AS CHEMISTRY 9701

Chemical Energetics

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3 Bond energies

3(a) Bond energies in diatomic molecules (these are exact values)

Homonuclear

Bond	Energy/kJ mol^{-1}
H–H	436
D–D	442
N≡N	944
O=O	496
P≡P	485
S=S	425
F–F	158
Cl–Cl	242
Br–Br	193
I–I	151

Heteronuclear

Bond	Energy/kJ mol^{-1}
H–F	562
H–Cl	431
H–Br	366
H–I	299
C≡O	1077

3(b) Bond energies in polyatomic molecules (these are average values)

Homonuclear

Bond	Energy/kJ mol^{-1}
C–C	350
C=C	610
C≡C	840
C⁚⁚⁚C (benzene)	520
N–N	160
N=N	410
O–O	150
Si–Si	222
P–P	200
S–S	264

Heteronuclear

Bond	Energy/kJ mol^{-1}
C–H	410
C–C*l*	340
C–Br	280
C–I	240
C–N	305
C=N	610
C≡N	890
C–O	360
C=O	740
C=O in CO_2	805
N–H	390
N–C*l*	310
O–H	460
Si–C*l*	359
Si–H	320
Si–O (in SiO_2(s))	460
Si=O (in SiO_2(g))	640
P–H	320
P–C*l*	330
P–O	340
P=O	540
S–H	347
S–C*l*	250
S–O	360
S=O	500

CHEMICAL ENERGETICS

Mcq 1.

3 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 $-402\,kJ\,mol^{-1}$

w/14/qp11

Mcq 2.

7 In an experiment to calculate the enthalpy change of combustion of a fuel, 1.5 g (0.0326 mol) of the fuel was used to heat 200 g of water. The temperature of the water rose from 25 °C to 55 °C. The specific heat capacity of water is $4.18\,J\,g^{-1}\,K^{-1}$.

There is significant heat loss in this experiment. Therefore, the experimental value for the enthalpy change of combustion, ΔH_c, of the fuel will be different from the theoretical value.

Using the information above, what is the experimental value for the enthalpy change of combustion, ΔH_c, of the fuel?

A $-1410\,kJ\,mol^{-1}$

B $-769\,kJ\,mol^{-1}$

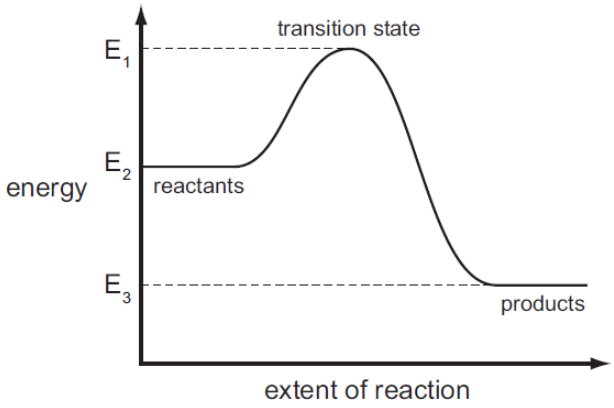
C $-30.7\,kJ\,mol^{-1}$

D $-16.7\,kJ\,mol^{-1}$

w/14/qp11

Mcq 3.

8 The reaction pathway diagram below illustrates the energies of the reactants, the products and the transition state of a reaction.



Which expression represents the activation energy of the forward reaction?

A $E_1 - E_2$ **B** $E_2 - E_1$ **C** $E_2 - E_3$ **D** $E_3 - E_2$

w/14/qp11

Mcq 4.

32 *Use of the Data Booklet is relevant to this question.*

The bond energy of the Br–O bond is 235 kJ mol^{-1}.

Which reactions are exothermic?

1 $OH\bullet + HBr \rightarrow H_2 + BrO\bullet$

2 $OH\bullet + HBr \rightarrow H_2O + Br\bullet$

3 $H\bullet + HBr \rightarrow H_2 + Br\bullet$

w/14/qp11

Mcq 5.

5 Hydrogen sulfide, H_2S, is released from volcanoes. It reacts with oxygen in the air to form sulfur dioxide.

$$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$$

$\Delta H_f^{\ominus}[H_2S(g)] = -21\,kJ\,mol^{-1}$

$\Delta H_f^{\ominus}[H_2O(l)] = -286\,kJ\,mol^{-1}$

$\Delta H_f^{\ominus}[SO_2(g)] = -297\,kJ\,mol^{-1}$

What is the standard enthalpy change of this reaction?

A $-1208\,kJ\,mol^{-1}$

B $-1124\,kJ\,mol^{-1}$

C $-562\,kJ\,mol^{-1}$

D $-541\,kJ\,mol^{-1}$

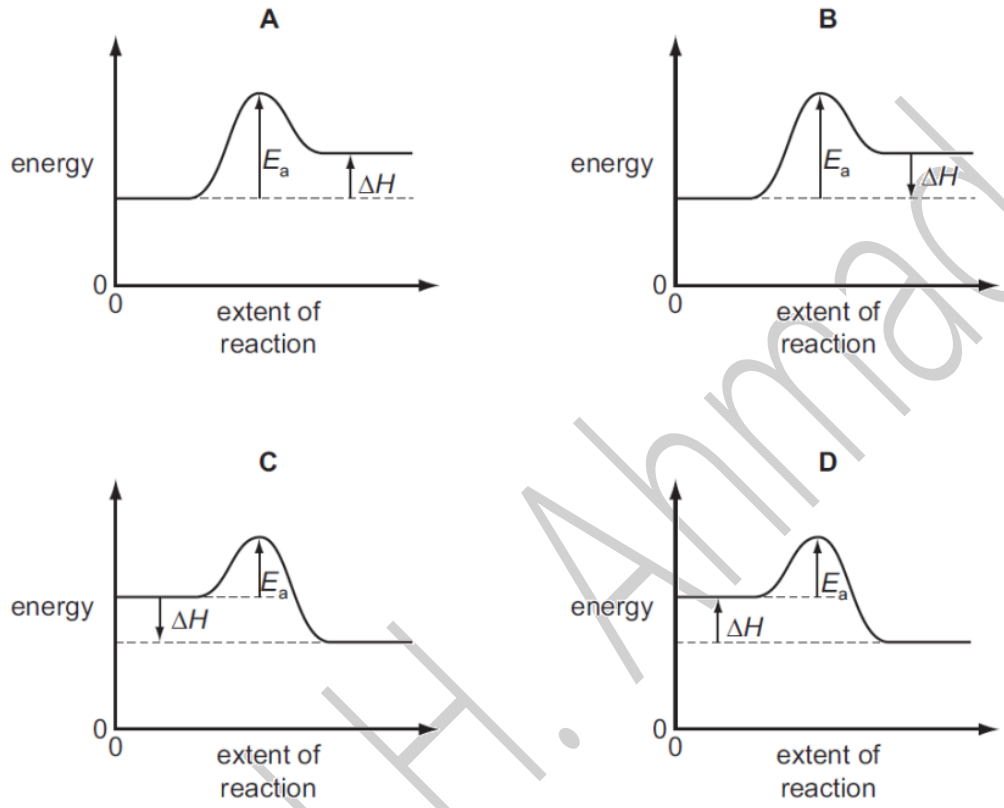
w/14/qp13

Mcq 6.

