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]

Markscheme

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

OR

$Mg(OH)_2(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + 2H_2O(l)$

b. $\frac{1.00}{58.33}$=0.0171«mol$Mg(OH)_2$»

«0.0171×2×36.46=»1.25«g»

*Award **[2]** for 1.25 or 1.26 «g».*

c. Award ***[1 max]*** for any similarity:

both compounds relieve symptoms of acid reflux/heartburn/indigestion

OR

both increase the stomach pH

both cause diarrhoea

*Award **[2 max]** for any two differences:*

omeprazole stops the production of acid/is a proton-pump inhibitor ***AND*** magnesium hydroxide neutralizes the «excess» acid that is present

omeprazole takes longer «than magnesium hydroxide» to provide relief

omeprazole is used to treat ulcers while magnesium hydroxide is not

omeprazole can prevent long term damage from overproduction of acid ***AND*** magnesium hydroxide does not
OR
omeprazole has a long term effect ***AND*** magnesium hydroxide has a short-term effect «only»

magnesium hydroxide affects ionic balance in the body ***AND*** omeprazole does not

*Award **[1 max]** if two or three correct points are given about one of the compounds without addressing the other compound.*

Examiners report

[N/A]

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

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]

Markscheme

a. Fe_2O_3 (s) + 3CO (g) → 2Fe (l) + $3CO_2$ (g)

b. *Fe_2O_3:*

paramagnetic

AND

unpaired electrons present «so magnetic moments do not cancel out»

Al_2O_3:
diamagnetic
AND
no unpaired electrons/all electrons are paired «so magnetic moments cancel out»

*Award **[1 max]** for "Fe_2O_3 paramagnetic **AND** Al_2O_3 diamagnetic".*

*Award **[1 max]** for "Fe_2O_3 unpaired electrons present **AND** Al_2O_3 no unpaired electrons/all electrons are paired".*

*Award **[1 max]** for "Magnetic moments do not cancel out in Fe_2O_3 but do in Al_2O_3".*

Unpaired and paired electrons may also be conveyed by orbital diagrams for the respective ions.

c. $n\,(\mathrm{e}) = \frac{2.00\times10^6}{96500} / 20.7 \ll \mathrm{mol} \gg$

OR
n(Al)=$\frac{1}{3}$n(e)/6.91«mol»

m(Al)=«6.91×26.98=»186«g»

*Award **[2]** for correct final answer for any value within the range 186–189 «g».*

Examiners report

[N/A]

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

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

$$(CH_3CO)_2O + HOC_6H_4COOH \rightarrow CH_3CO_2C_6H_4COOH + CH_3COOH$$

Salicylic acid Aspirin

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]

Markscheme

a. ***ALTERNATIVE 1:***

«theoretical yield = $\frac{1.552\ \text{g}}{138.13\ \text{g mol}^{-1}}$ × 180.17 g mol^{-1} =» 2.024 «g»

«experimental yield = $\frac{1.124\text{g}}{2.024\text{g}}$ × 100 =» 55.53 «%»

ALTERNATIVE 2:

«$\frac{1.552\ \text{g}}{138.13\ \text{g mol}^{-1}}$»= 0.01124 «mol salicylic acid/aspirin theoretical» ***AND***

«$\frac{1.124\ \text{g}}{180.17\ \text{g mol}^{-1}}$»= 0.006239 «mol aspirin experimental»

«experimental yield = $\frac{0.006239\text{mol}}{0.01124\text{mol}}$ x 100 =» 55.51 «%»

Accept answers in the range 55.4 % to 55.7 %.
*Award **[2]** for correct final answer.*

b. low temperature gives greater difference between solubility of aspirin and impurities

OR

«product» crystallizes out from cold solution/«ice-cold water/lower temperature» speeds up crystallization process

OR

aspirin/product has low solubility «in water» at low temperatures

c. [N/A]

d. intercepts pain stimulus at source/acts at site of pain

OR

interferes with production of pain sensitizing substances/prostaglandins «at site of pain»

