# ANALYSIS OF RESIDUE IN HISTORICAL MEDICINE BOTTLES

Hope E. Maunders*, Peter R. Ruppelt*, Jetty L. Duffy-Matzner, Duane E. Weisshaar†

Chemistry Department, Augustana University, Sioux Falls, South Dakota, 57197, United States

**Abstract**

**Contents of two historical bottles recovered during the repair of the historic Fremont Street retaining wall in Deadwood, S.D. became an analysis project for two students, conducted in collaboration with the Historical District of Deadwood and the Anthropology Department at Augustana University. One bottle, labeled Harper's Headache Medicine, contained several spots of dark, dried material. The other bottle, labeled Kirk G. Phillips Druggist Deadwood So. Dak., was about half full of a colorless liquid and a white solid. Raman, $^1$H NMR, attenuated total reflectance (ATR) FTIR, and x-ray fluorescence spectroscopies coupled with inorganic qualitative analysis were used to identify constituents of each bottle's contents. Results indicated that the Harper's bottle contents were likely residue from the original formula (acetanilide, antipyrine, caffeine, sodium/potassium bromide, and alcohol). The liquid in the Phillips bottle was primarily water and ethanol, and the majority of the solid proved to be lead sulfate and zinc carbonate.**

†Corresponding author: duane.weisshaar@augie.edu

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## Introduction

During the repair of the historic Fremont Street retaining wall in Deadwood, S.D., two historic medicine bottles were recovered. One was a Harper's headache medicine bottle (Washington, D.C.) containing spots of a dark solid residue on the inner sides and a few drops of a brown transparent liquid. The other was a Kirk G. Phillips (Deadwood SoDak) medicine bottle about half full of a colorless liquid and a white solid (Fig. 1). Reported here are results of the analyses of the contents of these two bottles. This analysis is of particular interest because it allowed two undergraduate chemistry majors to collaborate with the Historical District of Deadwood and the Anthropology Department at Augustana University while using classical and modern chemical analysis techniques to determine the identity of the liquids and solids.

**Figure 1. Harper's and Phillip's bottles from Deadwood, S.D.**

## Historical Background

Robert N. Harper first marketed his medicine in the late 1880's under the name Cephalgine, but later he changed the name to Cuforhedake Brane-Fude. The main ingredient in Harper's medicine was acetanilide due to its painkilling and anti-inflammatory effects. Other ingredients included antipyrine, caffeine, sodium/potassium bromide, and alcohol. Harper was convicted of false advertising under the Pure Food and Drug Act in 1908[1, 2].

The label on the Phillips bottle refers to one of several pharmacies in the Black Hills owned by Kirk G. Phillips in the early 1900's[3], but nothing is known about the original contents of this bottle.

## Experimental

*Reagents*:

All chemicals were reagent grade unless otherwise noted and used without further purification. Deuterium oxide ($D_2O$) (99.9%) and dimethylsulfoxide-$d_6$ (DMSO) (99.9%) were obtained from Cambridge Isotope Laboratories, Inc. Potassium bromide (KBr) was obtained from Baker. Sulfuric acid came from Fisher Scientific. The qualitative analysis reagents were solutions prepared for Inorganic Chemistry lab and came from a variety of sources.

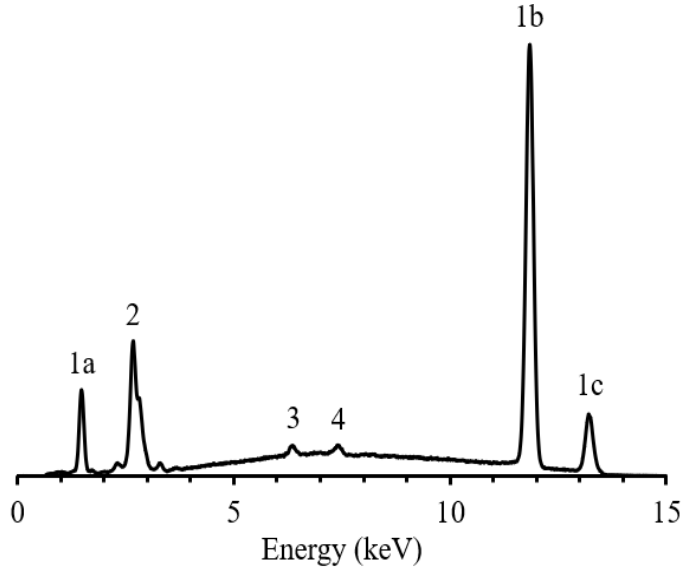
*Instrumentation*:

A Bruker Tracer IV-SD Handheld x-ray fluorescence spectrometer (XRF) was used for elemental analysis. The x-ray tube with a rhodium target was operated at 15 kV, the instrument chamber was evacuated, and fluorescent radiation was collected with no filter for 90 seconds. Deionized water was used for the blank. Several tests from the inorganic qualitative analysis scheme of Lagowski and Sorum[4] were used to further elucidate the XRF results.

