A* upgrade

Rates

Bill Indge takes you through calculations involving rates

I have met a number of teachers recently and also talked to a friend who is a senior examiner. I asked them about what I should use as the subject of my next *Upgrade* column. I have had the same answer every time — so you know who to blame for 'something mathematical'.

One of the most interesting aspects of marking A-level papers is that patterns emerge. I find evidence of topics that are well understood and skills that are firmly grasped. I also see areas that consistently result in disappointing responses, such as those involving simple calculations. In this *Upgrade*, we will look first at some of the more general issues that you should consider when answering questions involving calculations. A high proportion of calculations appearing in AS biology papers involve one of three topics:

- rates
- percentages
- magnification

If you can cope with these, you are almost home and dry. Here we look at calculations involving rates.

Key words

Calculations
Enzyme-controlled reaction
Tangent

Have a go

A few years ago, I looked through a large sample of AS biology papers — several hundred altogether. What interested me was the number of candidates who failed to attempt questions. Overall, the proportion was quite low; between 1 and 2% of candidates left blank spaces in answer to any one question. If the question involved a calculation, however, this percentage shot up, and approximately 20% of candidates failed to make any attempt.

Let's put this in a slightly different context. Suppose you are taking Unit 1 of your AS biology. You want a grade B. How many marks do you need? The answer may come as something of a surprise...one! Get this mark and you may be on the right side of the grade boundary. Fail to get it and it is a grade C — think of all the anguish that might bring. You cannot afford to turn down marks because you 'don't do maths'. Have a go. You may not get the answer completely correct but you stand a good chance of gaining some credit, and the mark you get may be the mark you need to put you on the right side of the grade boundary.

Show your working

This is an instruction that appears somewhere in most questions that involve calculations. There is a good reason for asking you to do this — working is worth credit. Suppose you are taking A-level maths as well as biology and you are a pretty competent mathematician. Have you ever made a trivial mistake? If you have, and all that you have done is written down the answer, you will not get credit. If, however, your working demonstrates that you have at least gone about your calculation in the right way, you stand to gain some marks.

On the other hand, you may not be a mathematician and perhaps even not particularly good at carrying out the simplest of calculations. Your answer may well be wrong but if your working shows that you have at least selected the correct figures, you may be awarded some credit. As we have said, every mark counts.

Think simple

One of the best pieces of advice that I was ever given when I took maths at school was to 'think simple' whenever I encountered a problem that I found difficult. Let's illustrate this with an example.

Suppose a person's pulse was measured and there were 140 beats in 96 seconds. Calculate his pulse rate in beats per minute.

You are struggling. Think simple and change this to make it a much easier question.

Suppose that there were 100 beats in 2 minutes. What was the pulse rate in beats per minute?

You should have no difficulty with this. All you have to do is divide 100 by 2, giving an answer of 50 beats per minute.

Now go back to the original question. Thinking simple tells you what to do and you need to do exactly the same here — divide the number of beats by the time.

140 divided by 96 gives 1.46

but, this is beats per second. We need beats per minute so we simply multiply our answer by 60 giving 87.5 beats per minute.

A little common sense

Before you finish, ask yourself, 'Is my answer sensible?' The pulse rate that we have just calculated was 87.5 beats per minute — a reasonable answer. Suppose that we had made a mistake in our method. Instead of dividing 140 by 96 we multiplied these two figures. We would have arrived at a pulse rate of 13 440 beats per second or 806 400 beats per minute. Something ought to tell you that you have made a mistake somewhere. If you have time, it would be worth looking back over your method.

Calculating rate

Wood pigeons are closely related to feral pigeons. They are widespread in both urban and rural areas. Wood pigeons feed on a range of plant matter. On agricultural land they frequently feed on grain, either when newly planted or when left in the stubble after harvesting. If a wood pigeon is feeding entirely on grain, it requires approximately 50 g per day to meet its needs. At high grain densities it spends relatively little time searching and pecks up the grain rapidly. Look at the points on the two curves on the graph in Figure 1 that correspond to a grain density of 24 grains per m^2 and you will find evidence to support this. At these high grain densities, a pigeon can collect its daily requirement in an hour or two, without having to search very hard. As grain density decreases, however, searching rate increases and feeding rate decreases. Feeding becomes uneconomic and the pigeons move to other food sources. Clearly, for the data in the graph to mean anything, time must be considered. Total number of pecks and number of paces on their own are meaningless, so we take time into account by calculating rate — peck and paces per minute (see Figure 1).

