# Hess's Law

## Question Paper 1

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|---|---|
| **Level** | International A Level |
| **Subject** | Chemistry |
| **Exam Board** | Edexcel |
| **Topic** | The Core Principles of Chemistry |
| **Sub Topic** | Hess's Law |
| **Booklet** | Question Paper 1 |

**Time Allowed:** **76 minutes**

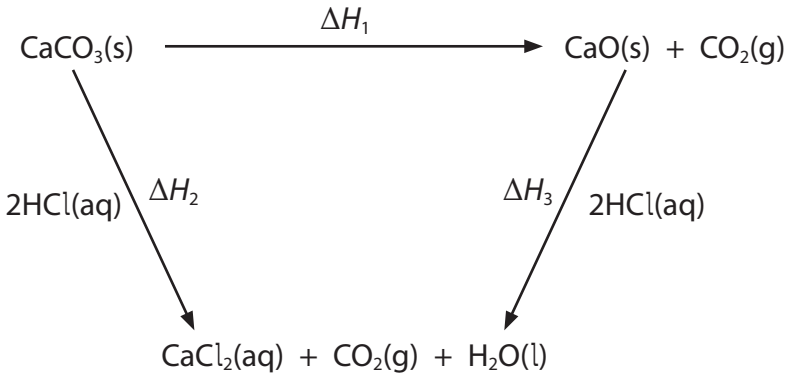
**Score:** **/63**

**Percentage:** **/100**

**Grade Boundaries:**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | '77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1** Hess's law can be used to determine enthalpy changes which cannot be measured directly, such as the thermal decomposition of calcium carbonate.




Using Hess's law, the expression to determine $\Delta H_1$ is

☒ **A** $\Delta H_1 = \Delta H_2 - \Delta H_3$

☒ **B** $\Delta H_1 = \Delta H_2 + \Delta H_3$

☒ **C** $\Delta H_1 = 2\Delta H_2 - 2\Delta H_3$

☒ **D** $\Delta H_1 = 2\Delta H_2 + 2\Delta H_3$

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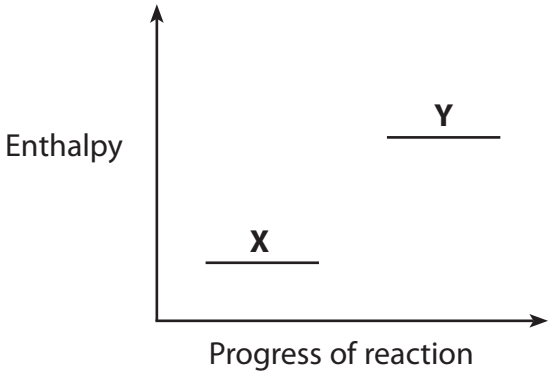
**2** An enthalpy level diagram for a reaction is




Which row in the table shows the correct terms for **X** and **Y** and the enthalpy change for this reaction?

| | X | Y | Enthalpy change |
|---|---|---|---|
| ☒ **A** | products | reactants | endothermic |
| ☒ **B** | products | reactants | exothermic |
| ☒ **C** | reactants | products | endothermic |
| ☒ **D** | reactants | products | exothermic |

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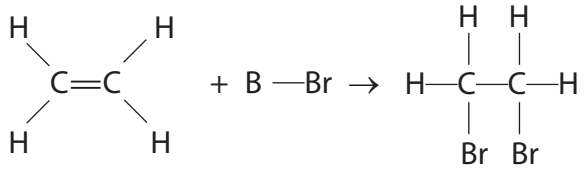
**3** The table shows the mean bond enthalpies for some covalent bonds.

| Covalent bond | C—C | C═C | Br—Br | C—Br | C—H |
|---|---|---|---|---|---|
| Mean bond enthalpy / kJ mol$^{-1}$ | 347 | 612 | 193 | 290 | 413 |

What is the approximate enthalpy change, in kJ mol$^{-1}$, for the reaction shown?




