The Chemical Wizardry of J. K. Rowling

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Flash and Bang

I am a chemist for many reasons, yet the primary draw for me is still the flash and bang. The charm of color changes, rising bubbles, and sudden precipitates has not faded through years of writing lab reports, plodding through graduate school, grading lab reports and exams, and introducing learners of all ages to this wonderful science.

For this reader, something in the first Harry Potter book—I think it was the little fire in the jam jar—got me to read closer (*1,* p 181):

> *The day before Harry's first Quidditch match the three of them were out in the freezing courtyard during break, and [Hermione] had conjured them up a bright blue fire that could be carried around in a jam jar.*

I know how to do that. And as I read on, I found a great deal of serious, explainable chemistry that pops, sparkles, bubbles, and otherwise decorates the pages in the Harry Potter series. A green fire, was it, or purple flames? With or without smoke? How did that potion mixture thicken?

The first six volumes of J. K. Rowling's series of Harry Potter adventures *(1–6)* provide plenty of inspiration for a chemical magic show as well as for scaled-down, teacup-sized experiments appropriate for children's classes and camps. A recent gig as Potions Master for children's summer camps sent me scurrying between the Rowling texts and a stack of demonstration reference books, chemical catalogs, and journal articles. Soon my Harry Potter books were bristling with bookmarks linked to chemical connections.

The purpose of this article is to serve as a Guide for Chemical Muggles (chemists who think they are not magically endowed) to help us reproduce some of the wizardly effects in the Harry Potter books. This is not a "how-to", but rather a "where to find" the necessary safety information, complete directions, disposal information, and explanations of a selection of "magical" effects. In a few cases where sources are more difficult to locate, I have included more complete directions. I've chosen a topical order (rather than the order of events in the books) to include colored fires, flames, and sparks; special inks and paper treatments; and transformations.

Table 1. Color Flames Demystified

Desired Color	Metal Chloride Source
Red–orange	Strontium
Orange (sparkly)	Calcium
Yellow	Sodium
Pale violet	Potassium
Red	Lithium
Green	Copper or barium

Colored Fires, Flames, and Sparks

Simple Colored Flames

Many scenes in the Harry Potter series mention colored fires or flames of various sorts. For example (*4,* p 262):

> *One by one, the Beauxbatons students stepped across the Age Line and dropped their slips of parchment into the blue-white flames. As each name entered the fire, it turned briefly red and emitted sparks.*

Both the commercial fireworks industry and traditional qualitative flame tests rely on vibrant colors produced when metal salts are heated to incandescence. Table 1 summarizes flame colors available from common metal chlorides.

Many contributors to this *Journal* have reported ingenious methods of introducing metal salts into flames. They include spraying solutions into a Meker burner flame *(7),* preparation of a colored Sterno *(8),* using a Bunsen burner's air vent to aspirate solutions *(9)*, and igniting methyl alcohol solutions in Petri dishes *(10)*. Flames from candles, alcohol burners, and oil lamps are not hot enough to produce convincing colored flames.

Useful Internet references include an explanation of how atoms and spectroscopy "work" *(11),* illustrations of classic organic Beilstein flame tests using a copper wire to detect halide ions *(12),* and a site describing the physics of light sources *(13).*

Little Fire in a Jam Jar

The jam jar fire comes in handy in more than one situation in our hero's first year at Hogwarts. To approximate this effect, chemists can prepare a gel of denatured alcohol with saturated aqueous calcium acetate solution *(14a).* The flame of burning alcohol is pale blue, quite visible in a darkened room. A metal can is a safer, if less charming, container than a jam jar or beaker.

Harry's Wand

Every wizard needs a magic wand, just as every chemist needs a stirring rod (perhaps with catalytic particles attached). After trying nearly every magic wand in Ollivander's shop, Harry finally holds exactly the right one and is justifiably pleased with its behavior (*1,* p 85):

> *Harry took the wand. He felt a sudden warmth in his fingers. He raised the wand above his head, brought it swishing down through the dusty air and a stream of red and gold sparks shot from the end like a firework, throwing dancing spots of light onto the walls.*

Firework sparklers might resemble a fast-acting, one-shot magic wand. Chemists can find a sparkler recipe that uses powdered metals and oxidizers in Keeney et al. *(15).* These Web references *(16)* give information on how fireworks work and link to many other sites.

