Q1.

(a) Draw the general structure of an amino acid.

(1)

(b) Describe how a peptide bond is formed between two amino acids to form a dipeptide.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(c) The secondary structure of a polypeptide is produced by bonds between amino acids.

Describe how.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(d) Two proteins have the same number and type of amino acids but different tertiary structures.

Explain why.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(2)
(Total 7 marks)

Q2.

Scientists measured the mean amino acid concentration in white wines made from grapes grown organically and white wines made from grapes that were not grown organically.

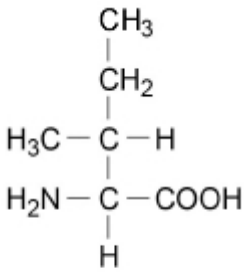
(a) Which test could the scientists have used to identify that there are amino acids in white wine?

_____

(1)

(b) All amino acids have the same general structure. The image below shows the structure of the amino acid isoleucine.

Draw a box around the part of the molecule that would be the same in all amino acids.



Isoleucine

(1)

(c) Name the chemical element found in all amino acids that is **not** found in triglycerides.

_____

(1)

(d) Haemoglobin is a protein with a quaternary structure. What is meant by a *quaternary* structure?

_____

_____

(1)
(Total 4 marks)

Q3.

(a) What is an enzyme?

