Demonstration corner

The Belousov-Zhabotinsky reaction

Ever wondered what to do with that 'redundant' overhead projector stored away in one of your cupboards? Within the Chemistry Team at SSERC we have been looking at variants of the Belousov-Zhabotinsky reaction (an example of an oscillating chemical reaction) and the version presented here is probably best seen using an OHP and screen. In addition to your OHP, you will need [1] the following solutions:

A) $NaBrO_3$ (5 g in 100 cm^3 distilled water);
B) NaBr (10 g in 100 cm^3 distilled water);
C) Malonic acid (10 g in 100 cm^3 distilled water);
D) Sulfuric acid (6.0 mol dm^{-3}) [**corrosive**];
E) Ferroin - prepared from 1, 10 phenanthroline* ([**toxic**] 1.35 g, CAS Number 5144 89-8]), $FeSO_4$ (0.7 g) in 100 cm^3 distilled water.

[$KBrO_3$ and KBr can be used in place of the sodium salts above].

1) In a well-ventilated laboratory or fume hood, place 5.0 cm^3 of solution A into a beaker and add 1.0 cm^3 of each of solutions B, C and D. The mixture will be a yellow/brown colour because bromine is produced.
2) Stir the mixture until the yellow/brown colour completely disappears.
3) Add 2.0 cm^3 of solution E and swirl to mix. Pour the mixture into a Petri dish and place the dish on the OHP. The solution at this stage may be blue in colour and will turn red in a short period of time (over a few seconds). Gently swirl the dish to ensure through mixing and leave it to stand on the OHP.

Over the next few minutes tiny blue spots will start to appear and these will expand eventually producing a series of concentric rings. The reaction, which can be re-started at any time by gently mixing the solution, will continue for up to an hour. For those of you with steady hands try joining blue rings together by gently dragging the point of some scissors across the surface of the mixture! The images shown in Figure 1 were taken at various times after mixing.

Mechanism

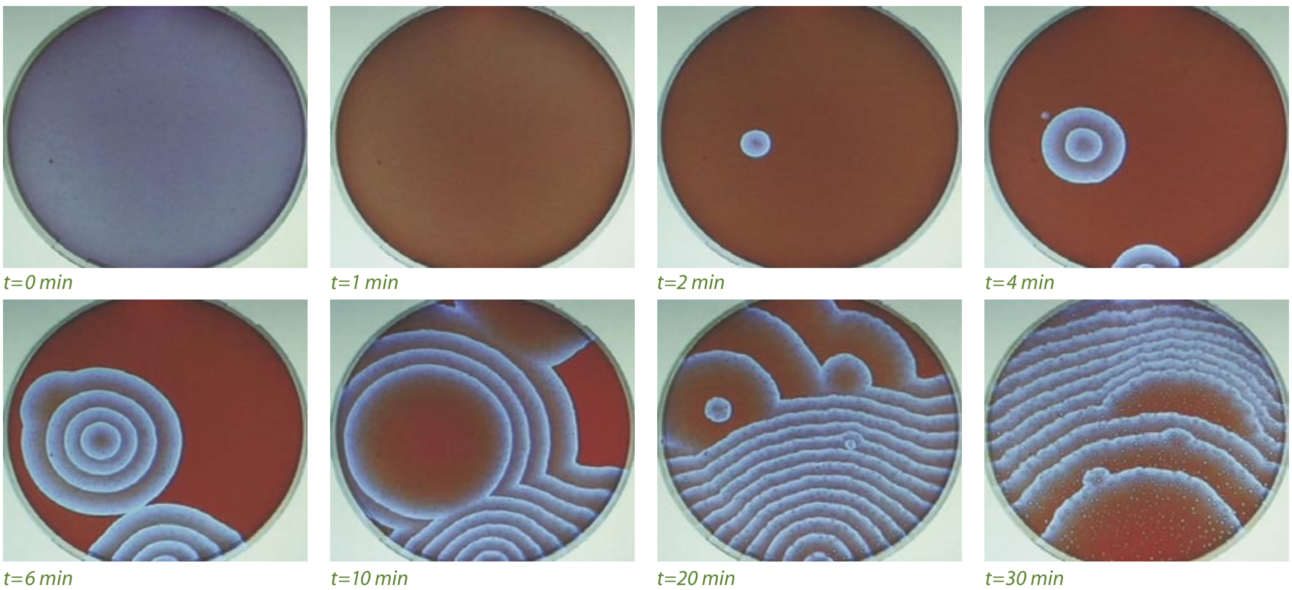
The reaction mechanism of the Belousov-Zhabotinsky is quite complex [2, 3] and the reaction mixtures for a number of variants have been published [3]. Figure 2, which has its origins in the work of Winfree [4], goes some way to summarise the overall series of reactions which is occurring.

The detailed sequence of reaction is more complex than that shown in Figure 2.