☒ **A** −225

☒ **B** −122

☒ **C** +122

☒ **D** +225

**4** Some energy changes involved in a Born-Haber cycle are

**A** electron affinity

**B** lattice energy

**C** standard enthalpy change of atomization

**D** standard enthalpy change of formation

(a) Which enthalpy or energy change is represented by **p**?

$$K(s) \rightarrow K(g) \qquad \Delta H^{\ominus} = \mathbf{p}$$

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which enthalpy or energy change is represented by **q**?

$$K(s) + \tfrac{1}{2}Cl_2(g) \rightarrow KCl(s) \qquad \Delta H^{\ominus} = \mathbf{q}$$

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which enthalpy or energy change is represented by **r**?

$$\tfrac{1}{2}Cl_2(g) \rightarrow Cl(g) \qquad \Delta H^{\ominus} = \mathbf{r}$$

**(1)**

☒ **A**

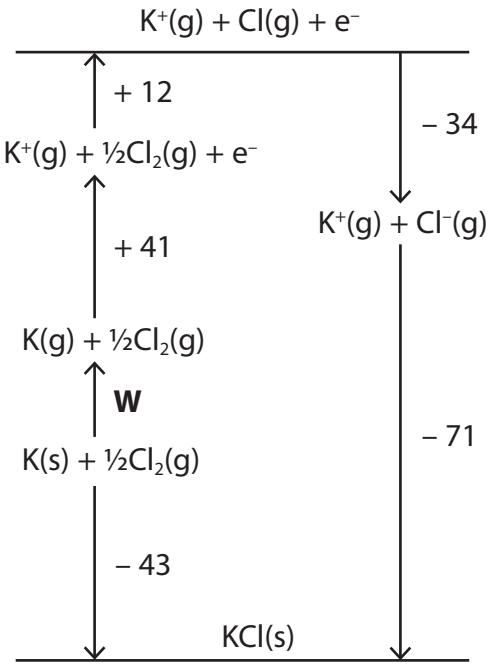
☒ **B**

☒ **C**

☒ **D**

**(Total for Question 4 = 3 marks)**

**5** The diagram, which is not drawn to scale, shows the Born-Haber cycle for potassium chloride. The energy changes given are in kJ mol$^{-1}$.




What is the value for **W**, in kJ mol$^{-1}$?

☒ **A** −956

☒ **B** −82

☒ **C** +82

☒ **D** +956

**(Total for Question 5 = 1 mark)**

**6** Consider the following data.

| | | | | | |
|---|---|---|---|---|---|
| $S(s)$ | + | $H_2(g)$ | → | $H_2S(g)$ | $\Delta H^{\ominus} = a$ |
| $H_2(g)$ | | $½O_2(g)$ | → | $H_2O(l)$ | $\Delta H^{\ominus} = b$ |
| $S(s)$ | + | $O_2(g)$ | → | $SO_2(g)$ | $\Delta H^{\ominus} = c$ |
| $H_2S(g)$ | + | $1½O_2(g)$ | → | $H_2O(l) + SO_2(g)$ | $\Delta H^{\ominus} = d$ |

What is the relationship between a, b, c and d?

☒ **A** a = b + c – d

☒ **B** a = d – b – c

☒ **C** a = b – c – d

☒ **D** a = d + c – b

**(Total for Question 6 = 1 mark)**

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**7** In which of the following does **X** represent the mean bond enthalpy for the O–H bond in water?

