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Classical approaches in analytical chemistry for students: practical works with titrimetry and gravimetry

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Abstract. Classical analytical techniques, such as titrimetry and gravimetry, remain foundational in chemical education despite the widespread use of modern instrumental methods. These techniques offer students essential hands-on experience in quantitative analysis, developing their precision, critical thinking, and laboratory skills. This article presents structured practical tasks based on titrimetric and gravimetric methods designed specifically for undergraduate and secondary-level chemistry students. By engaging in real laboratory exercises, students gain a deeper understanding of stoichiometry, chemical reactions, and analytical procedures. The implementation of these classical methods not only reinforces theoretical knowledge but also fosters a strong foundation for future scientific work.
Keywords: *Analytical chemistry, titrimetry, gravimetry, classical methods, laboratory practice, chemistry education, quantitative analysis, student-centered learning.*

Introduction. Analytical chemistry plays a central role in the understanding and advancement of chemical sciences. While contemporary analytical laboratories increasingly rely on advanced instrumentation such as spectroscopy, chromatography, and electrochemical sensors, classical analytical techniques—namely titrimetry and gravimetry—continue to hold significant educational value. These methods, which focus on quantitative analysis through volume and mass measurements respectively, are not only cost-effective and precise but also ideal for teaching fundamental principles of chemistry[1].

Titrimetric and gravimetric analyses allow students to directly engage with core concepts such as stoichiometry, limiting reagents, and chemical equilibria. Through careful execution of these methods, learners develop critical laboratory skills, including precise measurement, systematic thinking, and analytical interpretation. Furthermore, the simplicity of the required apparatus and reagents makes these methods highly accessible in educational settings with limited resources.

This paper aims to highlight the pedagogical relevance of classical methods in analytical chemistry education by presenting practical laboratory exercises tailored to student needs. Emphasis is placed on how these techniques can strengthen theoretical understanding, enhance manual skills, and promote scientific thinking in both secondary and undergraduate chemistry education[2].

Classical analytical techniques, such as titrimetry and gravimetry, are not only fundamental for developing laboratory skills, but also offer valuable opportunities to apply contemporary didactic strategies that enhance student engagement and learning outcomes. Integrating these methods into chemistry curricula through well-structured pedagogical approaches promotes active learning, conceptual understanding, and cognitive development.

1. Constructivist learning framework. Within a constructivist paradigm, students build new knowledge upon their prior experiences. Classical experiments, like acid-base titrations or gravimetric precipitation, allow learners to construct chemical concepts actively through observation, hypothesis testing, and data interpretation. This hands-on approach supports deeper learning and aligns with Bloom's taxonomy, advancing students from basic knowledge recall to higher-order analytical thinking.

2. Inquiry-Based and problem-oriented tasks. Designing laboratory exercises around open-ended questions such as "How can the concentration of an unknown acid be determined using titration?"—stimulates inquiry and critical thinking. Problem-solving tasks rooted in classical analysis encourage learners to apply theoretical principles, interpret experimental results, and draw scientifically justified conclusions. Classical methods can be effectively integrated into flipped or blended learning environments. Pre-laboratory digital modules or video demonstrations introduce theoretical concepts before class, enabling more time for active experimentation and guided inquiry during lab sessions. This approach fosters student autonomy and collaborative work.

Incorporating formative assessment techniques such as self-evaluation checklists, peer review of lab reports, and instructor feedback during classical experiments reinforces learning and helps students monitor their own progress. Reflective practice following each experiment cultivates metacognitive skills and scientific reasoning. Classical methods provide flexible learning opportunities in diverse educational contexts, especially in resource-limited schools. Tasks can be differentiated in complexity to accommodate students with varying levels of preparedness. For instance, advanced learners may be challenged to modify titration procedures or calculate uncertainty, while others focus on mastering basic techniques. In conclusion, when aligned with contemporary didactic strategies, classical analytical methods serve not only as tools of measurement but also as dynamic educational instruments. Their integration into chemistry instruction supports pedagogical diversity, student engagement, and the development of transferable scientific competencies [3].

