5. Chemical energetics

5.1 Enthalpy change

Paper 1

Question Paper

1 For which reaction is the enthalpy change an enthalpy change of formation?

A $C(g) + 2H_2(g) \rightarrow CH_4(g)$

B $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g)$

C $Na_2O(s) + SO_3(g) \rightarrow Na_2SO_4(s)$

D $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$

2 The standard enthalpy change of combustion of carbon is $-394\,kJ\,mol^{-1}$.

The standard enthalpy change of combustion of hydrogen is $-286\,kJ\,mol^{-1}$.

The standard enthalpy change of formation of butane is $-129\,kJ\,mol^{-1}$.

What is the standard enthalpy change of combustion of butane?

A $-551\,kJ\,mol^{-1}$

B $-2877\,kJ\,mol^{-1}$

C $-3135\,kJ\,mol^{-1}$

D $-4307\,kJ\,mol^{-1}$

3 Three processes are described.

1 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

2 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

3 $NH_3(g) \rightarrow NH_3(l)$

Which statement is correct?

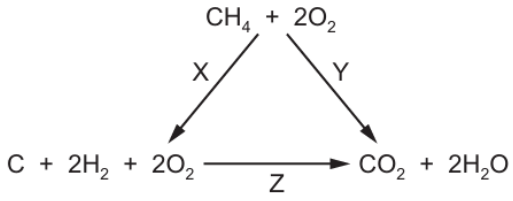
A None of the processes have a positive enthalpy change.

B Only process 1 has a positive enthalpy change.

C Only process 2 has a positive enthalpy change.

D Only process 3 has a positive enthalpy change.

4 An energy cycle is shown.



The energy changes involved are X, Y and Z.

The numerical value of energy change Y is either –890 or +890.

The numerical value of energy change Z is either –964 or +964.

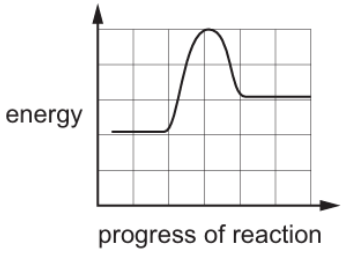
Which of the three values are negative?

A X and Z **B** X only **C** Y and Z **D** Y only

5 For a certain endothermic reaction, the activation energy is numerically equal to twice the enthalpy change of reaction.

Which reaction pathway diagram is correct for this reaction?

A



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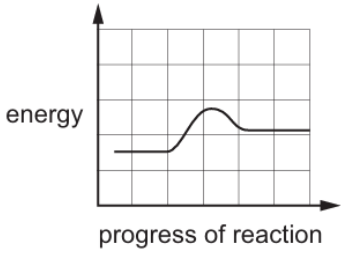

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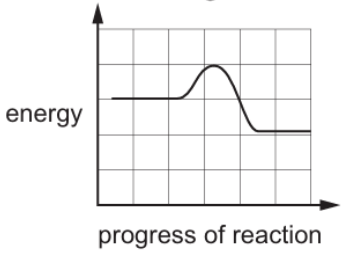

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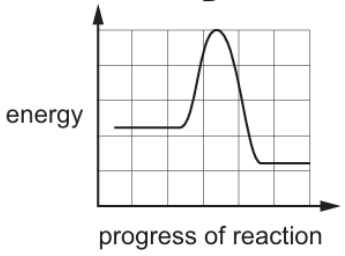


6 Ethane can react with fluorine to produce 1,2-difluoroethane, $C_2H_4F_2$.

$$C_2H_6 + 2F_2 \rightarrow C_2H_4F_2 + 2HF \qquad \Delta H = -960\,kJ\,mol^{-1}$$

bond	energy / kJ mol^{-1}
C–H	410
C–C	350
F–F	158
H–F	562

What is the bond energy of the C–F bond in 1,2-difluoroethane?

A 407 kJ mol^{-1} **B** 474 kJ mol^{-1} **C** 486 kJ mol^{-1} **D** 972 kJ mol^{-1}

7 Which equation has an enthalpy change equal to the standard enthalpy of formation of sodium oxide?

A $Na(s) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}Na_2O(s)$

B $Na(s) + O_2(g) \rightarrow Na_2O(s)$

C $2Na(s) + \frac{1}{2}O_2(g) \rightarrow Na_2O(s)$

D $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

8 Which statement about enthalpy changes is correct?

A Enthalpy changes of reaction are always negative.

