SL Paper 3

Magnesium hydroxide is the active ingredient in a common antacid.

a. Formulate the equation for the neutralization of stomach acid with magnesium hydroxide. [1]

b. Determine the mass of HCl, in g, that can be neutralized by the standard adult dose of 1.00g magnesium hydroxide. [2]

c. Compare and contrast the use of omeprazole (Prilosec) and magnesium hydroxide. [3]

Iron may be extracted from an ore containing Fe_2O_3 in a blast furnace by reaction with coke, limestone and air. Aluminium is obtained by electrolysis of an ore containing Al_2O_3.

a. State the overall redox equation when carbon monoxide reduces Fe_2O_3 to Fe. [1]

b. Predict the magnetic properties of Fe_2O_3 and Al_2O_3 in terms of the electron structure of the metal ion, giving your reasons. [2]

Fe_2O_3:

Al_2O_3:

c. Molten alumina, $Al_2O_3(l)$, was electrolysed by passing 2.00×10^6 C through the cell. Calculate the mass of aluminium produced, using sections 2 and 6 of the data booklet. [2]

The mild analgesic aspirin can be prepared in the laboratory from salicylic acid.

$$(CH_3CO)_2O + \underset{\text{Salicylic acid}}{HOC_6H_4COOH} \rightarrow \underset{\text{Aspirin}}{CH_3CO_2C_6H_4COOH} + CH_3COOH$$

After the reaction is complete, the product is isolated, recrystallized, tested for purity and the experimental yield is measured. A student's results in a single trial are as follows.

	Mass / g ±0.001	Melting point / °C ±1
Initial salicylic acid	1.552	
Crude product	1.398	106–114
Product after recrystallization	1.124	122–125

Literature melting point data: aspirin = 138–140 °C

a. Determine the percentage experimental yield of the product after recrystallization. The molar masses are as follows: *M*(salicylic acid) = 138.13 g mol^{-1}, *M*(aspirin) = 180.17 g mol^{-1}. (You do not need to process the uncertainties in the calculation.) [2]

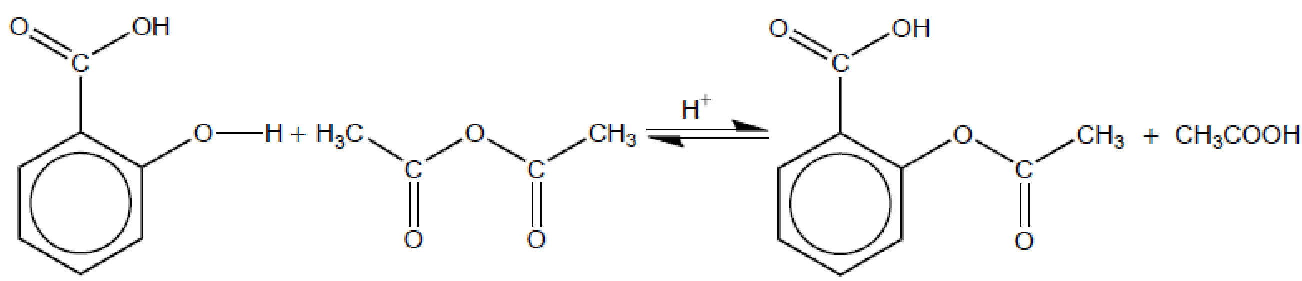
b. Suggest why isolation of the crude product involved the addition of ice-cold water. [1]

c. Justify the conclusion that recrystallization increased the purity of the product, by reference to **two** differences between the melting point data of the crude and recrystallized products. [2]

d. State why aspirin is described as a mild analgesic with reference to its site of action. [1]

Aspirin is one of the most widely used drugs in the world.

Aspirin was synthesized from 2.65 g of salicylic acid (2-hydroxybenzoic acid) (M_r = 138.13) and 2.51 g of ethanoic anhydride (M_r = 102.10).



a.i. Calculate the amounts, in mol, of each reactant. [1]

a.ii. Calculate, in g, the theoretical yield of aspirin. [1]

a.iii State **two** techniques which could be used to confirm the identity of aspirin. [2]

b.i. State how aspirin can be converted to water-soluble aspirin. [1]

b.ii. Compare, giving a reason, the bioavailability of soluble aspirin with aspirin. [1]

A student wished to determine the concentration of a solution of sodium hydroxide by titrating it against a 0.100moldm^{-3} aqueous solution of hydrochloric acid.

4.00g of sodium hydroxide pellets were used to make 1.00dm^{3} aqueous solution.

