ScienceNews

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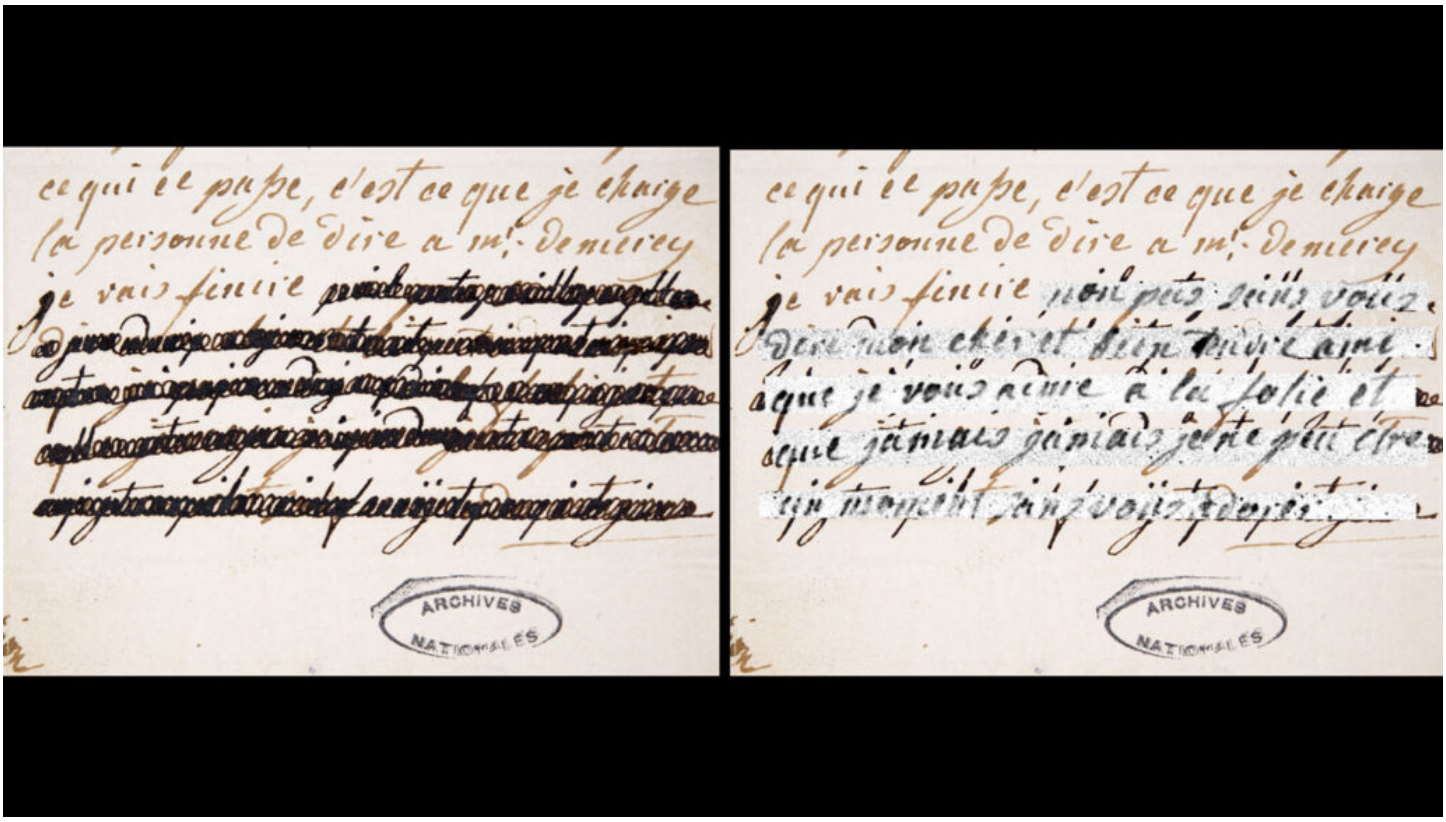

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November 6, 2021

Marie Antoinette's Letters Are Uncensored by X-rays

SOCIETY FOR SCIENCE

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About this Guide

In this Guide, based on the online *Science News* article "Ink analysis reveals Marie Antoinette's letters' hidden words and who censored them," students will learn how scientists used chemistry to unravel a historical mystery and discuss the uses and limitations of spectroscopy.

