Flinn Advanced Inquiry Laboratory Kits for AP* Chemistry Correlated to the College Board Investigative Labs

In 2012, the Advanced Placement chemistry curriculum was revised to integrate inquiry, content, and reasoning through an updated set of learning objectives and science practice skills. In addition to traditional or classic lab experiments, the updated framework requires six guided-inquiry labs. Flinn has created 16 all new Advanced Inquiry Laboratory Kits that align with inquiry investigations published by the College Board. These advanced inquiry kits complement our existing student laboratory kits for AP Chemistry.

- Each Advanced Inquiry Lab Kit meets the new AP Chemistry guidelines published by the College Board.
- Each experiment has been thoroughly tested, retested, and optimized to guarantee safety and success.
- Our trademark ChemFax kit instructions always include real sample data, never made up!
- Each write-up includes AP Chemistry Review Questions that seamlessly integrate inquiry, content, and reasoning to match the "Big Ideas" in the new curriculum framework.
- Science practices are applied to connect lab experiences to the real world.

Each Advanced Inquiry Lab write-up contains valuable background information, instructions, procedures, and all the materials needed for 12 groups of students. A new, signature section in each ChemFax, called “Guided Inquiry Design and Procedure,” asks leading questions to help students identify the variables for designing an effective laboratory experiment. The familiar Flinn “Teacher Notes” section wraps up the write-up with sample data, teaching tips, and summaries of possible results teachers may expect students to observe. In each Advanced Inquiry Lab, students begin with an introductory or baseline activity and then move on to the guided-inquiry portion of the lab. We provide extra materials where possible, with the understanding that students may choose to pursue a variety of different directions when exploring further opportunities for inquiry.

This publication will provide you with a short description of each Advanced Inquiry Lab kit, how the Advanced Inquiry Lab correlates to the College Board Investigative Labs, and also a list of additional required lab equipment and supplies such as balances, spectrophotometers, and common laboratory glassware.

As always, please call or email (800-452-1261 or flinn@flinnsci.com) Flinn Scientific if you have any questions. We are here to help!

*AP is a registered trademark of the College Board, which was not involved in the production of, and does not endorse, this product.

Publication No. 11193
061616

The Big Ideas of AP* Chemistry

The new AP Chemistry curriculum framework is organized around six Big Ideas. These big ideas provide the structure for the course and exam. Each Big Idea includes a set of Learning Objectives. These Learning Objectives are based on the Enduring Understanding and Essential Knowledge statements, which both serve to identify content knowledge and thinking skills that students should be able to demonstrate. There is also a greater emphasis on Science Practices, such as using mathematics skills, data collection and analysis, inquiry investigations, and using models and representations to communicate and solve scientific problems.

Big Idea 1—Atoms and Elements

The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.

- AP7642, Analysis of Food Dyes in Beverages (Investigation 1)
- AP7643, Percent Copper in Brass (Investigation 2)
- AP7660, Gravimetric Analysis of Calcium and Hard Water (Investigation 3)
- AP7645, Acidity of Beverages (Investigation 4)

Big Idea 2—Structure and Properties of Matter

Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

- AP7661, Separation of a Dye Mixture Using Chromatography (Investigation 5)
- AP7664, Qualitative Analysis and Chemical Bonding (Investigation 6)

Big Idea 3—Chemical Reactions

Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.

- AP7653, Green Chemistry Analysis of a Mixture (Investigation 7)
- AP7647, Analysis of Hydrogen Peroxide (Investigation 8)
- AP7662, Separating a Synthetic Pain Relief Mixture (Investigation 9)

Big Idea 4—Kinetics

Rates of chemical reactions are determined by details of the molecular collisions.

- AP7648, Rate of Decomposition of Calcium Carbonate (Investigation 10)
- AP7644, Kinetics of Crystal Violet Fading (Investigation 11)

Big Idea 5—Thermodynamics

The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

- AP7654, Designing a Hand Warmer (Investigation 12)

Big Idea 6—Equilibrium

Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

- AP7659, Applications of LeChâtelier's Principle (Investigation 13)
- AP7656, Acid–Base Titrations (Investigation 14)
- AP7665, Buffers in Household Products (Investigation 15)
- AP7663, Properties of Buffer Solutions (Investigation 16)

Save money by purchasing the Advanced Inquiry Kits for AP* Chemistry as a bundle rather than individually!

Catalog No.	Description
AP7655	Advanced Inquiry Labs for AP* Chemistry—16 Kit Bundle

Analysis of Food Dyes in Beverages—

Advanced Inquiry Laboratory Kit

Big Idea 1, Investigation 1

Primary Learning Objective 1.15

Food dyes are everywhere—from food to drink to cosmetics! How much food dye is actually contained in these products? This advanced inquiry lab allows students to utilize spectroscopy and graphical analysis to determine the concentration of dye in a sports drink.

The lab begins with an introductory activity in which students prepare a series of standard dilutions of an FD&C Blue 1 stock solution. Students then measure the percent transmittance of each and graph the results to identify an optimum linear relationship among various functions (T, $\%T$, $\log T$ and A) for a Beer's law calibration curve. A Beer's law plot of absorbance as a function of concentration may then be used to calculate the concentration of any "unknown" solution. Using this introductory procedure as a model, students design guided-inquiry experiments to determine the concentration of food dye(s) in sports drinks and other consumer beverages. Additional dyes (FD&C Yellow 5 and Red 40) and samples of sports drinks are included in the kit for optional extension or cooperative class inquiry studies.