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

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H = +66\,kJ\,mol^{-1}$$

Which labelled diagram correctly represents the energy profile for this reaction?



w/14/qp13

Mcq 7.

11 *Use of the Data Booklet is relevant to this question.*

When 0.47 g of a hydrocarbon was completely burnt in air, the energy released heated 200 g of water from 23.7 °C to 41.0 °C.

What was the amount of energy absorbed by the water?

A $0.47 \times 4.18 \times 17.3\,J$

B $0.47 \times 4.18 \times (273 + 17.3)\,J$

C $200 \times 4.18 \times 17.3\,J$

D $200 \times 4.18 \times (273 + 17.3)\,J$

w/14/qp13

Mcq 8.

6 Which stage in the free radical substitution of ethane by chlorine will have the lowest activation energy?

A $Cl_2 \rightarrow 2Cl\bullet$

B $Cl\bullet + C_2H_6 \rightarrow C_2H_5\bullet + HCl$

C $C_2H_5\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl\bullet$

D $Cl\bullet + C_2H_5\bullet \rightarrow C_2H_5Cl$

w/13/qp13

Mcq 9.

7 Which stage in the free radical substitution of methane by chlorine will have the lowest activation energy?

A $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

B $Cl\bullet + Cl\bullet \rightarrow Cl_2$

C $Cl\bullet + CH_4 \rightarrow CH_3\bullet + HCl$

D $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

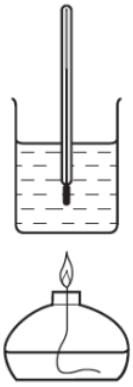
w/13/qp11

Mcq 10.

11 *Use of the Data Booklet is relevant to this question.*

A student carried out an experiment to determine the enthalpy change for the combustion of methanol.

The following results were obtained by the student.



start temperature of the water	20 °C
final temperature of the water	53 °C
mass of alcohol burner before burning	259.65 g
mass of alcohol burner after burning	259.15 g
mass of glass beaker plus water	150.00 g
mass of glass beaker	50.00 g

How much of the heat energy produced by the burning of methanol went into the water?

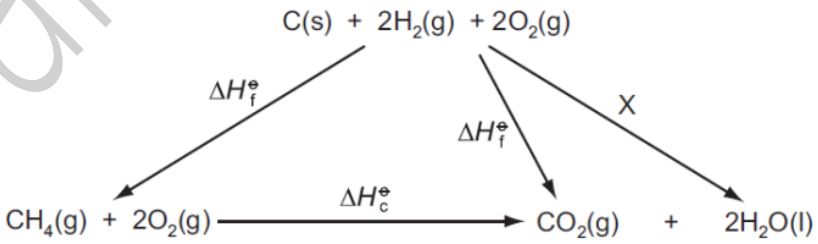
A 209 J **B** 13 794 J **C** 20 691 J **D** 22 154 J

w/13/qp11

Mcq 11.

3 Enthalpy changes that are difficult to measure directly can often be determined using Hess' Law to construct an enthalpy cycle.

Which enthalpy change is indicated by X in the enthalpy cycle shown?



A −4 × the enthalpy of combustion of hydrogen

B +4 × the enthalpy of combustion of hydrogen

C −2 × the enthalpy of formation of water

D +2 × the enthalpy of formation of water

s/14/qp11

Mcq 12.

5 A student mixed 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 rose by 2.50 °C. Assume that no heat was lost to the surroundings.

The final mixture had a specific heat capacity of 4.20 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

A –150 kJ mol^{-1}

B –60.0 kJ mol^{-1}

C –30.0 kJ mol^{-1}

D –0.150 kJ mol^{-1}

s/14/qp11

Mcq 13.

3 The enthalpy change of formation of carbon dioxide is –394 kJ mol^{-1}.
The enthalpy change of formation of water is –286 kJ mol^{-1}.
The enthalpy change of formation of methane is –74 kJ mol^{-1}.

What is the enthalpy change of combustion of methane?

A –892 kJ mol^{-1}

B –606 kJ mol^{-1}

C +606 kJ mol^{-1}

D +892 kJ mol^{-1}

s/14/qp12

Mcq 14.

11 The diagram shows the skeletal formula of cyclopropane.

The enthalpy change of formation of cyclopropane is +53.3 kJ mol^{-1} and the enthalpy change of atomisation of graphite is +717 kJ mol^{-1}.

The bond enthalpy of H–H is 436 kJ mol^{-1} and of C–H is 410 kJ mol^{-1}.

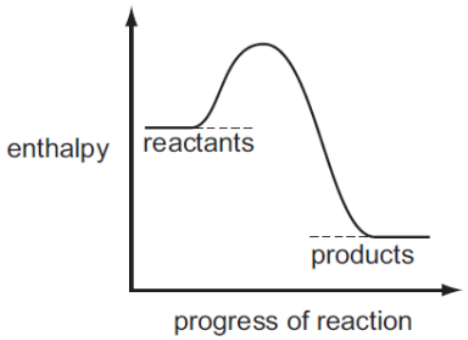
What value for the average bond enthalpy of the C–C bond in cyclopropane can be calculated from this data?

A 187 kJ mol^{-1} **B** 315 kJ mol^{-1} **C** 351 kJ mol^{-1} **D** 946 kJ mol^{-1}

s/14/qp12

Mcq 15.

3 A reaction pathway diagram is shown.



Which enthalpy change could the diagram **not** apply to?

A enthalpy of atomisation

B enthalpy of combustion

C enthalpy of formation

D enthalpy of neutralisation

s/14/qp13

Mcq 16.

6 Hydrazine, N_2H_4, is used as a rocket fuel because it reacts with oxygen as shown, producing 'environmentally friendly' gases.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta H = -534\,kJ\,mol^{-1}$$

Despite its use as a rocket fuel, hydrazine does not burn spontaneously in oxygen.

Which statement explains why hydrazine does **not** burn spontaneously?

A Hydrazine is a liquid.

B The activation energy is too high.

C The N≡N bond is very strong.

D The reaction is exothermic.

s/14/qp13

Mcq 17.

9 The enthalpy change of formation of $Mn(NO_3)_2(s)$ is $-696\,kJ\,mol^{-1}$.
The enthalpy change of formation of $MnO_2(s)$ is $-520\,kJ\,mol^{-1}$.
The enthalpy change of formation of $NO_2(g)$ is $+33\,kJ\,mol^{-1}$.

On heating, $Mn(NO_3)_2$ decomposes into MnO_2 and NO_2.

$$Mn(NO_3)_2(s) \rightarrow MnO_2(s) + 2NO_2(g)$$

What is the value of the standard enthalpy change of this reaction?

A $-242\,kJ\,mol^{-1}$

B $-209\,kJ\,mol^{-1}$

C $+209\,kJ\,mol^{-1}$

D $+242\,kJ\,mol^{-1}$

s/14/qp13

Mcq 18.

12 *Use of the Data Booklet is relevant to this question.*

This question should be answered using bond enthalpy data. The equation for the complete combustion of methane is given below.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

What is the enthalpy change of combustion of methane?

A $-1530\,kJ\,mol^{-1}$

B $-1184\,kJ\,mol^{-1}$

C $-770\,kJ\,mol^{-1}$

D $-688\,kJ\,mol^{-1}$

s/13/qp11

Mcq 19.