☒ **A** $H_2O(g) \rightarrow O(g) + H_2(g)$ $\Delta H = 2\mathbf{X}$

☒ **B** $H_2O(g) \rightarrow O(g) + 2H(g)$ $\Delta H = 2\mathbf{X}$

☒ **C** $H_2O(g) \rightarrow O(g) + H_2(g)$ $\Delta H = \mathbf{X}$

☒ **D** $H_2O(g) \rightarrow O(g) + 2H(g)$ $\Delta H = \mathbf{X}$

**(Total for Question 7 = 1 mark)**

**8** Consider the following data:

| | | | | | |
|---|---|---|---|---|---|
| $C(s)$ | + | $O_2(g)$ | → | $CO_2(g)$ | $\Delta H^{\ominus} = -394$ kJ mol$^{-1}$ |
| $Pb(s)$ | + | $\frac{1}{2}O_2(g)$ | → | $PbO(s)$ | $\Delta H^{\ominus} = -217$ kJ mol$^{-1}$ |
| $PbO(s)$ | + | $CO(g)$ | → | $Pb(s) + CO_2(g)$ | $\Delta H^{\ominus} = -66$ kJ mol$^{-1}$ |

Calculate the value of the enthalpy change, in kJ mol$^{-1}$, for the following reaction.

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

☒ **A** –243

☒ **B** –111

☒ **C** +111

☒ **D** +243

**(Total for Question 8 = 1 mark)**

**9** Which of the following equations represents a step that is **not** involved in the Born-Haber cycle for lithium iodide, LiI?

☒ **A** $Li(s) + \frac{1}{2}I_2(s) \rightarrow LiI(s)$

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

☒ **C** $Li(s) \rightarrow Li(g)$

☒ **D** $I(g) \rightarrow I^+(g) + e^-$

**(Total for Question 9 = 1 mark)**

**10** Which of the following statements is true?

- ☒ **A** Breaking covalent bonds requires energy and making ionic bonds requires energy.
- ☒ **B** Bond breaking is endothermic whereas bond making is exothermic.
- ☒ **C** Bond breaking is exothermic whereas bond making is endothermic.
- ☒ **D** Breaking ionic bonds releases energy whereas making covalent bonds requires energy.

**(Total for Question 10 = 1 mark)**

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**11** Consider the two equations given below.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -572 \text{ kJ mol}^{-1}$$

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \qquad \Delta H = -484 \text{ kJ mol}^{-1}$$

From this information, calculate the enthalpy change for the following process

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

- ☒ **A** –44 kJ mol$^{-1}$
- ☒ **B** +44 kJ mol$^{-1}$
- ☒ **C** –88 kJ mol$^{-1}$
- ☒ **D** +88 kJ mol$^{-1}$

**(Total for Question 11 = 1 mark)**

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**12** The standard enthalpy change for the formation of ethene, $C_2H_4$, is +52.2 kJ mol$^{-1}$ and that of ethane, $C_2H_6$, is –84.7 kJ mol$^{-1}$.

Calculate the standard enthalpy change for the reaction below, in kJ mol$^{-1}$.

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$$

☒ **A** –32.5

☒ **B** –136.9

☒ **C** +136.9

☒ **D** This cannot be calculated using only the data above.

**(Total for Question 12 = 1 mark)**

**13** Which of the following equations represents a reaction for which the enthalpy change is the standard enthalpy change of formation of water, $\Delta H^{\ominus}_{f,298}$?

☒ **A** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

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

☒ **C** $H_2O(g) \rightarrow H_2O(l)$

☒ **D** $H_2O(s) \rightarrow H_2O(l)$

**(Total for Question 13 = 1 mark)**

**14** Consider the following bond enthalpy values.

| Bond | Bond enthalpy / kJ mol$^{-1}$ |
|---|---|
| CO in carbon monoxide | +1077 |
| O=O | +498 |
| C=O in carbon dioxide | +805 |

