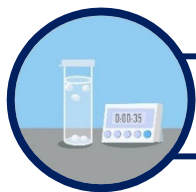




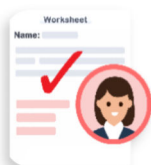
Yeast Bead Catalase Investigation



Yeast Bead Catalase Investigation

Table of Content

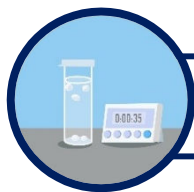
	Page
1 Introduction	1-2
• Overview	1
• Teaching Plan & Key Features	1-2
• Important Notes	2
2 Instructional Materials	3-27
• Student Worksheet 1	3-5
• 學生工作紙 (一)	6-8
• Student Worksheet 2	9
• 學生工作紙 (二)	10
• Student Samples 1 (Worksheet 2)	11-12
• Teacher Notes 1	13-17
• 教師筆記 (一)	18-19
• Laboratory Manual	20-21
• 實驗指南	22
• Teacher Notes 2	23-26
• 教師筆記 (二)	27
3 Supplementary Resources	28-29
• Possible Modifications	28
• Technician Notes	28-29
• References	29



Notes for teachers

- Scan the QR code to get the electronic files.
- Teachers are strongly encouraged to adapt and modify these resources as necessary.





Yeast Bead Catalase Investigation

Overview

- The *Yeast Bead Catalase Investigation* is about the industrial application of immobilised yeasts to remove hydrogen peroxide from factory effluents.
- Immobilised yeasts, known as yeast beads, contain catalase (Bryer, 2016a, b).
- Students collect quantitative data (i.e., the time for the yeast beads to rise to the surface of the hydrogen peroxide solution) to determine the catalase activity for compare the inhibitory effects of different types of heavy metal ions under different concentrations.
- Students have the opportunity to design and carry out experiments in which they set up replicates, consider the importance of a larger sample size, identify significant assumptions in their experimental designs.
- Students also analyse data, construct graphical representations to compare data sets, and use the information to inform decisions in the application of effluent treatment.

Teaching Plan

Prerequisite knowledge (scientific ideas)

- The properties, actions and roles of enzymes
- Factors affecting the actions of enzymes
- The action of catalase on hydrogen peroxide

Lesson	Lesson sequence	Duration (mins)	Resources
Stage 1 Preparing for the investigation <ul style="list-style-type: none"> It is situated in an authentic context related to the industrial application of yeast beads in removing hydrogen peroxide from factory effluents (Contextualisation). Students read information to familiarise themselves with the background of the investigation (<i>Reading Materials</i>). 			
Before Lesson 1	<ul style="list-style-type: none"> The teacher distributes <i>Worksheet 1</i> for students to complete at home so that they can be familiar with the background of the investigation. 		<i>Worksheet 1</i>
1	<ul style="list-style-type: none"> The teacher discusses the investigation context with students. The teacher provides feedback on students' responses in <i>Worksheet 1</i>. Students complete <i>Worksheet 2</i> to design an investigation. Students perform mini-trial run. 	40	<i>Worksheet 2</i>
Stage 2 Designing the investigation <ul style="list-style-type: none"> Students perform mini-trial run (<i>Trial Run</i>). Students interact with a virtual laboratory to familiarise themselves with the materials and apparatuses they use in the investigation (<i>Virtual Laboratory</i>). Students use a template to design their own experimental set-ups (<i>Investigation Planning Template</i>). Students have the chance to evaluate their own and their peers' experimental set-ups (<i>Self & Peer Evaluation</i>). Students' experimental designs of a similar investigation are collected and discussed in class (<i>Diagnostic Assessment</i>). 			
2	<ul style="list-style-type: none"> The teacher provides feedback on students' experimental designs in <i>Worksheet 2</i>. 	40	Student Samples 1
3	<ul style="list-style-type: none"> The teacher presents the main investigation context and discusses with students questions related to their experimental designs. The teacher provides students with the laboratory manual for preparation at home. 	40	Teacher Notes 1

Stage ③ Carrying out the investigation <ul style="list-style-type: none"> Students use microscale instrumentation that reduces the time of the experiments (Microscale Instrumentation). Students collect more complex data sets by setting up replicates (Complex Data Set). 			
3	<ul style="list-style-type: none"> Teacher asks questions to help students connect their lab experience and related ideas/scientific inquiry skills. Students carry out the investigation. 	40	Laboratory Manual
Stage ④ Explaining and evaluating data <ul style="list-style-type: none"> Students record and share data using <i>Google Spreadsheet</i>. (<i>Digital Tool</i>) Students use data to make claims about the inhibitory effects of different types of heavy metal ions under different concentrations and make decisions (Decision-making Task). 			
Before Lesson 4	<ul style="list-style-type: none"> Students complete data reporting and analysis at home. The teacher collects and marks student responses. 		Teacher Notes 2
4	<ul style="list-style-type: none"> The teacher provides feedback on students' performance related to data reporting and analysis. 	40	Teacher Notes 2

Important Notes

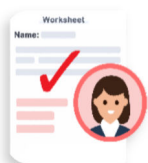
- Students should wear safety goggles and lab coats during the experiment.
- Students should avoid contact with hydrogen peroxide, as it can discolour clothing.



Instructional Materials

Stage 1 Preparing for the investigation

Student Worksheet 1



Notes for teachers

- Teachers can distribute *Worksheet 1* and ask students to read the background information related to the investigation at home.
- Students' responses can be collected using a *Google Form*.
- Scan the QR code to get a copy of the *Google Form*.



Task 1

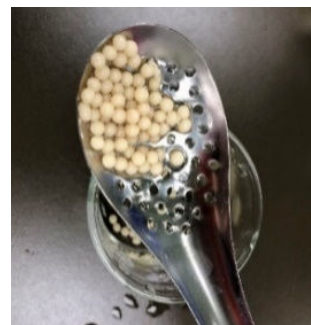
- Read the following information and the source materials in the data file.
- Answer the questions that follow.

Scenario

Hydrogen peroxide (H_2O_2) is widely used as a bleaching agent in textile industries. Hydrogen peroxide residues should be broken down to harmless substances before discharge to the environment.

Yeast (*Saccharomyces cerevisiae*) is a rich source of catalase, which is an enzyme that catalyses the breakdown of hydrogen peroxide into oxygen and water. Scientists make use of yeasts to remove hydrogen peroxide residues in wastewater. Yet, industrial liquid waste often contains heavy metal ions that can inhibit catalase activity of yeast beads.

Read the information in the *Data File* to familiarise yourself with the background of this investigation.



Yeast beads

Data file

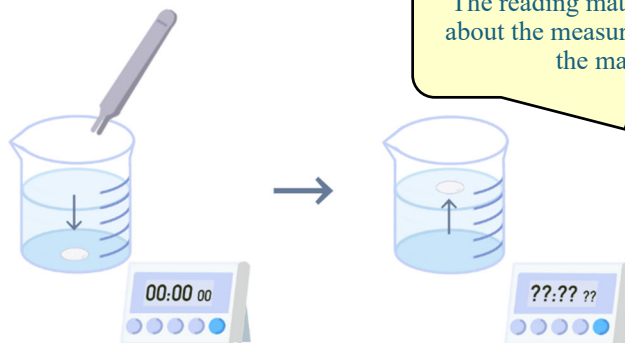
Your biology teacher asks you to read the following source materials to prepare yourself for designing an investigation related to studying catalase.

Source 1: Measuring the activity of catalase

Almost all organisms contain catalase. Catalase speeds up the breakdown of hydrogen peroxide, a toxic by-product of some metabolic reactions, into oxygen and water.

