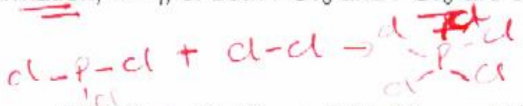
Chemical energetics – 2022 Nov/June AS Chemistry 9701

1. Nov/2022/Paper_11/No.9

The enthalpy changes of formation, $\Delta H_f^\ominus$, of both PCl_3 and PCl_5 are exothermic.

PCl_3 reacts with chlorine.



$$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s) \qquad \Delta H^\ominus_{reaction} = -124\,kJ\,mol^{-1}$$

Which pair of statements is correct?

	statement 1	statement 2
A	$\Delta H^\ominus_{reaction}$ is less negative than $\Delta H_f^\ominus(PCl_5)$.	The Cl_2 bond energy is needed in calculating $\Delta H^\ominus_{reaction}$ from enthalpies of formation.
B	$\Delta H^\ominus_{reaction}$ is more negative than $\Delta H_f^\ominus(PCl_5)$.	The Cl_2 bond energy is needed in calculating $\Delta H^\ominus_{reaction}$ from enthalpies of formation.
[✓ **C**]	$\Delta H^\ominus_{reaction}$ is less negative than $\Delta H_f^\ominus(PCl_5)$.	The Cl_2 bond energy is not needed in calculating $\Delta H^\ominus_{reaction}$ from enthalpies of formation.
D	$\Delta H^\ominus_{reaction}$ is more negative than $\Delta H_f^\ominus(PCl_5)$.	The Cl_2 bond energy is not needed in calculating $\Delta H^\ominus_{reaction}$ from enthalpies of formation.

Can use Hess laws to Convert enthalpy of reaction and formation

PapaCambridge

2. Nov/2022/Paper_11/No.10

A student mixes 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 increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

$NaOH + HCl \rightarrow NaCl + H_2O$

A –150 kJ mol^{-1}

[✓ **B** –60 kJ mol^{-1}]

C –30 kJ mol^{-1}

D –0.15 kJ mol^{-1}

$\frac{25}{1000} \times 0.35\,mol/dm^3$

$= 8.75 \times 10^{-3}$

$8.75 \times 10^{-3} \rightarrow 525\,J$

$1\,mole = 525/8.75 \times 10^{-3}$

$\Delta H = m \times c \times \Delta T$

$= (25+25) \times 4.2 \times 2.5$

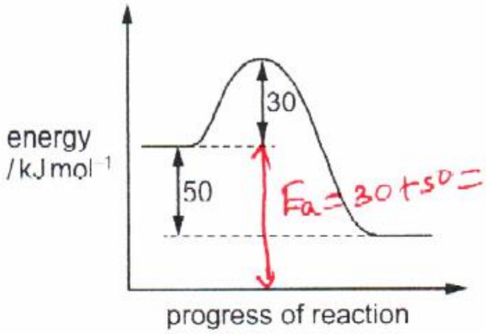
$= 525\,J.$

$\Rightarrow -60\,kJ/mol$

$NH_4^+ \longrightarrow NO_3^-$

3. Nov/2022/Paper_12/No.9

The reaction pathway for the forward reaction of a reversible reaction is shown.



Ea = 30 + 50 = 80 kJ/mol.

Enthalpy change ⇒ exothermic

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}.

PapaCambridge

4. Nov/2022/Paper_12/No.10

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

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

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

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

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

✓ feasible reactions have low activation energies

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

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

[✓ **B**] X is greater than W; Y is greater than Z.

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

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

⇒ reactions that give out heat are exothermic and have a lower activation energy.

5. Nov/2022/Paper_12/No.16

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

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

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

or use bond energies.

$CH_4 \rightarrow C + 4H$.

and $CH_2CH_2 + H_2 \rightarrow C_2H_6$

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

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

Hess law.

1 CH bond = 412

6(C-H) = 412×6 = 2822.

[✓ A] −2822 kJ mol^{-1}

B −2122 kJ mol^{-1}

C −1998 kJ mol^{-1}

D −1772 kJ mol^{-1}

$$\begin{tikzcd} C_2H_4 + H_2 \arrow[rr, "\Delta H_r^\circ"] & & C_2H_6 \\ & 2C + \frac{6}{2}H_2 \arrow[ul] \arrow[ur, "\Delta H_f^\circ"'] & \end{tikzcd}$$

PapaCambridge

6. Nov/2022/Paper_21/No.3(d)

(d) Sulfur, S_8, reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2. SCl_2 forms when sulfur reacts with an excess of chlorine.

reaction **1** $S_8(s) + 4Cl_2(g) \rightarrow 4S_2Cl_2(l)$ $\Delta H_r = -58.2\,kJ\,mol^{-1}$

reaction **2** $S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$ $\Delta H_r = -40.6\,kJ\,mol^{-1}$

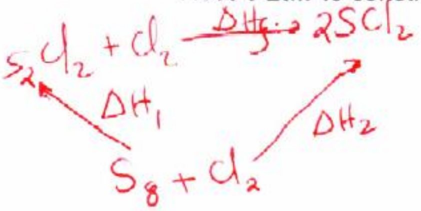
(i) SCl_2 is a cherry-red liquid that reacts vigorously with water to form an acidic solution.