Examiners report

a. [N/A]

b. [N/A]

c. recrystallized melting point is higher

OR

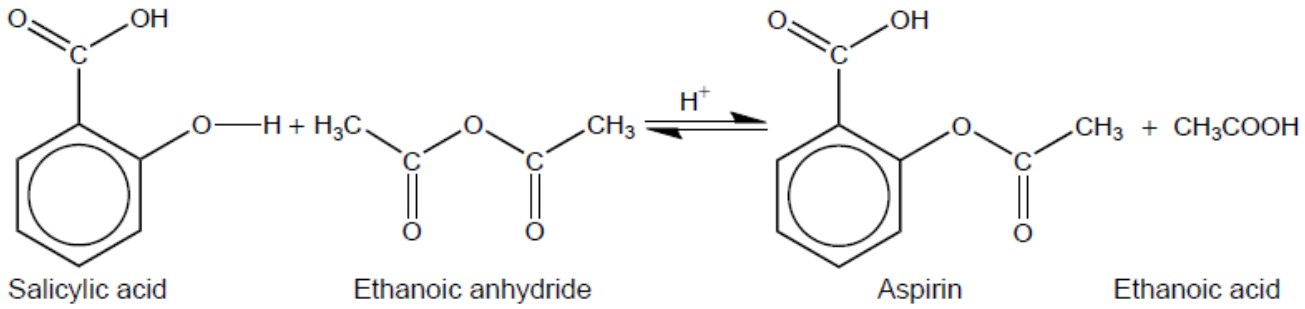
recrystallized melting point is closer to pure substance/literature value

smaller range of values

d. [N/A]

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]

Markscheme

a.i. n(salicylic acid) = «$\frac{2.65\ \text{g}}{138.13\ \text{g mol}^{-1}}$» 0.0192 «mol»

AND

n(ethanoic anhydride) = «$\frac{2.51\ \text{g}}{102.10\ \text{g mol}^{-1}}$» 0.0246 «mol»

[1 mark]

a.ii. «mass = 0.0192 mol x 180.17 g mol^{-1} =» 3.46 «g»

*Award ECF mark **only** if limiting reagent determined in (i) has been used.*

[1 mark]

a.iii *Any two of:*

melting point

mass spectrometry/MS

high-performance liquid chromatography/HPLC

NMR/nuclear magnetic resonance

X-ray crystallography

elemental analysis «for elemental percent composition»

*Accept "spectroscopy" instead of "spectrometry" where mentioned but **not** "spectrum".*

*Accept "infra-red spectroscopy/IR" **OR** "ultraviolet «-visible» spectroscopy/UV/UV-Vis".*

*Do **not** accept "gas chromatography/GC".*

Accept "thin-layer chromatography/TLC" as an alternative to "HPLC".

[2 marks]

b.i. react with NaOH

Accept "$NaHCO_3$" or "Na_2CO_3" instead of "NaOH".

*Accept chemical equation **OR** name for reagent used.*

[1 mark]

b.ii. «marginally» higher ***AND*** increase rate of dispersion

OR

«marginally» higher ***AND*** increase absorption in mouth/stomach «mucosa»

OR

«approximately the» same ***AND*** ionic salt reacts with HCl/acid in stomach to produce aspirin again

*Do not accept "«marginally» higher **AND** greater solubility in blood".*

[1 mark]

Examiners report

[N/A]

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

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]

Markscheme

a. *Key Procedural Steps:*

use volumetric flask

mix the solution

fill up to line/mark/«bottom of» meniscus/1 dm^3 «with deionized/distilled water»

Key Technique Aspects:
use balance that reads to two decimal places/use analytical balance/use balance of high precision
mix pellets in beaker with deionized/distilled water «and stir with glass rod to dissolve»
use a funnel «and glass-rod» to avoid loss of solution
need to rinse «the beaker, funnel and glass rod» and transfer washings to the «volumetric» flask

Safety Precautions:
NaOH corrosive/reacts with water exothermically
keep NaOH in dessicator
let the solution cool

Two marks may be awarded from two different categories or from within one category.
*Do **not** accept "use of a funnel to transfer the solid".*
*Do **not** accept "keep volumetric flask in cold water/ice".*

b. (i) blue to green/yellow

(ii) equivalence point has been exceeded
OR
greater volume of/too much acid has been added

«calculated» concentration increased

Accept "end-point" for "equivalence point".

c. colour difficult to detect

OR

using different HCl standards

OR

no significant figures used in subsequent calculation

OR

incorrect method of calculation

Accept any valid hypothesis.

