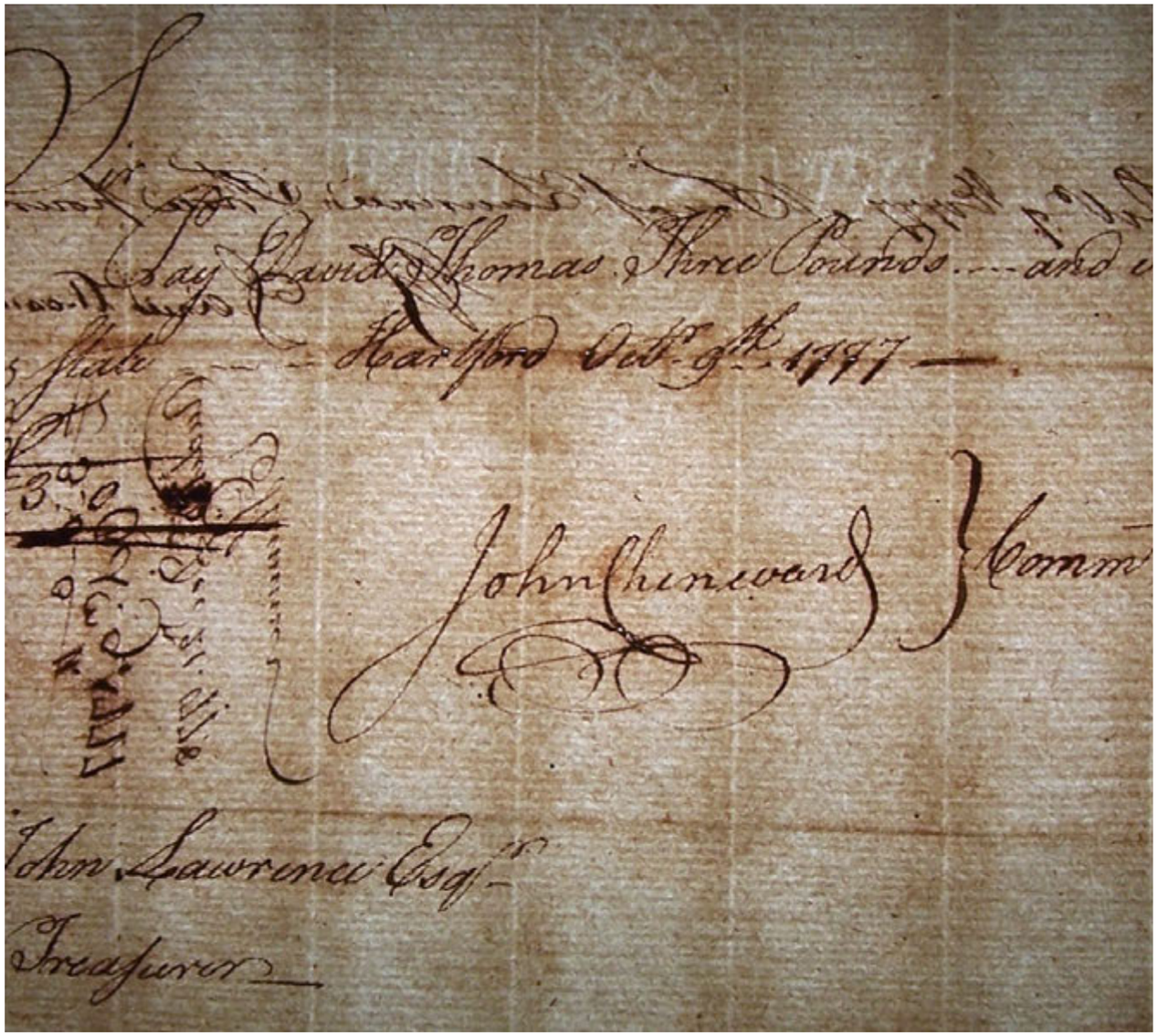
Chemistry of Invisible Inks



TEACHER GUIDE

Chemistry of Invisible Inks