Use this information to deduce the bonding and structure shown by SCl_2.
Explain your answer.

(i) It forms a simple molecular structure, due to its low b.p.

(ii) The bonding is covalent; its hydrolysed. [2]

(ii) Calculate the enthalpy change of formation, ΔH_f, of $SCl_2(l)$. You may find it useful to use Hess's Law to construct an energy cycle.



$(-58.2) + (-40.6)$

$-58.2 + 4(40.6) = 8\Delta H_f.$

$\Delta H_f = -27.6$

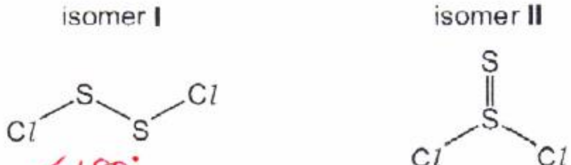
enthalpy change of formation of $SCl_2(l)$, ΔH_f = -27.6 $kJ\,mol^{-1}$ [2]

(iii) State the effect of a decrease in pressure on the position of equilibrium in reaction **2**. Explain your answer.

A decrease in pressure will shift the equilibrium to the left. there are more molecules. [1]

PapaCambridge

Fig. 3.1 shows the two structural isomers of S_2Cl_2.



∠180°

Fig. 3.1

(iv) Define the term structural isomer.

These are organic molecules with the same molecular formula; but different S.F. [2]

(v) Suggest a value for the Cl–S–S bond angle in isomer **I**. Explain your answer.

bond angle = 109 °

explanation Sulfur has two lone pairs of electron and two bonding pairs. - The repulsion from the lone pairs is greater. [2]

(vi) Draw a dot-and-cross diagram to show the bonding in isomer **II**. Show outer shell electrons only.

[2]

PapaCambridge

7. June/2022/Paper_11/No.9

The equation for an enthalpy change is shown. The enthalpy change is Q. (use Hess diagram)

$$2C(s) + 3H_2(g) + 3.5O_2(g) \xrightarrow{Q} 2CO_2(g) + 3H_2O(l)$$

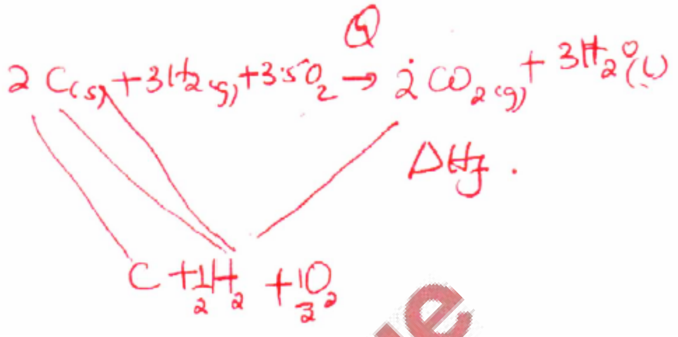
What is the correct expression to calculate Q?

A $2 \times \Delta H^{\ominus}_{c}[CO_2(g)] - 3 \times \Delta H^{\ominus}_{f}[H_2(g)]$

B $3 \times \Delta H^{\ominus}_{f}[H_2O(g)] + 2 \times \Delta H^{\ominus}_{c}[CO_2(g)]$

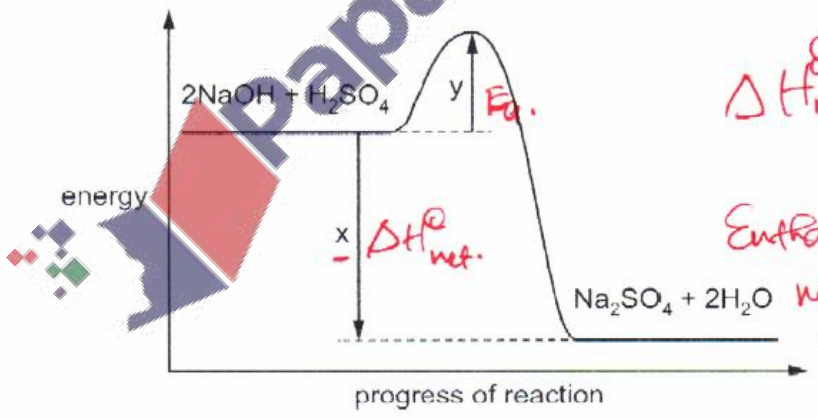
C $2 \times \Delta H^{\ominus}_{f}[CO_2(g)] - 3 \times \Delta H^{\ominus}_{f}[H_2(g)]$

