Cambridge AS & A Level

# CHEMISTRY

## Paper 1

Topical Past Paper Questions

+ Answer Scheme

**2015 - 2021**

PapaCambridge

# Chapter 5

# Chemical energetics

## 5.1 Enthalpy change, △H

228. 9701_m22_qp_12 Q: 8

The equation for reaction 1 is shown.

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

| | $\Delta H_c^e$ / 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?

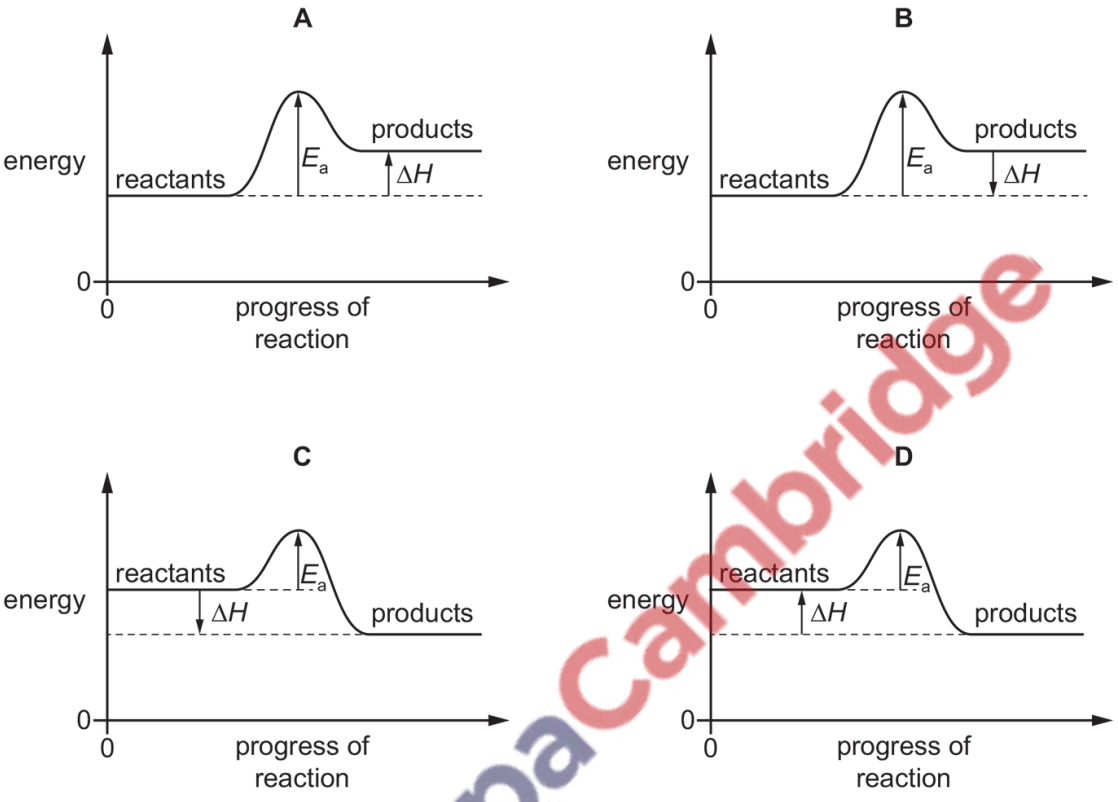
**A** $a + b$ **B** $a - b$ **C** $a + 2b$ **D** $a - 2b$

229. 9701_m22_qp_12 Q: 9

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

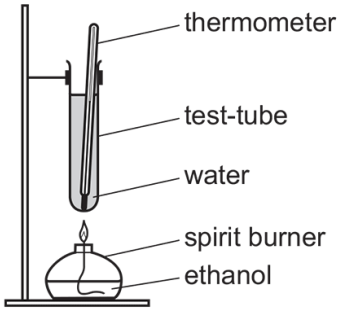
$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

Which diagram correctly represents the energy profile for this reaction?



230. 9701_m21_qp_12 Q: 7

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




The data collected are shown.

mass of water = $W$g

mass of ethanol burned = $X$g

temperature rise = $Y$°C

molar mass of ethanol = $Z$g 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** $\frac{-4.2X(Y+273)Z}{1000W}$

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231. 9701_s21_qp_11 Q: 4

$\Delta H_1^e$ is the standard enthalpy of formation of methane.

$\Delta H_2^e$ is the standard enthalpy of combustion of carbon.

$\Delta H_3^e$ is the standard enthalpy of combustion of hydrogen.

$$CH_4(g) + 2O_2(g) \xrightarrow{\Delta H_c^e} CO_2(g) + 2H_2O(l)$$

Which expression is equivalent to $\Delta H_c^e$?

