SL Paper 3

Students were asked to investigate how a change in concentration of hydrochloric acid, HCl, affects the initial rate of its reaction with marble chips, $CaCO_3$.

They decided to measure how long the reaction took to complete when similar chips were added to 50.0 cm^3 of 1.00 mol dm^{-3} acid and 50.0 cm^3 of 2.00 mol dm^{-3} acid.

Two methods were proposed:

(1) using small chips, keeping the acid in excess, and recording the time taken for the solid to disappear

(2) using large chips, keeping the marble in excess, and recording the time taken for bubbles to stop forming.

A group recorded the following results with 1.00 mol dm^{-3} hydrochloric acid:

Trial	Time / s ±0.01 s
1	120.56
2	136.83
3	108.49
Mean	121.96

a. Annotate the balanced equation below with state symbols. [1]

$CaCO_3(\_\_) + 2HCl(\_\_) \rightarrow CaCl_2(\_\_) + CO_2(\_\_) + H_2O(\_\_)$

b. Neither method actually gives the initial rate. Outline a method that would allow the initial rate to be determined. [1]

c.i. Deduce, giving a reason, which of the two methods would be least affected by the chips not having exactly the same mass when used with the different concentrations of acid. [1]

c.ii. State a factor, that has a significant effect on reaction rate, which could vary between marble chips of exactly the same mass. [1]

d.i. Justify why it is inappropriate to record the uncertainty of the mean as ±0.01 s. [1]

d.ii. If doubling the concentration doubles the reaction rate, suggest the mean time you would expect for the reaction with 2.00 mol dm^{-3} hydrochloric acid. [1]

d.iii. Another student, working alone, always dropped the marble chips into the acid and then picked up the stopwatch to start it. State, giving a reason, whether this introduced a random or systematic error. [1]

Markscheme

a. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

Accept "$CO_2(aq)$".

[1 mark]

b. measure the volume of gas at different times «plot a graph and extrapolate»

OR

measure the mass of the reaction mixture at different times «plot a graph and extrapolate»

Accept other techniques that yield data which can be plotted and extrapolated.

[1 mark]

c.i. method 2 ***AND*** marble is in excess «so a little extra has little effect»

OR

large chips ***AND*** marble is in excess «so a little extra has little effect»

OR

method 2 ***AND*** HCl is limiting reagent «so a little extra marble has little effect»

OR

large chips ***AND*** HCl is limiting reagent «so a little extra marble has little effect»

Accept, as a reason, that "as the mass is greater the percentage variation will be lower".

[1 mark]

c.ii. surface area

OR

purity «of the marble»

Accept "shape of the chip".

[1 mark]

d.i. variation of individual values is much greater «than this uncertainty»

OR

«uncertainty» does not take into account «student» reaction time

[1 mark]

d.ii. «$\frac{121.96\ \text{s}}{2}$ = 60.98 s» = 61 «s»

[1 mark]

d.iii. systematic ***AND*** always makes the time shorter «than the actual value»

OR

systematic ***AND*** it is an error in the method used «not an individual measurement»

OR

systematic ***AND*** more repetitions would not reduce the error

Accept, as reason, "it always affects the value in the same direction" ***OR*** *"the error is consistent".*

[1 mark]

Examiners report

a. [N/A]
b. [N/A]
c.i. [N/A]
c.ii. [N/A]
d.i. [N/A]
d.ii. [N/A]
d.iii. [N/A]

Penicillins and aspirin are important medicines.

a.i. Describe how penicillin combats bacterial infections. [2]

a.ii. State how penicillins may be modified to increase their effectiveness. [1]

b. State the type of reaction used to synthesize aspirin from salicylic acid. [1]

c. Explain why aspirin is **not** stored in a hot, humid location. [2]

Markscheme

a.i. «irreversibly» binds/bonds to enzyme/transpeptidase

OR

inhibits enzyme/transpeptidase «in bacteria» that produces cell walls

OR

prevents cross-linking of bacterial cell walls

cells absorb water ***AND*** burst

OR

cells cannot reproduce

[2 marks]

a.ii. modify side chain

[1 mark]

b. condensation

OR

esterification

OR

nucleophilic substitution/nucleophilic displacement/S_N2

*Do **not** accept just "substitution/displacement".*

[1 mark]

c. water causes hydrolysis

OR

aspirin reacts with water

heat increases the rate of hydrolysis

OR

heat increases the rate of the reaction with water

Accept "aspirin will convert into salicylic/ethanoic acid".

