EXPERIMENT 101

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CAK

CAKE CHEMISTRY

EXPECTED LEARNING OUTCOMES

- Compare three experimental cakes to a "control" cake to isolate the effects of dependent variables.
- Analyze each experimental condition to determine the effect of the variable on physical properties.
- Infer the effectiveness of leavening agents based on physical properties of experimental cakes.
- Summarize experimental findings in visual representations (graphs, tables).

INTRODUCTION

Is baking a cake a chemical change? Next time you bake a cake, think about this: The cake batter isn't really a cake, but when it's heated in the oven, a chemical reaction occurs, and new bonds are formed. When it comes to heat, there are two types of chemical reactions to consider; one is **exothermic,** a reaction that produces heat, and the other is **endothermic,** a reaction that takes heat in. As you bake a cake, an endothermic chemical reaction occurs that changes ooey-gooey batter into a fluffy, delicious treat!

A few things can happen when you bake a cake. Some items to keep in mind while doing this experiment are as follows:

- Heat helps baking powder react to produce tiny bubbles of gas, which results in a light and fluffy cake.
- Heat causes proteins in the egg to unfold and become tangled into a three-dimensional web that helps to make the cake firm.
- Oils tend to have low vapor pressures and high boiling points. The use of oils in place of water-based liquids prevents the cake from drying out.

MATERIALS REQUIRED

EQUIPMENT

- 4 600-mL beakers
- 400-mL beaker
- 250-mL beaker
- 100-mL graduated cylinder
- 10-mL graduated cylinder
- timer

COMMON EQUIPMENT

- analytical balance
- oven
- oven mitts
- whisk

CHEMICALS

- flour (200 g/pair)
- granulated sugar (150 g/pair)
- salt (2 g/pair)
- baking powder (2.5 g/pair)
- milk (120 mL/pair)
- vegetable oil (100 mL/pair)
- vanilla extract (4 mL/pair)
- egg (1 per pair)
- distilled water

CAUTIONS

Hot objects often look similar to cold objects; exercise appropriate caution. Use oven mitts to protect your hands from hot beakers when removing them from the oven. Nothing is fit for consumption after it enters the laboratory. **Anyone observed consuming anything used in this experiment will receive a zero for all aspects of this experiment.**

PROCEDURE

This experiment is performed in pairs. Discussions with your peers and lab instructor are encouraged.

1. Preheat an oven to 180 °C. While the oven preheats, prepare Cake #1 using Steps 2–6 below.
2. Prepare Cake #1 by weighing 48 g flour, 35 g granulated sugar, 0.5 g salt, and 0.75 g baking powder using an analytical balance. Combine these ingredients in a 400-mL beaker. Record the exact masses to the nearest 0.0001 g in your lab notebook.
3. Combine approximately 30 mL milk, 30 mL vegetable oil, 1 mL vanilla, and ⅓ of an egg in a 250-mL beaker. About ⅓ of an egg can be obtained by whisking one egg until the resulting liquid is homogenous and taking ⅓ of this mixture.
4. Add the mixture from Step 3 to the mixture in the 400-mL beaker from Step 2. Mix well until the batter is uniform.
5. Pour the batter into a 600-mL beaker, then record observations and the initial volume of the batter in your lab notebook. Bake the cake for 15 minutes, recording the cake volume as read from the calibration marks on the side of the beaker every minute in your lab notebook.

6. Remove the baked cake from the oven using oven mitts, allow it to cool for 5 minutes, then observe and record final characteristics. Wash the 250-mL and 400-mL beakers with soap and water, then dry.
7. Prepare Cake #2 by repeating Steps 2–6 above but omit vegetable oil in Step 3.
8. Prepare Cake #3 by repeating Steps 2–6 above but omit egg in Step 3.
9. Prepare Cake #4 by repeating Steps 2–6 above but omit baking powder in Step 2.

CLEAN UP AND WASTE DISPOSAL

Excess liquid reagents should be disposed of in the sink with a large amount of running water. Excess solid reagents should be discarded in the trash. Cakes should be disposed of in the trash. After cleaning up, wipe down your work area with 70% ethanol spray and a paper towel. Wash your hands thoroughly after completing this experiment.

REFERENCES

Adapted from: Education.com. Chemistry of Baking—Is Baking a Cake a Chemical Change? | Activity. https://www.education.com/activity/article/Bake_Cake_fifth/ (accessed Jun 3, 2019).

