10 The enthalpy changes for the possible reactions W, X, Y and Z are given.

W $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H^{\ominus} = -56\,kJ\,mol^{-1}$

X $NaCl(aq) + H_2O(l) \rightarrow NaOH(aq) + HCl(aq)$ $\Delta H^{\ominus} = +56\,kJ\,mol^{-1}$

Y $2HI(g) \rightarrow H_2(g) + I_2(g)$ $\Delta H^{\ominus} = +11\,kJ\,mol^{-1}$

Z $H_2(g) + I_2(g) \rightarrow 2HI(g)$ $\Delta H^{\ominus} = -11\,kJ\,mol^{-1}$

Which statement about the activation energies of these reactions is correct?

A X is greater than W; Z is greater than Y.

B X is greater than W; Y is greater than Z.

C W is greater than X; Z is greater than Y.

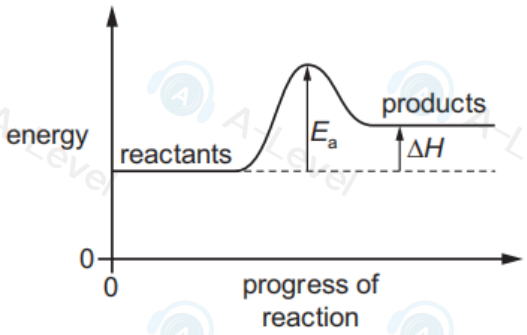
D W is greater than X; Y is greater than Z.

9 Nitrogen monoxide is an atmospheric pollutant that is formed inside car engines by an endothermic reaction between nitrogen and oxygen.

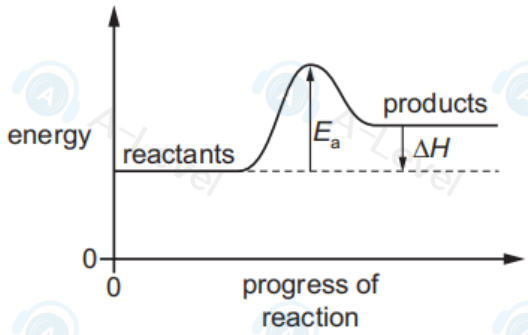
$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

Which diagram correctly represents the energy profile for this reaction?

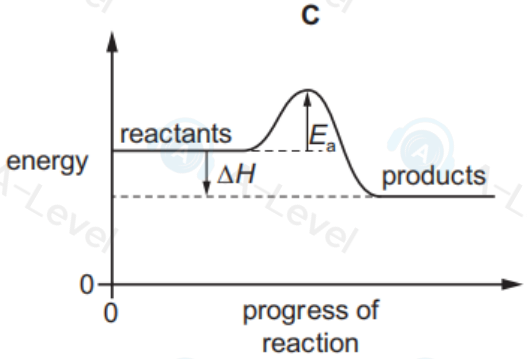
A



B



C



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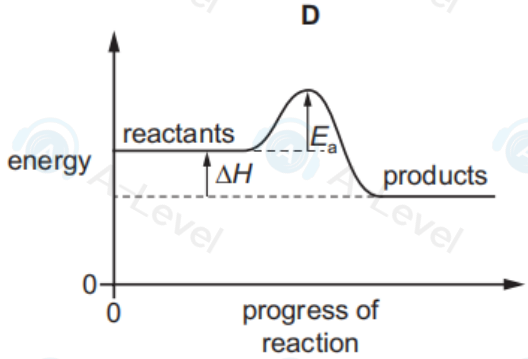


10 Two standard enthalpy change of formation values are given.

$$\Delta H_f^{\ominus}\,[VCl_2] = -452\,kJ\,mol^{-1}$$

$$\Delta H_f^{\ominus}\,[VCl_3] = -573\,kJ\,mol^{-1}$$

What is the enthalpy change for the reaction $3VCl_2 \rightarrow 2VCl_3 + V$?