Floo Powder

J. K. Rowling's Floo Powder is a magical substance that turns flames green and transports its users to distant locations through a system of linked fireplace flues (*2,* p 47).

> *He took a pinch of glittering powder out of the flowerpot, stepped up to the fire, and threw the powder into the flames. With a roar, the fire turned emerald green and rose higher than Fred, who stepped right into it, shouted "Diagon Alley!" and vanished.*

Muggles can reproduce the brilliant green flame, although not the unusual transportation effects, by sprinkling boric acid powder into a flame. Alternatively, aspirate a saturated solution of boric acid in methanol into a burner flame.

Handful of Flames

Chemists are advised to leave actual holding of flames to real wizards (*3,* p 83).

> *There was a soft, crackling noise, and a shivering light filled the compartment. Professor Lupin appeared to be holding a handful of flames.*

A muggle-chemist can make great use of flashpaper, a form of cellulose nitrate. It can be purchased at a magic shop or prepared by soaking paper in fuming nitric and sulfuric acids *(14b).* Flashpaper burns quickly and completely because its chemical structure contains plenty of oxygen to covert the paper into gaseous products. Ignite a small crumpled wad of flashpaper and toss it into the air away from your audience and other flammables.

The effect of a flame that does not consume the burning substrate is also charming *(17).* Soaking a cloth or paper towel or paper currency in 50% isopropyl alcohol offers a way to burn off the flammable liquid without harming the substrate. Be sure to hold the burning item with tongs rather than bare hands.

Violet Sparks, Purple Fire, and Black Flames

Muggle-chemists can mimic violet sparks and purple fire (*4,* p 87).

> *Behind him, a group of haggard-looking Ministry wizards rushed past, pointing at the distant evidence of some sort of a magical fire that was sending violet sparks twenty feet into the air.*

I regret to say that at my current stage of wizardry, I've not yet been able to produce black flames (*1,* pp 284–285).

> *They stepped over the threshold, and immediately a fire sprang up behind them in the doorway. It wasn't an ordinary fire either; it was purple. At the same instant, black flames shot up in the doorway leading onward. They were trapped.*

These special flame effects are extremely exothermic oxidation–reduction reactions. They should be done outdoors (or indoors with *plenty* of ventilation.) Even outside, wind can carry sparks toward you, your audience, or combustible materials. Chemists will recognize that these reactions consciously violate a major principle of chemical storage: keep strong oxidizers such as potassium permanganate and potassium chlorate away from organic materials. It cannot be stressed enough that you must wear proper safety gear, protect your audience from harm, follow exactly the directions for the demonstrations and disposal of wastes, practice several times, and have a fire safety plan.

Oxidations of zinc with ammonium nitrate and iodine *(14c),* potassium permanganate and glycerine *(14d),* and potassium chlorate with sugar *(14e)* provide varieties of purple flames with sizzling sound effects. A very fine demonstration that produces purple flames and a snakelike column of charred carbon avoids most of the choking fumes of the previous methods *(18).*

Special Inks and Paper Treatments

Invisible Inks

As a third-year student, Harry uses the magic of The Marauder's Map, a device his father helped construct in his own student days at Hogwarts. Once activated with the proper words, the map shows every detail of the Hogwarts castle and grounds, including moving ink dots indicating the location of everyone in the castle. What's more, the map can be wiped clean after use and then appears to be an old bit of parchment (*3,* pp 192–193).

> *"Just tap it again and say, 'Mischief managed!' And it'll go blank."*

Many invisible inks can be concocted with kitchen ingredients. Most of the effects are not reversible, although they are charming nonetheless. Table 2 summarizes several ways to write invisibly and develop a readable message. A porous paper such as white construction paper is very useful for invisible writing, and disposable cotton swabs are good "pens". In all except the last case (wax resist), be sure to let the message dry thoroughly on the paper before developing it. Small pump sprayers for the developers can be found in the cosmetic aisle of a pharmacy or a discount store. Be careful not to spray any solutions toward students' faces.