_____

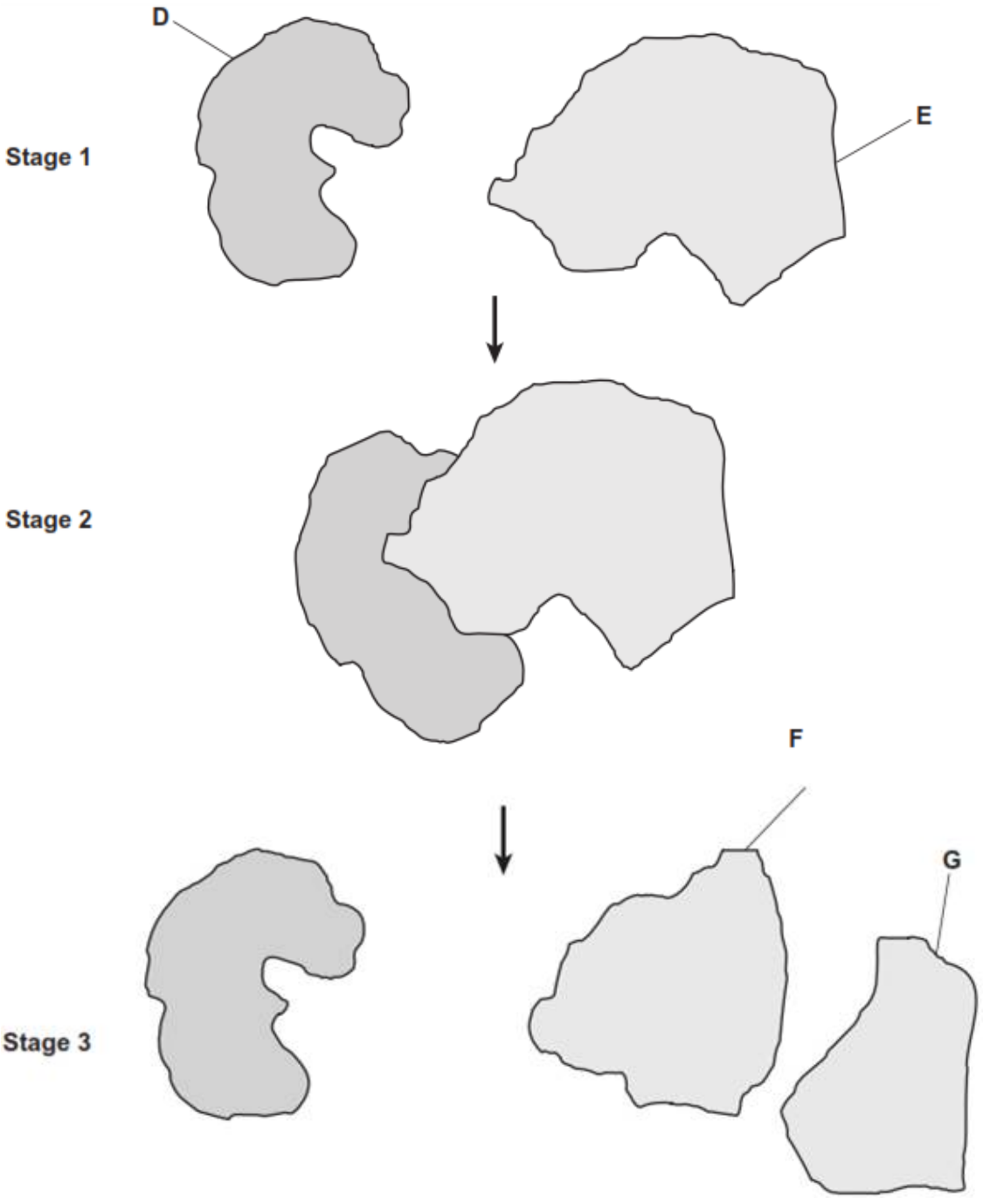
_____

_____

_____

(2)

The diagram shows stages during an enzyme-catalysed reaction.



(b) Using the letters in the diagram, describe what is happening in this reaction.

_____

_____

_____

_____

_____

_____

_____

(3)
(Total 5 marks)

Q4.

(a) In humans, the enzyme maltase breaks down maltose to glucose.
This takes place at normal body temperature.

Explain why maltase:
- only breaks down maltose
- allows this reaction to take place at normal body temperature.

(5)

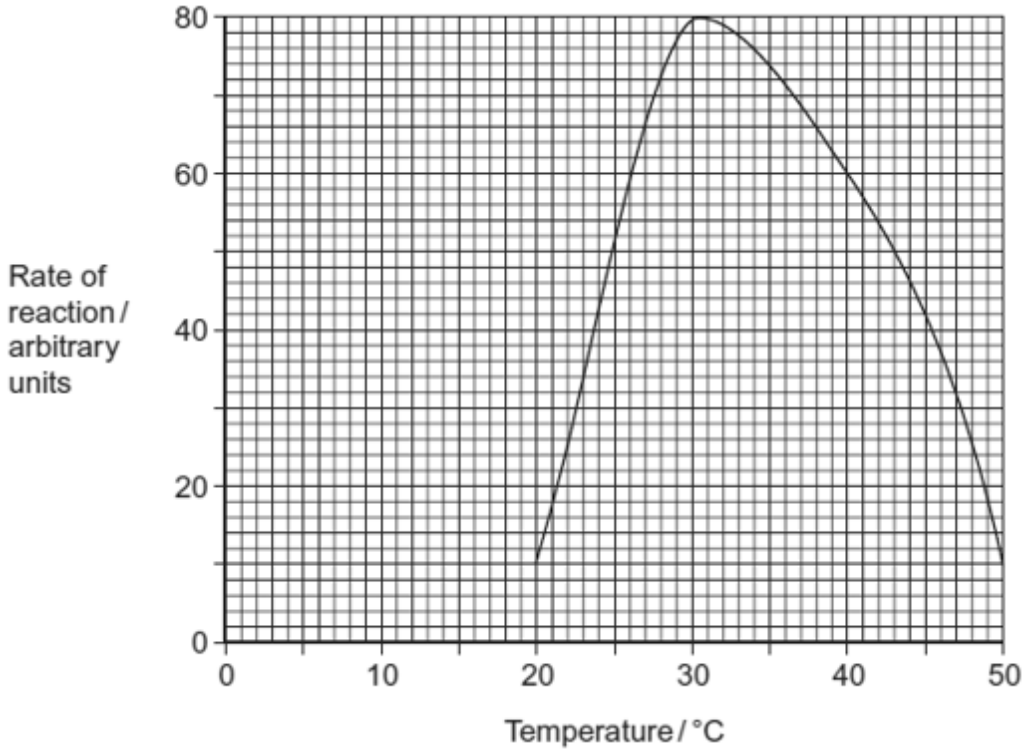
(b) Scientists have investigated the effects of competitive and non-competitive inhibitors of the enzyme maltase.

Describe competitive and non-competitive inhibition of an enzyme.

(5)
(Total 10 marks)

Q5.

