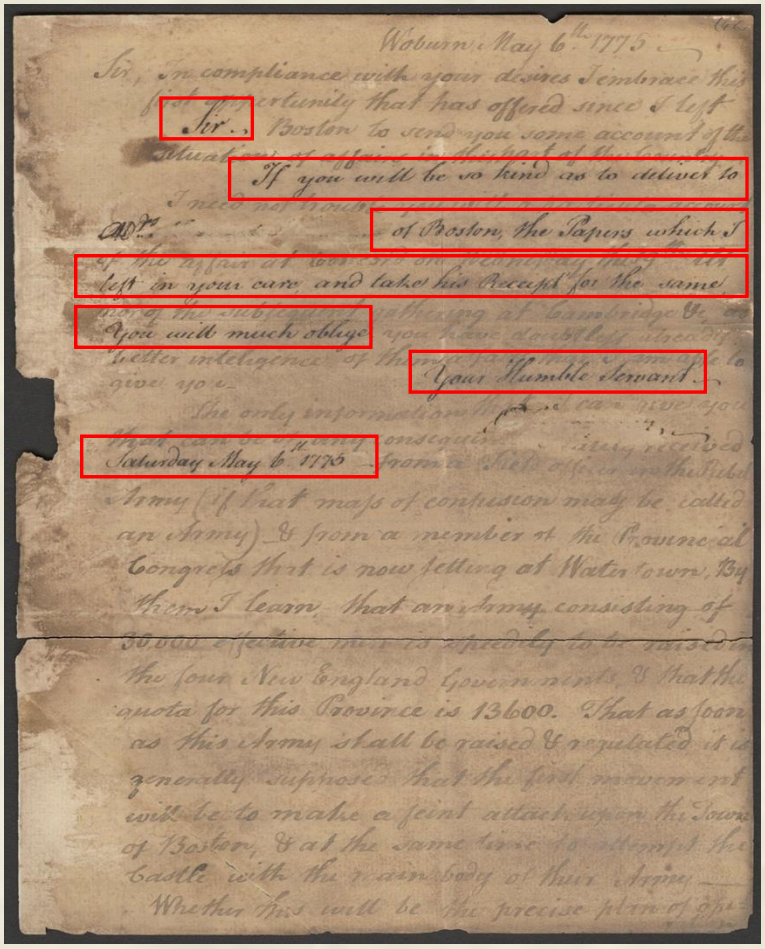
INVISIBLE INK


Woburn May 6th 1775

Sir, In compliance with your desires I embrace this

Sir,

If you will be so kind as to deliver to

of Boston, the Papers which I

left in your care and take his Receipt for the same

You will much oblige

Your Humble Servant

Saturday May 6th 1775

Army (if that mass of confusion may be called an Army) & from a member of the Provincial Congress that is now setting at Watertown. By them I learn that an Army consisting of

the four New England Governments & that the quota for this Province is 13600. That as soon as this Army shall be raised & regulated it is generally supposed that the first movement will be to make a feint attack upon the Town of Boston, & at the same time to attempt the Castle with the main body of their Army.

Whether this will be the precise plan of op

Figure 1: Image of a letter from the American Revolution written by Sir Benjamin Thompson. The letters in red were originally invisible.

Various forms of invisible ink have been used by humans for centuries, with origins that date back to Ancient Rome. One of the earliest recorded accounts of its use is attributed to a naturalist known as Pliny the Elder. He discovered that the milk of the tithymalus plant could be applied to skin and appears invisible when dry.[1] The milk could then later be revealed by spreading ashes over the hidden message.[2] In addition, intelligence agents during the American Revolution used invisible ink to deliver sensitive information to their allies. Typically, the messages would be encrypted within letters that are seemingly inconspicuous (figure 1). This tactic was used during the war by both British and American soldiers. In one example, George Washington's chief spymaster Benjamin Tallmadge gathered information on the British troop activities and safely delivered this knowledge by encoding the communication with invisible ink.[3] Typically, methods for revealing these secret correspondences involved utilizing heat or acids.[4]

Invisible ink is a reoccurring component of human history. In this problem, Benjamin Tallmadge has developed two different techniques for encoding secret messages. He has delivered their instructions to Agent 100981, whose role is to uncover the chemical principles behind revealing the invisible ink.

