Observing chemical changes – teacher notes

In this experiment students observe the changes that occur when they mix solutions of various chemicals in a range of displacement, redox and precipitation reactions.

Topic

Displacement, redox and precipitation reactions; 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/3xZITVp), which includes instructions for preparing a variety of solutions.

- Barium nitrate, 0.2 mol dm^{-3}
- Sodium sulfate, 0.5 mol dm^{-3}
- Lead nitrate, 0.5 mol dm^{-3}
- Ammonia solution, 3 mol dm^{-3}
- Ammonium vanadate(V), 0.2 mol dm^{-3} (acidified with sulfuric acid)
- Hydrochloric acid, 1 mol dm^{-3}
- Sodium hydroxide, 1 mol dm^{-3}
- Potassium manganate(VII), 0.01 mol dm^{-3}
- Silver nitrate, 0.1 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}
- Potassium thiocyanate, 0.2 mol dm^{-3}
- Zinc metal granules

Teaching notes and expected observations

The following notes explain the expected observations for each step/reaction:

1. A dense white precipitate of barium sulfate forms. Barium sulfate is used as a barium meal in medicine since it is opaque to X-rays. Because it is very insoluble it is non-toxic, unlike other, soluble, barium compounds.
2. A bright yellow precipitate of lead nitrate forms. Lead nitrate is a very effective pigment but it is toxic.
3. A deep red colour is produced due to iron(III) thiocyanate ions. This reaction is used to test for the presence of iron.
4. A deep blue colour of tetra-amminocopper(II) forms. There may also be some light blue precipitate of copper(II) hydroxide.
5. Bubbles (of hydrogen) are seen. The yellow colour of the ammonium vanadate gradually changes (as the vanadium is reduced) to blue owing to the formation of the vanadium(IV) ion (VO^{2+}). The colour then changes to green due to the vanadium(III) ion (V^{3+}) and finally to lilac due to the vanadium(II) ion (V^{2+}). The changes in oxidation states of vanadium salts have been investigated for applications in battery technology.
6. A greenish precipitate of iron(II) hydroxide forms. This gradually changes to the brown iron(III) hydroxide as the iron is oxidised.
7. The deep purple colour of the potassium manganate(VII) gradually fades first to the brown manganese(IV) dioxide and then to the pale pink manganese(II) ion (Mn^{2+}). Manganese(II) compounds in solution usually appear virtually colourless. However, a solid manganese(II) salt is pink.
8. Barium hydroxide forms. This is soluble so nothing is seen at first. Barium hydroxide is alkaline and gradually absorbs carbon dioxide from the air to form the insoluble barium carbonate. The drop takes on a hazy appearance as a skin of barium carbonate forms on the surface.
9. A glittering of metallic silver forms as the iron(III) reduces the silver nitrate. This is seen clearly using a magnifying glass.
10. The surfaces of the pieces of zinc turn red-brown as copper metal deposits via a displacement reaction. The blue colour of the copper(II) sulfate solution fades.

Steps 9 and 10 in the procedure both involve the displacement of a valuable, but less reactive, metal using a less valuable, but more reactive, metal. This could be used as a topic for discussion.

Health, safety and technical notes

- Read our standard health and safety guidance (https://rsc.li/3f5Yb13).
- Wear eye protection throughout (splash-resistant goggles to BS EN166 3).
- Silver nitrate, $AgNO_3(aq)$, 0.1 mol dm^{-3} is an eye irritant. Keep separate from organic waste containers. See CLEAPSS Hazcard HC087 and CLEAPSS Recipe Book RB077.

- Lead nitrate, $Pb(NO_3)_2(aq)$, 0.5 mol dm^{-3} is a reproductive toxin, causes eye damage, causes damage to organs (especially the CNS) and is harmful to the aquatic environment. Avoid inhalation and skin contact. See CLEAPSS Hazcard HC057a and CLEAPSS Recipe Book RB053.
- Ammonia solution, $NH_3(aq)$, 3 mol dm^{-3} is CORROSIVE. 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 extremely toxic if inhaled – but not by any other route. See CLEAPSS Hazcard HC009B.
- Sodium hydroxide solution, NaOH(aq), 1 mol dm^{-3} is corrosive. See CLEAPSS Hazcard HC091a and CLEAPSS Recipe Book RB085.
- 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.
- The following chemicals are all of low hazard:
    - Barium nitrate, $Ba(NO_3)_2(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC011 and CLEAPSS Recipe Book RB010.
    - Sodium sulfate, $Na_2SO_3(aq)$, 0.5 mol dm^{-3} – see CLEAPSS Hazcard HC098B and CLEAPSS Recipe Book RB107.
    - Hydrochloric acid, HCl(aq), 1 mol dm^{-3} – see CLEAPSS Hazcard HC047a and CLEAPSS Recipe Book RB043.
    - Iron(II) sulfate, $FeSO_4.7H_2O(aq)$, 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC055B and CLEAPSS Recipe Book RB051.
    - 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 manganate(VII), 0.01 mol dm^{-3} – see CLEAPSS Hazcard HC081 and CLEAPSS Recipe Book RB073.
    - Potassium thiocyanate, KSCN(aq), 0.2 mol dm^{-3} – see CLEAPSS Hazcard HC095A and CLEAPSS Recipe Book RB122.
    - Zinc metal granules – see CLEAPSS Hazcard HC107.