A $-210\,kJ\,mol^{-1}$ **B** $-121\,kJ\,mol^{-1}$ **C** $+121\,kJ\,mol^{-1}$ **D** $+210\,kJ\,mol^{-1}$

10 Nitrogen monoxide is rapidly oxidised to nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Nitrogen dioxide can then dimerise to form dinitrogen tetroxide.

$$2NO_2(g) \rightarrow N_2O_4(g) \qquad \Delta H^{\ominus} = -58\,kJ\,mol^{-1}$$

$$\Delta H_f^{\ominus}NO = +91\,kJ\,mol^{-1} \text{ and } \Delta H_f^{\ominus}NO_2 = +34\,kJ\,mol^{-1}$$

What is the value of the standard enthalpy change for the reaction shown?

$$2NO(g) + O_2(g) \rightarrow N_2O_4(g)$$

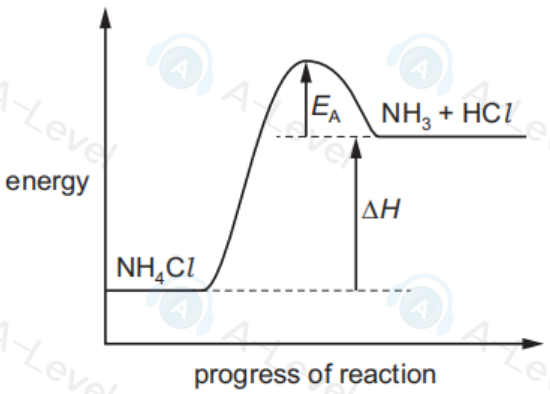
A $+56\,kJ\,mol^{-1}$ **B** $-1\,kJ\,mol^{-1}$ **C** $-115\,kJ\,mol^{-1}$ **D** $-172\,kJ\,mol^{-1}$

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

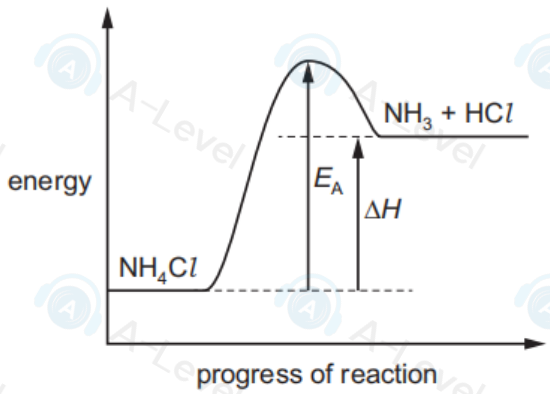
$$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s) \qquad \Delta H = -314\,kJ\,mol^{-1}$$

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

A



B



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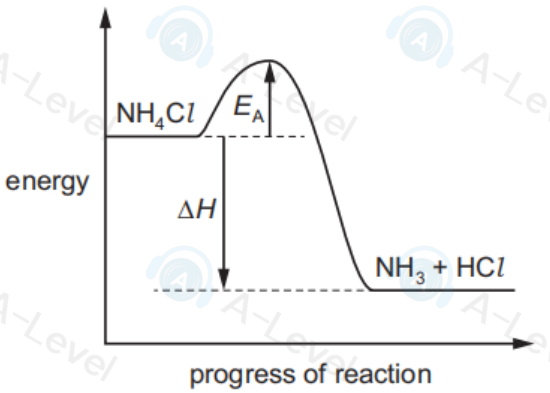

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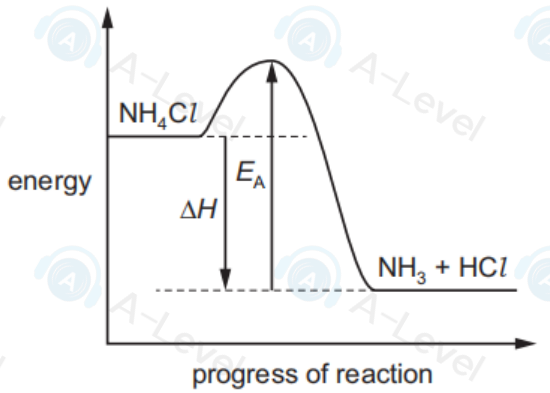
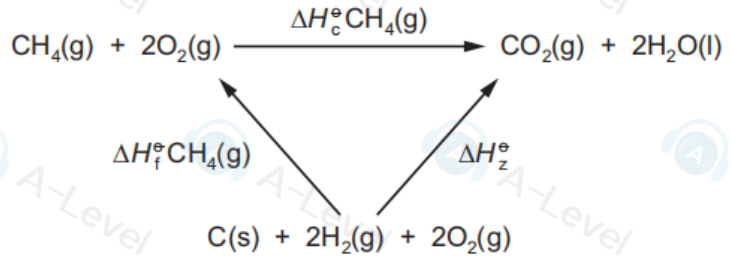


32 An energy cycle for the combustion of methane is shown.



Which expressions can be used to calculate the energy change, ΔH_z^e?

