**Catalytic Property of Cobalt(II) Ions**

**Experiment Handout**

**Objective**

* To demonstrate the catalytic property of cobalt(II) ions
* To demonstrate the formation of coloured ions of transition metal
* To demonstrate that transition metals can exist in more than one oxidation state

**Task**

* To carry out the oxidation of tartrate ions (2,3-dihydroxybutanedioate ions) by hydrogen peroxide in the presence of cobalt(II) ions as a catalyst

**Background**

Some reactions, even though they are energetically favorable, proceed very slowly under normal conditions. For example, tartrate ions (C4H4O62–) can be oxidised by hydrogen peroxide to give carbon dioxide, methanoate ions (formate ions) and water as the reaction products:



When mixing a potassium sodium tartrate solution and hydrogen peroxide solution at room temperature, however, it was found that this reaction proceeds very slowly. The reaction does not go much faster even though the reaction mixture is warmed up.

However, when a few drops of aqueous cobalt(II) chloride solution is added into the warmed reaction mixture, gas bubbles form vigorously. The bubbles are due to the gaseous carbon dioxide produced in the reaction. The observation suggests that the addition of cobalt(II) ions greatly accelerates the reaction.

At molecular level, the catalyst provides an alternative reaction path with lower activation energy so that more reactants have enough energy to pass through the energy barrier to form products. As a result, the reaction proceeds much faster in the presence of a catalyst than when there is no catalyst.

Cobalt(II) ions in an aqueous solution is pink in colour. When it is added into the reaction mixture, it is firstly oxidised by hydrogen peroxide to cobalt(III) ions which is green in colour. Then the cobalt(III) ions react with the tartrate ions, they are reduced back to cobalt(II) ions. Hence, the reaction mixture turns back to pink in colour. Therefore, cobalt(II) ions act as a catalyst in the reaction.

**Curriculum Link**

Topic VII Redox reactions, chemical cells and electrolysis

Topic IX Rate of reaction

Topic XII Patterns in the chemical world

Topic XIII Industrial chemistry

**Safety Precautions**

* Wear safety glasses, lab coats and disposable plastic gloves.
* Hydrogen peroxide is corrosive. Handle it with care and avoid contacting it with skin.
* The reaction may proceed vigorously when cobalt(II) solution is added into the reaction mixture. The vigorous formation of (carbon dioxide) gas bubbles may cause the content to spill out of the boiling tube. Have the open mouth of the boiling tube plugged loosely with cotton wool as soon as the cobalt(II) solution is added to prevent the content from spilling out.
* When carrying out the experiment, do not exceed the quantities of reagents as specified in the given procedure.
* After the experiment, dispose of the reaction mixture as instructed by your teacher.

**Apparatus (per group)**

* 250 cm3 beaker × 2
* Boiling tube × 1
* 10 cm3 measuring cylinder × 2
* Disposable plastic dropper × 3
* Thermometer (–10 to 110 oC) × 1
* Test-tube holder × 1
* Cotton wool
* Electric kettles (shared)

**Chemicals (per group)**

* 6% hydrogen peroxide solution 3 cm3
* 0.25 M potassium sodium tartrate solution 10 cm3
* 0.1 M cobalt(II) chloride solution 1 cm3

**Procedure**

1. Measure 10 cm3 of 0.25 M potassium sodium tartrate solution with a measuring cylinder. Pour the solution into a boiling tube.
2. Add 3 cm3 of 6% hydrogen peroxide solution into the boiling tube.
3. Insert a thermometer into the solution and measure the temperature of the solution.
4. Gently swirl the boiling tube to mix the content thoroughly. Record the observations.
5. Fill a 250 cm3 beaker with just-boiled hot water to half full. Place the boiling tube into the beaker to warm the content.
6. Gently swirl the content in the boiling tube while warming it in the hot water bath, until the temperature of the content reaches about 65oC. Record the observations. *(Avoid heating the mixture above 70oC).*
7. Remove the boiling tube from the hot water bath. Quickly add 1 cm3 of 0.1 M cobalt(II) chloride solution into the reaction mixture. Immediately place a cotton plug loosely to the mouth of the boiling tube. Stand the tube in an empty beaker. Record the observation.

**Disposal and Clean-up**

1. After the experiment, dispose of the reaction mixture as instructed by teacher. It is acceptable to rinse the mixture down into drain with plenty of water.
2. Rinse the cotton plug with water and dispose of it as normal refuse.
3. Rinse the boiling tube with plenty of water.

**Results**

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|  | Observations |
| Mixing of potassium sodium tartrate solution and hydrogen peroxide solution at room temperature. |  |
| Heating the reaction mixture in the hot water bath. |  |
| Addition of cobalt(II) chloride solution into the mixture. |  |

**Questions for Discussion**

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|  | 1. | Write the half-equation for the reduction of hydrogen peroxide in this experiment. | |
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|  | 2. | Write the half-equation for the oxidation of tartrate ions in this experiment. | |
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|  | 3. | Given that the reaction of potassium sodium tartrate and hydrogen peroxide is energetically favorable, but there is no reaction observed when they were mixed at room temperature. Explain briefly. | |
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|  | 4. | Explain why it is expected that the reaction may start when the reaction mixture is heated in a hot water bath. | |
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|  | 5. | Explain why gas bubbles are formed vigorously when cobalt(II) chloride solution is added into the mixture of potassium sodium tartrate and hydrogen peroxide. | |
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|  | 6. | Explain the colour changes observed when cobalt(II) chloride solution was added into the reaction mixture. | |
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|  | 7. | After storage for a long period, hydrogen peroxide solution eventually loses its oxidising power due to the following decomposition: | |
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|  |  | (a) | In reality, this process is slow at room temperature. Yet, the solution should still be stored in refrigerator. Why does storage of the solution in refrigerator help the oxidising power keep for a longer time? Explain at molecular level. |
|  |  | (b) | The decomposition can be speeded up with some transition metal ions. Search the internet to find out which transition metal ions act as catalysts for the process. |

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|  | 8. | (a) | Why can the amount of catalyst be much smaller than those of reactants? |
|  |  | (b) | Calculate the numbers of moles of catalyst and reactants used in this experiment. Is the amount of catalyst much smaller than those of reactants? |
|  |  |  |  |
|  | 9. | Complete the following table: | |
| |  |  |  | | --- | --- | --- | | Species | Colour of the species | Oxidation state of transition metal | | Fe2+(aq) |  |  | | Fe3+(aq) |  | +3 | | Cr3+(aq) |  |  | | CrO42–(aq) |  |  | | Cr2O72–(aq) |  |  | | Mn2+(aq) | Very pale pink |  | | MnO4–(aq) |  |  | | | | |

**Reference**

* “PP010 - a colourful catalysis reaction using cobalt(II) ions”,

<http://science.cleapss.org.uk/Resource-Info/PP010-a-colourful-catalysis-reaction-using-cobalt-II-ions.aspx>