CAK

Name: ______________________________

Partner's Name(s): ______________________________

Lab Date: __________ Lab Instructor's Name: ______________

CAK CHEMISTRY
LAB NOTEBOOK PAGES

All procedure(s) and data/observations must be recorded in the lab notebook in pen with permanent, waterproof ink (black or blue). Pencils, markers, highlighters, and correction fluid (white-out) are not permitted. No information can be recorded elsewhere and transferred after leaving the lab. Lab notebooks can be digital or paper; you may write directly on the lab notebook pages in your lab manual or download a digital copy onto your electronic device and then write in it.

- **Before Lab:** Make sure to complete the Procedure section in your lab notebook pages. Please refer to the front matter of your lab manual for additional guidance.
- **After Lab:** Upload your notebook pages to the appropriate Carmen assignment within 48 hours after the start time of your in-person lab session. If you used the notebook pages in your paper copy of your lab manual, you should scan or take photos of the pages. Do not remove them from your lab manual. Refer to the WRM Notebook upload assignment in Carmen for more detailed instructions.

PROCEDURE REFERENCE

Chemistry 1110: Elementary Chemistry Laboratory Manual, Fall 2025–Summer 2026.; Weaver, T. A., Opoku-Agyeman, B., Fontes N. Da Silva, C., Welch, A. N., Rundell, S. R., Stern, J. E., Wroblewski, R. A., Walter, C., van Helmond, A., Eds.; Van-Griner Learning: Cincinnati, OH; pp. XIX–XXI.

PROCEDURE

Write a summary or step-by-step procedure for this experiment in the space below.

CLEAN UP AND WASTE DISPOSAL

Excess liquid reagents should be disposed of in the sink with a large amount of running water. Excess solid reagents should be discarded in the trash. Cakes should be disposed of in the trash. After cleaning up, wipe down your work area with 70% ethanol spray and a paper towel. Wash your hands thoroughly after completing this experiment.

DATA AND OBSERVATIONS

When recording data, be sure to record all significant figures: all digits displayed on a balance, the appropriate precision of any glassware used, etc.

	CAKE #1	CAKE #2	CAKE #3	CAKE #4
Actual mass of flour used (g)				
Actual mass of granulated sugar used (g)				
Actual mass of salt used (g)				
Actual mass of baking powder used (g)				

CAKE	BATTER OBSERVATIONS	BAKED CAKE OBSERVATIONS
Cake #1		
Cake #2		
Cake #3		
Cake #4		

CAKE #1		CAKE #2		CAKE #3		CAKE #4	
Time (min)	Volume (mL)	Time (min)	Volume (mL)	Time (min)	Volume (mL)	Time (min)	Volume (mL)

THE LABORATORY NOTEBOOK

The laboratory notebook is a permanent record of procedures, observations, data, and conclusions. When a major discovery is made in a research lab, a patent is often filed. During the patent approval process, if there are any questions about the validity of the research, lawyers can request researchers' laboratory notebooks. An expert then reviews the notebooks, looking for sufficient detail to support the claims written in the patent. If the notebook is not organized, legible, and accurate, the patent can be denied. A patent can also be denied if the notebook appears to have been tampered with. Therefore, in every research lab, notebooks are essential. In General Chemistry, we aim to practice good notebook usage.

Paper notebooks must be written in pen with permanent, waterproof ink (black or blue). Pencils, markers, highlighters, and correction fluid (white-out) are not permitted. Paper notebooks will not be accepted if they are written in pencil. Entries made in digital notebooks must be blue or black. In either case, should you make a mistake, simply cross out the mistake with a straight single or double line, or with a simple "X" and then continue writing. **Do not scribble anything out, use white out, or use the "undo" button.**

PROPER STRIKE-OUT TECHNIQUES

During lab, mistakes may occur or changes may need to be made in your notebook. For small corrections, neatly cross out the error with a single or double line and write the correction nearby. For larger revisions, it may be clearer to start a new page to maintain legibility. If an entire section or data table is no longer needed, draw a large "X" through it—ensuring that the original content remains visible underneath. Your notebook is a professional document and should follow these guidelines to ensure clarity and accuracy.

- Use a relatively straight line.

  9. a. After the beaker has cooled (~5 mins), remove the beaker from the hot plate silicone trivet.

- A double line (two lines parallel to each other or as a simple "X").

  ~~f. Heat the beaker until it boils and let boil for 3–4 minutes.~~

  f. Turn on the hot plate and set temperature to ~350 °C.

- Crossing out a large section or an unused data table with a simple "X."

  6. a. Determine mass of a clean weigh boat on analytical balance and record to the nearest 0.0001 g.

     b. Use forceps to hook longest worm (don't pinch or puncture) and move worm to weigh boat.

     c. Determine combined mass of weigh boat + worm. Record combined mass (use same balance as before, close all doors).

     d. Record observations of worm.