The activity of catalase in different tissues can be studied using a simple method involving the following procedures:

- Put filter paper discs into extract of different tissues
- The filter paper discs are then put into plastic vials containing equal volumes of hydrogen peroxide
- Start timing when the filter paper disc reaches the solution
- Note the time (t) required for the filter paper disc to rise to the surface of the solution



The reading materials provide information about the measurement methods relevant to the main investigation.

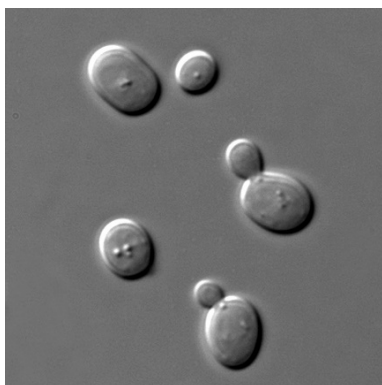


Scan the QR code to see what happens to a filter paper disc with fresh potato juice.

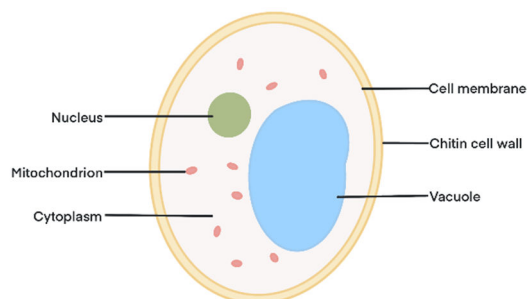


Source 2: What are yeast and yeast beads?

Yeast (*Saccharomyces cerevisiae*) is a eukaryotic organism. A eukaryotic cell has a true nucleus and membrane-bound organelle. Although yeast cells have cell wall, the chemical composition of cell wall of yeast cells is different from that of plant cells. The following diagrams show yeast cells under a light microscope and a drawing of yeast cell respectively.



Yeast cells under microscope



Drawing of a yeast cell

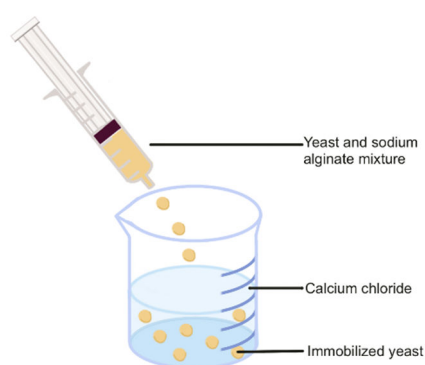
Yeast cells contain catalases. The catalase can break down hydrogen peroxide into oxygen and water.



Scan the QR code to see what happens when a dialysis bag containing yeast solution is put into a beaker of hydrogen peroxide solution.



Scientists make use of yeast for many industrial applications including brewing of beer, making of bread and etc. In some applications, scientists immobilise whole yeast cells to form yeast beads using sodium alginate and calcium chloride.



The reading materials provide information about yeast beads, which may be unfamiliar to the students.



Yeast in alginate solution + Calcium chloride \longrightarrow Yeast beads
(Yeast immobilised in insoluble calcium alginate)

Immobilised yeasts are also active. The yeast beads can be collected and reused after reaction.

Answer the questions below *after* reading the source materials.

- Write a word equation for the action of catalase on hydrogen peroxide.
- Suggest an animal organ in which catalase is present in great abundance and from which the enzyme can be obtained. Explain why this organ has so much catalase.
- With reference to *Source 1*, explain why the paper discs rise to the surface of the hydrogen peroxide solution.
- How is the time taken for the paper disc to rise to the surface of the solution related to the activity of catalase?
- With reference to *Source 2*, state *two* observations when a dialysis bag containing yeast solution is put into a beaker of hydrogen peroxide solution.

任務 1

- 閱讀以下資訊和資料檔案中的資料。
- 回答隨後的問題。

情境

過氧化氫(H_2O_2)是一種廣泛應用於紡織工業的漂白劑。過氧化氫殘留物在排放到環境之前應該被分解成無害的物質。

酵母(*Saccharomyces cerevisiae*)是過氧化氫酶的豐富來源，過氧化氫酶是一種催化過氧化氫分解為氧氣和水的酶。科學家利用酵母去除廢水中的過氧化氫殘留物。然而，工業廢液往往含有可抑制酵母珠中過氧化氫酶活性的重金屬離子。在這項探究實驗中，你的目標是研究不同類型的重金屬對過氧化氫酶活性的影響。請閱讀資料檔案內的資料，以便熟悉這次探究實驗的背景。

資料檔案

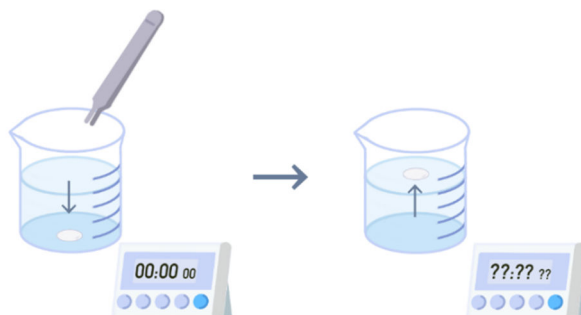
你的生物老師要求你閱讀下面的資料，為設計一個與酵母過氧化氫酶有關的科學探究做準備。

資料 1: 過氧化氫酶活性測定

幾乎所有生物都含有過氧化氫酶。過氧化氫是一些代謝反應產生的有毒副產物。過氧化氫酶加速過氧化氫的分解為氧氣和水。

過氧化氫酶在不同組織中的活性可以用一種簡單的方法研究，這涉及以下步驟：

- 將濾紙片放入不同組織的提取物中
- 然後將濾紙片放入裝有等量過氧化氫溶液的塑料小瓶中
- 在濾紙片到達溶液的時候開始計時
- 注意濾紙片上升到溶液表面所需的時間 (t)

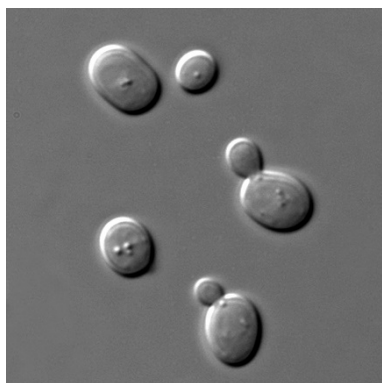


掃描二維碼以查看吸附了新鮮土豆汁的濾紙片放入過氧化氫溶液後會發生什麼事情。

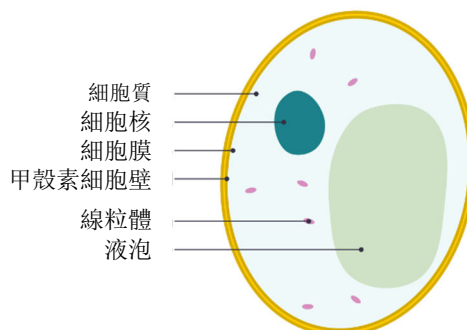


資料 2：什麼是酵母和酵母珠？

酵母(*Saccharomyces cerevisiae*)是一種真核生物。真核細胞有一個真正的細胞核和多種具有膜結構的細胞器。雖然酵母細胞有細胞壁，但其細胞壁的化學組成成分與植物細胞的不同。下圖分別為顯微鏡下的酵母細胞圖和酵母細胞繪圖¹。