B Enthalpy changes of combustion are always positive.

C Enthalpy changes of formation are always positive.

D Enthalpy changes of neutralisation are always negative.

9 What is the definition of standard enthalpy change of neutralisation, $\Delta H^{\ominus}_{neut}$?

A $\Delta H^{\ominus}_{r}$ when one mole of an aqueous acid is neutralised by an aqueous alkali

B $\Delta H^{\ominus}_{r}$ when one mole of an aqueous alkali is neutralised by an aqueous acid

C $\Delta H^{\ominus}_{r}$ when one mole of an aqueous acid is neutralised by one mole of an aqueous alkali

D $\Delta H^{\ominus}_{r}$ when an aqueous acid and an aqueous alkali react together to produce one mole of water

10 A student mixed 25.0 cm^3 of 4.00 mol dm^{-3} hydrochloric acid with an equal volume of 4.00 mol dm^{-3} sodium hydroxide. The initial temperature of both solutions was 15.0 °C. The maximum temperature recorded was 30.0 °C. The heat capacity of the final solution can be assumed to be 4.18 J K^{-1} g^{-1} and the density of this solution can be assumed to be 1.00 g cm^{-3}.

Using these results, what is the enthalpy change of neutralisation of hydrochloric acid?

A –62.7 kJ mol^{-1}

B –31.4 kJ mol^{-1}

C –15.7 kJ mol^{-1}

D –3.14 kJ mol^{-1}

11 A student mixes 25.0 cm^3 of 0.350 mol dm^{-3} sodium hydroxide solution with 25.0 cm^3 of 0.350 mol dm^{-3} hydrochloric acid. The temperature increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

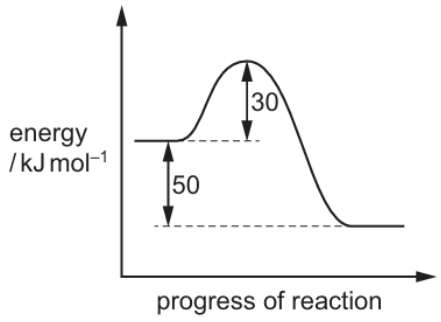
A –150 kJ mol^{-1}

B –60 kJ mol^{-1}

C –30 kJ mol^{-1}

D –0.15 kJ mol^{-1}

12 The reaction pathway for the forward reaction of a reversible reaction is shown.



Which statement is correct?

A The activation energy of the reverse reaction is +80 kJ mol^{-1}.

B The enthalpy change for the forward reaction is +30 kJ mol^{-1}.

C The enthalpy change for the forward reaction is +50 kJ mol^{-1}.

D The enthalpy change for the reverse reaction is +30 kJ mol^{-1}.

13 The equation for an enthalpy change is shown. The enthalpy change is Q.

$$2C(s) + 3H_2(g) + 3.5O_2(g) \xrightarrow{Q} 2CO_2(g) + 3H_2O(l)$$

What is the correct expression to calculate Q?

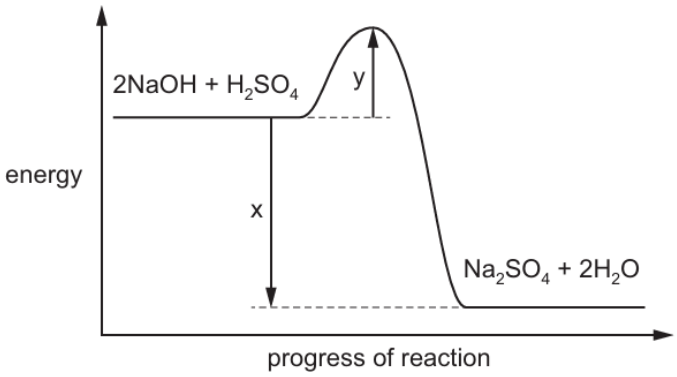
A $2 \times \Delta H_c^{\ominus}[CO_2(g)] - 3 \times \Delta H_f^{\ominus}[H_2(g)]$