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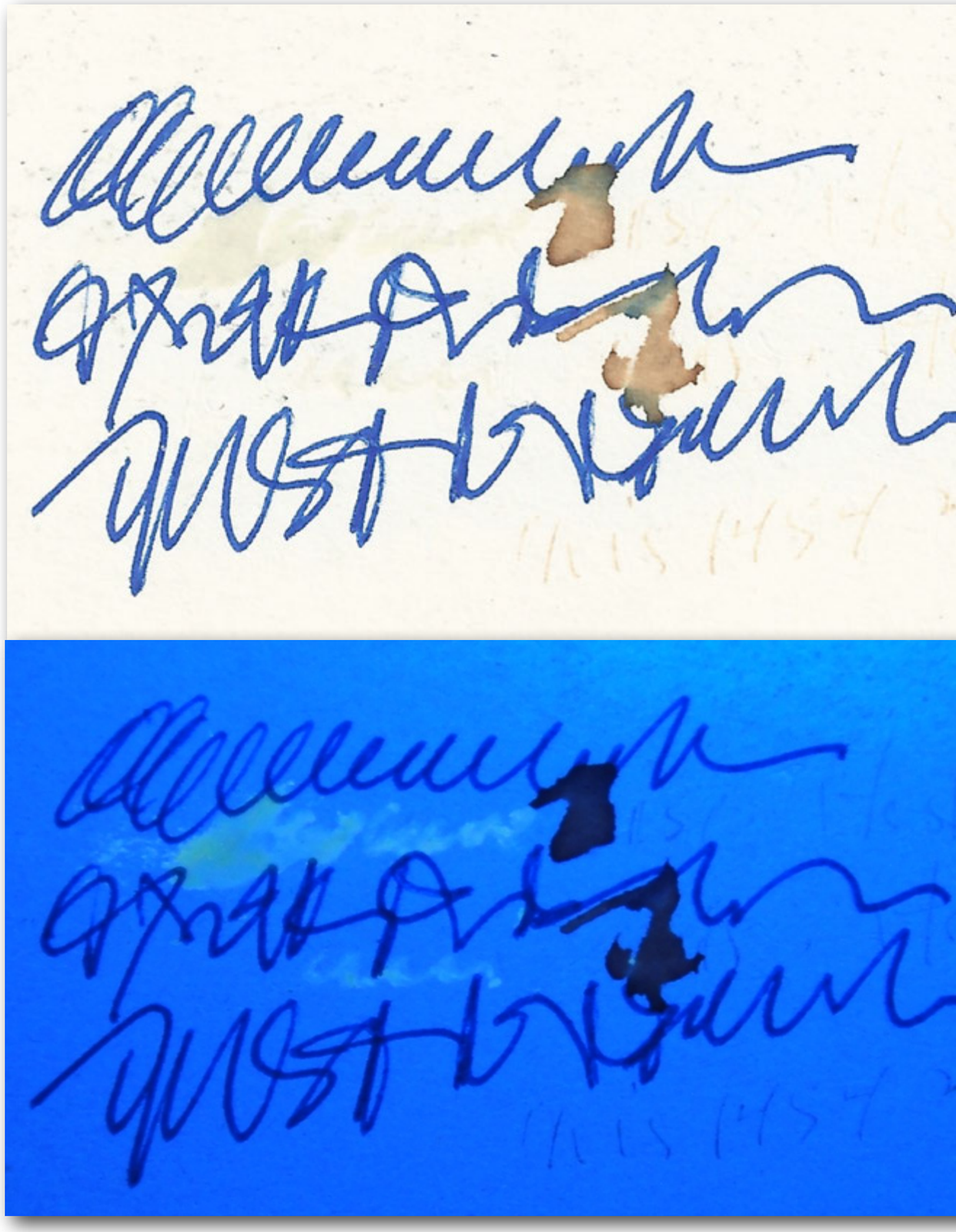