Rates are extremely important in biology and it is one of the mathematical requirements that you need to have mastered before you embark on topics such as enzyme biology, diffusion and active transport. Next we will work through an exercise involving rates of enzyme-controlled reactions. The questions have been chosen to involve as many of the calculations as possible that might be expected of you in an A-level biology examination.

Catalase is an enzyme that is found in many cells. It catalyses the reaction in which hydrogen peroxide is converted to water and oxygen. One way to follow the progress of the reaction is to measure its rate. The rate of an enzyme-controlled reaction can be measured in one of two ways. We can measure the rate at which a product is formed or we can measure the rate at which one of the reactants is used up. We will start by looking at the rate at which one of the products — oxygen — is produced in a given time.

25 cm^3 of oxygen was produced in 20 seconds. Calculate the rate of the reaction over this period.

In this case, the rate would be the volume of oxygen produced divided by the time. In other words 25/20 or 1.25 cm^3 per second.

When we carry out this reaction in a laboratory, its rate changes. As time progresses, the rate of reaction slows down.

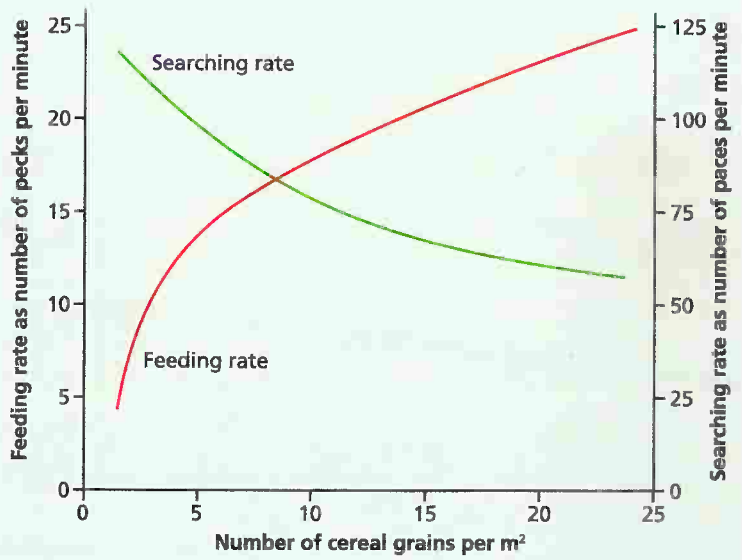

Figure 1 The effects of grain density on the searching rate and feeding rate of wood pigeons

Use your knowledge of the way in which enzymes work to explain why the rate of reaction slows down.

> The number of molecules of hydrogen peroxide will become fewer and fewer as they are broken down. The concentration of the enzyme catalase, however, does not change. This means that there will be fewer collisions between substrate molecules and the active sites of the enzyme molecules. Fewer collisions in a given time mean a slower rate of reaction.

A progress curve for a reaction in which catalase is involved in breaking down hydrogen peroxide is shown in Figure 2.

Calculate the rate of the reaction between 10 and 20 seconds. Explain how you arrived at your answer.

Calculating the rate of the reaction over a linear part of a curve is really no different from the calculation above. You need to read off the total volume of oxygen produced between 10 and 20 seconds.

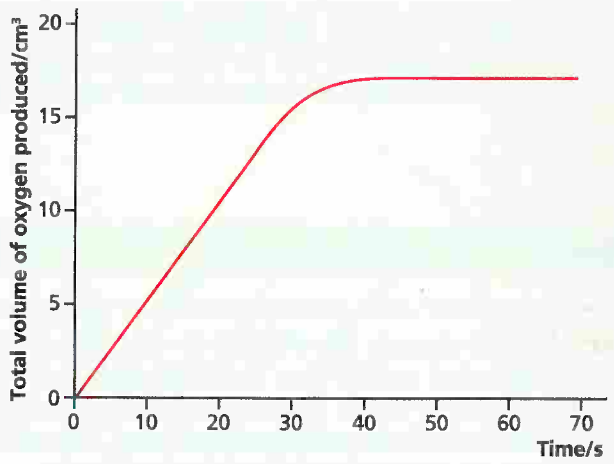

Figure 2 A progress curve for the effect of catalase on the breakdown of hydrogen peroxide

The searching rate and feeding rate of wood pigeons depends on grain density

This is 10 – 5 cm^3 (the volume produced after 20 seconds minus the volume produced after 10 seconds). 5 cm^3 of oxygen is therefore produced in 10 seconds. So the rate is 5/10 or 0.5 cm^3 per second.

