

23. Chemical energetics

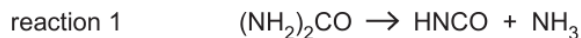
23.3 Entropy change, ΔS

Paper 4

Question Paper

- 1 (b) The exhaust systems of many diesel-fuelled cars contain an additional system to reduce vehicle emissions. This uses a liquid that is added to the exhaust system.

This liquid contains urea, $(\text{NH}_2)_2\text{CO}$, which decomposes on heating to isocyanic acid, HNCO , and ammonia.



Isocyanic acid reacts with water vapour to form ammonia and carbon dioxide.



Some values for standard enthalpy changes of formation, ΔH_f^\ominus , and standard entropies, S^\ominus , are given in Table 5.1.

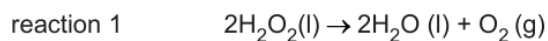
Table 5.1

compound	$\Delta H_f^\ominus/\text{kJ mol}^{-1}$	$S^\ominus/\text{JK}^{-1} \text{mol}^{-1}$
$\text{HNCO}(\text{g})$	-101.7	+238.2
$\text{H}_2\text{O}(\text{g})$	-241.8	+188.8
$\text{NH}_3(\text{g})$	-45.9	+192.8
$\text{CO}_2(\text{g})$	-393.5	+213.8

- (i) Explain what is meant by the term entropy of a system.

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 [1]

- 2 Hydrogen peroxide is a liquid at 298 K. It is moderately stable under room conditions but will decompose quickly if a catalyst is added.



- (a) (i) Define entropy.

.....
 [1]

- (ii) Predict the sign of the standard entropy change of reaction 1.

Explain your answer.

sign

explanation
 [1]

- 3 Potassium chloride, KCl , and magnesium chloride, $MgCl_2$, are both ionic solids.

Table 1.1

energy change	value/ kJ mol^{-1}
standard enthalpy change of solution, $\Delta H_{\text{sol}}^{\ominus}$, of KCl	+15
lattice energy, $\Delta H_{\text{latt}}^{\ominus}$, of $KCl(s)$	-701
standard enthalpy change of hydration, $\Delta H_{\text{hyd}}^{\ominus}$, of K^+	-322
standard enthalpy change of hydration, $\Delta H_{\text{hyd}}^{\ominus}$, of Cl^-	-364
standard enthalpy change of solution, $\Delta H_{\text{sol}}^{\ominus}$, of $MgCl_2$	-155
lattice energy, $\Delta H_{\text{latt}}^{\ominus}$, of $MgCl_2(s)$	-2493

- (e) (i) Explain what is meant by entropy, S .

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 [1]

- (ii) Potassium chloride is very soluble in water at 20°C .

Explain the solubility of potassium chloride by reference to change in entropy, ΔS .

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 [1]

- (iii) Use the Gibbs equation and your answer to (e)(ii) to predict whether potassium chloride is more soluble in water at 20°C or at 80°C . Explain your answer.

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 [1]

- 4 Calcium chloride, CaCl_2 , is an ionic solid.

The values of some energy changes are shown in Table 1.1.

Table 1.1

energy change	value / kJ mol^{-1}
lattice energy, $\Delta H_{\text{latt}}^\circ$, $\text{CaCl}_2(\text{s})$	-2237
standard enthalpy change of atomisation of calcium	+193
first ionisation energy of calcium	+590
second ionisation energy of calcium	+1150
standard enthalpy change of atomisation of chlorine	+121
first electron affinity of chlorine	-364

- (e) Calcium fluoride, $\text{CaF}_2(\text{s})$, can be synthesised directly from its elements.

The value of $\Delta H_f^\circ(\text{CaF}_2(\text{s}))$ is $-1214 \text{ kJ mol}^{-1}$.

- (i) Predict the sign of the entropy change, ΔS° , for this synthesis. Explain your answer.

The sign of the entropy change is

explanation

..... [1]

- 5 (c) (i) Explain what is meant by the term *entropy of a system*.

.....
 [1]

- (ii) Place one tick (\checkmark) in each row of the table to show the sign of each entropy change, ΔS .

process	ΔS is negative	ΔS is zero	ΔS is positive
NaCl dissolving in water			
water solidifying to ice			

[1]

- 6 (a) Explain what is meant by the term *entropy of a system*.

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..... [1]

- (b) State and explain whether the entropy change of each of the following processes is positive or negative. Do not consider the entropy change of the surroundings.

- liquid water at 80 °C is cooled to 60 °C

The entropy change is because

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- solid calcium chloride is added to water and the mixture is stirred

The entropy change is because

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- the change corresponding to the lattice energy of calcium chloride, $\Delta H_{\text{latt}} \text{CaCl}_2(\text{s})$, takes place

The entropy change is because

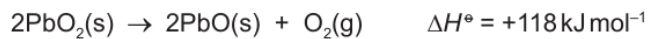
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[3]

- 7 The table shows some standard entropy data.

substance	standard entropy, S^\ominus / $\text{JK}^{-1}\text{mol}^{-1}$
$\text{PbO}_2(\text{s})$	77
$\text{PbO}(\text{s})$	69
$\text{O}_2(\text{g})$	205

Lead(IV) oxide, PbO_2 , decomposes to lead(II) oxide, PbO , and oxygen when heated.



- (a) Use the data to calculate the value of ΔS^\ominus for this reaction.

$$\Delta S^\ominus = \dots\dots\dots \text{JK}^{-1}\text{mol}^{-1} \quad [2]$$

- (c) Solid lead(II) oxide can be made by heating lead metal in air.

Predict the **sign** of the standard entropy change of this reaction. Explain your answer.

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 [1]