This advanced inquiry lab reinforces content learning objectives for the principles of spectroscopy and to integrate mathematical reasoning and graphing science practice skills. Use this investigation to develop—and test—skills in preparing accurate serial dilutions, understanding spectroscopic measurements, and extrapolating from graphical data.

Flinn Catalog Number: AP7642

Materials Included in Kit (for 24 students working in pairs)

- FD&C Blue 1 Stock Solution, 100 mL
- FD&C Red 40 Stock Solution, 100 mL
- FD&C Yellow 5 Stock Solution, 100 mL
- Blue and red consumer sports drinks
- Pipets, serological, 10-mL, 12

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Consumer beverages, blue, red and yellow
- Beakers, 50-mL, 2–3 (dependent on dilutions per group)
- Kimwipes or lens tissue
- Pipet bulb or pipet filler
- Spectrophotometer or colorimeter (shared)
- Test tube rack
- Test tubes or cuvets, 13 × 100 mm, 3–8

Additional Materials Required (for *Pre-Lab Preparation*)

- Graduated cylinder, 25-mL
- Volumetric flask, 1000-mL

Percent Copper in Brass—

Advanced Inquiry Laboratory Kit

Big Idea 1, Investigation 2

Primary Learning Objective 1.16

The relative proportions of copper, zinc, and iron in brass influence its properties and uses. How can the percent composition of brass be determined to verify these properties?

The purpose of this advanced inquiry lab is to design a procedure to analyze the amount of copper in brass using visible spectroscopy. The lab begins with an introductory activity, in which students measure the absorbance of various metal ion solutions at regular wavelength intervals from 400 nm to 700 nm and investigate the influence of the anion on the absorption spectra. Students identify the correlation among wavelength, absorbance, and concentration for each of three possible ions that may be obtained from brass: copper, zinc, and iron.

Once the introductory activity is completed, students design and carry out an experiment to construct a calibration curve and determine the concentration of copper ions in a solution prepared by dissolving brass in nitric acid. Students must investigate the concentration range over which Beer's law is valid and identify the optimum wavelength for analysis. The mass percent of copper in brass is determined from the results of the analysis. This experiment should be performed in a fume hood or well-ventilated lab.

Flinn Catalog Number: AP7643

Materials Included in Kit (for 24 students working in pairs)

- Brass sample, 75 g
- Copper(II) nitrate solution, $Cu(NO_3)_2$, 0.1 *M*, 75 mL
- Copper(II) nitrate stock solution, $Cu(NO_3)_2$, 0.40 *M*, 200 mL
- Copper(II) sulfate solution, $CuSO_4$, 0.1 *M*, 75 mL
- Iron(III) chloride solution, $FeCl_3$, 0.1 *M*, 75 mL
- Iron(III) nitrate solution, $Fe(NO_3)_3$, 0.1 *M*, 75 mL
- Nitric acid, concentrated, HNO_3, 15.8 *M*, 75 mL
- Zinc nitrate solution, $Zn(NO_3)_2$, 0.1 *M*, 75 mL
- Zinc sulfate solution, $ZnSO_4$, 0.1 *M*, 75 mL
- Pipets, serological, 10-mL, 12

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Beaker, 50-mL, with watch glass
- Cuvets or test tubes, 13 × 100 mm, 7
- Graduated cylinder, 50-mL
- Kimwipes or lens tissue
- Pipet bulb or pipet filler
- Stirring rod
- Test tube rack
- Volumetric flask, 100-mL
- Wash bottle
- Weighing dish

Shared Equipment

- Balance, 0.001-g precision
- Hot plate
- Spectrophotometer and cuvets

Gravimetric Analysis of Calcium and Hard Water—

Advanced Inquiry Laboratory Kit

Big Idea 1, Investigation 3

Primary Learning Objective 1.19

As water flows through rocks and soil, it picks up minerals from the Earth's surface. Although many minerals are essential for life and health, high levels of calcium, magnesium, and iron ions in hard water may also be a nuisance. In this advanced inquiry lab, students investigate the concentration of calcium ions in hard water and consumer products using gravimetric analysis.

The purpose of this advanced inquiry lab is to investigate the suitability of gravimetric analysis for determining the amount of water hardness in the form of calcium carbonate, $CaCO_3$, in various water samples. Six samples, representing a wide range of potential water hardness, from 50 ppm to 500 ppm, will be analyzed by various student groups as part of a cooperative class investigation to determine the accuracy and sensitivity of gravimetric analysis for water hardness testing.

The lab begins with an introductory activity to develop skill in the calculations and techniques of gravimetric analysis, in particular, quantitative transfer and vacuum or gravity filtration. The procedure provides a model for guided-inquiry design of the cooperative class investigation described above. Antacid tablets are also provided as an opportunity for further inquiry—the use of gravimetric analysis to determine the amount of calcium in an over-the-counter medication.