**A** $\Delta H_1^e - \Delta H_2^e + \Delta H_3^e$

**B** $\Delta H_1^e - 2\Delta H_3^e - \Delta H_2^e$

**C** $\Delta H_2^e - \Delta H_3^e + \Delta H_1^e$

**D** $\Delta H_2^e + 2\Delta H_3^e - \Delta H_1^e$

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232. 9701_s21_qp_13 Q: 7

Using the information in the table, what is the enthalpy change, $q$, for the reaction described?

$$Cs^+(g) + Br^-(g) \rightarrow CsBr(s) \qquad \Delta H = q\,kJ\,mol^{-1}$$

| standard enthalpy change | value / kJ mol$^{-1}$ |
|---|---|
| $\Delta H^{\ominus}_{sol}$ CsBr(s) | +25.9 |
| $\Delta H^{\ominus}_{hyd}$ $Cs^+(g)$ | –276 |
| $\Delta H^{\ominus}_{hyd}$ $Br^-(g)$ | –335 |

**A** –636.9 **B** –585.1 **C** +585.1 **D** +636.9

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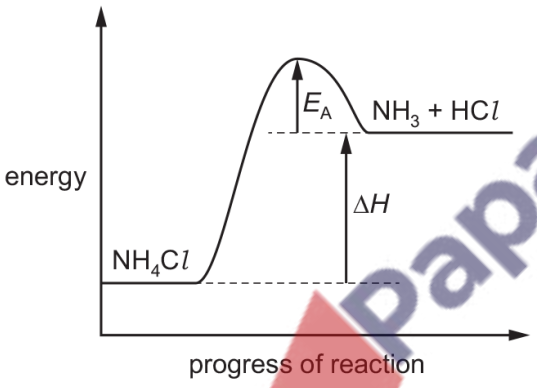
233. 9701_w21_qp_12 Q: 9

The equation for the formation of ammonium chloride is shown.

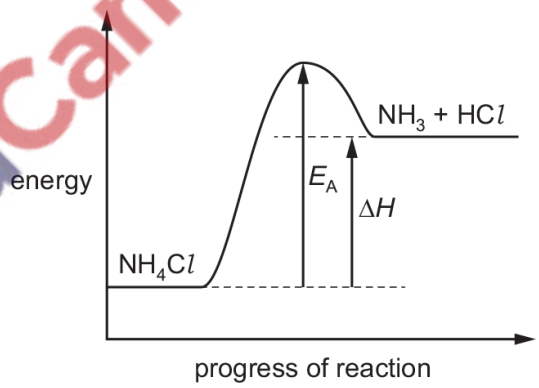
$$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s) \qquad \Delta H = -314\,kJ\,mol^{-1}$$

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

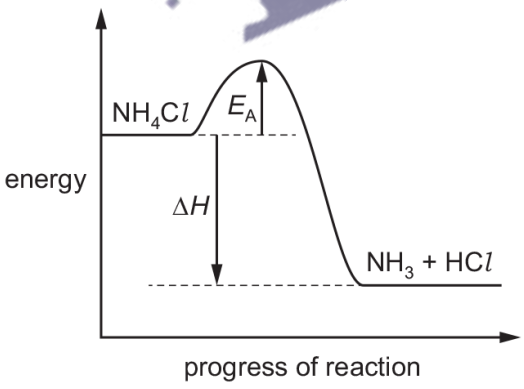
**A**



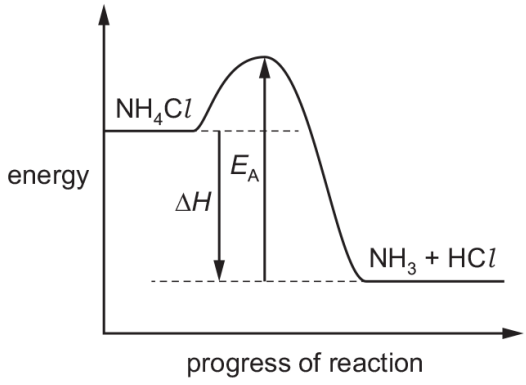

**B**




**C**




**D**



234. 9701_w21_qp_13 Q: 8

Which equation represents 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** $I_2(s) \rightarrow 2I(g)$

---

235. 9701_s20_qp_11 Q: 5

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

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236. 9701_m19_qp_12 Q: 8

The standard enthalpy changes of combustion of carbon, hydrogen and methanol are shown.

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_c^{\ominus} = -394\,kJ\,mol^{-1}$$

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

$$CH_3OH(l) + 1\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H_c^{\ominus} = -726\,kJ\,mol^{-1}$$

Which expression gives the standard enthalpy change of formation of methanol in $kJ\,mol^{-1}$?

**A** $-394 + (-286) - (-726)$

**B** $-394 + (-286 \times 2) - 726$

**C** $-394 + (-286 \times 2) - (-726)$

**D** $-726 - (-394) - (-286 \times 2)$

---

237. 9701_m19_qp_12 Q: 9

The equation for a chemical reaction is shown. All substances are in their standard states.

