How Far? - Entropy

Question Paper

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Rates, Equilibria & Further Organic Chemistry
Sub Topic	How Far? - Entropy
Booklet	Question Paper

Time Allowed: **48 minutes**

Score: **/40**

Percentage: **/100**

Grade Boundaries:

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

1 In which of the following reactions is there a **decrease** in the entropy of the system?

☒ **A** $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

☒ **B** $Ca(OH)_2(s) \rightarrow CaO(s) + H_2O(l)$

☒ **C** $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

☒ **D** $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

(Total for Question 1 = 1 mark)

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2 Which of the following statements is always true for an exothermic reaction?

☒ **A** $\Delta S_{surroundings}$ doubles when the temperature in kelvin doubles.

☒ **B** $\Delta S_{surroundings}$ doubles when the natural log of the temperature in kelvin, ln$T$, doubles.

☒ **C** The equilibrium constant, K, doubles when ΔS_{total} doubles.

☒ **D** The natural log of the equilibrium constant, ln$K$, doubles when ΔS_{total} doubles.

(Total for Question 2 = 1 mark)

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3 When one mole of magnesium chloride dissolves in water, the enthalpy change, $\Delta H_{solution}$, is more negative than the corresponding change for sodium chloride.

One explanation for this difference is that

☒ **A** the lattice enthalpy for magnesium chloride is more negative than the lattice enthalpy for sodium chloride.

☒ **B** the $\Delta H_{hydration}$ of magnesium ions is more negative than $\Delta H_{hydration}$ of sodium ions.

☒ **C** the $\Delta H_{formation}$ of magnesium chloride is more negative than $\Delta H_{formation}$ of sodium chloride.

☒ **D** magnesium chloride has more covalent character than sodium chloride.

(Total for Question 3 = 1 mark)

4 The table shows some data about metal ions, non-metal ions and their compounds.

Ion	Enthalpy change of hydration / kJ mol^{-1}	Compound	Lattice energy / kJ mol^{-1}
$Sr^{2+}(g)$	–1443	$SrF_2(s)$	–2492
$F^-(g)$	–483		
$Rb^+(g)$	–297	RbCl(s)	–685
$Cl^-(g)$	–340		

Use the data in the following calculations.

(a) What is the standard enthalpy change, in kJ mol^{-1}, for the following process?

$$Sr^{2+}(g) + 2F^-(g) \rightarrow Sr^{2+}(aq) + 2F^-(aq)$$

(1)

☒ **A** –477

☒ **B** –960

☒ **C** –1926

☒ **D** –2409

(b) What is the standard enthalpy change of solution, in kJ mol^{-1}, for rubidium chloride, RbCl?

(1)

☒ **A** –1322

☒ **B** –48

☒ **C** +48

☒ **D** +1322

(Total for Question 4 = 2 marks)

5 Which of the following is the correct order of **decreasing** entropy?

	Highest entropy	Middle entropy	Lowest entropy
☒ **A**	ice at 0 °C	water at 0 °C	steam at 120 °C
☒ **B**	ice at 0 °C	steam at 120 °C	water at 100 °C
☒ **C**	steam at 100 °C	water at 0 °C	ice at –20 °C
☒ **D**	steam at 100 °C	ice at –20 °C	water at 100 °C

(Total for Question 5 = 1 mark)

6 Ethanol burns in excess oxygen to produce carbon dioxide and water.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

The standard molar entropies of the reactants and products at 298 K are given in the table below.

Substance	$S^{\ominus}$/J mol^{-1} K^{-1}
$C_2H_5OH(l)$	161
$O_2(g)$	205
$CO_2(g)$	214
$H_2O(l)$	70

The value of $\Delta S^{\ominus}_{system}$ for this reaction, in J mol^{-1} K^{-1}, is

☒ **A** –138

☒ **B** –82

☒ **C** +82

☒ **D** +138

(Total for Question 6 = 1 mark)

7 Nitrogen reacts with hydrogen to form ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.2 \text{ kJ mol}^{-1}$$

What is the value of $\Delta S^{\ominus}_{\text{surroundings}}$, in J mol^{-1} K^{-1}, for this reaction at 25 °C?

☒ **A** −3688

☒ **B** −309.4

☒ **C** +309.4

☒ **D** +3688

(Total for Question 7 = 1 mark)

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8 The signs of $\Delta H^{\ominus}_{\text{reaction}}$ and $\Delta S^{\ominus}_{\text{system}}$ for four different gaseous reactions are shown in the table. Which reaction must be thermodynamically feasible at **all** temperatures?

	$\Delta H^{\ominus}_{\text{reaction}}$	$\Delta S^{\ominus}_{\text{system}}$
☒ **A**	negative	negative
☒ **B**	negative	positive
☒ **C**	positive	negative
☒ **D**	positive	positive

(Total for Question 8 = 1 mark)

9 Use the data in the table to calculate the enthalpy change of solution of calcium chloride, $CaCl_2$.

Lattice energy of calcium chloride	–2258 kJ mol^{-1}
Hydration enthalpy of Ca^{2+}	–1650 kJ mol^{-1}
Hydration enthalpy of Cl^-	–364 kJ mol^{-1}

The enthalpy change of solution of calcium chloride, in kJ mol^{-1}, is

☒ **A** –244

☒ **B** –120

☒ **C** +120

☒ **D** +244

(Total for Question 9 = 1 mark)