The reaction mechanisms of all known oscillating chemical reactions have at least three common features [3]:

- While the oscillations occur the chemical mixture is far from equilibrium and an energy releasing reaction occurs which drives the oscillating 'sideshow'.
- The energy-releasing reaction can follow at least two different pathways and the reaction periodically switches from one pathway to another.

Figure 1 *- Colour changes observed 0, 1, 2, 4, 6, 10, 20 and 30 minutes after mixing.*



* We use 1,10 phenanthroline monohydrate since that is what we have in stock. Because the reaction is inhibited by chloride ions it is important not to use the hydrochloride salt.

- One of the pathways produces an intermediate while another pathway consumes it and the change in concentration of the intermediate is a trigger to switch between pathways.

Summary and conclusions

An understanding of the kinetics of oscillating reactions has application in a number of different fields - some more surprising than others (for example see the link to predator/prey relations ships in [5]) and so their study is warranted for all sorts of reasons! Our advice though is to try out this interesting and intrinsically beautiful demonstration before you finally make the decision to throw away all the departmental OHPs!

Safety considerations

In addition to the cautionary statements above, solutions of phenanthroline are harmful to the environment and appropriate precautions should be taken to ensure their safe disposal.

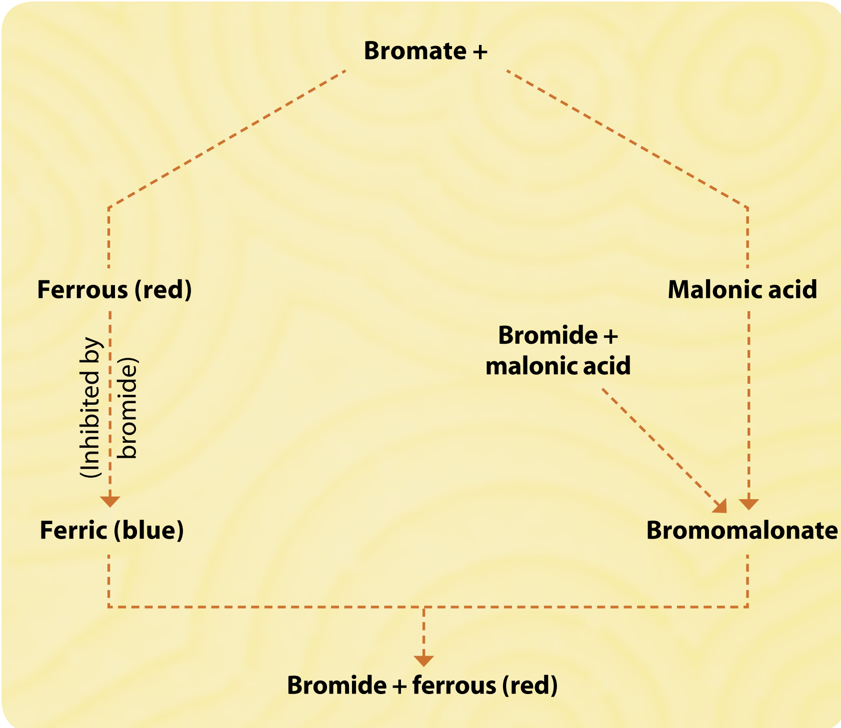


Figure 2 *- The Winfree Oscillator (see [4]).*

References

[1] Kolb, D. (1988), Oscillating reactions, *J. Chem. Educ.*, **65**, 1004.

[2] Kemsley, J. (2011), Chemical oscillations: The Belousov-Zhabotinsky reaction. Available at http://cenblog.org/the-safety-zone/2011/09/chemical-oscillations-the-belousov-zhabotinsky-reaction/ (accessed May 8th 2013).

[3] Shakhashiri, B.Z. (1985), Oscillating chemical reactions in *Chemical Demonstrations: A Handbook for Teachers of Chemistry Volume 2*, pp 232-247, University of Wisconsin Press, Madison.

[4] Walker, J. (1978), Chemical systems that oscillate between one color and another. Available at http://jesseenterprises.net/amsci/1978/07/1978-07-body.html (accessed May 8th 2013).

[5] Nuffield Foundation (Practical Chemistry), An oscillating reaction. Available at http://www.nuffieldfoundation.org/practical-chemistry/oscillating-reaction (accessed May 8th 2013).

Residential courses - Autumn term 2013/2014

Amongst other things, we're gearing up for our 2 part residential courses to support secondary chemistry, biology and physics teachers. Our focus for these courses will be practical work covering aspects of National 4 and 5. With lots of ideas, hints and tips (not to mention loads of resources to take-away) these events are not be missed!

Full details of these and all our other courses are available on our website - visit www.sserc.org.uk and look at the section marked CPD.

Don't wait too long the first parts of these courses are coming up soon!