Color-Changing Inks

As with the invisible inks described in the last section, the general idea is to write the message on absorbent paper with a cotton swab or small paintbrush, let the color-changing ink dry, then spray or brush the paper with the developing chemical (*1,* p 79).

> *They stopped to buy parchment and quills. Harry cheered up a bit when he found a bottle of ink that changed color as you wrote.*

Chemists are well-versed in using compounds that change colors to indicate a change in pH, voltage, or the nature of species in solutions. These indicators are ideal "inks" and "developers" because their color changes are vivid and their chemistry is generally well-understood. Concentrations of these inks and developers are typically not critical; suggestions in Table 3 are approximate.

The fading text effect of the first two entries in Table 3 is due to properties of the developer solutions. Both aqueous ammonia and sodium hydroxide produce the high pH (colored) forms of the indicators. When the ammonia evaporates, the acid form (colorless) of the indicator "appears". Sodium hydroxide, on the other hand, readily reacts with carbon dioxide in the air to change the indicator color back to its acidic, colorless form *(14f)*.

Ammonia is also used as a developer with "inks" of copper, cobalt, and nickel salts. These color-changing inks do not fade, however, because the metal ions and ammonia molecules are tightly bound in coordination complexes.

Paper Treatments

An easy way to prepare "aged" paper, resembling parchment, is to use a strong solution of ordinary black tea. Brew the tea at least quadruple-strength and let the solution cool. Then saturate plain paper with the tea and let the sheets dry overnight on newspapers. Any curling or crumpling of the paper adds to its appeal. Use any ordinary drawing implement,

Table 2. Invisible Inks and Their Development, Effects, and Reaction Types

Ink Source	Development Methods	Effects	Reaction Types
Lemon or orange juice	Heat gently over light bulb	Written message turns brown	Sugars char in the acidic juices
Baking soda solution	Heat gently over light bulb	Written message turns brown	Possible reaction with paper
Baking soda solution	Spray or brush with purple cabbage juice	Green letters appear on pink paper	Acid–base reaction of cabbage indicator
Cream of tartar solution	Spray or brush with purple cabbage juice	Red text appears on pink paper	Acid–base reaction of cabbage indicator
Corn starch solution	Spray or brush with dilute iodine solution	Dark blue text appears on light blue paper	Starch–iodine reaction
Lemon juice	Spray or brush with dilute iodine solution	White text appears on light blue paper	Iodine reacts with starch in paper sizing; Ascorbic acid reduces iodine to colorless iodide
Table salt solution; let dry and brush off salt residue	Rub with soft pencil	The texture of the writing will stand out from paper	
White wax candle or crayon	Spray or brush with any colored aqueous solution	White text appears on colored background	Wax and water don't mix

Table 3. Color-Changing Inks and Their Developers, Effects, and Reaction Types

Ink Source	Developer Solutions	Effects	Reaction Types
Phenolphthalein solution, 1% in alcohol	Dilute household ammonia or 0.1 M sodium hydroxide solution	Red text appears then disappears	Acid–base indicator
Thymolphthalein solution, 0.04% in alcohol	Dilute ammonia or 0.1 M sodium hydroxide solution	Blue characters appear then disappear	Acid–base indicator
Vinegar, 5% acetic acid	Purple cabbage juice	Magenta text appears on pink background	Acid–base indicator
Sodium carbonate solution, 0.1 M	Purple cabbage juice	Green letters appear on pink background	Acid–base indicator
Cobalt(II) salt solution, 0.1 M	Ammonia	Pale pink text turns deep blue	Ammine complex formation
Copper(II) salt solution, 0.1 M	Ammonia	Pale blue text turns deep blue	Ammine complex formation
Nickel(II) salt solution, 0.1 M	Ammonia	Pale green text turns purple	Ammine complex formation
Potassium thiocyanate solution, 0.1 M	Iron(III) chloride solution, 0.1 M	Blood-red letters appear	Fe–SCN complex formation

or try writing with lemon juice on tea-dyed paper. Does lemon juice affect the color of the paper as it does in a cup of tea?