顯微鏡下的酵母細胞圖



酵母細胞繪圖

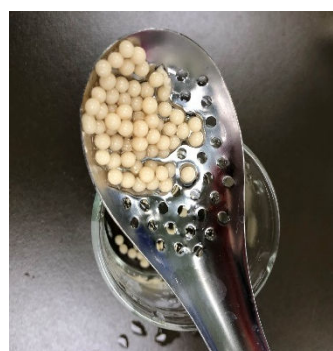
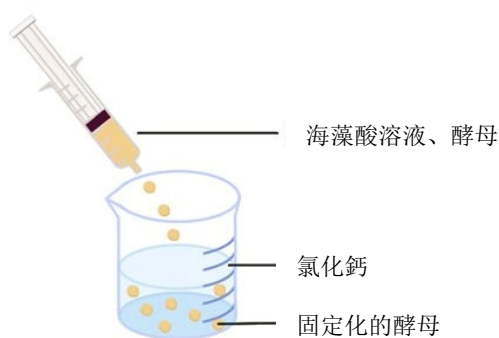
酵母細胞含有過氧化氫酶。過氧化氫酶能催化過氧化氫分解成氧氣和水。



掃描二維碼，看看當一個含有酵母溶液的透析袋被放入一個裝有過氧化氫溶液的燒杯中會發生什麼。



科學家利用酵母進行許多工業應用，包括釀造啤酒、製作麵包等。在某些應用中，科學家使用海藻酸鈉和氯化鈣使整個酵母細胞固定，以形成酵母珠。



海藻酸溶液中的酵母 + 氯化鈣 —————> 酵母珠

(酵母在非溶性的海藻酸鈣中固定)

固定化的酵母仍然有活性。酵母珠在反應後可被回收及重用。

閱讀資料後回答以下問題。

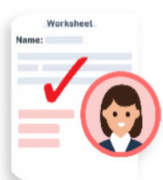
- (a) 寫出過氧化氫酶對過氧化氫的文字方程。
- (b) 建議一種含有大量過氧化氫酶、且此酶可被提取的動物器官。解釋為什麼這個器官有這麼多的過氧化氫酶。
- (c) 參考資料 1，解釋為什麼濾紙片會上升到過氧化氫溶液的表面。
- (d) 濾紙片上升到溶液表面的時間與過氧化氫酶的活性有什麼關係？
- (e) 參考資料 2，指出當一個含有酵母溶液透析袋被放入一個裝有過氧化氫溶液的燒杯時的兩個可觀察結果。



掃描二維碼以獲取 *Google Form* 的副本。



Student Worksheet 2



Notes for teachers

- Teachers distribute *Worksheet 2* and ask students to design the investigation at home.
- Teachers may ask students to perform a trial run before their design. See *Supplementary Resource* section for the material list.
- Students can see the materials and apparatuses in the *Virtual Laboratory*.
- Some student work samples are shown below to illustrate possible student thinking.

Task 2

- Answer the questions that follow.
1. Briefly describe how you would use the following materials to design an experiment to achieve the above aim. You can draw your experimental design.

1M Zinc sulphate solution	Timer	Distilled water
1M Nickel chloride solution	Forceps	0.1% Hydrogen peroxide
1M Copper sulphate solution	Yeast beads	Plastic vials
Autopipette	Autopipette tips	10 ml measuring cylinder
Petri dish		



Scan the QR code to see these materials.



The virtual laboratory provides students with opportunities to get familiar with materials used in the investigation.

Brief explanation of my design:

The mini trial run provides opportunities for students to see how the dependent variable can be measured (i.e., the time for the yeast beads to rise).

Mini trial run procedures

You may want to perform the following trial run before you design the investigations.

- Pour some hydrogen peroxide (H_2O_2) into a plastic vial.
- Use the forceps to transfer several yeast beads into the H_2O_2 solution.
- Observe what happens.

任務 2

- 回答以下問題。

(a) 簡要描述你將如何使用以下材料來設計探究，以達到上述目標。你可以畫出你的實驗設計。

1M 硫酸鋅溶液	計時器	蒸餾水
1M 氯化鎳溶液	鑷子	0.1%過氧化氫溶液
1M 硫酸銅溶液	酵母凝膠珠	塑料小瓶
自動移液管	自動移液管針尖	10 毫升量筒
培養皿		



掃描二維碼，以查看這些材料。



簡要說明我的設計：

小型試行步驟

在設計探究之前,你可以進行以下試驗:

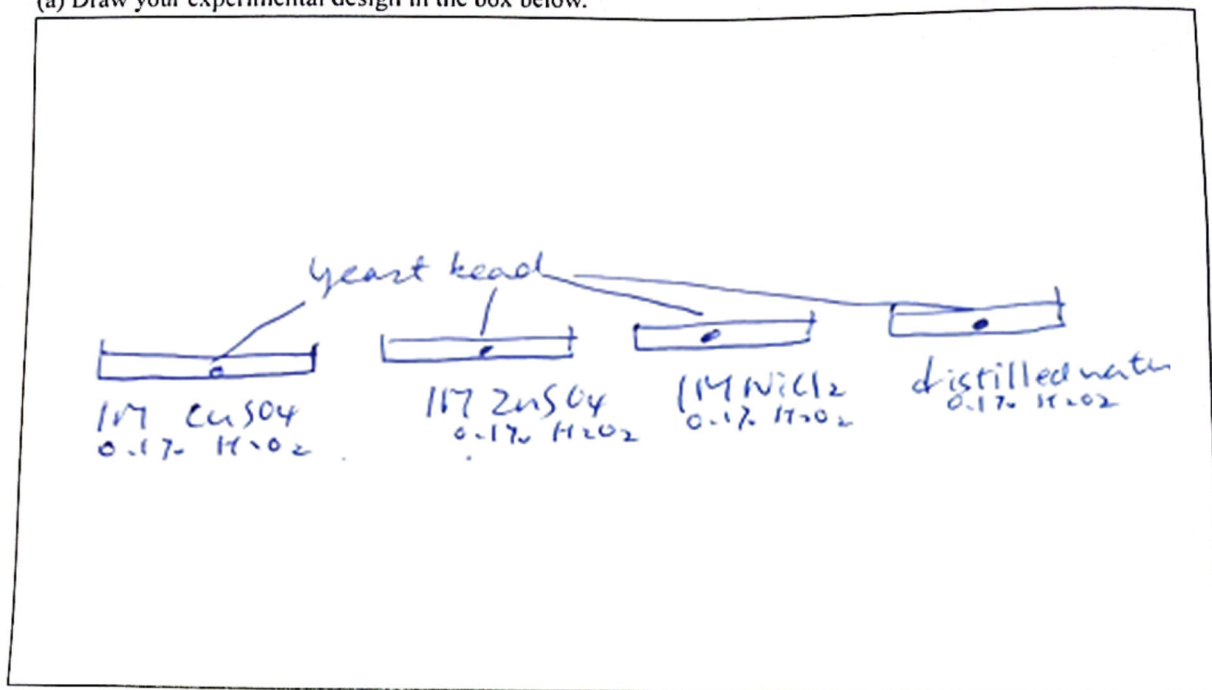
- 將一些過氧化氫倒入塑料小瓶中。
- 使用鑷子將幾顆酵母珠轉移到過氧化氫溶液中。
- 觀察發生的情況。

Student Sample 1 (Worksheet 2)

Examples of students' initial experimental designs

Sample 1

(a) Draw your experimental design in the box below.



(b) Briefly explain your design:

- 1) Set 4 set ups = 1M CuSO_4 , 1M ZnSO_4
1M NiCl_2 , distilled water
All set ups with 0.1% hydrogen peroxide
- 2) Put the yeast heads into the mixture solution
- 3) Use timer to time when the yeast heads reach the top of the petri dish

Students evaluate their own and their peers' designs on a similar experiment. Teachers provide feedback on important scientific thinking skills.