	$CaCl_2$ (*aq*)	+	2 NaF (*aq*)	→	CaF_2 (*s*)	+	2 NaCl (*aq*)
Before Reaction	3.00 mol		2.00 mol		0.00 mol		0.00 mol
Change (reaction)							
After Reaction							

Example of Improper Strike-Out

c. Record observations of ~~$CaCl_2$~~ Na Cl_2 and alginate ~~beakers~~ solutions.

The example above illustrates two instances (not all-inclusive) that would result in a point deduction for improper strike-outs. In this case, "$CaCl_2$" should have been corrected to "NaCl." However, crossing out "Ca" with more than two lines and using a curvy line through "beakers" are both incorrect strike-out methods.

The following pages provide guidance on proper lab notebook use in the context of Experiment CAK. A notebook template will be provided for all experiments. Before lab, you are expected to complete the Procedure and any required data tables in the Data and Observations section. During lab, you will record data, make procedural updates as needed, perform calculations, and answer all In-Lab Questions directly in your notebook.

1. NAME, PARTNER'S NAME(S), DATE OF EXPERIMENT, INSTRUCTOR'S NAME

2. PROCEDURE

In order to be successful in the lab, you must arrive prepared. Review the full experiment, including all background and procedure information, making sure you understand how the experiment will be performed. The experiment videos provided on each Overview page are a great way to see what will be done in each Part.

OPTION A—PROCEDURE SUMMARY

As you review the experiment, record a brief summary, 3–6 sentences, **for each part.** Think of it as giving a quick overview to a classmate who missed the pre-lab discussion. This must be completed before you enter the lab. Summarize the techniques and conditions used to complete each part of the experiment, and what data you will get out of that part.

OPTION B—PROCEDURE OUTLINE

As you review the experiment, record the procedure in your notebook **in your own words/diagrams.** Shorten each step in the given procedure into several smaller steps. In addition to short steps, you can include sketches, flow charts, diagrams, pictographs, or other visual representations to help you. The procedure you write in your lab notebook should be easy to follow at a glance.

EXAMPLE

Procedure in the Lab Manual

1. Preheat an oven to 180 °C. While the oven preheats, prepare Cake #1 using Steps 2–6 below.
2. Prepare Cake #1 by weighing 48 g flour, 35 g granulated sugar, 0.5 g salt, and 0.75 g baking powder using an analytical balance. Combine these ingredients in a 400-mL beaker. Record the exact masses to the nearest 0.0001 g in your lab notebook.
3. Combine approximately 30 mL milk, 30 mL vegetable oil, 1 mL vanilla, and ⅓ of an egg in a 250-mL beaker. About ⅓ of an egg can be obtained by whisking one egg until the resulting liquid is homogenous and taking ⅓ of this mixture.
4. Add the mixture from Step 3 to the mixture in the 400-mL beaker from Step 2. Mix well until the batter is uniform.
5. Pour the batter into a 600-mL beaker, then record observations and the initial volume of the batter in your lab notebook. Bake the cake for 15 minutes, recording the cake volume as read from the calibration marks on the side of the beaker every minute in your lab notebook.
6. Remove the baked cake from the oven using oven mitts, allow it to cool for 5 minutes, then observe and record final characteristics. Wash the 250-mL and 400-mL beakers with soap and water, then dry.
7. Prepare Cake #2 by repeating Steps 2–6 above but omit vegetable oil in Step 3.
8. Prepare Cake #3 by repeating Steps 2–6 above but omit egg in Step 3.
9. Prepare Cake #4 by repeating Steps 2–6 above but omit baking powder in Step 2.

Sample Notebook Entry: Procedure Summary

Prepare a control cake and three experimental cakes. Each experimental cake will be missing one vital ingredient. Data is collected to determine how the omission of an ingredient affects the physical characteristics of a cake.

Sample Notebook Entry: Procedure Outline

5. a. Pour batter into 600-mL beaker.
   b. Record observations and initial volume of cake batter before baking.
   c. Place pan in preheated oven.
   d. Bake for 15 minutes; record volume of cake from lines on beaker every minute.

What Should I Do When I'm Only Given General Instructions?

For some experiments, you—or your lab group—will need to develop your own procedure based on the General Instructions provided. In these cases, be sure to read through the entire experiment first to understand the overall goals. Then, before lab, create a step-by-step outline for how you plan to carry out the experiment. Think of it as a working plan: it doesn't need to be perfect, and we recommend leaving extra space between each step so you can easily make updates during lab if anything changes.

