17.1 The Equilibrium Law

Question Paper

Course	DP IB Chemistry
Section	17. Equilibrium (HL only)
Topic	17.1 The Equilibrium Law
Difficulty	Medium

Time allowed: 50

Score: /40

Percentage: /100

Question 1a

a)
Nitrogen(II) oxide is an atmospheric pollutant linked to acid rain. It can be formed by the combustion of fossil fuels or from the following dissociation of nitrosyl chloride.

$$2NOCl\,(g) \rightleftharpoons 2NO\,(g) + Cl_2\,(g)$$

Predict, giving your reason, the sign of the standard entropy change for the forward reaction.

[1 mark]

Question 1b

b)
At 230 ^{O}C, the value of K_C for the dissociation of nitrosyl chloride is 4.5×10^{-3}. Describe the significance of the value of K_C.

[1 mark]

Question 1c

c)
Using Sections 1 and 2 of the Data Booklet, calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, in kJ mol^{-1}, for this reaction at 230 ^{O}C.

[2 marks]

Question 1d

d)
At 465 ^{O}C, the value of K_C for the dissociation of nitrosyl chloride is 9.2×10^{-2}.

In terms of the equilibrium position, suggest how this K_C value supports the fact that the forward reaction is endothermic.

[1 mark]

Question 2a

a)
The following reaction is used to manufacture sulfuric acid.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

A mixture of 2.00 mol SO_2 (g) and 1.40 mol O_2 (g) is placed inside a 1.00 dm^3 flask and allowed to reach equilibrium at a temperature, T_1. At equilibrium, 0.30 mol of SO_3 (g) was present. Determine the equilibrium concentration of SO_2 (g) and O_2 (g), and hence calculate the value of K_C, including units, at this temperature.

[5 marks]

Question 2b

b)
Using Sections 1 and 2 of the Data Booklet and your answer to (a), calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, in kJ mol^{-1}, for this reaction at a temperature of 700K.

[2 marks]

Question 2c

c)
Experimental data can be used to calculate the reaction quotient, Q, and the equilibrium constant, K_C.
Distinguish between these two terms.

[1 mark]

Question 2d

d)
1.20 mol SO_2 (g), 1.60 mol O_2 (g) and 0.85 mol SO_3 (g) were mixed in a 1.00 dm^3 container at temperature, T_2.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Use your answer to (a) to deduce the direction of this reaction, showing your working.

[2 marks]

Question 3a

a)
Carbon monoxide and chlorine react to form phosgene, $COCl_2$, according to the following equation.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

Deduce the equilibrium constant expression, K_C, including units for this reaction.

[2 marks]

Question 3b

b)
0.50 mol CO (g) and 0.30 mol Cl_2 (g) were mixed in a 10.0 dm^3 container. At equilibrium, 0.10 mol of $COCl_2$ (g) was present.
Determine the equilibrium concentration of CO (g) and Cl_2 (g), and hence calculate the value of K_C.

[4 marks]

Question 3c

c)
Use Sections 1 and 2 of the Data Booklet with your answer to (b) to deduce, showing your working, the temperature of the reaction at which the standard Gibbs free energy change, $\Delta G^{\ominus}$, is -8.40 kJ.

[3 marks]

Question 3d

d)
At 873 K, the standard Gibbs free energy change, $\Delta G^{\ominus}$, was found to be +11.7 kJ.

Deduce, giving your reasons, whether the forward reaction is endothermic or exothermic. Use your answer to (c).

[2 marks]

Question 4a

a)
The following thermochemical data is for the oxidation of iron to produce iron(III) oxide at 300 K.

$$\Delta H^{\ominus} = -824.2 \text{ kJ mol}^{-1}$$

$$2Fe(s) + \frac{3}{2}O_2(g) \rightleftharpoons Fe_2O_3(s)$$

$$\Delta S^{\ominus} = -270.5 \text{ J K}^{-1} \text{ mol}^{-1}$$

Explain why the enthalpy value given is the enthalpy of formation, $\Delta H^{\ominus}_f$, of iron(III) oxide.

[1 mark]

Question 4b

b)
Using Section 1 of the Data Booklet, calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, for the oxidation of iron to iron(III) oxide at 300 K.

[2 marks]

Question 4c

c)
Use you answer to (b) and Sections 1 and 2 of the Data Booklet to calculate a value, in terms of e, for K_C for this reaction at 300 K.

[3 marks]

Question 4d

d)
Use your answer to (c) to explain why the following oxidation of iron to iron(III) oxide at 300 K can be considered to be irreversible.

$$2Fe\,(s) + \frac{3}{2}O_2\,(g) \rightleftharpoons Fe_2O_3\,(s)$$

[1 mark]

Question 5a

a)
Ethanol and ethanoic acid react to form ethyl ethanoate according to the following equation.

$$C_2H_5OH + CH_3COOH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

0.47 mol of ethanol and 0.25 mol of ethanoic acid were mixed in a 5.0 dm^3 container and left to reach equilibrium. At equilibrium, there was found to be 0.28 mol of ethanol. Calculate the number of moles of the remaining chemicals at equilibrium.

[2 marks]

Question 5b

b)
The reaction is performed in a 5.0 dm^3 container.

Deduce the equilibrium constant expression, K_C, for the reaction of ethanol and ethanoic acid and explain why the number of moles can be used directly in your expression.

[2 marks]

Question 5c

c)
Using your answer to part (b), calculate, showing your working, a value for the equilibrium constant expression, K_C, for the reaction of ethanol and ethanoic acid.

[1 mark]

Question 5d

d)
A second experiment reacting ethanol and ethanoic acid was performed. Analysis showed the equilibrium mixture to contain 0.16 mol ethanoic acid, 0.11 mol ethyl ethanoate and 0.12 mol water. Calculate the number of moles of ethanol in the equilibrium mixture.

[2 marks]