Oxidation–Reduction Titrations

Inquiry Guidance and AP* Chemistry Curriculum Alignment

Introduction

Determining the amount of a particular substance in a sample or product is a common task in analytical chemistry. If the product contains a substance that can be oxidized, then it is possible to determine the number of moles of that substance by titrating the sample with a strong oxidizing agent. In this lab, an oxidizing solution will be standardized and then used to determine the number of moles of oxalic acid.

Opportunities for Inquiry

Standardizing potassium permanganate by redox titration, then using that solution for quantitative analysis of another substance, fulfills key learning objectives involving redox titration, chemical reactions, and stoichiometry. Oxidation–reduction titrations require students to develop science practice skills for identifying data that must be collected and designing procedures to answer scientific questions.

The classic experiment can be modified to a guided-inquiry format by incorporating the following suggestions. Increasing the level of student preparation will also improve their level of understanding.

- Introduce the lab by demonstrating the general setup for redox titrations. Guide students to design the actual experimental procedure through a series of leading questions. What is the stoichiometry of the reaction involved in the redox titration? Determine a suitable concentration of potassium permanganate to analyze 0.25 M oxalic acid. What quantity of the primary standard, iron(II) ammonium sulfate, should be used in the standardization procedure? What is the purpose of adding an acid to the substance being titrated? Does the quantity of acid affect the stoichiometry of the redox titration? Answering these questions provides authentic opportunities for inquiry!
- Take away the data tables and post-lab questions. Replace worksheet calculations with a detailed overview of the experiment describing the general calculations: "The purpose of this lab is to standardize a solution of potassium permanganate by redox titration with a standard solution of iron(II) ions. A solution of oxalic acid is then titrated with the permanganate solution to determine the exact concentration of oxalic acid."
- Extend the lab to analyze unknowns and commercial products. Challenge students to determine the oxalic acid content in common household cleaning products by oxidation–reduction titration.
- Can students "make the leap" and generalize from one type of redox titration to another? Iodimetric titrations using iodine are perhaps the most versitile analytical procedures for redox reactions. The amount of vitamin C, a strong reducing agent, is analyzed by titration with I_3^-. Ask students to research iodimetric titration experiments and then design an experiment to analyze the vitamin C content in their favorite fruit juice.

Alignment with AP Chemistry Curriculum Framework—Big Ideas 1 and 3

Enduring Understandings and Essential Knowledge

All matter is made of atoms. There are a limited number of types of atoms; these are the elements. (Enduring Understanding 1A)

1A3: The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.

Atoms are conserved in physical and chemical processes. (Enduring Understanding 1E)

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1E2: Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation.

Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form. (Enduring Understanding 3A)

3A2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists.

Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions. (Enduring Understanding 3B)

3B3: In oxidation-reduction (redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced.

Learning Objectives

1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively.

1.20 The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution.

3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results.

3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.

3.9 Thestudent is able to design and/or interpret the results of an experiment involving a redox titration.

Science Practices

1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

4.2 The student can design a plan for collecting data to answer a particular scientific question.

5.1 The student can analyze data to identify patterns or relationships.

6.1 The student can justify claims with evidence.

6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

7.1 The student can connect phenomena and models across spatial and temporal scales.

The *Oxidation–Reduction Titrations—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, inc.

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