# THE FINAL PRACTICAL EXAM

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## EXAMEN FINAL DE LABORATORIO

**ABSTRACT:** This paper explores the role of the final laboratory exam as an effective tool for assessing student learning in introductory chemistry courses. It highlights students' areas of strength and weakness, proposes improvements to the assessment rubric and exam procedure, and introduces a sample titration experiment with a post-lab questionnaire. These modifications aim to better prepare students and enhance the exam's ability to measure conceptual understanding and practical competence.
**KEYWORDS:** Chemistry lab exam, student learning assessment

## EL EXAMEN PRÁCTICO FINAL

**RESUMEN:** Este artículo analiza la importancia del examen final de laboratorio como herramienta para evaluar el aprendizaje de los estudiantes en cursos introductorios de química. Se destacan tanto las áreas de dominio como las de dificultad, y se proponen mejoras en la rúbrica y el procedimiento del examen. Además, se presenta un experimento de titulación con un cuestionario posterior al laboratorio. Estos cambios buscan mejorar la preparación del estudiante y la eficacia del examen como instrumento de evaluación.
**PALABRAS CLAVE**: Examen final de Laboratorio, evaluación del aprendizaje

## INTRODUCTION

A final lab exam serves as a comprehensive assessment of a student's theoretical knowledge and laboratory skills. At **Tulsa Community College (TCC)**, students enrolled in *General Chemistry I* or *Chemistry for Engineers* are required to complete this capstone practical exam at the end of the semester. The exam evaluates competencies in:

- Laboratory techniques
- Data analysis
- Problem-solving

The exam consists of a series of hands-on laboratory exercises. Students are expected not only to perform standard procedures but also to apply theoretical principles in real time. Prior to the exam, students are encouraged to review their lab manual, perform practice exercises, and engage with digital simulations, such as an **online titration simulator**.

During the exam, students are provided with reagents and procedural instructions. They are allotted **one hour** to complete the lab work and submit a **written report** summarizing their data and conclusions.

## METHODOLOGY OF THE FINAL PRACTICAL EXAM

In the **Spring 2023 semester**, 59 students participated in the final practical exam. The assigned task was an **acid-base titration** of **NaOH** with **$H_2SO_4$**.

Students had access to practice simulations before the in-person exam. On exam day, they received a step-by-step procedure, carried out the titration, and submitted a lab report at the end.

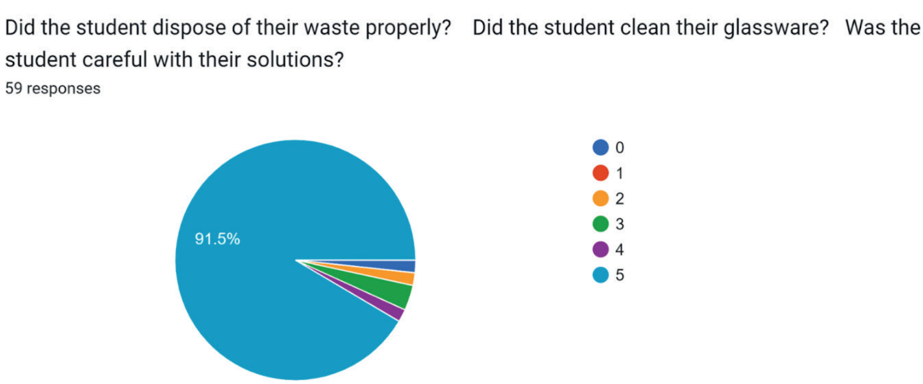
## RESULTS AND DISCUSSION

### Areas of Mastery

As shown in **Graphs 1 and 2**, students demonstrated proficiency in:

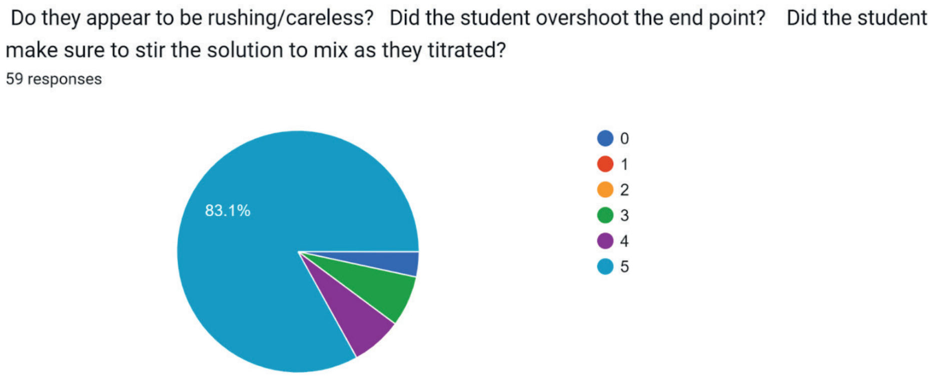
1. Correct use and cleaning of lab utensils
2. Execution of the titration procedure

These skills were well-practiced and retained across the student cohort.