Keep in mind that the procedure you write before lab might not match exactly what you end up doing in lab—and that's okay! Part of being a scientist is adapting your approach when needed. You may need to adjust which glassware you use, how much of a reagent is added, whether a control is included, or even change the order of your steps. Use the step-by-step procedures from other experiments as a guide for how detailed your outline should be.

During lab, make sure your notebook reflects what you actually did. As explained in the section on proper strike-outs, you can neatly cross out any outdated steps and write the corrections nearby or start a new page if needed. If you do start a new page, include a note like "continued on next page" so your notebook stays easy to follow. If you run out of space, extra paper is available at the lab support window (231/331 CE). If you're ever unsure about what to write or how to format your updates, just ask your lab instructor! Be sure your final procedure includes enough detail that you could turn it into a clear paragraph later.

Note: You cannot add details to your procedure after you leave the lab space. Be sure to be as detailed as possible.

3. PROCEDURE CITATION

An ACS style reference to the experimental procedure is provided for you in the lab notebook section of each experiment.

SAMPLE NOTEBOOK ENTRY: PROCEDURE CITATION

Chemistry 1110: Elementary Chemistry Laboratory Manual, Fall 2025–Summer 2026.; Weaver, T. A., Opoku-Agyeman, B., Fontes N. Da Silva, C., Welch, A. N., Rundell, S. R., Stern, J. E., Wroblewski, R. A., Walter, C., van Helmond, A., Eds.; Van-Griner Learning: Cincinnati, OH; pp. XIX–XXI.

4. DATA AND OBSERVATIONS

A template of data tables, observation boxes, etc. will be provided in this section. You should write directly into these in your lab manual or your digital lab notebook.

EXAMPLE

Data Table in the Lab Notebook Template

CAKE	BATTER OBSERVATIONS	BAKED CAKE OBSERVATIONS
Cake #1		
Cake #2		
Cake #3		
Cake #4		

Observations are vital when interpreting qualitative information and are as important as numerical data. The quality of the conclusions we can make from the data is only as good as the quality of the observations we record when performing the experiment. Make sure all observations are accurate, clearly written, detailed, and completely describe the specific situation. Observations can include colors, textures, amounts, and other details about the appearance of the experimental subject.

All numerical data taken should have the **correct number of significant figures and include units.** Experimental data that is collected and used in the Post-Lab and Data Analysis (any value you read directly off a buret, balance, spectrophotometer, etc.) needs to match **exactly** with the data written in your notebook pages and cannot be altered in any way—**you cannot add or remove digits after your data is collected. You cannot change observations or predictions after leaving the lab. This is considered academic misconduct. Email the lab supervisors immediately if you discover a problem with your data. Review the note about data integrity for further details.**

5. CALCULATIONS

All calculations performed in lab should be completed in the lab notebook or lab manual. Do these while you are still in the lab, time permitting. During select experiments, your lab instructor must check your calculations before the lab experiment is considered complete and eligible for full in-lab participation credit. Any unfinished calculations should be completed at home, and these do not need to be included in the laboratory notebook upload. If you made a mistake on a *calculated* value in the lab notebook, you **may** fix it before submitting a Post-Lab. Correcting a calculated value is not considered academic misconduct.

6. IN-LAB QUESTIONS

Some experiments require certain content questions to be answered while still in the laboratory space. Each experiment will direct you when to answer these questions, i.e., before beginning the experiment, during data collection, after data collection. Answers to these questions, as well as the question prompt itself, can be recorded in the lab notebook or directly in your lab manual. Typically, In-Lab Questions are at the end of the provided lab notebook or integrated into the lab notebook itself. Your lab instructor will need to check these before you leave to earn in-lab participation credit for completing them.

CAK

Name: Ima Student

Partner's Name(s): Imanother Student

Lab Date: 6/21/25 Lab Instructor's Name: Ima Instructor

CAK CHEMISTRY
LAB NOTEBOOK PAGES

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PROCEDURE REFERENCE

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PROCEDURE

Write a summary or step-by-step procedure for this experiment in the space below.

OPTION A: PROCEDURE SUMMARY

Prepare a control cake and three experimental cakes. Each experimental cake will be missing one vital ingredient. Data is collected to determine how the omission of an ingredient affects the physical characteristics of a cake.