Flinn Catalog Number: AP7660

Materials Included in Kit (for 24 students working in pairs)

- Calcium chloride solution, $CaCl_2$, 2 *M*, 500 mL
- Calcium chloride, anhydrous, $CaCl_2$, 30 g
- Sodium carbonate solution, Na_2CO_3, 0.5 *M*, 1000 mL
- Sodium carbonate, anhydrous, Na_2CO_3, 30 g
- Antacid tablets, bottle of 20

Additional Materials Required (for each lab group)

- Water, deionized or distilled, 40 mL
- Balance, electronic, 0.001-g accuracy (shared)
- Beakers, 150-mL, 3
- Drying oven (shared)
- Filter paper, 3 (to fit funnels)
- Funnel, Büchner and rubber adapter
- Graduated cylinder, 50-mL
- Wash bottle
- Watch glasses, 100-mm, 2
- Weighing dishes, 2
- Vacuum filtration apparatus setups
  - Filter flasks, 250-mL, 2
  - Glass tubing, 2
  - Latex rubber tubing
  - Pinch clamp
  - Rubber stopper, 2-hole
  - Rubber tubing
  - Spatula
  - Support stand and ring clamps
  - Vacuum pump or aspirator
  - Vacuum tubing, 2

Additional Materials Required (for *Pre-Lab Preparation*)

- Water, deionized or distilled, 600 mL
- Beakers or bottles to store water samples, 6
- Graduated cylinder, 25- or 50-mL
- Volumetric flask or graduated cylinder, 100-mL

Acidity of Beverages—

Advanced Inquiry Laboratory Kit

Big Idea 1, Investigation 4

Primary Learning Objective 1.20

How much acid is in fruit juice? Fruit juices get their sweet taste from sugars and their sour or tart taste from weak acids such as citric acid. If the juice contains too much sugar, it will taste bland, but too much acid and the juice will taste sour. The concentration of acids in various consumer beverages may be determined by titration with sodium hydroxide.

This advanced inquiry lab begins with an introductory activity for determining the proper indicator to use in the titration of acetic acid, a characteristic weak acid. The results provide a model for guided-inquiry design of a titration procedure to obtain titration curve data and calculate the molar concentration of acid in a beverage. Experiments may be performed as a cooperative class study or as open-inquiry activities. Three juice samples are provided, but students may also use any other light-colored soft drink or beverage.

A wonderful real-world example of everyday chemistry that fulfills key learning objectives such as designing experiments, interpreting data, and using stoichiometric calculations to predict reaction results!

Flinn Catalog Number: AP7645

Materials Included in Kit (for 24 students working in pairs)

- Acetic acid solution, 0.1 *M*, 100 mL
- Bromthymol blue indicator solution, 0.04%, 25 mL
- Hydrochloric acid solution, HCl, 0.1 *M*, 75 mL
- Phenolphthalein indicator solution, 1%, 30 mL
- Potassium hydrogen phthalate, $KHC_8H_4O_4$, 25 g*
- Sodium hydroxide solution, NaOH, 0.1 *M*, 2.5 L
- Thymol blue indicator solution, 0.04%, 25-mL
- Beral-type pipets, graduated, 40
- Orange juice, 400-mL
- Pineapple juice, 350-mL
- White grape juice, 350-mL

**For standardizing the NaOH solution.*

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Balance, 0.01-g precision* (shared)
- Beakers, 50-mL and 150-mL
- Buret, 50-mL
- Drying oven*
- Graduated cylinders, 10- and 100-mL
- Magnetic stirrer and stir bar, or stirring rod
- pH meters or pH papers (if meters are not available)
- Support stand and buret clamp
- Test tubes, 16 × 150 mm, 3
- Test tube rack

**For standardizing the NaOH solution.*

Separation of a Dye Mixture Using Chromatography—

Advanced Inquiry Laboratory Kit

Big Idea 2, Investigation 5

Primary Learning Objective 2.10

The entire palette of artificial food colors is derived from just seven dyes certified by the FDA for use in food, drugs, and cosmetics. How can these FD&C dyes be identified in a mixture? How do the molecular structures of the dye molecules influence their properties, relative solubility or affinity for different solvents? The purpose of this advanced inquiry lab is to investigate the factors that influence the separation of food dyes using paper chromatography.

The investigation begins with a baseline activity in which students compare the separation or resolution of three FD&C dyes using two solvents. Reviewing the evidence provided by the cooperative class data leads students to select a solvent for further study. In the guided-inquiry section of the lab, students design an experiment to identify a solvent that will give maximum resolution of a mixture of dyes. The results may be applied to study the connection between the structure and mobility of the food dyes. An investigation into the composition of colored candy shells may be incorporated into optional extension activities.

The primary learning objectives for this advanced inquiry lab focus on the effects of molecular structure on the nature and strength of intermolecular forces between molecules or ions. The lab also integrates key science practice skills for analyzing data to identify trends.

Flinn Catalog Number: AP7661

Materials Included in Kit (for 24 students working in pairs)

- Food Dye FD&C Blue No. 1, 2 g
- Food Dye FD&C Blue No. 2, 2 g
- Food Dye FD&C Green No. 3, 1 g
- Food Dye FD&C Red No. 3, 2 g
- Food Dye FD&C Red No. 40, 2 g
- Food Dye FD&C Yellow No. 5, 2 g
- Food Dye FD&C Yellow No. 6, 2 g
- Isopropyl alcohol, $CH_3CHOHCH_3$, 70%, 250 mL
- Sodium chloride solution, NaCl, 20%, 500 mL
- Chromatography paper strips, 200
- Toothpicks, 150

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Beaker, 50-mL
- Beakers, 100-mL, 2
- Erlenmeyer flasks, 250-mL, 2
- Graduated cylinder, 25-mL
- Wash bottle
- Watch glasses, 2

Additional Material Required (for *Pre-Lab Preparation*)

- Water, distilled or deionized
- Balance, 0.01-g accuracy
- Beaker, 100-mL
- Beakers, 250-mL, 7
- Graduated cylinders, 10-mL, 25-mL, 100-mL
- Spatulas, 7
- Stirring rods, 7
- Volumetric flask, 500-mL

Qualitative Analysis and Chemical Bonding—

Advanced Inquiry Laboratory Kit

Big Idea 2, Investigation 6

Primary Learning Objective 2.22

Looking for patterns in the properties of solids can help us understand how and why atoms join together to form compounds. What kinds of forces hold atoms together? How do these forces influence the properties of materials?

