# What Makes Magic Tricks Tick

By *Michael Tinnesand*

Two friends, Gary and Jim, walk through the crowded halls of a local high school. Without warning, a boy walking in the opposite direction reaches out and squirts something at one of the students. They look down to find a large splatter of blue ink across the front of Gary's shirt. The boy is lost in the crowd by the time they understand what has happened. As Gary waits in the principal's office to report the damage, he notices that the ink stain is beginning to fade. By the time the principal is ready to see Gary, the ink stain is totally gone! He has been tricked with "disappearing" ink.

## Is this magic?

Good tricks usually have some features in common. The first is an element of surprise, a sense of sudden wonder or amazement, especially when due to something unexpected. We are all familiar with ink stains, and we know they are very difficult to remove from a shirt once they get on it. But in the case of the "disappearing" ink, the stain goes away all by itself, and it does so relatively quickly. Another feature of a trick is the absence of any apparent explanation for what happened. It is not clear why the "disappearing" ink vanished all by itself. But if someone repeated the trick and told you that it wasn't real ink—just a substance that looks like ink—you would probably be much less surprised or confused when the stain vanished.

We can be sure that these tricks are not due to "magic." Magic is a supposed supernatural force that allows impossible things to happen or that changes the laws of nature. The only reason something *appears* to be magic is when the cause of the change is a mystery to us. One of the roles of chemistry is to demystify the unknown or to explain what is not readily explainable.

## Demystifying disappearing ink

How can we explain an unexpected change if it is not really magic? We can apply some chemistry. In the case of disappearing ink, the explanation is simple. The substance is not ink at all but a solution of a special chemical that can change color depending on how much acid or base is in the solution. This special substance is called an acid-base indicator. It turns into a different color when it goes from an acidic to a basic solution.

To tell whether a solution is acidic or basic, scientists use a quantity called pH. A solution is acidic if its pH is between 0 and 7 and basic if its pH is between 7 and 14. A very low pH means that a solution is vey acidic, and a pH close to 14 means that a solution is very basic (or barely acidic).

For instance, when an acid-base indicator called thymolphthalein is added to a solution, it is colorless when the pH of the solution is between 0 and 9.3 and dark blue when the pH is above 9.3 (Fig. 1).

When the disappearing ink is prepared, a strong base such as sodium hydroxide (NaOH) is added to the solution. This keeps the pH above 9.3, and the ink is blue. Things change when the ink is sprayed on clothing. Carbon dioxide ($CO_2$), which is always present in the air, reacts with the water in the solution to form carbonic acid ($H_2CO_3$). First, the

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carbon dioxide dissolves in the water and then very slowly reacts to form carbonic acid:

$$CO_2\ (gas) + H_2O\ (liquid) \rightarrow H_2CO_3\ (aqueous)$$

The carbonic acid rapidly neutralizes some of the sodium hydroxide in the solution, according to the following reaction:

$$2\ NaOH + H_2CO_3 \rightarrow Na_2CO_3 + 2\ H_2O$$

As the sodium hydroxide, which is responsible for the blue color and the high pH value, slowly vanishes from the solution, the pH decreases to the point that the thymolphthalein turns colorless. Not magic, just basic chemistry.

trick. Someone placed "magic" candles on the cake instead of normal birthday candles.

To understand how this trick works, let's see how regular candles work. In a regular candle, the wick is saturated with wax, so when you light the candle, the flame melts, vaporizes, and ignites the wax. This burning wax heats the wax of the main candle and "melts it. Then, the liquid wax rises in the wick and is vaporized by the flame.

The reason the lower part of the exposed wick does not burn—but the wax burns instead—is because the vaporizing wax cools it and prevents the wick from burning. This explains why the little part of the wick that burns is only at the tip, where the wax has completely evaporated.

After the flame has been blown out, it goes out because the draft blows away the wax vapor, which was the only hot part when the candle was lit.

