Oxidation states of iron – teacher notes

In this experiment, students compare the chemistry of the two main oxidation states of iron (a first row transition element) and consider explanations for any differences observed.

Students must wear eye protection.

Topic

Iron chemistry; transition elements; oxidation states; precipitation and redox reactions; complexes

Timing

20 minutes

Equipment

Apparatus

- Eye protection
- Student worksheet
- Clear plastic sheet (eg ohp sheet)
- Magnifying glass

Chemicals

Solutions should be contained in plastic pipettes. See the accompanying guidance on apparatus and techniques for microscale chemistry (https://rsc.li/3f8sm7Z), which includes instructions for preparing a variety of solutions.

- Sodium hydroxide, 1 mol dm^{-3}
- Potassium manganate(VII), 0.01 mol dm^{-3}
- Potassium iodide, 0.2 mol dm^{-3}
- Iron(II) sulfate, 0.2 mol dm^{-3}
- Iron(III) nitrate, 0.2 mol dm^{-3}
- Silver nitrate, 0.2 mol dm^{-3}
- Potassium thiocyanate, 0.1 mol dm^{-3}
- Starch solution (freshly made)

Teaching notes

Expected observations

1. The addition of sodium hydroxide produces a gelatinous green precipitate with iron(II) solution and a brown precipitate with iron(III) solution. On standing, oxidation causes

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the iron (II) hydroxide to turn brown-yellow colour due to gradual formation of iron(III) hydroxide.

$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$

2. The thiocyanate ion gives a deep red colour with iron(III) but should give virtually no colour with iron(II). However, unless it is very pure and freshly prepared, iron(II) will probably give a faint red colour due to the presence of some iron(III).

3. Iron(III) oxidises iodide ions to iodine which gives the characteristic blue-black colour with starch. Iron(II) should give no reaction unless it contains some iron(III).

   $2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow I2(aq) + 2Fe^{2+}(aq)$

4. The deep purple colour of manganate(VII) ions gradually diminishes as it is reduced by iron(II) whereas iron(III) has no effect.

   $MnO^{4-}(aq) + 5Fe^{2+}(aq) + 8H^{+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$

5. The reaction of silver nitrate and iron(II) ions produces a glittering of metallic silver which is seen using a magnifying glass. There is no corresponding reaction with iron(III) ions.

Tips

These experiments can be done quickly so students might be encouraged to develop their explanations for the reactions. A book of data would be useful so that students can look up redox potentials. A biochemical development would be to consider the role of iron in haemoglobin and the types of iron compounds found in iron tablets (iron(II) is required for haemoglobin, the +2 oxidation state being stabilised by complexation).

The fact that many iron(II) compounds contain some iron(III) could form the basis of a discussion on the purities of chemical compounds.

Health, safety and technical notes

- Read our standard health and safety guidance (https://rsc.li/33BtHyy).
- Wear eye protection throughout (splash-resistant goggles to BS EN166 3).
- Sodium hydroxide solution, NaOH(aq), 1 mol dm^{-3} is CORROSIVE. See CLEAPSS Hazcard HC091a and CLEAPSS Recipe Book RB085.
- Silver nitrate, $AgNO_3(aq)$, 0.2 mol dm^{-3} is a skin/eye irritant. Keep separate from organic waste containers. See CLEAPSS Hazcard HC087 and CLEAPSS Recipe Book RB077.
- The following chemicals are of low hazard:
  - Potassium iodide, KI(aq), 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC047b and CLEAPSS Recipe Book RB072.
  - Iron(II) sulfate, $FeSO_4.7H_2O(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC055B and CLEAPSS Recipe Book RB051.

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- Iron(III) nitrate, $Fe(NO_3)_3.9H_2O(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC055C and CLEAPSS Recipe Book RB052.
- Potassium thiocyanate, KSCN(aq), 0.1 mol dm^{-3} – see CLEAPSS Hazcard HC095A and CLEAPSS Recipe Book RB122.
- Potassium manganate(VII), $KMnO_4(aq)$, 0.01 mol dm^{-3} (not hazardous < 0.01 M) – see CLEAPSS Hazcard HC081 and CLEAPSS Recipe Book RB073.
- Starch solution – see CLEAPSS Recipe Book RB123.

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