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

Which statement describes the standard enthalpy change of reaction for this reaction?

**A** the enthalpy change when a total of one mole of products is produced

**B** the enthalpy change when a total of one mole of reactants is reacted

**C** the enthalpy change when one mole of water reacts

**D** the enthalpy change when six moles of hydrogen fluoride are produced

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238. 9701_s19_qp_11 Q: 8

Two reactions and their enthalpy changes are shown.

$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^\ominus = +52.2\,kJ\,mol^{-1}$$

$$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^\ominus = -175.8\,kJ\,mol^{-1}$$

These data can be used to calculate the enthalpy change for the reaction shown.

$$2C(s) + H_2(g) \rightarrow C_2H_2(g) \qquad \Delta H^\ominus = X$$

What is the value of X?

**A** $-228.0\,kJ\,mol^{-1}$

**B** $-123.6\,kJ\,mol^{-1}$

**C** $+123.6\,kJ\,mol^{-1}$

**D** $+228.0\,kJ\,mol^{-1}$

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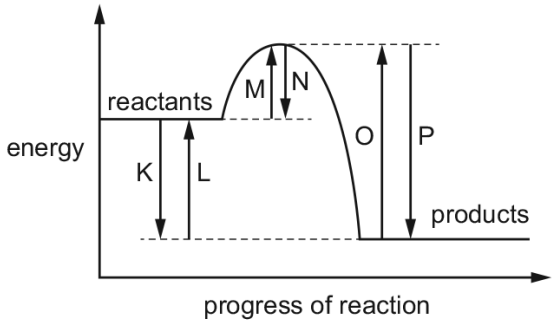
239. 9701_s19_qp_12 Q: 8

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 |

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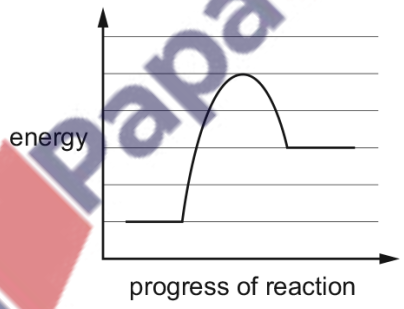
240. 9701_s19_qp_13 Q: 6

The reaction pathway diagram for a chemical reaction is shown.




Which statement is correct?

**A** The activation energy of the forward reaction and the enthalpy change of the backward reaction have the same sign.

**B** The activation energy of the forward reaction is more than twice the enthalpy change of the backward reaction and opposite in sign.

**C** The enthalpy change of the forward reaction and the activation energy of the backward reaction have the same sign.

**D** The enthalpy change of the forward reaction is more than twice the activation energy of the backward reaction.

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241. 9701_w19_qp_11 Q: 7

The following data are needed for this question.

$\Delta H_f^\ominus(N_2H_4(l)) = 50.6\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(N_2O_4(g)) = 9.2\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(H_2O(g)) = -241.8\,kJ\,mol^{-1}$

Hydrazine, $N_2H_4(l)$, reacts with dinitrogen tetraoxide, $N_2O_4(g)$, to form nitrogen gas and water vapour.

$$2N_2H_4(l) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

What is the enthalpy change for this reaction?

**A** $-1077.6\,kJ\,mol^{-1}$

**B** $-856.8\,kJ\,mol^{-1}$

**C** $-301.6\,kJ\,mol^{-1}$

**D** $-182.0\,kJ\,mol^{-1}$

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242. 9701_w19_qp_11 Q: 8

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.

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243. 9701_w19_qp_12 Q: 6

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

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244. 9701_m18_qp_12 Q: 8

Which equation represents the standard enthalpy change of formation of water?

**A** $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$

**B** $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$

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

**D** $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

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245. 9701_s18_qp_11 Q: 7

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, $\Delta H_f^{\ominus}$, of butane?

| substance | $\Delta H_c^{\ominus}$ / kJ mol$^{-1}$ |
|---|---|
| C(s) | –394 |
| $H_2(g)$ | –286 |
| $C_4H_{10}(g)$ | –2877 |

**A** –5883 kJ mol$^{-1}$

**B** –129 kJ mol$^{-1}$

**C** +129 kJ mol$^{-1}$

**D** +2197 kJ mol$^{-1}$

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246. 9701_s18_qp_12 Q: 7

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

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

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

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

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

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247. 9701_s18_qp_13 Q: 7

Anhydrous copper(II) chloride, $CuCl_2$, combines with water to form $CuCl_2.2H_2O$. The standard enthalpy changes of formation for this reaction are shown in the table.

| | $\Delta H_f^\ominus$ / kJ mol$^{-1}$ |
|---|---|
| $H_2O$ | –286 |
| $CuCl_2$ | –206 |
| $CuCl_2.2H_2O$ | –808 |

What is the standard enthalpy change of the reaction shown?

$$CuCl_2 + 2H_2O \rightarrow CuCl_2.2H_2O$$

**A** –1586 kJ mol$^{-1}$

**B** –316 kJ mol$^{-1}$

**C** –110 kJ mol$^{-1}$

**D** –30 kJ mol$^{-1}$

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248. 9701_w18_qp_11 Q: 6

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

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249. 9701_w18_qp_12 Q: 1

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.