10 *Use of the Data Booklet is relevant to this question.*

A student mixed $25\,cm^3$ of $0.10\,mol\,dm^{-3}$ sodium hydroxide solution with $25\,cm^3$ of $0.10\,mol\,dm^{-3}$ hydrochloric acid and noted a temperature rise of 2.5 °C.

What is the enthalpy change of the reaction per mole of NaOH?

A $-209\,kJ\,mol^{-1}$

B $-104.5\,kJ\,mol^{-1}$

C $-209\,J\,mol^{-1}$

D $-522.5\,J\,mol^{-1}$

s/13/qp12

Mcq 20.

11 Which energy change corresponds to the enthalpy change of atomisation of hydrogen at 298 K?

A the bond energy of a H–H bond

B half the bond energy of a H–H bond

C minus half the bond energy of a H–H bond

D minus the bond energy of a H–H bond

s/13/qp12

Mcq 21.

12 Propanone has molecular formula C_3H_6O.

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

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

The enthalpy change of formation of propanone is $-254\,kJ\,mol^{-1}$.

Using this information, what is the enthalpy change of combustion of propanone?

A $-2644\,kJ\,mol^{-1}$

B $-2294\,kJ\,mol^{-1}$

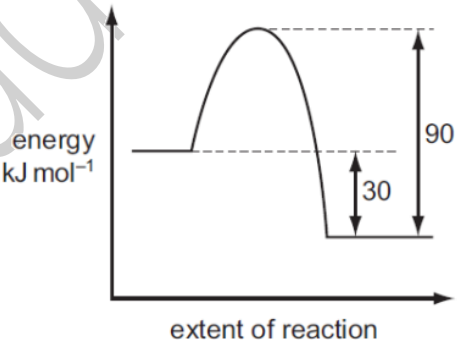
C $-1786\,kJ\,mol^{-1}$

D $-426\,kJ\,mol^{-1}$

s/13/qp12

Mcq 22.

32 The diagram shows the reaction pathway for a reversible reaction.



Which statements are correct?

1 The enthalpy change for the backward reaction is $+90\,kJ\,mol^{-1}$.

2 The forward reaction is exothermic.

3 The enthalpy change for the forward reaction is $-30\,kJ\,mol^{-1}$.

s/13/qp12

Mcq 23.

11 *Use of the Data Booklet is relevant to this question.*

This question should be answered using bond enthalpy data. The equation for the complete combustion of methanal is given below.

$$H_2C{=}O + O_2 \rightarrow CO_2 + H_2O$$

What is the enthalpy change of combustion of methanal?

A $+416\,kJ\,mol^{-1}$

B $+396\,kJ\,mol^{-1}$

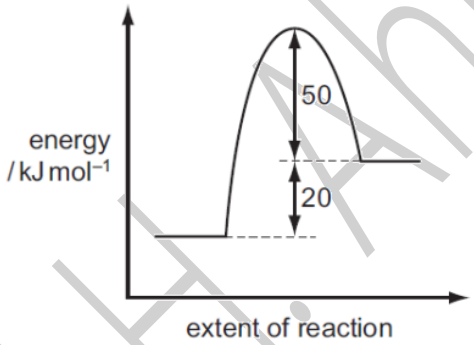
C $-344\,kJ\,mol^{-1}$

D $-690\,kJ\,mol^{-1}$

s/13/qp13

Mcq 24.

33 The reaction pathway for a reversible reaction is shown below.



Which statements are correct?

1 The enthalpy change for the backward reaction is $-20\,kJ\,mol^{-1}$.

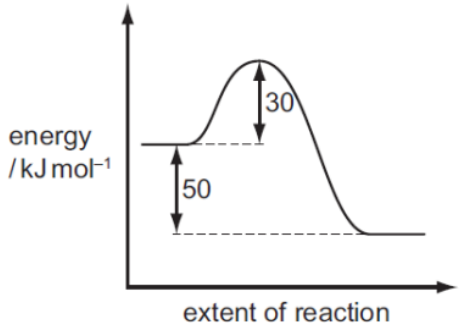
2 The forward reaction is endothermic.

3 The activation energy for the forward reaction is $+70\,kJ\,mol^{-1}$.

s/13/qp13

Mcq 25.

7 The reaction pathway for a reversible reaction is shown below.



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}.

s/13/qp11

Mcq 26.

10 The enthalpy change of the neutralisation given below is –114 kJ mol^{-1}.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

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

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$$

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

w/12/qp13

Mcq 27.

5 Ethyne, C_2H_2, completely combusts, as shown in the equation.

$$H-C\equiv C-H \; + \; 2\tfrac{1}{2}O=O \; \rightarrow \; H_2O \; + \; 2CO_2$$

Using the average bond enthalpies in the table, what is the enthalpy change of combustion of ethyne?

bond	average bond enthalpy / kJ mol^{-1}
C—H	410
C≡C	840
O=O	496
C=O	740
O—H	460
C—O	360

A –980 kJ mol^{-1} **B** –540 kJ mol^{-1} **C** +540 kJ mol^{-1} **D** +980 kJ mol^{-1}

w/12/qp13

Mcq 28.

10 A student calculated the standard enthalpy change of formation of ethane, C_2H_6, using a method based on standard enthalpy changes of combustion.

He used correct values for the standard enthalpy change of combustion of ethane (–1560 kJ mol^{-1}) and hydrogen (–286 kJ mol^{-1}) but he used an incorrect value for the standard enthalpy change of combustion of carbon. He then performed his calculation correctly. His final answer was –158 kJ mol^{-1}.

What did he use for the standard enthalpy change of combustion of carbon?

A –1432 kJ mol^{-1}

B –860 kJ mol^{-1}

C –430 kJ mol^{-1}

D –272 kJ mol^{-1}

w/12/qp11

Mcq 29.

11 Which process could be used to calculate the bond energy for the covalent bond X-Y by dividing its ΔH by n?

A $XY_n(g) \rightarrow X(g) + nY(g)$

B $2XY_n(g) \rightarrow 2XY_{n-1}(g) + Y_2(g)$

C $Y(g) + XY_{n-1}(g) \rightarrow XY_n(g)$

D $nXY(g) \rightarrow nX(g) + \frac{n}{2}Y_2(g)$

w/12/qp11

Mcq 30.

4 *Use of the Data Booklet is relevant to this question.*

A reaction which causes the presence of oxides of nitrogen in car exhausts is the formation of NO.

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

What is the bond energy in $kJ\,mol^{-1}$ of the bond between the atoms in NO?

A 655 **B** 835 **C** 1310 **D** 1670

w/12/qp11

Mcq 31.

5 In the table below,

- '+' means that this type of standard enthalpy change can **only** have positive values,
- '–' means that this type of standard enthalpy change can **only** have negative values,
- '+/–' means that **either** positive **or** negative values are possible.

Which row is correct?

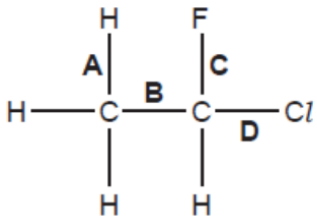
	atomisation	formation	solution
A	+	+	+/–
B	+	+/–	+/–
C	–	+/–	–
D	–	–	+

w/12/qp11

Mcq 32.

22 *Use of the Data Booklet is relevant to this question.*

Which bond in the structure below has the lowest bond energy?



w/11/qp12

Mcq 33.