The enthalpy change for the reaction

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

in units of kJ mol$^{-1}$ is

☒ **A** –284

☒ **B** +35

☒ **C** +521

☒ **D** +770

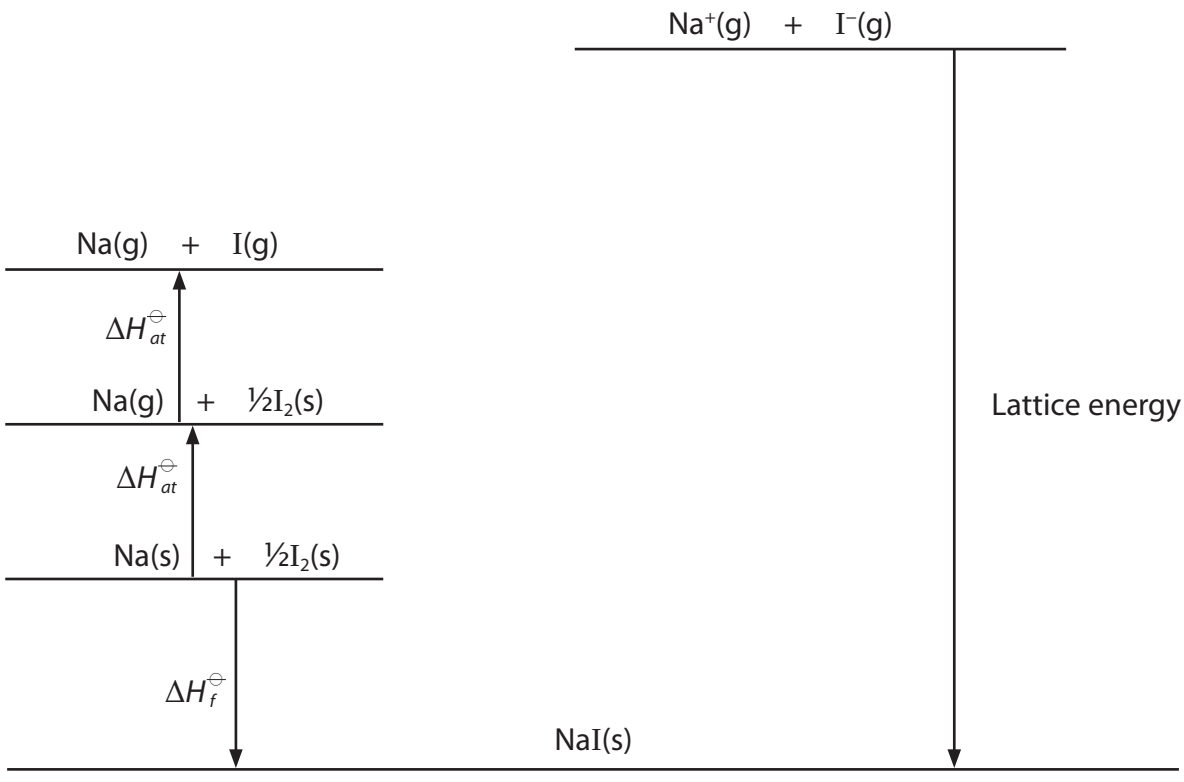
**(Total for Question 14 = 1 mark)**

**15** The following data can be used in the Born-Haber cycle for sodium iodide, NaI.

| Energy change | $\Delta H$ / kJ mol$^{-1}$ |
|---|---|
| Enthalpy change of atomisation of iodine | +107 |
| Enthalpy change of atomisation of sodium | +107 |
| First ionisation energy of sodium | +496 |
| First electron affinity of iodine | −295 |
| Enthalpy change of formation of sodium iodide | −288 |

(a) Complete the Born-Haber cycle diagram for sodium iodide by adding the first ionisation energy of sodium and the first electron affinity of iodine. Include any relevant entities and arrow directions.

**(3)**



(b) Calculate the lattice energy for sodium iodide.

Give a sign and units in your answer.

**(1)**

(c) Explain why the enthalpy changes of atomisation of sodium and of iodine are endothermic. For each substance, state the type of bonding present in the solid.