Materials

MATERIALS

1. Kit Materials
2. Local Materials
3. Safety

KIT MATERIALS

Quantity	Description
1	Package / 100, plain index cards (white; 3x5") ACTIVITY 1, ACTIVITY 2
50	Small cups, plastic ACTIVITY 1, ACTIVITY 2
10	Steel nib dipping pens ACTIVITY 1, ACTIVITY 2
1	Bottle, security ink[1] ACTIVITY 2
1	Black light / flashlight handheld ✦ ACTIVITY 1, ACTIVITY 2
10	Magnifiers ACTIVITY 1, ACTIVITY 2
1	Box, cotton swabs ACTIVITY 2

✦ Required 4 double-A batteries; not included

CD-ROM *Understanding the Chemistry of Invisible Inks*

ACTIVITY 1 *Investigating Organic Fluids as Invisible Inks*

ACTIVITY 2 *Investigating Chemical Reagents as Invisible Inks*

Teacher Guide

Student Guide

Glossary

Background Information: *Chemistry of Invisible Inks*

PowerPoint: *Chemistry of Invisible Inks* PPT and MOV

Folder: Engraving Images

- 1862 US Treasury seal
- Norwegian Banknote, 1778
- 1770 South Carolina Banknote

[1] The commercial invisible ink included in this kit has a volatile (combustible) vehicle component. Keep away from sparks and open flames.

LOCAL MATERIALS

Quantity	Description
	Dry iron ACTIVITY 1
	Kitchen towels (or similar) ACTIVITY 1
100 mL	Cabbage extract (170 g red cabbage) ACTIVITY 2
1	Bottle, ferric sulfate tablets (drug store) ACTIVITY 2
1	Bottle, white vinegar (grocery store) ACTIVITY 2
100 mL	Milk ACTIVITY 1 – INDEPENDENT INVESTIGATION
100 mL	Grapefruit juice ACTIVITY 1 – INDEPENDENT INVESTIGATION
100 mL	Orange juice (non-pulp) ACTIVITY 1 – INDEPENDENT INVESTIGATION
100 mL	Honey ACTIVITY 1 – INDEPENDENT INVESTIGATION
5g	Table sugar ACTIVITY 1 – INDEPENDENT INVESTIGATION
1	White onion ACTIVITY 1 – INDEPENDENT INVESTIGATION
1	Bottle, lemon juice (or juice from lemons) ACTIVITY 1
1	Box, baking Soda ($NaHCO_3$) (grocery store) ACTIVITY 2
1	Box, cornstarch (grocery store) ACTIVITY 2
1	Tide® detergent (grocery store) INDEPENDENT INVESTIGATION, ACTIVITY 2
1	Box, washing Soda (Na_2CO_3) (grocery store) ACTIVITY 2
1	Bottle, Betadine® (iodine solution) (drug store) ACTIVITY 2
1	Beaker, 1000 mL (or similar) ACTIVITY 1 – INDEPENDENT INVESTIGATION, ACTIVITY 2

LOCAL MATERIALS (CONT)

Quantity	Description
1	Beaker, 100mL (or similar) ACTIVITY 2
1	Kitchen knife ACTIVITY 1 – INDEPENDENT INVESTIGATION, ACTIVITY 2
1	Kitchen funnel ACTIVITY 2
10	Pencils (No. 2) ACTIVITY 1, ACTIVITY 2
10	Ballpoint pens ACTIVITY 2
1	Marking pen ACTIVITY 2
1	Bottle, rubbing alcohol (70% isopropyl alcohol) ACTIVITY 2
1	Coffee filter ACTIVITY 1
2	Table spoons (or mortar and pestle) ACTIVITY 2

Access to: Computers, tablets, or iPads with internet access *

* Useful but not absolutely necessary

SAFETY

Quantity	Description
10	eye goggles ACTIVITY 2

SECTION 2

STEM Correlation Information

SKILL / CONCEPT

Experimental / Engineering Design
Investigating
Scientific Method
Measurement
Data Analysis
Communication
Technology

