Colorado State University

Upper Division Courses in Experimental Chemistry

Notes on Notebooks

OVERVIEW

Each student in this course will be responsible for the creation and maintenance of a laboratory notebook documenting the work performed by the student in this course. The National Institute of Standards and Technology (NIST), one of our country's oldest and most esteemed science laboratories, has explained the purpose and use of laboratory notebooks so well and is quoted here:

> From the Summary Report on Scientific Integrity - November 2019
>
> The National Institute of Standards and Technology (NIST) is a non-regulatory agency within the U.S. Department of Commerce.
> NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.
>
> Foundation of Scientific Integrity in Government
>
> NIST has in place a number of policies and procedures to ensure the integrity of the scientific and technological information it develops and disseminates to the public. Relevant policies currently in effect are summarized below.
> The NIST Manual sets forth policies and defines responsibilities that apply to the communication of NIST technical program results by staff members, guest researchers, research associates, and others who participate in technical programs.
>
> Research Notebooks
>
> The NIST Manual explains that all NIST technical communications are derived from the technical activities of its employees and supported by the technological records (e.g., research notebooks) they maintain.
> It is NIST policy that all NIST employees engaged in research and development activities are responsible for maintaining a thorough and accurate record of their work by keeping a research notebook following internal Operating Unit policies.
> Recognizing that scientific data at NIST are increasingly generated, stored and reported digitally, the NIST Leadership Board established a Scientific Data Lifecycle Management Working Group to study the collection, storage, use, repurposing and preservation of NIST's digital scientific data.

This document (Notes on Notebooks) lays out the requirements and considerations for student notebooks used in upper division undergraduate (UG) laboratory courses.

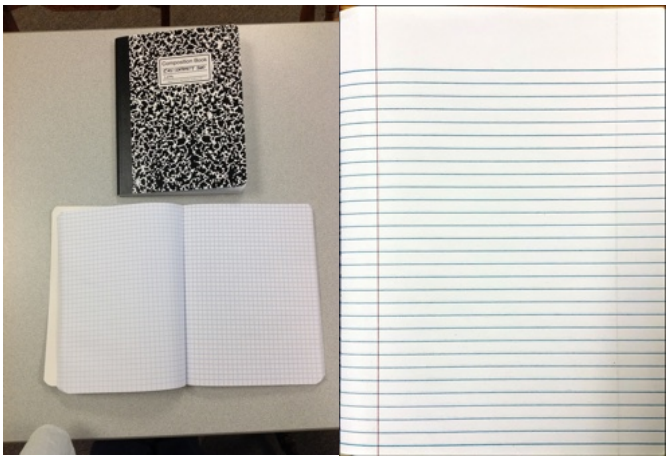
It is important to note at the outset that different disciplines (even sub-disciplines) vary in their standard style for notebooks and within those variations there are elements of constancy and consistency that transcend the differences. At this stage in the UG education there is a somewhat more relaxed format and structure in use however, the need for completeness, accuracy and discipline remains present and important.

The particulars are described in this document.

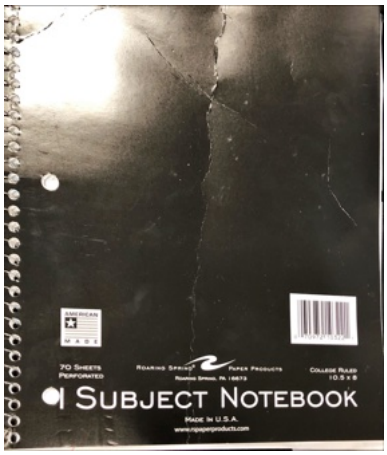
MECHANICS – BOOK STYLE

At the time of this writing, "UG notebook" means a hardcopy, paper, bound book. Looking forward, there will come a time when fully electronic notebooks will be in use at the UG level. Not these days. Note the last paragraph in the NIST text quoted above – we'll get there some day.