Do not accept any mistakes associated with techniques (based on stem of question) eg. parallax error, not rinsing glassware, etc.

Do not accept "HCl was not standardized".

Accept "reaction of NaOH with CO_2 «from air»".

Accept "NaOH hygroscopic/absorbs moisture/H_2O «from the air/atmosphere»".

Accept "impurities in NaOH".

Accept "temperature changes during experiment".

Ignore a general reference to random errors.

Examiners report

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

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]

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. $100\ \text{cm}^3$ of water was taken from a river and analysed using this method. The reactions taking place are summarized below.

$$\text{Step 1} \quad 2\text{Mn}^{2+}(\text{aq}) + 4\text{OH}^-(\text{aq}) + \text{O}_2(\text{aq}) \rightarrow 2\text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l})$$
$$\text{Step 2} \quad \text{MnO}_2(\text{s}) + 2\text{I}^-(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{I}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$$
$$\text{Step 3} \quad 2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^-(\text{aq})$$

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.iii0.0002 moles of I^- were formed in step 3. Calculate the amount, in moles, of oxygen, O_2, dissolved in water. [1]

Markscheme

a. amount of oxygen needed to decompose organic matter;

in a specified time/five days / at a specified temp/ 20 °C;

Second mark can only be awarded if reasonable attempt made to define BOD.

c.i. gained electrons;

c.ii.+4 to +2 / decrease by 2;

c.iii$0.00005/5 \times 10^{-5}$ (moles);

Examiners report

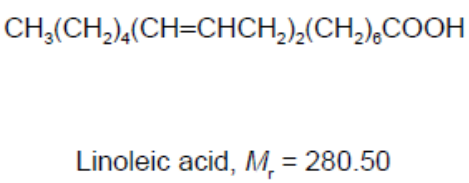
a. In part (a) the term *biochemical oxygen demand (BOD)* was not well known. Very few candidates could explain that it is related to the level of organic waste in the water measured at a specific temperature for a specific time period.

c.i. Many candidates understood that oxygen gained electrons.

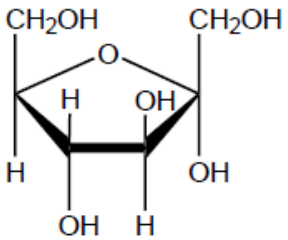
c.ii.Many candidates understood that the oxidation number of manganese dropped from +4 to +2.

c.iiiMany candidates understood that oxygen gained electrons in (c) (i) and that the oxidation number of manganese dropped from +4 to +2 in (ii). However, they struggled to calculate the moles of dissolved oxygen.

Consider the following lipid and carbohydrate.



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]

Markscheme

a.i. $C_9H_{16}O$

a.ii. ratio of oxygen to carbon in linoleic acid lower

OR

linoleic acid less oxidized

OR

linoleic acid more reduced

Accept "«average» oxidation state of carbon in linoleic acid is lower".

b.i. «electrophilic» addition/A_E

OR

oxidation–reduction/redox

b.ii. «$\frac{1.24\ \text{g}}{280.50\ \text{g mol}^{-1}}$ =» 0.00442 «mol»

0.00884 mol of C=C

OR

ratio of linoleic acid : iodine = 1:2

«volume of I_2 solution = $\frac{0.00884\ \text{mol}}{0.300\ \text{mol dm}^{-3}}$ =» 0.0295 «dm^3» / 29.5 «cm^3»

*Award **[3]** for correct final answer.*

c. *Any two of:*

increases «ratio of» HDL «to LDL» cholesterol

OR

decreases LDL cholesterol «level»

removes plaque from/unblocks arteries

OR

decreases risk of heart disease

decreases risk of stroke «in the brain»

Accept "essential fatty acid".

*Do **not** accept "bad cholesterol" for "LDL cholesterol" **OR** "good cholesterol" for "HDL cholesterol".*

*Do **not** accept general answers such as "source of energy" **OR** "forms triglycerides" **OR** "regulates permeability of cell membranes" etc.*

[Max 2 Marks]

Examiners report

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

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 + $BaCl_2 \cdot \mathbf{x}H_2O$ 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]

Markscheme

a. repeat steps 3 and 4

OR

repeat step 5

OR

conduct a third heating

OR

«re»heat ***AND*** «re»weigh

water still present
OR
need two consistent readings
OR
heat to constant mass

Accept "ensure even/strong heating" for M1.
*Do **not** accept "cleaning/washing the crucible".*

b. soot/carbon deposited

OR

incomplete combustion

OR

air hole of Bunsen burner closed/not fully open

Accept "using a yellow «Bunsen burner» flame" for M1.