Spectra of the Phillip's solid and liquid were obtained using the diamond anvil attenuated total reflectance (ATR) accessory on a Thermo Nicolet iS-50 FTIR. Baseline correction and advanced ATR correction were applied to the ATR spectra.

An Agiltron PeakSeeker Raman Spectrometer was used to analyze the liquid from the Phillip's bottle.

$^1$H NMR spectra of the liquid from the Phillip's bottle and of the solid from the Harper's bottle were obtained on a JEOL ECS 400




**Fiure 2. XRF spectrum of liquid from the Harper's bottle. Peak's 1a, 1b, 1c were the Lα, Kα, and Kβ bromine peaks (respectively), the envelope of peak 2 was the Lα rhodium (x-ray tube target) peaks, peak 3 was the Kα iron peak, and peak 4 was the Kα nickel peak. Iron and nickel came from the blank.**

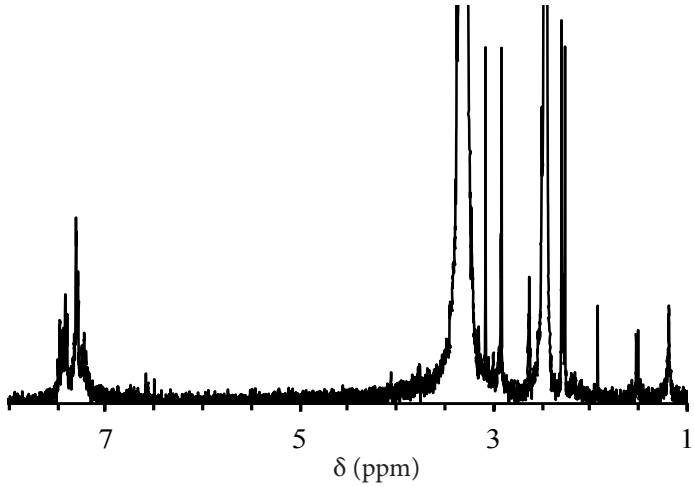



**Fig. 3. NMR spectrum of solid from the Harper's bottle dissolved in DMSO. See the text for details.**

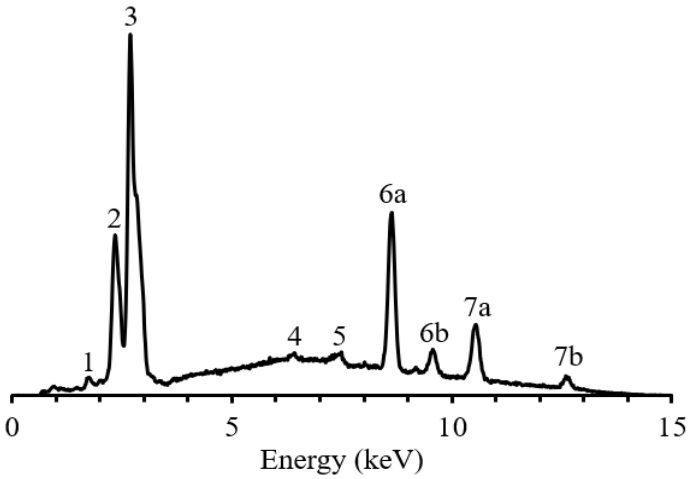



**Fig. 4. XRF spectrum of solid from the Phillip's bottle. Peak 1 was the Kα silicon peak, peak 2 was the Kα sulfur peak, peak envelope 3 was the Lα rhodium peak (x-ray tube target), peak 4 was the Kα iron peak, and peak 5 was the Kα nickel peak, peaks 6a and 6b were the Kα and Kβ zinc peaks, and peaks 7a and 7b were the Lα and Lβ lead peaks. Silicon, iron and nickel came from the blank.**