17 The standard enthalpy changes of formation of HC*l* and HI are –92 kJ mol^{-1} and +26 kJ mol^{-1} respectively.

Which statement is **most** important in explaining this difference?

A Chlorine is more electronegative than iodine.

B The activation energy for the $H_2 + Cl_2$ reaction is much less than that for the $H_2 + I_2$ reaction.

C The bond energy of HI is smaller than the bond energy of HC*l*.

D The bond energy of I_2 is smaller than the bond energy of Cl_2.

w/11/qp12

Mcq 34.

10 Hess's Law can be used to calculate the average C-H bond energy in methane.

$\Delta H^{\ominus}_{at}$ = standard enthalpy change of atomisation

$\Delta H^{\ominus}_{f}$ = standard enthalpy change of formation

$\Delta H^{\ominus}_{c}$ = standard enthalpy change of combustion

Which data values are needed in order to perform the calculation?

A $\Delta H^{\ominus}_{at}$ (C), $\Delta H^{\ominus}_{at}$ (H), $\Delta H^{\ominus}_{f}$ (CH_4)

B $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ (H_2), $\Delta H^{\ominus}_{c}$ (CH_4)

C $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ (H_2), $\Delta H^{\ominus}_{f}$ (CH_4)

D $\Delta H^{\ominus}_{f}$ (CH_4) only, as $\Delta H^{\ominus}_{f}$ (C), and $\Delta H^{\ominus}_{f}$ (H_2), are defined as zero

w/11/qp12

Mcq 35.

19 Which reaction is endothermic?

A $2HBr \rightarrow H_2 + Br_2$

B $N_2 + 3H_2 \rightarrow 2NH_3$

C $2SO_2 + O_2 \rightarrow 2SO_3$

D $SO_3 + H_2O \rightarrow H_2SO_4$

w/11/qp11

Mcq 36.

6 The standard enthalpy change for the reaction

$$2NF_3(g) \rightarrow 2N(g) + 6F(g) \qquad \text{is } \Delta H^{\ominus} = +1668\,kJ$$

What is the bond energy of the N–F bond?

A $-556\,kJ\,mol^{-1}$

B $-278\,kJ\,mol^{-1}$

C $+278\,kJ\,mol^{-1}$

D $+556\,kJ\,mol^{-1}$

w/11/qp11

Mcq 37.

8 *Use of the Data Booklet is relevant to this question.*

The enthalpy change of formation, ΔH_f, of hydrated calcium ions is the enthalpy change of the following reaction.

$$Ca(s) + aq - 2e^- \rightarrow Ca^{2+}(aq)$$

The following enthalpy changes are **not** quoted in the *Data Booklet*.

$$Ca(s) \rightarrow Ca(g) \qquad \Delta H_a = 177\,kJ\,mol^{-1}$$

$$Ca^{2+}(g) + aq \rightarrow Ca^{2+}(aq) \qquad \Delta H_{hyd} = -1565\,kJ\,mol^{-1}$$

What is the enthalpy change of formation of hydrated calcium ions?

A $-1388\,kJ\,mol^{-1}$

B $-798\,kJ\,mol^{-1}$

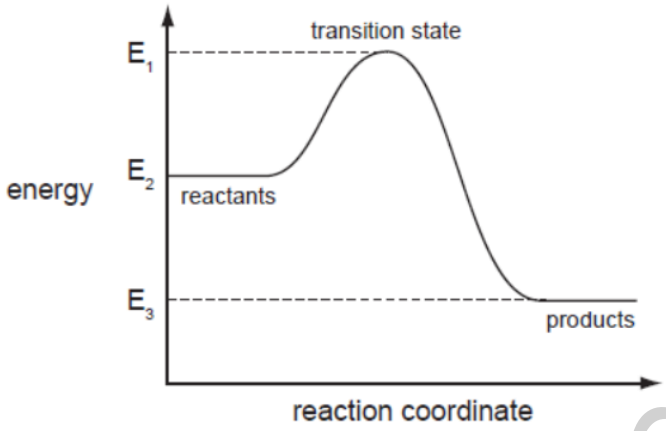
C $-238\,kJ\,mol^{-1}$

D $+352\,kJ\,mol^{-1}$

w/10/qp12

Mcq 38.

6 The reaction pathway diagram below illustrates the energies of reactants, products and the transition state of a reaction.



Which expression represents the activation energy of the forward reaction?

A $E_1 - E_2$ **B** $E_1 - E_3$ **C** $E_2 - E_3$ **D** $(E_1 - E_2) - (E_2 - E_3)$

w/10/qp12

Mcq 39.

4 Methanol may be prepared by the reaction between carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

The relevant average bond energies are given below.

E(C≡O)	1077 kJ mol^{-1}
E(C–O)	360 kJ mol^{-1}
E(C–H)	410 kJ mol^{-1}
E(H–H)	436 kJ mol^{-1}
E(O–H)	460 kJ mol^{-1}

What is the enthalpy change of this reaction?

A –537 kJ mol^{-1}

B –101 kJ mol^{-1}

C +101 kJ mol^{-1}

D +537 kJ mol^{-1}

w/10/qp12

Mcq 40.

11 Which equation represents the change corresponding to the enthalpy change of atomisation of iodine?

A $\frac{1}{2}I_2(g) \rightarrow I(g)$

B $I_2(g) \rightarrow 2I(g)$

C $\frac{1}{2}I_2(s) \rightarrow I(g)$

D $I_2(s) \rightarrow 2I(g)$

w/10/qp11

Mcq 41.

8 Enthalpy changes of combustion can be used to determine enthalpy changes of formation. The following equation represents the enthalpy change of formation of butane.

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

By using the following standard enthalpy of combustion data, what is the value of the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, for this reaction?

compound	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
carbon	–394
hydrogen	–286
butane	–2877

A –5883 kJ mol^{-1}

B –129 kJ mol^{-1}

C +129 kJ mol^{-1}

D +2197 kJ mol^{-1}

w/10/qp11

Mcq 42.

9 In a calorimetric experiment 1.60 g of a fuel is burnt. 45 % of the energy released is absorbed by 200 g of water whose temperature rises from 18 °C to 66 °C. The specific heat capacity of water is 4.2 J g^{-1} K^{-1}.

What is the total energy released per gram of fuel burnt?

A 25 200 J B 56 000 J C 89 600 J D 143 360 J

w/10/qp11

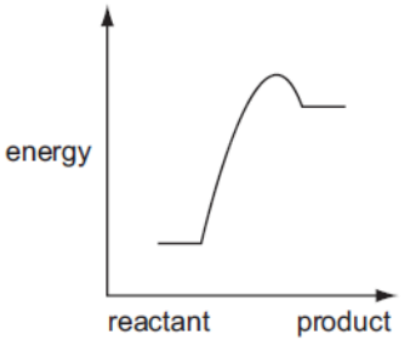
Mcq 43.

10 Four reactions of the type shown are studied at the same temperature.

$$X(g) + Y(g) \rightarrow Z(g)$$

Which is the correct reaction pathway diagram for the reaction that would proceed **most** rapidly and with the **highest** yield?