The purpose of this advanced inquiry lab is to design a procedure to identify twelve unknown solids based on systematic testing of their physical and chemical properties. The lab begins with an introductory activity to select measurable properties that will help identify the type of bonding in a solid. Given four solids representing the four types of chemical bonds—ionic, polar covalent, nonpolar covalent, and metallic—students review the properties of each solid with a minimum of four tests. The results provide a basis for a guided-inquiry design of a flow chart procedure that uses physical and chemical property tests to separate and identify twelve unknown solids.

Flinn Catalog Number: AP7664

Materials Included in Kit (for 8 student groups)

- Copper(II) sulfate pentahydrate, $CuSO_4{\cdot}5H_2O$, 25 g
- Dextrose, monohydrate, $C_6H_{12}O_6{\cdot}H_2O$, 20 g
- Ethyl alcohol, CH_3CH_2OH, 250 mL
- Hexane, C_6H_{14}, 250 mL
- Hydrochloric acid solution, HCl, 0.1 M, 250 mL
- Paraffin wax, CnH_{2n+2} (n = 20–40), 20 g
- Sodium hydroxide solution, NaOH, 0.1 M, 250 mL
- Zinc, Zn, granular, 20 g
- The "Unknowns"
  - Adipic acid, $HO_2C(CH_2)_4CO_2H$, 20 g
  - Aluminum granules, Al, 20 g
  - Calcium carbonate powder, $CaCO_3$, 25 g
  - Dodecyl alcohol, $CH_3(CH_2)_{11}OH$, 20 g
  - Glycine, $NH_2CH_2CO_2H$, 20 g
  - Graphite, C, 20 g
  - Iron oxide, Fe_2O_3, 20 g
  - Iron powder, Fe, 20 g
  - Potassium nitrate, KNO_3, 20 g
  - Salicylic acid, 2-HOC_6H_4COOH, 20 g
  - Silicon lumps, Si, 20 g
  - Sodium carbonate, Na_2CO_3, 20 g
- Aluminum dishes, 12
- Test tubes, 48

Additional Materials Required (for each lab group)

- Water, distilled or deionized, 20 mL
- Beaker, 100-mL
- Bunsen burner
- Conductivity meter or tester
- Hot plate
- pH paper
- Stirring rod
- Test tube holder
- Test tube rack
- Thermometer
- Tongs

Additional Materials Required (for *Pre-Lab Preparation*)

- Bottles or 48 capped vials to store the unknowns

Green Chemistry Analysis of a Mixture—

Advanced Inquiry Laboratory Kit

Big Idea 3, Investigation 7

Primary Learning Objectives 3.5 and 3.3

Many stoichiometry experiments use hazardous chemicals, generate toxic byproducts, and waste excess chemicals. In this lab activity, students design and carry out a green chemistry experiment that can quantitatively measure the weight percent of one compound in a mixture of two compounds.

The investigation begins with an introductory activity to verify the decomposition reaction of a solid bicarbonate, either potassium or sodium bicarbonate. Students review the principles of green chemistry and evaluate a high school stoichiometry lab procedure in terms of prevention, atom economy, and use and production of nontoxic materials.

Once the introductory activity is completed, students design and carry out an experiment to quantitatively measure the weight percent of solid mixtures containing either sodium carbonate and sodium bicarbonate or potassium carbonate and potassium bicarbonate. Students assess their procedures in terms of the green chemistry principles.

Flinn Catalog Number: AP7653

Materials Included in Kit (for 24 students working in pairs)

- Potassium bicarbonate, $KHCO_3$, 50 g
- Potassium carbonate, K_2CO_3, 50 g
- Sodium bicarbonate, $NaHCO_3$, 50 g
- Sodium carbonate, Na_2CO_3, 50 g
- Stoichiometry Lab Procedure

Additional Materials Required (for each lab group)

- Balance, 0.001-g precision (shared)
- Bunsen burner
- Crucible and cover
- Matches or lighter
- Ring clamp
- Spatula
- Supporting stand
- Tongs, crucible
- Triangle, pipe stem
- Wire gauze

Additional Materials Required (for *Pre-Lab Preparation*)

- Marking pen
- Sample containers, 8-oz, 2
- Weighing dishes, 4

Analysis of Hydrogen Peroxide—

Advanced Inquiry Laboratory Kit

Big Idea 3, Investigation 8

Primary Learning Objective 3.9

Old bottles of hydrogen peroxide that are past their expiration dates are often found in medicine cabinets and chemical stockroom shelves. Does the concentration of hydrogen peroxide deteriorate as it ages? In this advanced inquiry lab, students design an experiment to determine the percent composition of a common "drug store" bottle of hydrogen peroxide using an oxidation–reduction titration.