[✓ **D**] $3 \times \Delta H^{\ominus}_{f}[H_2O(l)] + 2 \times \Delta H^{\ominus}_{f}[CO_2(g)]$



8. June/2022/Paper_11/No.10

A reaction pathway diagram for the reaction of aqueous sodium hydroxide and dilute sulfuric acid is shown.



ΔH°neut is exothermic

Enthalpy change of neutralisation is when one mole of H2O is formed.

$x/2$

What is the value of the enthalpy change of neutralisation, ΔH_{neut}?

A x

B x – y

[✓ **C**] $\frac{x}{2}$

D $\frac{(x-y)}{2}$

papaCambridge

9. June/2022/Paper_12/No.9

The standard enthalpy of formation of $NO_2(g)$ is +33.2 kJ mol^{-1}.

The standard enthalpy of formation of $N_2O_4(g)$ is +9.2 kJ mol^{-1}.

What is the standard enthalpy change for the reaction $2NO_2(g) \rightarrow N_2O_4(g)$?

[✓ **A**] −57.2 kJ mol^{-1}

B −24.0 kJ mol^{-1}

C +42.4 kJ mol^{-1}

D +75.6 kJ mol^{-1}

$$\begin{tikzcd} 2NO_2 \arrow[rr] & & N_2O_4 \\ & N_2 + 2O_2 \arrow[ul, "+33.2\times2"] \arrow[ur, "+9.2"'] & \end{tikzcd}$$

$(33.2 \times 2) \times \Delta H_r^{\circ} = 9.2$

$\Delta H_r = -\underline{\underline{57.2}}$

10. June/2022/Paper_12/No.10

Separate samples of 25.0 cm^3 of 0.1 mol dm^{-3} NaOH(aq) are added to each of three different acid solutions, as described. The temperature of each of the solutions was 298 K before mixing.

sample	acid	type of acid	concentration / mol dm^{-3}	volume / cm^3
1	H_2SO_4	strong	0.05	25.0
2	HCl	strong	0.05	25.0
3	CH_3CO_2H	weak	0.05	25.0

Which statement describes the temperature rises that occur on mixing each of these three acids separately with NaOH?

A The temperature rise in all three mixtures is the same.

B The temperature rise using H_2SO_4 and HCl is the same.

C The temperature rise using CH_3CO_2H is greater than using HCl.

[✓ **D**] The greatest temperature rise occurs using H_2SO_4.

⇒ weak acids do not give out much heat.

⇒ write chemical eqns of each and with NaOH.

⇒ calculate moles of each.

PapaCambridge

11. June/2022/Paper_13/No.9

Which equation represents an enthalpy change that is the average bond energy of the C–H bond in methane?

A $\frac{1}{4}C(g) + H(g) \rightarrow \frac{1}{4}CH_4(g)$ ✗

[✓ B] $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$

C $CH_4(g) \rightarrow C(g) + 4H(g)$

D $CH_4(g) \rightarrow CH_3(g) + H(g)$ ✗ ⇒ not avg, you need to break all the 4 bonds.

12. June/2022/Paper_13/No.10

Magnesium carbonate decomposes when heated in a Bunsen burner flame.

Values for the standard enthalpies of formation, ΔH_f°, of the species involved are shown.

ΔH_f° $MgCO_3$ = –1095.8 kJ mol^{-1}

ΔH_f° MgO = –601.7 kJ mol^{-1}

ΔH_f° CO_2 = –393.5 kJ mol^{-1}

Use Hess diagram

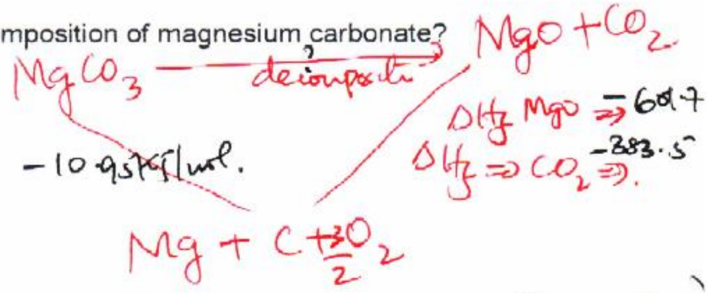
What is the standard enthalpy change for the decomposition of magnesium carbonate?