20.0cm^{3} samples of the sodium hydroxide solution were titrated using bromothymol blue as the indicator.

a. Outline, giving your reasons, how you would carefully prepare the 1.00dm^{3} aqueous solution from the 4.00g sodium hydroxide pellets. [2]

b. (i) State the colour change of the indicator that the student would see during his titration using section 22 of the data booklet. [3]

(ii) The student added the acid too quickly. Outline, giving your reason, how this could have affected the calculated concentration.

c. Suggest why, despite preparing the solution and performing the titrations very carefully, widely different results were obtained. [1]

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(__) → $CaCl_2$(__) + 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]

Water purity is often assessed by reference to its oxygen content.

The Winkler method uses redox reactions to find the concentration of oxygen in water. $100\ \mathrm{cm^3}$ of water was taken from a river and analysed using this method. The reactions taking place are summarized below.

$$\begin{array}{ll}\text{Step 1} & 2Mn^{2+}(aq) + 4OH^-(aq) + O_2(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)\\ \text{Step 2} & MnO_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)\\ \text{Step 3} & 2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)\end{array}$$

a. Outline the meaning of the term *biochemical oxygen demand* (BOD). [2]

c.i. State what happened to the O_2 in step 1 in terms of electrons. [1]

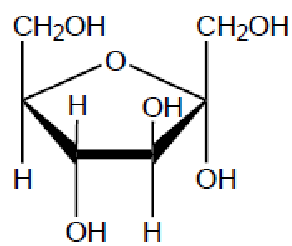
c.ii. State the change in oxidation number for manganese in step 2. [1]

c.iii. 0.0002 moles of I^- were formed in step 3. Calculate the amount, in moles, of oxygen, O_2, dissolved in water. [1]

Consider the following lipid and carbohydrate.

$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$

Linoleic acid, M_r = 280.50



Fructose, M_r = 180.18

In order to determine the number of carbon-carbon double bonds in a molecule of linoleic acid, 1.24 g of the lipid were dissolved in 10.0 cm^3 of non-polar solvent.

The solution was titrated with a 0.300 mol dm^{-3} solution of iodine, I_2.

a.i. Determine the empirical formula of linoleic acid. [1]

a.ii. The empirical formula of fructose is CH_2O. Suggest why linoleic acid releases more energy per gram than fructose. [1]

b.i. State the type of reaction occurring during the titration. [1]

b.ii. Calculate the volume of iodine solution used to reach the end-point. [3]

c. Outline the importance of linoleic acid for human health. [2]

In a class experiment, students were asked to determine the value of **x** in the formula of a hydrated salt, $BaCl_2 \cdot \mathbf{x}H_2O$. They followed these instructions:

1. Measure the mass of an empty crucible and lid.
2. Add approximately 2 g sample of hydrated barium chloride to the crucible and record the mass.
3. Heat the crucible using a Bunsen burner for five minutes, holding the lid at an angle so gas can escape.
4. After cooling, reweigh the crucible, lid and contents.
5. Repeat steps 3 and 4.

Their results in three trials were as follows:

	Trial 1	Trial 2	Trial 3
Mass of crucible + lid / g ±0.001	20.088	20.122	20.105
Mass of crucible + lid + $BaCl_2 \cdot xH_2O$ before heating / g ±0.001	22.166	22.184	22.186
Mass of crucible + lid + $BaCl_2$ after 1st heating / g ±0.001	21.859	22.080	21.926
Mass of crucible + lid + $BaCl_2$ after 2nd heating / g ±0.001	21.859	21.865	21.927

a. State and explain the further work students need to carry out in trial 2 before they can process the results alongside trial 1. [2]

b. In trial 3, the students noticed that after heating, the crucible had turned black on the outside. Suggest what may have caused this, and how this might affect the calculated value for **x** in the hydrated salt. [2]