«value of **x**» lower

Only award M2 if M1 correct.

c. all mass loss is due to water loss

all the water «of crystallization» is lost

crucible does not absorb/lose water

crystal/$BaCl_2$ does not decompose/hydrolyse/oxidize/react with oxygen/air «when heated»

Accept "no loss of crystals/$BaCl_2$ occurs", "no impurities in the «weighed hydrated» salt", "reaction goes to completion", "heat was consistent/strong", "crystal/$BaCl_2$ does not absorb water during cooling", "balance has been calibrated" or "crucible was clean at the start".

*Do **not** accept "heat loss to surroundings" or "no carbon deposited on crucible".*

Reference to defects in apparatus not accepted.

*Do **not** penalize if $BaCl_2.\mathbf{x}H_2O$ is used for $BaCl_2$.*

Examiners report

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

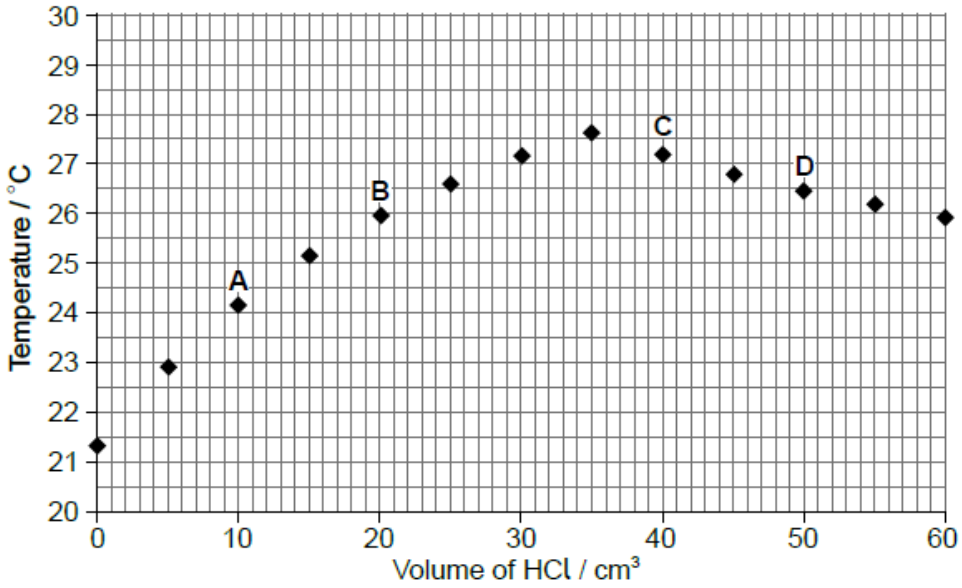
A class was determining the concentration of aqueous sodium hydroxide by titrating it with hydrochloric acid, whilst monitoring the pH of the solution.

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.

Markscheme

graph would peak/maximum at 17.5 cm^3

OR

smaller volume of acid «needed to reach equivalence»

sulfuric acid is dibasic/diprotic

higher temperature would be reached

Accept "gradient/slope «of graph» is greater/steeper" for M1.

Accept "one mole of sulfuric acid neutralizes two moles of NaOH" for M2.

[2 marks]

Examiners report

[N/A]