B $3 \times \Delta H_f^{\ominus}[H_2O(g)] + 2 \times \Delta H_c^{\ominus}[CO_2(g)]$

C $2 \times \Delta H_f^{\ominus}[CO_2(g)] - 3 \times \Delta H_f^{\ominus}[H_2(g)]$

D $3 \times \Delta H_f^{\ominus}[H_2O(l)] + 2 \times \Delta H_f^{\ominus}[CO_2(g)]$

14 A reaction pathway diagram for the reaction of aqueous sodium hydroxide and dilute sulfuric acid is shown.



What is the value of the enthalpy change of neutralisation, ΔH_{neut}?

A x **B** x – y **C** $\frac{x}{2}$ **D** $\frac{(x-y)}{2}$

15 The standard enthalpy of formation of $NO_2(g)$ is $+33.2\,kJ\,mol^{-1}$.

The standard enthalpy of formation of $N_2O_4(g)$ is $+9.2\,kJ\,mol^{-1}$.

What is the standard enthalpy change for the reaction $2NO_2(g) \rightarrow N_2O_4(g)$?

A $-57.2\,kJ\,mol^{-1}$

B $-24.0\,kJ\,mol^{-1}$

C $+42.4\,kJ\,mol^{-1}$

D $+75.6\,kJ\,mol^{-1}$

16 Separate samples of 25.0 cm^3 of 0.1 mol dm^{-3} NaOH(aq) are added to each of three different acid solutions, as described. The temperature of each of the solutions was 298 K before mixing.

sample	acid	type of acid	concentration / mol dm^{-3}	volume / cm^3
1	H_2SO_4	strong	0.05	25.0
2	HC*l*	strong	0.05	25.0
3	CH_3CO_2H	weak	0.05	25.0

Which statement describes the temperature rises that occur on mixing each of these three acids separately with NaOH?

A The temperature rise in all three mixtures is the same.

B The temperature rise using H_2SO_4 and HC*l* is the same.

C The temperature rise using CH_3CO_2H is greater than using HC*l*.

D The greatest temperature rise occurs using H_2SO_4.

17 In order to determine the enthalpy of neutralisation of a strong acid and a strong alkali, 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid. The increase in temperature is 12 °C.

In a second experiment, the same method is used, but 50.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 50.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

What is the increase in temperature in the second experiment?

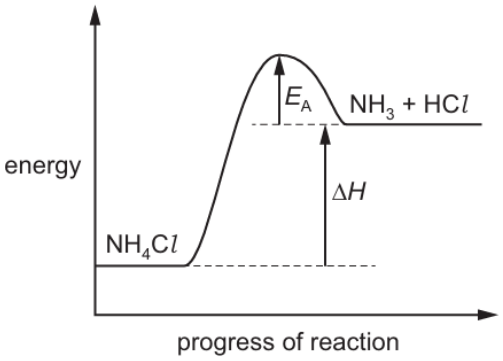
A 6 °C **B** 12 °C **C** 24 °C **D** 48 °C

18 The equation for the formation of ammonium chloride is shown.

$$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s) \qquad \Delta H = -314\,kJ\,mol^{-1}$$

Which diagram shows the correctly labelled reaction pathway diagram for the decomposition of ammonium chloride?

A



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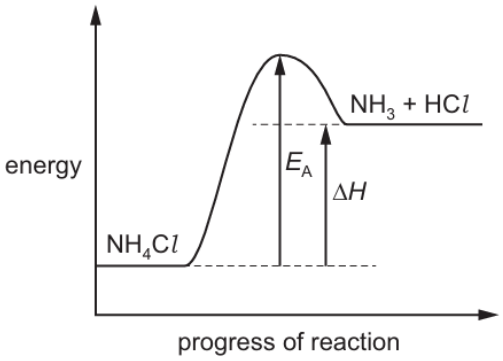