A protease is an enzyme that digests protein. The graph shows how the activity of a protease varies with temperature.



(a) (i) Describe what the graph shows about the effect of temperature on the rate of reaction.

_____

_____

_____

(1)

(ii) Explain the shape of the curve between 30 °C and 50 °C.

_____

_____

_____

_____

_____

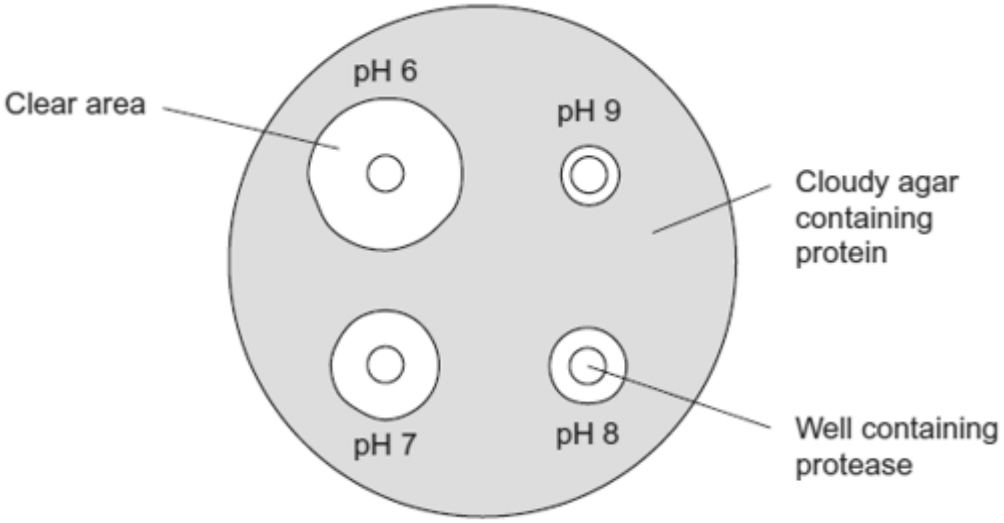
_____

(3)

(b) Students investigated the effect of pH on the activity of the protease.

- The students used agar plates containing protein. The protein made the agar cloudy.
- They made four wells of equal size in the agar of each plate.
- They added a drop of protease solution to each of the wells. The protease solution in each well was at a different pH.
- The students incubated the agar plates for 4 hours at a constant temperature.

The diagram shows the agar plates after they were incubated and the pH of the protease solution in each well.



(i) How should the students make sure that the pH of the protease solution did **not** change?

_____

(1)

(ii) Use the graph to suggest a suitable temperature for incubating the agar plates.

Explain your answer.

_____

_____

_____

(1)

(iii) Use the diagram to describe the effect of pH on the activity of this protease.

_____

_____

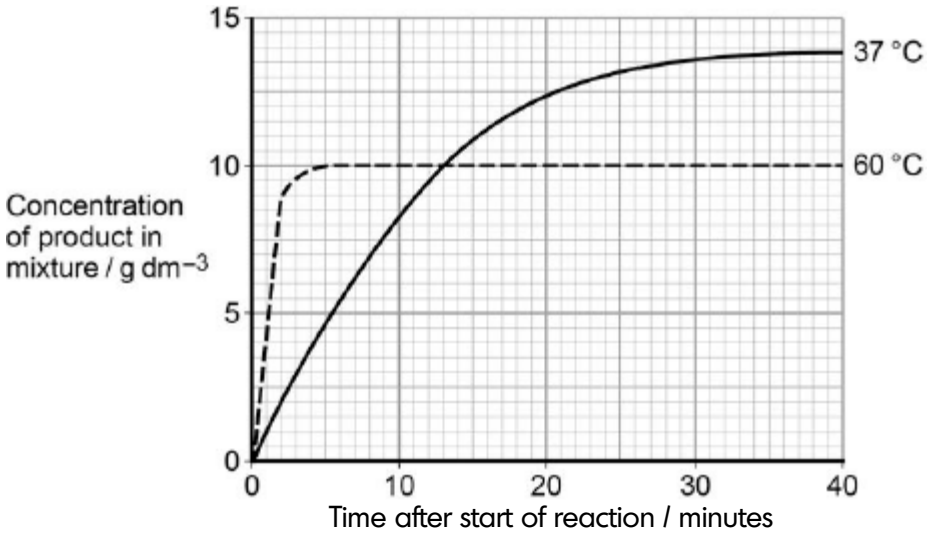
_____

(1)
(Total 7 marks)

Q6.

