SECRET STOPPERS

How do you reveal a message written using lemon juice?

How do you reveal a message written using baking soda?

What properties make these good for invisible inks?

Equipment required:

2 x Glasses
45g baking soda
Lemon
Water
2 x piece paper
Paintbrush
Hairdryer
Grape juice

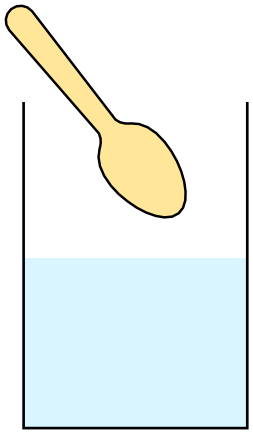
Can you explain the findings?

Secret Stoppers

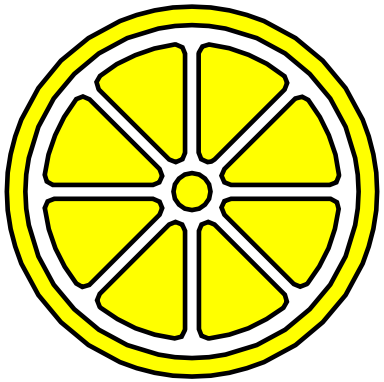
DEPARTMENT OF CHEMISTRY

UNIVERSITY OF OXFORD

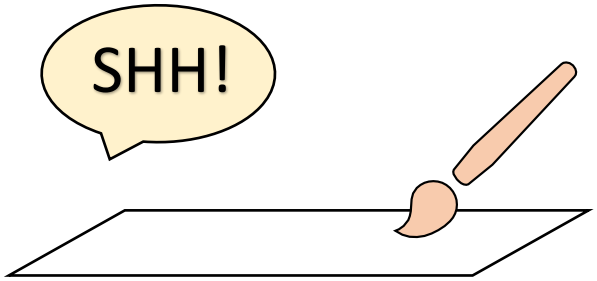
1 Mix together 45g baking soda with 60 mL water



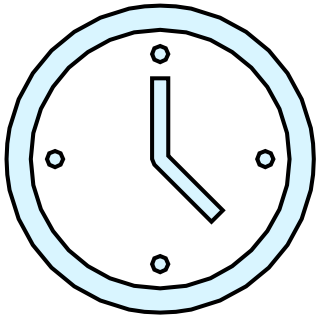
2 Squeeze the juice of half a lemon into a bowl. Add a few drops of water



3 Write two messages on separate pieces of paper using the two solutions

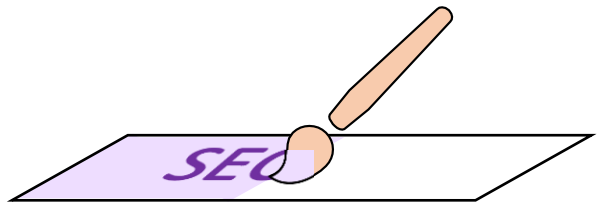


4 Label each message with which solution was used. Leave the secrets to dry.



5 Using a hairdryer, heat the paper containing the lemon juice message to reveal!

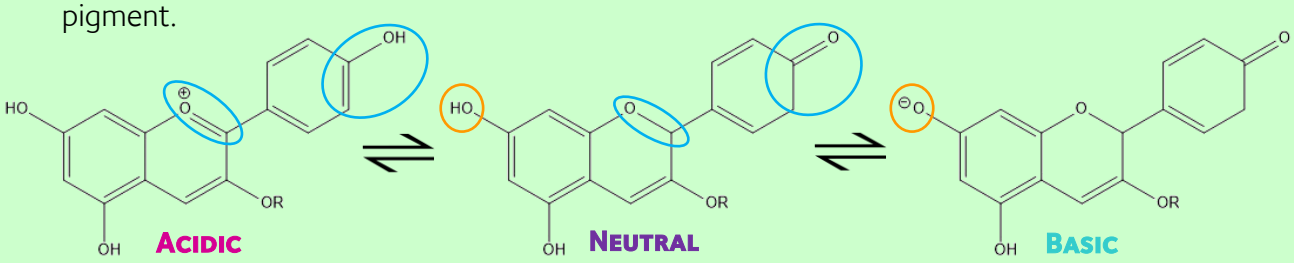
6 Paint over the baking soda message with grape juice to reveal the secret!



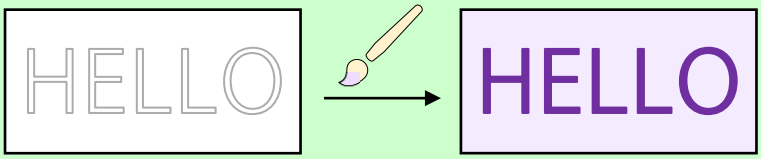
The science behind the scenes...