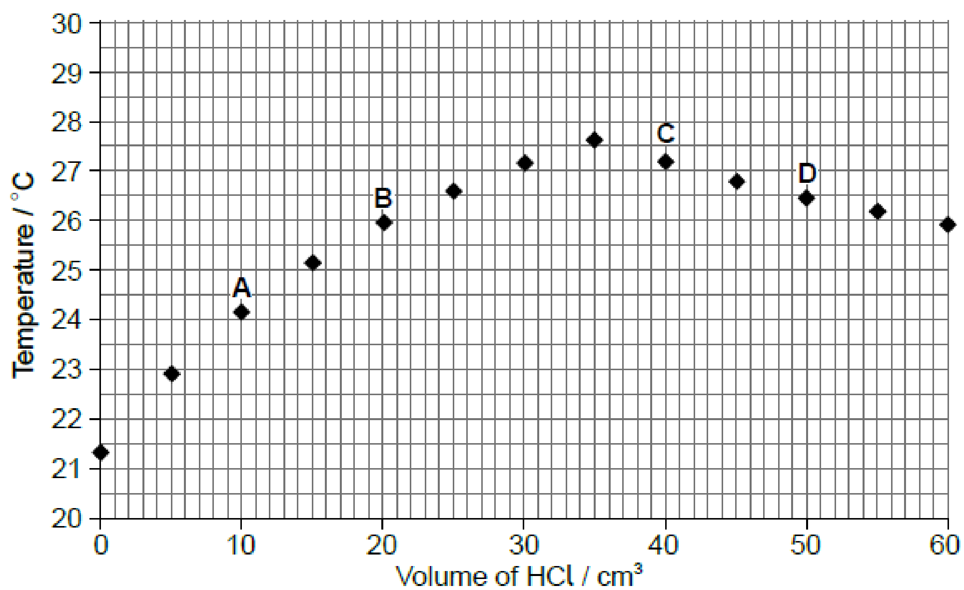
c. List **two** assumptions made in this experiment. [2]

A class was determining the concentration of aqueous sodium hydroxide by titrating it with hydrochloric acid, whilst monitoring the pH of the solution. The sodium hydroxide solution was added into a glass beaker from a measuring cylinder and the hydrochloric acid added using a burette. One group of students accidentally used a temperature probe rather than a pH probe. Their results are given below.

Volume of aqueous NaOH = 25.0 ± 0.5 cm^3

Concentration of HCl = 1.00 ± 0.01 mol dm^{-3}

Volume HCl ± 0.1 / cm^3	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
Temperature ± 0.1 / °C	21.3	22.9	24.2	25.1	25.9	26.6	27.2	27.6	27.2	26.8	26.5	26.2	25.9



State and explain how the graph would differ if 1 mol dm^{-3} sulfuric acid had been used instead of 1 mol dm^{-3} hydrochloric acid.

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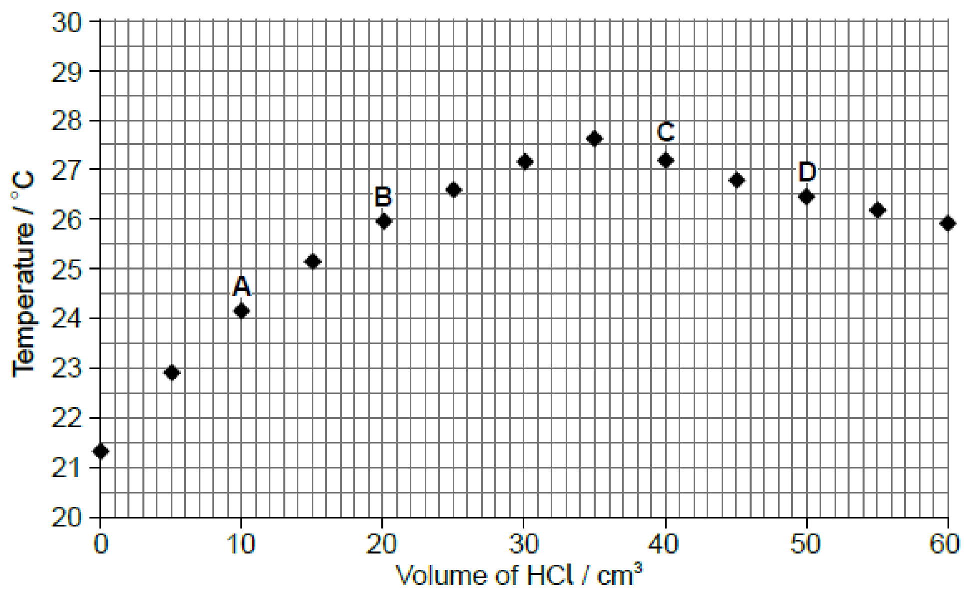
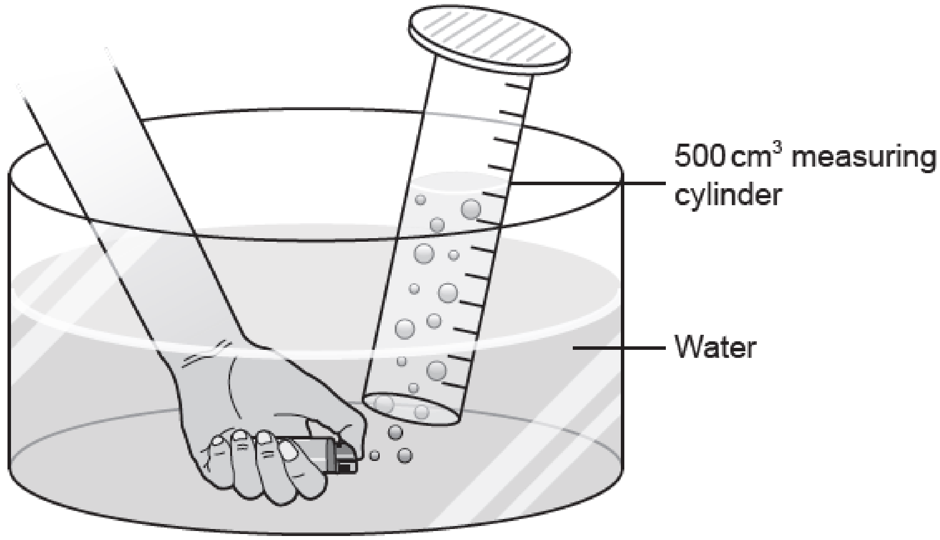