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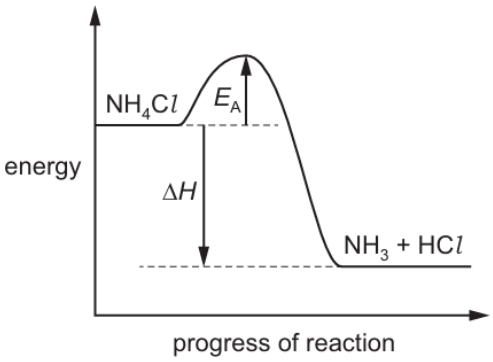

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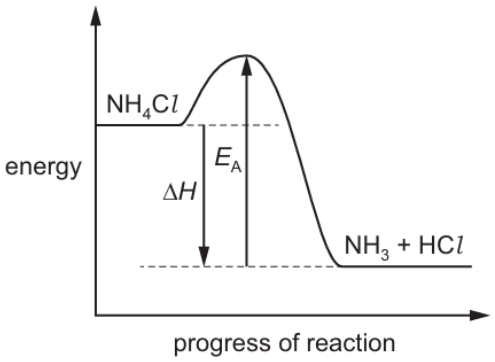
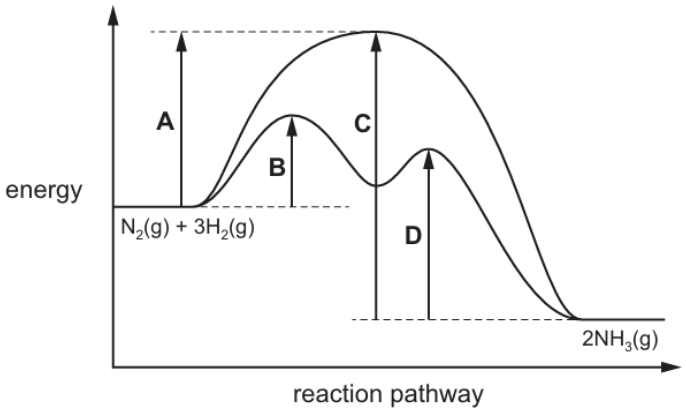


19 The reaction pathway diagram for the catalysed reaction and the uncatalysed reaction between N_2 and H_2 is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which letter represents the activation energy for the first step in the decomposition of NH_3 in the presence of a catalyst?



20 Nitrogen and oxygen can react together to form nitrogen monoxide, NO.

$$N_2 + O_2 \rightarrow 2NO \qquad \Delta H = +180\,kJ\,mol^{-1}$$

What is the bond energy of the bond between the atoms in NO?

A $630\,kJ\,mol^{-1}$ **B** $810\,kJ\,mol^{-1}$ **C** $1260\,kJ\,mol^{-1}$ **D** $1620\,kJ\,mol^{-1}$

21 Which pair of standard enthalpy changes are numerically equal?

A atomisation of $CH_4(g)$ and formation of $CH_4(g)$

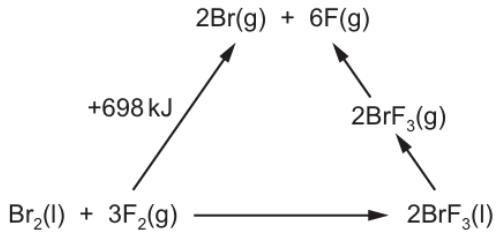
B combustion of $CH_3OH(l)$ and combustion of graphite + 2(combustion of $H_2(g)$)

C combustion of graphite and formation of $CO_2(g)$

D neutralisation of $HCl(aq)$ with NaOH(aq) and formation of $H_2O(l)$

22 An energy cycle is drawn for the following reaction.

$$Br_2(l) + 3F_2(g) \rightarrow 2BrF_3(l)$$



The standard enthalpy of formation of $BrF_3(l)$ = –301 kJ mol^{-1}.

The enthalpy change of $BrF_3(l)$ to $BrF_3(g)$ is +44 kJ mol^{-1}.

What is the average bond energy of the Br–F bond in BrF_3?

A 152 kJ mol^{-1} **B** 202 kJ mol^{-1} **C** 304 kJ mol^{-1} **D** 404 kJ mol^{-1}

23 Which pair of enthalpy changes will **always** share the same sign (i.e. both are always exothermic **or** both are always endothermic)?