A



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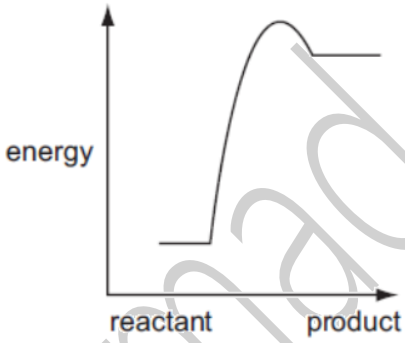

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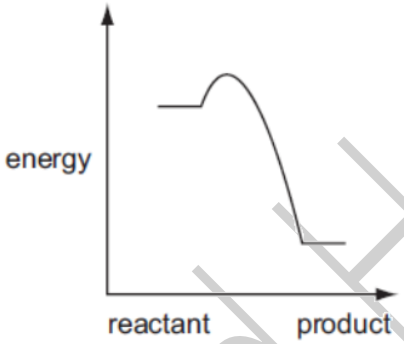

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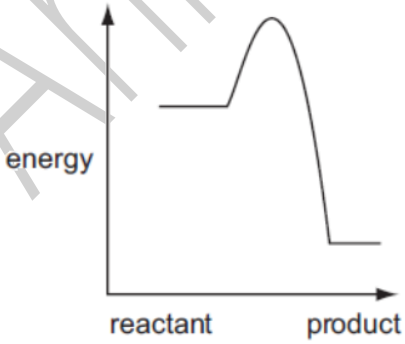


w/09/qp11

Mcq 44.

6 The first stage in the industrial production of nitric acid from ammonia can be represented by the following equation.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

Using the following standard enthalpy change of formation data, what is the value of the standard enthalpy change, $\Delta H^{\ominus}$, for this reaction?

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$NH_3(g)$	–46.1
$NO(g)$	+90.3
$H_2O(g)$	–241.8

A +905.2 kJ mol^{-1}

B –105.4 kJ mol^{-1}

C –905.2 kJ mol^{-1}

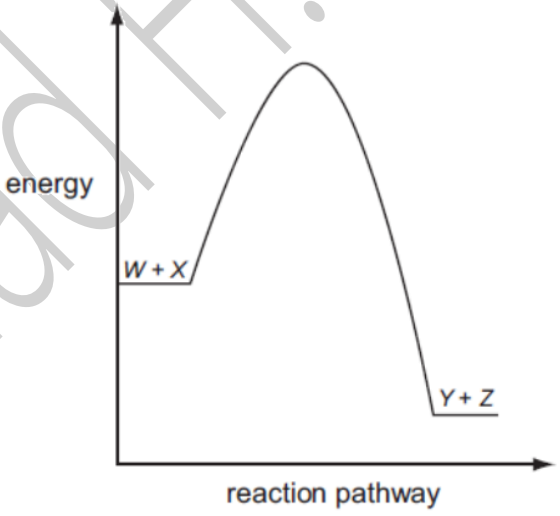
D –1274.0 kJ mol^{-1}

w/09/qp11

Mcq 45.

9 The diagram represents the reaction pathway for the following reaction.

$$W(g) + X(g) \rightarrow Y(g) + Z(g)$$



What statement can be made about the reverse reaction, $Y(g) + Z(g) \rightarrow W(g) + X(g)$?

A It will have a larger activation energy and a positive ΔH.

B It will have a larger activation energy and a negative ΔH.

C It will have a smaller activation energy and a positive ΔH.

D It will have a smaller activation energy and a negative ΔH.

w/08/qp1

Mcq 46.

8 Red lead oxide, Pb_3O_4, is used in metal priming paints. It can be made by heating PbO in air.

$$6PbO(s) + O_2(g) \rightarrow 2Pb_3O_4(s)$$

Which two values are needed to calculate the enthalpy change for this reaction?

A enthalpy change of combustion of lead and enthalpy change of formation of Pb_3O_4

B enthalpy change of combustion of PbO and enthalpy change of formation of Pb_3O_4

C enthalpy change of formation of PbO and enthalpy change of atomisation of O_2

D enthalpy change of formation of PbO and enthalpy change of formation of Pb_3O_4

w/08/qp1

Mcq 47.

32 Carbon monoxide burns readily in oxygen to form carbon dioxide.

What can be deduced from this information?

1 The +4 oxidation state of carbon is more stable than the +2 state.

2 The standard enthalpy change of formation of carbon dioxide is more negative than that of carbon monoxide.

3 The value of the equilibrium constant for the reaction, $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$, is likely to be high.

w/07/qp1

Mcq 48.

8 For which equation is the enthalpy change correctly described as an enthalpy change of formation?

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

B $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

C $H_2O(l) + NaCl(s) \rightarrow NaCl(aq)$

D $K(s) + Mn(s) + 2O_2(g) \rightarrow KMnO_4(s)$

w/06/qp1

Mcq 49.

9 Given

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -283\ kJ\,mol^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -286\ kJ\,mol^{-1}$$

$$H_2O(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -44\ kJ\,mol^{-1}$$

what is the change in enthalpy, $\Delta H^{\ominus}$, for the following reaction?

$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$$

A $-525\ kJ\,mol^{-1}$ **B** $-41\ kJ\,mol^{-1}$ **C** $+41\ kJ\,mol^{-1}$ **D** $+525\ kJ\,mol^{-1}$

w/06/qp1

Mcq 50.

6 Given $S(s) + O_2(g) \rightarrow SO_2(g)$, $\Delta H_f^{\ominus} = -297\,kJ\,mol^{-1}$
and $S(s) + 1\frac{1}{2}O_2(g) \rightarrow SO_3(g)$ $\Delta H_f^{\ominus} = -395\,kJ\,mol^{-1}$

what is the enthalpy change of reaction, $\Delta H^{\ominus}$, of $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$?

A $-196\,kJ\,mol^{-1}$ **B** $-98\,kJ\,mol^{-1}$ **C** $+98\,kJ\,mol^{-1}$ **D** $+196\,kJ\,mol^{-1}$

w/05/qp1

Mcq 51.

7 The table shows the enthalpy change of neutralisation per mole of water formed, ΔH, for various acids and bases.

acid	base	ΔH / kJ mol^{-1}
hydrochloric acid	sodium hydroxide	–57.0
P	sodium hydroxide	–54.0
hydrochloric acid	**Q**	–52.0
nitric acid	**R**	–57.0

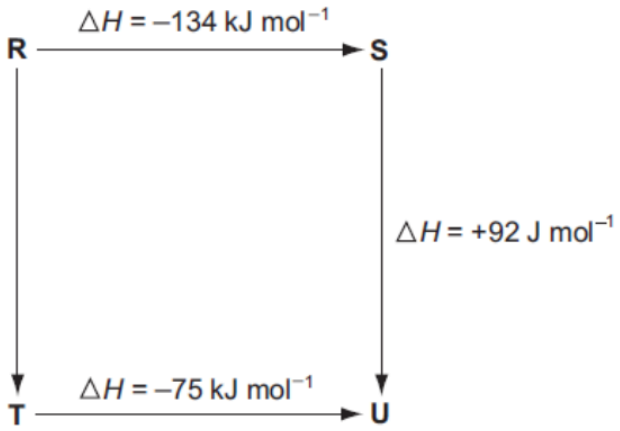
What are **P**, **Q** and **R**?