In a "magic" candle, finely divided particles of metal, usually magnesium, have been added to the wick. These particles ignite easily and burn hot enough to ignite the wax vapor after the flame has been blown out. If you look up close, you can see these white-hot particles flashing off the wick.

| pH | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10. | 11. | 12. | 13. | 14. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thymolphthalein | | | | | | | | | | | | | | | |

**Figure 1. Thymolphthalein appears colorless in a solution with a pH between 0 and 7 and blue in a solution with a pH between 11 and 14. For intermediate pH values (between 8 and 10), thymolphthalein's color gradually changes from colorless to blue.**


**Michael has been splattered with disappearing ink. At first, the ink has a blueish color. But after a few minutes, the ink starts to fade!**

## A trick that takes the cake

A better natured trick is a frequent joke at birthday parties. A birthday cake full of candles is placed in front of a person—let's call this person Mike—to celebrate his birthday. After making a wish, he draws a big breath to blow out the candles. At first, he seems successful in blowing them out, but then, slowly, the candles sputter to life and soon, they are burning brightly again. No matter how many times Mike tries, he cannot seem to blow the candles out so they stay out. It's a birthday


**"Magic" candle (left); normal candle (right)**

## Performing under pressure

Some tricks come in the form of a challenge. Two friends, Joe and Anne, set each other up. Anne asks Joe if he thinks he can put a peeled hard-boiled egg into a bottle that

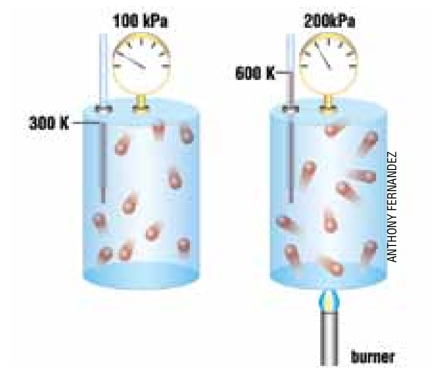
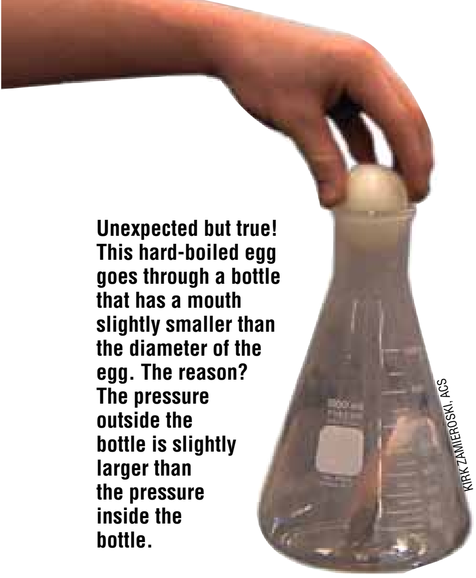



**Figure 2. Schematic representation of Gay-Lussac's Law: The pressure of a given volume of gas increases when its temperature increases and the volume increase is proportional to the temperature increase. Also, the gas molecules move faster at higher temperatures.**

has a mouth slightly smaller than the diameter of the egg. When Joe tries to push the egg into the bottle, it breaks apart into a total mess. He gives up after trying with several more eggs, only to watch in amazement as Anne shows him how it can be done.

First, she lights a small scrap of paper on fire and drops it into the bottle. After a moment, she places an egg on top of the bottle. The paper scrap burns for another second and goes out. Then, as if by magic, the egg slowly begins to move into the neck of the bottle and drops into the bottom of the bottle. Is it a tricked bottle, a tricked egg, or something else?

This trick can be explained with a basic understanding of the behavior of gases. Gases are made of molecules that are relatively far apart. Unlike solids and liquids, gases don't have a defined volume, so they


KIRK ZAMEROSKI, ACS

**Unexpected but true! This hard-boiled egg goes through a bottle that has a mouth slightly smaller than the diameter of the egg. The reason? The pressure outside the bottle is slightly larger than the pressure inside the bottle.**

expand to fill any container. If the temperature of a gas in a closed container is raised, the molecules move faster, and the pressure increases—a phenomenon called the Gay-Lussac's Law.

