Teaching Chemistry Using *October Sky*

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Just over fifty years ago, on October 4, 1957, the Soviet Union launched *Sputnik,* which marked the beginning of the space race. In response, the United States created the National Aeronautics and Space Administration (NASA) and approved major increases in government funding for science and mathematics programs nationwide. Sputnik also inspired six coal miners' sons in Coalwood, West Virginia, to form a rocket research program. The story of these coal miners' sons was told by Homer Hickam, Jr., in the book *Rocket Boys: A Memoir (1).* The book was later adapted into the movie *October Sky (2).*

Several papers have been published on the subject of using popular movies and television shows to teach chemistry *(3–10).* Some of the popular media include the movies *Apollo 13, Jurassic Park, Awakenings, Lorenzo's Oil, 1776, The Incredibles, Silkwood,* and the HBO television miniseries *From the Earth to the Moon.* An article by Becky Ham in the spring 2006 edition of *Chemistry* explores how chemistry is portrayed in popular television shows such as *Good Eats, CSI,* and *Mythbusters (11).* A recent paper by Lon Porter describes how popular novels such as *Prey* are used to teach nanochemistry, while Jane Snell Copes uses the Harry Potter series as a theme for chemical demonstrations *(12, 13).* Thomas Waddell and R. Reed Sanderlin describe the chemistry in the classic novel *Moby Dick (14).* Thomas Waddell and Thomas Rybolt penned *The Chemical Adventures of Sherlock Holmes,* a compilation of papers that use the characters from Sir Arthur Conan Doyle stories to explore chemical principles *(15).* Ken Shaw has recently added to the *Chemical Adventures of Sherlock Holmes* series *(16).*

Rocket Boys and *October Sky*

As told in *Rocket Boys: A Memoir* and in the movie *October Sky,* the story of the Rocket Boys provides an opportunity to use a popular book and a movie adaptation as teaching tools. Commentary by the author Homer Hickam, Jr. is helpful in making connections between the memoir and the movie. Online sources provide ways that this movie and memoir combination can be used to teach literary and film analysis, psychological analysis of father–son conflict, and the physics and mathematics of projectile motion *(17–23).* However, there is no detailed information available that describes the chemistry found in the movie and the book. The only such information available online consists primarily of simply identifying components of propellant mixtures.

This paper will explain, in greater depth, and with special focus on rockets, the chemistry portrayed in the movie and described in the book. Principles portrayed in the movie still apply to solid rockets such as those used to launch the space shuttles. By following the development of rockets in *October Sky* and *Rocket Boys: A Memoir,* students can learn the scientific process, chemical principles, and the importance of mentoring from teachers. When using this book and movie as teaching tools, instructors teaching at the high school and introductory college levels can also explain the many dangerous activities depicted that should not be attempted by students. As Homer Hickam, Jr. states, when used correctly books and movies provide teachers with "a springboard to a serious discussion of science and scientists and the creative process" *(17, 24).*

Influence of a Teacher

The movie *October Sky* begins with a depiction of life in Coalwood, West Virginia. Homer Hickam, Jr. seemed destined to follow in the footsteps of his father and many other West Virginians by pursuing a career in coal mining. However, the *Sputnik* launch changed Homer's life forever. With the encouragement of his teacher, Freida Riley of Big Creek High School, Homer formed the Rocket Boys, a group of six students interested in constructing and perfecting homemade rockets. Dedicated to her students' education, Riley not only had confidence in the boys' talents, she also taught them some of the principles necessary to succeed at rocket building. She obtained an important book for Homer that contained the scientific and engineering basics of building rockets *(25).* Freida Riley told Homer that, "All I've done is given you a book. You have to have the courage to learn what's inside it" *(1).* The mentoring and support from Riley was important to the success of the Rocket Boys and especially to Homer whose father discouraged their endeavors. Homer went on to represent the Rocket Boys in the 1960 National Science Fair where they won a gold medal. This recognition at such an early stage contributed to Homer fulfilling his dream of joining NASA. To commemorate Riley's support for and dedication to her students, the Freida J. Riley Teacher Award was created *(26).*

Developing Small-Scale Rockets

Success did not come easily for the six Rocket Boys of Coalwood. Their first attempt at preparing a rocket used fireworks as a propellant. The trial led to an explosion that destroyed Homer's mother's fence *(27).* The boys soon realized that success in launching rockets would not be easy. It would require a more extensive education in mathematics, engineering, physics, and chemistry. Some of the more advanced concepts were not taught in their high school; instead, the Rocket Boys had to learn the information on their own. They also realized that a systematic approach, careful observations, detailed record keeping, and analysis of results would allow them to develop a body of knowledge necessary to improve their rockets.