Sample 2

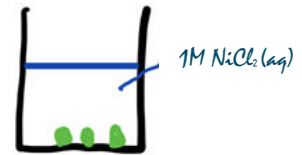
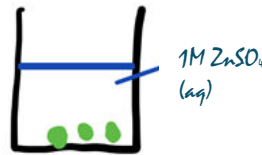
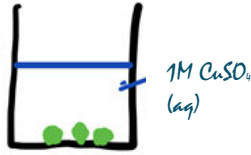
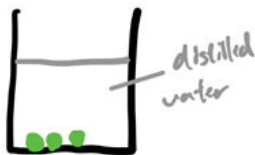
Many students tend to overlook the preincubation step in their experimental designs.

Control
Set up

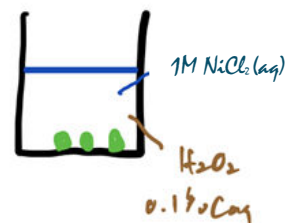
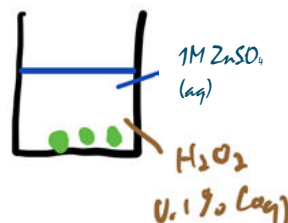
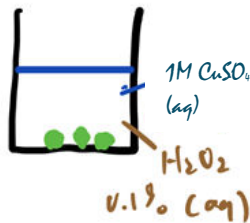
Set up I

Set up II

Set up III



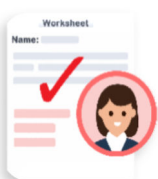
15 min



Repeat experiment 3 times
Take average time

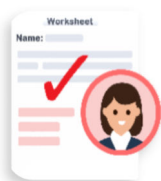
Notes for teachers

- Teachers can choose some students' diagrams (anonymised) of experimental setups for students to evaluate.
- Teachers can discuss the following scientific inquiry skills: (1) the importance of precautionary step; (2) the number of yeast beads in each vial; (3) the number of replicates they would set up.



Teacher Notes 1

Notes to teachers



- After receiving feedback on their experimental designs, the following shows the main investigation context for students to design another investigation that involves continuous independent variable.
- There are some questions that teachers may use to guide students in thinking about or assessing the scientific inquiry skills related to experimental designs.
- Some student work samples are shown below to illustrate possible student thinking to some questions.

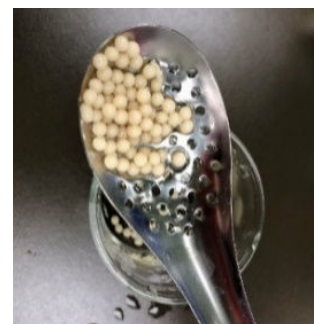
Task 3

Scenario

Hydrogen peroxide (H_2O_2) is widely used as a bleaching agent in textile industries. Hydrogen peroxide residues should be broken down to harmless substances before discharge to the environment.

Baker's yeast (*Saccharomyces cerevisiae*) is a rich source of catalase. Catalase is an enzyme that catalyses the breakdown of hydrogen peroxide into oxygen and water. Scientists make use of yeasts to remove hydrogen peroxide residues in wastewater. However, industrial liquid waste often contains heavy metal ions that can inhibit catalase activity of yeast beads. More yeast beads need to be used to achieve the same efficiency.

Your biology teacher has asked you to design an investigation *to investigate the effect of different types of heavy metal ions on the activity of yeast bead catalase under different concentrations*. This information is important for determining the catalase activity of yeast beads in removing hydrogen peroxide in water with heavy metal.



Yeast beads

Design of investigation

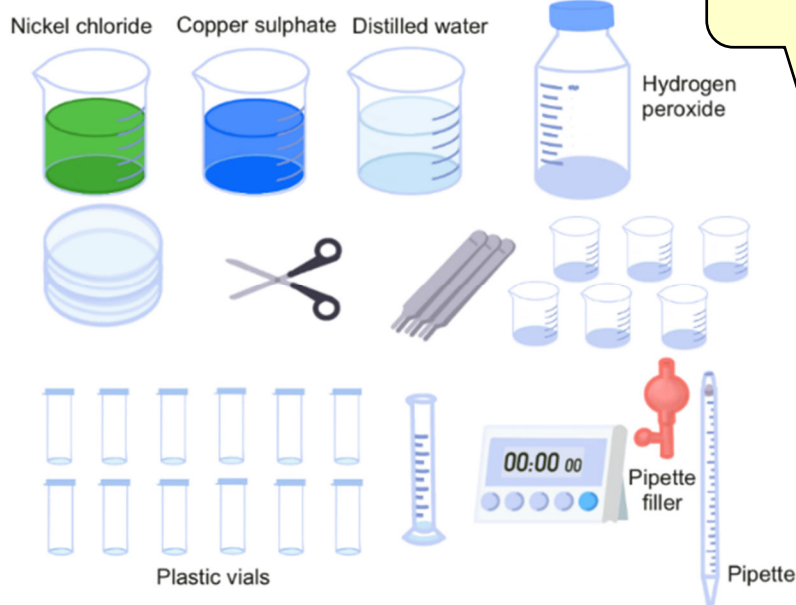
Aim of the investigation

- To investigate the effect of different types of heavy metal ions on the activity of yeast bead catalase under different concentrations

Materials and apparatus:

- You have been given the following materials and apparatus:

1M Nickel chloride solution	Forceps	Plastic vial
1M Copper sulphate solution	Petri dish	Timer
0.1% Hydrogen peroxide solution	1 mL Pipette	10 mL Measuring cylinder
Distilled water	Pipette filler	25 mL Beaker
Yeast beads	Scissors	



The diagrams provide visual scaffolds to help students understand the materials and apparatuses for the investigation.

Scan this QR code to see the materials.



Possible questions:

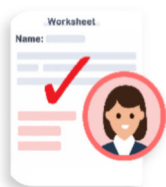
1. State how the dependent variable can be measured using the above materials and apparatus.

Hints: Make sure that you include the following parts in your answers:

- ☐ the measurement tools and the methods of measurement.
- ☐ the relationship between the measurement and the dependent variable

The checklist serves to scaffold students' responses.

2. Will you choose to use one single yeast bead or more than one yeast bead in each trial? Why?
3. Your teacher advised you not to use hydrogen peroxide solution that is too concentrated ($>5\%$ hydrogen peroxide). Discuss the importance of using a suitable concentration of hydrogen peroxide solution in relation to the overall validity of the investigation.



Notes for teachers

- Q.1 assesses students' ability to connect the measurement to the dependent variable.
- Q.2 assesses students' ability to explain how increasing the sample size can help reduce the impact of individual differences inherent in biological samples on the quality of the data.
- Q.3 assesses students' ability to explain design that relates to the validity of the design.

The following are some examples of students' responses to Q.1:

Sample 1

Explain how the dependent variable could be measured using the above materials and apparatus.

Soak the yeast beads in the petri dishes and use forceps to put the beads inside the hydrogen peroxide. Use the pipette and pipette filler connect it to a water trough and an inverted measuring cylinder. Use the timer to measure the time taken for colourless bubbles to appear.

Sample 2

Explain how the dependent variable could be measured using the above materials and apparatus. *respectively*

After adding same amount of yeast bead into four beakers, time the timer immediately and stop the timer after the yeast bead rise to the surface of the mixture.

Sample 3

Explain how the dependent variable could be measured using the above materials and apparatus.

Use the timer to measure the time taken for the paper disk to rise to the surface of the solution. The shorter the time taken for the paper disk to rise to the surface, the higher the activity of yeast bead catalase.