Students begin by standardizing a solution of potassium permanganate using ferrous ammonium sulfate. This procedure provides a model for a guided-inquiry activity, during which students design a titration experiment to determine the precise concentration of hydrogen peroxide in solution. Additional samples of hydrogen peroxide are available separately and may be used for further open-inquiry experiments. Fulfill key learning objectives relating to quantitative analysis, stoichiometry calculations, and balancing redox reactions with this great real-world application that also develops science practice skills for collecting and analyzing data and refining measurements.

Flinn Catalog Number: AP7647

Materials Included in Kit (for 24 students working in pairs)

- Ferrous ammonium sulfate, $Fe(NH_4)_2(SO_4)_2{\cdot}6H_2O$, 50 g
- Hydrogen peroxide solution, H_2O_2, 3%, 50 mL
- Potassium permanganate solution, $KMnO_4$, 0.10 M, 500 mL
- Sodium hydroxide solution, NaOH, 6 M, 500 mL (included for disposal procedure)
- Sulfuric acid solution, H_2SO_4, 3 M, 750 mL
- Pipet, serological, 1-mL, 12
- Weighing dishes, 25

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Balance, 0.001-g accuracy (shared)
- Beaker, 100-mL
- Buret, 50-mL
- Buret clamp
- Erlenmeyer flasks, 250-mL, 3
- Graduated cylinders, 10-mL, 2
- Pipet bulb or filler
- Support stand
- Wash bottle
- Wax pencil

Additional Materials Required (for *Pre-Lab Preparation*)

- Water, distilled or deionized
- Graduated cylinder, 250-mL
- Volumetric flask, 1000-mL

Separating a Synthetic Pain Relief Mixture—

Advanced Inquiry Laboratory Kit

Big Idea 3, Investigation 9

Primary Learning Objective 3.10

Most over-the-counter drugs consist of mixtures, or physical blends, of active drug ingredient(s) and binders. The main characteristic of a mixture is that it has a variable composition—the components of the mixture may be present or mixed in varying proportions. The substances in a mixture retain their distinctive chemical identities, as well as some of their unique physical properties. The purpose of this investigation is to study the physical properties of ingredients in a synthetic pain relief mixture and determine its percent composition.

The lab begins with an introductory activity to test the solubility of each possible component in an organic solvent, ethyl acetate, and in a basic aqueous solution of sodium bicarbonate. The results provide a model for the guided-inquiry design of a flow chart that will map the procedure used to separate components in a mixture and determine percent composition. Optional extension activities include varying the amounts of individual components in the synthetic mixtures and analyzing consumer samples. Students may also measure the melting points of the isolated components, acetylsalicylic acid and acetaminophen, to confirm their identity.

This advanced inquiry lab enforces understanding of solubility and chemical reactions as students carry out their own step-by-step experiments and work collaboratively with their peers. Perform this experiment in a fume hood or well-ventilated lab.

Flinn Catalog Number: AP7662

Materials Included in Kit (for 24 students working in pairs)

Acetaminophen, $C_8H_9NO_2$, 15 g

Acetylsalicylic acid (aspirin), $C_9H_8O_4$, 15 g

Ethyl acetate, $CH_3CO_2CH_2CH_3$, 800 mL

Hydrochloric acid, HCl, 6 *M*, 500 mL

Silica gel (binder), 5 g

Sodium bicarbonate solution, $NaHCO_3$, 10%, 600 mL

pH test strips, vial of 100

Additional Materials Required (for each lab group)

Balance, 0.001-g precision (shared)

Beakers, 150-mL, 2

Boiling stones, 2

Capillary tubes, 2 (optional)

Erlenmeyer flask, 125-mL

Filter paper

Funnel

Graduated cylinder, 50-mL

Hot plate

Ice bath

Magnetic stirrer and stir bar, or stirring rod

Melting point apparatus (optional)

Separatory funnel, 250-mL

Spatula

Support stand and ring clamp

Test tubes, 5

Watch glasses, 2

Weighing dishes

Additional Materials Required (for *Pre-Lab Preparation*)

Beakers, 50-mL, 2 (to store pain relief mixtures)

Parafilm

Stirring rod

Weighing dishes

Rate of Decomposition of Calcium Carbonate—

Advanced Inquiry Laboratory Kit

Big Idea 4, Investigation 10

Primary Learning Objective 4.1

What factors determine how fast a chemical reaction will occur? The answer has applications not just in chemistry, but also food science, engineering, and even art and architecture. Consider the weathering of beautiful marble statues from antiquity! In this advanced inquiry lab, students learn how reaction rates are measured and how concentration affects the rate of a reaction as they design kinetics experiments for the heterogeneous reaction of calcium carbonate with hydrochloric acid.

The investigation begins with an introductory activity in which students observe and measure the gradual evolution of carbon dioxide gas from the decomposition of calcium carbonate with acid. Special equipment is provided for this purpose. The procedure provides a model for guided-inquiry design of kinetics experiments to determine the rate of reaction with different concentrations of acid. Using a cooperative classroom approach, students compare data obtained from measurements of both mass loss and volume of gas generation versus time. Students also employ graphical analysis to determine initial reaction rates. Other factors, such as the effect of particle size in a heterogeneous reaction, provide opportunities for further inquiry.

The lab fulfills key learning objectives relating to experimental measurements and interpretation of results for rate law determinations. Comparing results from two approaches reinforces science practice skills for evaluating sources of data.