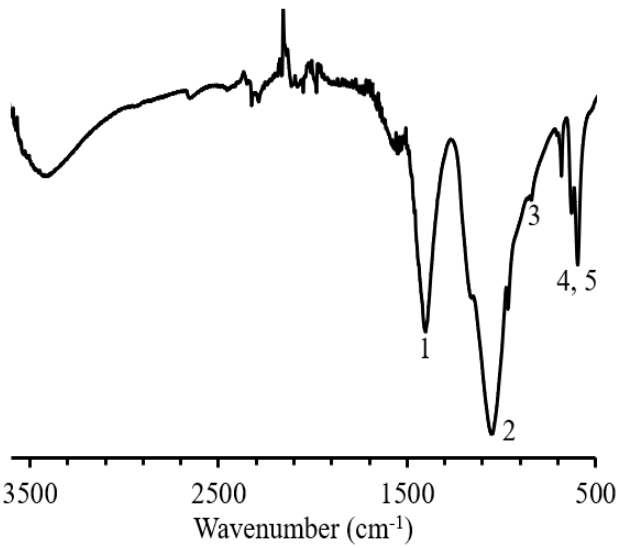



**Fig. 5. ATR-FTIR spectrum of solid from the Phillip's bottle. Peaks 2, 4, and 5 matched a known sulfate spectrum, while the broad peak at about 3400 cm-1 indicated some degree of protonation. Peaks 1 and 3 matched a known carbonate spectrum.**

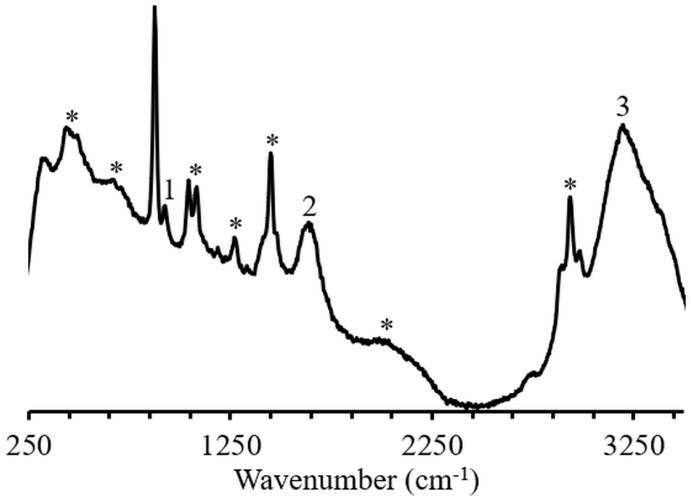



**Figure 6. Raman spectrum of liquid from the Phillip's bottle. The * peaks were from ethanol, peak 3 was from water, and peaks 1 and 2 were unidentified.**

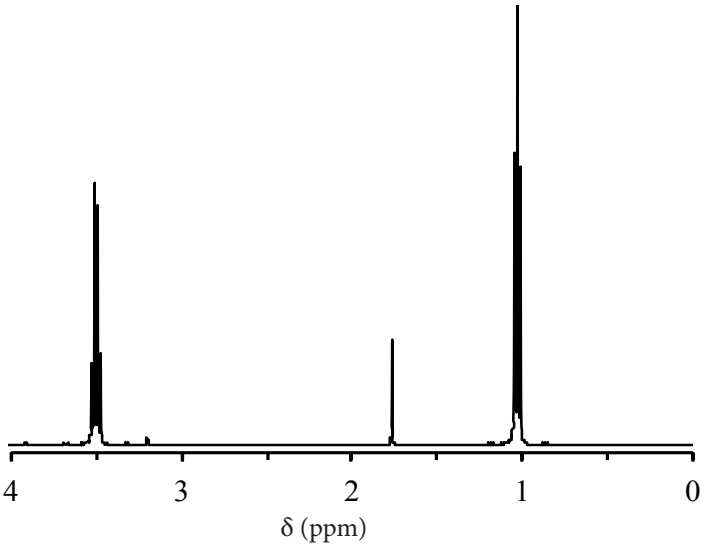



**Figure 7. NMR spectrum of liquid from the Phillip's bottle dissolved in $D_2O$. The peaks at 1 ppm and 3.5 ppm were from ethanol. The peak at 1.8 ppm was from an unknown component.**

MHz NMR. The liquid from the Phillip's bottle was dissolved in $D_2O$. The solid from the Harper's bottle was dissolved in DMSO.