	P	Q	R
A	ethanoic acid	ammonia	potassium hydroxide
B	ethanoic acid	sodium hydroxide	ammonia
C	sulphuric acid	ammonia	potassium hydroxide
D	sulphuric acid	sodium hydroxide	ammonia

w/05/qp1

Mcq 52.

31 The diagram illustrates the energy changes of a set of reactions.



Which of the following 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}.

w/04/qp1

Mcq 53.

11 The 'flash' produced by nineteenth century photographers to take indoor photographs was obtained from the following reaction.

$$3Mg + KClO_3 \longrightarrow 3MgO + KCl$$

The standard enthalpy changes of formation are given below.

	$\Delta H_f^\ominus$ / kJ mol^{-1}
MgO	–602
KCl	–437
$KClO_3$	–391

What is the standard enthalpy change of the 'flash' reaction?

A –3(–602) + (–437) – (–391)

B (–602) + (–437) – (–391)

C 3(–602) + (–437) – (–391)

D (–602) + 3(–437) – 3(–391)

w/03/qp1

Mcq 54.

12 Why does the exothermic reaction

$$C(\text{diamond}) \longrightarrow C(\text{graphite}) \qquad \Delta H = -3\,\text{kJ mol}^{-1}$$

not occur spontaneously?

A A tetrahedral configuration is always more stable than a planar one.

B Diamond has only strong covalent bonds whereas graphite has both covalent bonds and van der Waals' forces.

C The change from diamond to graphite has a high activation energy.

D The density of graphite is less than that of diamond.

w/03/qp1

Mcq 55.

12 Red lead oxide, Pb_3O_4, is used in metal priming paints. It can be made by heating PbO in air.

$$6PbO(s) + O_2(g) \rightarrow 2Pb_3O_4(s)$$

Which two values are needed to calculate the enthalpy change for this reaction?

A enthalpy change of atomisation of O_2 and enthalpy change of formation of Pb_3O_4

B enthalpy change of formation of O_2 and enthalpy change of formation of Pb_3O_4

C enthalpy change of formation of PbO and enthalpy change of atomisation of O_2

D enthalpy change of formation of PbO and enthalpy change of formation of Pb_3O_4

s/12/qp12

Mcq 56.

7 Propanone has the molecular formula C_3H_6O.

The enthalpy change of combustion of hydrogen is $-286\,\text{kJ mol}^{-1}$.
The enthalpy change of combustion of carbon is $-394\,\text{kJ mol}^{-1}$.
The enthalpy change of combustion of propanone is $-1786\,\text{kJ mol}^{-1}$.

Using this information, what is the enthalpy change of formation of propanone?

A $-1106\,\text{kJ mol}^{-1}$

B $-540\,\text{kJ mol}^{-1}$

C $-254\,\text{kJ mol}^{-1}$

D $+1106\,\text{kJ mol}^{-1}$

s/12/qp11

Mcq 57.

3 The equation for a reaction is shown.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)\ ;\ \Delta H = x\ kJ\,mol^{-1}$$

Which pair of descriptions is fully correct for this reaction?

	type(s) of enthalpy change	value of *x*
A	formation only	positive
B	formation only	negative
C	combustion, formation	positive
D	combustion, formation	negative

s/12/qp11

Mcq 58.

7 Titanium occurs naturally as the mineral rutile, TiO_2. One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

$$TiO_2(s) + 2C(s) \rightarrow Ti(s) + 2CO(g)$$

The standard enthalpy changes of formation of $TiO_2(s)$ and $CO(g)$ are –940 kJ mol^{-1} and –110 kJ mol^{-1} respectively.

What is the standard enthalpy change of this reaction?

A –830 kJ mol^{-1}

B –720 kJ mol^{-1}

C +720 kJ mol^{-1}

D +830 kJ mol^{-1}

s/11/qp12

Mcq 59.

8 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 $3C(s) + 4H_2(g) \rightarrow C_3H_8(l)$

s/11/qp12

Mcq 60.

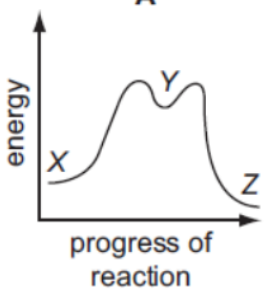
9 In the conversion of compound *X* into compound *Z*, it was found that the reaction proceeded by way of compound *Y*, which could be isolated. The following steps were involved.

$X \rightarrow Y$; ΔH, positive

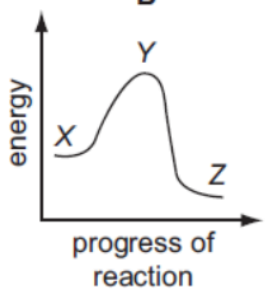
$Y \rightarrow Z$; ΔH, negative

Which reaction profile fits these data?

A



B



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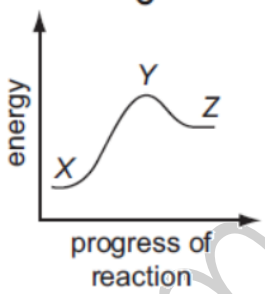

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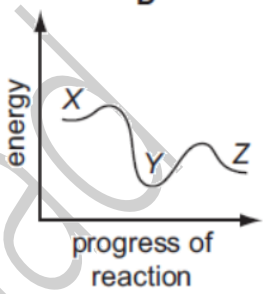


s/11/qp12

Mcq 61.

9 50 cm^3 of 2.50 mol dm^{-3} hydrochloric acid was placed in a polystyrene beaker of negligible heat capacity. Its temperature was recorded and then 50 cm^3 of 2.50 mol dm^{-3} NaOH at the same temperature was quickly added, with stirring. The temperature rose by 17 °C.

The resulting solution may be considered to have a specific heat capacity of 4.2 $Jg^{-1}K^{-1}$.

What is an approximate value for the molar enthalpy change of neutralisation of hydrochloric acid and sodium hydroxide from this experiment?

A $\frac{-(50 \times 4.2 \times 17)}{(0.050 \times 2.5)}$ J mol^{-1}

B $\frac{-(50 \times 4.2 \times 17)}{(0.10 \times 2.5)}$ J mol^{-1}

C $\frac{-(100 \times 4.2 \times 17)}{(0.050 \times 2.5)}$ J mol^{-1}

D $\frac{-(100 \times 4.2 \times 17)}{(50 \times 2.5)}$ J mol^{-1}

s/11/qp11

Mcq 62.

8 The equation below represents the combination of gaseous atoms of non-metal X and of hydrogen to form gaseous X_2H_6 molecules.

$$2X(g) + 6H(g) \rightarrow X_2H_6(g) \qquad \Delta H = -2775\,kJ\,mol^{-1}$$

The bond energy of an X–H bond is $395\,kJ\,mol^{-1}$.

What is the bond energy of an X–X bond?

A $-405.0\,kJ\,mol^{-1}$

B $-202.5\,kJ\,mol^{-1}$

C $+202.5\,kJ\,mol^{-1}$

D $+405.0\,kJ\,mol^{-1}$

s/11/qp11

Mcq 63.

4 Some bond energy values are listed below.

bond	bond energy/kJ mol^{-1}
C–H	410
C–Cl	340
Cl–Cl	244
Br–Br	193

These bond energy values relate to the following four reactions.

P $Br_2 \rightarrow 2Br$

Q $2Cl \rightarrow Cl_2$

R $CH_3 + Cl \rightarrow CH_3Cl$

S $CH_4 \rightarrow CH_3 + H$

What is the order of enthalpy changes of these reactions from most negative to most positive?