Suggest how the end point of the titration might be estimated from the graph.

Disposable plastic lighters contain butane gas. In order to determine the molar mass of butane, the gas can be collected over water as illustrated below:

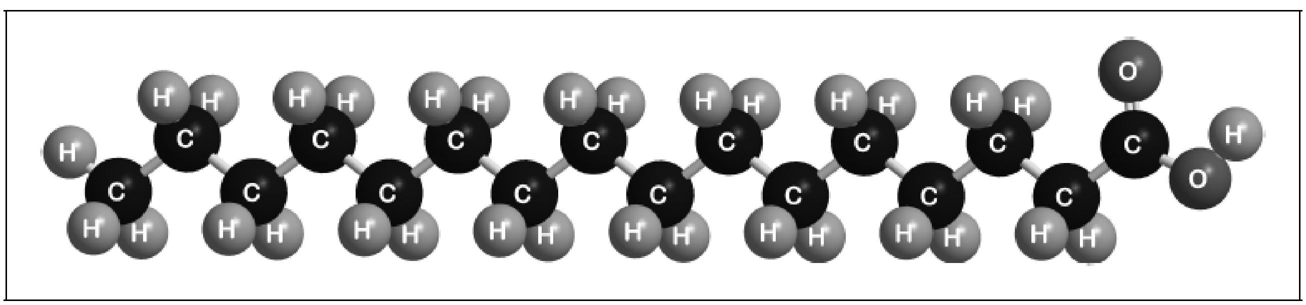


a. List the data the student would need to collect in this experiment. [4]

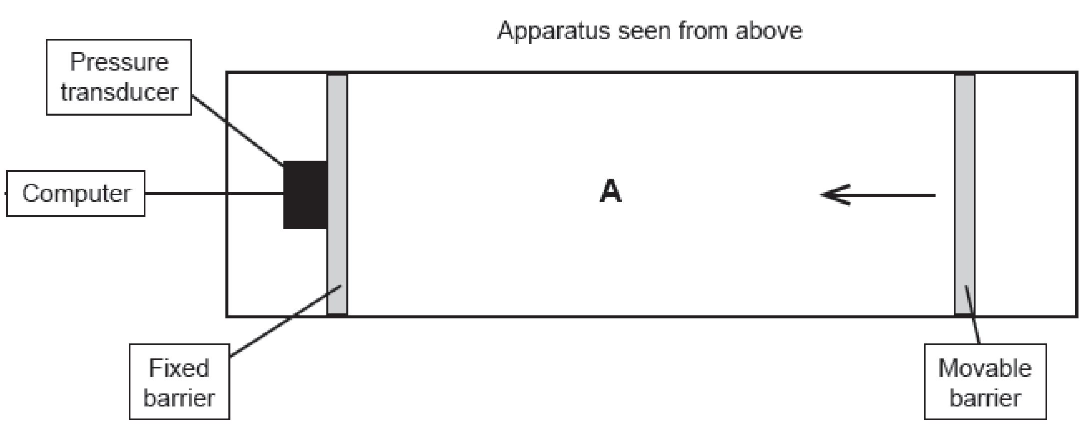
b.i. Explain why this experiment might give a low result for the molar mass of butane. [2]

b.ii. Suggest **one** improvement to the investigation. [1]

