R1.1 Measuring enthalpy changes

■ Paper 1

1 Which of the following must have a negative value for a reaction to be exothermic?

    ✓ (A) enthalpy change

    B entropy change

    C equilibrium constant

    D standard cell potential

2 Which of the following reactions would you expect to have the most exothermic enthalpy change? *← This is the most*

    ✗ (A) CH_4 (l) + $2O_2$ (l) → CO_2 (g) + $2H_2O$ (g) *Most state endo-*

    B CH_4 (l) + $2O_2$ (g) → CO_2 (g) + $2H_2O$ (g) *changes thermic.*

    C CH_4 (g) + $2O_2$ (g) → CO_2 (g) + $2H_2O$ (g)

    (D) CH_4 (g) + $2O_2$ (g) → CO_2 (g) + $2H_2O$ (l)

3 A temperature change of 6.4 °C is measured when adding 5.0 cm³ of 1.0 mol dm⁻³ hydrochloric acid to 5.0 cm³ of 1.0 mol dm⁻³ potassium hydroxide. Both solutions had the same initial temperature. For the resulting mixture assume the density is 1.0 g cm⁻³ and the specific heat capacity is 4.18 J g⁻¹ K⁻¹.

What is the change in enthalpy of the reaction in kJ mol⁻¹?

    A $\Delta H^\ominus = -\dfrac{10 \times 4.18 \times 6.4}{1.0 \times 0.005}$ *Make all dm³*

    B $\Delta H^\ominus = -\dfrac{10 \times 4.18 \times 6.4}{1.0 \times 0.005 \times 2}$ *n at limiting reactant, not all reactants.*

    (C) $\Delta H^\ominus = -\dfrac{10 \times 4.18 \times 6.4}{1.0 \times 0.005 \times 1000}$

    ✗ (D) $\Delta H^\ominus = -\dfrac{10 \times 4.18 \times 6.4}{1.0 \times 0.005 \times 2 \times 1000}$ ✓ *NO*

4 When equal masses of X and Y absorb the same amount of heat energy, their temperatures rise by 5 °C and 10 °C respectively. Which is correct?

    ✓ (A) The specific heat capacity of X is twice that of Y.

    B The specific heat capacity of X is half that of Y.

    C The specific heat capacity of X is one fifth that of Y.

    D The specific heat capacity of X is the same as Y.

5 The potential energy profile of a reaction is shown.
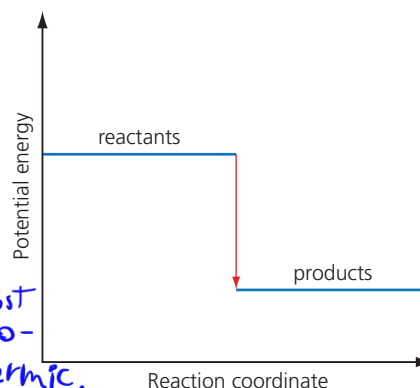
What can be determined about stability and energy change from the potential energy profile shown?

	More stable	Reaction
A	reactants	exothermic
B	reactants	endothermic
✓ (C)	products	exothermic
D	products	endothermic

6 A sample of an ideal gas is cooled by 20 K. Which of the following is always true?

    A The gas has increased its volume at constant pressure.

    ✓ (B) The particles have less average kinetic energy.

    C The gas has condensed into a liquid.

   **D** The pressure of the gas has increased at constant volume.

7 The table shows the specific heat capacities of four metals.

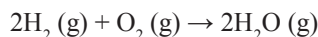| Metal	Specific heat capacity (J g⁻¹ K⁻¹)
copper	0.385
magnesium	1.02
mercury	0.138
lead	0.129

If 100 kJ of heat energy is absorbed by 10.0 g samples of each of the metals above, which are all at 25 °C, which metal will have the lowest temperature?