**Graph 1:** Accuracy in performing titrations

The overwhelming majority (91.5%) of participants rated the practices with a score of 5, highlighting a strong adherence to proper lab procedures. The smaller percentages for other ratings (0 through 4) reinforce this positive trend, indicating that very few respondents perceived issues with the practices evaluated.



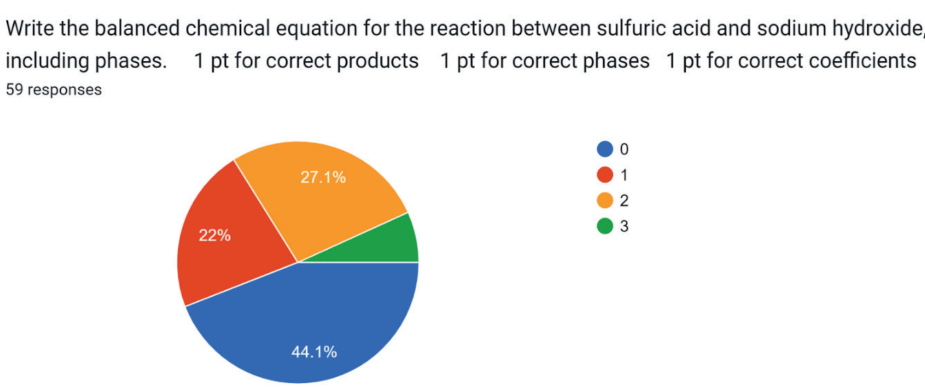

**Graph 2:** Grades based on titration execution

Many responses (83.1%) rated the practices as "0," suggesting there were no issues detected in these areas.

## AREAS OF DIFFICULTY

Most student errors occurred in the **written portion** of the exam (see Graphs 3–5). The most common mistakes included:

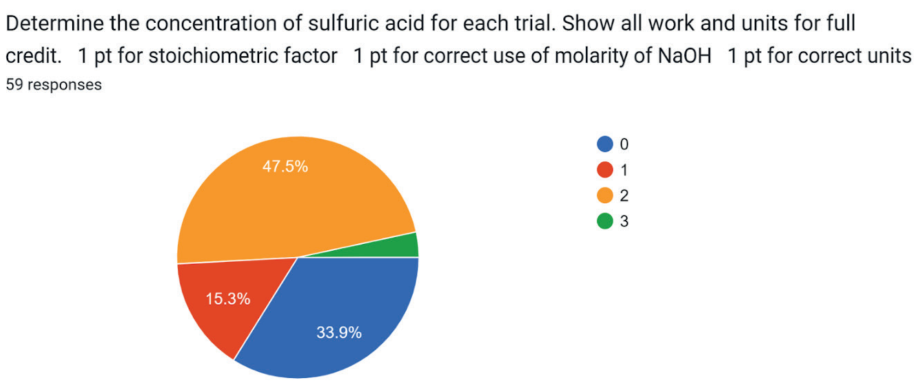
- Failure to write a balanced chemical equation for a diprotic acid–base reaction
- Incorrect molarity calculations due to omission of reaction stoichiometry
- Miscalculations when preparing solutions of specific molarity
- Lack of clarity in describing solution preparation steps




**Graph 3:** Writing balanced chemical equations

- The largest segment (44.1%) scored 0 points, indicating challenges in identifying the correct products, phases, or coefficients.
- 22% achieved 1 point, suggesting partial accuracy in addressing some components of the problem.
- 27.1% scored 2 points, showing a good understanding but with minor errors.
- Only 6.8% earned the full 3 points, demonstrating complete mastery of balancing the equation.

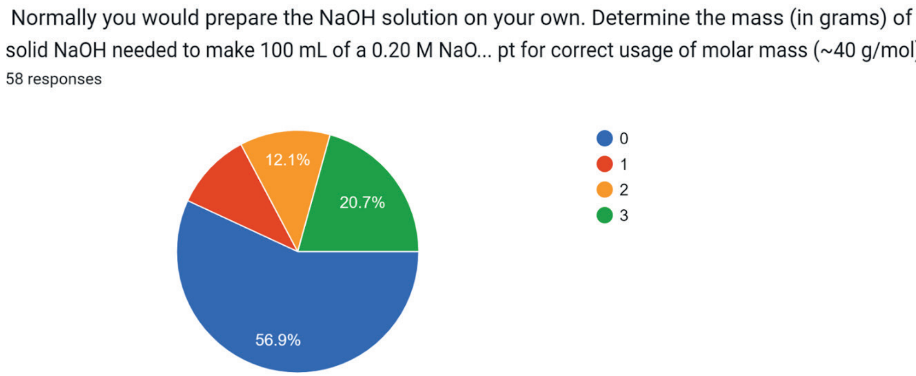
The data suggests a need for additional focus on teaching the principles of chemical equation balancing, as nearly half of the students struggled to meet the basic criteria for this task.