1 $\Delta H_f^e CH_4(g) + \Delta H_c^e CH_4(g)$

2 $\Delta H_c^e C(s) + 2\Delta H_c^e H_2(g)$

3 $\Delta H_c^e CO(g) + 2\Delta H_c^e H_2(g)$

11 Nitric acid is made industrially by the oxidation of ammonia. The overall equation for the process is shown.

equation 1 $\quad NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$

The process happens in three stages. The equations and enthalpy changes for these stages are given.

stage 1	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	$\Delta H = -904\,kJ\,mol^{-1}$
stage 2	$2NO + O_2 \rightarrow 2NO_2$	$\Delta H = -114\,kJ\,mol^{-1}$
stage 3	$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$	$\Delta H = -348\,kJ\,mol^{-1}$

What is the enthalpy change of the process shown in equation 1?

A $-1480\,kJ\,mol^{-1}$

B $-370\,kJ\,mol^{-1}$

C $-341.5\,kJ\,mol^{-1}$

D $+82\,kJ\,mol^{-1}$

8 The equation for reaction 1 is shown.

reaction 1 $\quad C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$

	$\Delta H_c^e / kJ\,mol^{-1}$
$C_6H_{12}O_6$	a
C_2H_5OH	b

What is the correct expression for the enthalpy change of reaction 1?

A $a + b$ **B** $a - b$ **C** $a + 2b$ **D** $a - 2b$

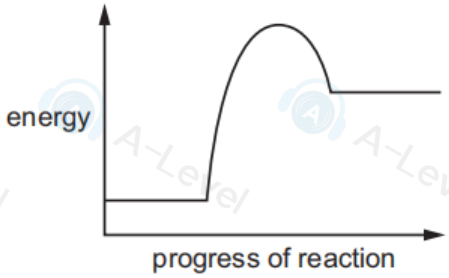
8 Nitrogen and oxygen can react together to form nitrogen monoxide, NO.

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

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** $1620\,kJ\,mol^{-1}$

32 Which reactions would have the reaction profile shown?

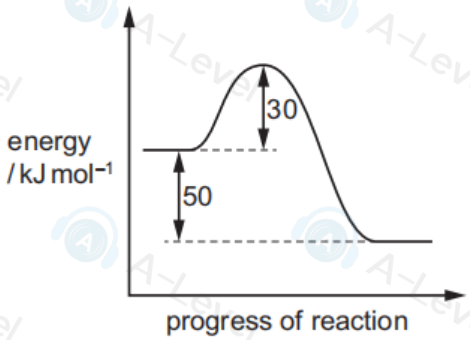


1 $NaOH + HCl \rightarrow NaCl + H_2O$

2 $CaCO_3 \rightarrow CaO + CO_2$

3 $2MgO \rightarrow 2Mg + O_2$

9 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 $+30\,kJ\,mol^{-1}$.

33 A reaction between carbon and oxygen is shown.

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

How can the standard enthalpy change of this reaction be described correctly?

1 standard enthalpy change of formation

2 standard enthalpy change of combustion

3 standard enthalpy change of atomisation

8 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

4 The following data are needed for this question.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -38.97\,kJ\,mol^{-1}$$

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -96.59\,kJ\,mol^{-1}$$

On heating, sodium hydrogencarbonate decomposes as shown.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

What is the enthalpy change for this decomposition?

A $-57.62\,kJ\,mol^{-1}$

B $-18.65\,kJ\,mol^{-1}$

C $18.65\,kJ\,mol^{-1}$

D $57.62\,kJ\,mol^{-1}$

34 When the liquid N_2F_4 is heated, it decomposes into a **single** product, X.

Which statements are correct?

1 N–F bonds are broken during this decomposition.

2 The enthalpy change when N_2F_4 decomposes into X is approximately $+160\,kJ\,mol^{-1}$.

3 Molecules of X are non-linear.

4 Solid sulfur consists of S_8 molecules.

Which equation represents the standard enthalpy of atomisation of sulfur?

