

5. Chemical energetics

5.2 Hess's law

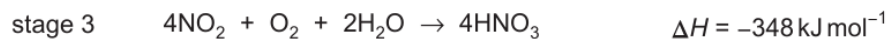
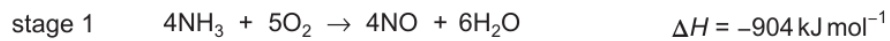
Paper 1

Question Paper

- 1** Nitric acid is made industrially by the oxidation of ammonia. The overall equation for the process is shown.



The process happens in three stages. The equations and enthalpy changes for these stages are given.



What is the enthalpy change of the process shown in equation 1?

- A** $-1480 \text{ kJ mol}^{-1}$
- B** -370 kJ mol^{-1}
- C** $-341.5 \text{ kJ mol}^{-1}$
- D** $+82 \text{ kJ mol}^{-1}$

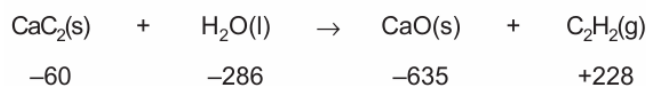
- 2 Two standard enthalpy change of formation values are given.

$$\Delta H_f^\ominus [\text{VCl}_2] = -452 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\ominus [\text{VCl}_3] = -573 \text{ kJ mol}^{-1}$$

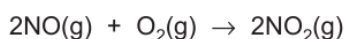
What is the enthalpy change for the reaction $3\text{VCl}_2 \rightarrow 2\text{VCl}_3 + \text{V}$?

- A -210 kJ mol^{-1} B -121 kJ mol^{-1} C $+121 \text{ kJ mol}^{-1}$ D $+210 \text{ kJ mol}^{-1}$
- 3 Calcium carbide, CaC_2 , reacts with water, as shown. The data below the equation show, in kJ mol^{-1} , the standard enthalpies of formation of the compounds involved.

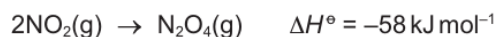


What is the standard enthalpy change of the reaction shown?

- A -753 kJ mol^{-1}
 B -61 kJ mol^{-1}
 C $+61 \text{ kJ mol}^{-1}$
 D $+753 \text{ kJ mol}^{-1}$
- 4 Nitrogen monoxide is rapidly oxidised to nitrogen dioxide.

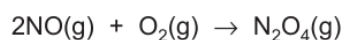


Nitrogen dioxide can then dimerise to form dinitrogen tetroxide.



$$\Delta H_f^\ominus \text{NO} = +91 \text{ kJ mol}^{-1} \text{ and } \Delta H_f^\ominus \text{NO}_2 = +34 \text{ kJ mol}^{-1}$$

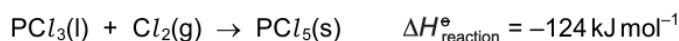
What is the value of the standard enthalpy change for the reaction shown?



- A $+56 \text{ kJ mol}^{-1}$ B -1 kJ mol^{-1} C -115 kJ mol^{-1} D -172 kJ mol^{-1}

- 5 The enthalpy changes of formation, ΔH_f^\ominus , of both PCl_3 and PCl_5 are exothermic.

PCl_3 reacts with chlorine.



Which pair of statements is correct?

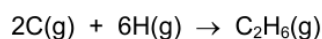
	statement 1	statement 2
A	$\Delta H_{\text{reaction}}^\ominus$ is less negative than $\Delta H_f^\ominus(\text{PCl}_5)$.	The Cl_2 bond energy is needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.
B	$\Delta H_{\text{reaction}}^\ominus$ is more negative than $\Delta H_f^\ominus(\text{PCl}_5)$.	The Cl_2 bond energy is needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.
C	$\Delta H_{\text{reaction}}^\ominus$ is less negative than $\Delta H_f^\ominus(\text{PCl}_5)$.	The Cl_2 bond energy is not needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.
D	$\Delta H_{\text{reaction}}^\ominus$ is more negative than $\Delta H_f^\ominus(\text{PCl}_5)$.	The Cl_2 bond energy is not needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.