**Results**

*Harper's medicine bottle*:

The XRF spectrum of the liquid (most likely aqueous) is shown in Fig. 2. Peaks 1a, 1b, and 1c are characteristic of bromine (Lα, Kα, and Kβ, respectively). The spectrum of the solid was similar, but the bromine peaks were of much lower intensity. Peak 3 (iron) and peak 4 (nickel) were present in the blank, and therefore not likely to be present in the samples. Peak 2 was the Lα envelope from the rhodium x-ray tube target. The presence of bromine could point to Harper's medicine ingredient KBr. If the residue were remnants of the original Harper's medicine, potassium and chlorine might also be expected, but these two peaks in the XRF spectrum would be hidden under the rhodium envelope. Because of the low quantity of sample, further testing on the liquid was not attempted.

Fig. 3 shows the $^1$H NMR spectrum of the solid dissolved in DMSO. The large peak at 3.4 ppm was from water. Since this was a mixture and the NMR signal intensity was low, specific compounds could not be identified. However, the cluster of peaks centered around 7.4 ppm and the peaks between 2 ppm and 3 ppm were consistent with the organic ingredients in Harper's medicine (specifically acetanilide, antipyrine, and caffeine) or their degradation products. The NMR and XRF results indicated that the current contents of the Harper's medicine bottle were likely the residue from the original ingredients.

*Phillip's bottle – solid component*

The XRF spectrum of the solid is shown in Fig. 4. The inorganic components in this sample were indicated by the sulfur Kα peak (peak 2), the zinc Kα and Kβ peaks (peaks 6a, 6b), and the lead Lα and Lβ peaks (peaks 7a, 7b). The peaks that also appeared in the blank were peak 1 (silicon), peak 4 (iron), and peak 5 (nickel). Peak 3 is the Lα envelope from rhodium (x-ray tube target). The position of peak 2 (~2.2 keV) in Fig. 4 corresponds with a small peak in the rhodium envelope of Fig. 2. However, in Fig. 4 the peak at 2.2 keV constitutes a much higher percentage of the rhodium envelope than it does in Fig. 2, indicating the presence of sulfur in the solid.

Several tests from the inorganic analysis scheme of Lagowski and Sorum[4] confirmed the presence of lead and indicated that sulfur was present as sulfate. Blanket tests with 3 M $HNO_3$, concentrated $H_2SO_4$, and 0.2 M $AgNO_3$ indicated the presence of at least one more anion, but the tests did not provide sufficient evidence to identify it. An anion other than sulfate must be present to form the insoluble compound with zinc.

The ATR-FTIR spectrum of the solid is shown in Fig. 5. Peaks 2, 4, and 5 confirmed the presence of sulfate, with the broad peak around 3400 $cm^{-1}$ suggesting that some of the sulfate may be protonated. Peaks 1 and 3 indicated the presence of carbonate, which explained the presence of zinc in the solid (insoluble zinc carbonate). Thus, the primary composition of the solid is lead sulfate and zinc carbonate with a possibility that insoluble lead carbonate may also be present. Qualitative analysis results and additional peaks in the IR spectrum suggested that traces of other components are possible as well.

*Phillip's bottle – liquid component*

The liquid had a pH of about 7. The XRF spectrum of the liquid (not shown) exhibited only a trace of zinc for inorganic content.

The ATR-FTIR spectrum of the liquid matched a known water spectrum with no other obvious peaks.

Ethanol was clearly identified in the Raman spectrum of the liquid (starred peaks in Fig. 6). Peak 3 confirmed the presence of water, while peaks 1 and 2 were from unidentified components.

In the $^1$H NMR spectrum of the liquid in $D_2O$ (Fig. 7), the 3:2 integration ratio of the peaks at 1 ppm ($CH_3$) and 3.5 ($OCH_2$) ppm with appropriate splitting confirmed the presence of ethanol. The water peak at about 4.8 ppm (not shown) dominated the spectrum. The peak at 1.8 ppm gave evidence that at least one other component was present although at low concentration. Taken together, these results demonstrated that water and ethanol were the primary components of the liquid.

**Conclusion**

This project was a great practical experience that enabled the students to learn how to combine information from a variety of techniques to solve a problem. The project also demonstrated how chemical analysis is used in other fields.

The Harper's headache medicine bottle probably contained remnants of the original contents.

The liquid in the Phillip's Pharmacy bottle was a mixture of water and ethanol with a trace of other, unidentified components. The percentage of ethanol in the mixture was not determined, but based on signal intensities in the Raman and NMR spectra it was probably less than 10%.

The solid in the Phillip's Pharmacy bottle contained lead, zinc, sulfate, and carbonate along with lower concentrations of unidentified compounds. Most likely, the main components were insoluble lead sulfate and zinc carbonate, with perhaps some lead carbonate. Other trace components were present but not identified.

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