STARTER FOR 10...

6.3. Hess's law

This question is all about the possible fuels you might come across when going camping. Use your knowledge of Hess's law to investigate the energetics of the processes involved.

1. One form of camping stove runs on the fuel butane. Along with other isomers this contains the gas *iso*-butane or 2-methylpropane.

(a) The enthalpy change of formation of *iso*-butane is –134.5 kJ mol^{-1}. Write an equation, including state symbols, for the reaction to which this enthalpy change applies. (2 marks)

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(b) In a camping stove, the *iso*-butane undergoes combustion. Write an equation to represent the enthalpy change of combustion of *iso*-butane in excess oxygen. (2 marks)

....

(c) Using the answers to part (i) and part (ii) together with the information in the table below, calculate $\Delta H_c^{\ominus}$ for *iso*-butane. (2 marks)

Compound	Standard enthalpy of formation / kJ mol^{-1}
CO_2 (g)	–394
H_2O (g)	–242

2. An alternative to a gas camping stove is a Trangia™. This burns methylated spirits which is predominantly ethanol with additives to make it more poisonous or unpalatable.

(a) Write an equation to represent the enthalpy change of formation of ethanol (CH_3CH_2OH)

....

(2 marks)

(b) Use the information in the table together with Hess's law to calculate $\Delta H_f^{\ominus}$ for ethanol.

(2 marks)

Compound	Standard enthalpy of combustion / kJ mol^{-1}
C (s)	–394
H_2 (g)	–242
CH_3CH_2OH (l)	–1367

4. The liquids are not allowed to equilibrate to similar temperatures before use; the H_2SO_4 is removed from the fridge!

5. Only two readings were taken before the addition of the H_2SO_4. It is therefore impossible to draw a line to indicate the average temperature of the NaOH before addition.

6. It is more usual to mix the reagents on the 3rd minute say and take no measurement at this point then measure the temperature again on the 4th, 5th minutes etc.

7. There is no mention of the mixture being stirred.

8. Not all temperatures are recorded to 1 decimal point in the student's results table

9. A straight line is drawn for the temperature of the solution after addition of the H_2SO_4 despite the fact that the temperature clearly drops more steeply initially – better extrapolation needed.

10. A volume of 100 cm^3 is indicated in the student's calculation for the energy transferred. The volume is in fact 150 cm^3 (100 cm^3 of NaOH and 50 cm^3 of H_2SO_4).

11. The calculation requested is per mole of NaOH reacting. This reaction involves two equivalents of NaOH so the final enthalpy change must be divided by 2.

NOTE The experimental data is made up and in no way represents the real enthalpy of neutralisation of NaOH.

6.3. Hess's law

1. (a) $4\ C(s) + 5\ H_2(g) \rightarrow C_4H_{10}(g)$

(1 mark equation + balancing; 1 mark state symbols)

(b) $C_4H_{10}(g) + 6\tfrac{1}{2}\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g)$

(1 mark equation; 1 mark balancing)
(**NOTE** Must be combustion of 1 mole of C_4H_{10})

(c) $C_4H_{10}(g) + 6\tfrac{1}{2}\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g)$

–134.5 kJ mol^{-1} 4 × –394 kJ mol^{-1} 5 × –242 kJ mol^{-1}

$4\ C(s),\ 5\ H_2(g),\ 6\tfrac{1}{2}\ O_2(g)$

$\Delta H_c^{\ominus} = [-(-134.5) + (4 \times -394) + (5 \times -242)]$
$= \mathbf{-2651.5\ kJ\ mol^{-1}}$

(1 mark for the cycle or equiv)
(1 mark answer)

2. (a) $2\ C(s) + 3\ H_2(g) + \tfrac{1}{2}\ O_2(g) \rightarrow CH_3CH_2OH(l)$

(1 mark equation + balancing; 1 mark state symbols)

(b) $2\ C(s) + 3\ H_2(g) + \tfrac{1}{2}\ O_2(g) \rightarrow CH_3CH_2OH(l)$

2 × –394 kJ mol^{-1} 3 × –242 kJ mol^{-1} –1367 kJ mol^{-1}

$2\ CO_2(g),\ 3\ H_2(g),\ \tfrac{1}{2}\ O_2(g)$

$\Delta H_f^{\ominus} = [(2 \times -394) + (3 \times -242) - (-1367)]$
$= \mathbf{-147\ kJ\ mol^{-1}}$

(1 mark for the cycle or equiv)
(1 mark answer)