

5.1.1 Enzyme experiments: turning times into rates, and explaining the curve

Name: _____ Class: _____ Date: _____

Total: 36 marks**KEY WORDS** enzyme • temperature • rate • investigation • catalyst

Objective

Use enzyme-investigation data to calculate relative rates, describe temperature and pH curves, explain their shapes and identify variables. This sheet applies the enzyme action taught in 5.1. Keep the amount of substrate and the endpoint comparable when interpreting reaction times.

1 Key knowledge and worked examples

■ Enzyme action and the required explanation

An **enzyme** is a protein that acts as a biological **catalyst** : it speeds a reaction without being used up. Enzymes make metabolic reactions fast enough to support life. A **substrate** fits a complementary **active site** , forming an enzyme-substrate complex. Products leave and the enzyme can act again. Specificity depends on the matching shapes. **Denaturation** changes the active-site shape so the substrate no longer fits; an enzyme is not alive and cannot be “killed”.

■ Turn a fixed-endpoint time into a relative rate

time / s	rate = $1000 \div \text{time}$
100	$1000 \div 100 = 10$
50	$1000 \div 50 = 20$
40	$1000 \div 40 = 25$

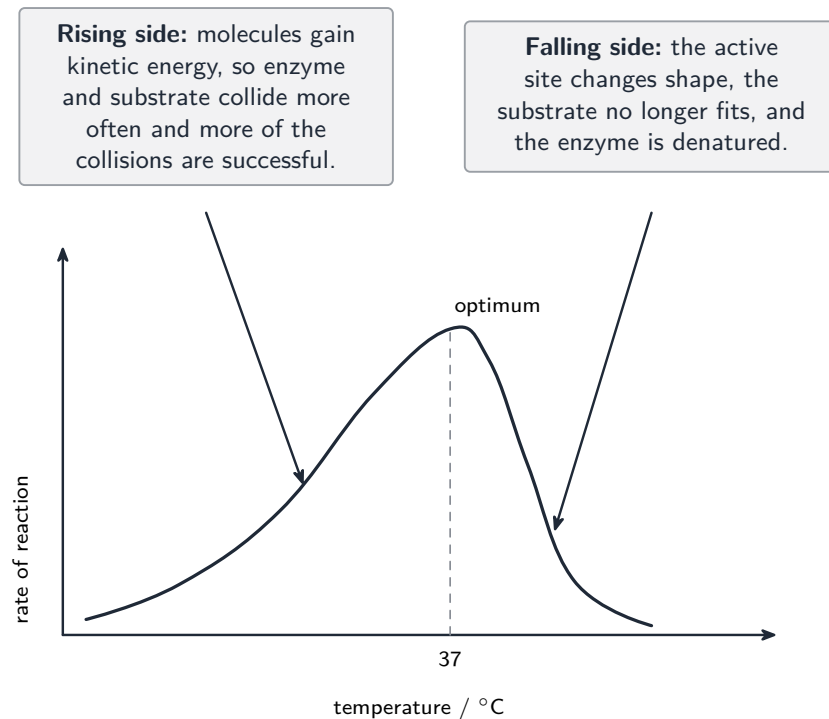
A shorter time always means a faster rate.
Never compare the times themselves.

For the same amount of reaction and the same endpoint, relative rate is proportional to $1/t$. This sheet scales it by 1000 for convenient numbers; it is not a universal rate unit.

$$\text{relative rate} = \frac{1000}{\text{time in s}}$$

Worked example: times of 100 s and 40 s give relative rates $1000/100 = 10$ and $1000/40 = 25$. The rate ratio is $25/10 = 2.5$. Equivalently, divide the longer time by the shorter, $100/40 = 2.5$. Subtracting gives a time difference, not a rate ratio.

■ Describe both sides, then explain them

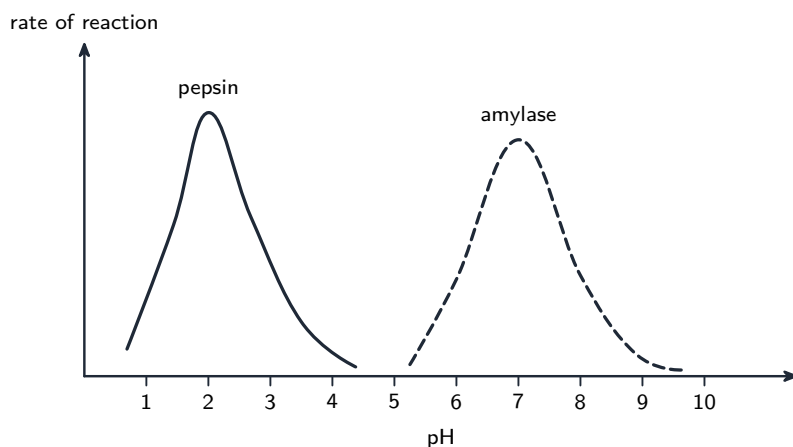


Describe: quote the axes and peak: the rate rises to its maximum near 37°C in this graph, then falls towards zero near 60°C.