About the samples

- Sample 1 proposed a set-up that required additional materials and apparatus not provided in the list. It is also not feasible to measure the time it takes for the colourless gas bubbles to appear.
- Sample 2 described the measurement (i.e., time for the yeast beads to rise to the surface of the solution) but did not state the relationship between the measurement and the relative rate of catalase activity.
- Sample 3 confused yeast beads with paper discs (information in the *Data File*.)

The following are some examples of students' responses to Q.2:

Sample 1

Will you choose to use one single yeast bead or more than one yeast bead in each trial? Why?

More than one yeast bead because the higher amount of yeast beads have a larger surface area for the catalase in the yeast beads to react and it can decrease the time needed

Sample 2

Will you choose to use one single yeast bead or more than one yeast bead in each trial? Why?

I will choose more than one yeast bead in each trial because more yeast beads have a larger sample size. Therefore, the reliability of the results could be increased by minimizing the individual differences.

Sample 3

Will you choose to use one single yeast bead or more than one yeast bead in each trial? Why?

More than one yeast bead. Different yeast bead may contain different amount of catalase. By using more than one yeast bead, the reliability of the results could be increased by minimizing the individual differences.



About the samples

- Sample 1 wrongly believed using more than one yeast can lead to a shortening of the duration of the experiment. The surface area to volume ratio of each yeast does not change when more than one yeast bead is used.
- Sample 2 and Sample 3 related to the reliability of the data. Sample 2 described the differences between the yeast beads in terms of the differences in the amount of catalase. Increasing the number of yeast beads in each trial can reduce the impact of the inherent variations in catalase in the yeast beads.

The following are some examples of students' responses to Q.3:

Sample 1

Your teacher advised you not to use hydrogen peroxide that is too concentrated (>5% hydrogen peroxide). Discuss the importance of using a suitable concentration of hydrogen peroxide in relation to the overall validity of the investigation.

As hydrogen peroxide is acidic, a too concentrated hydrogen peroxide will affect the action of catalase by denaturing it. A suitable concentration of hydrogen peroxide ensures the catalase in the yeast beads are able to work in a suitable pH.

Sample 2

(h) Your teacher advised you not to use hydrogen peroxide that is too concentrated (>5% hydrogen peroxide). Discuss the importance of using a suitable concentration of hydrogen peroxide in relation to the overall validity of the investigation.

Catalase works best in a certain concentration of hydrogen peroxide. Too concentrated hydrogen peroxide will affect the rate of catalase activity and affect the overall validity of the investigation.

Sample 3

Your teacher advised you not to use hydrogen peroxide that is too concentrated (>5% hydrogen peroxide). Discuss the importance of using a suitable concentration of hydrogen peroxide in relation to the overall validity of the investigation.

Because too concentrated hydrogen peroxide will lead to higher rate of catalase reaction, so, the rate of yeast bead to reach the surface will be too fast and ~~the~~ it will be too hard to measure the difference of rate of reaction between different solutions. Suitable concentration can ensure the result is obvious to compare.



About the samples

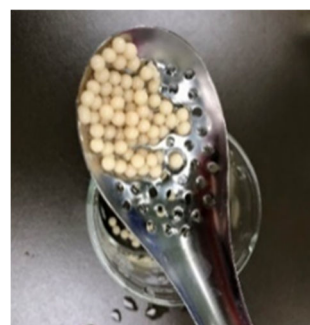
- Sample 1 wrongly stated that more concentrated hydrogen peroxide solution is more acidic.
- Sample 2 did not pinpoint what the changes in the rate of catalase activity would be when too concentrated hydrogen peroxide is used and its effect on the measurement.
- Sample 3 was able to relate the difficulty of discerning the differences if the rate is too high for both treatments.

任務 3

情境

過氧化氫(H_2O_2)在紡織工業中被廣泛用作漂白劑。過氧化氫殘留物在排放到環境中之前應被分解成無害物質。

麵包酵母(*Saccharomyces cerevisiae*)是過氧化氫酶的豐富來源。過氧化氫酶是一種催化過氧化氫分解為氧氣和水的酶。科學家們利用酵母菌來清除廢水中的過氧化氫殘留物。然而，工業液體廢物通常含有重金屬離子，會抑制酵母凝膠珠中的過氧化氫酶活性。因此，為了達到同樣的催化效率，需要使用更多的酵母凝膠珠。



酵母凝膠珠

你的生物老師要求你設計一項實驗，探究不同類型的重金屬離子在不同濃度下對酵母凝膠珠中過氧化氫酶活性的影響。這項實驗提供的資訊對於確定酵母凝膠珠中去除含重金屬的水中的過氧化氫的過氧化氫酶活性非常重要。

實驗設計

實驗目的

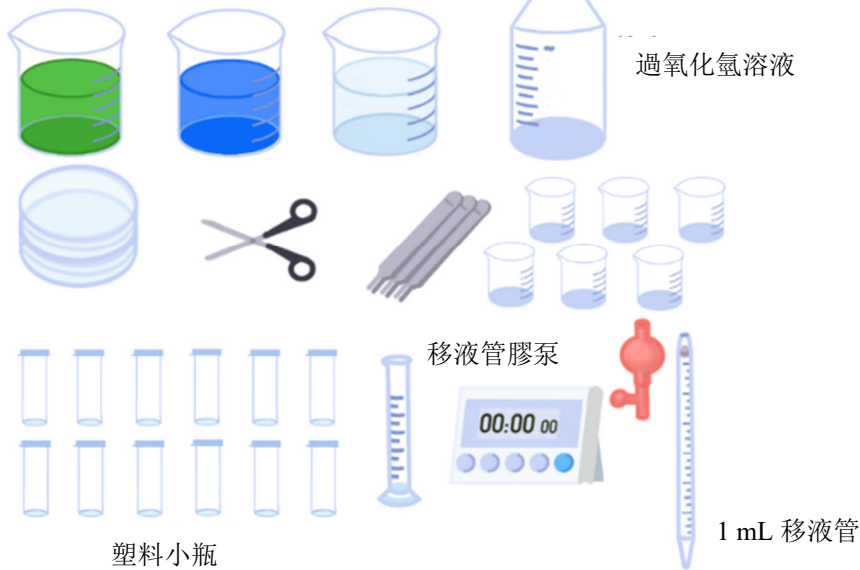
- 探究不同類型的重金屬離子在不同濃度下對酵母凝膠珠中過氧化氫酶活性的影響

物料和儀器

- 你有以下實驗物料和儀器。

1M 氯化鎳溶液	鑷子	塑料小瓶
1M 硫酸銅溶液	培養皿	計時器
0.1%過氧化氫溶液	1 mL 移液管	10 mL 量筒
蒸餾水	移液管膠泵	25 mL 燒杯
酵母凝膠珠	剪刀	

1M 氯化鎳溶液 1M 硫酸銅溶液 蒸餾水



掃描此二維碼以
查看實驗材料



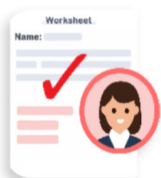
參考問題

1. 說明如何使用上述材料和儀器量度因變量。

提示：請確保你的答案包括以下部分。

- ☐ 量度工具和測量方法。
 - ☐ 量度方法和因變量之間的關係
2. 在每次試驗中，你會選擇使用一個的酵母凝膠珠還是一個以上的酵母凝膠珠？為什麼？
 3. 你的老師建議你不要使用濃度過高的過氧化氫溶液（例如 >5% 的過氧化氫溶液）。試討論使用適當濃度的過氧化氫溶液對實驗的整體信度的重要性。

Notes to teachers



- Teachers can distribute the manual for students to read and prepare before the investigation.
- It is suggested that half of the class investigate the effect of copper ions while the other half study the effect of nickel ions.
- Teachers can ask questions to check if students fully understand the procedures (e.g., how many yeast beads will you need in this experiment? Why?).
- The *Supplementary Resource* section contains the material list.
- Scan the QR code to view the process of the experiment.