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250. 9701_w18_qp_12 Q: 7

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$^{-1}$

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251. 9701_m17_qp_12 Q: 7

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.

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$^{-1}$

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252. 9701_m17_qp_12 Q: 9

All the reactants and products of an exothermic reaction are gaseous.

Which statement about this reaction is correct?

**A** The total bond energy of the products is less than the total bond energy of the reactants, and $\Delta H$ for the reaction is negative.

**B** The total bond energy of the products is less than the total bond energy of the reactants, and $\Delta H$ for the reaction is positive.

**C** The total bond energy of the products is more than the total bond energy of the reactants, and $\Delta H$ for the reaction is negative.

**D** The total bond energy of the products is more than the total bond energy of the reactants, and $\Delta H$ for the reaction is positive.

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253. 9701_s17_qp_11 Q: 7

Which expression gives the standard enthalpy change of combustion of methane?

**A** $\Delta H_f^\ominus(CH_4) + \Delta H_f^\ominus(CO_2) - 2\Delta H_f^\ominus(H_2O)$

**B** $\Delta H_f^\ominus(CO_2) + 2\Delta H_f^\ominus(H_2O) + \Delta H_f^\ominus(CH_4)$

**C** $\Delta H_f^\ominus(CH_4) + 2\Delta H_f^\ominus(H_2O) - \Delta H_f^\ominus(CO_2)$

**D** $\Delta H_f^\ominus(CO_2) + 2\Delta H_f^\ominus(H_2O) - \Delta H_f^\ominus(CH_4)$

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254. 9701_s17_qp_12 Q: 7

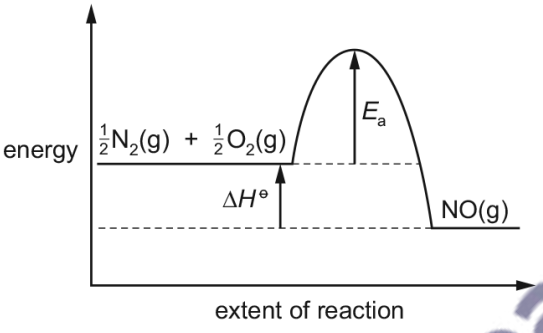
In the high temperatures of car engines, nitrogen reacts with oxygen to give nitrogen monoxide.

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \rightarrow NO(g) \qquad \Delta H^\ominus = +90\,kJ\,mol^{-1}$$

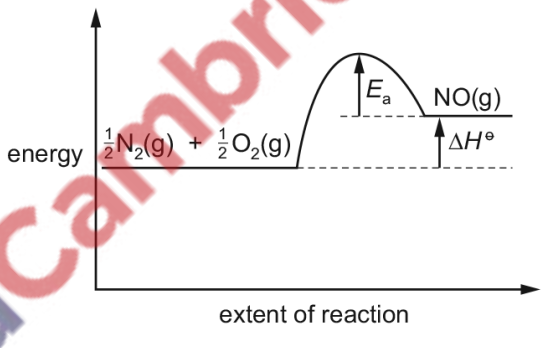
This reaction has activation energy $E_a$.

Which reaction pathway diagram could correctly represent this reaction?

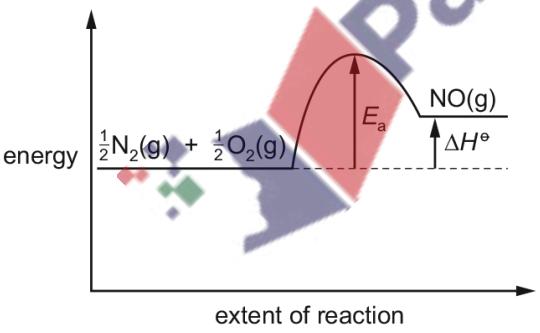
**A**



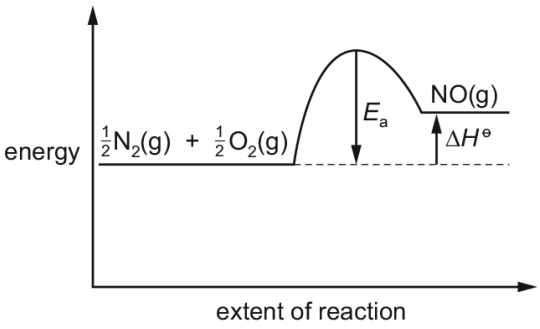

**B**




**C**




**D**

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255. 9701_s17_qp_13 Q: 6

The following data are needed for this question.