    A copper

    ✓ (B) magnesium

    C mercury

    D lead

8 Consider the following reaction.

$$H_2O\ (g) \rightarrow H_2\ (g) + \tfrac{1}{2}O_2\ (g) \qquad \Delta H^\ominus = x\,\text{kJ}\,\text{mol}^{-1}$$
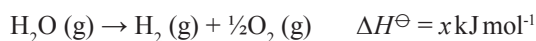
What is the enthalpy change of:

$$2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$$

A $\Delta H^\ominus = -x\,\text{kJ}\,\text{mol}^{-1}$

B $\Delta H^\ominus = 2x\,\text{kJ}\,\text{mol}^{-1}$

C $\Delta H^\ominus = -\tfrac{1}{2}x\,\text{kJ}\,\text{mol}^{-1}$

D $\Delta H^\ominus = -2x\,\text{kJ}\,\text{mol}^{-1}$ ✓

9 Which change of state is exothermic?

A $CO_2(s) \rightarrow CO_2(g)$

B $H_2O(l) \rightarrow H_2O(g)$

C $NH_3(g) \rightarrow NH_3(l)$ ✓

D $Fe(s) \rightarrow Fe(l)$
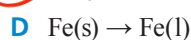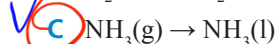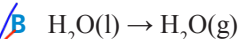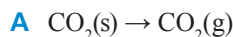
10 When $25.0\,\text{cm}^3$ $0.100\,\text{mol}\,\text{dm}^{-3}$ NaOH (aq) is mixed with $25.0\,\text{cm}^3$ $0.100\,\text{mol}\,\text{dm}^{-3}$ HCl (aq) at the same temperature, a temperature rise, ΔT, is recorded. What is the expression, in $\text{kJ}\,\text{mol}^{-1}$, for the enthalpy of neutralization? (Assume the density of the mixture = $1.00\,\text{g}\,\text{cm}^{-3}$ and its specific heat capacity = $4.18\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$.)

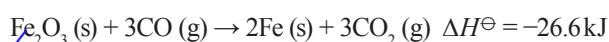A $-\dfrac{25.0 \times 4.18 \times \Delta T}{50.0 \times 0.100}$

B $-\dfrac{25.0 \times 4.18 \times \Delta T}{25.0 \times 0.100}$

C $-\dfrac{50.0 \times 4.18 \times \Delta T}{50.0 \times 0.100}$ ✗

D $-\dfrac{50.0 \times 4.18 \times \Delta T}{25.0 \times 0.100}$

V of limiting reactant, not sum Vs of all reactants.

11 Which statement is correct for this reaction?

$$Fe_2O_3\ (s) + 3CO\ (g) \rightarrow 2Fe\ (s) + 3CO_2\ (g) \quad \Delta H^\ominus = -26.6\,\text{kJ}$$
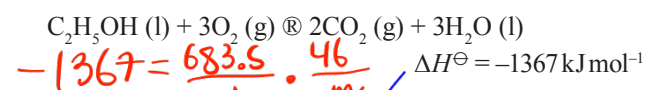
A 13.3 kJ are released for every mole of Fe produced. ✓

B 26.6 kJ are absorbed for every mole of Fe produced.

C 53.2 kJ are released for every mole of Fe produced.

D 26.6 kJ are released for every mole of Fe produced.

12 Which expression gives the mass, in g, of ethanol required to produce 683.5 kJ of heat upon complete combustion? (molar mass for ethanol = $46.0\,\text{g}\,\text{mol}^{-1}$)

$$C_2H_5OH\ (l) + 3O_2\ (g) \rightarrow 2CO_2\ (g) + 3H_2O\ (l) \qquad \Delta H^\ominus = -1367\,\text{kJ}\,\text{mol}^{-1}$$

$-1367 = \dfrac{683.5}{1} \cdot \dfrac{46}{m}$

A $\dfrac{683.5}{1367 \times 46.0}$

B $\dfrac{1367}{683.5 \times 46.0}$

C $\dfrac{683.5 \times 46.0}{1367}$ ✓

D $\dfrac{1367 \times 46.0}{683.5}$

13 Which of the following is true for all endothermic reactions?

A The reaction has a negative enthalpy change.