Task 4

- Read the following procedures to carry out the investigation.

Procedure

Preparation of yeast beads

1. Add 10 mL of 10% yeast (in a vial) to 10 mL of 2% sodium alginate solution in a 50 mL tube.
2. Mix the solution well by inverting the 50 mL tube to make a yeast–sodium alginate solution.
3. Hold the plastic dropper (without cap) with a stand and clamp.
4. Pour 50 mL 2% CaCl_2 (calcium chloride) into a plastic cup/100 mL beaker.
5. Assemble the set up shown in *Figure 1*.
6. Add the yeast-sodium alginate solution to the plastic dropper (a bead should form when the drop comes into contact with the CaCl_2 solution and falls to the bottom of the beaker).
7. Wait 5 minutes until the beads have hardened.
8. Discard any floating yeast beads with a plastic spoon.
9. Collect the beads with a sieve.
10. Wash the beads several times with distilled water from a wash bottle over a plastic cup.

> 17 cm

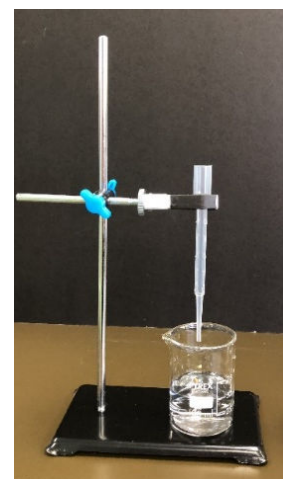


Figure 1

Inhibition of catalase activity

1. Add the heavy metal solution (e.g., 5 mL depending on the size of the petri dish) with different concentrations (1M, 0.5 M, 0.25M) and distilled water to four different petri dishes.
2. Use forceps to gently move at least 15 yeast beads into each labelled petri dish for at least 5 minutes.

Testing the catalase activity

1. Measure 10 mL of 0.1% hydrogen peroxide solution with a measuring cylinder and pour the solution into a plastic vial. (You can use the dropper to transfer the solution).
2. Repeat *Step 1* three times.
3. Use the forceps to carefully transfer five yeast beads from each petri dish into each plastic vial.
4. Start the timer as soon as the yeast beads touch the surface of the hydrogen peroxide solution or as soon as they touch the bottom of the vial.
5. Record the time when all the beads have reached the surface of the hydrogen peroxide solution.
6. Repeat your measurements at least two more times.
7. Report your group data in this *Google Sheet* by scanning the QR code.



Scan the QR code to get a copy of the *Google Sheet*.



任務 4

- 閱讀以下實驗步驟以進行探究：

實驗步驟

酵母凝膠珠的製備

- 將 10 mL 10% 的酵母(在小瓶中)加入到盛有 10 mL 2% 的海藻酸鈉溶液的 50 mL 的試管中。
- 倒置 50 mL 試管將溶液充分混合，使之成為酵母-海藻酸鈉溶液。
- 用支架和夾子夾住塑料滴管(無蓋)。
- 將 50 mL 2% 的 CaCl_2 (氯化鈣)倒入一個塑料杯中/100 mL 燒杯。
- 組裝圖 1 中所示的裝置。
- 在塑料滴管中加入海藻酸鈉酵母溶液(當滴管接觸到 CaCl_2 溶液並落到燒杯底部時應形成一個珠子)。
- 等待 5 分鐘，直到珠子變硬。
- 用塑料勺子丟棄任何漂浮的酵母珠。
- 用篩子收集珠子。
- 用洗瓶中的蒸餾水沖洗幾次塑料杯上的酵母凝膠珠。

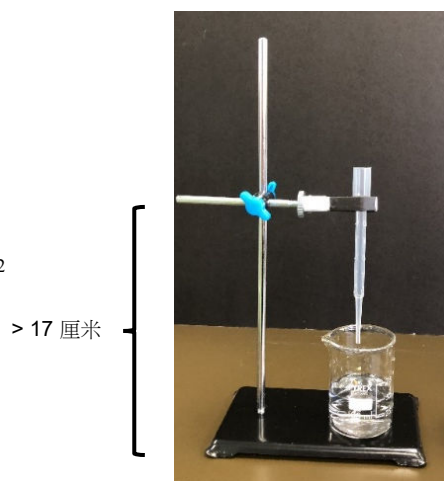


圖 1

過氧化氫酶活性的抑制

- 將不同濃度的重金屬溶液(1M、0.5M、0.25M)和蒸餾水倒入四個不同的培養皿中(5 mL 視乎培養皿的大小)。
- 用塑料小匙及鑷子在每一個已標記的培養皿中緩緩加入至少 15 粒酵母凝膠珠，並至少靜候 5 分鐘。

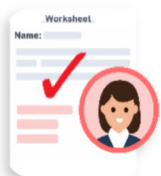
測量過氧化氫酶活性

- 用量筒測量 10 mL 0.1% 過氧化氫溶液，並將溶液倒入塑料小瓶中。(你可以使用滴管轉移溶液。)
- 重複步驟 1 三次。
- 使用鑷子小心地將每個培養皿中的五個酵母珠轉移到每個塑料小瓶中。
- 酵母凝膠珠接觸過氧化氫溶液表面或接觸小瓶底部時，立即啟動計時器。
- 記錄所有酵母凝膠珠到達過氧化氫溶液表面的時間。
- 至少再重複兩次測量。
- 掃描二維碼，在此 Google Sheet 報告你小組的數據。

掃描二維碼以獲取
Google Sheet 的副本



Teacher Notes 2



Notes for teachers

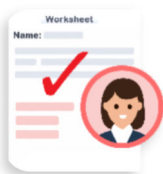
- The following are some possible questions that teachers can use to guide students in thinking about or assessing their scientific inquiry skills related to data analysis and interpretation.
- Some student work samples are shown below to illustrate possible student thinking.

Task 5

Possible questions

1. Based on the class data, which data set concerning the effect of 0.5 M of the two heavy metal ions on the yeast bead catalase activity is more variable? Explain your answer.
2. Plot a graph to show the class data.
 - Which type of graph would you choose to show the effect of different types of heavy metals on the activity of catalase under different concentrations? Why?
 - Which axis, the x-axis or the y-axis, should be the independent and dependent variables respectively?
 - What should be a suitable title for your graph?
3. Describe and compare the effect of different concentrations of the two heavy metal ions on the activity of catalase in the yeast beads.
4. If 1,000 yeast beads are typically used to remove hydrogen peroxide from industrial effluents without heavy metals, how many yeast beads would be needed to achieve the same removal efficiency in effluents containing 0.1 M nickel chloride and 0.1 M copper sulphate, respectively?

Some reminders are added to guide students in constructing graphical representations appropriately.