In the previous tables, purple cabbage juice was suggested as a developer for acidic and basic inks on plain paper. It is also possible to prepare sheets of paper soaked in cabbage juice indicator and write messages with acidic and basic solutions. This traditional Japanese technique called *orizome* is described by Suzuki *(19),* who suggests extracting the cabbage dyes with isopropanol, in which case drying the paper in a fume hood would be prudent. Chopping purple cabbage with hot water in a blender, followed by filtering the solution, makes a perfectly acceptable dye solution. Be aware that cabbage juice has a very short shelf life, even when refrigerated.

Transformations

Shrinkable Badges

Making badges that wink messages or behave in odd or rude ways is a common student pastime at Hogwarts School of Witchcraft and Wizardry (*3,* p 10; *3,* p 67).

> *Percy was looking particularly smug. He had pinned his Head Boy badge to the fez perched jauntily on top of his neat hair.*
>
> *Fred whispered to Harry. "We've been improving it." The badge now read Bighead Boy.*

Muggle-chemists can make Shrinkable Badges from pieces of extruded polystyrene. Take-out food containers marked with recycle code #6 have been formed with heat to a useful shape for salads or sandwiches. When such containers are reheated near to the extrusion temperature, they crumple and shrink rather dramatically back to the original volume of the polymer. Polystyrene film is also sold in toy stores as Shrinky Dinks.[1]

The general idea is to decorate pieces of polystyrene with permanent markers, heat to 325 °F for a few minutes, and cool the resulting shrunken object thoroughly before handling it *(20).* If you wish to make name badges that hang from a neck cord, punch holes in the thin plastic before shrinking. Yes, the holes shrink also!

A Charm To Repel Water from Glasses

Although it isn't known exactly where Hogwarts School is, the weather extremes described by J. K. Rowling lead one to believe it must be in northern Scotland. Winter weather on the ground in Scotland is difficult enough, but for Quidditch players in a thunderstorm, it can be life-threatening. Quidditch, favorite sport of Wizards and Witches, might be likened to three-dimensional soccer played on broomsticks. During one particularly wild match in the rain, Harry couldn't see either with or without his glasses. During a break in the game, his friend Hermione thinks of a perfect charm (*3,* p 177):

> *"I've got an idea, Harry! Give me your glasses, quick!" He handed them to her, and as the team watched in amazement, Hermione tapped them with her wand and said, "Impervius!" "There!" she said, handing them back to Harry. "They'll repel water!"*

Thanks to applied research, chemists have available a wide variety of silicone-based, surface-active agents. Fabrics, paper, and glass can be given a thin coating of silicone polymer molecules, rendering the surface hydrophobic *(14g)*. A commercial plaything called Magic Sand[2] uses silicones for similar water-repelling properties *(21).*

A Swelling Potion and Its Antidote

Harry's potions classes at Hogwarts are hardly his favorites. His professor, Severus Snape, is particularly hard on Harry, and potions experiments often have dangerous outcomes (*2,* p 187).

> *Goyle's potion exploded, showering the whole class . . . Malfoy got a face full and his nose began to swell like a balloon; Goyle blundered around, his hands over his eyes, which had expanded to the size of dinner plates . . .*
>
> *Snape was trying to restore calm and find out what had happened. . .*
>
> *"Silence! SILENCE!" Snape roared. "Anyone who has been splashed, come here for a Deflating Draft."*

Some protective eye wear would have been in order there! Although Rowling's characters can produce magic effects instantly, laboratory experiments usually take more time. A week-long investigation of swelling and shrinking with chicken eggs can provide slow-motion charm and an understanding of osmosis. One can dissolve the calcium carbonate shell of a raw egg in vinegar, a process that takes 1–3 days. The egg's inner membrane is tough enough to allow gentle handling. If this shell-less egg is placed in distilled water, it will swell over a period of several hours as water diffuses through the cell membrane. A second naked egg can be placed in corn syrup (a concentrated fructose solution). In this solution, water in the inside of the egg membrane moves out to dilute the surrounding solution, and the egg deflates *(14h).*

Thickening Potion

Who would not benefit from having a good thickening recipe on hand (*3,* p 318)?

