The chemistry of thiosulfate ions – teacher notes

Topic
Redox reactions; transition elements – redox reactions, catalysis, variable oxidation states.

Timing
20 minutes

Description
Sixth-form students usually encounter sodium thiosulphate in volumetric analysis where it is used as the titrant in a redox reaction with iodine:

$I_2(s) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

However, in this experiment students investigate some of the many interesting reactions of sodium thiosulphate. These reactions illustrate many important chemical principles.

Apparatus
- Student worksheet
- Clear plastic sheet (eg OHP sheet)

Chemicals
Solutions should be contained in plastic pipettes. See the accompanying guidance on apparatus and techniques for microscale chemistry, which includes instructions for preparing a variety of solutions here https://rsc.li/3ydAQom

- Silver nitrate, 0.1 mol dm^{-3}
- Sodium chloride, 0.1 mol dm^{-3}
- Potassium bromide, 0.2 mol dm^{-3}
- Potassium iodide, 0.2 mol dm^{-3}
- Iron(III) nitrate, 0.1 mol dm^{-3}
- Copper(II) sulfate, 0.2 mol dm^{-3}
- Iodine solution, 0.05 mol dm^{-3} in 0.2 mol dm^{-3} KI.

Observations
Part A
The brown colour of iodine is discharged as it is reduced by thiosulphate ions:
$I_2(aq) + S_2O_3^{2-}(aq) \rightarrow 2I–(aq) + S_4O_6^{2-}(aq)$

Part B
The addition of halide ions to the silver nitrate solution produces precipitates of the silver halides – pale yellow (silver bromide) and deeper yellow (silver iodide). Silver bromide dissolves readily in sodium thiosulphate solution, whereas silver iodide is less soluble. This could be used as a test to distinguish a bromide from an iodide.

$Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$

Silver Ion	Halide Ion	Silver Halide

The dissolution of silver bromide in thiosulfate solution is used in the fixing stage in photographic developing. Here, thiosulfate is used to dissolve unreacted silver bromide through the formation of soluble complexes such as $Ag(S_2O_3)_2^{3-}(aq)$.

Part C

The reaction of iron(III) with thiosulfate produces a deep violet complex anion, Fe(S2O3)2– This decomposes slowly with the fading of the violet colour:

$Fe(S_2O_3)_2^-(aq) + Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + S_4O_6^{2-}(aq)$

The presence of copper(II) ions catalyses the decomposition reaction, and the violet colour fades more rapidly.

Thiosulfate reduces Cu(II) to Cu(I) and complexes the Cu(I):

$2S_2O_3^{2-} + 2Cu^{2+}(aq) \rightarrow 2Cu^+(aq) + S_4O_6^{2-}(aq)$
$2Cu^+(aq) + 2S_2O_3^{2-} \rightarrow Cu_2(S_2O_3)_2^{2-}(aq)$

The characteristic blue colour of copper(II) fades, leaving a colourless solution containing the complex ion $Cu_2(S_2O_3)_2^{2-}(aq)$.

Health, safety and technical notes

- Read our standard health and safety guidance here https://rsc.li/3SWS6q5
- Wear eye protection for part B and splash resistant goggles to BS EN166 3 for part C.
- Silver nitrate, AgNO3(aq), 0.1 mol dm^{-3} is an eye irritant (see CLEAPSS Hazcard HC087). Keep separate from organic waste containers.
- Copper(II) sulfate 0.2 mol dm^{-3} causes eye damage and is toxic to aquatic life (see CLEAPSS Hazcard HC027c).
- Iron(III) nitrate, $Fe(NO_3)_3.9H_2O(aq)$,0.1 mol dm^{-3} (see CLEAPSS Hazcard HC055c), potassium bromide, KBr(aq), 0.2 mol dm^{-3}, and potassium iodide, KI(aq), 0.2 mol dm^{-3} (see CLEAPSS Hazcard HC047b), are low hazard. As is Iodine solution 0.05 mol dm^{-3}, but this is also toxic to aquatic life (see CLEAPSS Hazard HC054).
- Sodium thiosulphate, 0.1 mol dm^{-3} is low hazard (see CLEAPSS RB087 for preparation and Hazcard HC95a).