Homer and the Rocket Boys learned chemistry in a class taught by Freida Riley. Chemistry would be the key to developing successful propellant systems for their rockets. The Rocket Boys created a second propellant using a mixture of saltpeter (potassium nitrate), charcoal, and sulfur bound together with glue. The material was mixed in Homer's basement using utensils and bowls obtained from the kitchen. This propellant system resulted in many launch failures due to uneven combustion. Careful grinding and curing of the propellant for nearly five

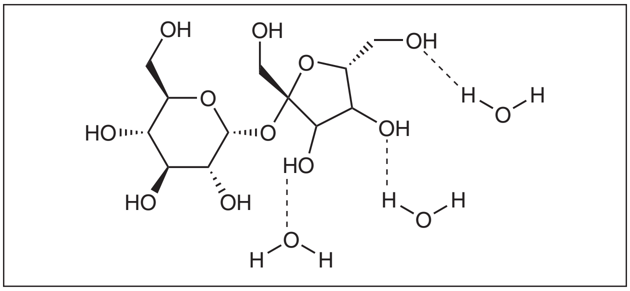

Figure 1. Structure of sucrose and water.

days still did not solve the homogeneity problem that caused the uneven combustion.

As the Rocket Boys learned from their failures, Freida Riley continued to provide them with the necessary inspiration to improve their rocketry. A demonstration that Riley prepared showed the rapid oxidation of sugar with potassium chlorate. After this demonstration, the Rocket Boys devised a plan for a propellant that used sugar and potassium nitrate, a less reactive substitute for potassium chlorate. In *October Sky,* the reactivity of potassium chlorate with sucrose (table sugar) is depicted in a science class supervised by a substitute teacher *(28)*. A small amount of the chemicals were placed in a flame causing a bright flash as the reaction occurred. At this point in the movie, two chemical misconceptions are depicted. Homer and another Rocket Boy, Quentin, wash extra chemicals down the sink with water. In another part of the classroom, a student drops a match in the sink and flames shoot from every sink. When these chemicals are wet, they are not volatile enough to react in such a manner. Movie dialogue also states that three parts oxygen and two parts carbon dioxide will be produced in the reaction. The balanced chemical equation for the reaction between potassium chlorate and sucrose is given here.

$$C_{12}H_{22}O_{11}(s) + 8KClO_3(s) \longrightarrow 8KCl(s) + 11H_2O(g) + 12CO_2(g)$$

Initial tests of this new propellant system resulted in several more failures due to uneven combustion. Sugar, which contains alcohol groups in its structure, readily interacts with water via hydrogen bonding, making the propellant difficult to dry sufficiently. (See Figure 1.)

The boys discovered that by melting the mixture to form a solution and carefully drying it they could prepare a homogeneous mixture. This successful propellant system was called rocket candy and today these are known as sugar rockets. Using rocket candy, the Rocket Boys created their first successful rocket named after the auk, an extinct, flightless bird.

The success of rocket candy revealed a structural problem with the designs the Rocket Boys developed. The material used for the rockets was unable to withstand both the heat and effects of oxidation produced by the new propellant *(29)*. The Rocket Boys observed pitting on the rocket caused by heat and oxidation of iron in the rocket body *(21)*. The boys turned to the machinists employed at the coal company for advice about materials suitable for rocket construction. The Rocket Boys discovered that skilled welding by the machinists would be necessary to fabricate the rockets *(30)*. They also learned to communicate their requirements to the machinists, just as scientists learn to communicate their results to the outside world *(31)*. And, just as learning laboratory techniques is an important objective to becoming a chemist, the Rocket Boys learned the techniques necessary to prepare successful rockets.