*Do **not** accept "aspirin dissolves in water" **OR** "aspirin absorbs water/is hygroscopic".*

[2 marks]

Examiners report

a.i. [N/A]
a.ii. [N/A]
b. [N/A]
c. [N/A]

Fuel cells and rechargeable batteries are both convenient ways of providing portable electric power.

a. Compare fuel cells and rechargeable batteries giving **one** similarity and **one** difference. [2]

Similarity:

Difference:

b. One common type of rechargeable cell is the nickel–cadmium (NiCad) battery. For each terminal of this battery state the initial and final oxidation number of the element when the cell is delivering a current. Hence deduce which electrode is acting as the anode and which the cathode. [3]

	Positive terminal (when delivering a current)	Negative terminal (when delivering a current)
Initial oxidation number		
Final oxidation number		
Anode / cathode		

c. A common type of fuel cell uses hydrogen and oxygen with an acidic electrolyte. State the half-equations for the reactions at the two electrodes. [2]

Positive electrode:

Negative electrode:

d. The electrodes of fuel cells and rechargeable batteries have a feature in common with heterogeneous catalysts. Identify this feature and state why it is important for them to work efficiently. [2]

Markscheme

a. *Similarity:*

both turn chemical energy into electrical energy / use chemical reactions to produce electricity/lectrical energy / *OWTTE*;

*Difference **[1 max]**:*

rechargeable batteries have reversible reactions **but** fuel cells do not;

fuel cells consume fuel **but** rechargeable batteries do not require (external) fuel;

rechargeable batteries can be recharged by electricity **but** fuel cells cannot;

b.

	Positive terminal (when delivering a current)	Negative terminal (when delivering a current)
Initial oxidation number	+3	0
Final oxidation number	+2	+2
Anode / cathode	cathode	anode

*All correct **[3]**, 4 or 5 correct **[2]**, 2 or 3 correct **[1]***

c. *Positive electrode:*

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$;

Negative electrode:

$H_2(g) \rightarrow 2H^+(aq) + 2e^-$;

d. large surface area;

changes only occur on the surface / where electron transfer occurs / *OWTTE*;

Examiners report

a. Some candidates were able to write one similarity and one difference between fuel cells and rechargeable batteries.

b. Part (b) was very poorly answered.

c. None of the candidates scored full marks particularly in part (c) where it was rare to see any correct half-equations; the candidates also overlooked the fact that the electrolyte was acidic.

d. Part (d) seldom had any correct answers.

Antacids react with hydrochloric acid in the stomach to relieve indigestion. A student investigated different brands of antacid to see which caused the largest increase in pH in a given time. She added the antacids to hydrochloric acid, and recorded the change in pH over five minutes.

Antacid brand	Active ingredient(s)	Recommended dosage	Dose used	Initial pH ±0.02	Final pH ±0.02	Change in pH
A	magnesium hydroxide aluminium hydroxide	2–3 tablets	2 tablets	1.68	4.53	+2.85
B	sodium hydrogen carbonate calcium carbonate	2–4 tablets	2 tablets	1.70	5.31	+3.61
C	calcium carbonate	1–2 tablets	1 tablet	1.70	4.52	+2.82
D	magnesium hydroxide aluminium oxide aluminium hydroxide	1–2 tablets	1 tablet	1.69	2.21	+0.52

a. State an equation for the reaction of magnesium hydroxide with hydrochloric acid. [1]

b. Suggest two variables, besides the time of reaction, which the student should have controlled in the experiment to ensure a fair comparison of the antacids. [2]

c. Calculate the uncertainty in the change in pH. [1]

d. The student concluded that antacid **B** was the most effective, followed by **A** then **C** and finally **D**. Discuss two arguments that reduce the validity of the conclusion. [2]

Markscheme

a. $Mg(OH)_2$ (s) + 2HCl (aq) → $MgCl_2$ (aq) + $2H_2O$ (l)

Accept full or net ionic equation.

b. *Any two from:*

volume «of HCl»

concentration «of HCl»/[HCl]

temperature «of HCl»

mass of antacid/tablets

size of antacid particles/tablets

OR

surface area of antacid «particles»/tablets

Accept "number of tablets/different doses".

*Do **not** accept "same pH meter" **OR** "initial pH" **OR** "concentration of antacid/[antacid]".*

A variable must be given so do not accept answers such as "stirring", "whether tablets are whole or crushed" etc.

[Max 2 Marks]

c. (±) 0.04

OR

(±) 0.03

d. *Any two of:*

uncertainty «(±)0.04/(±)0.03» means **A** and **C** cannot be distinguished

each measurement was conducted once

stomach pH should not be raised a lot «so antacid **B** is not necessarily effective»

mass/number of tablets/dose «of antacid» used was not controlled

actual environment in stomach is different

Accept "amount of tablets" for "dose".

