IB Chemistry HL - R1.4

Entropy and spontaneity

Exercises + Practice questions

Official answers appended at the end

Exercise

Q1. Identify the process expected to have a value of ΔS closest to zero.

A $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$ **B** $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

C $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ **D** $H_2O(l) \rightarrow H_2O(g)$

Q2. Identify the processes which have an associated increase in entropy.

I. $Br_2(g) \rightarrow Br_2(l)$

II. $Br_2(g) \rightarrow 2Br(g)$

III. $KBr(s) \rightarrow K^+(aq) + Br^-(aq)$

A I and II **B** I and III **C** II and III **D** I, II and III

Q3. Which is the best description of the entropy and enthalpy changes accompanying the sublimation of iodine?

$$I_2(s) \rightarrow I_2(g)$$

A ΔS +, ΔH +, reaction is endothermic

B ΔS +, ΔH −, reaction is exothermic

C ΔS −, ΔH +, reaction is endothermic

D ΔS −, ΔH −, reaction is exothermic

Q4. Identify the reaction which has the largest increase in entropy.

A $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

B $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

C $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

D $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

Q5. Predict the entropy change ΔS for the following reactions.

(a) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

(b) $3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$

(c) $Ba(OH)_2{\cdot}8H_2O(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(aq) + 2NH_3(aq) + 10H_2O(l)$

Q6. Sketch a graph to show how the entropy of a solid changes as the temperature increases.

Q7. Calculate the entropy change ΔS for the Haber process, shown below, using tabulated standard molar entropies at 25 °C.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Q8. Calculate the standard entropy change associated with the formation of methane from its elements.

Q9. Calculate the standard entropy change associated with the combustion of one molecule of hydrogen.

Exercise

Q10. The equation for the complete combustion of methane is shown below.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

Which is the best description of the enthalpy and entropy changes for the process?

	$\Delta H^\ominus$	$\Delta S^\ominus$
A	+	+
B	+	−
C	−	+
D	−	−

Q11. Ammonium chloride dissolves in water spontaneously in an endothermic process. Identify the best explanation for these observations.

A Endothermic processes are energetically favourable.

B The bonds in solid NH_4Cl are very weak.

C The entropy change of the system drives the process.

D The entropy change of the surroundings drives the process.

Q12. The enthalpy and entropy changes for the reaction

$$A(s) + B(aq) \rightarrow C(aq) + D(g)$$

are $\Delta H^\ominus = 100\,kJ\,mol^{-1}$ and $\Delta S^\ominus = 100\,J\,K^{-1}\,mol^{-1}$

What does this tell you about the reaction?

A The reaction is not spontaneous at any temperature.

B The reaction is spontaneous at all temperatures.

C The reaction is spontaneous at all temperatures below 1000 °C.

D The reaction is spontaneous at all temperatures above 1000 K.

Q13. Calculate $\Delta G^\ominus$ for the thermal decomposition of calcium carbonate:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

from the following data, and comment on the significance of the value obtained.

Compound	$\Delta G_f^\ominus$ / **kJ mol^{-1}**
$CaCO_3(s)$	−1129
$CaO(s)$	−604
$CO_2(g)$	−394

Q14. Consider the reaction between aqueous copper sulfate and zinc.

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

$$\Delta H^\ominus = -217\,kJ\,mol^{-1};\ \Delta G^\ominus = -212\,kJ\,mol^{-1}$$

(a) Calculate the entropy change of the reaction at 298 K and comment on the value.

(b) Deduce how much electrical energy can be obtained from this reaction.

from a reaction.

Exercise

Q15. Which property of an element has a value of zero in its standard state?

I. $\Sigma\Delta H_f^\ominus$ II. $S^\ominus$ III. $\Sigma\Delta G_f^\ominus$

A I and II **B** I and III **C** II and III **D** I, II and III

Q16. Identify the combination of ΔH and ΔS which results in a reaction being spontaneous at low temperatures but non-spontaneous at higher temperatures.

A $\Delta S-$ and $\Delta H-$ **B** $\Delta S+$ and $\Delta H-$

C $\Delta S-$ and $\Delta H+$ **D** $\Delta S+$ and $\Delta H+$

Q17. Identify the combination of ΔH and ΔS which leads to a reaction that is **not** spontaneous at low temperatures but becomes spontaneous at higher temperatures.

A $\Delta H-$ and $\Delta S-$ **B** $\Delta H-$ and $\Delta S+$

C $\Delta H+$ and $\Delta S-$ **D** $\Delta H+$ and $\Delta S+$

Q18. The ΔH and ΔS values for the combustion of hydrogen are both negative. Which is the correct description of this reaction at different temperatures?

	Low temperature	High temperature
A	not spontaneous	not spontaneous
B	spontaneous	not spontaneous
C	spontaneous	spontaneous
D	not spontaneous	spontaneous

Q19. Magnesium carbonate, $MgCO_3$, is a white solid that occurs in nature as the mineral magnesite.

Magnesite decomposes to the oxide at temperatures above 540 °C.

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

Identify the correct description of this reaction at 800 °C.

	ΔG	ΔH	ΔS
A	+	+	+
B	+	−	−
C	−	+	+
D	−	+	−

Q20. Calculate ΔG at 2000 K for the thermal decomposition of calcium carbonate from the data given in the worked example.

Q21. The standard enthalpy change for the formation of ethanol, $C_2H_5OH(l)$, and its molar entropy are given in Section 13 of the data booklet.

(a) Write an equation for the formation of ethanol.

(b) Calculate the entropy change for this process. The entropies of its constituent elements are:

$C(graphite) = 5.7\ J\ K^{-1}\ mol^{-1}$

$H_2(g) = 130.6\ J\ K^{-1}\ mol^{-1}$

$O_2(g) = 102.5\ J\ K^{-1}\ mol^{-1}$

(c) Calculate the standard Gibbs energy change of formation of ethanol at 500 K.

(d) Deduce whether the reaction is spontaneous at 500 K, and give a reason.

(e) Predict the effect, if any, of an increase in temperature on the spontaneity of this reaction.

Q22. **(a)** Use data from Section 13 of the data booklet and additional data ($\Delta H_f^{\ominus}(H_2O(s)) = -292\ kJ\ mol^{-1}$) to calculate the enthalpy change that occurs when ice melts.

(b) The entropy change when ice melts is $22.0\ J\ K^{-1}\ mol^{-1}$. Deduce a value for the melting point of ice.

Exercise

Q23. Which of the following correctly describes the entropy and Gibbs energy of a system at equilibrium?

	Entropy, S	Gibbs energy, G
A	maximum value	maximum value
B	minimum value	maximum value
C	maximum value	minimum value
D	minimum value	minimum value

Q24. What signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ result in a complete reaction at all temperatures?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A	−	−
B	+	−
C	−	+
D	+	+

Q25. Which conditions correspond to a system at equilibrium?

I. The entropy of the system is at a maximum.

II. The Gibbs energy of the system is at a minimum.

III. $\Delta G^{\ominus} = 0$

A I and II only **B** I and III only **C** II and III only **D** I, II and III

Q26. Which values correspond to a reaction that can be reversed by changing the temperature?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
I.	−	−
II.	+	−
III.	+	+

A I and II only **B** I and III only **C** II and III only **D** I, II and III