Flinn Catalog Number: AP7648

Materials Included in Kit (for 24 students working in pairs)

- Calcium carbonate (marble chips), $CaCO_3$, 70 g
- Hydrochloric acid solution, HCl, 1 *M*, 500 mL
- Hydrochloric acid solution, HCl, 2 *M*, 500 mL
- Hydrochloric acid solution, HCl, 6 *M*, 500 mL
- Gas Collection Apparatus Sets
  - Syringes, disposable, with Luer lock, 140-mL, 6
  - Stopcocks, plastic, with Luer lock, 6
  - Stoppers, one-hole, rubber, size 5, 6
- Syringe extenders or adapters, 6

Additional Materials Required (for each lab group)

- Water, distilled
- Balance, 0.001-g precision (shared)
- Beakers, 100- or 150-mL, 3
- Buret clamp
- Erlenmeyer flasks, 125-mL, 3
- Graduated cylinders, 10- and 25-mL
- Mortar and pestle (shared)
- Silicone grease or petroleum jelly (optional)
- Support stand
- Timer or stopwatch
- Wash bottle

Additional Materials Required (for *Pre-Lab Preparation*)

- Bottles to store solutions
- Flask, volumetric or Erlenmeyer, 250-mL
- Graduated cylinder, 250-mL
- Magnetic stirrer and stir bar

Kinetics of Crystal Violet Fading—

Advanced Inquiry Laboratory Kit

Big Idea 4, Investigation 11

Primary Learning Objective 4.2

One of the most important considerations in a "green chemistry" analysis is how fast a chemical degrades. Crystal violet is a common, beautiful purple dye. In strongly basic solutions, the bright color of the dye slowly fades and the solution becomes colorless. The kinetics of this "fading" reaction can be analyzed by measuring the color intensity or absorbance of the solution versus time to determine the rate law. In this advanced inquiry lab, students use spectroscopy and graphical analysis to determine the rate law for the color-fading reaction of crystal violet with sodium hydroxide.

Students begin by constructing a calibration curve of absorbance versus concentration for crystal violet. A series of known or standard solutions is prepared from a stock solution of crystal violet and the absorbance of each solution is measured at an optimum wavelength. A Beer's law plot of absorbance as a function of concentration may be used to calculate the concentration of an "unknown" solution of the dye in a rate law experiment.

This procedure provides a model for the guided-inquiry portion of the lab, during which students design experiments to determine the order of reaction with respect to both crystal violet and sodium hydroxide. Two dyes with similar structures, malachite green and phenolphthalein, are provided for optional extension or cooperative class inquiry studies.

Flinn Catalog Number: AP7644

Materials Included in Kit (for 24 students working in pairs):

- Crystal violet solution, 1% alcoholic, 25 mL
- Malachite green solution, 1% aqueous, 25 mL
- Phenolphthalein solution, 1% alcoholic, 30 mL
- Pipets, serological, 10-mL, 12
- Sodium hydroxide solution, NaOH, 0.02 *M*, 500 mL

Additional Materials Required (for each lab group):

- Water, distilled or deionized
- Beaker, 50-mL
- Computer interface system*
- Computer or calculator for data collection*
- Cuvets or test tubes
- Data collection software (LoggerPro)
- Kimwipes or lens paper
- Pipet bulb or pipet filler
- Spectrophotometer or colorimeter*
- Stirring rod
- Stopwatch (if not using data collection software)

**For use with colorimeter option.*

Additional Materials Required (for *Pre-Lab Preparation*):

- Water, distilled or deionized
- Pipet, serological, 1-mL
- Pipet bulb filler
- Volumetric, flask, borosilicate, 1000-mL

Designing a Hand Warmer—

Advanced Inquiry Laboratory Kit

Big Idea 5, Investigation 12

Primary Learning Objective 5.7

From instant cold packs to flameless ration heaters and hand warmers, the energy changes accompanying physical and chemical transformations have many consumer applications. The backbone of these applications is calorimetry—measuring heat transfer.

In this advanced inquiry lab, students investigate the energy changes accompanying the formations of solutions for common laboratory salts, and then apply the results to design a hand warmer that is reliable, safe, nontoxic, and inexpensive. The students begin by familiarizing themselves with the principles of calorimetry and heat of solution calculations. The results provide a model for the guided-inquiry challenge. Students are given a series of solids, along with their costs and individual Material Safety Data Sheets (MSDS). The challenge is to determine the heat of solution for each solid and analyze the cost and safety information to propose a design for the best, all-around hand warmer. Students love a challenge—this design challenge will surely inspire creativity!

Flinn Catalog Number: AP7654

Materials Included in Kit (for 24 students working in pairs)

- Ammonium chloride, NH_4Cl, 120 g
- Calcium chloride, anhydrous, $CaCl_2$, 120 g
- Lithium chloride, LiCl, 120 g
- Magnesium sulfate, anhydrous, $MgSO_4$, 120 g
- Sodium acetate, $NaCH_3CO_2$, 120 g
- Sodium carbonate, anhydrous, Na_2CO_3, 120 g
- Sodium chloride, NaCl, 120 g
- Cups, polystyrene, 8 oz., 24

Additional Materials Required (for each lab group)

- Water, deionized or distilled
- Balance, 0.01-g precision (shared)
- Beaker, 250-mL
- Graduated cylinder, 100-mL
- Heat-resistant gloves
- Hot plate (shared)
- Magnetic stirrer and stir bar, or stirring rod
- Paper towels
- Support stand and ring clamp
- Thermometer, digital
- Timer or stopwatch
- Weighing dishes

Applications of LeChâtelier's Principle—

Advanced Inquiry Laboratory Kit

Big Idea 6, Investigation 13

Primary Learning Objective 6.9

Equilibrium is a balancing act between the rates of forward and reverse reactions involving a system of reactants and products. What happens when the equilibrium is disturbed? Is there a way to predict and explain the effects of the disturbances? In this advanced inquiry lab, students investigate six chemical equilibrium systems to analyze patterns and trends in the principles, concepts, and definitions of equilibrium.