*Do **not** accept "nature/composition of tablets differs".*

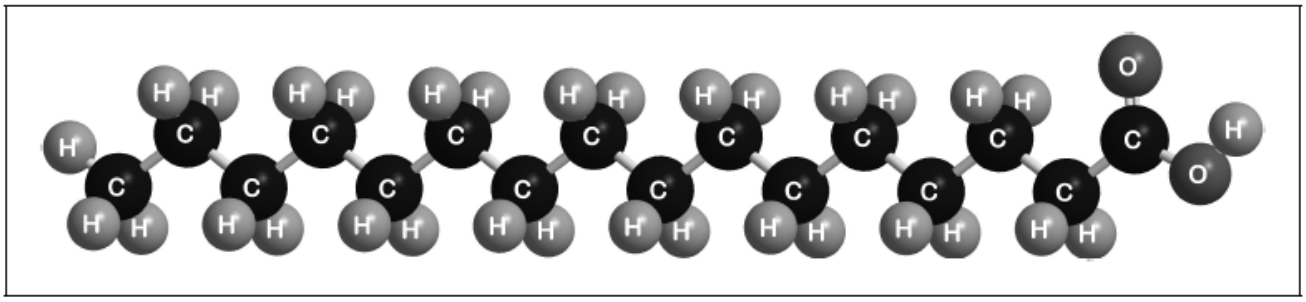
Accept an answer such as "time frame is too short since some antacids could be long-acting drugs if they contain a gelatinisation/delaying agent" but not just "time frame is too short since some antacids could be long-acting drugs".

[Max 2 Marks]

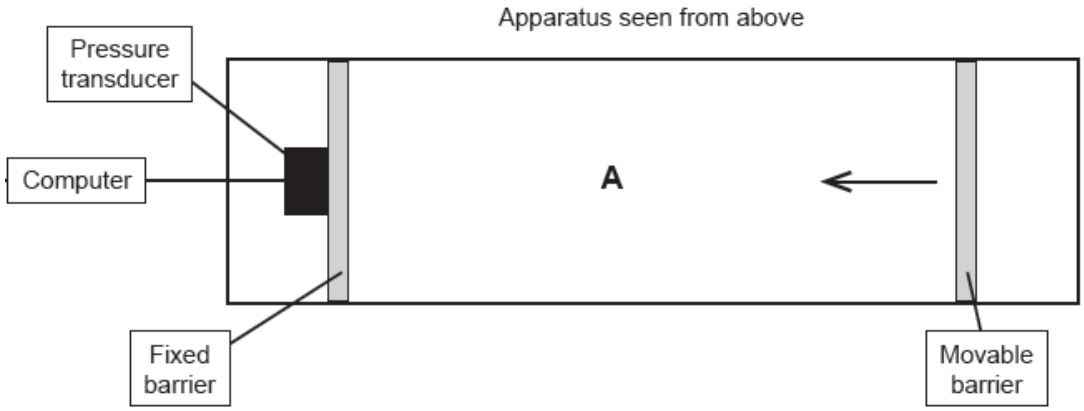
Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

Palmitic acid has a molar mass of 256.5 g mol^{-1}.

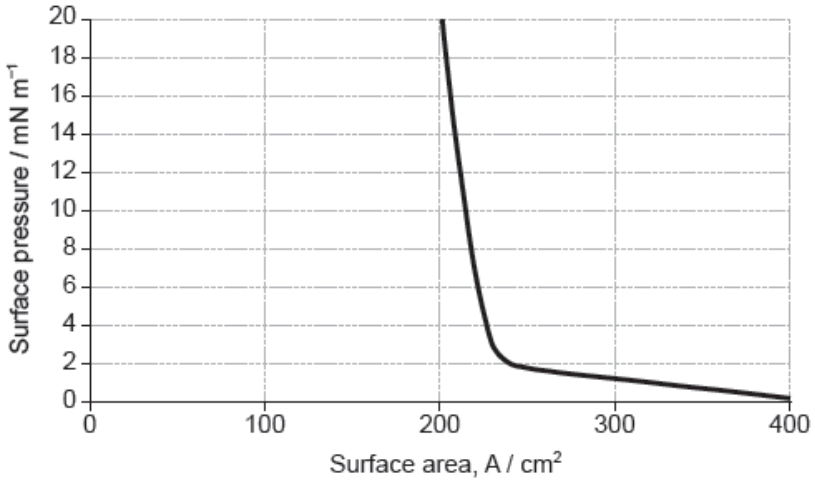


The apparatus in the diagram measures the surface pressure created by palmitic acid molecules on the surface of water. This pressure is caused by palmitic acid molecules colliding with the fixed barrier. The pressure increases as the area, **A**, available to the palmitic acid is reduced by the movable barrier.