OPTION B: PROCEDURE OUTLINE

1. a. Preheat oven to 180 °C.
   b. Prepare Cake #1 batter while oven preheats by following Steps 2–6.
2. a. Weigh 48 g flour; record exact mass.
   b. Weigh 35 g granulated sugar; record exact mass.
   c. Weigh 0.5 g salt; record exact mass.
   d. Weigh 0.75 g baking powder; record exact mass.
   e. Combine all solids in a 400-mL beaker.
3. a. Measure out 30 mL of milk.
   b. Measure out 30 mL of vegetable oil.
   c. Measure out 1 mL of vanilla.
   d. Whisk an egg until homogenous.
   e. Combine milk, vegetable oil, vanilla, and 1/3 of egg in a 250-mL beaker.
4. a. Add the mixture from Step 3 to the 400-mL beaker containing the mixture from Step 2.
   b. Mix well until uniform.
5. a. Pour batter into 600-mL beaker.
   b. Record observations and initial volume of cake batter before baking.
   c. Place beaker in preheated oven.
   d. Bake for 15 minutes; record volume of cake from lines on beaker every minute.
6. a. Use oven mitts to remove cake from oven.
   b. Let cake cool for 5 mins.
   c. Record observations of cooled cake.
   d. Wash 250-mL and 400-mL beakers with soap and water, then dry.
7. Make Cake #2 using Steps 2–6. Leave out the vegetable oil.
8. Make Cake #3 using Steps 2–6. Leave out egg.
9. Make Cake #4 using Steps 2–6. Leave out baking powder.

CLEAN UP AND WASTE DISPOSAL

Excess liquid reagents should be disposed of in the sink with a large amount of running water. Excess solid reagents should be discarded in the trash. Cakes should be disposed of in the trash. After cleaning up, wipe down your work area with 70% ethanol spray and a paper towel. Wash your hands thoroughly after completing this experiment.

DATA AND OBSERVATIONS

When recording data, be sure to record all significant figures: All digits displayed on a balance, the appropriate precision of any glassware used, etc.

	CAKE #1	CAKE #2	CAKE #3	CAKE #4
Actual mass of flour used (g)	47.9987	48.032	48.0541	47.9848
Actual mass of granulated sugar used (g)	34.9896	34.9907	35.0034	35.0103
Actual mass of salt used (g)	0.5012	0.4991	0.5015	0.4983
Actual mass of baking powder used (g)	0.7500	0.7493	0.7485	N/A

CAKE	BATTER OBSERVATIONS	BAKED OBSERVATIONS
Cake #1	~~Thick~~ viscous liquid with a pale yellow color	Golden brown solid, slightly springy
Cake #2	Slightly more viscous than #1, same pale yellow color	Golden brown solid, less springy than #1, very dry
Cake #3	Viscous liquid (similar to #1), pale yellow color (lighter in color than #1 and #2)	Golden brown solid, more spongy than springy, drier than #1
Cake #4	Viscous liquid (similar to #1) pale yellow color (similar to #1 and #2)	Golden brown solid, not springy at all, very dry

The power went out while baking Cake #1 for approximately one minute. The oven temperature dropped to 170 °C; the temperature rebounded after about 2 minutes.

A full egg was used in Cake #4 instead of 1/3 of an egg.

CAKE #1		CAKE #2		CAKE #3		CAKE #4	
Time (min)	Volume (mL)	Time (min)	Volume (mL)	Time (min)	Volume (mL)	Time (min)	Volume (mL)
0	250	0	210	0	230	0	270
1	250	1	210	1	230	1	270
2	260	2	220	2	240	2	280
3	270	3	230	3	240	3	280
4	280	4	240	4	250	4	290
5	300	5	250	5	260	5	290
6	320	6	260	6	270	6	290
7	340	7	270	7	280	7	300
8	360	8	280	8	290	8	300
9	380	9	290	9	300	9	310
10	400	10	300	10	310	10	310
11	420	11	310	11	320	11	310
12	430	12	320	12	330	12	320
13	440	13	330	13	340	13	320
14	450	14	340	14	350	14	330
15	450	15	340	15	350	15	330

A GUIDE FOR COMPLETING POST-LABS

After each experiment, you will complete a Post-Lab on Carmen. Post-Labs are due by the date and time listed on Carmen. See your lab syllabus for further details on late submissions and late penalties.

Post-Labs are a series of questions that aim to gauge your understanding of the experiment and related course concepts. Below, we will briefly discuss common tasks that you will complete in a Post-Lab and give examples from the Cake Chemistry experiment when applicable.

You must complete the "Introduction to LabRight" assignment with a score of 100% in order to access all Pre-lab, Post-Lab, and notebook assignments. You will need to reference Ima Student's lab notebook examples above when completing this assignment. Note that any Pre-Lab or Post-Lab assignments that are missed as a result of failing to complete the "Introduction to LabRight" assignment will not be reopened and result in a score of 0.