$\Delta H_f^\ominus(CO(g)) = -111\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(CO_2(g)) = -394\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(Fe_2O_3(s)) = -822\,kJ\,mol^{-1}$

Carbon monoxide reacts with iron(III) oxide.

$$3CO(g) + Fe_2O_3(s) \rightarrow 3CO_2(g) + 2Fe(s)$$

What is the enthalpy change when 55.8 g of iron are produced by this reaction?

**A** –27.0 kJ **B** –13.5 kJ **C** +13.5 kJ **D** +27.0 kJ

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256. 9701_w17_qp_11 Q: 8

Sulfur can be oxidised in two ways.

$$S(s) + O_2(g) \rightarrow SO_2(g) \qquad \Delta H^\ominus = -296.5\,kJ\,mol^{-1}$$

$$2S(s) + 3O_2(g) \rightarrow 2SO_3(g) \qquad \Delta H^\ominus = -791.4\,kJ\,mol^{-1}$$

Sulfur trioxide can be made from sulfur dioxide and oxygen.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

What is the standard enthalpy change for this reaction?

**A** $-1384.4\,kJ\,mol^{-1}$

**B** $-989.8\,kJ\,mol^{-1}$

**C** $-494.9\,kJ\,mol^{-1}$

**D** $-198.4\,kJ\,mol^{-1}$

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257. 9701_w17_qp_11 Q: 11

200 g of water are at 25 °C.

The water is heated to 75 °C by burning 2 g of ethanol.

What is the amount of energy transferred to the water?

**A** 0.418 kJ **B** 10.4 kJ **C** 41.8 kJ **D** 62.7 kJ

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258. 9701_w17_qp_12 Q: 6

In calculating the enthalpy change, $\Delta H$, of an experiment involving solutions, the mass of the solution, $m$, specific heat capacity of the solution, $c$, and the temperature change, $\Delta T$, are needed.

$$\Delta T = T_{final} - T_{initial}$$

Which expression for $\Delta H$ is correct?

**A** $\Delta H = \frac{mc}{\Delta T}$ **B** $\Delta H = \frac{-mc}{\Delta T}$ **C** $\Delta H = mc\Delta T$ **D** $\Delta H = -mc\Delta T$

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259. 9701_w17_qp_12 Q: 7

The following data are needed for this question.

$\Delta H_f^\ominus (P_4O_{10}(s)) = -3012\,kJ\,mol^{-1}$

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

$\Delta H_f^\ominus (H_3PO_4(s)) = -1279\,kJ\,mol^{-1}$

What is $\Delta H^\ominus$ for the reaction shown?

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(s)$$

**A** $-9844\,kJ\,mol^{-1}$

**B** $-388\,kJ\,mol^{-1}$

**C** $-97\,kJ\,mol^{-1}$

**D** $+2019\,kJ\,mol^{-1}$

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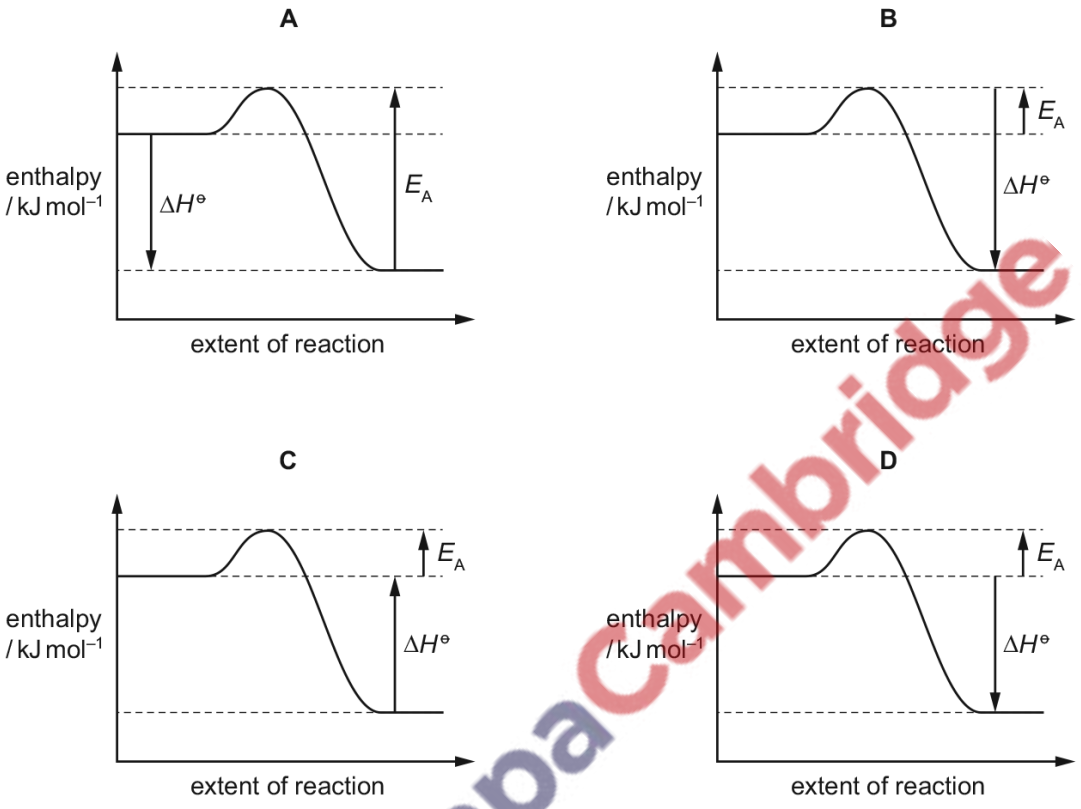
260. 9701_m16_qp_12 Q: 5

Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H^{\ominus} = -23\,kJ\,mol^{-1}$$

The reaction has an activation energy of $+5.4\,kJ\,mol^{-1}$.

What is the correct reaction pathway diagram for this reaction?

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261. 9701_s16_qp_11 Q: 8

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

| bond | bond energy / kJ mol$^{-1}$ |
|---|---|
| P–Cl (in both chlorides) | 330 |
| Cl–Cl | 242 |

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

**A** $-418\,kJ\,mol^{-1}$

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

**C** $+88\,kJ\,mol^{-1}$

**D** $+418\,kJ\,mol^{-1}$

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262. 9701_s16_qp_12 Q: 8

The equation for the complete combustion of propan-1-ol is shown.

$$CH_3CH_2CH_2OH(l) + 4\tfrac{1}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

Standard enthalpy changes of formation are given.

| compound | $CH_3CH_2CH_2OH(l)$ | $CO_2(g)$ | $H_2O(l)$ |
|---|---|---|---|
| $\Delta H_f^\ominus$ | $-303\,kJ\,mol^{-1}$ | $-394\,kJ\,mol^{-1}$ | $-286\,kJ\,mol^{-1}$ |

What is the standard enthalpy change of combustion of propan-1-ol, in $kJ\,mol^{-1}$?

**A** –394 – 286 – 303

**B** 303 – (4 × 286) – (3 × 394)

**C** 394 + 286 – 303

**D** (3 × 394) + (4 × 286) + 303

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263. 9701_s16_qp_13 Q: 1

Enthalpy changes, $\Delta H$, can be positive or negative.

Which row is correct?

| | $\Delta H$ positive | $\Delta H$ negative |
|---|---|---|
| **A** | atomisation | bond breaking |
| **B** | bond breaking | neutralisation |
| **C** | bond making | combustion |
| **D** | combustion | bond making |

---

264. 9701_s16_qp_13 Q: 8

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.

$E(C\equiv O)$ 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$^{-1}$

---

265. 9701_w16_qp_11 Q: 8

An important reaction in the manufacture of nitric acid is the catalytic oxidation of ammonia.

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

For every mole of $O_2$ that reacts in this way, 181.8 kJ of energy are released.

A factory makes $2.50 \times 10^5$ mol of NO every day.

How much energy, in kJ, is released every day?

**A** $3.64 \times 10^7$ **B** $4.55 \times 10^7$ **C** $5.68 \times 10^7$ **D** $2.27 \times 10^8$

---

266. 9701_w16_qp_12 Q: 9

In a calorimetric experiment 1.60 g of a fuel are burnt. 45.0% of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18.0 °C to 66.0 °C.

What is the total energy released per gram of fuel burnt (to 3 significant figures)?

**A** 25 100 J **B** 55 700 J **C** 89 200 J **D** 143 000 J

---

267. 9701_s15_qp_11 Q: 7

The standard enthalpy changes of combustion of glucose and ethanol are given as –2820 and –1368 kJ mol$^{-1}$ respectively.

Glucose, $C_6H_{12}O_6$, can be converted into ethanol.

$$C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

What is the standard enthalpy change for this reaction?

**A** –1452 kJ mol$^{-1}$

**B** –84 kJ mol$^{-1}$

**C** +84 kJ mol$^{-1}$

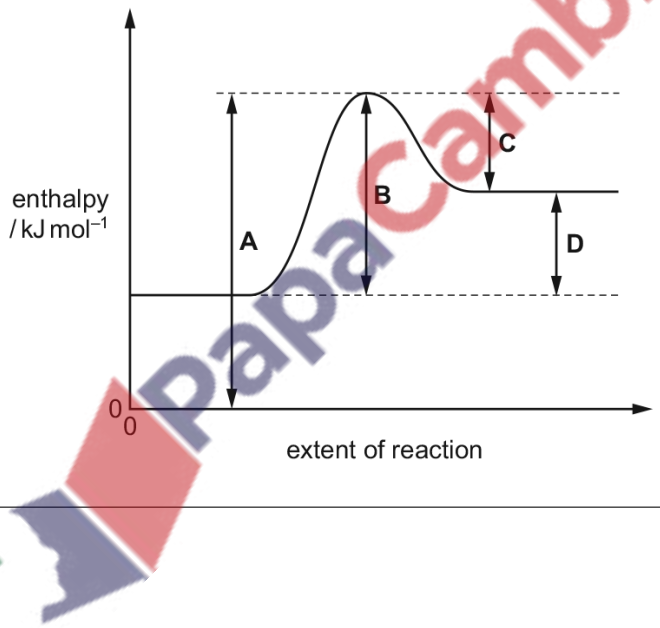
**D** +1452 kJ mol$^{-1}$

---

268. 9701_s15_qp_11 Q: 11

The diagram shows a reaction pathway for an endothermic reaction.