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

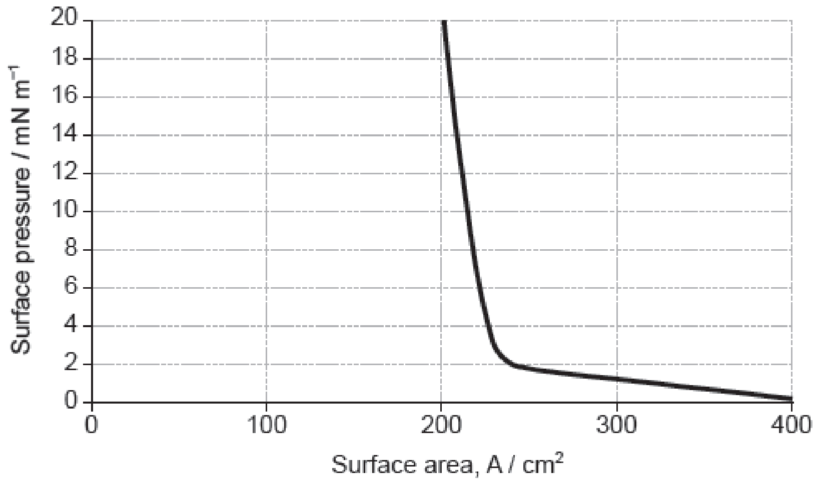


The apparatus in the diagram measures the surface pressure created by palmitic acid molecules on the surface of water. This pressure is caused by palmitic acid molecules colliding with the fixed barrier. The pressure increases as the area, **A**, available to the palmitic acid is reduced by the movable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

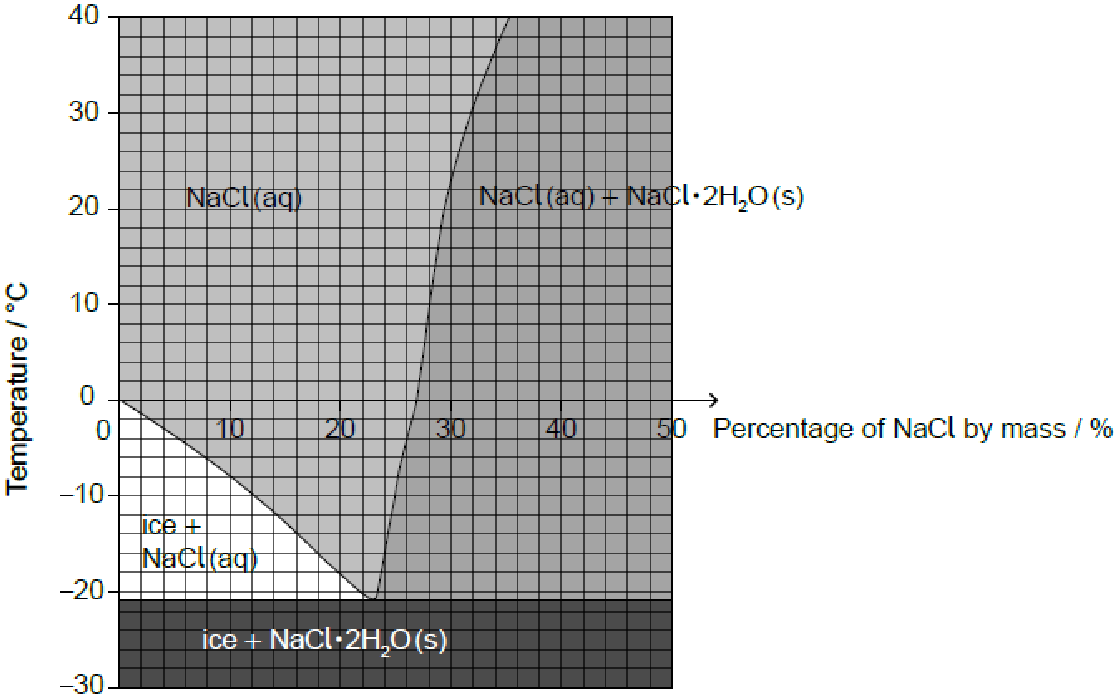
b.ii. The solution of palmitic acid had a concentration of 0.0034 mol dm^{-3}. Calculate the number of molecules of palmitic acid present in the 0.050 cm^3 drop, using section 2 of the data booklet. [2]

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.

Sodium chloride, NaCl, can be spread on icy roads to lower the freezing point of water.

The diagram shows the effects of temperature and percentage by mass of NaCl on the composition of a mixture of NaCl and H_2O.



a. Estimate the lowest freezing point of water that can be reached by adding sodium chloride. [1]

b. Estimate the percentage by mass of NaCl dissolved in a saturated sodium chloride solution at +10 °C. [1]

c. Calculate the percentage of water by mass in the $NaCl \cdot 2H_2O$ crystals. Use the data from section 6 of the data booklet and give your answer to two decimal places. [2]

d. Suggest a concern about spreading sodium chloride on roads. [1]