Students begin with an activity that introduces the properties of a system at equilibrium: the reversible complex-ion reaction between iron(III) nitrate and potassium thiocyanate. Deliberate "stresses," such as temperature changes and changes in the amounts of reactants and products, are added to the system and students analyze the resulting color changes. This procedure provides a model for guided-inquiry analysis of five additional equilibrium systems. Inquiry activities include a reversible acid–base indicator reaction, copper and cobalt complex ions, gas–liquid solubility of carbon dioxide, and the solubility of magnesium hydroxide. For convenience, these systems may be set up as lab stations. Students may also be tasked to create a rainbow-colored display using the equilibrium systems as an optional extension or cooperative class activity.

This advanced inquiry lab integrates essential science practice skills and analyzing evidence based on data to construct explanations of natural phenomena

Flinn Catalog Number: AP7659

Materials Included in Kit (for 24 students working in pairs)

- Ammonium hydroxide solution, concentrated, NH_3, 14.8 *M*
- Bromcresol green indicator solution, 0.04%
- Bromthymol blue indicator solution, 0.04%
- Calcium chloride, anhydrous, $CaCl_2$
- Cobalt chloride solution, $CoCl_2$, 1% in alcohol
- Copper(II) sulfate solution, $CuSO_4$, 0.2 *M*
- Hydrochloric acid solution, HCl, 0.1 *M*
- Hydrochloric acid solution, HCl, 1 *M*
- Hydrochloric acid solution, HCl, 3 *M*
- Hydrochloric acid solution, HCl, 6 *M*
- Iron(III) nitrate solution, $Fe(NO_3)_3$, 0.2 *M*
- Milk of magnesia solution
- Potassium nitrate, KNO_3
- Potassium thiocyanate, KSCN
- Potassium thiocyanate solution, KSCN, 0.1 *M*
- Seltzer water
- Silver nitrate solution, $AgNO_3$, 0.1 *M*
- Sodium hydroxide solution, NaOH, 0.1 *M*
- Sodium phosphate, monobasic, $NaH_2PO_4 \cdot H_2O$
- Universal indicator solution
- Bromcresol green color chart
- Petri dishes, disposable
- Pipet, Beral-type, graduated
- Syringe, 35-mL
- Syringe tip caps (septum)

Additional Materials Required

- Water, distilled or deionized
- Beaker, 250-mL
- Beaker, 50-mL
- Graduated cylinders, 10-mL
- Graduated cylinder, 25- or 50-mL
- Hot plate
- Ice
- Labeling or marking pens
- Magnetic stir plates
- Magnetic stir bars
- Spatula
- Stirring rods
- Test tubes
- Test tube holder
- Test tube rack
- Thermometer, digital
- Wash bottle

Additional Materials Required (for *Pre-Lab Preparation*)

- Water, distilled or deionized
- Graduated cylinder, 10-mL
- Volumetric flask, 500-mL
- Wash Bottle

Acid–Base Titrations—

Advanced Inquiry Laboratory Kit

Big Idea 6, Investigation 14

Primary Learning Objective 6.13

Most products we use every day, including food, beverages, medication and cleaning solutions, have acidic and basic properties! A common question chemists have to answer is how much of a specific acid or base is present in a product. The amount or concentration of acid or base in a sample may be determined by acid–titration.

In this advanced inquiry lab, students conduct a series of acid–base titrations and determine the concentrations of two unknowns. The lab begins with an introductory activity in which students qualitatively analyze an acid and base using pH paper. This activity provides a model for a guided-inquiry experiment, during which students collect quantitative titration data using a buret and pH meter. Each group uses two acids and two bases. One of the acids will have a known molarity and the other will have an unknown molarity. The same applies to the two bases. Students will graph titration curves from the collected data and determine the concentration of each unknown. A variety of acids and bases, strong and weak, are provided for the class to perform different combinations of titrations.

Flinn Catalog Number: AP7656

Materials Included in Kit (for 24 students working in pairs)

- Acetic acid solution, CH_3CO_2H, 0.1 *M*, 500 mL
- Ammonia water solution, NH_3, 0.2 *M*, 1000 mL
- Calcium hydroxide, $Ca(OH)_2$, reagent, 50 g
- Hydrochloric acid solution, HCl, 0.2 *M*, 500 mL
- Methyl red indicator solution, 0.02%, 50 mL
- Nitric acid solution, HNO_3, 0.05 *M*, 500 mL
- pH test strips, vial of 100
- Phenolphthalein indicator solution, 1%, 30 mL
- Sodium hydroxide solution, NaOH, 0.1 *M*, 1000 mL
- Sulfuric acid solution, H_2SO_4, 0.1 *M*, 500 mL
- Thymolphthalein indicator solution, 0.04%, 30 mL

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Beakers, 50-mL, 150-mL, 250-mL
- Beral-type pipets, granduated
- Buret, 50-mL
- Graduated cylinders, 10-mL and 100-mL
- Magnetic stirrer and stir bar, or stirring rod
- pH sensor or pH meter
- Support stand and buret clamp
- Test tubes, medium, 16 mm × 150 mm, 4
- Test tube rack
- Wash bottle

Buffers in Household Products—

Advanced Inquiry Laboratory Kit

Big Idea 6, Investigation 15

Primary Learning Objective 6.20

Every living cell contains natural buffer systems to maintain the constant pH needed for proper cell function. Consumer products are also often buffered to safeguard their activity. Students discover the wide range of buffering action in common household products using this advanced inquiry lab activity.

