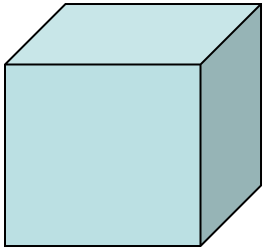
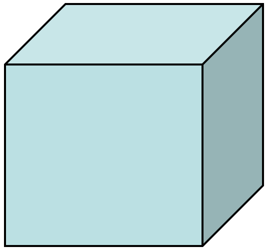
WWW.CHEMSHEETS.CO.UK

CALORIMETRY



1 g of water 1 ^oC hotter

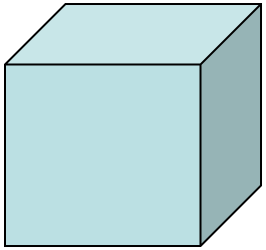
Energy required = 4.18 J



1 g of water 2 ^oC hotter

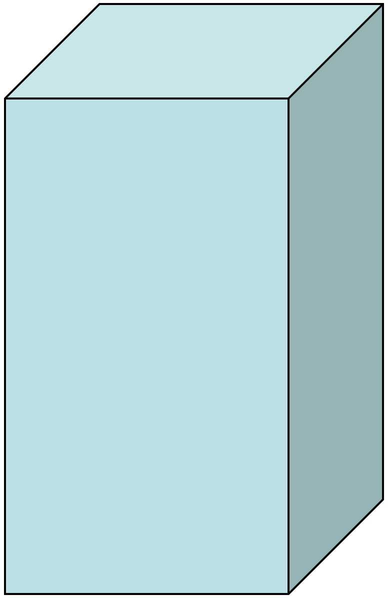
Energy required = 2 x 4.18 J

= 8.36 J



1 g of water 1 °C hotter

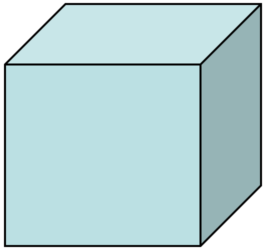
Energy required = 4.18 J



5 g of water 1 °C hotter

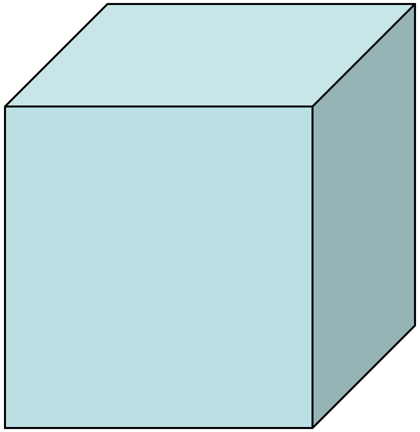
Energy required = 5 x 4.18 J

= 20.9 J



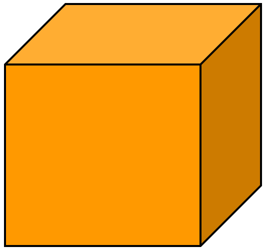
1 g of water 1 °C hotter

Energy required = 4.18 J



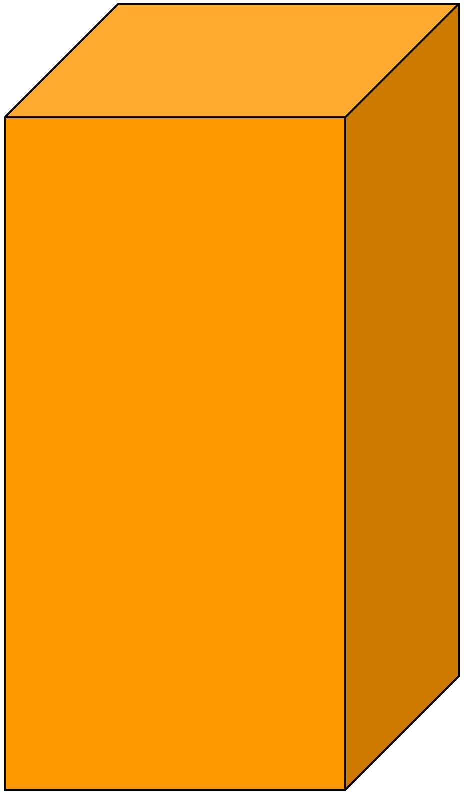
3 g of water 10 °C hotter

Energy required = 3 x 10 x 4.18
= 125.4 J



1 g of copper 1 °C hotter

Energy required = 0.39 J



10 g of copper 5 °C hotter

Energy required = 10 x 5 x 0.39

= 19.5 J

Energy required (q) =

mass heated (m)

x

energy needed to make 1 g of substance 1°C hotter

x

temperature rise (ΔT)

