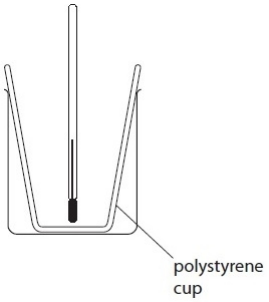
Questions

Q1.

A student investigated the neutralisation of acids by measuring the temperature changes when alkalis were added to acids of known concentrations.

He used this apparatus to add different volumes of sodium hydroxide solution to a fixed volume of dilute nitric acid.



He used this method.

- measure the temperature of 25.0 cm^3 of the acid in the polystyrene cup
- add the sodium hydroxide solution in 5.0 cm^3 portions until a total of 30.0 cm^3 has been added

(a) State two properties of the sodium hydroxide solution that should be kept constant for each 5.0 cm^3 portion.

(2)

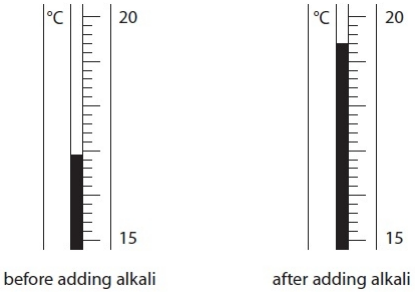
1 .....

.....

2 .....

.....

(b) The diagram shows the thermometer readings in one experiment.



before adding alkali after adding alkali

Write down the thermometer readings and calculate the temperature change.

(3)

temperature after adding alkali .....°C

temperature before adding alkali .....°C

temperature change .....°C

(c) The student carried out the experiment three times.

The table shows his results.

Volume of alkali added in cm^3	Temperature in °C		
	experiment 1	experiment 2	experiment 3
0.0	17.4	16.6	15.9
5.0	18.5	21.0	18.0
10.0	19.6	24.5	20.0
15.0	20.5	23.6	22.2
20.0	21.4	22.7	23.6
25.0	22.5	21.4	22.8
30.0	23.4	20.5	22.0

The teacher said that only the results for experiment 3 showed the expected increase and decrease in temperature.

(i) Why was there no temperature decrease in experiment 1?

(1)

- ☐ **A** The alkali was added too quickly
- ☐ **B** The starting temperature of the acid was too high
- ☐ **C** The acid concentration was half what it should have been
- ☐ **D** The volume of acid used was 50.0 cm^3 instead of 25.0 cm^3

(ii) Why were the temperature increases in experiment 2 much greater than expected?

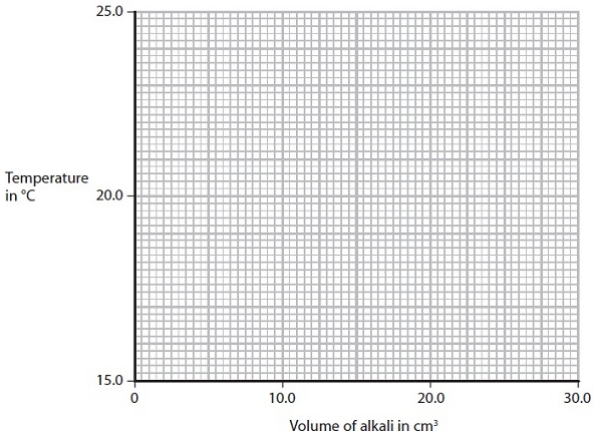
(1)

- ☐ **A** The starting temperature of the acid was too high
- ☐ **B** The acid concentration was double what it should have been
- ☐ **C** The volume of acid used was 50.0 cm^3 instead of 25.0 cm^3
- ☐ **D** The alkali was added in 10.0 cm^3 portions but were recorded as 5.0 cm^3 portions

(d) Plot the results of experiment 3 on the grid.

Draw a straight line of best fit through the first four points, and another straight line of best fit through the last three points. Make sure that the two lines cross.

(4)



(e) The point where the lines cross indicates the volume of alkali added to exactly neutralise the acid and also the maximum temperature reached.

Record these values.

(2)

volume of alkali..... cm^3

maximum temperature..... °C

(f) Another student used sulfuric acid instead of nitric acid in her experiments. She started with 25.0 cm^3 of sulfuric acid of concentration 0.650 mol/dm^3.

She added 0.500 mol/dm^3 sodium hydroxide solution until the acid was completely neutralised.

The equation for this reaction is

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

(i) Calculate the amount, in moles, of sulfuric acid used.

(2)

amount = ... mol

(ii) Calculate the amount, in moles, of sodium hydroxide needed to neutralise this amount of sulfuric acid.

