Entropy

Question Paper 1

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Entropy-Free energy and entropy
Booklet	Question Paper 1

Time Allowed: **50 minutes**

Score: **/42**

Percentage: **/100**

Grade Boundaries:

1. The elements of Group 14 can all form monoxides and dioxides. The stabilities of the monoxides, with respect to disproportionation into the element and the dioxide, vary. The equations for the disproportionation reactions are given in Table 3.1 together with some thermodynamic data for the reactions.

Table 3.1

disproportionation equation	$\Delta_r S^\ominus$ (298 K) / J K^{-1} mol^{-1}	$\Delta_r H^\ominus$ (298 K) / kJ mol^{-1}	$\Delta_r G^\ominus$ (298 K) / kJ mol^{-1}
$2CO(g) \rightarrow C(s) + CO_2(g)$	–175.9	–172.5	–120.1
$2SiO(g) \rightarrow Si(s) + SiO_2(s)$	–362.9	–711.5	–603.4
$2GeO(s) \rightarrow Ge(s) + GeO_2(s)$		–126.8	
$2SnO(s) \rightarrow Sn(s) + SnO_2(s)$	–9.200	–9.100	–6.360
$2PbO(s) \rightarrow Pb(s) + PbO_2(s)$	–4.000	+157.2	+158.4

(a) Explain why the entropy change for the disproportionation of

(i) SiO is so much bigger than for CO,

....

....

....[2]

(ii) PbO is so close to zero.

....

....

....[2]

(b) Table 3.2 gives the standard molar entropies for germanium and its oxides.

Table 3.2

name	standard molar entropy at 298 K, $S^{\ominus}(298\,K)$ / J K^{-1} mol^{-1}
germanium, Ge(s)	31.1
germanium monoxide, GeO(s)	50.0
germanium dioxide, GeO_2(s)	55.3

(i) Calculate the standard entropy change, $\Delta_r S^{\ominus}(298\,K)$, for the disproportionation of germanium monoxide.

.... [2]

(ii) Calculate the standard free energy change, $\Delta_r G^{\ominus}(298\,K)$, for the same reaction.

.... [2]

(c) Use data from Table 3.1 to calculate

(i) the value of the equilibrium constant, K_p, for the disproportionation of carbon monoxide, CO,

.... [2]

(ii) the temperature above which the disproportionation of carbon monoxide ceases to be favourable.

.... [2]

(d) Explain why carbon monoxide does not spontaneously disproportionate at room temperature.

....

....[1]

[Total: 13]

2. The familiar light blue colour of copper(II) sulfate solution is due to the presence of the hexaaquacopper(II) ion, $[Cu(H_2O)_6]^{2+}(aq)$.

Equations for two different partial ligand substitution reactions of the hexaaquacopper(II) ion are shown. In the first of these equations 'en' represents diaminoethane, $H_2NCH_2CH_2NH_2$.

$$[Cu(H_2O)_6]^{2+}(aq) + en(aq) \rightarrow [Cu(en)(H_2O)_4]^{2+}(aq) + 2H_2O(l)$$

$$\Delta_r H^\ominus = -54\,kJ\,mol^{-1}; \quad \Delta_r S^\ominus = +23\,J\,K^{-1}\,mol^{-1}$$

$$[Cu(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow [Cu(NH_3)_2(H_2O)_4]^{2+}(aq) + 2H_2O(l)$$

$$\Delta_r H^\ominus = -46\,kJ\,mol^{-1}; \quad \Delta_r S^\ominus = -8.4\,J\,K^{-1}\,mol^{-1}$$

(a) Explain why the enthalpy changes, $\Delta_r H^\ominus$, of the two partial ligand substitution reactions shown are so similar.

....

....

....

....[2]

(b) Comment on the values of the entropy changes, $\Delta_r S^\ominus$, of the two partial ligand substitution reactions shown and explain why they are different.

....

....

....

....[2]

(c) The cation produced in the reaction with ammonia, NH_3, can exist as two different isomers.

(i) State the type of isomerism exhibited by this cation.

....[1]

(ii) Draw and label the two different isomers of this cation.

[2]

(d) Further ligand substitution leads to the production of the complex ion $[Cu(en)_3]^{2+}$, which also exhibits isomerism.

(i) State the type of isomerism exhibited by $[Cu(en)_3]^{2+}$.

.... [1]

(ii) Draw 3-D representations of the two isomers of $[Cu(en)_3]^{2+}$.

[2]

[Total: 10]

3. Quicklime is manufactured from limestone by the reaction shown.

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

Thermodynamic data for these compounds, at 298 K, is given in the table.

compound	standard entropy / $J K^{-1} mol^{-1}$	standard enthalpy change of formation / $kJ mol^{-1}$
$CaCO_3(s)$	to be calculated in **(a)(iii)**	–1206.9
$CaO(s)$	39.7	to be calculated in **(b)(ii)**
$CO_2(g)$	213.6	–393.5

(a) **(i)** What type of reation is involved in the conversion of limestone to quicklime?

....[1]

(ii) Explain why the value for the standard entropy of CO_2 is greater than the value for CaO.

....

....

....[1]

(iii) The standard entropy change of the system, $\Delta S^{\ominus}(298\,K)$, for the conversion of limestone to quicklime is $+160.4\,J\,K^{-1}\,mol^{-1}$.

Calculate the standard entropy of $CaCO_3(s)$.
Give your answer to one decimal place.

$S^{\ominus}(298\,K)$ = ... $J\,K^{-1}\,mol^{-1}$ [2]

(b) **(i)** State Hess's law.

....

....

....[2]

(ii) The standard enthalpy change of reaction, $\Delta_r H^{\ominus}(298\,K)$, for the conversion of limestone to quicklime is $+178.3\,kJ\,mol^{-1}$.

Calculate the standard enthalpy change of formation, $\Delta_f H^{\ominus}(298\,K)$, for CaO(s). Give your answer to one decimal place and include a sign in your answer.

$\Delta_f H^{\ominus}$ CaO(s)(298 K) = ... $kJ\,mol^{-1}$ [2]

(iii) Calculate the entropy change of the surroundings, at 298 K, during the conversion of limestone to quicklime and hence calculate the total entropy change of the reaction.
Give your answers to one decimal place and include signs in your answers.

$\Delta S^{\ominus}_{surroundings}(298\,K)$ = ... $J\,K^{-1}\,mol^{-1}$

$\Delta S^{\ominus}_{total}(298\,K)$ = ... $J\,K^{-1}\,mol^{-1}$ [3]

(iv) Calculate the temperature at which $\Delta S^{\ominus}_{total}$ is zero and explain the significance of this temperature.
Assume that $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ are independent of temperature.

temperature = ... K

explanation ....

....

....[3]

(c) A sample of calcium carbonate, $CaCO_3$, was heated in a sealed container at 1200 °C until no further change occurred.

(i) Give the expression for the equilibrium constant, K_p, for the reaction.

K_p =

[1]

(ii) Using equations from the *Data Booklet*, and appropriate information from **(a)(iii)** and **(b)(ii)**, calculate the value of the equilibrium constant, K_p, for the reaction. Assume that $\Delta_r H^{\circ}$ and ΔS° are independent of temperature and pressure.

K_p = ...[4]

[Total: 19]