Energy required (q) =

mass heated (m)

x

specifc heat capacity (c)

x

temperature rise (ΔT)

$$q = m c \Delta T$$

2 moles of ethanol burned

Energy given out = 2734 kJ

Energy given out by 1 mole = $\frac{2734}{2}$ kJ

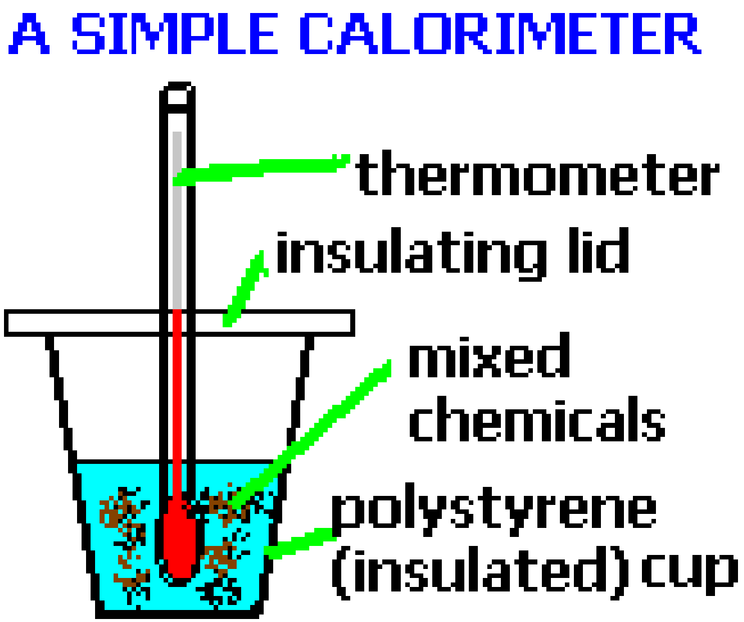
= 1367 kJ

$\Delta H = -1367\ \text{kJ mol}^{-1}$

Copper calorimeter (copper “beaker” with water)

Alcohol burner

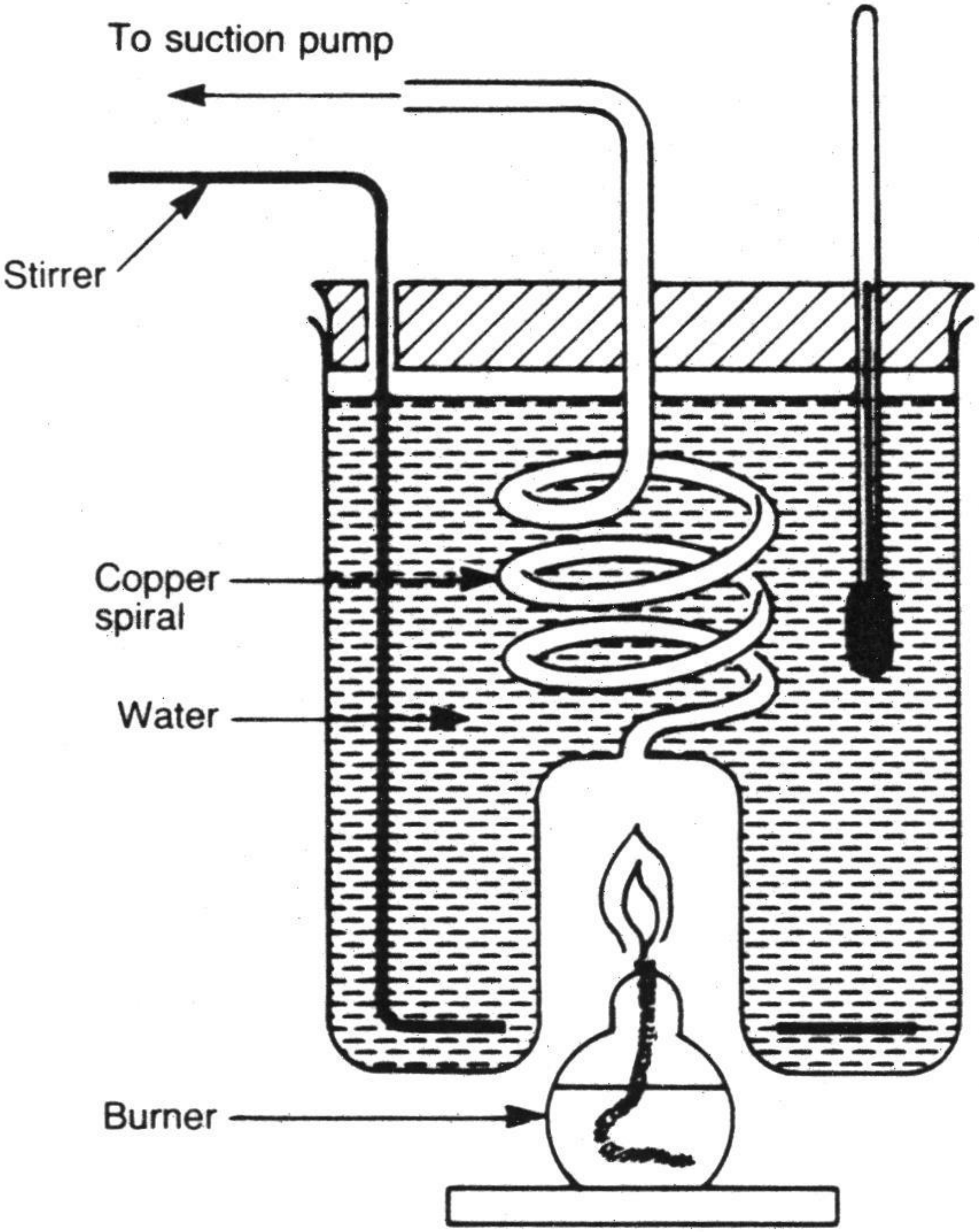
$$\Delta H = \frac{q}{\text{moles in reaction}}$$