A P → Q → R → S

B Q → R → S → P

C R → Q → P → S

D S → P → Q → R

s/10/qp11

Mcq 64.

5 Given the following enthalpy changes,

$$I_2(g) + 3Cl_2(g) \rightarrow 2ICl_3(s) \qquad \Delta H^{\ominus} = -214\,kJ\,mol^{-1}$$

$$I_2(s) \rightarrow I_2(g) \qquad \Delta H^{\ominus} = +38\,kJ\,mol^{-1}$$

What is the standard enthalpy change of formation of iodine trichloride, $ICl_3(s)$?

A $+176\,kJ\,mol^{-1}$

B $-88\,kJ\,mol^{-1}$

C $-176\,kJ\,mol^{-1}$

D $-214\,kJ\,mol^{-1}$

s/10/qp11

Mcq 65.

33 For which reactions does the value of $\Delta H^{\ominus}$ represent **both** a standard enthalpy change of combustion **and** a standard enthalpy change of formation?

1 $C(s) + O_2(g) \rightarrow CO_2(g)$

2 $2C(s) + O_2(g) \rightarrow 2CO(g)$

3 $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

s/09/qp1

Mcq 66.

8 Hydrogen peroxide slowly decomposes into water and oxygen. The enthalpy change of reaction can be calculated using standard enthalpies of formation.

$\Delta H_f^{\ominus}$(hydrogen peroxide(l)) $= -187.8\,kJ\,mol^{-1}$

$\Delta H_f^{\ominus}$(water(l)) $= -285.8\,kJ\,mol^{-1}$

Using a Hess cycle, what is the enthalpy change of reaction for this decomposition?

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

A $+98\,kJ\,mol^{-1}$

B $-98\,kJ\,mol^{-1}$

C $-196\,kJ\,mol^{-1}$

D $-947.2\,kJ\,mol^{-1}$

s/09/qp1

Mcq 67.

9 For which equation does the enthalpy change correspond to the enthalpy change of atomisation of iodine?

A $\frac{1}{2}I_2(s) \rightarrow I(s)$

B $\frac{1}{2}I_2(s) \rightarrow I(g)$

C $I_2(g) \rightarrow 2I(g)$

D $I_2(s) \rightarrow 2I(g)$

s/08/qp1

Mcq 68.

10 Titanium occurs naturally as the mineral rutile, TiO_2. One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

$$TiO_2(s) + 2C(s) \rightarrow Ti(s) + 2CO(g)$$

The standard enthalpy changes of formation of $TiO_2(s)$ and $CO(g)$ are $-940\ kJ\ mol^{-1}$ and $-110\ kJ\ mol^{-1}$ respectively.

What is the standard enthalpy change of this reaction?

A $-830\ kJ\ mol^{-1}$

B $-720\ kJ\ mol^{-1}$

C $+720\ kJ\ mol^{-1}$

D $+830\ kJ\ mol^{-1}$

s/08/qp1

Mcq 69.

37 Nitrogen and oxygen react in a hot car engine to form nitrogen monoxide which is a serious pollutant in our cities and in the countryside. However, nitrogen and oxygen do not react at room temperature.

Which statements help to explain why nitrogen and oxygen do not react at room temperature?

1 The reaction is endothermic.

2 A high activation energy is required.

3 Nitrogen has a high bond energy.

s/07/qp1

Mcq 70.

14 Slaked lime, $Ca(OH)_2$, may be made from limestone, $CaCO_3$.

On heating in a lime kiln at 1000 °C, limestone decomposes as follows.

reaction 1 $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Water is then reacted with calcium oxide, CaO, as follows.

reaction 2 $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

What are the enthalpy changes of these reactions?

	reaction 1	reaction 2
A	endothermic	endothermic
B	endothermic	exothermic
C	exothermic	endothermic
D	exothermic	exothermic

s/07/qp1

Mcq 71.

8 Skiers trapped by snowstorms use heat packs to keep warm. The heat may be generated by the reaction below.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \quad ; \quad \Delta H^{\ominus} = -1648\,kJ$$

What is the standard enthalpy change of formation of iron(III) oxide?

A $0\,kJ\,mol^{-1}$

B $-824\,kJ\,mol^{-1}$

C $-1648\,kJ\,mol^{-1}$

D $-3296\,kJ\,mol^{-1}$

s/07/qp1

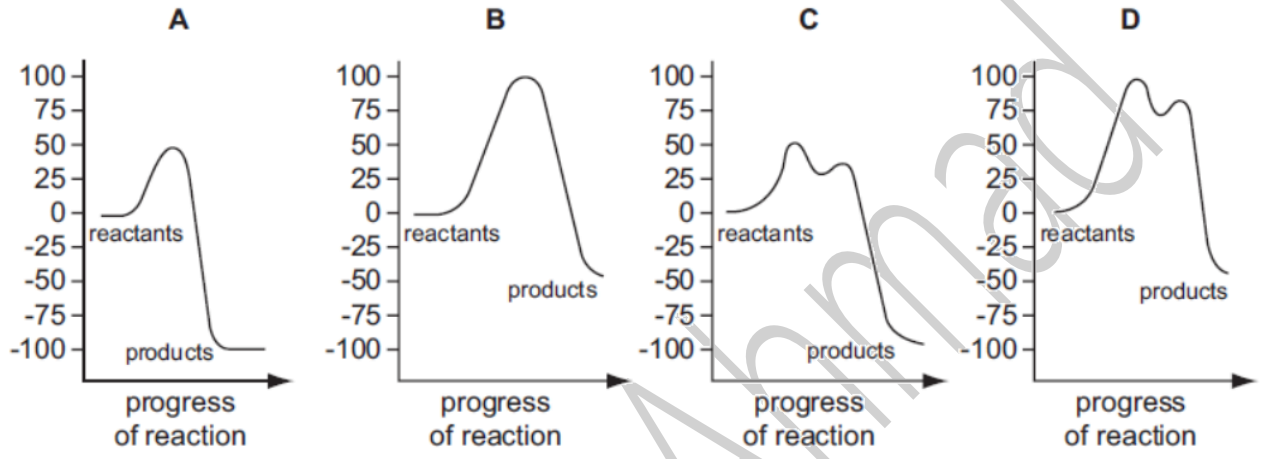
Mcq 72.

7 An exothermic chemical reaction proceeds by two stages.

$$\text{reactants} \xrightarrow{\text{stage 1}} \text{intermediate} \xrightarrow{\text{stage 2}} \text{products}$$

The activation energy of stage 1 is 50 kJ mol^{-1}. The overall enthalpy change of reaction is –100 kJ mol^{-1}.

Which diagram represents the reaction pathway for this reaction?



s/07/qp1

Mcq 73.

32 Sodium ions can be formed from sodium atoms.

$$Na(s) \rightarrow Na^{+}(g)$$

Which quantities are required to calculate the enthalpy change of formation of gaseous sodium ions?

1 enthalpy change of atomisation of sodium

2 first ionisation energy of sodium

3 enthalpy change of formation of sodium

s/06/qp1

Mcq 74.