A technician investigated the effect of temperature on the rate of an enzyme-controlled reaction. At each temperature, he started the reaction using the same concentration of substrate.

The following graph shows his results.



(a) Give **two** other factors the technician would have controlled.

1. _____

2. _____

(1)

(b) Draw a tangent on each curve to find the initial rates of reaction.
Use these values to calculate the ratio of the initial rates of reaction at 60 °C : 37 °C.
Show your working.

Ratio = _____ :1

(2)

(c) Explain the difference in the initial rate of reaction at 60 °C and 37 °C.

_____

_____

_____

_____

(2)

(d) Explain the difference in the rates of reaction at 60 °C and 37 °C between 20 and 40 minutes.

(Extra space)

(4)
(Total 9 marks)

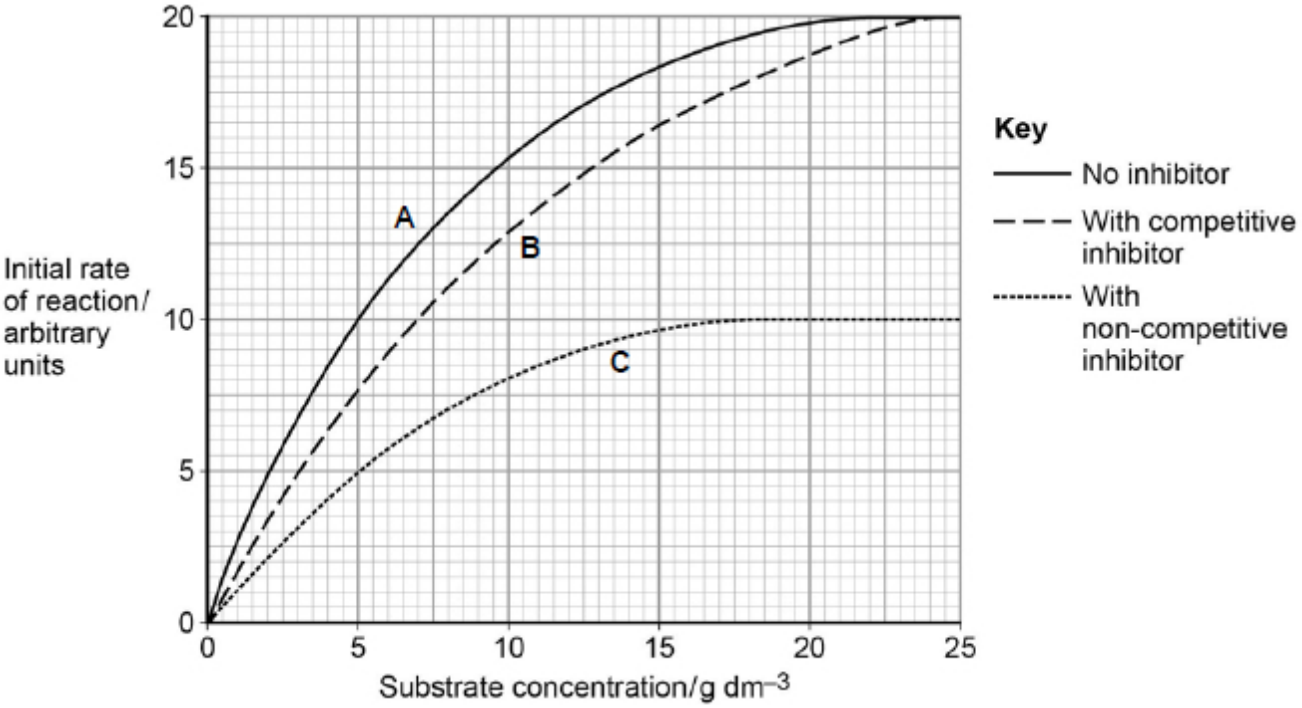
Q7.

A student investigated the effect of substrate concentration on the initial rate of an enzyme-catalysed reaction.