A SIMPLE CALORIMETER
thermometer
insulating lid
mixed chemicals
polystyrene (insulated) cup

Reaction in solution

Reaction in plastic cup (inside beaker for stability)

© www.chemsheets.co.uk


To suction pump
Stirrer
Copper spiral
Water
Burner

1) In an experiment, 0.600 g of propane (C_3H_8) was completely burned in air. The heat evolved raised the temperature of 100 g of water by 64.9°C. Use this data to calculate the enthalpy of combustion of propane (the specific heat capacity of water is $4.18\ J\ g^{-1}\ K^{-1}$).

$q = mc\Delta T$ $m = 100$ $c = 4.18$ $\Delta T = 64.9$

$q = 100 \times 4.18 \times 64.9 = 27130\ J$

$\Delta H = q / mol$

moles of propane = mass / M_r

$= 0.600 / 44.0 = 0.01364$

$\Delta H = -27.13 / 0.01364 = \underline{-1990\ kJ\ mol^{-1}}$ (3 sig fig)

2) 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid was added to 50 cm^3 of 1.0 mol dm^{-3} sodium hydroxide solution. The temperature rose by 6.8°C. Calculate the enthalpy of neutralisation for this reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

$q = mc\Delta T \qquad m = 100 \qquad c = 4.18 \qquad \Delta T = 6.8$

$q = 100 \times 4.18 \times 6.8 = 2842\ J$

$\Delta H = q / mol$

Mol HCl = conc x vol = $1.0 \times {}^{50}/_{1000} = 0.050$

Mol NaOH = conc x vol = $1.0 \times {}^{50}/_{1000} = 0.050$

$HCl + NaOH \rightarrow NaCl + H_2O$

$\Delta H = -2.842 / 0.050 \qquad = \underline{-57\ kJ\ mol^{-1}}$ (2 sig fig)

3) 100 cm^3 of 0.200 mol dm^{-3} copper sulphate solution was put in a calorimeter and 2.00 g of magnesium powder added. The temperature of the solution rose by 25.1°C. Work out which reagent was in excess and then calculate the enthalpy change for the reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}. Ignore the heat capacity of the metals.

$q = mc\Delta T$ $m = 100$ $c = 4.18$ $\Delta T = 25.1$

$q = 100 \times 4.18 \times 25.1 = 10490$ J

$\Delta H = q / mol$

Mol $CuSO_4$ = conc x vol = $0.200 \times {}^{100}/_{1000} = 0.020$

Mol Mg = mass / M_r = 2.00 / 24.3 = 0.0823 XS

$CuSO_4 + Mg \rightarrow MgSO_4 + Cu$

$\Delta H = -10.49 / 0.020$ = -525 kJ mol^{-1} (3 sig fig)

1) In an experiment, 1.00 g of propanone (CH_3COCH_3) was completely burned in air. The heat evolved raised the temperature of 150 g of water from 18.8°C to 64.3°C. Use this data to calculate the enthalpy of combustion of propanone (the specific heat capacity of water is 4.18 J g^{-1} K^{-1}).