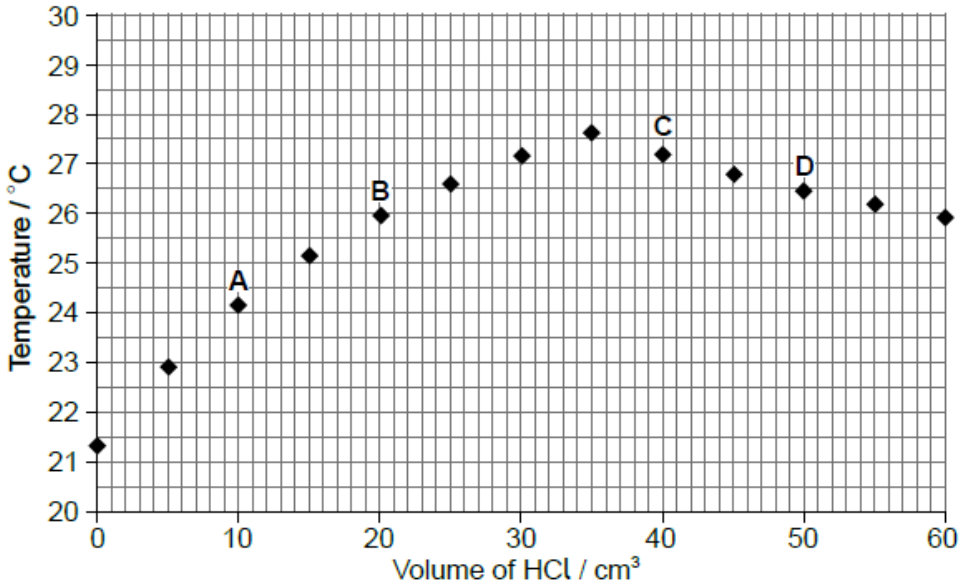
A class was determining the concentration of aqueous sodium hydroxide by titrating it with hydrochloric acid, whilst monitoring the pH of the solution.

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



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

Markscheme

volume «found by extrapolation of the two best fit lines» required to give the highest temperature

OR

extrapolate «two best fit» lines to the point where they meet

Accept "where lines through the points meet".

Accept "at maximum temperature".

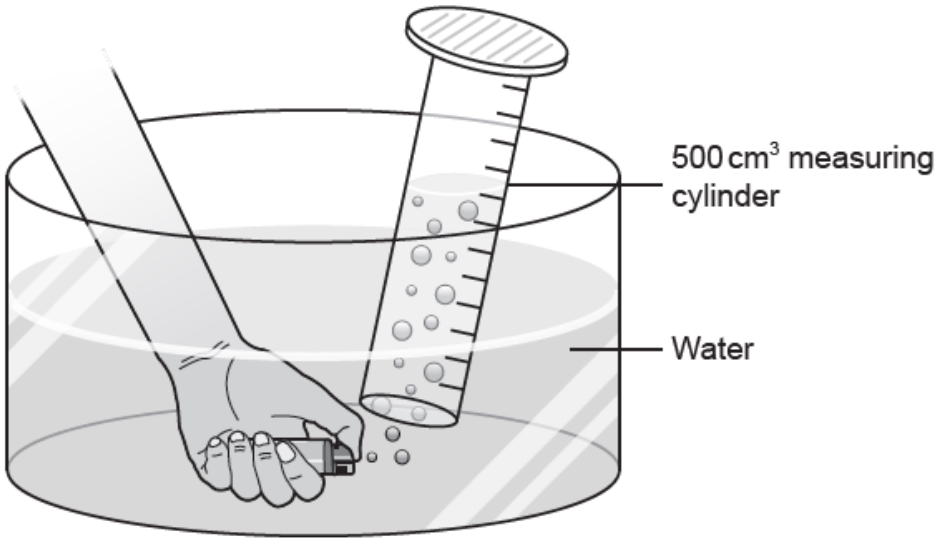
Accept "at 35 cm^3 of HCl".

[1 mark]

Examiners report

[N/A]

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]

Markscheme

a. mass/*m* of lighter before ***AND*** after the experiment

volume of gas/V_{gas} «collected in the cylinder»

«ambient» pressure/*P* «of the room»

temperature/*T*

Accept "change in mass of lighter".

Accept "weight" for "mass".

*Do **not** accept just "mass of lighter/gas".*

Accept "volume of water displaced".

*Do **not** accept "amount" for "volume" or "mass".*

[4 marks]

b.i. *Any two of:*

pressure of gas not equalized with atmospheric/room pressure

too large a recorded volume «of gas produces a lower value for molar mass of butane»
OR
cylinder tilted

difficult to dry lighter «after experiment»
OR
higher mass of lighter due to moisture
OR
smaller change in mass but same volume «produces lower value for molar mass of butane»

using degrees Celcius/°C instead of Kelvin/K for temperature

Accept "vapour pressure of water not accounted for" ***OR*** *"incorrect vapour pressure of water used"* ***OR*** *"air bubbles trapped in cylinder". Do* ***not*** *accept "gas/bubbles escaping «the cylinder»" or other results leading to a larger molar mass.*

Accept "lighter might contain mixture of propane and butane".

