1. The alcohol 2-methylpropan-2-ol, (CH3)3COH, reacts to form esters that are used as flavourings by the food industry. The alcohol can be oxidised to produce carbon dioxide and water.

A student carried out an experiment on a pure sample of 2-methylpropan-2-ol to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner and positioned under a beaker containing 50 cm3 of water. The spirit burner was ignited and allowed to burn for several minutes before it was extinguished.

The results for the experiment are shown in **Table 1**.

**Table 1**

|  |  |  |
| --- | --- | --- |
|  | Initial temperature of the water / °C | 18.1 |
|  | Final temperature of the water / °C | 45.4 |
|  | Initial mass of spirit burner and alcohol / g | 208.80 |
|  | Final mass of spirit burner and alcohol / g | 208.58 |

(a)     Use the results from **Table 1** to calculate a value for the heat energy released from the combustion of this sample of 2-methylpropan-2-ol.   
The specific heat capacity of water is 4.18 J K–1 g–1.   
Show your working.

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**(2)**

(b)     Calculate the amount, in moles, of 2-methylpropan-2-ol burned in the experiment.   
Hence calculate a value, in kJ mol–1, for the enthalpy of combustion of   
2-methylpropan-2-ol.   
Show your working.

(If you were unable to calculate an answer to part (a), you should assume that the heat energy released was 5580 J. This is **not** the correct value.)

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**(3)**

(c)     An equation for the combustion of 2-methylpropan-2-ol is

(CH3)3COH(I) + 6O2(g)   4CO2(g) + 5H2O(I)

**Table 2** contains some standard enthalpy of formation data.

**Table 2**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | (CH3)3COH(I) | O2(g) | CO2(g) | H2O(I) |
|  | ∆***H*f / kJ mol–1** | –360 | 0 | –393 | –286 |

Use the data from **Table 2** to calculate a value for the standard enthalpy of combustion of 2-methylpropan-2-ol. Show your working.

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**(3)**

(d)     An accurate value for the enthalpy of combustion of 2-methylpropan-2-ol in which water is formed as a gas is –2422 kJ mol–1.

Use this value and your answer from part (b) to calculate the overall percentage error in the student’s experimental value for the enthalpy of combustion of 2-methylpropan-2-ol.

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**(1)**

(e)     Suggest **one** improvement that would reduce errors due to heat loss in the student’s experiment.

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**(1)**

(f)      Suggest **one** other source of error in the student’s experiment. Do **not** include heat loss, apparatus error or student error.

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**(1)**

**(Total 11 marks)**

**2.** A 50.0 cm3 sample of a 0.200 mol dm–3 solution of silver nitrate was placed in a polystyrene beaker. An excess of powdered zinc was added to this solution and the mixture stirred. Zinc nitrate, Zn(NO3)2, and silver were formed and a rise in temperature of 3.20 °C was recorded.

(a)     Write an equation for the reaction between silver nitrate and zinc.

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**(1)**

(b)     Calculate the number of moles of silver nitrate used in the experiment.

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**(2)**

(c)     Calculate the heat energy evolved by the reaction in this experiment assuming that all the energy evolved is used to heat only the 50.0 g of water in the mixture.  
(Specific heat capacity of water is 4.18 J g–1 K–1)

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**(2)**

(d)     Calculate the heat energy change for the reaction per mole of zinc reacted.

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**(2)**

(e)     Explain why the experimental value for the heat energy evolved in this experiment is less than the correct value.

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**(1)**

**(Total 8 marks)**

**4.**          (a)     State what is meant by the term *mean bond enthalpy*.

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**(2)**

(b)     Ethanal has the structure 

Gaseous ethanal burns as shown by the equation

CH3CHO(g)   +   2½O2(g)   →   2H2O(g)   +   2CO2(g)

Use the mean bond enthalpy data given below to answer the following questions.

|  |  |
| --- | --- |
| Bond | Mean bond enthalpy/kJ mol–1 |
| C—H | +413 |
| C—C | +347 |
| C==O | +736 |
| O==O | +498 |
| O—H | +464 |

(i)      Calculate the enthalpy change which occurs when all the bonds in the reactants shown in the above equation are broken.

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(ii)     Calculate the enthalpy change which occurs when all the bonds in the products shown in the above equation are formed.

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(iii)     Hence, calculate the enthalpy change for the complete combustion of ethanal as shown in the equation above.

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**(5)**

**(Total 7 marks)**