1.10 Amino acids, proteins and enzymes

Name: _____ Class: _____ Date: _____ **Total: 22 marks**

KEY WORDS peptide bond • primary structure • tertiary structure • active site • induced fit • denaturation

Objective

Practise statements 2.6–2.8 with Core Practical 4: amino-acid and protein structure, enzyme specificity and the induced-fit model, and the rate graphs the examiners always set.

1 Key knowledge and worked examples

■ Four levels of structure

Primary : amino-acid sequence, joined by **peptide bonds** formed in condensation between the amino group of one and the carboxyl group of the next. **Secondary**: hydrogen bonds coil or fold the chain (α-helix, β-pleated sheet). **Tertiary**: hydrogen, ionic and disulfide bonds fold the chain into its functional 3-D shape, where the **active site** forms. **Quaternary**: separate chains assemble (haemoglobin, with a haem group – a **prosthetic group**).

■ Enzymes lower the activation energy

The active site is complementary to the substrate but not a rigid lock: both flex on binding (**induced fit**) until the substrate is strained into its transition state. Temperature and pH act on tertiary structure – hence optima, and irreversible **denaturation** above them.

■ Reading the three rate curves

Temperature: rises (more kinetic energy, more successful collisions) to an optimum, then collapses (denaturation). pH: a sharp optimum reflecting the ionisation of the active site's R groups. Substrate concentration: rate rises then plateaus when every active site is saturated.

■ Worked example: competitive vs non-competitive

A drug halves the rate at low substrate concentration but not at very high concentration – competitive: at saturation, substrate out-competes the inhibitor for the active site. If the rate stays halved at every concentration, the inhibitor binds elsewhere (non-competitive) and removes working enzyme permanently.

2 Practice

2.1 Describe how a peptide bond forms between two amino acids. [3]

2.2 Explain why a change in pH can reduce enzyme activity without denaturing the enzyme. [2]

2.3 State what happens to the rate of an enzyme reaction when substrate concentration is doubled from a very low value, and when doubled from a saturating value. [2]

3 Exam-style questions

3.1 The table shows the rate of an enzyme-controlled reaction at five temperatures.

Temperature / °C	Rate / µmol min^{-1}
10	4
20	9
30	17
40	24
50	6

Calculate the Q10 between 10 °C and 20 °C, describe the trend including what happens above 40 °C, and explain the fall at 50 °C in terms of protein structure. [6]

3.2 An enzyme digests plastic. Chemical A added to the reaction does not change the rate at saturating substrate but lowers it at all lower concentrations by the same fraction. Chemical B added alone lowers the rate at every substrate concentration. Identify the type of inhibition for A and for B, and explain each observation. [5]

3.3 Amylase is linked to a second enzyme so that starch is broken down and the product immediately converted in one place. Suggest how linking the two enzymes could increase the overall rate of product formation, referring to the movement of the intermediate molecule. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 A condensation reaction between the amino group of one amino acid and the carboxyl group of the next removes a molecule of water and forms a peptide bond.

2.2 Away from the optimum, the ionisation of R groups in the active site changes, so the active site's shape or charge no longer fits the substrate well – activity falls before the tertiary structure itself breaks down.

2.3 From very low: rate approximately doubles. From saturating: no change – the enzyme's active sites are already all occupied.

3.1 Q10 = 9/4 = 2.25. Rate rises with temperature up to an optimum at 40 °C, then collapses to 6 µmol min^{-1} by 50 °C. Above the optimum, kinetic energy breaks the hydrogen and ionic bonds holding the tertiary structure, the active site's shape is lost (denaturation) and substrate no longer fits.

3.2 A is competitive: it competes for the active site, so at saturating substrate it is always out-competed and the maximum rate is unchanged. B is non-competitive: it binds away from the active site and distorts the enzyme's shape, effectively removing enzyme whatever the substrate concentration, so the rate falls at every concentration.

3.3 The intermediate does not have to diffuse away to find the second enzyme; its local concentration at the second active site is far higher, so it is converted as soon as it is made, raising throughput of the two-step sequence overall.