Do ***not*** *accept only "human errors"* ***OR*** *"faulty equipment" (without a clear explanation given for each) or "mistakes in calculations".*

[2 marks]

b.ii record vapour pressure of water «at that temperature»

OR

equalize pressure of gas in cylinder with atmospheric/room pressure

OR

tap cylinder before experiment «to dislodge trapped air»

OR

collect gas using a «gas» syringe/eudiometer/narrower/more precise graduated tube

OR

collect gas through tubing «so lighter does not get wet»

OR

dry lighter «before and after experiment»

OR

hold «measuring» cylinder vertical

OR

commence experiment with cylinder filled with water

Accept "adjust cylinder «up or down» to ensure water level inside cylinder matches level outside".

Accept "repeat experiment/readings «to eliminate random errors»".

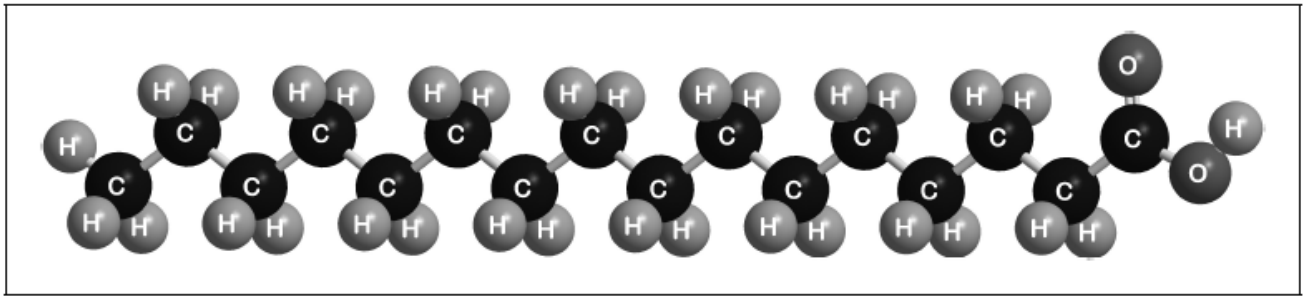
Accept "use pure butane gas".

[1 mark]