Many household products contain buffering chemicals such as citric acid, sodium carbonate, sodium benzoate, and phosphates or phosphoric acid. The lab begins with an introductory activity to identify the buffering regions in the neutralization of a polyprotic weak acid. The results provide a model for guided-inquiry design of a procedure to determine the buffering agents in eight different household products, including foods and beverages and over-the-counter drugs. Procedures may include creating titration curves, calculating pK_a values, and analyzing the buffer capacity and composition. Students may recommend additional consumer products for further inquiry study.

Flinn Catalog Number: AP7665

Materials Included in Kit (for 24 students working in pairs)

- Citric acid, $C_6H_8O_7$, 3 g
- Hydrochloric acid solution, HCl, 0.1 *M*, 2.0 L
- Sodium hydroxide solution, NaOH, 0.1 *M*, 2.0 L
- Alka-Seltzer® tablets, 6
- Gatorade®, G2 series, red, 12-ounce bottle
- Lemon-lime Kool-Aid® packets, 3
- Lactaid® tablets, 4
- Pineapple juice, 6-ounce can, 2
- Starch, liquid, 50 mL
- Tomato paste, 6-ounce can
- Tonic water, 1-liter bottle

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Beakers, 150-mL, 2
- Beakers, 250-mL, 2
- Buffer, pH 7 (to calibrate pH meter)
- Buret, 50-mL
- Clamp, buret
- Magnetic stirrer and stir bar
- pH sensor or pH meter
- Support stand
- Wash bottle

Additional Materials Required (for *Pre-Lab Preparation*)

- Balance, 0.01-g precision
- Flask, volumetric, 500-mL

Properties of Buffer Solutions—

Advanced Inquiry Laboratory Kit

Big Idea 6, Investigation 16

Primary Learning Objective 6.18

A buffer protects against rapid changes in pH when working with acids or bases. What are buffers made of? How does a buffer work? Can a buffer be designed to be effective in a given pH range? Is there such a thing as an ideal buffer? The purpose of this advanced inquiry lab kit is to design a buffer solution that will be effective in a specific pH range and to verify its buffer capacity.

Students begin the investigation with an introductory activity to explore the composition and pH of ideal buffers and compare their pH changes when a strong acid and base are added. Understanding the properties of buffers prepares students for the guided-inquiry challenge—to design a buffer that will provide effective protection at a specific pH and that will have the capacity to maintain the pH within a narrow range when prescribed amounts of acid and base are added.

This lab provides a culminating activity that ties together essential learning objectives relating to strong and weak acids, conjugate acid–base pairs, equilibrium constants and K_a values for acid–base reactions, and mole ratio and stoichiometry calculations.

Flinn Catalog Number: AP7663

Materials Included in Kit (for 24 students working in pairs)

- Ammonium hydroxide solution, NH_3, 0.1 *M*, 500 mL
- Ammonium chloride, NH_4Cl, 10 g
- Acetic acid solution, CH_3CO_2H, 0.1 *M*, 1 L
- Buffer envelope, pH 7
- Citric acid solution, $H_3C_6H_5O_7$, 0.1 *M*, 500 mL
- Hydrochloric acid solution, HCl, 0.5 *M*, 500 mL
- Seltzer water, carbonic acid, H_2CO_3, assume 0.07 *M*, 8 oz
- Sodium acetate trihydrate, $NaCH_3CO_2{\cdot}3H_2O$, 30 g
- Sodium bicarbonate, $NaHCO_3$, 10 g
- Sodium dihydrogen citrate, $NaH_2C_6H_5O_7$, 12 g
- Sodium hydrogen phosphate, heptahydrate, $Na_2HPO_4{\cdot}7H_2O$, 20g
- Sodium dihydrogen phosphate solution, NaH_2PO_4, 0.1*M*, 500 mL
- Sodium hydroxide solution, NaOH, 0.5 *M*, 500 mL

Additional Materials Required (for each lab group)

- Water, distilled or deionized
- Balance, 0.01-g precision (shared)
- Beakers, 150-mL, 2
- Burets, 25- or 50-mL, 2
- Graduated cylinder, 10- or 25-mL
- Graduated cylinders, 100-mL, 2
- pH meter or paper (indicators, optional)
- Pipets, disposable (optional)
- Spatula
- Stirring rod
- Test tubes, medium, 16 × 150 mm, 5
- Test tube rack
- Wash bottle
- Weighing dishes

Additional Materials Required (for *Pre-Lab Preparation*)

- Bottles to store solutions, 6
- Erlenmeyer or volumetric flasks, 500-mL, 6
- Graduated cylinders, 100- and 250-mL
- Magnetic stirrer and stir bar