[Source: Physical Chemistry Chemical Physics, 2001, 3, 4774-4783 - Reproduced by permission of The Royal Society of Chemistry]

When a drop of a solution of palmitic acid in a volatile solvent is placed between the barriers, the solvent evaporates leaving a surface layer. The graph of pressure against area was obtained as the area **A** was reduced.



[Source: Influence of Lecithin on Structure and Stability of Parenteral Fat Emulsions, Christoph Wabel, 1998, Figure 34. Used with permission]

a.i. Part of this molecule is hydrophilic (bonds readily to water) and part hydrophobic (does not bond readily to water). Draw a circle around all of the hydrophilic part of the molecule. [1]

a.ii. When a small amount of palmitic acid is placed in water it disperses to form a layer on the surface that is only one molecule thick. Explain, in terms of intermolecular forces, why this occurs. [2]

b.i. Suggest why there is a small increase in the surface pressure as the area is reduced to about 240 cm^2, but a much faster increase when it is further reduced. [2]

Above about 240 cm^2:

. . . . . .

. . . . . .

. . . . . .

At less than about 240 cm^2:

. . . . . .

. . . . . .

. . . . . .

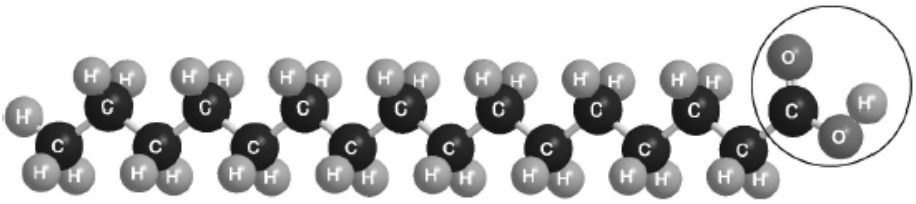
b.ii. The solution of palmitic acid had a concentration of 0.0034 mol dm^{-3}. Calculate the number of molecules of palmitic acid present in the 0.050 cm^3 drop, using section 2 of the data booklet. [2]

b.iii. Assuming the sudden change in gradient occurs at 240 cm^2, calculate the area, in cm^2, that a single molecule of palmitic acid occupies on surface of the water. [1]

If you did not obtain an answer for (b)(ii) use a value of 8.2×10^{16}, but this is not the correct answer.

Markscheme

a.i.



*Must cut CH_2–CO bond **AND** enclose all of the –COOH group.*

[1 mark]

a.ii *Any two of:*

–COOH/CO/OH/carboxylate/carboxyl/hydroxyl/hydroxy group forms hydrogen bonds/H-bonds to water

London/dispersion/instantaneous induced dipole-induced dipole forces occur between hydrocarbon chains

hydrocarbon chain cannot form hydrogen bonds/H-bonds to water

strong hydrogen bonds/H-bonds between water molecules exclude hydrocarbon chains «from the body of the water»

Accept "hydrophilic part/group forms hydrogen bonds/H-bonds to water".

Accept "hydrophobic section" instead of "hydrocarbon chain".

*Award **[1 max]** for answers based on "the –COOH group being polar **AND** the hydrocarbon chain being non-polar".*

[2 marks]

b.i. *Above about 240 cm^2:*

greater collision frequency/collisions per second between «palmitic acid» molecules and the barrier «as area reduced»

At less than about 240 cm^2:

molecules completely cover the surface

OR

there is no space between molecules

OR

force from movable barrier transmitted directly through the molecules to the fixed barrier

OR

«palmitic acid» molecules are pushed up/down/out of layer

For both M1 and M2 accept "particles" for "molecules".

*For M1 accept "space/area between molecules reduced" **OR** "molecules moving closer together".*

[2 marks]

b.ii amount of acid = «5.0×10^{-5} dm^3 × 0.0034 mol dm^{-3}» = 1.7×10^{-7} «mol»

number of molecules = «1.7×10^{-7} mol × 6.02×10^{23} mol^{-1} =» 1.0×10^{17}

*Award **[2]** for correct final answer.*

*Award **[1]** for "1.0×10^{20}".*

[2 marks]

b.iii «area = $\frac{240\ \text{cm}^2}{1.0\times10^{17}}$ » 2.4×10^{-15} «cm^2»

[1 mark]

Examiners report

a.i. [N/A]
a.ii. [N/A]
b.i. [N/A]
b.ii. [N/A]
b.iii. [N/A]