She added 10 cm^3 of an enzyme solution to 10 cm^3 of substrate solutions of different concentrations. At 30-second intervals, she tested samples of each mixture for the presence of substrate.

- **A** – in the absence of an inhibitor.
- **B** – with a competitive inhibitor added to the substrate solution.
- **C** – with a non-competitive inhibitor added to the substrate solution.

Her results are shown in the graph below.



(a) Explain the results **without** inhibitor (curve **A**) shown in the graph.

_____

_____

_____

_____

_____

_____

(2)

(b) The graph shows that the maximum initial rate of reaction (V_{max}) when a competitive inhibitor was present (curve **B**) is different from that when a non-competitive inhibitor was present (curve **C**).

Explain this difference.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(c) The Michaelis constant (K_m) is the substrate concentration at which the initial rate of reaction is half its maximum value (V_{max}).

How could you use the Michaelis constant to determine the type of inhibition occurring in an enzyme-catalysed reaction?

Use information from the graph to support your answer.

_____

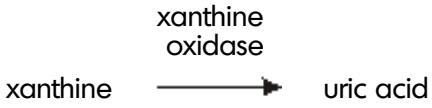
_____

_____

(1)
(Total 7 marks)

Q8.

Uric acid is produced in the body. One of the reactions involved in the production of uric acid is catalysed by xanthine oxidase.



(a) A sample of xanthine oxidase was tested by mixing with biuret reagent. Describe and explain the result of this test.

_____

_____

_____

_____

(2)

(b) Explain why xanthine oxidase is able to catalyse this reaction but it is not able to catalyse other reactions.

_____

_____

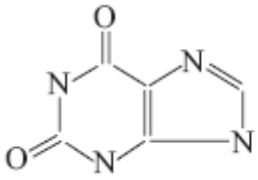
_____

_____

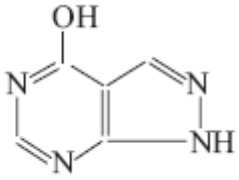
(2)

(c) Gout is a painful condition caused by uric acid crystals in the joints. It is often treated with a drug that inhibits xanthine oxidase. The diagram shows a molecule of xanthine and a molecule of this drug.

Xanthine



Drug used to treat gout



Use the diagram to explain why this drug is effective in the treatment of gout.

_____

_____

_____

_____

_____

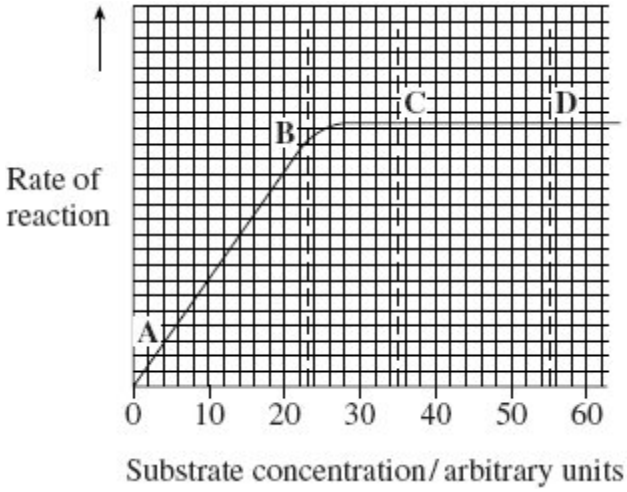
_____

(3)

(Total 7 marks)

Q9.

The graph shows the effect of substrate concentration on the rate of an enzyme-controlled reaction.



(a) (i) Describe what the graph shows about the effect of substrate concentration on the rate of this enzyme-controlled reaction.

_____

_____

_____

_____

(2)

(ii) What limits the rate of this reaction between points **A** and **B**? Give the evidence from the graph for this.

_____

_____

_____

_____

(2)

(iii) Suggest a reason for the shape of the curve between points **C** and **D**.

_____

_____

(1)

(b) Sketch a curve on the graph to show the rate of this reaction in the presence of a competitive inhibitor.

(1)

(c) Methotrexate is a drug used in the treatment of cancer. It is a competitive inhibitor and affects the enzyme folate reductase.

(i) Explain how the drug lowers the rate of reaction controlled by folate reductase.