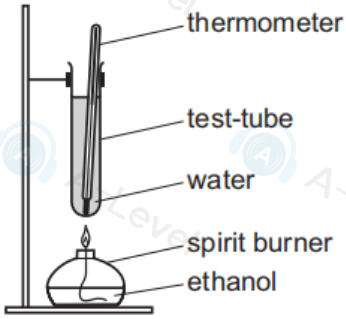
A $\frac{1}{8}S_8(s) \rightarrow S(g)$

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

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

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

7 An experiment was performed to determine the enthalpy of combustion of ethanol.



The data collected are shown.

mass of water = Wg

mass of ethanol burned = Xg

temperature rise = Y°C

molar mass of ethanol = Zg mol^{-1}

specific heat capacity of water = 4.2 J K^{-1} g^{-1}

Which expression can be used to calculate the enthalpy of combustion of ethanol in kJ mol^{-1}?

A $\frac{-4.2WYZ}{1000X}$ **B** $\frac{-4.2WYX}{1000Z}$ **C** $\frac{-4.2XYZ}{1000W}$ **D** $\frac{-4.2X(Y+273)Z}{1000W}$

9 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}

9 The enthalpy change for a reaction can be calculated from values of:

- enthalpies of formation, $\Delta H_f^\ominus$
- enthalpies of combustion, $\Delta H_c^\ominus$
- bond energies, E.

The enthalpy change of the reaction given = $\Delta H_r^\ominus$.

$$2C_2H_6(g) + 3O_2(g) \rightarrow 2CH_4(g) + 2CO_2(g) + 2H_2O(l)$$

Which expression could be used to calculate $\Delta H_r^\ominus$?

A $\Delta H_c^\ominus(C_2H_6(g))$

B $2\Delta H_c^\ominus(C_2H_6(g)) - 2\Delta H_c^\ominus(CH_4(g))$

C $E(C–C) + 2E(C–H) - 4E(C=O) - 4E(H–O)$

D $\Delta H_f^\ominus(CH_4(g)) + \Delta H_f^\ominus(CO_2(g)) + \Delta H_f^\ominus(H_2O(l)) - \Delta H_f^\ominus(C_2H_6(g))$

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

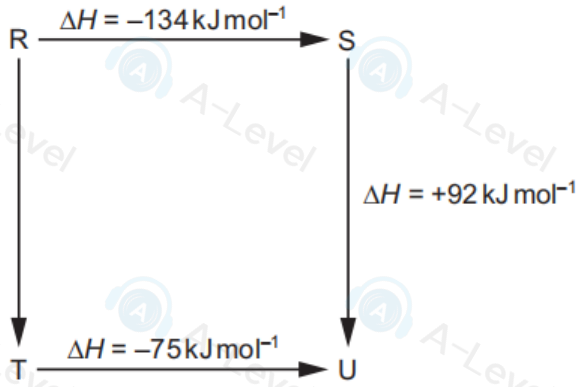
A $C(g) + 2H_2(g) \rightarrow CH_4(g)$

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

33 The diagram illustrates the enthalpy changes of a set of reactions.



Which statements are correct?

1 The enthalpy change for the transformation U → R is +42 kJ mol^{-1}.

2 The enthalpy change for the transformation T → S is endothermic.

3 The enthalpy change for the transformation R → T is –33 kJ mol^{-1}.

16 Use relevant enthalpy changes from the tables to answer this question.

reaction	ΔH / kJ mol^{-1}
$C(s) + 2H_2(g) \rightarrow CH_4(g)$	–76
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	–890
$CH_4(g) \rightarrow C(g) + 4H(g)$	1648
$3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$	–105

bond	bond enthalpy / kJ mol^{-1}
H–H	436
C–C	350
C=C	610
C=O	805

Which value can be calculated for the enthalpy change for the following reaction?

$$2C(g) + 6H(g) \rightarrow C_2H_6(g)$$

A –2822 kJ mol^{-1}

B –2122 kJ mol^{-1}

C –1998 kJ mol^{-1}

D –1772 kJ mol^{-1}

10 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 $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

9 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}

9 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}

10 Which reaction has an enthalpy change equal to the standard enthalpy change of formation of propane?

A $3C(g) + 4H_2(g) \rightarrow C_3H_8(g)$

B $3C(g) + 8H(g) \rightarrow C_3H_8(g)$

C $3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$

D $3C(s) + 4H_2(g) \rightarrow C_3H_8(l)$