Reaction Rates

Part 1 (Classroom-based)

In chemistry, the *rate of reaction* describes the speed at which *reactants* are converted to the *products* of the reaction. To quantify it, we measure the change in concentration of a substance between the beginning and end of a measured time period. (The concentration of a product increases during a reaction.)

> so, for example, if you are looking at how much hydrogen is produced when magnesium and hydrochloric acid react, the rate will be calculated from

$$\frac{volume \;\; of \;\; hydrogen \;\; produced}{reaction \;\; time}$$

Here are some typical results from a reaction involving hydrochloric acid and magnesium (with the concentration of the acid at 0.5 mol dm^{-3}).

Time (minutes)	Volume of hydrogen (cm^3)
0	0
0.5	8
1	14
1.5	20
2	25
2.5	29
3	33
3.5	36
4	38
4.5	39
5	40
5.5	40
6	40
6.5	40
7	40
7.5	40
8	40

1.   Plot these results on a graph.

2.   Describe what they show you about the rate of reaction. (Why is the curve flat at the end?)

The rate of reaction can be altered by: change in the concentration of the reactants
                                                temperature change
                                                use of catalysts

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If the concentration of acid is increased to 1.0 mol dm^{-3}, the results are as follows:

Time/minutes	Volume of hydrogen/cm^3
0	0
0.5	14
1	25
1.5	33
2	37
2.5	38
3	39
3.5	40
4	40
4.5	40
5	40
5.5	40
6	40
6.5	40
7	40
7.5	40
8	40

3.   Plot this on to the same graph, and comment on what the results show you about changes in the reaction rate when you use a more concentrated acid.

4.   Take a clean piece of graph paper; set out the axes as before; and sketch in the first curve you drew.

Now sketch in, on the same graph, how you think the curve would look if you repeated the experiment:

(a)   at a lower temperature
(b)   at a higher temperature *and* with a catalyst present.

(Label each curve clearly.)

5.   *Extension*:

On the first graph, calculate and compare actual rates of reaction: the average over the whole period in which hydrogen is produced and the rates at different times during the process.

Part 2 (IT-based)

Dinitrogen pentoxide (N_2O_5) undergoes thermal decomposition to form nitrogen dioxide and oxygen at rates which vary according to temperature.

The following data were obtained at 45°C.

Conc $N_2O_5/10^{-3}$mol dm^{-3}	Rate/10^{-3}mol dm^{-3}min^{-1}
24.30	0.710
16.27	0.498
6.89	0.197
3.68	0.121
2.74	0.078
0.00	0.000

Enter these data on a spreadsheet.

1. Plot the points to produce a graph of rate of decomposition against concentration (at 45°C).

    Use the option which shows individual data points (Option 2 in Excel 5) rather than simply a line.

    Label, print off, and comment.

2. Does this seem to be a straight line graph?

    Use the original data to work out what equation relating rate and concentration will give you a line of best fit for these data.

    (Do this by trial and error using the spreadsheet to help you.)

3. Produce a graph showing

    (a) the individual data points

    (b) the line of best fit

    Label the line of best fit with the formula you used to produce it.

Teacher Notes

Check that students are familiar with normal chemical notation.