_____

_____

_____

_____

_____

(2)

(ii) Methotrexate only affects the rate of the reaction controlled by folate reductase.

Explain why this drug does not affect other enzymes.

_____

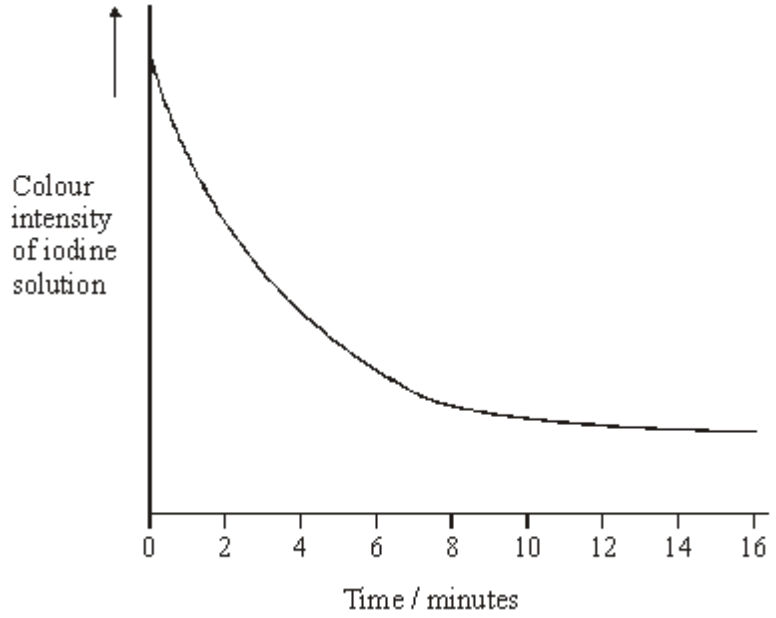
_____

(1)

(Total 9 marks)

Q10.

In an investigation into carbohydrase activity, the contents from part of the gut of a small animal were collected. The contents were added to starch solution at pH 7 and kept in a water bath at 25°C. At one-minute intervals, samples were removed and added to different test tubes containing dilute iodine solution. The colour intensity of each sample was determined. The graph shows the results.



(a) Explain the change in colour intensity.

_____

_____

_____

_____

(2)

(b) Draw clearly labelled curves on the graph to show the expected result if the experiment was repeated

(i) at 35 °C;

(ii) at pH 2.

(2)

(c) Explain how

(i) raising the temperature to 35 °C affects carbohydrase activity;

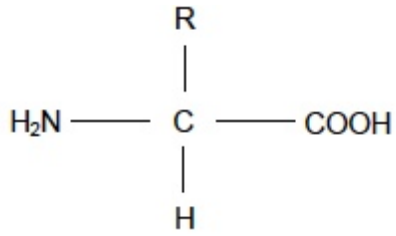
(ii) decreasing the pH affects carbohydrase activity.

(7)
(Total 11 marks)

Mark schemes

Q1.

(a)



Accept other correct representations.

1

(b) 1. Condensation (reaction) / loss of water;
Accept each marking point if shown clearly in diagram.

2. Between amine / NH_2 and carboxyl / COOH;
Accept between amino (group) and carboxylic / acid (group)

2

(c) 1. Hydrogen bonds;
Accept as a diagram
Reject N - - - C / ionic / disulfide bridge / peptide bond

2. Between NH (group of one amino acid) and C=O (group);
OR
Forming β pleated sheets / α helix;

2

(d) 1. Different sequence of amino acids
OR
Different primary structure;
If candidate assumes proteins are the same, accept effect of different pH/ temperature

2. Forms ionic / hydrogen / disulfide bonds in different places;

2

[7]

Q2.

(a) Biuret;

Ignore any other detail

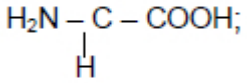
Accept

- *Copper sulfate and sodium hydroxide*
- *$CuSO_4$ + NaOH*
- *Alkaline copper sulfate*
- *Copper sulphate and sodium hydroxide*
- *Alkaline copper sulphate*
- *Biurette*
- *Buiret*
- *Biruet*
- *Bieuret*

Reject burette or Beirut

1

(b) Draw around



1

(c) Nitrogen;

Ignore N

1

(d) Structure resulting from aggregation of several polypeptide chains / tertiary structures / eq:

1

[4]

Q3.