Invisible inks remain unseen and invisible until we do something/apply something to the paper to expose the message.

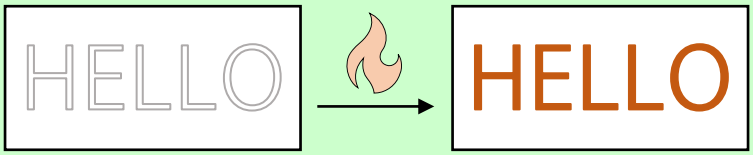
Baking soda dissolved in water acts as a good invisible ink. When the ink is left to dry, the water evaporates leaving behind the baking soda as small white crystals on the paper. We can use grape juice to reveal the hidden baking soda message. Grape juice contains a molecule called anthocyanin, which acts as a natural **indicator**. The molecule changes structure slightly in acidic and basic environments which changes the colour of the pigment.



Grape juice itself is **acidic** (pH<7) and so has a purple-red colour. In **basic** environments (pH>7), the molecule darkens to a blue-green colour. Baking soda is a basic substance, so a **neutralization** reaction occurs with the grape juice when its applied to raise the pH, darkening the juice. Therefore, painting over the baking soda message with grape juice reveals the message, darkening the areas where the baking soda solution was applied.



Lemon juice is another example of an invisible ink. Lemon juice contains the **organic** (=carbon containing) molecule citric **acid**. When heated, the citric acid begins to break down. As the molecule breaks down, the carbons in the molecule become exposed to the air and reacts with the oxygen in the air. This reaction is an **oxidation** reaction, and it is this reaction which causes the darkening on the paper that reveals the secret message.



Practical investigation:

Equipment:

- ☐ 2 x Glasses
- ☐ 45g baking soda
- ☐ Lemon
- ☐ Water
- ☐ 2 x piece paper
- ☐ Paintbrush
- ☐ Hairdryer
- ☐ Grape juice

Method:

1. Add 4 level tablespoons of baking soda to a glass. Add 60mL water and mix together thoroughly.
2. Squeeze the juice of half a lemon into a bowl. Add a few drops of water to the lemon juice to dilute.
3. Write a message on a piece of paper using the baking soda solution. Label the piece of paper as "soda".
4. Write a second message on another piece of paper using the lemon juice solution. Label the piece of paper as "lemon".
5. Leave the messages to dry completely- the messages will become invisible when completely dry.
6. Use a hairdryer to heat the piece of paper with the lemon juice secret message to reveal the secret message.
7. Use a paintbrush to paint the piece of paper with the baking soda secret message with grape juice to reveal the secret message.

Questions:

(a) Is lemon juice acidic or basic? [acidic]

(b) What happened when you heated the piece of paper with the lemon juice secret message on?
[the message revealed as a dark brown colour as the citric acid in lemon juice breaks down upon heating and is oxidized by the oxygen in the air]

(c) Are baking soda and grape juice acidic or basic?
[baking soda is basic, grape juice is acidic]

(d) What happened when you painted the grape juice over the piece of paper with the baking soda secret message on?
[the message revealed as a darker purple/blue colour as the natural pigment anthocyanin acts as an indicator responding to the change of pH where the baking soda is present]

(e) **Challenge:** Do you think the baking soda ink could also be revealed by being exposed to a heat source?

[Yes, it can! The baking soda disrupts the cellulose fibres in the paper. The exposed ends of the fibres then darken and burn before the undamaged sections of the paper, revealing the ink as it darkens.]

Science isn't just useful in the lab...

Invisible inks have an interesting history, with their use dating back over 2000 years.

Invisible inks have been widely developed and used to send messages during war. During the American revolution, the British used two types of invisible inks as methods of communication. One would be revealed upon exposure to **heat** (which would be labelled by "F") and the other would be made visible when exposed to **acid** (labelled by "A"). These could be easily exposed by their enemies, so there become a desire to find inks which would be revealed only by a certain chemical, as a result of a **reaction**.

During World War One, it was discovered that iodine could be used as a universal reagent to expose lots of different inks. Iodine turns the inks brown by revealing where the fibres in the paper had been changed by the moisture. The task for scientists then became to find an ink that could be used that would **not** be easily revealed by the other side using heat, iodine or UV light. One example of such an ink, which was developed by the Germans, was an ink that would be revealed once the paper had been moistened, sprinkled with a red powder containing a molecule called naphthalene, heated to 60 °C and exposed to UV light- a long process making it harder to be discovered!

If you liked this activity, make sure to check out our Kitchen Chemistry: **Food Indicators** activity!

Photo citations:

https://www.gettyimages.co.uk/detail/illustration/hair-dryer-icon-royalty-free-illustration/1135950301?adppopup=true