1. LABRIGHT POST-LAB

Your purchase of the lab manual also includes access to LabRight Post-Labs that are used with each experiment to grade your data, calculations, and Post-Lab questions. The Post-Labs are all linked through Carmen and will contain Data Analysis sections for applicable experiments. You must access the Post-Labs through Carmen each time you open one.

Only have the Post-Lab open when you are working on it. If the Post-Lab has been idle for more than an hour, quit and save your work, and re-open the link from Carmen. Never open more than one Post-Lab at a time, and never open multiple Post-Labs in multiple tabs or browsers simultaneously. The data integrity policies listed in the Presentation of Data section apply to the data submitted in the LabRight Post-Lab.

You can only submit each Post-Lab once; they will not be reset for any reason. However, you can attempt each Post-Lab question twice. After answering a Post-Lab question, you may click on the "How Did I Do?" button at the top of the question to see which answers are incorrect. You can then review the relevant topics and revise your response(s). Your revised response(s) will not be graded until you submit the completed Post-Lab by clicking the "Submit Assignment" button.

Some Post-Labs contain Data Analysis sections in which you will enter the raw data you collected in lab and complete your data analysis. For these sections, you will receive targeted feedback as you work up your data. When entering numerical values in a Post-Lab, unless otherwise indicated, be sure to follow the Significant Figure rules outlined in **Appendix D** of this lab manual.

2. WRITTEN PROCEDURE

For some Post-Labs, you'll need to summarize the procedure that you or your group followed during the experiment. This Written Procedure should be a clear, concise summary—different from the detailed, step-by-step version recorded in your lab notebook.

Your **notebook** is meant to capture everything you did in lab, including exact steps, materials used, and any changes made during the experiment. In contrast, the **Written Procedure** in your Post-Lab should focus on the key techniques and steps, assuming the reader is another scientist familiar with standard lab practices.

This section will guide you in converting your informal notebook procedure into a professional summary suitable for your Post-Lab.

KEY FEATURES OF A WRITTEN PROCEDURE

A **written procedure** is different from the step-by-step format in your notebook. It should be:

- Written in **paragraph form** (no bullets or numbered steps)
- Written in **past passive voice**
- **Example:** *"20 mL of water was pipetted into Solution 1."*
    - Avoid: Commands ("*Pipet 20 mL …*"), first person ("*I pipetted …*"), or second person ("*The chemist pipetted …*")

WHAT TO INCLUDE

When deciding what to include in your written procedure, keep these tips in mind:

- **Be concise.** Focus on the key steps and techniques used—this is a summary, not a full log.
- **Stick to what's in your notebook.** Only include details that were actually recorded during lab. If something wasn't written down, it shouldn't appear in your post-lab.
- **Leave out unnecessary details.** Assume your reader understands standard lab practices, so you don't need to describe basic tasks like labeling glassware, disposing of waste, or how to use common lab equipment.

On the following pages, you'll find four sample written procedures from the Cake Chemistry (CAK) Experiment. Each includes feedback on what works well and what could be improved to help you learn how to compose a strong Written Procedure for your Post-Lab.

EXAMPLE #1

> Preheat an oven to 180 and make 4 cake batters. Omit various ingredients (oil, eggs, or baking powder). Bake each cake for 15 min; measure the volume of the cake every 1 minute. Observe before and after.

Weakness

- Not in passive (third-person) past tense.
- Using commands.
- Missing details, i.e., approximate reagent amounts, units on temperature, how the cake volume was measured, power outage when baking Cake #1, excess egg used in Cake #4.

EXAMPLE #2

An investigation of how each ingredient in a cake affects the final pastry was performed. Various single ingredients (oil, eggs, and baking powder) were omitted from a cake batter which normally included flour, granulated sugar, salt, baking powder, milk, vegetable oil, vanilla extract, and egg. The physical characteristics of the resulting cake were observed during baking at 180 °C for 15 minutes. The volume of the cake was read from the side of the baking vessel every minute during baking to test how much the cake rose. Other characteristics such as color and texture were evaluated after cooling.

Strengths

- Procedure is written in paragraph form.
- Past passive tense used.
- Procedure is reproducible. All major steps in the procedure are included.
- No excessive details, i.e., how the ingredients were obtained, which balance was used, etc.

Weaknesses

- Missing details, i.e., approximate reagent amounts, the power outage when baking Cake #1, and the excess egg used in Cake #4.