(a) Protein;

Catalyst;

Accept speeds up a reaction (but is not changed by the reaction)

(For reaction involving a) specific substrate;

Lowers activation energy;

2 max

(b) Enzyme D binds/collides with substrate E;

Ignore lock and key references

Active site forms/changes shape to fit substrate/E;

Max 2 if no reference to letters

(By) induced fit;

(As) enzyme-substrate complex forms;

(Breaks down to give) products F and G;

Enzyme is unchanged (at end);

3 max

[5]

Q4.

(a) 1. Tertiary structure / 3D shape of enzyme (means);
Accept references to active site

2. Active site complementary to maltose / substrate / maltose fits into active site / active site and substrate fit like a lock and key;
Idea of shapes fitting together

3. Description of induced fit;

4. Enzyme is a catalyst / lowers activation energy / energy required for reaction;
Accept "provides alternative pathway for the reaction at a lower energy level"

5. By forming enzyme-substrate complex;
Accept idea that binding stresses the bonds so more easily broken
Do not award point 5 simply for any reference to E-S complex

5

(b) 1. Inhibitors reduce binding of enzyme to substrate / prevent formation of ES complex;
Max 3 if only one type of inhibition dealt with. Accept maltase and maltose as examples of enzyme and substrate (and others)
Only once, for either inhibitor

(Competitive inhibition),

2. Inhibitor similar shape (idea) to substrate;

3. (Binds) in to active site (of enzyme);
Accept allows max rate of reaction to be reached / max product will eventually be formed
Accept complementary to active site

4. (Inhibition) can be overcome by more substrate;

(Non-competitive inhibition),

5. Inhibitor binds to site on enzyme other than active site;

6. Prevents formation of active site / changes (shape of) active site;
Accept does not allow max rate of reaction to be reached / max product will not be formed

7. Cannot be overcome by adding more substrate;

5 max

[10]

Q5.

(a) (i) Increase to 30 °C / 31 °C and then decreases / optimum or max rate at 30 °C / 31 °C;

Accept: peak at 30 °C / 31 °C

1

(ii) 1. Enzyme denatured / hydrogen bonds / bonds holding tertiary structure broken / tertiary structure changed;

2. Change in shape of active site (of enzymes);

3. Substrate / protein no longer fits / binds (into active site) / few or no ES complexes;

1. Reject: Peptide bonds broken
Denatures active site = 2 marks for mp 1 and 2
2. Q Only allow second point if active site is used correctly
Accept: active site no longer complementary
3. Accept: Substrate cannot bind to enzyme

3

(b) (i) Use buffer / test pH (at end / at intervals);

Accept a method of measuring pH.
Reject litmus.

1

(ii) (30 °C / 31 °C) Maximum rate / optimum temperature;

Accept other valid answers e.g. temp below 30 °C as enzyme not denatured.

1

(iii) Works best at pH 6 / at higher pH activity decreases;

Accept converse
Insufficient: pH 6 had largest clear area

1

[7]

Q6.

(a) Any **two** of the following:
Concentration of enzyme
Volume of substrate solution
pH.

Allow same concentration of substrate

1

(b) Ratio between 5.18:1 and 5.2:1
Initial rates incorrect but correctly used = 1 mark.

Allow 1 mark if rate at:

60°C = 0.83g dm^{-3} s^{-1} /49.8g dm^{-3} $minute^{-1}$

OR

37°C = 0.16g dm^{-3} s^{-1} /9.6g dm^{-3} $minute^{-1}$

2

(c) At 60 °C:
1. More kinetic energy;
2. More E–S complexes formed.

Allow converse for 37 °C

2

(d) Different times:
1. Higher temperature / 60 °C causes denaturation of all of enzyme;

Accept converse for 37 °C

2. Reaction stops (sooner) because shape of active site changed;

Reject if active site on substrate

Different concentrations of product (at 60 °C)
3. Substrate still available (when enzyme denatured);
4. But not converted to product.

4

[9]

Q7.