CONCEPT PRINCIPLES / KNOWLEDGE

- Chemical & Physical Processes
- Chemical Reactions
- Data analysis; constructing tables and graphs
- Fluorescence
- Light, Light Spectrum
- Optical Contrast
- Organic & Inorganic compounds
- Chemical Reaction Types
- pH, pH Indicators
- Reflectance / Transmittance

CONSOLIDATED STEM STANDARDS

S = National Science Education Standards (NSES) - K-4, 5-8, 9-12
T = International Technology & Engineering Educators Association (ITEA) - K-2, 3-5, 6-8, 9-12
A framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC; 2011) - Draft
E = Accreditation Board for Engineering and Technology (ABET) - 11-12
A framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC; 2011) - Draft
M = National Council of Teachers of Mathematics (NCTM) - PreK-2, 3-5, 6-8, 9-12 Consolidated STEM Standards

SCIENCE

A.1.2 Design and conduct scientific investigations.

A.1.3 Use technology and mathematics to improve investigations and communications.

A2.1 Conceptual principles and knowledge guide scientific inquiries.

A.2.3 Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

E.1.1 Identify a problem or design an opportunity.

E.1.2 Propose designs – choose alternative solutions.

E.1.3 Implement a proposed solution.

E.1.4 Evaluate a proposed solution.

TECHNOLOGY

2.A An identification of the criteria and constraints of a product or system.

8.H Begin the design process …

9.K Create a prototype to test a design concept.

11.O Refine the design.

11.P Evaluate the design solution.

11.R Communicate observations.

12.O Operate the system to validate the design.

ENGINEERING

ET 1 **(Designed World)** Study of designed systems, processes, materials, and products.

ET1.A **(Products, Processes, Systems)**

ET1.B **(Nature of Technology)**

ET1.C **(Using Tools and Materials)**

ET 2 **(Engineering Design)** Creative and iterative process for identifying and solving problems under constraints.

ET2.A **(Defining and Researching Technical Problems)**

ET2.B **(Generating and Evaluating Solutions)**

ET2.C **(Optimizing and making Tradeoffs)**

ET3 **(Technological Systems)** Effectively using technology systems.

ET3.A **(Identifying and Modeling Technological systems)**

ET3.C **(Control and Feedback)**

ET4 **(Interactions of technology & Society)** Decisions are affected by technology.

ET4.A **(Interactions of Technology & Society)**

ET4.B **(Interactions of Technology and Environment)**

ET4.C **(Analyzing issues involving Technology & Society)**

MATH

1.0 **Understand:** numbers, ways of representing numbers, relationships among numbers, and number systems.

2.0 **Algebra:** Understand numbers, ways of representing numbers, relationships among numbers, and number systems.

3.0 **Geometry:** Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

4.0 **Measurement:** Understand measurable attributes of objects and the units, systems, and processes of measurement.

5.0 **Data Analysis & Probability:** Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

6.0 **Problem Solving:** Build new mathematical knowledge through problem solving.

7.0 **Recognize:** reasoning and proof as fundamental aspects of mathematics.

8.0 **Organize and consolidate:** their mathematical thinking through communication.

9.0 **Connections:** Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.

10.0 **Create and use representations to:** organize, record, and communicate mathematical ideas.

SECTION 3

EXPERIMENTAL DESIGN CONSIDERATIONS

LAB OVERVIEW & LEARNING OBJECTIVES

In this guided, open investigation, students will investigate invisible inks from various recipe sources to create 'secret' documents as well as to determine the effectiveness and mode of action (chemical / physical process) for the invisible ink 'developer.'