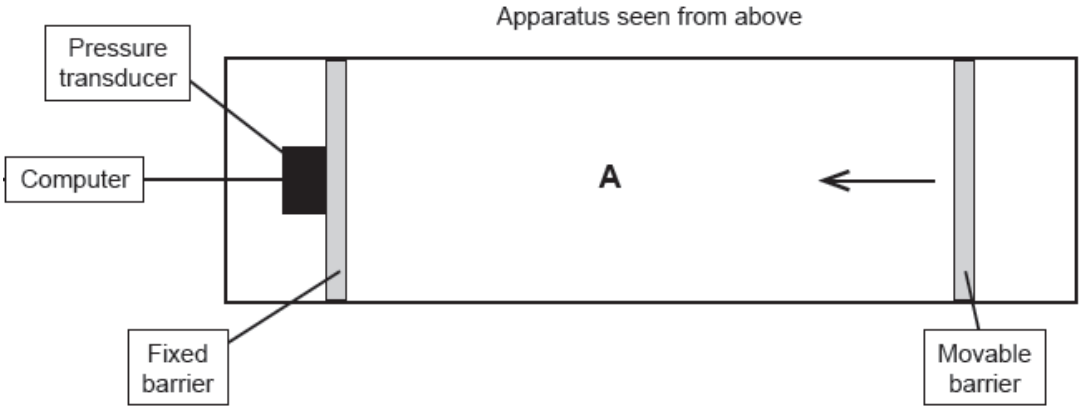
Examiners report

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

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

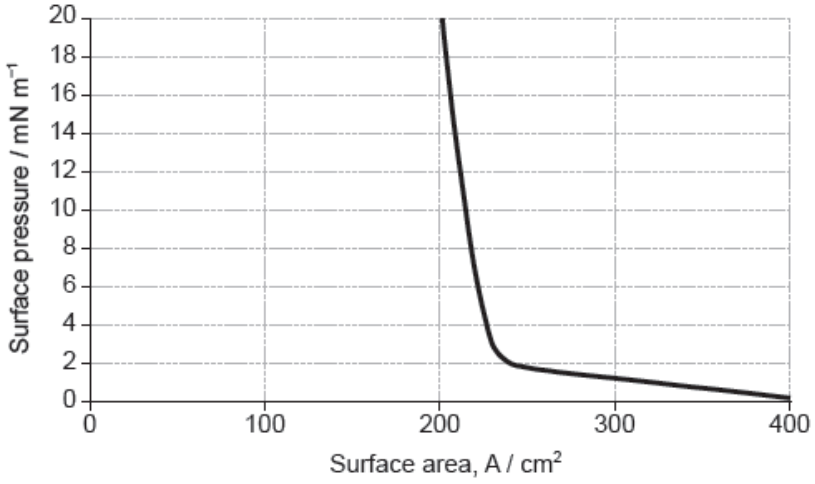


The apparatus in the diagram measures the surface pressure created by palmitic acid molecules on the surface of water. This pressure is caused by palmitic acid molecules colliding with the fixed barrier. The pressure increases as the area, **A**, available to the palmitic acid is reduced by the movable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

. . . . . .

. . . . . .

. . . . . .

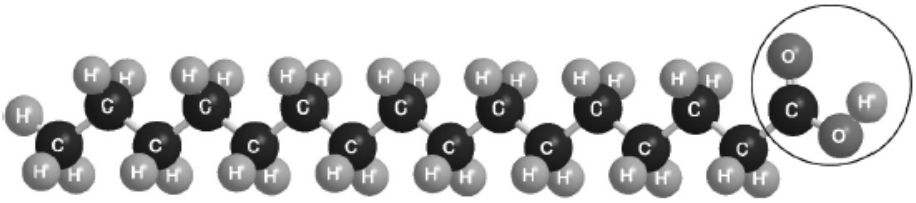
b.ii. The solution of palmitic acid had a concentration of 0.0034 mol dm^{-3}. Calculate the number of molecules of palmitic acid present in the 0.050 cm^3 drop, using section 2 of the data booklet. [2]

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} $dm^3 \times 0.0034$ mol dm^{-3}» = 1.7×10^{-7} «mol»

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

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

Award ***[1]*** *for "1.0×10^{20}".*

[2 marks]

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

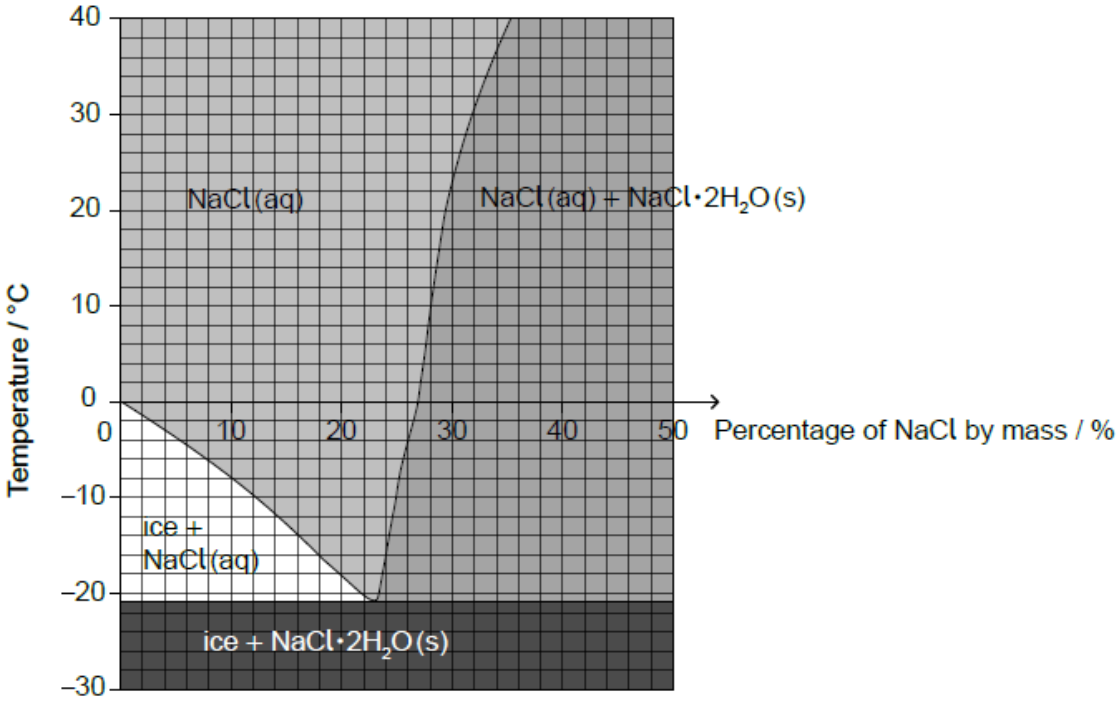
[1 mark]

