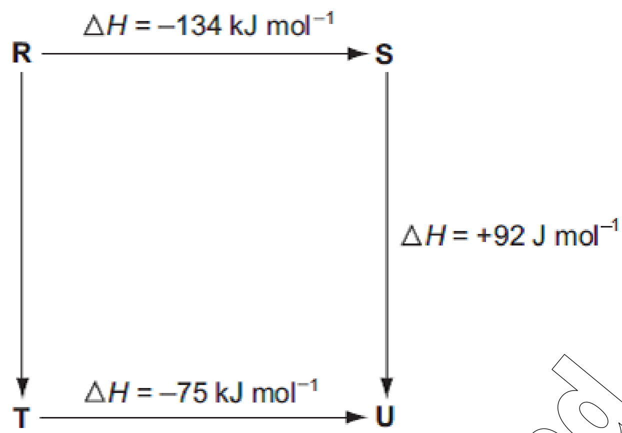
HESS LAW : DRAWING HESS CYCLE

MULTIPLE CHOICE QUESTIONS

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** $\longrightarrow$ **R** is +42 kJ mol^{-1} .

2 The enthalpy change for the transformation **T** $\longrightarrow$ **S** is endothermic.

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

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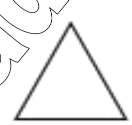
11 The diagram shows the skeletal formula of cyclopropane.



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}

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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

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

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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** $+525\ kJ\ mol^{-1}$

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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

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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

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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

THEORY QUESTIONS

3 For some chemical reactions, such as the thermal decomposition of potassium hydrogencarbonate, $KHCO_3$, the enthalpy change of reaction cannot be measured directly.

In such cases, the use of Hess' Law enables the enthalpy change of reaction to be calculated from the enthalpy changes of other reactions.

(a) State Hess' Law.

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.... [2]

In order to determine the enthalpy change for the thermal decomposition of potassium hydrogencarbonate, two separate experiments were carried out.

experiment 1

30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid (an excess) was placed in a conical flask and the temperature recorded as 21.0 °C.
When 0.0200 mol of potassium carbonate, K_2CO_3, was added to the acid and the mixture stirred with a thermometer, the maximum temperature recorded was 26.2 °C.

(b) **(i)** Construct a balanced equation for this reaction.

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(ii) Calculate the quantity of heat produced in **experiment 1**, stating your units.
Use relevant data from the *Data Booklet* and assume that all solutions have the same specific heat capacity as water.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of K_2CO_3.
Give your answer in kJ mol^{-1} and include a sign in your answer.

(iv) Explain why the hydrochloric acid must be in an excess.

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.... [4]

experiment 2

The experiment was repeated with 0.0200 mol of potassium hydrogencarbonate, $KHCO_3$.
All other conditions were the same.
In the second experiment, the temperature fell from 21.0 °C to 17.3 °C.

(c) **(i)** Construct a balanced equation for this reaction.

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(ii) Calculate the quantity of heat absorbed in **experiment 2**.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of $KHCO_3$.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[3]

(d) When $KHCO_3$ is heated, it decomposes into K_2CO_3, CO_2 and H_2O.

$$2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$$

Use Hess' Law and your answers to **(b)(iii)** and **(c)(iii)** to calculate the enthalpy change for this reaction.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[2]

[Total: 11]

w/11/qp21