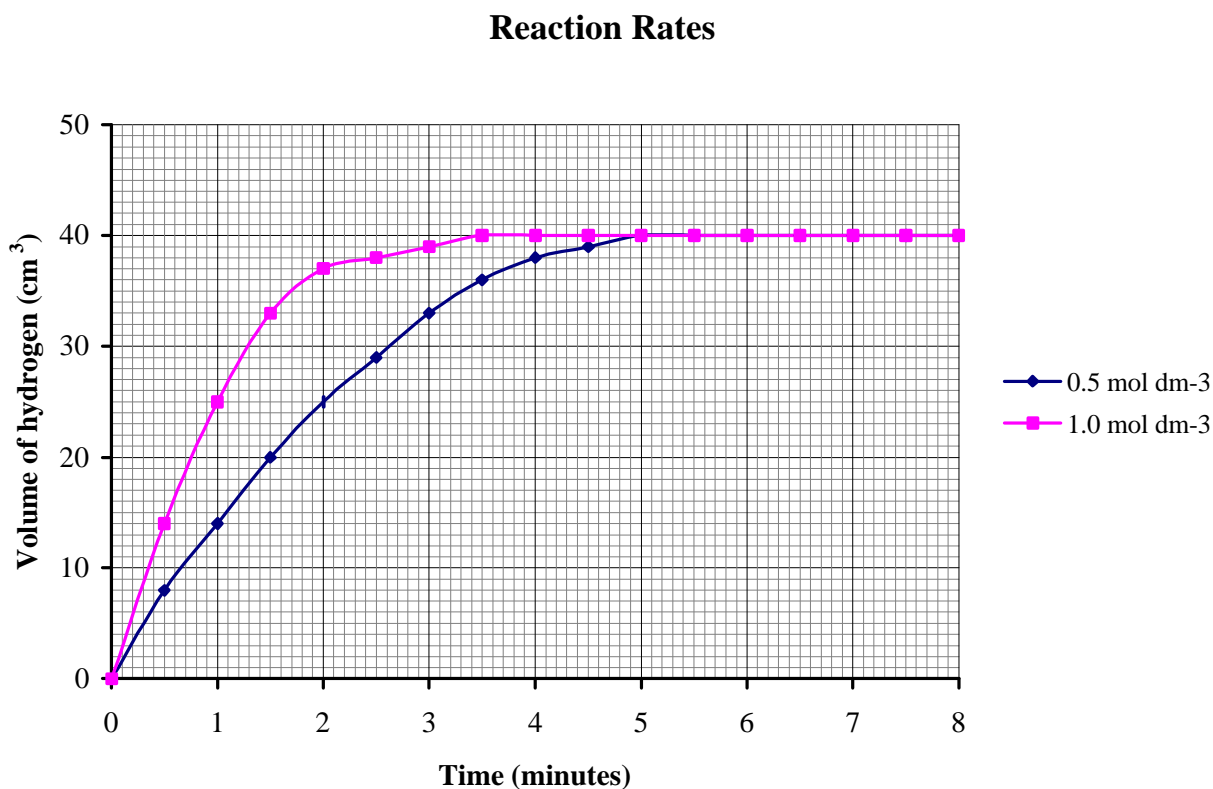In particular have they met mol dm^{-3} (and use s^{-1}?)

Would they normally write $10^{-2}/10^{-3}$ or $.001/\frac{1}{1000}$ etc?

You may need to change the notation or spend some time explaining accordingly.

Answers

Part 1 (Class-room based)

1   The data given on the worksheet gives the following graph:

Reaction Rates

2   The rate of reaction decreases as time goes by. The curve becomes flat when the

rate of reaction reduces to zero and no more hydrogen is being produced.

3   Reaction rate increases when you use a more concentrated acid.

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4   Reaction rate is

        (a) lower if the temperature is decreased

        (b) higher if the temperature in increased and/or a catalyst is used.

5   For a concentration of 0.5 mol dm^{-3} hydrogen is produced over a 3.5 minute

        period at an average rate of 11.4 cm^3 per minute (to 3 sf).

        For a concentration of 1.0 mol dm^{-3} hydrogen is produced over a 5 minute

        period at an average rate of 8 cm^3 per minute (to 3 sf).

        Other rates found will depend on the points chosen.

Part 2 (IT-based)

This part involves the preparation and labelling of line graphs using a spreadsheet. The
worksheet assumes students are using Excel 5 and may need altering if this is not the
case. The work is straightforward, requiring only the production of the relevant graph
(given below). The rate of reaction is proportional to the concentration of dinitrogen
pentoxide.

Thermal decomposition of dinitrogen pentoxide

y = 0.0296x

Rate (10^{-3} mol dm^{-3} min^{-1}) vs Conc N$_2$O$_5$ (10^{-3} mol dm^{-3})

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