(1)

amount = ... mol

(iii) Calculate the volume, in cm^3, of sodium hydroxide solution needed to neutralise this amount of sulfuric acid.

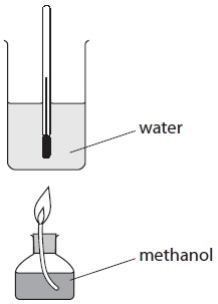
(2)

volume = ... cm^3

(Total for Question = 18 marks)

Q2.

A student uses this apparatus to find the increase in temperature of water when methanol, CH_3OH, is burned.



(a) There are several reasons why the increase in temperature is less than expected.

(i) One reason is the incomplete combustion of methanol to form only carbon monoxide and water.
Write the chemical equation for this incomplete combustion.

(2)

.....

(ii) State another reason why the increase in temperature is less than expected.

(1)

.....

.....

(b) The student records these results.

mass of burner and methanol before combustion	84.7 g
mass of burner and methanol after combustion	83.2 g
mass of water	125 g
temperature of water at start	22 °C
temperature of water at end	58 °C

(i) Calculate the heat energy change (Q), in joules, in this experiment using the expression

$$Q = m \times 4.2 \times \Delta T$$

where m is the mass of water in grams and ΔT represents the increase in temperature.

(2)

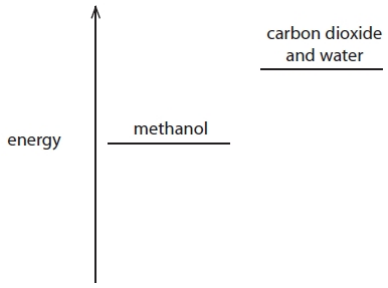
Q = ... J

(ii) The relative molecular mass of methanol is 32
Use this information and your value for Q to calculate the molar enthalpy change, ΔH, for the combustion of methanol.
Give your answer in kJ/mol.

(4)

ΔH = ... kJ/mol

(iii) The student draws an energy level diagram for the complete combustion of methanol.



Identify the two mistakes in his diagram.

(2)

1 .....

.....

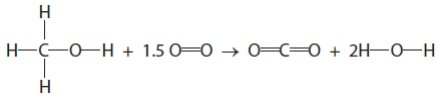
2 .....

.....

(c) The student is given this table of average (mean) bond energies.

Bond	C—H	C—O	O—H	O═O	C═O
Average bond energy in kJ/mol	412	360	463	496	743

The equation for the complete combustion of methanol is



Use this equation and the information in the table to calculate another value for the molar enthalpy change, ΔH, for the combustion of methanol.

(4)

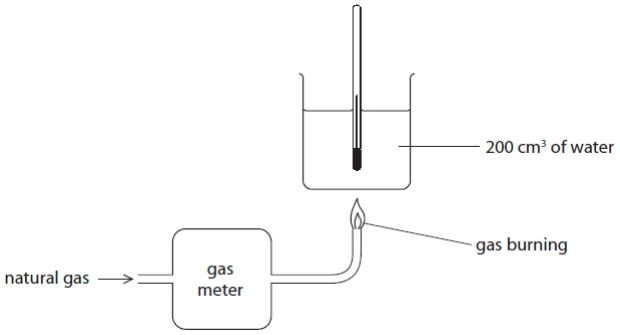
ΔH = ... kJ/mol

(Total for question = 15 marks)

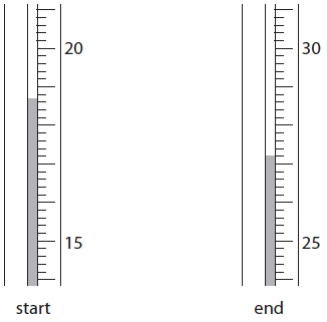
Q3.

A student does some experiments to find the heat energy released when natural gas burns.

She uses this apparatus.



(a) The diagram shows the thermometer readings in one of her experiments.



Use these readings to complete the table, entering all values to the nearest 0.1 °C.

(3)

temperature of water at start in °C	
temperature of water at end in °C	
temperature change in °C	

(b) The student repeats the experiment three times.

The table shows her results.

Experiment	Volume of gas burned in cm³	Temperature rise of water in °C
1	1450	34.8
2	1875	41.2
3	1620	37.7

(i) Calculate the amount, in moles, at room temperature and pressure, of methane burned in experiment 1.

Assume that natural gas contains only methane.

(The volume of 1 mol of a gas at room temperature and pressure is 24 000 cm^3)

(2)

amount = ... mol

(ii) The quantity of heat energy released in experiment 1 is 29 200 J.
Calculate the molar enthalpy change, in kJ/mol, for the combustion of methane.