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the online *Science News* article "Ink analysis reveals Marie Antoinette's letters' hidden words and who censored them," which details how scientists used chemistry to unravel a mystery from the French Revolution. A version of the article, "Marie Antoinette's letters are uncensored by X-rays," appears in the November 6, 2021 issue of *Science News*. Related standards include NGSS-DCI: HS-PS1; HS-PS3.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will discuss how spectroscopy relates to atomic structure, how the technology can help solve historical mysteries and the limitations and ethics of such work. Related standards include NGSS-DCI: HS-PS1; HS-PS3.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

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Article-based Comprehension, Q&A

Directions for teachers: Ask students to read the online *Science News* article "Ink analysis reveals Marie Antoinette's letters' hidden words and who censored them," which details how scientists used chemistry to unravel a mystery from the French Revolution, and answer the questions below. A version of the article, "Marie Antoinette's letters are uncensored by X-rays," appears in the November 6, 2021 issue of *Science News*.

1. Who was Marie Antoinette? Who did she write secret letters to while imprisoned during the French Revolution?

Marie Antoinette was a queen of France. She wrote letters to Swedish Count Axel von Fersen.

2. What mysteries surround the letters?

Three mysteries surround the letters, which have some words that are scribbled out with ink: What are the redacted words, who redacted them and what might they reveal about the relationship between Marie Antoinette and Count Axel von Fersen?

3. What technology helped scientists reveal the scribbled-out words? How does the technology work?

Scientists used X-ray fluorescence spectroscopy, or XRF. The technology works by shooting an X-ray beam at a sample to cause electrons within the sample's atoms to jump to higher energy levels. That energy boost causes the sample to release its own X-rays, which scientists can use to figure out the sample's elemental makeup.

4. How did the technology reveal the scribbled-out words? What are the words?

Using XRF, scientists determined that the ink Marie Antoinette used to write the letters and the ink used to redact the letters were made from iron sulfate. But each ink had distinctive ratios of copper-to-iron and zinc-to-iron. By scanning the letters pixel by pixel and mapping each pixel's elemental differences onto a gray scale, the scientists revealed the hidden words, including "beloved," "madly" and "tender friend."

5. Who crossed out the words, and how did scientists identify the person?

Count Axel von Fersen redacted the letters himself. The ratios of certain elements in the ink used to redact the letters matches the elemental ratios in the ink von Fersen used to make copies of other letters Marie Antoinette wrote him.

6. What is one mystery that remains unsolved?

Though the letters are now uncensored, it is still unclear whether the nature of the relationship between Marie Antoinette and von Fersen was romantic or political.

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Student Comprehension Worksheet

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6. What is one mystery that remains unsolved?

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Cross-curricular Discussion, Q&A

Directions for teachers:
Ask students to read the online *Science News* article "Ink analysis reveals Marie Antoinette's letters' hidden words and who censored them" and answer the following questions with a partner. A version of the article, "Marie Antoinette's letters are uncensored by X-rays," appears in the November 6, 2021 issue of *Science News*.

In order to answer the first set of questions, students should have a basic understanding of atomic structure and the electromagnetic spectrum. To aid in their brainstorming, you could point students to the *Science News for Students* article "The ultimate wordfind puzzle."

Want to make it a virtual lesson? Post the online *Science News* article to your virtual classroom. Discuss the article and questions with your class on your virtual platform.