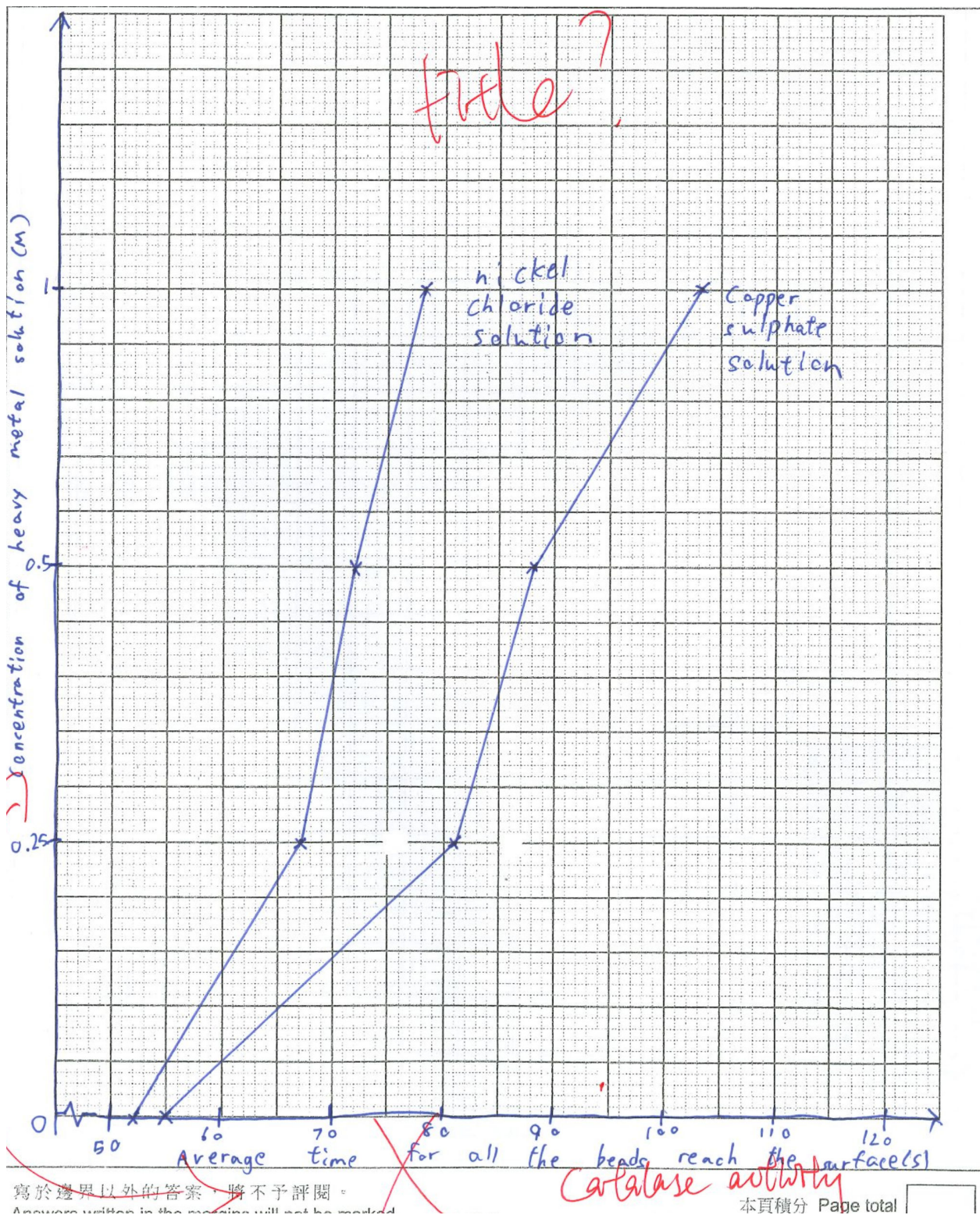


Notes for teachers

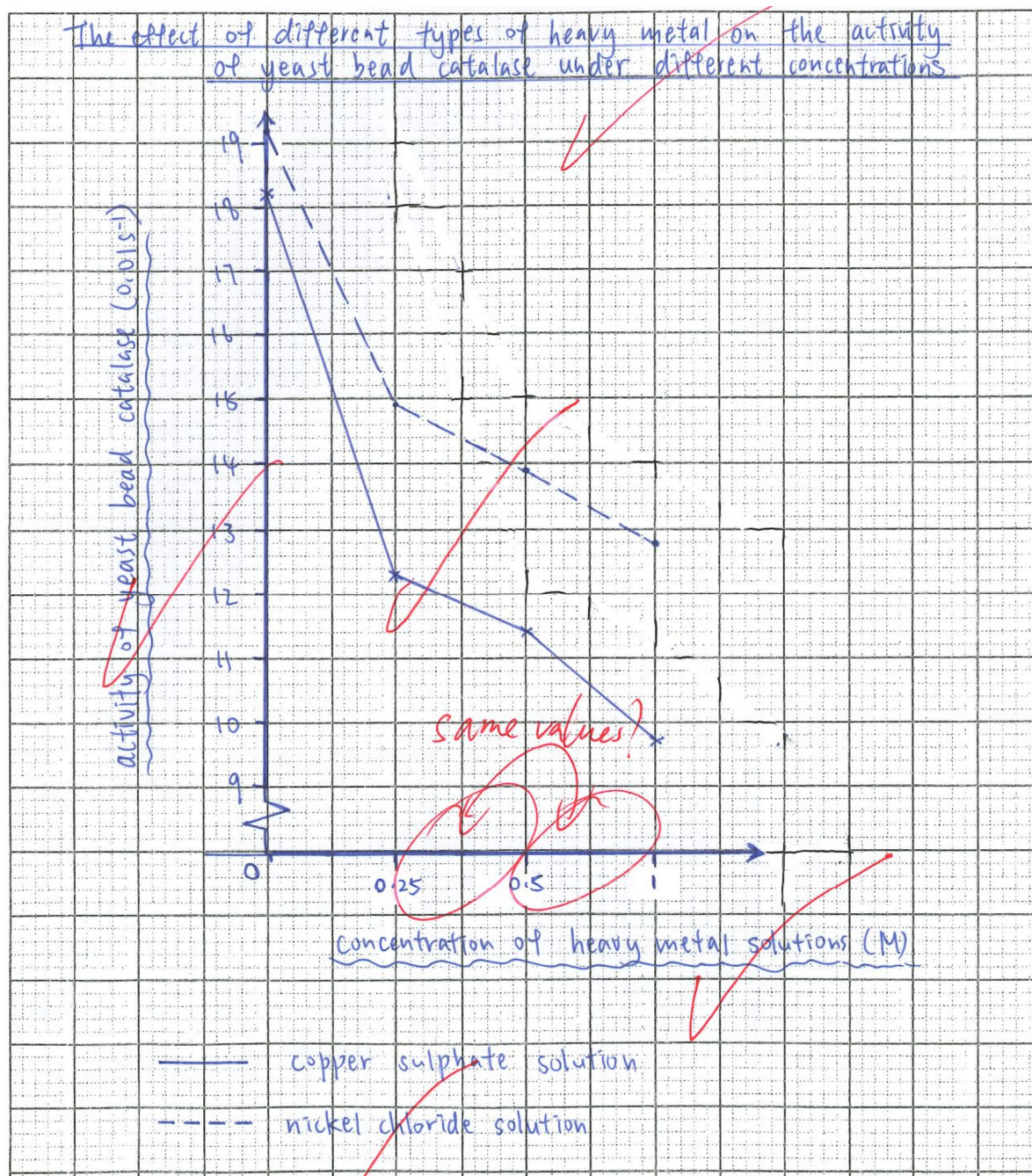
- Q.1 assesses students' ability to apply basic statistics to compare the variability of datasets.
- Q.2 assesses students' ability to construct appropriate graphical representations.
- Q.3 assesses students' ability to describe and compare more complex data sets involving more than one independent variable.
- Q.4 assesses students' ability to read data from the graph and perform simple calculation based on their data.