A enthalpy change of atomisation and enthalpy change of neutralisation

B enthalpy change of atomisation and enthalpy change of solution

C enthalpy change of combustion and enthalpy change of hydration

D enthalpy change of solution and enthalpy change of hydration

24 Two reactions are shown.

$$H_2(g) \rightarrow 2H(g)$$

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g)$$

If molar amounts are used, how can the two energy changes associated with these reactions be described?

A enthalpy of atomisation and enthalpy of combustion

B enthalpy of atomisation and enthalpy of formation

C bond energy and enthalpy of combustion

D bond energy and enthalpy of formation

25 Solid sulfur consists of S_8 molecules.

Which equation represents the standard enthalpy of atomisation of sulfur?

A $\frac{1}{8}S_8(s) \rightarrow S(g)$

B $\frac{1}{8}S_8(g) \rightarrow S(g)$

C $S_8(s) \rightarrow 8S(g)$

D $S_8(g) \rightarrow 8S(g)$

26 Sodium burns in oxygen giving out heat energy and forming the compound Na_2O. The equation for this reaction is shown.

$$2Na(s) + \tfrac{1}{2}O_2(g) \rightarrow Na_2O(s)$$

Which statement about the reaction is correct?

A $\Delta H^{\ominus}$ for the reaction is equal to twice the bond energy of the Na–O bond.

B $\Delta H^{\ominus}$ for the reaction is positive.

C The equation represents the standard enthalpy change of combustion of sodium.

D The equation represents the standard enthalpy change of formation of sodium oxide.

27 Which reaction is endothermic?

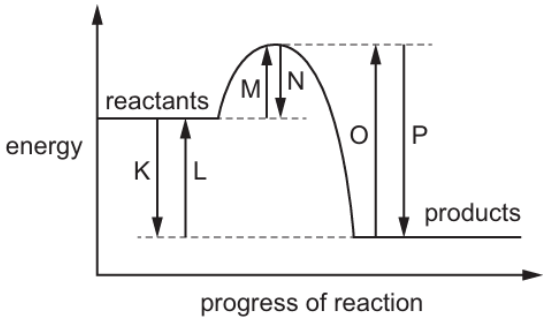
A $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$

B $2Cl(g) \rightarrow Cl_2(g)$

C $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$

D $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

28 A reaction pathway diagram is shown.



Which row is correct?

	enthalpy change of the forward reaction	activation energy of the reverse reaction
A	K	M
B	K	O
C	L	O
D	P	M

29 A butane burner is used to heat water. The M_r of butane is 58.

- $\Delta H_c^{\ominus}$ of butane is –2877 kJ mol^{-1}.
- 250 g of water is heated from 12 °C to 100 °C.
- The burner transfers 47% of the heat released from the burning fuel to the water.

Assume that the butane undergoes complete combustion and none of the water evaporates.

What is the minimum mass of butane that must be burnt?

A 0.068 g **B** 1.85 g **C** 3.94 g **D** 4.48 g

30 Which statement about enthalpy changes is correct?

A Enthalpy changes of atomisation are always negative.

B Enthalpy changes of combustion are always positive.

C Enthalpy changes of formation are always positive.

D Enthalpy changes of neutralisation are always negative.

31 Ethanol is increasingly being used as a fuel for cars.

The standard enthalpy change of formation of carbon dioxide is –393 kJ mol^{-1}.
The standard enthalpy change of formation of water is –286 kJ mol^{-1}.
The standard enthalpy change of formation of ethanol is –277 kJ mol^{-1}.

What is the standard enthalpy change of combustion of ethanol?

A –1921 kJ mol^{-1}

B –1367 kJ mol^{-1}

C –956 kJ mol^{-1}

D –402 kJ mol^{-1}

32 The enthalpy change of reaction 1 is –114 kJ mol^{-1}.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) \qquad \text{reaction 1}$$

By using this information, what is the most likely value for the enthalpy change of reaction 2?

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l) \qquad \text{reaction 2}$$

A –57 kJ mol^{-1} **B** –76 kJ mol^{-1} **C** –114 kJ mol^{-1} **D** –228 kJ mol^{-1}