S.E.C.R.E.T

From: Chief Spymaster Benjamin Tallmadge 18th June 1778

To: Agent 100981

I have generated two techniques for encoding top secret correspondence with invisible ink. All methods of communication will be enciphered to allow military information to be protected from a potential enemy interception. Hidden messages will be revealed by completing a specific chemical reaction. I have encoded the decipher in this correspondence. Identify the stepwise chemical equation for revealing future messages. A list of potential chemicals has been provided below the hidden message (Hint: Some of the chemicals provided in the table are already on the page). Not all chemicals will be necessary to generate the correct chemical reaction.

Invisible Ink #1

Fear not as the invisible can be made visible.
A basic message is hidden.
Apply the correct chemical to reveal what you seek.
Accurate addition causes two reactions.
Double displacement occurs first,
second is a reaction that decomposes
the product from the first.
Finding the correct chemical is easy.
The definitions from Arrhenius will guide you.
The addition of a coloured indicator will reveal your success.

Message:

Acetic Acid	Food dye	Tartaric Acid
Sodium Bicarbonate	Hydrochloric Acid	Sodium Hydroxide
Acetone	Diethyl Ether	Ethanol

S.E.C.R.E.T

Invisible Ink #2

Reveal the invisible with two half reactions.

Two steps are needed.

Indicator production is step one of two.

Electrons are transferred, iron donates, and acetic acid takes.

Combine and seal the indicator reagents away.

The process is long, it lasts a few days.

Bubbles disappearing will reveal when the ink is ready.

Indicator application is step two of two.

Exposing the ink occurs through a redox reaction.

The ink has an alternative application as a disinfectant.

Message:

Acetic Acid	Ethanol	Steel Wool
Sodium Bicarbonate	Hydrogen Peroxide	Sodium Hydroxide
Sodium Chloride	Phosphoric Acid	Sulfuric Acid

When the correct reaction scheme is discovered, deliver this message to George Washington. Report the chemical reactions that enable messages #1 and #2 to be encrypted. Demonstrate their utility by replicating the entire experiment and provide a thorough explanation on why each reaction works. In your explanation elaborate on potential safety regulations through analyzing the chemicals on the SDS database provided https://chemicalsafety.com/sds-search/.

S.E.C.R.E.T

Pre-Lab: Reaction #1

Materials Required:

- x 2 Glass Bowls
- x 1 Cotton Swab
- x 1 Blank A4 Paper
- x 1 Paintbrush
- x 2 Teaspoons
- x 1 Measuring Tablespoon
- ___ tbs _____
- ___ tbs _____
- ___ drops _____
- ___ tbs _____

Reaction Type:

Balanced Chemical Equation:

1.) Double Displacement Equation:

2.) Decomposition Equation:

Name of Chemical	Chemical Formula	Melting Point	Boiling Point	Molar Mass	Hazards

S.E.C.R.E.T

Experimental Observations

S.E.C.R.E.T

Pre-Lab: Reaction #2

Materials Required:

- x 1 Glass Bowls
- x 1 Cotton Swab
- x 1 Blank A4 Paper
- x 1 Paintbrush or x 1 Common Swab
- Container with a sealable lid
- x 1 Measuring Teaspoon
- x 1 Measuring Tablespoon
- ___ tbs _____
- ___ tsp _____
- ___ tbs _____

Reaction Type:

Balanced Chemical Equation:

1.) Equation1:

O: ____ → ____ + $2e^-$

R: $2H_3O^+$ + $2e^-$ → ____ + ____

2.) Equation 2:

O: ____ + ____ → ____ + $6H_3O^+$ + $2e^-$

R: ____ + $2H_3O^+$ + $2e^-$ → ____

S.E.C.R.E.T

Name of Chemical	Chemical Formula	Melting Point	Boiling Point	Molar Mass	Hazards

Experimental Observations

S.E.C.R.E.T

References

1.) Raggo, M.; Hosmer, C. Chapter 1 - History of Secret Writing. In *Data Hiding*; Raggo, M., Hosmer, C., Eds.; Syngress: Boston, 2013; pp 1–17. https://doi.org/10.1016/B978-1-59-749743-5.00001-8.

2.) The American Revolution http://www.ouramericanrevolution.org/index.cfm/people/view/pp0057 (accessed Apr 17, 2021).

3.) Benjamin Thompson Letter to an Unidentified Recipient, May 6, 1775. UM Clements Library.

4.) Invisible Ink | American Bookbinders Museum, 2014.