Which arrow represents the activation energy for the forward reaction?

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269. 9701_s15_qp_12 Q: 6

Metaldehyde, $(CH_3CHO)_4$, is used as a solid fuel for camping stoves. The equation for the complete combustion of metaldehyde is shown.

$$(CH_3CHO)_4(s) + 10\,O_2(g) \rightarrow 8CO_2(g) + 8H_2O(l)$$

$\Delta H_c^e$ = standard enthalpy change of combustion.

Which expression will give a correct value for the enthalpy change of formation of metaldehyde?

**A** $\Delta H_c^e$metaldehyde – ($8\Delta H_c^e$carbon + $8\Delta H_c^e$hydrogen)

**B** $\Delta H_c^e$metaldehyde – ($8\Delta H_c^e$carbon + $16\Delta H_c^e$hydrogen)

**C** ($8\Delta H_c^e$carbon + $8\Delta H_c^e$hydrogen) – $\Delta H_c^e$metaldehyde

**D** ($8\Delta H_c^e$carbon + $16\Delta H_c^e$hydrogen) – $\Delta H_c^e$metaldehyde

---

270. 9701_s15_qp_13 Q: 3

A student performed an experiment to measure the enthalpy change of combustion of ethane.

He used the following values for the standard enthalpy changes of combustion of carbon and hydrogen.

$\Delta H_c^e$carbon = –394 kJ mol$^{-1}$

$\Delta H_c^e$hydrogen = –286 kJ mol$^{-1}$

He calculated the enthalpy change of formation of ethane to be –140 kJ mol$^{-1}$.

What was his experimental value for the standard enthalpy change of combustion of ethane?

**A** –2364 kJ mol$^{-1}$

**B** –1506 kJ mol$^{-1}$

**C** –1112 kJ mol$^{-1}$

**D** –540 kJ mol$^{-1}$

---

271. 9701_s15_qp_13 Q: 7

Carbon monoxide and methanol can react together to form ethanoic acid.

$$CO(g) + CH_3OH(l) \xrightarrow{\Delta H_r^e} CH_3CO_2H(l)$$

Standard enthalpy changes of combustion are given in the table.

| compound | standard enthalpy change of combustion, $\Delta H_c^e$ |
|---|---|
| CO | –283.0 kJ mol$^{-1}$ |
| $CH_3OH$ | –726.0 kJ mol$^{-1}$ |
| $CH_3CO_2H$ | –874.1 kJ mol$^{-1}$ |

What is the value for $\Delta H_r^e$ for the reaction between carbon monoxide and methanol?

**A** –1883.1 kJ mol$^{-1}$

**B** –134.9 kJ mol$^{-1}$

**C** +134.9 kJ mol$^{-1}$

**D** +1883.1 kJ mol$^{-1}$

---

272. 9701_w15_qp_11 Q: 6

Solid sulfur consists of molecules made up of eight atoms covalently bonded together.

The bonding in sulfur dioxide is O=S=O.

enthalpy change of combustion of $S_8$, $\Delta H_c^e S_8(s)$= –2376kJ mol$^{-1}$

energy required to break 1 mole $S_8(s)$ into gaseous atoms = 2232 kJ mol$^{-1}$

O=O bond enthalpy = 496 kJ mol$^{-1}$

Using these data, what is the value of the S=O bond enthalpy?

**A** 239 kJ mol$^{-1}$ **B** 257 kJ mol$^{-1}$ **C** 319 kJ mol$^{-1}$ **D** 536 kJ mol$^{-1}$

---

273. 9701_w15_qp_11 Q: 7

*Use of the Data Booklet is relevant for this question.*

In an experiment, the burning of 1.45 g (0.025 mol) of propanone was used to heat 100 g of water. The initial temperature of the water was 20.0 °C and the final temperature of the water was 78.0 °C.

Which experimental value for the enthalpy change of combustion for propanone can be calculated from these results?

