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Perspectives on Incorporating Background Information and Graph Presentation in Chemistry Laboratory Manual

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Abstract

Chemistry is a highly experimental science and the laboratory manual is an integral part of the curriculum. Laboratory work must be incorporated as a component element of a theory course in organic/inorganic chemistry to impart experimental skills. This paper presents the significance of incorporating background information and the basics of graphical presentation in the lab manual. It emphasizes the design of laboratory content to reflect the changes in the chemistry field.

Keywords: *Chemistry experimentation, Laboratory manual, Experimental procedure, Report writing*

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INTRODUCTION

Chemistry laboratory experiments help students develop scientific skills, understand chemical concepts, and learn the application of concepts to the real world. They also learn precision and accuracy, logical reasoning, a keen sense of observation, safety awareness, experimentation to test hypotheses, data analyses, and collaboration, interpersonal, and problem-solving skills. The theory class in chemistry must be supplemented by practical experiments in the laboratory as a single demonstration experiment can teach as much practical knowledge as several books on the subject can reveal. This approach to holistic learning results in an improved learning experience, enhanced memory retention, and a renewed sense of confidence. It will be in the student's interest to improve their skills by performing experiments individually or in batches under supervision to obtain hands-on learning experience. Demonstration experiments will have an impact on the minds of students as they are exposed to the crucial and latest experimental techniques, working principles, and operational procedures of several sophisticated instruments (Beran, 2010). The laboratory experiments must be related to the lecture material to a significant extent that helps maintain the continuity in the discussion and should be designed to suit graduate-level/undergraduate students (DeMeo, 2001). While conducting the experiments, students can visualize each step, write down observations, and perform calculations to prepare laboratory reports that will help them retain information for a long time (Domin, 1999). The experiments must be carefully selected to provide the students with a wide range of laboratory experience in the specific area to fill in the gaps in the learning flow. The practical demonstrations or experimentation reinforces theoretical concepts taught in the classroom for the integral growth of the students.

Background Information

Description of background information and scientific concepts involved in undergraduate/postgraduate chemistry experiments helps the performer understand the experiment's purpose, significance, and context (Dupen, June). It also allows the learner to understand the experiment's aim and the meaning of the results obtained. This information can be two paragraphs of about ten sentences each. The goal-directed experiential learning management protocols would help enhance learning outcomes. The chemistry experimentation practices and protocols using evidence-based approaches in interactive case-based clear discussions during a practical session help optimize learning management (Girolami et al., 1999). Cutting-edge teaching strategies in explaining the significance of developing a keen sense of observation and critical data analysis to arrive at useful results help science students comprehend the results obtained in each regular laboratory experiment. The section will unlock the learning potential, furthering learner empowerment by leveraging the power of technology and good learning material in the laboratory manuals. Chemistry lab manuals include information about laboratory methods, safety, and policies. They also include information about the proper use of laboratory equipment, theory, and good laboratory practices (Miller & Yeung, 2022). For instance, it involves procedures to experiment with titrimetric analysis and handling chemicals safely. Basic laboratory techniques in a chemistry experimental manual include information about how to heat solutions, measure volume, handle chemicals and safety equipment, prepare solutions, purify samples, and weigh substances. In a typical chemistry laboratory report, the following components are included: a title, objective, introduction, concise theoretical background, procedure (which covers equipment requirements, the experiment itself, collected data, and safety precautions), results (here data is interpreted, trends and patterns are identified, significant observations are noted, and visual aids such as tables, graphs, or diagrams may be presented), and finally, conclusions. A sample background information to be incorporated before the procedure section is given below.

One of the common experiments to learn and practice quantitative techniques for estimating the concentrations of solutions is the determination of the total hardness of water by the complexometric EDTA method by titrating water with EDTA using an indicator. The hardness is expressed in mg/L as CaCO3 equivalents. Hardness in water is primarily due to the dissolved salts of calcium and magnesium, including carbonates, bicarbonates, and sulfates. In certain areas, iron, aluminum, and manganese salts can also contribute to water hardness (Gopalan & Sugumar, 2013). When hard water is used for washing clothes, it significantly reduces the effectiveness of soap. Hard water requires more soap to create lather, leading to excessive soap consumption. The presence of metal ions in hard water reacts with stearate ions from soap, forming an insoluble scum that hampers lather formation. This scum can leave visible deposits on fabrics, making them feel stiff, and also accumulates in bathtubs, sinks, and washing machines. Additionally, hard water can cause scale buildup on the inside of water pipes, tea kettles, and other industrial equipment like boilers. The presence of this insoluble deposit is indicative of water hardness (Laredo, 2013).

