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Let's make a chemical clock

Info sheet 3: The hypothesised chemical clock mechanism

It's well known that the decomposition of hydrogen peroxide into water and oxygen is catalysed by the iodide ion: a famous example of this is the elephant toothpaste experiment![1] However, the oscillating mechanism in the decomposition of hydrogen peroxide occurs only when the iodide ion is generated by reduction through vitamin C. In this case, as in the experiment described, hydrogen peroxide appears to 'hesitate' before decomposing. Why? That suggests the presence of oscillations caused by interacting intermediate chemical species developed both in the reaction with vitamin C and in the hypothesised mechanism of iodide-catalysed decomposition of hydrogen peroxide. When the decomposition of hydrogen peroxide is realised using potassium iodide, the following steps are currently considered the most likely:[2,3]

$H_2O_2 + I^- \rightarrow H_2O + OI^-$

$H_2O_2 + I^- + H^+ \rightarrow H_2O + HOI$

$OI^- + H_2O_2 \rightarrow H_2O + I^- + O_2$

$HOI + H_2O_2 \rightarrow H_2O + H^+ + I^- + O_2$

The reported mechanism is the result of many studies, starting from research on similar reactions such as those initially examined by Bray and Caulkin in the 1920s. According to recent research, the reaction between iodine and vitamin C most likely involves the intermediates OI^- and HOI, the same ones present in the decomposition:

$H_2O_{2\,(aq)} \rightarrow H_2O_{(l)} + O_{2(g)}$

This decomposition is catalysed by the iodide ion, which evolves according to the steps described above, **also generating iodine** in the process:

$3\ I^-_{(aq)} + H_2O_{2(aq)} \rightarrow I_3^-{}_{(aq)} + 2\ OH^-_{(aq)}$

(The triiodide ion dissociates into iodine and iodide within an equilibrium reaction).

The intermediates formed during the reactions involved in the chemical clock interact via parallel pathways involving autocatalytic and autoinhibitory stages. These pathways give rise to the concentration oscillations, which cause the periodic changes mixture's hue.

References

[1] Eldridge DW (2015) Using Elephant's Toothpaste as an Engaging and Flexible Curriculum Alignment Project. *J. Chem. Educ.* **92**: 1406-1408- doi: 10.1021/acs.jchemed.5b00037

[2] Wright SW, Reedy P (2002) The vitamin C clock reaction. *J. Chem. Educ.* **79**: 41-43. doi: 10.1021/ed079p41

[3] Ruekberg B (2020) A Closer Examination of the Mechanism of the Hydrogen Peroxide Iodine-Clock Reaction with Respect to the Role of Hypoiodite Species. *J. Chem. Educ.* **97**:1688-1693. doi: 10.1021/acs.jchemed.9b00006