Zincoshine

The Rocket Boys maximized the altitude attainable by their small-scale rockets using the rocket candy propellant system. They needed a new system that provided greater amounts of energy. Another demonstration by Freida Riley provided inspiration. She began by mixing sulfur and zinc dust, then carefully added heat to initiate a reaction that produced a large amount of additional heat, light, and smoke. A binding agent was required to use zinc and sulfur together as a propellant system. Ideally, this binding agent would be volatile, so that excess material would evaporate and provide energy for the rocket. The Rocket Boys

Table 1. Comparison of Fuel–Oxidant Mixtures

Type of Fuel Mixture	Organic Base	Oxidant	Added Reductant
Gunpowder	Charcoal	KNO_3	Sulfur
Rocket candy	Sugar	KNO_3	None
Zincoshine	Ethanol	Sulfur	Zinc powder
Solid rocket booster	Polymer and epoxy	NH_4ClO_4	Aluminum powder

Table 2. Composition of Solid Rocket Boosters Used by NASA To Propel Space Shuttles

Material	Function in the Mixture	Percent by Mass of Total Material *(34)*
Ammonium perchlorate	Oxidant	69.6
Aluminum powder	Added reductant	16.0
Iron(III) oxide	Catalyst	0.4
Polybutadiene acrylic acid acrylonite	Organic binder	12.04
Epoxy	Organic curing agent	1.96

used ethanol prepared by distillation of fermented vegetation and obtained from an illicit homemade distillation apparatus operated by some local inhabitants *(32)*. In the movie, this ethanol is touted as being 100% pure, which is a chemical misconception. Ethanol obtained from a simple distillation forms an azeotrope that is 94.5% ethanol and the rest is water. However, it served well as a binding agent. Careful preparation, loading, and curing of this propellant system—called zincoshine—produced a rocket propellant system able to lift their rocket to an altitude of over 33,000 feet (10,058 m) *(24)*.

Comparison of Propellant Systems

October Sky concludes with a scene of a space shuttle lifting off *(33)*. An interesting comparison of the propellant systems used by the Rocket Boys, listed in Table 1, and the propellant system used by the space shuttle, listed in Table 2, shows common features of oxidation–reduction chemistry *(34–36)*. Each system consists of an oxidizing agent and a reducing agent held together with a binding agent that is also oxidizable. Each system also required an initiator to overcome the activation barrier to start the reaction. The only differences are the use of a small amount of an iron(III) oxide catalyst and an epoxy as a curing agent in the solid rocket boosters of the space shuttles. The propellant systems developed by the Rocket Boys were mixed with kitchen equipment and the solid rocket boosters are mixed using very large versions of similar kitchen equipment. Eventually, the Rocket Boys ignited their rockets electrically, similar to the solid rocket booster ignition system of the space shuttle *(34–37)*.

Safety Concerns and Representations

Preparing and launching rockets are very dangerous activities and it must be emphasized that events shown in the movie and described in the book should not be duplicated. In one scene, a rocket flies into an occupied area of the mine near the company offices *(38)*. After this experience, the boys moved to an isolated area on a slack heap of waste material from the mine, which they named Cape Coalwood. They built a blockhouse on Cape Coalwood to protect themselves during launch and developed an electrical system to launch their rockets *(39)*. Rocket candy preparation required the hazardous procedure of melting sugar containing potassium nitrate. In the book, a minor mishap is described when a small amount of rocket candy touches a hot plate. The movie does show the use of protective gear when preparing propellants. However, the extremely dangerous act of pouring alcohol over an open flame was shown in the movie *(32)*. In Homer Hickam, Jr.'s commentary of the movie he states that this dangerous practice never occurred *(2)*.

Conclusion

Movies and books have been used by teachers as effective teaching tools to demonstrate: the impact a teacher can have on children, scientific methodology, and real-life examples of science being used by individuals of all ages *(3–23)*. However, as Homer Hickam, Jr. asserts, it is important to keep in mind that movies and other media often exaggerate to create a more compelling story *(2, 17, 24)*. The story told in the book *Rocket Boys: A Memoir* and in the movie *October Sky* represents the trials, tribulations, and triumphs associated with science and engineering.

This paper shows how a movie and book previously used to examine father–son conflict, physics, and mathematics can also be used to teach chemistry. Classroom discussions about the chemistry topics of homogeneity, intermolecular interactions, kinetics, thermodynamics, and oxidation–reduction chemistry can draw upon *Rocket Boys: A Memoir,* the movie *October Sky,* and Homer Hickam, Jr.'s commentary for real-world examples. In fact, the first page of the memoir speaks of using an enthalpy change to provide kinetic energy for rockets *(1)*. This movie–memoir combination is another exciting example of using popular media as a tool to teach chemical principles. One must also heed Homer's warning, just as seen in the opening scene of *Mythbusters,* that the events depicted in these popular media should never be duplicated at home!

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