Spectroscopy and atomic structure

1. Define and explain the process of spectroscopy based on what you learned from reading the *Science News* article. What type of electromagnetic radiation did researchers use to study Marie Antoinette's letters? What data comes out of using the spectroscopic technique?

Spectroscopy is a technique that helps scientists determine the chemical or elemental makeup of a sample. The technique relies on the interaction of electromagnetic radiation (including infrared, ultraviolet, visible, X-rays and gamma rays) with matter. Light is shot from an external source at a sample and based on the sample's interaction with the light, a spectrum is produced that can help scientists determine what elements or molecules are in the sample. Researchers used X-rays to study the letters' ink.

2. What happens to the electrons in an atom when certain types of electromagnetic radiation or light interact with it? How does this behavior relate to your understanding of atomic structure?

When electrons in an atom absorb certain types, or wavelengths, of electromagnetic radiation, the particles jump from their stable ground state energy level to a higher energy level. As electrons in atoms jump to higher energy levels, the particles' most probable locations become farther from the nucleus. When the electrons emit the radiation they absorbed, the particles return to their ground state energy level. This behavior of electrons aligns with electrons existing in discrete energy levels around the nucleus.

3. How did spectroscopy allow scientists to distinguish two separate inks used on the letters? What can you infer about the relationship between elements' atomic structures and the spectra produced?

The spectrum of each ink was unique because the inks contained different ratios of trace elements such as iron and copper. Each element is made up of atoms that have a unique number of protons, neutrons and electrons. While protons and neutrons reside in atoms' nuclei, electrons reside in discrete energy levels outside of the nuclei. To jump between energy levels, electrons must absorb and emit radiation at energies

that are specific to each element. As a result, scientists can ID elements in a sample based on the radiation energy that the sample absorbs and/or emits.

4. Draw a simple diagram of the process of X-ray fluorescence spectroscopy. Make sure you show the external light source, the ink and the result of the interaction. In another diagram, draw the light's interaction with an electron in one of the atoms in the ink.

Student answers will vary, but should include X-ray light shining on the ink and the ink absorbing the light and then emitting light. Students may show that a detector will display a spectrum from the sample. In their diagram of the atom, students should show light being absorbed when an electron moves from a ground energy level to an excited energy level, and light being emitted from the reverse process.

More mysteries to solve

1. Brainstorm examples of other historical or scientific mysteries that could be solved using spectroscopy.

Student answers will vary, but could focus on historical artifacts such as art and documents, or scientific artifacts such as fossils. Examples of mysteries could be authenticating the artifacts, knowing where they came from and who created them.

2. Beyond the information gathered using spectroscopy, what else would you need to know to solve one of the mysteries that you brainstormed?

Students should focus on the need for context to make sense of any discoveries. Scientists can gather data about an artifact, but to truly solve a mystery, they would need to combine that with historical or scientific context from the artifact's time period.

3. Discuss what ethical issues exist around uncovering messages that were purposely concealed. What other ethical concerns should researchers consider when solving historical mysteries? What ethical concerns might you need to consider when solving one of the mysteries that you brainstormed?

Students should discuss whether or not it is ethical to have scientists uncover redacted material and share it with the public.

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Student Discussion Worksheet

Directions: Read the online *Science News* article "Ink analysis reveals Marie Antoinette's letters' hidden words and who censored them" and answer the following questions as directed by your teacher. A version of the article, "Marie Antoinette's letters are uncensored by X-rays," appears in the November 6, 2021 issue of *Science News*.

Spectroscopy and atomic structure

1. Define and explain the process of spectroscopy based on what you learned from reading the *Science News* article. What type of electromagnetic radiation did researchers use to study Marie Antoinette's letters? What data comes out of using the spectroscopic technique?

2. What happens to the electrons in an atom when certain types of electromagnetic radiation or light interact with it? How does this behavior relate to your understanding of atomic structure?

3. How did spectroscopy allow scientists to distinguish two separate inks used on the letters? What can you infer about the relationship between elements' atomic structures and the spectra produced?

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