A titration technique is employed to quantitatively assess water hardness. The hardness is measured in parts per million (ppm) and is categorized into six levels: very soft (0-70), soft (70-140), slightly hard (140-210), moderately hard (210-320), hard (320-530), and very hard (above 530). If a water sample is classified as very hard, it is deemed unsuitable for drinking and industrial applications. The water purification and recycling industry has become increasingly significant as we address these challenges. The experiment aims to determine the total hardness of a water sample quantitatively by titrating it against a standard solution of ethylenediamine tetraacetic acid (EDTA), utilizing eriochrome black-T (EBT) as an indicator.

METHODS

The experiment was conducted by collecting data through titration using the EDTA complexometric method to determine the total hardness of water. Measurements of potential, absorbance, or pH were recorded corresponding to the volume of standard solution or amount of reagent added. These data points were plotted on a graph, with the y-axis representing the measured values (e.g., EMF, absorbance, pH) and the x-axis representing the volume or concentration of the standard solution. A calibration line or curve was drawn by connecting the data points to represent the relationship between variables (Timberlake, 2021). The equivalence point was identified at the steepest part of the curve. The titration results were analyzed by interpolation or extrapolation from the calibration graph to determine the analyte concentration in the sample. All procedures were followed with appropriate safety protocols and proper laboratory techniques

FINDING AND DISCUSSIONS

The experimental data can be analyzed by plotting a graph that results in a straight line or a curve. These data shown graphically clearly represent the interrelationship between two variables and provide a pictorial representation of results, which is more readily comprehended than a set of tabular results. The plot is particularly useful for determining the endpoints in potentiometric or conductometric titrations or the amount of analyte in the sample in colorimetric determinations. Remember the following rules for proper representation of data in graphical form (Henrie, 2015).

1. Graph Construction: Mark the points corresponding to the measured variables using graph paper and a pencil. For instance, plot the observed potentials (EMF values)/absorbance/ pH on the y-axis (ordinate) and the volumes of reagent added/the concentrations of the standard solutions (amount of analyte) on the x-axis (abscissa).
2. Data Representation: Draw a line through these data points that best represents the relationship between the two variables. A straight-line plot/calibration curve will be obtained. While experimental data do not fall on a smooth curve and may lie on either side due to measurement errors, aim to draw a smooth curve that closely fit all the data points. This curve should represent the best fit (weighted average) for the calibration data, which is crucial for the method's accuracy.
3. Interpolation and Extrapolation: Results for unknowns can be interpolated from the calibration graph. Extrapolate a straight line beyond the data range that cuts the x-axis at a point corresponding to the volume of the titrant solution or calculate the slope of a straight line as appropriate.
4. Equivalence Point: In potentiometric titrations or pKa determination using a pH meter, the equivalence point corresponds to the volume of the solution added at the steepest portion of the curve.
5. Slope Considerations: Note that the slope of a straight line remains constant across all points, while it changes from point to point on a curve. The slope can be calculated as, $m = \Delta Y/\Delta X$.
6. Graph Title/Caption: The graph should have a proper title or caption that explains the data being presented therein. Examples include a graph of the concentrations versus absorbance in the determination of copper or a potential /volume curve for the titration of acetic acid versus sodium hydroxide solution or a conductometric titration curve for strong acid and strong base.
7. Axis Labels: Both the horizontal and vertical axes should be labeled with the associated variables and their appropriate units.

8. Scale Indication: Indicate the scale used in the upper right-hand corner. For example; X-axis –1cm = 0.5 mL. Y- axis –1cm = 0.5 pH
9. Results Presentation: Present the results obtained from the graph on the right-hand bottom portion and their proper units.
10. Graph Boundaries: Do not attempt to draw the graph outside the boundaries corresponding to the maximum and minimum data values measured. Learn from your mistakes, and don't hesitate to ask questions-chemistry books will undoubtedly expose you to new insights.