$q = mc\Delta T$ $m = 150$ $c = 4.18$ $\Delta T = 45.5$

$q = 150 \times 4.18 \times 45.5 = 28530$ J

$\Delta H = q / mol$

moles of propane = mass / M_r

$= 1.00 / 58.0 = 0.01724$

$\Delta H = -28.53 / 0.01724 =$ -1650 kJ mol^{-1} (3 sig fig)

2) In an experiment, 1.00 g of hexane (C_6H_{14}) was completely burned in air. The heat evolved raised the temperature of 200 g of water from 293.5 K to 345.1 K. Use this data to calculate the enthalpy of combustion of hexane (the specific heat capacity of water is 4.18 J g^{-1} K^{-1}).

$q = mc\Delta T$ $m = 200$ $c = 4.18$ $\Delta T = 51.6$

$q = 200 \times 4.18 \times 51.6 = 43140$ J

$\Delta H = q / mol$

moles of propane = mass / M_r

= 1.00 / 86.0 = 0.01163

$\Delta H = -43.14 / 0.01163 = \underline{-3710\ kJ\ mol^{-1}}$ (3 sig fig)

3) In an experiment, 1.56 g of propan-1-ol ($CH_3CH_2CH_2OH$) was completely burned in air. The heat evolved raised the temperature of 0.250 dm^3 of water from 292.1 K to 339.4 K. Use this data to calculate the enthalpy of combustion of propan-1-ol (the specific heat capacity of water is 4.18 $J\ g^{-1}\ K^{-1}$).

$q = mc\Delta T$ $m = 250$ $c = 4.18$ $\Delta T = 47.3$

$q = 250 \times 4.18 \times 47.3 = 49430\ J$

$\Delta H = q / mol$

moles of propane = mass / M_r

$= 1.56 / 60.0 = 0.02600$

$\Delta H = -49.43 / 0.02600 =$ $-1900\ kJ\ mol^{-1}$ (3 sig fig)

4) 25 cm^3 of 2.0 mol dm^{-3} nitric acid was added to 25 cm^3 of 2.0 mol dm^{-3} potassium hydroxide solution. The temperature rose by 13.7°C. Calculate the enthalpy of neutralisation for this reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

$q = mc\Delta T$ $m = 50$ $c = 4.18$ $\Delta T = 13.7$

$q = 50 \times 4.18 \times 13.7 = 2863$ J

$\Delta H = q / mol$

Mol HNO_3 = conc x vol = $2.0 \times {}^{25}/_{1000}$ = 0.050

Mol KOH = conc x vol = $2.0 \times {}^{25}/_{1000}$ = 0.050

$HNO_3 + KOH \rightarrow NaNO_3 + H_2O$

$\Delta H = -2.863 / 0.050$ = -57.3 kJ mol^{-1} (3 sig fig)

5) 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid was added to 50 cm^3 of 2.0 mol dm^{-3} ammonia solution. The temperature rose by 12.4°C. Calculate the enthalpy of neutralisation for this reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

$q = mc\Delta T$ $m = 100$ $c = 4.18$ $\Delta T = 12.4$

$q = 100 \times 4.18 \times 12.4 = 5183$ J

$\Delta H = q / mol$

Mol HCl = conc x vol $= 2.0 \times {}^{50}/_{1000} = 0.100$

Mol NH_3 = conc x vol $= 2.0 \times {}^{50}/_{1000} = 0.100$

$HCl + NH_3 \rightarrow NH_4Cl$

$\Delta H = -5.183 / 0.100$ = -51.8 kJ mol^{-1} (3 sig fig)

6) 50 cm^3 of 1.0 mol dm^{-3} nitric acid was added to 20 cm^3 of 1.0 mol dm^{-3} barium hydroxide solution. The temperature rose by 7.9°C. Calculate the enthalpy of neutralisation for this reaction (per mole of nitric acid reacting). Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

$q = mc\Delta T$ $m = 70$ $c = 4.18$ $\Delta T = 7.9$

$q = 70 \times 4.18 \times 7.9 = 2312$ J

$\Delta H = q / mol$

Mol HNO_3 = conc x vol = $1.0 \times {}^{50}/_{1000}$ = 0.050 XS

Mol $Ba(OH)_2$ = conc x vol = $1.0 \times {}^{20}/_{1000}$ = 0.020

$2\ HNO_3 + Ba(OH)_2 \rightarrow Ba(NO_3)_2 + 2\ H_2O$

$\Delta H = -2.312 / 0.040$ = -57.8 kJ mol^{-1} (3 sig fig)

7) 25 cm^3 of 1.00 mol dm^{-3} copper sulphate solution was put in a calorimeter and 6.0 g of zinc powder added. The temperature of the solution rose by 50.6°C. Work out which reagent was in excess and then calculate the enthalpy change for the reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}. Ignore the heat capacity of the metals.