33 Hydrazine, N_2H_4, is widely used as a rocket fuel because it reacts with oxygen as shown, producing 'environmentally friendly' gases.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta H = -534\,\text{kJ mol}^{-1}$$

Despite its use as a rocket fuel, hydrazine does not spontaneously burn in oxygen.

Why does hydrazine not burn spontaneously?

1 The activation energy is too high.

2 The N≡N bond is very strong.

3 Hydrazine is a liquid.

s/06/qp1

Mcq 75.

19 The gaseous oxides of nitrogen have positive enthalpy changes of formation.

Which factor is likely to make the most significant contribution to these enthalpy changes?

A the high bond energy of the nitrogen molecule, N_2

B the high electron affinity of nitrogen atoms

C the high electron affinity of oxygen atoms

D the similarity of the electronegativities of oxygen and nitrogen

s/06/qp1

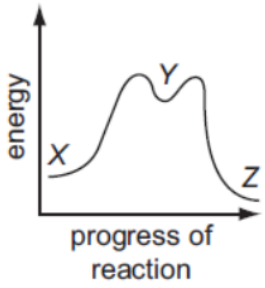
Mcq 76.

8 In the conversion of compound *X* into compound *Z*, it was found that the reaction proceeded by way of compound *Y*, which could be isolated. The following steps were involved.

$X \rightarrow Y$; ΔH, positive
$Y \rightarrow Z$; ΔH, negative

Which reaction profile fits these data?

A



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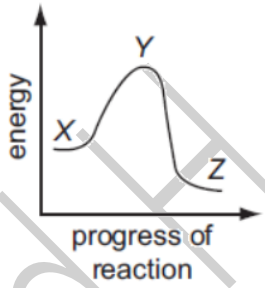

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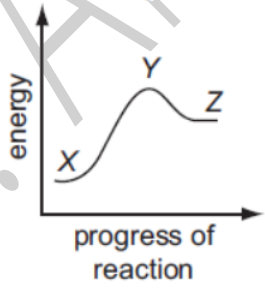

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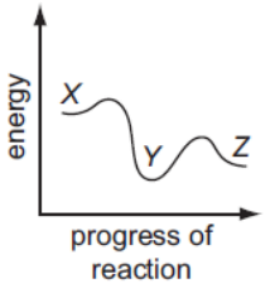

s/06/qp1

Mcq 77.

33 Which of the enthalpy changes of the following reactions can **only** be obtained by application of Hess' Law?

1 The hydration of anhydrous copper sulphate to form crystals of $CuSO_4.5H_2O$.

2 The formation of methane from its elements.

3 The combustion of glucose, $C_6H_{12}O_6$.

s/05/qp1

Mcq 78.

7 Iodine trichloride, ICl_3, is made by reacting iodine with chlorine.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(s) \; ; \; \Delta H^{\ominus} = +14\,kJ\,mol^{-1}$$

$$ICl(s) + Cl_2(g) \rightarrow ICl_3(s) \; ; \; \Delta H^{\ominus} = -88\,kJ\,mol^{-1}$$

By using the data above, what is the enthalpy change of the formation for solid iodine trichloride?

A $-60\,kJ\,mol^{-1}$

B $-74\,kJ\,mol^{-1}$

C $-81\,kJ\,mol^{-1}$

D $-162\,kJ\,mol^{-1}$

s/05/qp1

Mcq 79.

36 When a hot glass rod is placed in a gas jar of hydrogen iodide, there is an immediate reaction as the hydrogen iodide decomposes.

Which statements about this reaction are correct?

1 Hydrogen iodide is purple coloured.

2 The hot rod provides the activation energy.

3 One of the products is a solid.

s/04/qp1

Mcq 80.

32 The conversion of graphite has only a small positive value of ΔH.

$$C\ (graphite) \rightarrow C\ (diamond) \qquad \Delta H = +2.1\ kJ\ mol^{-1}$$

However, the production of synthetic diamonds using this reaction is very difficult.

Which statements help to explain this?

1 The activation energy of the reaction is large.

2 An equilibrium exists between diamond and graphite.

3 Only exothermic reactions can be made to occur readily.

s/04/qp1

Mcq 81.

8 The standard enthalpy changes of formation of iron(II) oxide, FeO(s), and aluminium oxide, $Al_2O_3(s)$, are $-266\,kJ\,mol^{-1}$ and $-1676\,kJ\,mol^{-1}$ respectively.

What is the enthalpy change under standard conditions for the following reaction?

$$3FeO(s) + 2Al(s) \rightarrow 3Fe(s) + Al_2O_3(s)$$

A $+878\,kJ$ **B** $-878\,kJ$ **C** $-1942\,kJ$ **D** $-2474\,kJ$

s/04/qp1

Mcq 82.

33 The conversion of graphite into diamond is an endothermic reaction ($\Delta H = +3\,kJ\,mol^{-1}$).

$$C(graphite) \rightarrow C(diamond)$$

Which statements are correct?

1 The enthalpy change of atomisation of diamond is smaller than that of graphite.

2 The bond energy of the C–C bonds in graphite is greater than that in diamond.

3 The enthalpy change of combustion of diamond is greater than that of graphite.

s/03/qp1

Mcq 83.

7 Gaseous phosphorus pentachloride can be decomposed into gaseous phosphorus trichloride and chlorine by heating. The table below gives the bond energies.

bond	bond energy / kJ mol^{-1}
P-C*l* (in both chlorides)	330
C*l*-C*l*	240

What is the enthalpy change in the decomposition of PCl_5 to PCl_3 and Cl_2?

A –420 kJ mol^{-1} **B** –90 kJ mol^{-1} **C** +90 kJ mol^{-1} **D** +420 kJ mol^{-1}

s/03/qp1

mcq1	3B
mcq2	7B
mcq3	8A
mcq4	32C
mcq5	5B
mcq6	10A
mcq7	11C
mcq8	6D
mcq9	7C
mcq10	11B
mcq11	3D
mcq12	5B
mcq13	3A
mcq14	11B
mcq15	3A
mcq16	6B
mcq17	9D
mcq18	12D
mcq19	10A
mcq20	20D
mcq21	12C
mcq22	32C
mcq23	11C
mcq24	33A
mcq25	7A
mcq26	10C
mcq27	5A
mcq28	10C
mcq29	11A
mcq30	4A

mcq31	5B
mcq32	22D
mcq33	17C
mcq34	10A
mcq35	19A
mcq36	6C
mcq37	8D
mcq38	6A
mcq39	4B
mcq40	11C
mcq41	8B
mcq42	9B
mcq43	10C
mcq44	6C
mcq45	9A
mcq46	8D
mcq47	32A
mcq48	8D
mcq49	9C
mcq50	6A
mcq51	7A
mcq52	31D
mcq53	11C
mcq54	12C
mcq55	12D
mcq56	7C
mcq57	3D
mcq58	7C
mcq59	8C
mcq60	9C

mcq61	9C
mcq62	8D
mcq63	4C
mcq64	5B
mcq65	33D
mcq66	8C
mcq67	9B
mcq68	10C
mcq69	37A
mcq70	14B
mcq71	8B
mcq72	7C
mcq73	32B
mcq74	33D
mcq75	19A
mcq76	8A
mcq77	33B
mcq78	7C
mcq79	36C
mcq80	32D
mcq81	8B
mcq82	33A
mcq83	7D
mcq84	
mcq85	
mcq86	
mcq87	
mcq88	
mcq89	
mcq90	