D–block ions as catalysts

Introduction



Transition metals and their compounds are important catalysts in industry and in living systems. Some industrial reactions which are catalysed by transition metals and their compounds include:

- *Haber Process* (iron or iron(III)oxide)
- *Contact Process* (vanadium(V) oxide)
- Hydrogenation of unsaturated oils in margarine manufacture (finely divided nickel).

These are examples of **heterogeneous** catalysts. However, transition metals ions can also act as **homogeneous** catalysts because they have variable oxidation states.

Today, you are going to study the effect of some transition metal ions on the oxidation of iodide ions by peroxodisulphate ions, $S_2O_8^{2-}$. This occurs according to the following equation:

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

A convenient way to measure the rate of this reaction is to add a fixed volume of sodium thiosulphate solution to the reaction mixture. This reacts with the free iodine formed in the reaction:

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

When the sodium thiosulphate has been used up, the free iodine is produced. If some starch solution has also been added, a deep blue colour will be produced.

Apparatus

Goggles
Bench mat
$10cm^3$ measuring cylinder
$25cm^3$ measuring cylinder
$100cm^3$ conical flask
$1cm^3$ and $10cm^3$ bulb pipettes
pipette filler
teat pipettes
stopwatch

0.1M sodium thiosulphate ☒
0.2M potassium iodide ☒
saturated potassium peroxodisulphate solution ☒
starch solution (indicator)
de-ionised water
0.1M solutions containing:
$Cr^{3+}(aq)$, $Fe^{3+}(aq)$, $Cu^{2+}(aq)$, $Co^{2+}(aq)$ ☒

Methods

1. Put the following solutions into the conical flask: $10cm^3$ of 0.2M potassium iodide; $10cm^3$ of 0.1M sodium thiosulphate; and $5cm^3$ of starch solution.
2. Add $20cm^3$ of saturated potassium peroxodisulphate solution. Write down your observations.
3. The change that you have observed should help you to work out how you can study the effect of adding small quantities of transition metal ions (in solution) on the rate of the oxidation reaction.

   Write a brief plan of the experiments you are going to carry out and give it to your teacher for checking.
4. Carry out your experiment, and record your results in an appropriate way.

   At the end of your practical work, note any modifications you might have made while carrying out your plan.

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Technician's Notes

Per pupil

1 x 10cm^3 measuring cylinder
1 x 25cm^3 measuring cylinder
1 x 100cm^3 conical flask
1 x de–ionised water bottle (please make sure that additional supplies are available)
1 x pipette filler
1 x teat pipette
1 x stopwatch

access to:
1cm^3 and 10cm^3 bulb pipettes

Reagents

0.1M sodium thiosulphate, $Na_2S_2O_3$ (allow 80cm^3 approx. per student)

0.2M potassium iodide, KI (allow 80cm^3 approx. per student)

starch solution (indicator) (allow 40cm^3 approx. per student)

saturated potassium peroxodisulphate solution, $K_2S_2O_8$ (allow 160cm^3 approx. per student)

For 1dm^3 , put 75g of $K_2S_2O_8$ into about 200cm^3 of distilled water.
Warm and stir to dissolve.
Add to about 700cm^3 of distilled water on the magnetic stirrer, then make up to 1dm^3 with distilled water. On cooling, some white crystals will form on the bottom – this is normal.

For the following reagents, any soluble form will do (e.g. nitrates, chlorides, sulphates).
Allow approx. 10cm^3 per student of 0.1M solutions of:

Cr^{3+}	chromium(III)
Fe^{3+}	iron(III)
Cu^{2+}	copper(II)
Co^{2+}	cobalt(II)