The equilibrium between two coloured cobalt species

Demonstration

The two different coloured Co(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, exist together in equilibrium in solution in the presence of chloride ions:

$[Co(H_2O)_6]^{2+}(aq)$(**pink**) + $4Cl^-(aq)$ ⇌ $[CoCl_4]^{2-}(aq)$(**blue**) + $6H_2O(l)$

This **equilibrium** can be disturbed by changing the chloride ion **concentration** or by changing the **temperature**. The colour changes accompanying the changes in equilibrium position are as predicted by **Le Chatelier's principle**.

Lesson organisation

The distinctive colours of the two cobalt(II) species in solution produce an attractive visual demonstration of a reversible reaction and the effect of concentration and temperature on the position of equilibrium.

The demonstration can be used to introduce reversible reactions and chemical equilibrium or to illustrate Le Chatelier's principle once these concepts have been established. If students are unfamiliar with the formulae of complex ions this may confuse the issue. For the purposes of this discussion the equilibrium could adequately be represented by:

Pink cobalt species + chloride ions ⇌ Blue cobalt species + water molecules

A white background will help to show the colour changes to best effect. For big groups the reactions should be scaled up, using larger containers such as measuring cylinders or beakers, to improve visibility.

The demonstration could also be adapted for use as a class experiment with suitable groups.

Time taken should be about 10 min.

Apparatus	Chemicals
Eye protection for the demonstrator **Boiling tubes, 6** **Rack for boiling tubes, 1 or 2 (depending on capacity)** **Measuring cylinder (100 cm^3)** **Beakers (250 cm^3), 3** **Dropping pipettes, 2** **Access to a top-pan balance**	*The quantities of chemicals given are for one demonstration:* Cobalt(II) chloride-6-water (TOXIC, DANGEROUS FOR THE ENVIRONMENT), 4.0 g Concentrated hydrochloric acid (CORROSIVE), 100 cm^3 Crushed ice, about 200 cm^3 **Refer to Health & Safety and Technical notes section below for additional information.**

Health &Safety and Technical notes

Read our standard health &safety guidance

Cobalt(II) chloride-6-water, $CoCl_2.6H_2O(s)$, (TOXIC, DANGEROUS FOR THE ENVIRONMENT) - see CLEAPSS *Hazcard*. As cobalt(II) chloride is a skin sensitiser, take care to avoid skin contact and wash hands well after use.

Concentrated hydrochloric acid, HCl(aq), (CORROSIVE) - see to CLEAPSS *Hazcard*.

Procedure

Before the demonstration

a Boil a beaker of water and prepare a beaker of crushed ice and water.

b Dissolve about 4 g of cobalt(II) chloride-6-water in 40 cm^3 of water in a beaker. A reddish-pink, approximately 0.4 M solution will be formed, which should be labelled as TOXIC.

The demonstration

c Make the pink cobalt chloride solution up to 100 cm^3 with 60 cm^3 concentrated hydrochloric acid from a measuring cylinder. A violet-coloured solution should be formed. Adding a more hydrochloric acid will produce a blue solution containing mainly $[CoCl_4]^{2-}$, while adding water will restore the pink colour.

d If necessary, add more hydrochloric acid or water by trial and error to produce an 'in-between' violet-coloured solution containing a mixture of the two cobalt ions. Place about 2 cm depth of it in each of the six boiling tubes in two groups of three in suitable racks.

1 Effect of concentration

e Keeping one tube as a control, use dropping pipettes to add water to the second tube and concentrated hydrochloric acid to the third until the colours change to pink and blue respectively. Swirl to mix well as the liquids are added. If desired, show that these changes are reversible by adding concentrated HCl to the second test-tube and water to the third.

2 Effect of temperature

f Starting with three tubes of violet-coloured solution, keep one tube as a control, and place another tube in the hot water (over 90 °C). It will turn blue. Put the third tube in the ice/water mixture. It will turn pink. If desired, show that the changes are reversible by swapping over the two test-tubes.

Teaching notes

The change in colour from blue to pink of the cobalt complexes here has been the basis of cobalt chloride indicator papers for the detection of the presence of water. It is also used in self-indicating silica gel desiccant granules.

The reaction $[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$ is endothermic. Therefore, in accordance with Le Chatelier's principle, when the temperature is raised, the position of the equilibrium will move to the right, forming more of the blue complex ion at the expense of the pink species.

Adding concentrated hydrochloric added raises the chloride ion concentration, causing the equilibrium to move to the right, in accordance with Le Chatelier. Adding water lowers the chloride ion concentration, moving the equilibrium in the opposite direction

As an extension it is possible to show that it is the Cl^- ions in the hydrochloric acid that shift the equilibrium by adding a spatula of sodium chloride instead to the pink solution. This produces a bluer colour, but this may take some time because the salt is slow to dissolve.

Health &Safety checked, August 2016

Credits

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