When Anne dropped the slip of burning paper into the bottle, it caused the temperature of the air inside to increase. Putting the egg in the bottle opening closed the bottle, so the pressure inside the bottle increased. Because the egg was just sitting on top of the bottle, it was lifted by the higher pressure inside, so some air escaped to equalize the pressure inside and outside the bottle.

After the fire went out, the air cooled back down, causing the air molecules to slow down, and the pressure inside dropped. The pressure outside the bottle—now higher than inside the bottle—started pushing the egg against the top of the bottle. Once the air inside the bottle cooled enough and the pressure inside dropped enough, the higher pressure outside pushed the egg through the bottle neck.

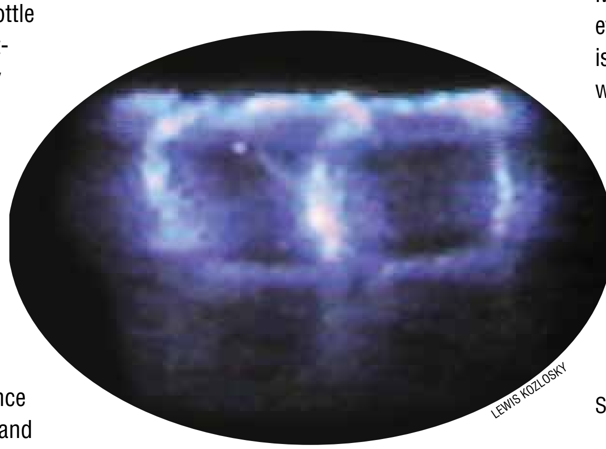
## An illuminating trick

One final trick starts when two students, Sarah and Audrey go into a dark room. There is no light coming in through openings in the door or windows. Sarah puts a wintergreen candy into her mouth and crushes it with her teeth. She pulls her lips back so Audrey can see a beautiful flash of light each time a bit of the candy is crushed between Sarah's teeth. Although the light is pale, it definitely occurs when the wintergreen candy is crushed. Could it be some kind of magic? Or is it chemistry?

This is actually a combination of two effects called triboluminescence and fluorescence. Triboluminescence is the emission of light that results from crushing or pulling apart a material; fluorescence is the emission of light by a substance that has absorbed light of a different color.

When Sarah crushes the candy with her teeth, she shatters sugar crystals. As the sugar crystals are torn apart, they emit light by triboluminescence. For each piece of sugar crystal that is cracked, one section of the crystal ends up with more electrons, giving it a temporary negative charge, while the section that loses the electrons has a temporary positive charge.

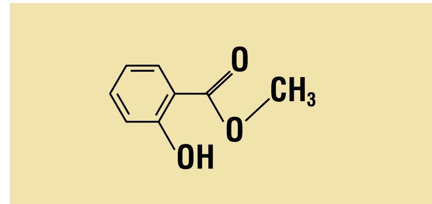

MIKE CIESIELSKI


LEWIS KOZLOSKY

**Crushing a Wint-O-Green Lifesaver gives off a burst of blue light.**

Immediately after these electrons move in the crystal, they rush back to their original positions. Some of them jump through the air in a crack, creating an electrical current that excites nitrogen molecules ($N_2$) in the air. In these excited nitrogen molecules, electrons move from their original energy levels to higher energy levels. A fraction of a second later, these electrons go back to their original energy levels and emit light. Most of this light is ultraviolet, which is invisible.

In addition to this ultraviolet light, there is also light produced by a chemical called methyl salicylate that




**Methyl salicylate**

gives wintergreen its flavor. This chemical produces light by fluorescence—it emits light after absorbing light of a different color. In this case, methyl salicylate absorbs the ultraviolet light produced by the sugar crystals and emits visible, blue light. So, the invisible light created by crushing the sugar crystals in the candy is changed into blue light by the methyl salicylate present in the candy.

## Is it magic or chemistry?

Should we be disappointed that none of these tricks are magical? Not in the least! Maybe the fact that each of the unexpected effects in these tricks was due to basic chemistry should inspire us. After all, much of what we know and understand today is a result of someone observing something unexpected and looking for an explanation. In the end, demystifying everyday chemistry is where we find true magic!

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