**Graph 4:** Molarity calculations of the unknown acid

- 33.9% (blue): Students scored 0 points, suggesting issues in applying the stoichiometric factor, molarity of NaOH, or correct units.
- 15.3% (red): Students earned 1 point, indicating partial accuracy in addressing some components of the problem.
- 47.5% (orange): Students achieved 2 points, showing a good understanding with minor errors.
- 3.4% (green): Students earned full marks (3 points), demonstrating complete accuracy and mastery.

The distribution indicates that while nearly half the students showed a solid grasp of the concepts, there is significant room for improvement, particularly for those scoring 0 or 1 point. This suggests the need for more targeted instruction and practice in stoichiometry, molarity calculations, and the proper use of units.




**Graph 5:** Calculating mass to prepare solutions

- **56.9% (0 grams):** Indicates a misunderstanding of the calculation or the problem requirements.
- **12.1% (1 gram):** Suggests partial accuracy but an overestimation of the required mass.
- **20.7% (2 grams):** Reflects a correct understanding of the calculation, as this is the accurate answer.
- **10.3% (3 grams):** Shows an overestimation, possibly due to a miscalculation or misinterpretation.

The data highlights that while a significant portion of respondents (20.7%) arrived at the correct answer, the majority struggled with the concept, suggesting a need for further instruction on molarity and stoichiometric calculations

## CONCLUSIONS AND RECOMMENDATIONS

The final laboratory exam is a valuable tool for both assessing student learning and reinforcing laboratory concepts. However, to maximize its effectiveness, the following improvements are recommended:

## PROCEDURE ENHANCEMENTS

- Provide **step-by-step instructions** for complex procedures
- Divide intricate experiments into **clear, manageable steps**

## RUBRIC IMPROVEMENTS

- Increase **specificity** in evaluation criteria
- Include dimensions like **accuracy**, **clarity**, and **problem-solving**

## FUTURE EXAM RECOMMENDATIONS

- Incorporate **diverse, course-relevant experiments**
- Allow **slightly extended time** for completion to reduce student stress

## PROPOSED FINAL LABORATORY EXAM

### Titration of NaOH with $H_2SO_4$

### Objective

To determine the concentration of an unknown **$H_2SO_4$ solution** by titrating it with **0.2 M NaOH**, using **phenolphthalein** as an indicator.

## MATERIALS

| Reagent/Equipment | Quantity |
|---|---|
| 0.2 M NaOH | As needed |
| Unknown $H_2SO_4$ solution | As needed |
| Phenolphthalein indicator | A few drops |
| Burette | 1 |
| 50 mL Erlenmeyer flask | 1 |
| Distilled water | As needed |
| Graduated cylinder | 1 |

## PROCEDURE

1. Rinse burette with distilled water and then with NaOH solution
2. Fill burette with 0.2 M NaOH
3. Pipette 5–10 mL of $H_2SO_4$ into a 50 mL Erlenmeyer flask
4. Dilute with equal volume of distilled water
5. Add 2–3 drops of phenolphthalein
6. Titrate until a permanent pale pink color is achieved
7. Record burette readings
8. Repeat for a second trial

## DATA TABLE

| Measurement | Trial 1 | Trial 2 |
|---|---|---|
| Volume of acid used (mL) | | |
| Initial burette reading (mL) | | |
| Final burette reading (mL) | | |
| Volume of base used (mL) | | |
| Calculated [$H_2SO_4$] (M) | | |

## POST-LAB QUESTIONS (20 PTS)

1. Write the balanced chemical equation for NaOH and $H_2SO_4$. (5 pts)
2. Why is phenolphthalein used as an indicator? (3 pts)
3. How would the titration curve change if $H_2SO_4$ had twice the concentration of NaOH? (2 pts)
4. If the final burette reading is 22.5 mL and initial is 0.5 mL, what volume of NaOH was used? (5 pts)
5. Given 25 mL of $H_2SO_4$, 0.195 M NaOH, and final equivalence, calculate the acid concentration. (5 pts)

## RUBRIC: LAB PRACTICAL – TITRATION

| Category | Criteria | Points |
|---|---|---|
| **Setup** | Equipment prep, measurement, safety | 4 |
| **Execution** | Control of titration, indicator use | 3 |
| **Data Collection** | Accurate readings, repeatability | 3 |
| **Calculations** | Correct math, stoichiometry, logic | 4 |
| **Lab Technique** | Cleanliness, safety protocols | 3 |
| **Presentation** | Clarity, organization, explanation | 3 |
| **Total** | | 20 |

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