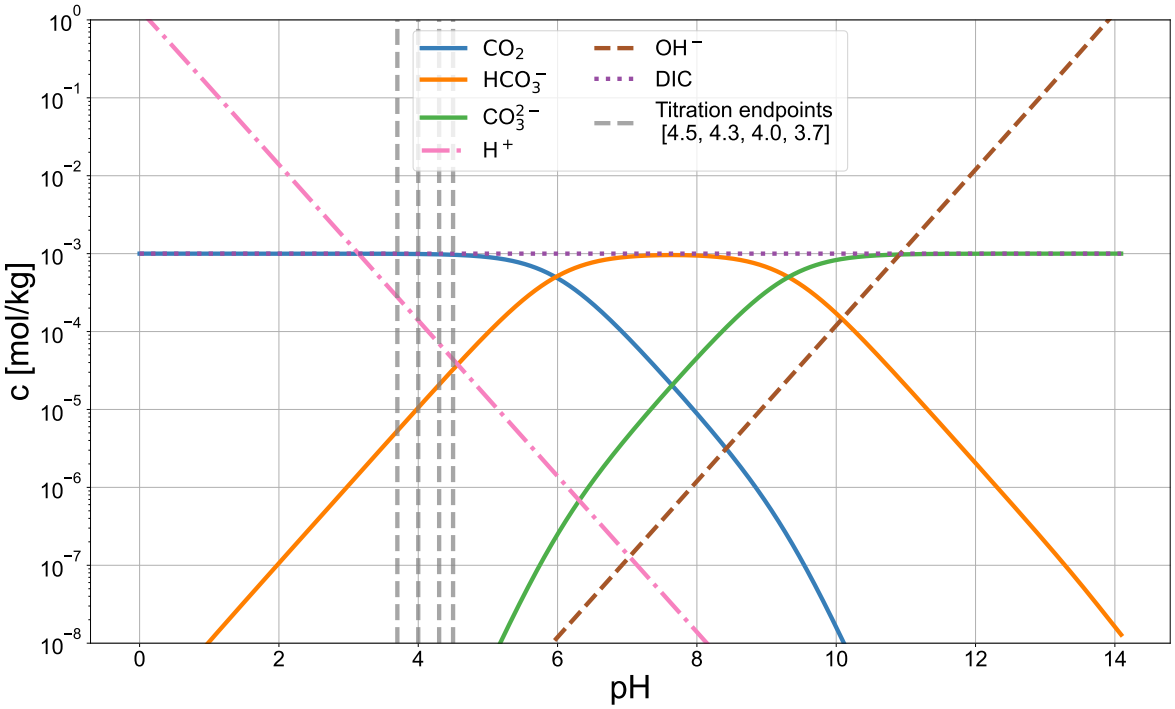


Figure B.1: Example plot

C

Appendix for Chapter 4

Acknowledgements

First and foremost, I would like to thank myself for my exceptional intellect, unwavering dedication to science, and remarkable ability to tolerate the intellectual limitations of those around me.

I would also like to acknowledge Dr. Leonard Hofstadter for his assistance, companionship, and occasional usefulness in discussions that were, admittedly, often beyond his comprehension.

My gratitude extends to Dr. Amy Farrah Fowler, whose patience, scientific curiosity, and willingness to challenge my conclusions have been both admirable and, at times, deeply inconvenient.

I must also thank Penny for reminding me that there is a world outside theoretical physics, although I remain unconvinced that this world deserves quite so much attention.

Finally, I would like to acknowledge the scientific community for providing a foundation upon which my contributions can inevitably advance human understanding.

Bazinga!

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