> *They had Potions that afternoon, which was an unqualified disaster. Try as Harry might, he couldn't get his Confusing Concoction to thicken. . .*

Pectins for gelling jams and jellies, starches for gravy and pudding making, and gelatin to thicken sweet or savory liquids are all easily available at a grocery store. Failing those thickeners, Harry should look for a disposable diaper, which contains granules of a water-absorbing polymer that would most certainly thicken his potion. Sodium polyacrylate forms a cross-linked gel in water, and it has an "antidote". Adding common table salt to the gel will return it to its original fluidity *(22, 14i).*

Crystal Ball in a Teacup

Even chemists could use a crystal ball on occasion (*3,* p 296).

> *Together they climbed the ladder into the dim, stifling tower room. Glowing on every little table was a crystal ball full of pearly white mist.*

For pure charm, it's hard to beat experiments with dry ice, the solid form of carbon dioxide. The fact that dry ice sublimes (passes from solid to gas at ambient conditions) and can be trapped in various ways leads to fascinating effects.

To make a large-sized crystal ball in a bucket, partly fill the bucket with water and add several chunks of dry ice. Have available a small amount of dilute detergent solution and a piece of polyester fleece fabric[3] two inches wide and several inches longer than the diameter of the bucket. Wet the fleece well with the detergent solution. Hold one end of the fleece in each hand, and gently pull the fabric across the rim of the bucket. You want to make a film of bubble solution completely across the container. As the dry ice continues to sublime, the bubble film will expand with "pearly white mist" *(23).*

Students can make teacup-sized crystal balls using small plastic cups and shorter strips of fleece fabric. It is important not to drip detergent solution into the cup with the dry ice and water, because many small bubbles will form instead of a single "dome".

Wizard Coins

Conjuring the coin of the realm pays off with interest (*1,* p 75).

> *"The gold ones are Galleons", he explained.*
> *"Seventeen silver Sickles to a Galleon and twenty-nine Knuts to a Sickle."*

Wizard coins come in copper, silver, and gold. An old standard method for turning pennies to "silver" and then to "gold" uses granular zinc and boiling sodium hydroxide solution *(24).* The treatment plates a thin layer of zinc on the copper penny. One then heats the zinc-coated penny in a hot burner flame to produce a gold-looking brass surface.

This writer has had better results with a zinc metal in zinc chloride solution *(25),* which seems to produce more reliably adherent zinc coatings. These "Sickles" are turned to "Galleons" with the same hot flame treatment. Heating a zinc-coated coin on a smooth hot plate surface also serves to produce the layer of brass.

Conclusion: More Than Just Magic

J. K. Rowling's series of Harry Potter books has captured the imaginations of millions of readers worldwide. This reader is convinced that Rowling must have had an excellent secondary school science education or an editor who knew some flashy chemistry.

As chemists and educators, we understand the necessity of getting the attention of our audience and the power of illustrating complex phenomena with well-chosen and well-performed demonstrations. The Harry Potter series offers us an opportunity to share science with avid readers, and to encourage our most enthusiastic science students to pick up a well-crafted tale.

Notes

1. K&B Innovations, Inc. Home Page. *http://www.shrinkydinks.com/* (accessed Jul 2006).

2. Magic Sand is a brand of hydrophobic sand. These sites offer more information: *http://www.reade.com/Products/Sand/hydrophobic-sand.html* and *http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=vc2%5c1rp%5crp1_sand.html* (accessed Jul 2006).

3. Malden Mills Polarfleece is one brand. See this Web site for further details: *http://www.maldenmills.com/* (accessed Jul 2006).

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14. (a) Shakhashiri, B. Z. *Chemical Demonstrations*: *A Handbook for Teachers of Chemistry,* Vol. 3; Univ. of WI Press: Madison, WI, 1989; pp 360–361; (b) pp 43–45; (c) pp 51–52; (d) pp 83–84; (e) pp 79–80; (f) 47–49; (g) pp 305–306; (h) pp 283–285; (i) pp 368–371.
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16. Larry Crump's Fireworks Pages. *http://www.wf.net/~lcrump1/* (Provides pictures and general information.) For a general article with links, see the How Fireworks Work Page of the How Stuff Works Web Site: *http://www.howstuffworks.com/fireworks.htm* (both sites accessed Jul 2006).
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19. Suzuki, C. *J. Chem. Educ.* **1991,** *68,* 588–589.
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