SECTION 1 – CORE CHEMICAL EQUILIBRIUM

Dynamic equilibrium, equilibrium position, K/Kc/Kp, reversible reactions, Le Chatelier, equilibrium calculations, reaction quotient / Gibbs–equilibrium links, and solubility–equilibrium questions. Context pages are included where a continuation page would otherwise be incomplete.

(b) An equilibrium is established when hydrated cobalt ions are mixed with concentrated hydrochloric acid.

$$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$$

Pink Blue

(i) Predict the effect on the value of *K* and the equilibrium position when solid sodium chloride, NaCl(s), is added to the mixture at constant temperature. [1]

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(ii) Heating an equilibrium mixture that is initially pink changes the colour to purplish-blue. Deduce, giving a reason, whether the formation of $[CoCl_4]^{2-}(aq)$ is an exothermic or endothermic process. [1]

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3. An equilibrium is established between gaseous carbon monoxide and steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

Under certain conditions of temperature and pressure, 2.7 mol of CO(g) and 2.9 mol of $H_2O(g)$ were placed in a 1 dm^3 container and allowed to reach equilibrium.

(a) State the equilibrium constant expression, *K*, for this equilibrium. [1]

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(b) At equilibrium, there was 1.5 mol of $CO_2(g)$ present. Calculate the amount, in mol, of the other gases and hence find the value of the equilibrium constant, *K*. [2]

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(This question continues on the following page)

(iv) $[Fe^{2+}]$ is 2.20×10^{-7} mol dm^{-3} in a 1.00 mol dm^{-3} solution of the complex ion.

Determine the value of the equilibrium constant, K, for the formation of $[Fe(CN)_6]^{4-}$ from its constituent ions. [3]

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(iii) Determine the enthalpy change for the reaction between carbon monoxide and chlorine from bond enthalpies. Use section 12 of the data booklet. [3]

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(v) Calculate the standard entropy change, $\Delta S^{\ominus}$, of the reaction between carbon monoxide and chlorine to form phosgene. Use section 13 of the data booklet and the following data:

Standard entropy $S^{\ominus}$, of chlorine $= 223\,J\,mol^{-1}\,K^{-1}$

Standard entropy $S^{\ominus}$, of phosgene $= 284\,J\,mol^{-1}\,K^{-1}$ [1]

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(This question continues on the following page)

(vi) Deduce whether the reaction would go to completion or reach equilibrium at 298 K. Use sections 1 and 2 of the data booklet along with your answers to (a)(iii) and (a)(v).

If you did not get an answer to (a)(iii) and/or (a)(v) use the following values, though these are not the correct answers: (a)(iii) $= -120\,kJ\,mol^{-1}$, (a)(v) $= -150\,J\,mol^{-1}\,K^{-1}$. [3]

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