(2)

molar enthalpy change = ... kJ/mol

(iii) The temperature rise in experiment 2 is 41.2 °C.
Calculate the heat energy change in experiment 2 using the expression
heat energy change = volume of water × 4.2 × temperature change

(in J) (in cm^3) (in °C)

(2)

heat energy change = ... J

(iv) The student uses the results from experiment 3 to calculate the molar enthalpy change, in kJ/mol, for the combustion of methane.
She compares her value with the value in a data book.

student's value	$\Delta H = -510$ kJ/mol
data book value	$\Delta H = -890$ kJ/mol

Which is the best explanation for the large difference between these two values?

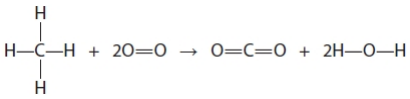
(1)

- ☐ **A** natural gas contains other gases that release heat energy when burned
- ☐ **B** not all of the heat energy is transferred to the water
- ☐ **C** some of the water evaporates during the experiment
- ☐ **D** the student measures the gas by volume instead of by mass

(c) The student uses a table of average bond energies to calculate another value for the molar enthalpy of combustion of methane.

Bond	C—H	O=O	C=O	H—O
Average bond energy in kJ/mol	412	496	743	463

The equation for the combustion can be shown using displayed formulae.



(i) Use values from the table to calculate the energy taken in when the bonds in the reactants are broken.

(2)

energy taken in = ... kJ

(ii) Use values from the table to calculate the energy given out when the bonds in the products are formed.

(2)

energy given out = ... kJ

(iii) Use your answers to (i) and (ii) to calculate the molar enthalpy change for the combustion of methane.

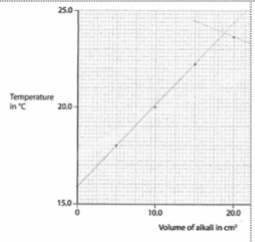
(1)

molar enthalpy change = ... kJ/mol

(Total for question = 15 marks)

Mark Scheme

Q1.

Question number				Answer	Notes	Marks
	a		M1	concentration	Ignore from the same bottle	1
			M2	temperature / same temperature as acid		1
					Accept in either order Ignore references to volume	
	b		M1	19.4	Award 1 for both temperatures correct but in wrong order	1
			M2	16.9		1
			M3	(+)2.5	CQ on temperatures recorded Penalise negative sign	1
	c	i		cross in box D (The volume of acid used was 50.0 cm^3 instead of 25.0 cm^3)		1
		ii		cross in box D (The alkali was added in 10.0 cm^3 portions but were recorded as 5.0 cm^3 portions)		1
	d		M1	all points plotted correctly to nearest gridline	Deduct 1 for each error If points not visible beneath line, assume them to be on the line	2
			M2			
			M3	straight line of best fit through first 4 points	Lines must be drawn with a ruler Penalise freehand once only	1
			M4	straight line of best fit through last 3 points	ECF on incorrectly plotted points	1
					If first line drawn to (23.6,20.0), do not award M3 If lines do not cross or are joined by curve or straight line, only one of M3 and M4 can be awarded	
	e		M1	volume of alkali CQ on where lines cross	Accept answer to nearest gridline to min 1 dp	1
			M2	maximum temperature CQ on where lines cross	Accept answer to nearest gridline to min 1 dp	1
					Penalise missing dp once only If both values correct but in wrong order, award 1/2 0/2 if lines do not cross	
	f	i	M1	0.650 × 0.025		1
			M2	0.01625 / 0.0163	16.25 scores 1/2 Accept 0.016 and 0.0162	1
		ii	M1	0.0325	CQ on fi	1
		iii	M1	$\frac{0.0325 \times 1000}{0.500}$	CQ on fii	1
			M2	65 (cm^3)	If M1 wrong because ×1000 missing, then award M2 by ECF	1
					Penalise failure to use 1000 once only in i and iii Do not penalise rounding of intermediate answers and consequent final answer eg 65.2	
					If final answer obtained by use of $\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2}$ both marks may be awarded in iii	
TOTAL						18

Q2.