[✓ A] +100.6 kJ mol^{-1}

B +887.6 kJ mol^{-1}

C +1095.8 kJ mol^{-1}

D +2091 kJ mol^{-1}



PapaCambridge

13. June/2022/Paper_21/No.1(f)

(f) Magnesium, Mg, burns in oxygen, O_2.
The activation energy, E_a, for this reaction is +148 kJ mol^{-1}.

(i) State **one** observation when magnesium burns in oxygen.
Do **not** refer to temperature changes in your answer.

Burns with a bright white flame. [1]

(ii) On Fig. 1.1:

- sketch a reaction pathway diagram for the reaction that occurs when Mg burns in O_2
- label the diagram to show the enthalpy change, ΔH, and the activation energy, E_a, for the reaction.

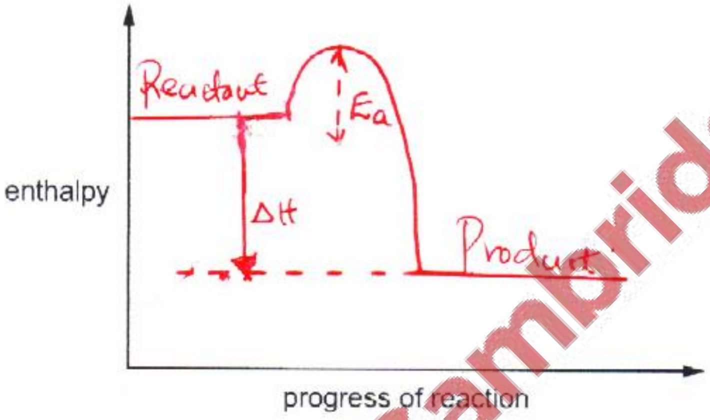


Fig. 1.1

[3]

PapaCambridge

14. June/2022/Paper_22/No.1(b)

(b) When magnesium is heated in air, magnesium oxide, MgO, is the major product. Smaller amounts of magnesium nitride, Mg_3N_2, are also made.

(i) Calculate the oxidation number for magnesium and for the nitrogen species in Mg_3N_2 to complete Table 1.1.

Table 1.1

species	magnesium in Mg_3N_2	nitrogen in Mg_3N_2
oxidation number	+ II or 2+	− III or 3−

[1]

(ii) Identify the type of reaction which takes place between magnesium and nitrogen. Explain your answer.

Redox reaction. Mg loses its electrons to Nitrogen.

[1]

(iii) Define enthalpy change of formation.

Energy change when 1 mol of a substance is formed from its elements under standard conditions.

[2]

(iv) When 3.645 g of Mg(s) burns in excess $N_2(g)$ to form $Mg_3N_2(s)$, 23.05 kJ of energy is released.

Calculate the enthalpy change of formation, ΔH_f, of Mg_3N_2. Show your working.

Mg : N_2
3 : 1
moles of N_2 = $0.15/3$ = 0.05

$$\frac{23.05\ kJ}{0.05} = 461\ kJ/mol.$$

3   1

$$3Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$$

$$\frac{3.645g}{24.3}$$

0.15 moles

0.05 moles

$\Delta H_f(Mg_3N_2)$ = −461 kJ/mol [3]

[Total: 9]

PapaCambridge

15. June/2022/Paper_23/No.3a(ii)

(ii) Calculate the bond energy of C≡O using the bond energy values in Table 3.1 and the enthalpy change, Δ*H*, for the thermal decomposition of **G**. Show your working.

Table 3.1

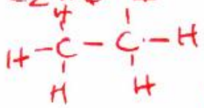
bond	bond energy / kJ mol⁻¹
C–C	350
C–O (in **G**)	360
C–H	410

$C_4H_{10}O_{(g)} \xrightarrow{ht} C_2H_{6(g)} + \overset{x\cdot}{CO} + CH_4$

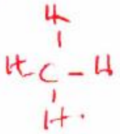
ΔH<u>react</u> $(410\times10)+(2\times360)+(2\times350) = 53$[illegible] kJ/mol (+).

$-7 = -(x+4450)+(5520)$

C_2H_6



CH₄ →



<u>Product</u>

$\Rightarrow x + (10\times410) + 350$

$\Rightarrow x + 4450.$

bond energy (C≡O) = ...+1077........ kJ mol⁻¹ [2]

PapaCambridge