There are many styles of books available for purchase. They range in cost and suitable (that is, not all are suitable). Here are a few representative examples:

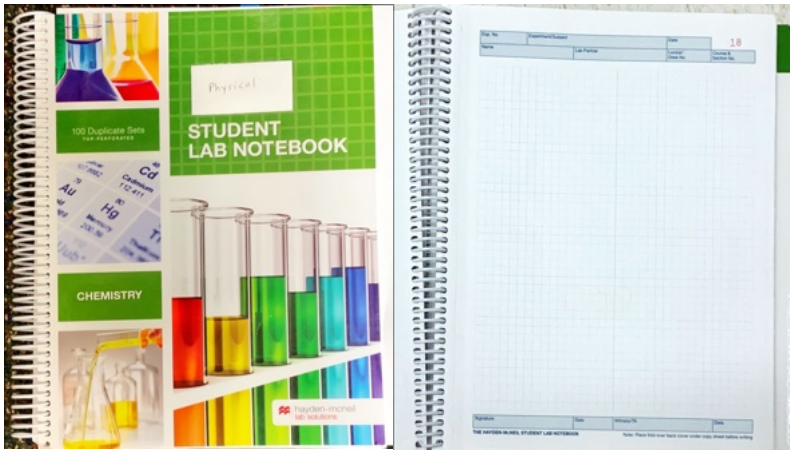


This is a very good notebook. The binding is actually sewn and pages can only be torn out with some difficulty (although it is still possible to do so, even though it is totally inappropriate). A gridline ruling and an alternate regular horizontal ruling are displayed. Both are suitable, however, the gridline is slightly superior as it facilitates table and figure construction. Books like this are quite inexpensive and represent an excellent choice. Sometimes these books can be found with pagination (page numbering) already in place which saves you the trouble of doing it yourself. More on this later.

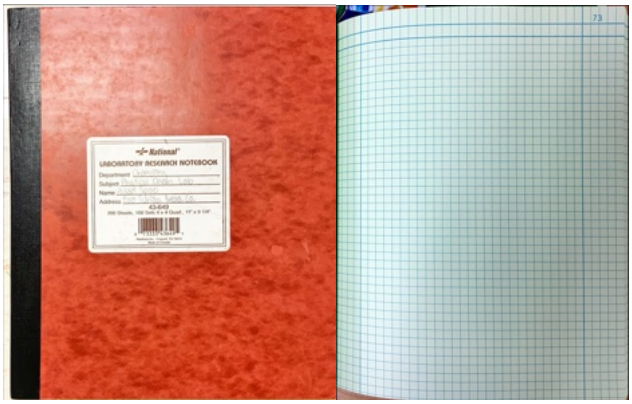


This is an awful notebook. The spiral binding permits easy tearing out of pages (totally inappropriate). This type of book is perfectly suitable for personal notetaking in a lecture course yet falls far short of the requirements for rigorous laboratory work. Don't be the person using this book.

The particulars are described in this document.



Now, here's a book that might be thought to be appropriate for use in this course. Actually, it has some interesting features yet it has some that are lacking. It is spiral bound, which is considered a negative, however, the pages are hard numbered which would make tampering (that is, page removal) clear. There are boxes at the top and bottom of each page which mimic those found in use in certain industries, for example, pharmaceutical. While totally appropriate for situations where Intellectual Property (IP) is a real concern they are overkill for our uses here. Also present are "carbon" copies for each page which are irrelevant to our needs and work. It also offers a brightly colored cover and reminds you of the spelling of the word "chemistry" every time you view it. You can use this book, however, you will pay dearly for the privilege and get little benefit for your trouble.



This book combines some of the features of those seen above it. The binding is sewn and glued, the pages are numbered, grid ruling rules and "carbon" copies are present. Except for the copies, which double the thickness and weight of the book the rest of the features are quite positive. The cost of this book is intermediate among the rest and is actually popular among many science graduate students.

CONTENT

Having dispensed with the type of book being used, the next step is to consider the book's content. First, a few simple ground rules:

1. All pages in use in the notebook must be numbered in typical fashion, that is, consecutively.
2. A Table of Contents (TOC) must be present on the first (and second and so on, if necessary).
3. All content written in the notebook must be made using INK and never pencil. (avoid crayon also)
4. Both the left and right sides of the book are used and are numbered as above.
5. Written text, numeric notations, hand-crafted tables and figures are all suitable content.
6. Items can be "scratched out" ONLY with a single strike-through so that the original content remains legible.
7. No pages can be removed from a notebook.

8. Items (spectra, photos, *etc.*) can be affixed to the notebook pages using tape, staples, glue and other so long as they are permanently affixed. Loose items must not be included.

This is a good place to note in the strongest terms that it is totally appropriate to consider (or perform) "rewriting" the notebook at the end of a semester to "pretty it up." This flies in the face of the most basic principle of the notebook, that it is a contemporary record of the work performed at the time it was performed and not rewritten later.

ASSESSMENT

The following is a simple scoring sheet which identifies the various components of a notebook together with a representative relative weighting of those components. This is an example and the weights may vary somewhat according to the course and time.