Examiners report

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

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]

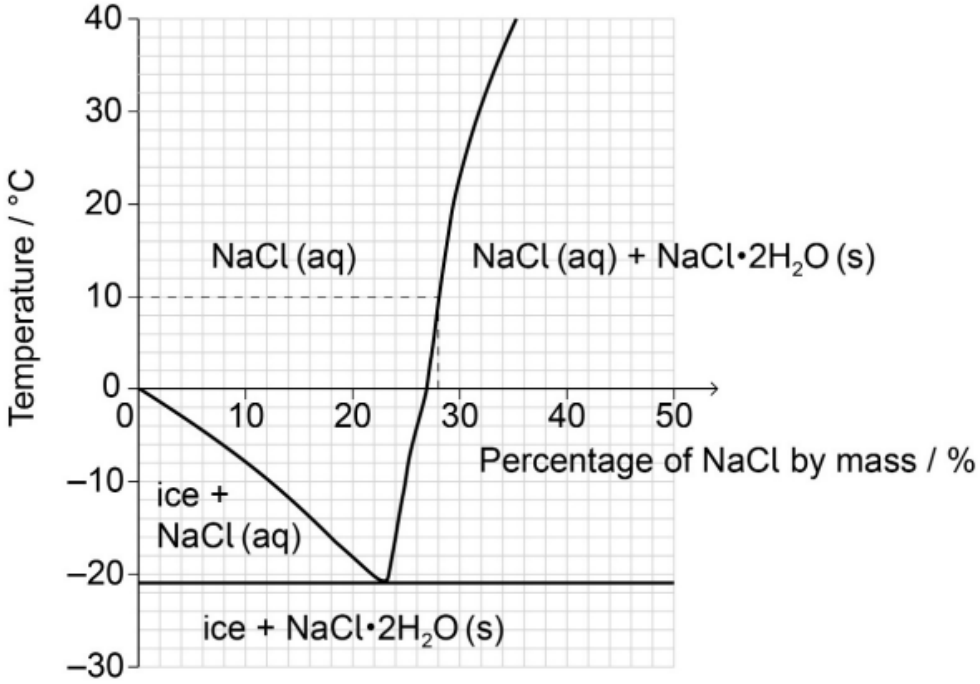
c. Calculate the percentage of water by mass in the $NaCl \cdot 2H_2O$ crystals. Use the data from section 6 of the data booklet and give your answer to two decimal places. [2]

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

Markscheme

a. –21 «°C»

b.



28 «%»

Accept any specific answer in the range 27 to 29 «%».

c. M_r = 94.48

«$2\frac{(1.01\times2+16.00)}{94.48}\times100=$» 38.15 «%»

Award M2 only if answer is to 2 decimal places.

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

*Award **[1 max]** for 38.10 %.*

d. rust/corrosion «of cars and bridges»

OR

waste of important raw material

OR

soil/water salination/pollution «from run off»

OR

erosion of/damage to the road surface

OR

specific example of damage to the ecosystem

OR

«outdoor» temperatures may go below effective levels for NaCl «to lower freezing point» so NaCl could be wasted

OR

roads can refreeze causing hazards

*Do **not** accept "tyre damage".*

*Do **not** accept "economic issues" **OR** "environmental issues" unless specified (eg accept "increase in costs for local councils road budgets" but **not** "cost" alone).*

*Do **not** accept "makes roads more slippery".*

Examiners report

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