**(3)**

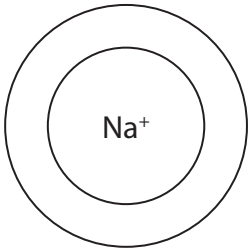
(d) The numerical value for the lattice energy of sodium iodide obtained from the Born-Haber cycle is more negative than the theoretical value.

(i) Explain why the Born-Haber value is more negative than the theoretical value.

**(2)**

(ii) Draw an electron density map for the iodide ion in sodium iodide showing any effect the sodium ion has on the iodide ion.

**(1)**



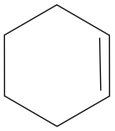

$I^-$

**(Total for Question 15 = 10 marks)**

**16** The reaction of liquid bromine is a standard test for alkenes.

(a) (i) Complete the equation for the reaction of cyclohexene with liquid bromine, using a skeletal formula.

**(1)**



$+ Br_2 \rightarrow$

(ii) What colour change would you see when this reaction occurs?

**(1)**

From ..... to .....

(b) Gaseous but-1-ene is another alkene that readily reacts with liquid bromine.

Using molecular formulae, the equation for the reaction is

$$C_4H_8 + Br_2 \rightarrow C_4H_8Br_2$$

(i) Using the bond enthalpy values in the table, calculate the enthalpy change for this reaction.

**(2)**

| Bond | Bond enthalpy /kJ mol$^{-1}$ |
|---|---|
| C—H | 413 |
| C—C | 347 |
| C═C | 612 |
| C—Br | 290 |
| Br—Br | 193 |

(ii) Give **one** reason why the value calculated for the reaction in part (b)(i) using bond enthalpies is different from the true value.
Do **not** consider experimental error, mean bond enthalpy values or non-standard conditions.

**(1)**

(iii) Using appropriate curly arrows, write the mechanism of the reaction between but-1-ene and bromine.

**(3)**

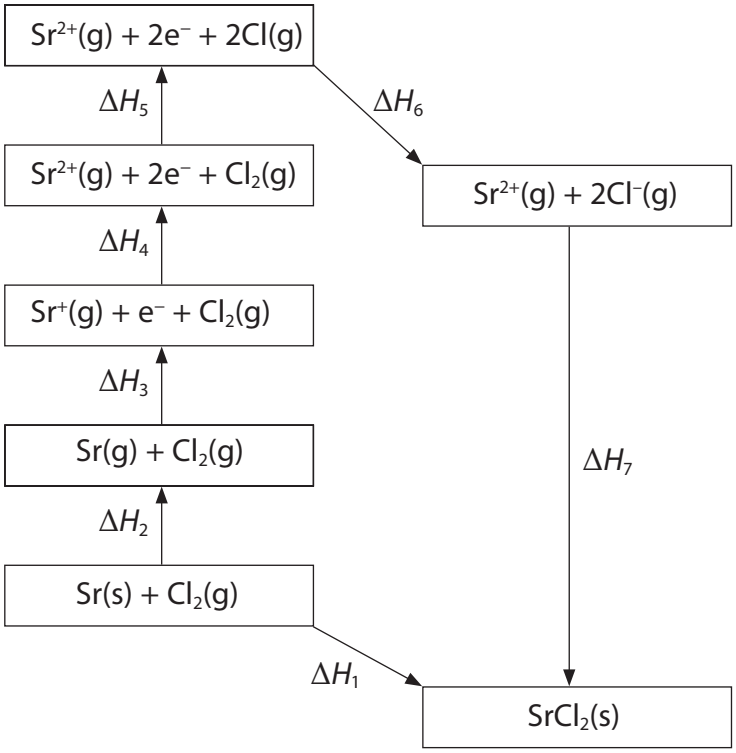
(iv) Identify, by name or by displayed formula, the product formed when bromine **water** is added to but-1-ene.

**(1)**

**(Total for Question 16 = 9 marks)**

**17** Born-Haber cycles can be used to determine experimental values of lattice energies.

(a) The diagram below shows a Born-Haber cycle for the formation of strontium chloride from strontium and chlorine.