Suppose, however, that we want to look a little later on when the rate of the reaction is changing.

Calculate the rate of reaction at 32 seconds

You cannot simply divide the volume produced by 32. This will give you the mean rate over the whole 32 second period. You need to find the rate at one particular time — 32 seconds. Figure 3 shows you what you should do in this case.

1 Draw a tangent to the curve at the time concerned. This is 32 seconds. Extend the tangent as far as is convenient.

2 Use the construction lines to read off the volume of oxygen produced at the times on either end of your tangent. In this case, 12 cm^3 are produced after 10 seconds and 19 cm^3 after 50 seconds.

   That is a total of 19 – 12 cm^3 produced in 50 – 10 seconds or 7 cm^3 in 40 seconds.

3 Now calculate the rate by dividing the volume of oxygen produced by the time.

   $\frac{7}{40}$ or 0.18 cm^3 per second

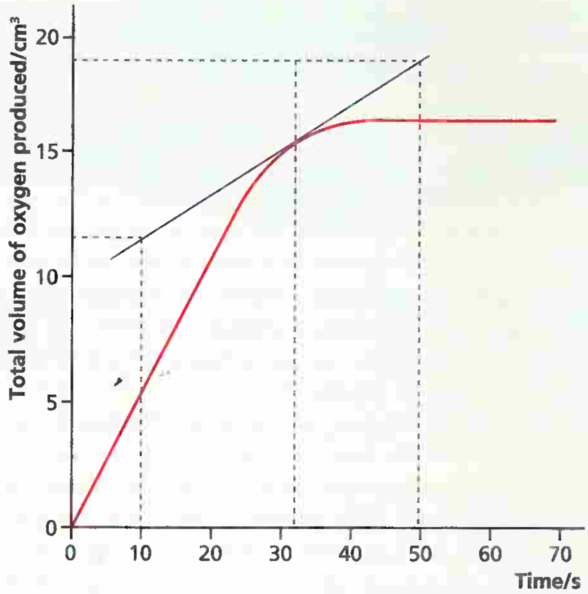

Figure 3 Using a tangent to calculate rate

The other way in which you could measure the progress of an enzyme-controlled reaction is to measure the rate at which one of the reactants is used up. Amylases are enzymes that catalyse the hydrolysis of starch to maltose. We could follow the progress of this reaction by taking the time for drops of iodine solution to stay brown and not turn blue-black when added to samples of a mixture of starch and amylase. This will tell us when the starch has been used up.

It took 6 minutes for the drop of iodine solution to fail to turn blue-black when added to the mixture of starch and amylase. Calculate the rate of the reaction.

The faster the rate of a reaction, the shorter the time it takes for the reactants to be converted into products. In other words, rate of reaction is inversely proportional to time and rate can be calculated from the equation:

rate = 1/time

so, in this case it is:

1/6 or 0.17

You need to be careful when calculating the rate of a reaction in this way, however. In this example we calculated the rate from the time in minutes. Suppose we had used the time in seconds. The rate would have been 1/(6 × 60) or 1/360 or 0.0028. This is a very different figure from 0.17 so we clearly need to specify the units that we are using. This can be done in one of two ways, so, where we used minutes we could write:

0.17 min^{-1}

or we could write:

rate = 1/time in minutes = 0.17

Where we used seconds we could write:

0.0028 s^{-1}

or:

rate = 1/time in seconds = 0.0028

So there we have rate calculations. Make sure you understand the question, think simple, show your working and check that your answer is reasonable. In the next issue of Biological Sciences Review, we will consider the other two topics — percentages and magnification.

Bill Indge has had many years' experience as a senior examiner in A-level biology. He is a member of the Biological Sciences Review editorial board and the author of a number of books, including the *Biology A–Z Handbook*. Visit **www.hoddereducation.co.uk** for more information and to see Bill's other publications.