Question number	Answer	Notes	Marks
(a)(i)	$CH_3OH + O_2 \rightarrow CO + 2H_2O$ **M1** all formulae correct **M2** correctly balanced	**ACCEPT** multiples and fractions **M2** DEP on **M1**	2
(ii)	thermal energy/heat (energy) lost to the surroundings/environment	**ACCEPT** lost to atmosphere/beaker/thermometer **ACCEPT** evaporation of water/methanol	1

(b)(i)	**M1** (Q =) 125 × 4.2 × 36 **M2** = 18 900 (J) /19 000 (J)	 **ACCEPT** answer in kJ if unit included Correct final answer with no working scores 2 **ALLOW** one mark for 1.5 x 4.2 x 36 = 226.8 **ALLOW** one mark for 126.5 x 4.2 x 36 = 19 126.8	2
(ii)	**M1** mass[CH_3OH] = 84.7 – 83.2 **OR** 1.5 (g) **M2** *n*[CH_3OH] = 1.5 ÷ 32 **OR** 0.046875 (mol) **OR M1** ÷ 32 **M3** ΔH = 18 900 ÷ **M2** OR 403 200 (J/mol) **M4** ΔH = – 400 (kJ/mol)	 **ACCEPT** any number of sig fig except 1, eg 0.047 **ACCEPT M2** from (b)(i) ÷ **M2** from (b)(ii) **ACCEPT** any number of sig fig **ACCEPT** any number of sig fig, eg 403, 403.2 Negative sign must be included (+) 400/403/403.2 etc scores 3 **Mark CSQ throughout** Correct final answer with no working scores 4	4

Alternative Method

(b)(ii)	**M1** mass[CH_3OH] = 84.7 – 83.2 **OR** 1.5 (g) **M2** 18 900 ÷ 1.5 OR 12 600 **OR** 18 900 ÷ **M1** **M3** ΔH = 12 600 x 32 **OR** 403 200 (J) **M4** ΔH = – 400 (kJ/mol)	 **ACCEPT** any number of sig fig except 1, eg 0.047 **ACCEPT M2** from (b)(i) ÷ **M2** from (b)(ii) **ACCEPT** any number of sig fig **ACCEPT** any number of sig fig, eg 403, 403.2 Negative sign must be included (+) 400/403/403.2 etc scores 3 **Mark CSQ throughout** Correct final answer with no working scores 4	4

(b)(iii)	**M1** oxygen/other reactant missing from methanol **M2** product level / carbon dioxide and water above reactant level	 **ACCEPT** product level should be below reactant level **ACCEPT** answers shown on diagram **IGNORE** references to activation energy **IGNORE** references to missing x-axis	2

(c)	**Route 1:** **M1** Σ(bonds broken) = (412 × 3) + 360 + 463 + (496 × 1.5) OR 2803 (kJ/mol) **M2** Σ(bonds made)= (743 x 2) + (463 x 4) OR 3338 (kJ/mol) **Route 2:** **M1** Σ(bonds broken) = (412 × 3) + 360 + (496 × 1.5) OR 2340 (kJ/mol) **M2** Σ(bonds made) = (743 x 2) + (463 x 3) OR 2875 (kJ/mol) **M3** Correct calculation of **difference** between **M1** and **M2** **M4** If **M2** > **M1** final answer must be negative If **M2** < **M1** final answer must be positive	**IGNORE** negative sign **IGNORE** negative sign **IGNORE** sign Expected final answer is -535 Positive sign not required If a clear statement is made that the reaction is exothermic, then sign can be negative Correct final answer with no working scores 4	4
		Total	**15**

Q3.

Question number	Answer	Notes	Marks
a	18.7	Give 1 mark for 18.7 and 27.2 wrong way around	1
	27.2		1
	M2−M1 / (+)8.5		1
b i	1450 ÷ 24000		1
	0.0604(16)	Accept minimum of 2 dp Award 1 mark for a correct answer using a volume from either experiment 2 or 3	1
ii	29.2 ÷ M2 from (b)(i) / 29.2 ÷ 0.0604(16)	Accept 29200 ÷ 0.0604	1
	(−)483(.315678)	Final answer in joules scores 1/2	1
iii	200 × 4.2 × 41.2		1
	(−)34608	Accept minimum of 2 sf Award 1 mark for a correct calculation using 1875 for the volume of water.	1
iv	cross in box **B** (not all of the heat energy is transferred to the water)		1

c i	(4 × C-H) + (2 × O=O) 2640	Accept (4 × 412) + (2 × 496) / 1648 + 992 Deduct 1 mark for each mistake Ignore sign	1 1
ii	(2 × C=O) + (4 × H–O) 3338	Accept (2 × 743) + (4 × 463) / 1486 + 1852 Deduct 1 mark for each mistake Ignore sign	1 1
iii	– 698 (kJ/mol)	CSQ on answers given to (c)(i) and (c)(ii)	1