Using symbols from $\Delta H_1$ to $\Delta H_7$ as appropriate, identify the

(i) enthalpy change of atomization of strontium

**(1)**

.....

(ii) bond enthalpy of chlorine

**(1)**

.....

(iii) first electron affinity of chlorine

**(1)**

.....

(iv) enthalpy change of formation of strontium chloride

**(1)**

.....

(b) The table below shows the energy changes that are needed to determine the lattice energy of strontium chloride, $SrCl_2$.

| Energy change | $\Delta H$ / kJ mol$^{-1}$ |
|---|---|
| enthalpy change of atomization of strontium | +164 |
| first ionization energy of strontium | +550 |
| second ionization energy of strontium | +1064 |
| enthalpy change of atomization of chlorine, $\frac{1}{2}Cl_2$ | +122 |
| first electron affinity of chlorine | −349 |
| enthalpy change of formation of strontium chloride | −829 |

(i) Define the term **lattice energy**.

**(2)**

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.....

.....

.....

(ii) Calculate the lattice energy of strontium chloride, in kJ mol$^{-1}$.

**(2)**

lattice energy = ..... kJ mol$^{-1}$

*(c) The lattice energies of sodium fluoride and magnesium fluoride are shown in the table below.

| Compound | Lattice energy / kJ $mol^{-1}$ |
|---|---|
| Sodium fluoride, NaF | −918 |
| Magnesium fluoride, $MgF_2$ | −2957 |

Explain, in terms of the sizes and charges of the ions involved, why the lattice energy of $MgF_2$ is more negative than that of NaF.

**(3)**

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**(Total for Question 17 = 11 marks)**

**18** This question is about alkenes.

(a) Give the general formula for the homologous series of alkenes.

**(1)**

(b) Give the **structural** formula of the organic product formed when **ethene**, $CH_2=CH_2$, reacts with

(i) hydrogen

**(1)**

(ii) chlorine

**(1)**

(iii) acidified aqueous potassium manganate(VII)

**(1)**

(iv) bromine **water**

**(1)**

(c) When **propene**, $CH_3CH=CH_2$, reacts with hydrogen chloride, there are **two** possible products, a major product and a minor product.

(i) Draw the **displayed** formulae of these products.

**(2)**

| | |
|---|---|
| | |
| Major product | Minor product |

(ii) Give the mechanism for the reaction of **propene** with hydrogen chloride which forms the major product.

**(3)**

(d) Propene can be polymerized.

(i) Write a balanced equation for the polymerization of propene to form poly(propene), drawing the **displayed** formula of the repeat unit of poly(propene).

**(3)**

(ii) State a problem associated with the disposal of waste poly(propene).

**(1)**

.....

.....

(e) Standard enthalpy changes of combustion can be used to calculate the standard enthalpy change of formation of propene.

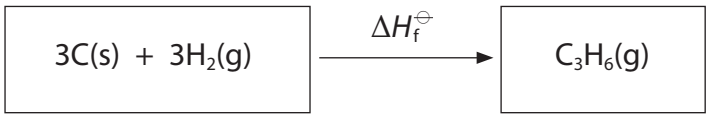
$$3C(s) + 3H_2(g) \longrightarrow C_3H_6(g)$$

Values for some standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, are shown in the table below.

| Substance | $\Delta H_c^{\ominus}$ / kJ mol$^{-1}$ |
|---|---|
| C(s) | −394 |
| $H_2(g)$ | −286 |
| $C_3H_6(g)$ | −2058 |

(i) Complete the Hess cycle below to enable you to calculate $\Delta H_f^{\ominus}$ from combustion data.

**(1)**




(ii) Calculate $\Delta H_f^{\ominus}$, in kJ mol$^{-1}$.

**(2)**

standard enthalpy change of formation of propene = ..... kJ mol$^{-1}$

**(Total for Question 18 = 17 marks)**