Practical work in titrimetry.Titrimetry, as a fundamental classical method in analytical chemistry, offers students an accessible and effective approach to understanding quantitative chemical analysis. It involves measuring the volume of a titrant required to completely react with an analyte, allowing learners to explore concepts such as acid-base neutralization, redox reactions, and complex formation.

Educationally, titrimetric exercises aim to develop students' skills in precise liquid handling, use of volumetric apparatus, stoichiometric calculations, and endpoint detection using indicators. One common laboratory task is the determination of acetic acid concentration in vinegar using sodium hydroxide (NaOH). Through this simple but illustrative experiment, students apply the neutralization principle and perform calculations using the relationship

$C_1V_1 = C_2V_2$. This hands-on activity reinforces theoretical knowledge, cultivates accurate laboratory techniques, and enhances students' confidence in performing independent analytical procedures making titrimetry an essential part of chemistry education. Practical work in gravimetry.Gravimetric analysis is a classical and reliable method of quantitative chemical analysis based on measuring the mass of a compound formed in a chemical reaction. In educational laboratories, it provides students with hands-on experience in filtration, drying, and accurate mass measurement. A common example involves the determination of sulfate ions (SO_4^{2-}) by precipitating them as barium sulfate ($BaSO_4$) using barium chloride ($BaCl_2$).

This exercise helps students understand the principles of gravimetric precipitation, the importance of constant mass, and the stoichiometric relationships between reactants and products. The procedure includes sample preparation, addition of the precipitating agent, filtration, drying, and final weighing. Calculations are based on the known molar mass of $BaSO_4$ (233.39 g/mol), allowing students to determine the amount of sulfate ions present. Through this practical task, learners develop key analytical skills such as accuracy, attention to detail, and systematic laboratory technique all essential for future scientific research and education.

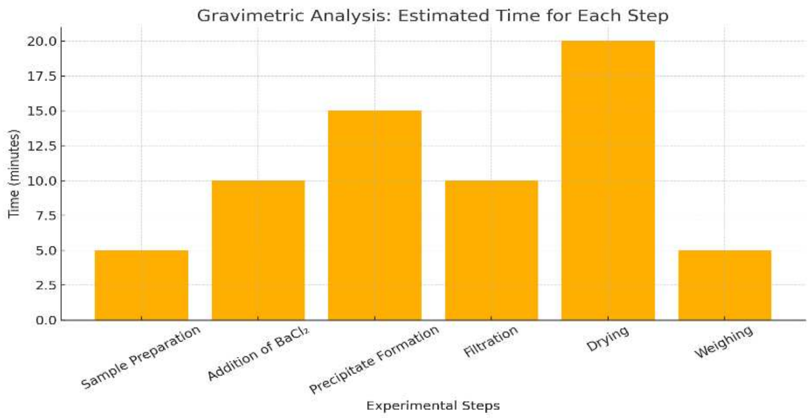

Figure 1
Estimated time allocation for steps in gravimetric analysis

The estimated time distribution for each stage of the gravimetric experiment is illustrated in Figure 1, providing a practical overview of the laboratory workflow[4-6].

Table 1

Estimated time allocation for steps in gravimetric analysis

Experimental step	Estimated time (minutes)
Sample Preparation	5
Addition of $BaCl_2$	10
Precipitate Formation	15
Filtration	10
Drying	20
Weighing	5

This table presents the approximate duration for each step in a standard gravimetric analysis procedure, aiding effective time management in laboratory practice.

Conclusion. Classical analytical techniques such as titrimetry and gravimetry continue to play a significant role in chemistry education, offering valuable opportunities for students to gain hands-on experience with quantitative analysis. These methods not only reinforce essential chemical principles such as stoichiometry, reaction completeness, and solubility but also help students develop critical laboratory skills including precision, accuracy, and systematic problem-solving.

Through well-designed practical tasks, students become actively engaged in the analytical process, fostering both conceptual understanding and confidence in experimental procedures. The use of simple, accessible equipment in these methods further supports their application in a variety of educational contexts, especially where advanced instrumentation is not available.Incorporating classical methods into modern curricula ensures that students receive a well-rounded chemical education grounded in both theoretical knowledge and practical competency. Their pedagogical value remains high, making titrimetric and gravimetric analysis indispensable components of student-centered learning in analytical chemistry.

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