EXAMPLE #3

Four cakes were made omitting various ingredients to observe how each ingredient affects the baking process and overall rise of the cake. To start, an oven was preheated. The first cake was a control and was made by combining approximately 48 g of flour, 35 g of sugar, 0.5 g of salt, 0.75 g of baking powder, 30 mL of milk, 30 mL of oil, 1 mL of vanilla extract, and ⅓ of an egg. The initial appearance of the batter and the initial volume were recorded. The beaker was then placed in a 180 °C oven, the oven light was turned on, and the cake was left to bake for 15 minutes. The calibration lines on the beaker were used to determine the cake volume every minute during baking. While the cake was baking, a power outage occurred for approximately 2 minutes. After the cake was fully baked, and cooled for 5 minutes, final observations of the cake's appearance were made. This same process was carried out for the 3 other cakes, baking for 15 minutes at 180 °C, but this time omitting a single ingredient. In the second cake, the batter used the same amount of each ingredient, but no oil was added. In the third cake, the batter used the same amount of each ingredient, but no egg was added. And in the fourth cake, the batter used the same amount of each ingredient, but no baking powder was added and a full egg was used instead of ⅓ of an egg. Again, the volume was recorded over the 15 minutes of baking and the initial and final appearances of the batter and cake were observed. All liquid waste was discarded in the sink with plenty of running water, and all solid waste was disposed of in the trash.

Strengths

- Procedure is written in paragraph form.
- Past passive tense used.
- Procedure is reproducible. All major steps in the procedure are included.

- Included details about how the actual procedure used deviated from the procedure in the lab manual, i.e., the power outage while baking Cake #1 and the excess egg used in Cake #4.

Weaknesses

- Excessive details, i.e., preheating the oven, placing cake in oven and turning on light, restating conditions for other cakes, waste disposal.

EXAMPLE #4

We investigated how one ingredient (namely oil, eggs, or baking powder) affected the baking process of different cakes if we omitted it while making the batter. My partner and I baked four cakes in total: a control cake with all ingredients, a cake with no oil, a cake with no egg, and a cake with no baking powder. We got the ingredients we needed from the reagent cart at the front of the lab. We made the control cake by using the second balance in the balance area to weigh out 47.9987 g of flour, 34.9896 g of sugar, 0.5012 g of salt, and 0.7500 g of baking powder and mixed them together in a beaker. Then we mixed 30 mL of milk, 30 mL of oil, 1 mL of vanilla extract, and ⅓ of an egg in a separate beaker and poured it into the flour, sugar, salt, and baking powder mixture. Then we poured the cake batter in a 600-mL beaker. While my partner was getting the ingredients and setting up our workstation for the next cake, I recorded the initial appearance of the cake batter, which was a viscous liquid with a pale-yellow color, and the initial volume (250 mL) in my lab notebook. I placed the beaker with the cake batter in a 180 °C oven, the oven light was turned on, and the cake was left to bake for 15 minutes. While our first cake was baking, the power went out for about 2 minutes. We left the cake in the oven during the power outage even though the temperature dropped to 170 °C. We recorded the cake volume every minute during baking. At the same time we were measuring the baking cake volume, we started preparing the next cake. We repeated the same process as we did for the first cake but this time, we did not include oil in the cake batter. Once the control cake was completely baked, my partner took it out of the oven and set it on the bench at our workstation to cool for 5 minutes. The cake appeared to be golden brown and was slightly springy. We recorded the final appearance in our individual notebooks. We then recorded the initial observations and volume for the second cake, placed it in the oven, and repeated the baking process. The third and fourth cakes were also baked using the same process and the same amount of ingredients. This time we did not include the egg in the third cake and the baking powder in the fourth cake. We mistakenly added a full egg to the fourth cake. We recorded the initial appearances and volumes of each cake batter, then continued to record the cake volume over the 15 minutes of baking. The final cake appearances were observed and recorded in our lab notebooks. All the cakes were golden brown in color. The second cake (no oil) was less springy and very dry. The third cake (no egg) was more spongy than springy and drier than the control cake. The last cake (no baking powder) was very dry and not springy at all.

Strengths

- Procedure is written in paragraph form.
- Procedure is reproducible. All major steps in the procedure are included.
- Included details about how the actual procedure used deviated from the procedure in the lab manual, i.e., the power outage when baking Cake #1 and the excess egg used in Cake #4.

Weaknesses

- Not in passive (third-person) past tense.
- Excessive details, i.e., indicating where reagents were obtained, where the balance is located, division of labor, specifying where, how and when data was recorded, when preparation of the second cake was started, including exact data and observations.

3. CALCULATION QUESTIONS

Many Post-Labs include questions that ask you to calculate the correct answer. Some of these questions may be formatted as multiple choice, dropdown, or matching questions. Others may provide a small box for you to enter your response.

Be sure to review the instructions for each individual question, as they may vary. Some questions may ask you to report your answer with a specific number of decimal places or select the answer with the correct number of significant figures. In many cases, the numerical values shown in the question are randomized and will change between attempts.

