Catalyst experiment

Background

In the absence of a catalyst, hydrogen peroxide decomposes slowly at room temperature. In the presence of a catalyst, the reaction is much faster. Hydrogen peroxide is produced as a by-product of metabolism in many living organisms, but it is toxic to the organism. To deal with this, living organisms produce an enzyme (a catalyst) that breaks down hydrogen peroxide before it can do much damage. In this experiment you will compare effects of an inorganic catalyst, iron(III) nitrate, and an organic enzyme found in animal liver, catalase.

Equipment

- 10% hydrogen peroxide solution
- 0.5M iron(III) nitrate solution
- fresh ground liver as a source of catalase
- test tubes and rack
- Bunsen and beaker for water bath

Method

Label four large test tubes A, B, C and D, and follow the steps described below for each.

A Iron(III) nitrate catalyst 1. Make a mark about 3 cm from the bottom of the test tube. 2. Add H_2O_2 up to the mark. 3. Add about 1 mL of iron(III) nitrate solution. 4. When reaction stops, add about 2 mL more H_2O_2. 5. Record your observations in Table 1.	**B Liver enzyme (catalase)** 1. Make a mark about 3 cm from the bottom of the test tube. 2. Add H_2O_2 up to the mark. 3. Add about 1 teaspoon of fresh, ground liver. 4. When reaction stops, add about 2 mL more H_2O_2. 5. Record your observations in Table 1.
C Boiled liver 1. Set up a beaker of water on a Bunsen, and bring to boil. 2. Make a mark about 3 cm from the bottom of the test tube. 3. Add a teaspoon of fresh, ground liver to the test tube and a little water. 4. Place the test tube in a boiling water bath, for five minutes. 5. Pour off excess water and allow the test tube to cool. 6. Add H_2O_2 up to the mark. 7. Record your observations in Table 1.	**D Control** 1. Make a mark about 3 cm from the bottom of the test tube. 2. Add H_2O_2 up to the mark. 3. When reaction stops, add about 2 mL more H_2O_2. 4. Record your observations in Table 1.

Further investigations

Investigate the effect of temperature on liver enzyme activity.

- Cool both the liver and hydrogen peroxide on ice before combining.
- Warm both liver and hydrogen peroxide to 37 °C before combining.

Investigate the effect of pH on liver enzyme activity:

- Add 2 mL of 0.1M HCl to the hydrogen peroxide before adding liver.
- Add 2 mL of 0.1M NaOH to the hydrogen peroxide before adding liver.

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Table 1: Observations from catalyst experiment

EXPERIMENT		COMPARATIVE RATE +++ = STRONG REACTION - = NO REACTION	OBSERVATIONS
A	iron(III) nitrate		
B	liver (catalase)		
C	boiled liver		
D	control		

Questions

1. What is the reason for setting up a control in this experiment?

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2. Write an equation for the decomposition of hydrogen peroxide.

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3. What effect did adding iron(III) nitrate to the solution of hydrogen peroxide have on the decomposition of the solution?

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4. What effect did adding fresh liver to the solution of hydrogen peroxide have on the decomposition of the solution?

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5. Explain why there was a difference in the rate of reaction between trials B and C above.

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6. Using data in Table 2, draw an energy profile diagram for the decomposition of hydrogen peroxide without catalyst, in the presence of iron(III) nitrate, and in the presence of catalase.

Table 2: Energy values for the decomposition of hydrogen peroxide at 27 °C

	NO CATALYST	IRON(III) NITRATE	CATALASE
energy change ΔH	-98.2 kJ mol^{-1}	-98.2 kJ mol^{-1}	-98.2 kJ mol^{-1}
activation energy E_A	75.3 kJ mol^{-1}	35 kJ mol^{-1}	23 kJ mol^{-1}

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Research questions

7. What is catalase, and how does it increase the rate of decomposition of hydrogen peroxide?

8. Describe the effect of temperature and pH on catalase activity. Either use results from 'Further investigations' above, or research your answer.

9. Iron(III) nitrate catalyses the reaction by forming an intermediate complex with hydrogen peroxide. What evidence is there for the formation of this intermediate complex, and what evidence supports the hypothesis that the catalyst is reformed at the end of the reaction?

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