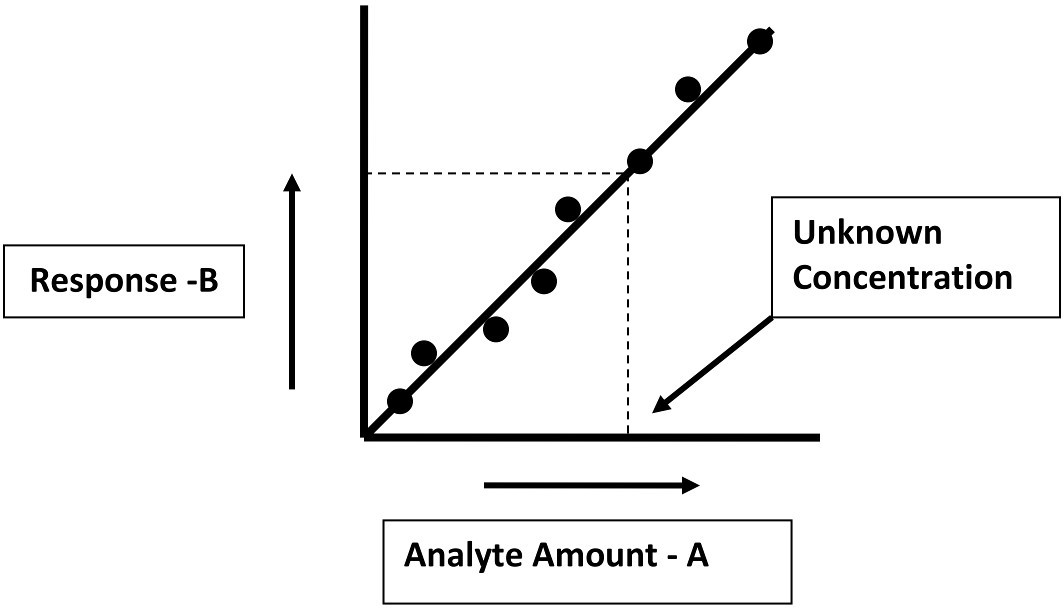

Fig.1. A typical (ideal) calibration curve of variable B versus variable A. The amount of an unknown can be determined from the graph as shown.

Summary and Outlook:

Laboratory work is an integral part of the chemistry experience. By maximizing both real and virtual practical activities, learner's knowledge and competency aspects in a topic can be improved. Laboratory activities for chemistry education and microscale laboratory experiments allow young learners to view changes in matter (García et al., 2015). Chemistry laboratory manuals include a title page, foreword, table of contents, safety guidelines, instructions for performing individual experiments, and tips for writing a laboratory book (theory, experiments, observations, inference, diagrams, tables, results, and review questions). Background information in chemistry laboratory manuals helps learners understand the scientific context and the relevance of each experiment. Graphical data presentation is visually more engaging and helps learners to understand, visualize patterns and relationships, compare results, identify trends, identify trends, and memorize data (Keller & Trendelenburg, 2019). The data points must be precise and properly presented in the graphs to avoid misinterpretation. Encouraging the students with questioning and experimentation will help them acquire the ability to provide rational explanations, identify the sources of uncertainties, and respond to problems in the field of chemistry. The manuals on green chemistry, food chemistry, and environmental chemistry are available (Kennepohl, 2001). It is essential to provide experiments to demonstrate the synthesis of various nanoparticles, characterization, and applications as an integral part of the learning process in the trending field of nanochemistry. Experimental examples in this field include the synthesis of carbon nanotubes, preparation of titanium oxide nanoparticles, physical characterization of various nanoparticles, application of nanoparticles in catalysis, use of nanoparticles in composite materials, and medical application demonstration (Poinern, 2014). The list of ten experiments related to synthesis, property measurement, and different types of applications could reasonably be completed in a semester course. There is much scope for laboratory content development and analyses, teaching instructions in chemical experimentation, laboratory experiments using computer simulation, and problem-based small-scale laboratory projects (Reid & Shah, 2007).

CONCLUSION

The chemistry practical using graphical data presentation and EDTA complexometric titration effectively determines water hardness quantitatively. Presenting data graphically facilitates understanding of the variable relationships and accurate identification of the equivalence point. The titration method and graphical data analysis enhance students' abilities to interpret experimental results and deepen their understanding of chemical concepts. Comprehensive laboratory manuals and adherence to proper laboratory techniques are essential to support effective and safe learning. Furthermore, integrating technology and practical approaches empowers learners to develop critical observation skills and accurate data analysis, which are vital in chemistry education.

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