$q = mc\Delta T$ $m = 25$ $c = 4.18$ $\Delta T = 50.6$

$q = 25 \times 4.18 \times 50.6 = 5288$ J

$\Delta H = q$ / mol

Mol $CuSO_4$ = conc x vol = $1.0 \times {}^{25}/_{1000}$ = 0.025

Mol Zn = mass / M_r = 6.0 / 65.4 = 0.0917 XS

$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$

$\Delta H = -5.288 / 0.025$ = -212 kJ mol^{-1} (3 sig fig)

8) 50 cm^3 of 0.10 mol dm^{-3} silver nitrate solution was put in a calorimeter and 0.2 g of zinc powder added. The temperature of the solution rose by 4.3°C. Work out which reagent was in excess and then calculate the enthalpy change for the reaction (per mole of zinc that reacts). Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}. Ignore the heat capacity of the metals.

$q = mc\Delta T$ $m = 50$ $c = 4.18$ $\Delta T = 4.3$

$q = 50 \times 4.18 \times 4.3 = 898.7$ J

$\Delta H = q / mol$

Mol $AgNO_3$ = conc x vol = $0.1 \times {}^{50}/_{1000} = 0.005$

Mol Zn = mass / M_r = $0.2 / 65.4 = 0.00306$ XS

$2\,AgNO_3 + Zn \rightarrow Zn(NO_3)_2 + 2\,Ag$

$\Delta H = -0.8987 / 0.0025$ = -359 kJ mol^{-1} (3 sig fig)

9) 3.53 g of sodium hydrogencarbonate was added to 30.0 cm^3 of 2.0 mol dm^{-3} hydrochloric acid. The temperature fell by 10.3 K. Work out which reagent was in excess and then calculate the enthalpy change for the reaction. Assume that the density of the solution is 1.00 g cm^{-3}, the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

$q = mc\Delta T$ $m = 30$ $c = 4.18$ $\Delta T = 10.3$

$q = 30 \times 4.18 \times 10.3 = 1292$ J

$\Delta H = q$ / mol

Mol HCl = conc x vol = $2.0 \times {}^{30}/_{1000}$ = 0.060 XS

Mol $NaHCO_3$ = mass / M_r = 3.53 / 84.0 = 0.0420

$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$

ΔH = 1.292 / 0.0420 = +30.8 kJ mol^{-1} (3 sig fig)

10) A calorimeter was calibrated by burning 2.00 g of methanol (CH_3OH) whose enthalpy of combustion is -715 kJ mol^{-1}. The temperature of the calorimeter rose from 19.6°C to 52.4°C. The same calorimeter was used to measure the enthalpy of combustion of propan-2-ol. 1.50 g of propan-2-ol $CH_3CH(OH)CH_3$ raised the temperature by from 19.8°C to 56.2°C. Calculate the heat capacity of the calorimeter and then the enthalpy of combustion of propan-2-ol.

$\Delta H = q / mol$ $\qquad$ $q = \Delta H \times mol$

Mol CH_3OH = mass / M_r = 2.00 / 32.0 = 0.0625

$q = \Delta H \times mol = 715 \times 0.0625 = 44.69$ kJ

$q = mc\Delta T$

$mc = q/\Delta T = 44.69 / 32.8 = 1.363$ kJ K^{-1}

10) A calorimeter was calibrated by burning 2.00 g of methanol (CH_3OH) whose enthalpy of combustion is -715 kJ mol^{-1}. The temperature of the calorimeter rose from 19.6°C to 52.4°C. The same calorimeter was used to measure the enthalpy of combustion of propan-2-ol. 1.50 g of propan-2-ol $CH_3CH(OH)CH_3$ raised the temperature by from 19.8°C to 56.2°C. Calculate the heat capacity of the calorimeter and then the enthalpy of combustion of propan-2-ol.

$q = mc\Delta T$ $mc = 1.363$ $\Delta T = 36.4$

$q = 1.363 \times 36.4 = 49.61$ kJ

$\Delta H = q / \text{mol}$

Mol C_3H_7OH = mass / M_r

$= 1.50 / 60.0 = 0.0250$

$\Delta H = -49.61 / 0.0250 = $ -1984 kJ mol^{-1} (3 sig fig)