B The reaction occurs slowly.

C There is a transfer of energy from the surroundings to the system. ✓

D The surroundings will increase in temperature.

14 Which of the following is not implied by the $\ominus$ symbol?

A reacting 1 mole of a compound *(at 1 mol dm^{-3} IS implied.)*

B gas pressure of 1 bar or 10^5 pascal ✗

C the most stable allotrope under standard conditions

D concentration of $1.0\,\text{mol}\,\text{dm}^{-3}$ (for solutions).

15 400 J of energy is transferred to two 1 kg blocks of different metals. One block of metal is made from copper and the other aluminium. The specific heat capacities of copper and aluminium are different. Which of the following statements is true?

A The blocks will increase in temperature by the same amount.

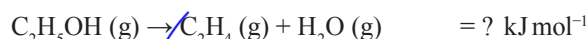B The blocks will decrease in temperature by the same amount.

C The block with the highest specific heat capacity will have the largest temperature increase.

D The block with the lowest specific heat capacity will have the largest temperature increase. ✓

16 Consider the following reaction.

$$2C_2H_4\ (g) + 2H_2O\ (g) \rightarrow 2C_2H_5OH\ (g) = y\,\text{kJ}\,\text{mol}^{-1}$$
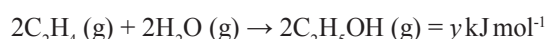
What will the enthalpy change of this reaction be?

$$C_2H_5OH\ (g) \rightarrow C_2H_4\ (g) + H_2O\ (g) \qquad = ?\ \text{kJ}\,\text{mol}^{-1}$$

A $+\tfrac{1}{2}y$ B $-\tfrac{1}{2}y$ ✓   C $-y$ D $+y$

▊ Paper 2

1 a Explain what is meant by the term *standard enthalpy of reaction*.   [3]

   b Describe an experiment to determine the enthalpy change of the reaction between dilute hydrochloric acid and aqueous sodium hydroxide. Show how the value of would be calculated from the data obtained.   [9]

2 In aqueous solution, lithium hydroxide and hydrochloric acid react as follows.

$$LiOH\ (aq) + HCl\ (aq) \rightarrow LiCl\ (aq) + H_2O\ (l)$$
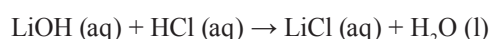
The data below is from an experiment to determine the standard enthalpy change of this reaction.

50.0 cm³ of a 0.500 mol dm⁻³ solution of LiOH was mixed rapidly in a glass beaker with 50.0 cm³ of a 0.500 mol dm⁻³ solution of HCl.

Initial temperature of each solution = 20.6 °C

Final temperature of the mixture = 24.1 °C

a State, with a reason, whether the reaction is exothermic or endothermic. [1]

b Explain why the solutions were mixed rapidly. [1]

c Calculate the enthalpy change of this reaction in kJ mol⁻¹. Assume that the specific heat capacity of the solution is the same as that of water. [4]

d Identify the major source of error in the experimental procedure described above. Explain how it could be minimized. [2]

e The experiment was repeated but with an HCl concentration of 0.520 mol dm⁻³ instead of 0.500 mol dm⁻³. State and explain what the temperature change would be. [2]

3 The data below is from an experiment used to measure the enthalpy change for the combustion of sucrose (common table sugar), $C_{12}H_{22}O_{11}$ (s). The time–temperature data was taken from a data-logging software program.