10 The expression that relates ΔS_{system} to the equilibrium constant, K, for a reaction is

☒ **A** $\Delta S_{system} = R\ln K + \Delta H/T$

☒ **B** $\Delta S_{system} = R\ln K - \Delta H/T$

☒ **C** $\Delta S_{system} = T\ln K + \Delta H/R$

☒ **D** $\Delta S_{system} = T\ln K - \Delta H/R$

(Total for Question 10 = 1 mark)

11 Energy is given out when one mole of gaseous strontium ions is hydrated.

$$Sr^{2+}(g) + aq \rightarrow Sr^{2+}(aq)$$

This reaction is less exothermic than the corresponding reaction for magnesium ions, $Mg^{2+}(g)$, because

- ☒ **A** the sum of the first two ionization energies of magnesium is more than that of strontium.
- ☒ **B** the lattice energies of magnesium compounds are more exothermic than the lattice energies of corresponding strontium compounds.
- ☒ **C** the solubility of magnesium hydroxide is less than the solubility of strontium hydroxide.
- ☒ **D** the ionic radius of Mg^{2+} is less than the ionic radius of Sr^{2+}.

(Total for Question 11 = 1 mark)

12 Use the data below to calculate the enthalpy change of solution of magnesium chloride.

Lattice energy of magnesium chloride	−2526 kJ mol^{-1}
Enthalpy of hydration of $Mg^{2+}(g)$	−2003 kJ mol^{-1}
Enthalpy of hydration of $Cl^{-}(g)$	−340 kJ mol^{-1}

The enthalpy change of solution of magnesium chloride, in kJ mol^{-1}, is

- ☒ **A** +183
- ☒ **B** +157
- ☒ **C** −157
- ☒ **D** −183

(Total for Question 12 = 1 mark)

13 Nitrogen monoxide, NO, reacts with oxygen as shown below.

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g) \qquad \Delta H^{\ominus} = -57 \text{ kJ mol}^{-1}$$

(a) (i) Calculate the standard entropy change of the system, $\Delta S^{\ominus}_{\text{system}}$.

The standard molar entropy of $\tfrac{1}{2}O_2(g)$ is 102.5 J mol^{-1} K^{-1}.

Use other standard molar entropy values from your Data Booklet.

Include a sign and units in your answer.

(2)

(ii) Calculate the entropy change of the surroundings, $\Delta S^{\ominus}_{\text{surroundings}}$ at 298 K and hence the total entropy change, $\Delta S^{\ominus}_{\text{total}}$ at this temperature.

Include a sign and units in your answers.

(2)

(iii) Calculate the temperature at which the reaction ceases to be spontaneous.

(2)

(b) Nitrogen monoxide and carbon monoxide are formed in car engines. To prevent these pollutant gases being released into the atmosphere, car exhausts are fitted with a catalyst and the reaction below occurs.

$$CO(g) + NO(g) \rightarrow CO_2(g) + \tfrac{1}{2}N_2(g)$$

At the temperature of the car exhaust, ΔS_{total} for this reaction is positive.

Suggest why this reaction needs a catalyst.

(1)

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(Total for Question 13 = 7 marks)

14 This question is about sucrose, the chemical commonly known as sugar. Some thermochemical data for sucrose and oxygen are given in the table below.

Standard entropy of sucrose, $S^{\ominus}$ [$C_{12}H_{22}O_{11}(s)$]	+392.4 J mol^{-1} K^{-1}
Standard enthalpy change of combustion of sucrose, $\Delta H_c^{\ominus}$	–5639.7 kJ mol^{-1}
Standard entropy of oxygen, $S^{\ominus}$ [$\frac{1}{2}O_2(g)$]	+102.5 J mol^{-1} K^{-1}

The equation for the complete combustion of sucrose, $C_{12}H_{22}O_{11}$, is

$$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$$

(a) (i) Calculate the standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this combustion, using the data given in the table and your Data Booklet. Include a sign and units in your answer.

(3)

(ii) Calculate the standard entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$, for this combustion at 298 K. Include a sign and units in your answer.

(2)

(iii) Calculate the total standard entropy change for the combustion, $\Delta S^{\ominus}_{total}$, at 298 K.

State the significance of your answer.

(2)

(iv) State and explain the effect, if any, of increasing the temperature on $\Delta S^{\ominus}_{surroundings}$, $\Delta S^{\ominus}_{total}$ and the extent of the reaction.

(3)

(v) Icing sugar can be hazardous when it is being finely powdered in a factory.

Explain why sucrose is stable at room temperature, in spite of your answer to part (iii), but its manufacture is hazardous.

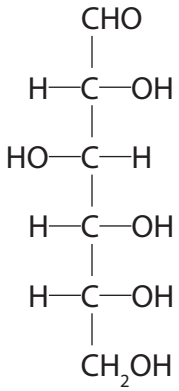
(2)

(vi) Suggest **two** risks associated with high levels of sucrose in the diet.

(2)

(b) Sucrose can be hydrolysed by warming with dilute hydrochloric acid to form glucose and fructose.

In aqueous solution, a structure of glucose is



(i) Circle or mark with an asterisk (*) all the chiral centres on the structure of glucose.

(2)

(ii) State the physical property associated with molecules which have chiral centres.

(1)

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(iii) State what change you would expect to see when glucose is boiled with Benedict's or Fehling's solutions.

Explain the chemistry involved in this reaction.

(3)

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(Total for Question 14 = 20 marks)