4. EXTENDED RESPONSE QUESTIONS (NOT INCLUDING WRITTEN PROCEDURES)

Extended response questions come in many varieties: some give you an opportunity to explain your analysis and interpretation of data, while others may ask you to explain a chemical concept. Responses must be written in full sentences, and personal pronouns such as "I" and "my" are permitted. Extended response prompts will often pose multiple questions. **Be sure to answer all of them.** When the questions asked are thematically similar, it may be appropriate to address them together. Avoid including individual paragraphs for each question, especially when they become repetitive.

EXAMPLE

Post-Lab Question

How did Cake #2, the cake with no oil, compare to the control cake? What is the purpose of including oil in the cake batter recipe? What physical characteristics changed significantly when it was removed?

Response

The cake with no oil was much less moist than the control cake. There are two plausible explanations. First, the oil was simply omitted from the recipe and was not replaced. As a result of this procedure, the cake batter had approximately 30 mL less liquid in it, which could have made the cake dry out faster when baking. Second, oil is less volatile than water (milk) at 180 °C, meaning a cake batter with a moisture content containing water and oil would retain more moisture than a cake batter with a moisture content that is primarily water.

5. ERROR ANALYSIS

Many Post-Labs will ask you to consider errors in the experiment. When we perform experiments, our results can contain uncertainty for a variety of reasons. These inherent limitations of the experiment can be one of two types:

RANDOM ERRORS

Also known as indeterminate errors, arise because it is impossible to make any measurement completely exact. Random errors have an equal chance to be positive or negative. For example, suppose we have a volume of water whose true value is 3.46 liters (L). If we use a graduated cylinder that is marked every 0.1 L, repeated measurements may give us values from 3.42 to 3.49 L. It is equally likely for the value to be above or below 3.46 L when reading the scale. Therefore, this is random error.

While random error is always present when we take measurements, we can minimize it. If we were able to measure the water with a graduated cylinder that is marked to every 0.01 L, our uncertainty in the measurements would change. This is precisely why we use an analytical balance (that can determine masses to ±0.0001 g) instead of a top loading balance (that can determine masses to ±0.01 g) whenever possible. This minimizes random error. Another way to minimize random error is to take multiple readings and average them.

SYSTEMATIC ERRORS

Also known as determinate errors, arise due to flaws in the experimental methods or the design of the experiment. In other words, if you or another chemist did the experiment again in exactly the same way, the error will still be present. We also call these experimental limitations.

Systematic errors tend to always be positive or always be negative, i.e., always over or underestimating the true value with a directional bias in all measurements. One example is a balance that always adds 0.0020 g to the mass of an object if calibrated incorrectly, making our view of the true value always higher than it is. Systematic errors can also be subjective, such as determining the color of a solution. In a titration with a colored indicator, you are the "detector" that determines when the end point has been reached. If you detect the end point via color change in the same way each time, but your observation actually comes a little too late, your titration will be systematically different from the true value for all measurements. Systematic errors can be identified and corrected. A good way to approach discussing systematic errors in Post-Labs can be to think about what parts of the experiment would not be improved by doing the experiment again as written. Many of our experiments include a procedure we developed for you—there are sometimes shortcomings of the design. Systematic errors cannot be corrected by changing your behavior, but by redesigning the experiment, such as using different equipment.

HUMAN MISTAKE

Neither a random nor systematic error, a human mistake describes a mistake made by the chemist completing the experiment. This type of error can be considered anything from dropping a sample, forgetting to take the temperature in one trial, or performing a calculation incorrectly. Human mistakes are essentially errors within your direct control. For our experiments, human mistakes can be considered changes to the procedure as written and should be included in the Written Procedure.

Post-Lab Question

Describe one random error, one systematic error, and one human mistake (if one occurred), and how they could impact your results in this experiment.

Response

Random errors have an equal chance of being positive or negative. When separating the egg into three portions, it's likely each portion was not exactly the same volume. Each portion had an equal chance of being slightly larger or slightly smaller than the others. A systematic error, an error that has a directional bias, could have occurred if the actual average oven temperature was cooler than 180 °C. An oven is not perfect and will lose heat over time. At a certain point, the oven temperature will drop low enough to turn the heating element back on. An actual average oven temperature lower than 180 °C could have stunted the growth of the cakes as they baked. A human mistake did occur while completing the procedure: a full egg was added to Cake #4 instead of ⅓ of an egg. The additional egg could have contributed to making Cake #4 less springy.

Many works were consulted in the writing of this guide. We acknowledge the following:

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