Explain below the optimum: molecules gain kinetic energy, increasing successful enzyme-substrate collisions and complex formation.

Explain above the optimum: high temperature changes the active-site shape; the substrate no longer fits and the enzyme is denatured. The optimum is the temperature giving the highest measured rate; read it from the supplied graph.

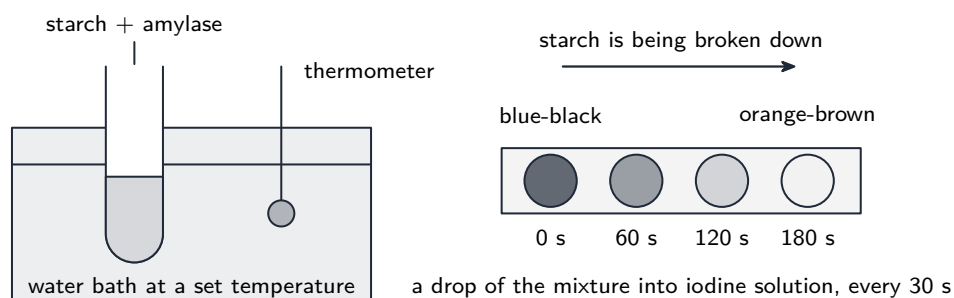
■ pH optima differ between enzymes



Each enzyme has its OWN optimum pH.
Away from it, on either side, the active site
changes shape and the enzyme is denatured.

Pepsin in the stomach has an optimum near pH 2; amylase has an optimum near pH 7. Read each peak rather than assuming every enzyme prefers neutral conditions. Moving away from the optimum can affect active-site shape and fit; sufficiently extreme pH can denature the enzyme. Do not use the temperature explanation of increased kinetic energy to explain a pH change.

■ Plan a fair investigation



What you measure is a **TIME**: how long until iodine solution stays orange-brown, which is the moment the last of the starch has gone.

- **Independent variable** : deliberately changed, such as temperature or pH.
- **Dependent variable** : measured, such as time to an endpoint or product volume in a fixed time.
- **Control variables** : enzyme/substrate volumes and concentrations, and whichever of temperature or pH is not changed. Use a water bath to maintain temperature.

- Repeat measurements and calculate a mean. Repeats support reliability; they do not by themselves remove a systematic error.

reaction	measurement
amylase and starch	time until iodine stays orange-brown: starch is no longer detected
catalase and hydrogen peroxide	oxygen volume in a fixed time
pectinase and crushed apple	juice volume after a stated reaction time
protease and cloudy milk	time until the milk clears

2 Practice

Now use the methods above.

2.1 A student timed how long amylase took to break down all the starch at three temperatures.

temperature / °C	time taken / s
20	100
30	50
40	40

Calculate the rate of reaction at each temperature, using $\text{rate} = 1000 \div \text{time}$. [3]

2.2 State which temperature gave the fastest reaction, and explain how the times show this. [2]

2.3 Name the independent variable and the dependent variable in this investigation. [2]

2.4 State **two** variables the student must keep the same. [2]

2.5 Explain why the reaction was faster at 40 °C than at 20 °C. Use the words *kinetic energy* and *collisions*. [3]

2.6 The student repeated the experiment at 70 °C. After 10 minutes the iodine solution was still blue-black. Explain this result. [3]

3 Exam-style questions

3.1 An enzyme breaks down its substrate in 250 s at 15 °C and in 50 s at 35 °C. How many times faster is the reaction at 35 °C? [1]

☐

- A 0.2
- B 5
- C 200
- D 300

3.2 Pepsin digests protein in the stomach. A student timed how long pepsin took to digest a piece of cooked egg white at four pH values.

pH	time taken / s
1	120
2	60
4	200
7	no change after 600

(a) Calculate the rate of reaction at pH 2 and at pH 4, using $\text{rate} = 1000 \div \text{time}$. Give each answer to 2 significant figures. [2]

(b) State the optimum pH of pepsin, and give the evidence from the table. [2]

(c) Explain why no protein was digested at pH 7. [2]

3.3 A food company uses the enzyme **pectinase** to get more juice out of crushed apples. A student investigated how temperature affects pectinase.

She put 20 g of crushed apple and 2 cm³ of pectinase into each of six test tubes. She kept each tube at a different temperature for 20 minutes, then filtered the mixture and measured the volume of juice collected.

temperature / °C	volume of juice / cm ³
10	3.0
20	5.5
30	9.0
40	12.5
50	6.0
60	0.5

(a) Name the independent variable and the dependent variable. [2]

(b) State **two** variables that were kept the same. [2]

(c) Describe the results shown in the table. [3]

(d) Explain the results between 10 °C and 40 °C. [3]

(e) Explain why almost no juice was collected at 60 °C. [3]

(f) Suggest one change the student could make so that her results are more reliable. [1]
