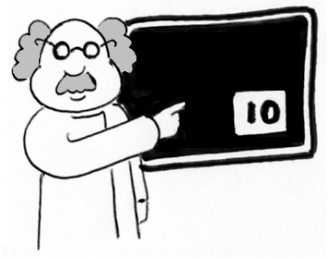

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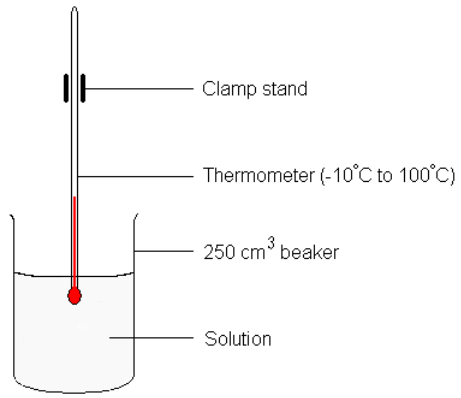
6.2. Calorimetry

Below is a student's write up of the calorimetry practical he recently completed in class. There are 10 ways in which the teacher thinks he could have improved his experimental technique and analysis. Can you spot them?

Measuring the enthalpy change for the neutralisation of one mole of NaOH by H_2SO_4

Method

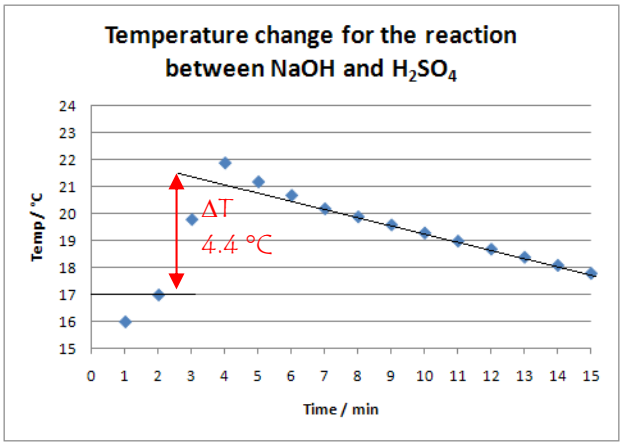


$$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$$

100 cm^3 of a 1 mol dm^{-3} solution of NaOH was placed in a 250 cm^3 beaker and the temperature recorded every minute for two minutes using the equipment shown in the diagram. On the second minute, a solution of 1 mol dm^{-3} H_2SO_4 was removed from the fridge and 50 cm^3 added to the beaker. The temperature of the mixture was recorded on the third minute and repeated every minute for a further 12 min.

Results

Time / min	Temp / °C
1	16
2	17
3	19.8
4	21.9
5	21.2
6	20.7
7	20.2
8	19.9
9	19.6
10	19.3
11	19
12	18.7
13	18.4
14	18.1
15	17.8



$Q = mC\Delta T$ $\quad m = 100\ cm^3 @ 1\ g\ cm^{-3} = 100\ g$ $\quad \therefore Q = 100\ g \times 4.18\ J\ g^{-1}\ K^{-1} \times 4.4\ °C$

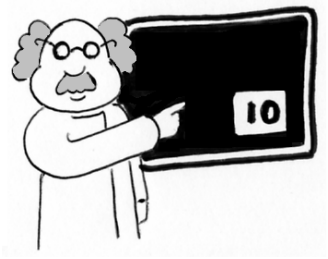
$C = 4.18\ J\ g^{-1}\ K^{-1}$ $\quad = 1839.2\ J$

$\Delta T = 4.4\ K$

No. of moles of NaOH $= \dfrac{100\ cm^3}{1000\ cm^3\ dm^{-3}} \times 1\ mol\ dm^{-3} = 0.1\ mole$

$\therefore$ Enthalpy change per mole of NaOH reacting $= \dfrac{1}{0.1\ mole} \times 1839.2\ J = 18392\ J\ mol^{-1}$

$= 18.4\ kJ\ mol^{-1}$



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6. Thermodynamics answers

6.1. Definitions

Standard enthalpy change, $\Delta H^{\ominus}$

Definition; The heat energy change at constant pressure under standard conditions (pressure 100 kPa ; temperature 298 K). (one mark for both conditions)

(2 marks)

Standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$

Definition; The enthalpy change when one mole of a compound is formed from its constituent elements under standard conditions, with all reactants and products in their standard states.

e.g. $\Delta H_f^{\ominus}(NH_3)$; $1/2\ N_2(g) + 3/2\ H_2(g) \rightarrow NH_3(g)$

(3 marks)

Standard molar enthalpy change of combustion, $\Delta H_c^{\ominus}$

Definition; The enthalpy change when one mole of a compound is completely burned in excess oxygen under standard conditions, all reactants and products in their standard states.

e.g. $\Delta H_c^{\ominus}(C_4H_{10})$; $C_4H_{10} + 13/2\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$

(one mark for symbols, one for balancing)

(3 marks)

Mean bond energy

Definition; The enthalpy change when 1 mole of a particular type of bond is broken or made (all species in the gas phase) averaged over many different molecules

(2 marks)

6.2. Calorimetry

Possible improvements / corrections include (any 10 from);

1. The beaker needs some form of insulation (or a polystyrene beaker should be used)
2. An accurate thermometer is needed (not one that records –10 to 100 °C)
3. The thermometer is placed too near the surface of the mixture. It must be in the centre.

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

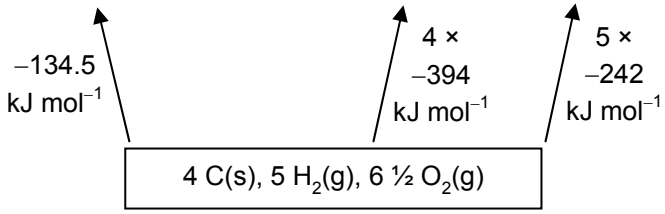
1. (a) $4\ C(s) + 5\ H_2(g) \rightarrow C_4H_{10}(g)$

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

(b) $C_4H_{10}(g) + 6\ ½\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g)$

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

(c) $C_4H_{10}(g) + 6\ ½\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g)$



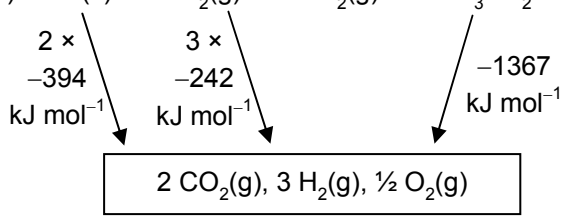
$\Delta H_c^{\ominus} = [-(-134.5) + (4 \times -394) + (5 \times -242)]$
$= -2651.5$ kJ mol^{-1}

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

2. (a) $2\ C(s) + 3\ H_2(g) + ½\ O_2(g) \rightarrow CH_3CH_2OH(l)$

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

(b) $2\ C(s) + 3\ H_2(g) + ½\ O_2(g) \rightarrow CH_3CH_2OH(l)$



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

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