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

reaction	$\Delta H/\text{kJ mol}^{-1}$
$\text{C}(\text{s}) + 2\text{H}_2(\text{g}) \rightarrow \text{CH}_4(\text{g})$	-76
$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$	-890
$\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g})$	1648
$3\text{C}(\text{s}) + 4\text{H}_2(\text{g}) \rightarrow \text{C}_3\text{H}_8(\text{g})$	-105

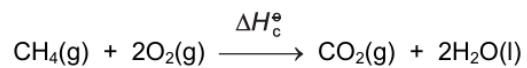
bond	bond enthalpy / kJ mol^{-1}
H-H	436
C-C	350
C=C	610
C=O	805

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



- A** $-2822 \text{ kJ mol}^{-1}$
B $-2122 \text{ kJ mol}^{-1}$
C $-1998 \text{ kJ mol}^{-1}$
D $-1772 \text{ kJ mol}^{-1}$

- 7 ΔH_1° is the standard enthalpy of formation of methane.
 ΔH_2° is the standard enthalpy of combustion of carbon.
 ΔH_3° is the standard enthalpy of combustion of hydrogen.



Which expression is equivalent to ΔH_c° ?

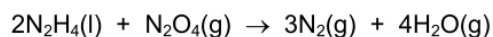
- A $\Delta H_1^\circ - \Delta H_2^\circ + \Delta H_3^\circ$
B $\Delta H_1^\circ - 2\Delta H_3^\circ - \Delta H_2^\circ$
C $\Delta H_2^\circ - \Delta H_3^\circ + \Delta H_1^\circ$
D $\Delta H_2^\circ + 2\Delta H_3^\circ - \Delta H_1^\circ$
- 8 The following data are needed for this question.

$$\Delta H_f^\circ(\text{N}_2\text{H}_4(\text{l})) = 50.6 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ(\text{N}_2\text{O}_4(\text{g})) = 9.2 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ(\text{H}_2\text{O}(\text{g})) = -241.8 \text{ kJ mol}^{-1}$$

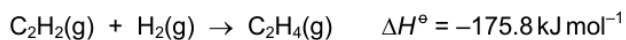
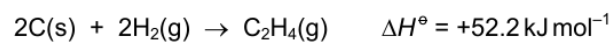
Hydrazine, $\text{N}_2\text{H}_4(\text{l})$, reacts with dinitrogen tetraoxide, $\text{N}_2\text{O}_4(\text{g})$, to form nitrogen gas and water vapour.



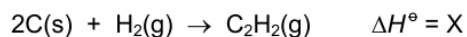
What is the enthalpy change for this reaction?

- A $-1077.6 \text{ kJ mol}^{-1}$
B $-856.8 \text{ kJ mol}^{-1}$
C $-301.6 \text{ kJ mol}^{-1}$
D $-182.0 \text{ kJ mol}^{-1}$

- 9 Two reactions and their enthalpy changes are shown.

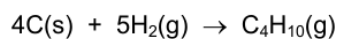


These data can be used to calculate the enthalpy change for the reaction shown.



What is the value of X?

- A $-228.0 \text{ kJ mol}^{-1}$
B $-123.6 \text{ kJ mol}^{-1}$
C $+123.6 \text{ kJ mol}^{-1}$
D $+228.0 \text{ kJ mol}^{-1}$
- 10 Enthalpy changes of combustion can be used to determine enthalpy changes of formation. The following equation represents the enthalpy change of formation of butane.



By using the following standard enthalpy of combustion data, what is the value of the standard enthalpy change of formation, ΔH_f^\ominus , of butane?

substance	$\Delta H_c^\ominus / \text{kJ mol}^{-1}$
C(s)	-394
H ₂ (g)	-286
C ₄ H ₁₀ (g)	-2877

- A $-5883 \text{ kJ mol}^{-1}$
B -129 kJ mol^{-1}
C $+129 \text{ kJ mol}^{-1}$
D $+2197 \text{ kJ mol}^{-1}$