(a) 1. Increases because more enzyme-substrate complexes formed;
Neutral; more collisions

2. Levels off because all enzyme molecules involved in enzyme-substrate complexes (at a given time)
1. and 2. Accept ES
2. Reject enzymes are used up
OR
Levels off because no free active sites (at a given time)
OR
Levels off because enzyme (concentration) is limiting factor.

2

(b) 1. Competitive inhibitor binds to active sites of enzyme but non-competitive inhibitor binds at allosteric site / away from active site;

2. (Binding of) competitive inhibitor does not cause change in shape of active site but (binding of) non-competitive does (cause change in size of active site);

3. So with competitive inhibitor, at high substrate concentrations (active) enzyme still available but with non-competitive inhibitor (active) enzymes no longer available;

4. At higher substrate concentrations likelihood of enzyme-substrate collisions increases with competitive inhibitor but this is not possible with non-competitive inhibitor;

4

(c) Reaction with non-competitive inhibitor has the same value of K_m as with no inhibitor / value is *5* (g dm^{-3}) / reaction with competitive inhibitor has higher K_m value than with no inhibitor / value is *7* (g dm^{-3}).

1

[7]

Q8.

(a) Lilac / purple / mauve / violet;

Xanthine oxidase is a protein;
Reject pink or blue as the resulting colour with biuret.

2

(b) Substrate has specific shape;

Allows binding / fitting / forms ES complex with active site;

Or

Active site has specific shape;

Allows binding / fitting / forms ES complex with substrate;
Accept structure ≡ shape

2

(c) Xanthine <u>similar</u> shape to drug;

Drug fits active site / competes for active site / is a competitive inhibitor;

Less / no uric acid formed;

3

[7]

Q9.

(a) (i) Increases then plateaus / constant / steady / rate does not change;

Neutral: 'peaks' / 'reaches a maximum' / 'stops increasing' / 'no effect' instead of 'plateaus'
Reject: rate decreases / reaction stops

Correct reference. to 27 / 28 units;
e.g. increases up to / plateaus at 27 / 28

2

(ii) Substrate concentration / amount of substrate;

As substrate concentration increases, rate increases / positive correlation (between rate and substrate concentration);

2

(iii) All active sites occupied / saturated / enzyme limiting (rate of reaction) / maximum number of E-S complexes;

Reject: enzymes used up
Reject: substrate limits rate of reaction
Neutral: substrate no longer limits the reaction
Neutral: reference to temperature

1

(b) Curve is lower and plateaus at a higher substrate concentration (it must also start at zero);

Accept: curve lower and joins existing curve at final point (with no plateau)
Reject: if curve plateaus before original
Reject: if curve plateaus lower than original

1

(c) (i) Methotrexate / drug is a similar shape / structure to substrate so binds to / fits / is complementary to active site;

***Q** Reject: same structure / shape*
***Q** Reject: reacts with active site*

Less substrate binds / less enzyme-substrate complexes formed;

Accept: substrate cannot bind / enzyme-substrate complex not formed

2

(ii) Methotrexate / drug is only similar shape to specific substrate / only fits this active site;

Assume that 'it' refers to the drug

OR

Methotrexate / drug is a different shape to other substrates / will not fit other active sites;

1

[9]

Q10.

(a) colour results from starch-iodine reaction;
decrease due to breakdown of starch by carbohydrase / enzyme;

2

(b) (i) curve drawn below curve on graph and starting at same point;

1

(ii) curve drawn above curve on graph and starting at same point but finishing above;

(allow curve or horizontal line)

(allow alternative curve for pH if explanation in (ii) is consistent)

1

(c) (i) 1. increase in temperature increases kinetic energy;
2. increases collisions (between enzyme / active site and substrate) / increases formation of enzyme / substrate complexes;
3. increases rate of breakdown of starch / rate of reaction / carbohydrase activity;

(ii) 4. (decrease in pH) increases H^+ ions / protons which attach / attracted to amino acids;
5. hydrogen / ionic bonds disrupted / broken which denatures enzyme / changes tertiary structure;
6. changes shape / charge of active site so active site / enzyme unable to combine / fit with starch / enzyme-substrate complex no longer able to form;
7. decreases rate of breakdown of starch / rate of reaction / carbohydrase activity;

(allow alternative explanation for pH if consistent with line drawn in (ii))

7

[11]