- To *understand* the history of invisible inks and their use
- To c*ompound* (make) invisible inks from selected recipe sources
- To *determine* the mode of action (mechanism) of various chemical and physical processes
- To *understand* the difference between transmitted and reflected light
- To develop comparison criteria for evaluating the 'effectiveness' of an invisible ink:
  - contrast (against a background)
  - sharpness (line strokes not visible distorted)
  - stroke width (discernibility)
- To *recommend* the 'most effective' invisible ink / developer combination

EXPERIMENTAL DESIGN CONSIDERATIONS

These activities allow students to learn about physical and chemical processes, chemical reactions involved in creating and using invisible inks and their application in creating secret messages!

Suggested investigation order:

ACTIVITY 1 ***Investigating Organic Fluids as Invisible Inks***
(INTRODUCTORY to INTERMEDIATE)

Understanding how a natural material (lemon juice / organic acids and sugars) can be employed as an invisible ink and how the application of heat sets up a chemical reaction [oxidation (caramelization)] of organic materials (organic acids and sugars).

MODEL Investigation (30 minutes)
INDEPENDENT Investigation (45 minutes)

ACTIVITY 2 ***Investigating Chemical Reagents as Invisible Inks***
(INTERMEDIATE / ADVANCED)

Understanding how various chemical reagents (acids, bases, fluorescent compounds, inorganic salts, organic compounds) can be employed as an invisible inks and developers. Creating "secret messages" and security documents.

MODEL Investigation (30 minutes)
INDEPENDENT Investigations (30 minutes - up to 2 lab periods)

EXPERIMENTAL DESIGN CONSIDERATIONS

To help students effectively integrate the information they will be expected to apply in these investigations, they need to understand and discuss the following concepts before starting this lab activity. (See the Glossary files and power point The Chemistry of Invisible Inks.)

- Types chemical and physical processes
- Using heat as a “developer”
- Use of pH indicators as “developers”
- The process of caramelization
- Types of chemical reactions in developing invisible inks
- How an invisible ink is constructed
- What role paper plays in the success of an invisible ink
- The cursive line
- Light, the visible spectrum and fluorescence
- Reflected and transmitted lighting

MODEL EXPERIMENT

At one time or another, most students have created documents containing an ‘invisible ink’ to communicate information to a special recipient without allowing others to view it.

An invisible ink is any substance that can be used for writing (typically on a paper substrate) that is not easily detected by the naked eye under general lighting conditions. The process of rendering the ink visible – a color change - (ideally by the intended recipient) is known as developing the ink. The procedure or materials used in that purpose is the developer.

In the model experiment your students will use a steel nib dipping pen to create a various stroke lines (cursive and printing) on a piece of copy paper using lemon juice as the invisible ink. A pencil line will circle these ink strokes. This invisible ink document will then examined using reflected and transmitted light as well as being subjected to heat energy of a dry iron. An evaluation of the ink/developer combination will be made using three criteria: contrast, sharpness, and stroke width.

INDEPENDENT INQUIRY PATHS

After completing the model experiment, your students will be given suggested paths to take for their Independent Inquiry Investigations.

Scientific inquiry will help your students develop skills in communication, teamwork, critical thinking, and commitment to lifelong learning. This investigation can help foster these skills.

An important part of becoming a scientist is to learn to keep clear, concise, and accurate laboratory notes. At the conclusion of the independent investigations, you may choose to have students create mini-posters that showcase their investigational results or provide a formal report to you. Remind students that an organized lab notebook should demonstrate originality and reflection while serving as a record of their work.

Section 4

Getting Ready ...

Getting Ready ...

Prior to beginning the model experiment, your students should read through or view the background information pdf as well as the power point presentation (*Chemistry of Invisible Inks*) to review and understand what invisible inks are; a brief history of their use, and some selected invisible ink recipes. Further, your students should read and understand the following terms: *chemical* and *physical processes*, *chemical reactions*, *oxidation*, *pH*, *fluorescence*, and *chemical precipitation*.

Students should refer to the *Glossary* (see PDF file on CD-ROM) as well as the PowerPoint *Chemistry of Invisible Inks*