Plot of T versus t
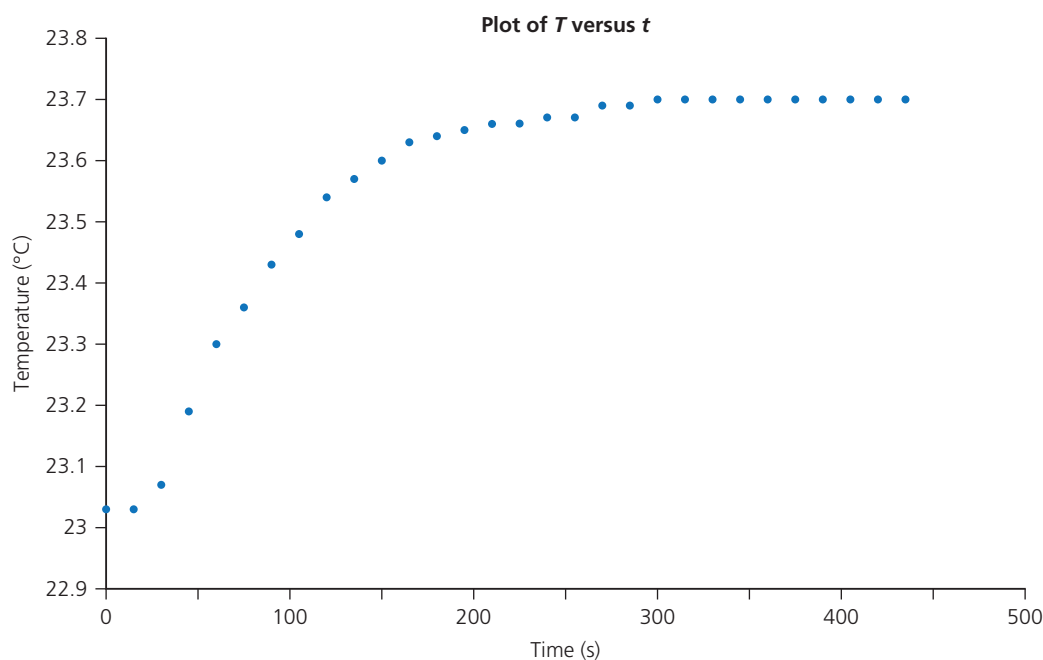
Mass of sample of sucrose, m = 0.4835 g

Heat capacity of the system, C_{system} = 10.114 kJ K⁻¹

a Calculate ΔT for the water surrounding the chamber in the calorimeter. [1]

b Determine the amount, in moles, of sucrose. [1]

c i) Calculate the enthalpy change for the combustion of 1 mole of sucrose. [2]

ii) The literature value for the combustion of sucrose is -5.6×10^3 kJ mol⁻¹. Calculate the percentage error in your calculated value. [1]

d A hypothesis is suggested that TNT, 2-methyl-1,3,5-trinitrobenzene, is a powerful explosive because it has:

− a large enthalpy of combustion

− a high reaction rate

− a large volume of gas generated upon combustion.

Use you answer in part (c)(i) and the following data to evaluate this hypothesis. [3]

Equation for combustion	Relative rate of combustion	Enthalpy of combustion / kJ mol⁻¹
$C_{12}H_{22}O_{11}$ (s) + $12O_2$ (g) → $12CO_2$ (g) + $11H_2O$ (g)	low	−5600
$2C_7H_5N_3O_6$ (s) → $7CO_2$(g) + 7C (s) + $5H_2O$ (g) + $3N_2$ (g)	high	−3406

Higher Level Paper 2, IB Specimen Paper 2009, Section A, Q1

1a. The change in enthalpy when one mole of two substances react under standard conditions.

2c. No limiting reactant. $n = 50 \cdot 10^{-3} dm^3 \cdot 0.500 \, mol \, dm^{-3} = 2.5 \cdot 10^{-2} \, mol$

$$\Delta H = \frac{-(100g \cdot 4.18 \, J \, g^{-1} K^{-1} \cdot (24.1 - 20.6) K)}{2.5 \cdot 10^{-2} \, mol}$$

$\Delta H = -58520 \, J \, mol^{-1} = -58.5 \, kJ \, mol^{-1}$