**A** $-1304\ kJ\ mol^{-1}$

**B** $-970\ kJ\ mol^{-1}$

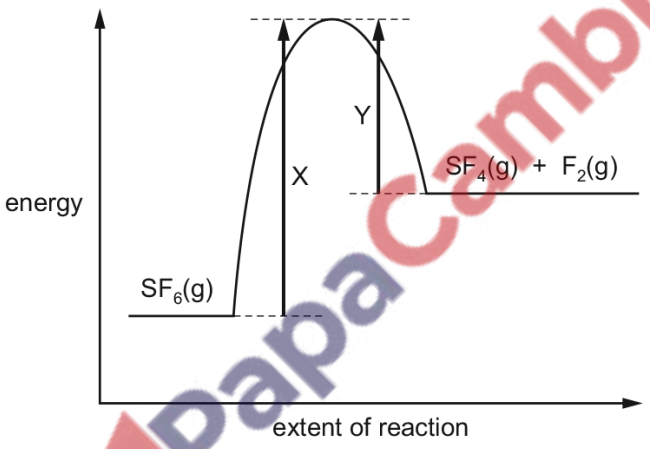
**C** $-352\ kJ\ mol^{-1}$

**D** $-24.2\ kJ\ mol^{-1}$

---

274. 9701_w15_qp_12 Q: 10

The decomposition reaction $SF_6(g) \rightarrow SF_4(g) + F_2(g)$ can be described by the reaction pathway diagram shown.




What are the values of $\Delta H^{\ominus}$ and $E_a$ for this reaction?

| | $\Delta H^{\ominus}$ | $E_a$ |
|---|---|---|
| **A** | X | X + Y |
| **B** | X | Y |
| **C** | X – Y | X |
| **D** | Y – X | X |

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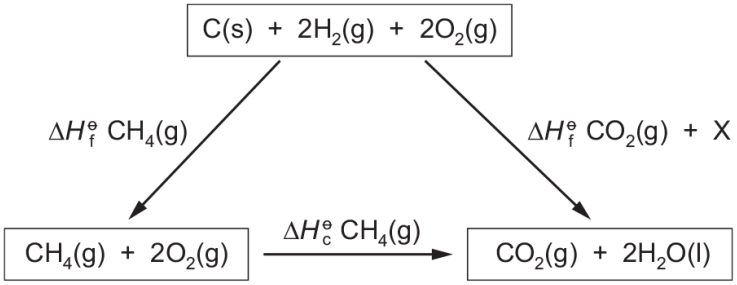
## 5.2 Hess's Law

275. 9701_s21_qp_13 Q: 8

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

---

276. 9701_m20_qp_12 Q: 4

The following data are needed for this question.

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

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

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

---

277. 9701_s20_qp_13 Q: 4

The enthalpy changes of two reactions are shown.

$$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -34.0\,kJ\,mol^{-1}$$

$$KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = +32.8\,kJ\,mol^{-1}$$

What is the enthalpy change for the reaction shown?

$$2KHCO_3(s) \rightarrow K_2CO_3(s) + H_2O(l) + CO_2(g)$$

**A** $-31.6\,kJ\,mol^{-1}$

**B** $1.2\,kJ\,mol^{-1}$

**C** $66.8\,kJ\,mol^{-1}$

**D** $99.6\,kJ\,mol^{-1}$

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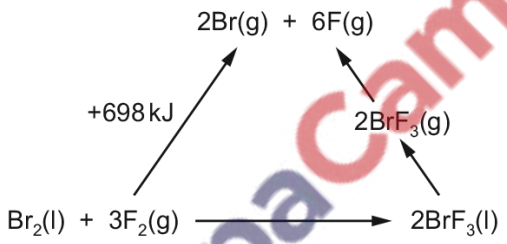
278. 9701_w20_qp_11 Q: 7

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** $404\,kJ\,mol^{-1}$

---

279. 9701_m18_qp_12 Q: 9

Hess' Law and bond energy data can be used to calculate the enthalpy change of a reaction.

Bromoethane, $CH_3CH_2Br$, can be made by reacting ethene with hydrogen bromide.

$$CH_2{=}CH_2 + HBr \rightarrow CH_3CH_2Br$$

What is the enthalpy change for this reaction?

**A** $-674\,kJ\,mol^{-1}$

**B** $-64\,kJ\,mol^{-1}$

**C** $+186\,kJ\,mol^{-1}$

**D** $+346\,kJ\,mol^{-1}$

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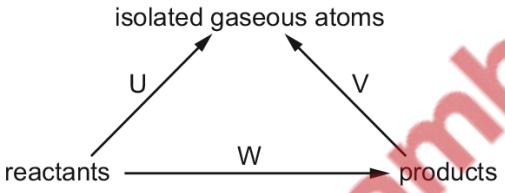
280. 9701_w15_qp_12 Q: 6

Hess' law may be used to determine enthalpy changes using average bond energies, as shown in the diagram.




U is the sum of the average bond energies of the reactants, and V is the sum of the average bond energies of the products.

For the reaction shown below, which expression will give a value for W, the enthalpy change of combustion of methane?

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

**A** U – V **B** U + V **C** 2(U – V) **D** V – U

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