The transition elements – teacher notes

In this experiment, students conduct a series of tests to examine the chemistry of the transition elements on a microscale. In particular, they identify evidence of complex formation and change in oxidation state – two important general characteristics of transition elements.

Topic

Transition elements – variable oxidation state, redox and precipitation reactions, complex compounds; chemistry and colour

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/3nRRXpz), including instructions for preparing a variety of solutions.

- Potassium chromate, 0.2 mol dm^{-3}
- Potassium manganate(VII), 0.2 mol dm^{-3}
- Cobalt nitrate, 0.5 mol dm^{-3}
- Ammonia solution, 3 mol dm^{-3}
- Ammonium vanadate(V), 0.2 mol dm^{-3}
- Hydrochloric acid, 1 mol dm^{-3}
- Sodium hydroxide, 1 mol dm^{-3}
- Copper(II) sulfate, 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}
- Potassium iodide, 0.2 mol dm^{-3}
- Starch solution (freshly made)
- Zinc metal granules

Teaching notes and expected observations

Vanadium

Bubbles (of hydrogen) are seen. The yellow colour of the ammonium vanadate (vanadium(V) ions) gradually changes (as the vanadium is reduced) to blue due to the formation of the vanadium(IV) ions (VO^{2+}). The colour changes to green due to vanadium(III) ions (V^{3+}) and possibly to lilac due to vanadium(II) ions (V^{2+}) (although this species is a strong reducing agent and is very air-sensitive).

Chromium

A red precipitate of silver chromate(VI) is seen. This is an interesting example of the modification of the colour of a coloured anion (yellow chromate(VI) by a colourless cation (silver(I)).

Manganese

The deep purple colour of the potassium manganate(VII) gradually fades, first to the brown manganese(IV) oxide then to the very pale pink manganese(II) ions.

(Manganese(II) compounds in solution usually appear virtually colourless. However, a bottle of a solid manganese(II) salt – eg the sulfate – is pink.)

Iron

A yellowish colour (due to iodine) starts to form as the iron(II) oxidises the iodide. Addition of starch produces the characteristic intense blue-black colour of the starch– iodine complex.

Cobalt

The addition of one drop of ammonia gives a deep green precipitate. Addition of further ammonia gives a green or brown solution.

Copper

The addition of ammonia gives a light blue precipitate of copper(II) hydroxide together with the deep blue tetra-amminocopper(II) ion.

Zinc

A white precipitate of zinc hydroxide is observed. (Zinc is not a transition metal because it only has one oxidation state in its compounds and the Zn^{2+} ion has a full d-sub-shell.)

Health, safety and technical notes

- Read our standard health and safety guidance (https://rsc.li/3vDwEuC).
- Wear eye protection throughout (splash-resistant goggles to BS EN166 3).
- Potassium chromate, K_2CrO_4, 0.2 mol dm^{-3} is a carcinogen, mutagen and skin sensitiser. It is also toxic to aquatic life. Wear splash-proof eye protection if transferring large amounts. Avoid skin contact. See CLEAPSS Hazcard HC078a and CLEAPSS Recipe Book RB069.

- Potassium manganate(VII), 0.2 mol dm^{-3} is hazardous to the aquatic environment. Avoid direct contact and store in the dark, stains glass, plastic, clothing and skin. See CLEAPSS Hazcard HC081 and CLEAPSS Recipe Book RB073.
- Ammonia solution, $NH_3(aq)$, 3 mol dm^{-3} is CORROSIVE and a respiratory irritant. See CLEAPSS Hazcard HC006 and CLEAPSS Recipe Book RB006.
- Ammonium vanadate(V), NH_4VO_3, 0.2 mol dm^{-3} (acidified with sulfuric acid) is a mutagen and very TOXIC if inhaled (but not by other routes). See CLEAPSS Hazcard HC009B.
- Sodium hydroxide solution, NaOH(aq), 1 mol dm^{-3} is CORROSIVE. See CLEAPSS Hazcard HC091a and CLEAPSS Recipe Book RB085.
- Cobalt nitrate, 0.5 mol dm^{-3} is a carcinogen, mutagen, reproductive toxin, skin and respiratory sensitiser and hazardous to the aquatic environment. See CLEAPSS Hazcard HC025 and CLEAPSS Recipe Book RB030.
- Copper(II) sulfate solution, $CuSO_4(aq)$, 0.2 mol dm^{-3} causes eye damage and is hazardous to the aquatic environment. See CLEAPSS Hazcard HC027c and CLEAPSS Recipe Book RB031.
- Silver nitrate, $AgNO_3(aq)$, 0.1 mol dm^{-3} is a skin/eye irritant. Keep separate from organic waste containers. See CLEAPSS Hazcard HC087 and CLEAPSS Recipe Book RB077.
- Zinc powder, Zn(s) is FLAMMABLE and hazardous to the aquatic environment. See CLEAPSS Hazcard HC107.
- The following are of low hazard:
    - Hydrochloric acid, HCl(aq), 1 mol dm^{-3} – see CLEAPSS Hazcard HC047a and CLEAPSS Recipe Book RB043.
    - Potassium thiocyanate, KSCN(aq), 0.1 mol dm^{-3} – see CLEAPSS Hazcard HC095A and CLEAPSS Recipe Book RB122.
    - Potassium iodide, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC047b and CLEAPSS Recipe Book RB072.
    - Starch solution – see CLEAPSS Recipe Book RB123.
    - Iron(III) nitrate, $Fe(NO_3)_3.9H_2O(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC055C and CLEAPSS Recipe Book RB052.
    - Iron(II) sulfate, $FeSO_4.7H_2O(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC055B and CLEAPSS Recipe Book RB051.