The following are some examples of students' responses to Q.2:

Sample 1



Sample 2



About the samples

- Sample 1 has various mistakes in the graph plotting. These include: (1) missing a title for the graph; (2) reversing the x-axis and y-axis; (3) using a measurement parameter rather than the dependent variable on the axis.
- Sample 2 shows a scaling issue in the graph. The interval between 0.25 M and 0.5 M is the same as the interval between 0.5 M and 1.0 M, which is not an appropriate scaling.

The following are some examples of students' responses to Q.3:

Sample 1

For nickel chloride solution, the activity of catalase is decreased from 0.0192 to 0.0128. And for copper sulphate solution, the activity of catalase is also decreased from 0.0181 to 0.00971.
when ...

Sample 2

With copper sulphate solution, the time for all the yeast beads reach the solution's surface becomes longer, which means that copper sulphate affects catalase to carry out enzymatic reaction. With nickel chloride solution, the time for all the yeast beads reach the solution's surface also becomes longer but shorter than copper sulphate solution does. It means that nickel chloride affects the activity of catalase. Yet, it affects less comparing with copper sulphate.

Sample 3

The activity of catalase in the yeast beads decrease when the concentration of copper sulphate solution increase from 0M to 1M. The activity of catalase in yeast beads decrease when the concentration of nickel chloride solution increase from 0M to 1M.

The effect of increasing concentrations of copper sulphate solution that lead to the decrease in activity of catalase is larger than that of nickel chloride solution.



About the samples

- Sample 1 did not clearly identify how the different concentrations of copper/nickel ions influenced the yeast bead catalase activity.
- Sample 2 did not specify the range of heavy metal ion concentrations over which there was a decrease in yeast bead catalase activities. There was also no explicit comparison of the effects of the two different heavy metal ions.
- Sample 3 showed that as the concentration of heavy metal ions increased, there was a decrease in yeast bead catalase activity. It also identified that the copper ions caused a greater decrease in activity compared to the nickel ions. However, the description of the differential effects between the two heavy metal ions could be more nuanced.

任務 5

參考問題

1. 根據全班數據，那一組關於摩爾濃度為 0.5 M 的兩種重金屬離子對酵母凝膠珠中的過氧化氫酶活性影響的數據可變性較大？解釋你的答案。
2. 以圖表的形式呈現全班數據。
 - 你會選擇那種類型的圖表來展示不同類型的重金屬離子在不同濃度下對酵母凝膠珠中過氧化氫酶活性的影響？為什麼？
 - X 軸和 Y 軸應分別代表哪些因變量及自變量？
 - 您的圖表應該有一個合適的標題是什麼？
3. 描述並比較兩種重金屬離子在不同濃度下對酵母凝膠珠中過氧化氫酶活性的影響。
4. 如果在沒有重金屬離子的工業廢水雖要使用 1,000 粒酵母凝膠珠以去除過廢水中的過氧化氫,那麼在含有 0.1 M 氯化鎳和 0.1 M 硫酸銅的廢水中,需要分別使用多少粒酵母凝膠珠才能達到同樣的去除效率？



Supplementary Resources

Possible Modifications

1. Studying plant material beads

- Catalase can be found in many different tissues of plants and animals. Crude extract from plant materials can also be used to make alginate beads (Andrews et al., 2019). Potato, banana and cucumber beads can be prepared using the following protocol:

Procedure

Preparation of alginate beads using crude extract from plant materials

1. Weigh 20 g of potato/cucumber.
2. Cut the potato/cucumber into small pieces.
3. Add 20 mL of distilled water to the potato/cucumber.
4. Blend the potato/cucumber and the distilled water with a blender.
5. Filter the potato/cucumber juice with a muslin bag.
6. Add 10 mL of 3% or 4% sodium alginate solution to 10 mL of filtered potato/cucumber juice.
7. Mix the mixture well.
8. Store at 4°C to remove air bubbles.
9. Add the potato/cucumber juice-sodium alginate solution to the plastic dropper (a bead should form when the drop comes into contact with the CaCl₂ solution and falls to the bottom of the beaker) above a beaker of 2% calcium chloride.



Scan the QR code to watch a video on how to prepare plant material alginate beads.



Important notes

- It is important to make sure that the plant extract is dense enough for the beads to sink to the bottom.
- Storing the plant extract–alginate mixture overnight at 4°C can effectively remove the air bubbles (the beads will float if they contain many air bubbles).

Technician Notes

1. Materials for Task 2

Materials to for each group

- 1% H₂O₂ (50 ml) in 100 mL beakers
- 3% H₂O₂ (50 ml) in 100 mL beakers (Handle with care!)
- 5 plastic vials
- Forceps X2
- Irregular yeast beads in a petri dish



2. Materials for Task 4

Chemicals to be prepared

- 10% yeast extract (1 mL in 1.5 mL tube) (to be prepared on that day) (Add 15 g yeast in 150 mL distilled water. Add a spoonful of sugar. Stir on a magnetic stirrer. Wait for 30 minutes to activate the yeast. Keep stirring. Aliquot just before the experiment.)
- 2% sodium alginate (food grade). Add 200 mL of distilled or deionised water and a stir bar. Heat the solution. Slowly add some sodium alginate to dissolve it. Add more powder slowly (5 g in total). Make up volume to 250 mL. Store the solution at 4°C.
- 0.1% hydrogen peroxide (150 mL per group) You may perform a trial run with 0.2% H₂O₂ as the catalase activity depends on the quality of the yeast. It is desirable if the yeast beads rise within 1 minute in the control (i.e., without metal ion treatment).



Scan the QR code to watch a video on how to prepare 2% sodium alginate.



Materials for each group

• 10 mL 2% Sodium alginate in 50 mL tube	• Plastic forceps X 4	• Plastic vials X 12
• 10 mL 10% Yeast in a plastic vial X 1	• 3 mL Plastic disposable pipette (with part of the head cut)	• 10 mL Measuring cylinder
• 100 mL Beaker X 2	• Mini-petri dish X 4	• 5 mL 1 M CuSO ₄ /NiCl ₂ solution in 15 mL tube
• Spoon (for removing floating yeast bead)	• 3 mL Disposable dropper (for measuring H ₂ O ₂)	• 5 mL 0.75 M CuSO ₄ /NiCl ₂ solution in 15 mL tube
• Sieve	• Stand and clamp	• 5 mL 0.25 M CuSO ₄ /NiCl ₂ solution in 15 mL tube
• 50 mL 2% Calcium chloride	• Wash bottle (with distilled water) X 1	• 5 mL Distilled water in 15 mL tube
• Timer	• 0.1% Hydrogen peroxide (>120 mL)	• Rubbish bin

Notes

- Do *not* use tap water to prepare heavy metal solutions.



Scan the QR codes to watch the videos.



References

- Andrews, K., Beaumont, P., & Louis, M. (2019). Catalase activity in immobilised yeast. *School Science Review*, 100(373), 13–16.
- Bryer, P. J. (2016a). A twist on measuring catalase. *Science Teacher*, 83(6), 69–73.
- Bryer, P. J. (2016b). Exploring catalase and invertase activity using sodium alginate–encapsulated yeast (yeast spheres). *Journal of Microbiology & Biology Education*, 17(3), 490–491.

This project is supported by Quality Education Fund
(Project No. 2019/0283)

The Trustee of the Quality Education Fund is the owner
of the copyright of this product. Any reproduction of this
product for commercial purposes is strictly prohibited
unless prior written consent has been obtained from the
Trustee of the Quality Education Fund.

此計劃由優質教育基金贊助 (計劃編號 2019/0283)
此計劃產品版權屬優質教育基金擁有，未經許可，
不得翻印以作商業用途。



Faculty of **Education**
The University of Hong Kong
香港大學教育學院



優質教育基金
Quality Education Fund