Laboratory Notebook Evaluation
Course: CHEM
Fall Semester 2010

Student name:

Keeping and Organization	Content
	___ / 15 Procedural details (quantities, sequences, reaction times)
___ / 5 Table of contents	
___ / 5 Page numbers	___ / 15 Chemical information (manufacturer, lot number, purity)
___ / 5 Experiment titles	
___ / 5 Dates	___ / 15 Instrument information (manufacturer, specific parameters used)
___ / 5 Use of pen	
___ / 5 Properly cross out errors	___ / 15 Calculations (completeness, clarity, units)
___ / 5 Overall legibility	
	___ / 5 Appropriate chemical language
Total score	___ / 100

The following is a simple table demonstrating various levels of proficiency, each in individual categories in a scientific notebook.

CATEGORY	Proficient (4-5)	Developing (2-3)	Basic (0-1)
Organization	• All pages are numbered and dated. • Each experiment contains title, purpose, brief procedure or reference to lab manual. • Observations, recorded data and calculations are present. • All information recorded in pen not pencil. • Experiment listed in table of content.	• Most pages are numbered and dated. • Some of the experiments are missing one or two of the following: title, purpose, brief procedure or reference to lab manual. • Recorded data and observations are incomplete in some areas. • Some of the information is recorded in pencil. • Some experiments are not recorded in table of content.	• Most pages are not numbered and dated. • Most of the experiments are missing several of the following: title, purpose, brief procedure or reference to lab manual. • Recorded data and observations are incomplete in most areas or not present. • All information is recorded in pencil. • Most experiments are not recorded in table of content.
Content	• All observations are recorded completely. • All data is recorded and neatly presented with units to the correct number of significant figures. • All calculations are included and neatly presented with details including units and significant figures.	• Observations are not complete and missing important details. • Data is recorded, but is not presented neatly or some are missing units or the correct number of significant figures. • Calculations are included, but are not presented neatly or missing details including units and significant figures.	• Observations are mostly missing. • All data is not recorded and not neatly presented with missing units and have incorrect number of significant figures. • Calculations are not included or are very sparse with no units and incorrect significant figures.
Analysis	• Data is explicitly analyzed, methods of analysis are described with appropriate detail. • Calculations are presented neatly. • Graphs, if appropriate, are included with analysis of slope and related information. • Sources of error are explored and considered when evaluating data.	• Data analysis is implied, but not explicit, and methods of analysis are not described or properly used. • Calculations are not complete. • Graphs, if appropriate, are included, but they are done incomplete or incorrect. • Sources of error are explored, but they are inadequate or incomplete.	• Data analysis is not included. • Calculations are missing. • Graphs, if appropriate, are missing or grossly incorrect. • Sources of error are not explored.
Conclusion	• Results are explicitly interpreted and compared with literature data and/or concepts discussed in lecture. • Conclusion is written in coherent manner with proper English syntax.	• Superficial and immediate conclusions are recorded. • Results are interpreted but interpretation is not explicit. • Conclusions are not written coherently and contain some spelling or grammatical errors.	• Conclusions are not logical and/or do not agree with data presented. • Conclusions are written in non-coherent manner with many spelling and grammatical errors.

MEASUREMENT REPORTING AND UNCERTAINTY

There is another piece of the NIST Summary Report that is reproduced here:

> Statements of Uncertainty
>
> A key element of Scientific Integrity relating to scientific and technical research has to do with statements of uncertainty associated with measurement results.
>
> According to long-standing published NIST policy, a measurement result is considered complete only when accompanied by a quantitative statement of its uncertainty.
>
> NIST policy requires uncertainty statements, and also requires that a uniform approach to expressing measurement uncertainty be followed.

> To ensure that uncertainty statements are consistent with each other and with international practice, the NIST policy adopts the approach to expressing measurement uncertainty recommended by the International Committee for Weights and Measures (CIPM).

Consider this statement of the need for a quantitative statement of every measurement's uncertainty to be true in this course. For example, when weighing out a substance the (only) proper way to report the weight is: 0.123 ± 0.002 g, that is, with full units and an uncertainty of the measurement. The uncertainty may itself be an estimate yet it must be an educated estimate. Note the following figure:

The temperature is read as: 22.58 ± 0.02 °C. The last decimal place is an estimate as is the uncertainty. It is legitimate to make estimates in scientific work; it is often required and it is a skill to be developed.

It is also worth noting that digital readouts are intrinsically no more "accurate" than analog ones and uncertainty must also be estimated for them also although the methodology is slightly different.