QUESTIONS: Equilibria

QUESTION (2012:2)

Phosphorus pentachloride gas, $PCl_5(g)$, decomposes to form phosphorus trichloride gas, $PCl_3(g)$, and chlorine gas, $Cl_2(g)$. The equilibrium can be represented as:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

(a) Complete the equilibrium constant expression for this reaction. K_C =

(b) The table below shows the value of the equilibrium constant, K_C at two different temperatures.

Temperature / ^oC	Value of K_C
200	8.00×10^{-3}
350	0.612

(i) Circle the species that will be in the highest concentration at 200°C.

$PCl_5(g)$ $PCl_3(g)$

(ii) Explain your answer.

(iii) Calculate the concentration of PCl_5 at equilibrium at 350°C, if the concentrations of PCl_3 and Cl_2 are both 0.352 mol L^{-1}.

(c) For each of the following changes applied to this system:

(i) State if the amount of chlorine gas, $Cl_2(g)$, would increase or decrease.

(ii) Justify your answers using equilibrium principles.

$PCl_3(g)$ is removed.
Amount of $Cl_2(g)$
Reason:

The pressure is decreased.
Amount of $Cl_2(g)$
Reason:

(d) When the temperature of the equilibrium system is increased from 200°C to 350°C (at constant pressure), the value of K_C increases, as shown in the table above (in (b)).
Use this information to determine whether the decomposition of PCl_5 is endothermic or exothermic. Justify your reasoning using equilibrium principles.

QUESTION (2009:3)

(a) Nitrogen monoxide gas reacts with oxygen gas to form nitrogen dioxide gas. The equilibrium reaction can be represented by:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

colourless colourless brown

At 230°C the equilibrium constant for this reaction has a value of 6.44×10^5.

(i) Complete the equilibrium constant expression for this reaction. K_C =

(ii) State which gas will be in the highest concentration at 230°C.

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(b) The following equilibrium system is formed when hydrogen gas is mixed with iodine gas.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

colourless purple colourless

The reaction has a negative value for $\Delta_r H$.

For each of the following changes applied to this system:

(i) describe the expected observation
(ii) use equilibrium principles to discuss the reason for this observation.

HI(g) is added.

The reaction mixture is cooled

The pressure is increased.

QUESTION (2008:2)

Complete the equilibrium constant expressions for the following equations.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

$$2O_3(g) \rightleftharpoons 3O_2(g)$$

QUESTION (2008:6)

One step in the production of sulfuric acid involves forming sulfur trioxide from sulfur dioxide.

The equilibrium reaction can be represented by

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta_r H = -196 \text{ kJ mol}^{-1}$$

(a) (i) Explain why a low temperature favours the formation of $SO_3(g)$.

(ii) The temperature that is actually used is approximately 450°C. However, this is not considered to be a low temperature. Discuss why this temperature is used.

(b) (i) Describe another way of increasing the amount of $SO_3(g)$ present at equilibrium without adding any more reactants.
(ii) Explain why this will increase the amount of $SO_3(g)$ present at equilibrium.

QUESTION (2008:7)

Carbon dioxide is added to drinks to make them fizzy. The following equilibria are involved:

$CO_2(g) \rightleftharpoons CO_2(aq)$ Equation One

$CO_2(aq) + 2H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$ Equation Two

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The drink is fizzy when there is dissolved carbon dioxide, $CO_2(aq)$. The drink stops being fizzy when the carbon dioxide escapes from the drink as a gas.

Using equilibrium principles, discuss the changes that occur as a bottle containing fizzy drink is opened.

Your answer must include reference to:

- equilibrium shift in Equation One and Equation Two
- changes in the fizziness of the drink
- any change in pH.

QUESTION (2007:5)

The following equilibrium system is formed when potassium thiocyanate solution is added to a solution of iron(III) nitrate.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

orange colourless dark red

The reaction has a positive value for $\Delta_r H$. For each of the following changes applied to this system:

(i) describe the expected observation

(ii) use equilibrium principles to discuss the reason for this observation.

(a) The reaction mixture is cooled.

(b) Solid sodium fluoride is added to the reaction mixture. The fluoride ions react with Fe^{3+} ions.

(c) Solid iron(III) chloride is added to the reaction mixture.

QUESTION (2006:5)

An equilibrium system is shown below.

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

(a) Complete the equilibrium constant expression for this reaction. $K_C =$

The pressure of the system is increased, while maintaining a constant temperature. The percentage of NH_3 in the reaction mixture is recorded and graphed.

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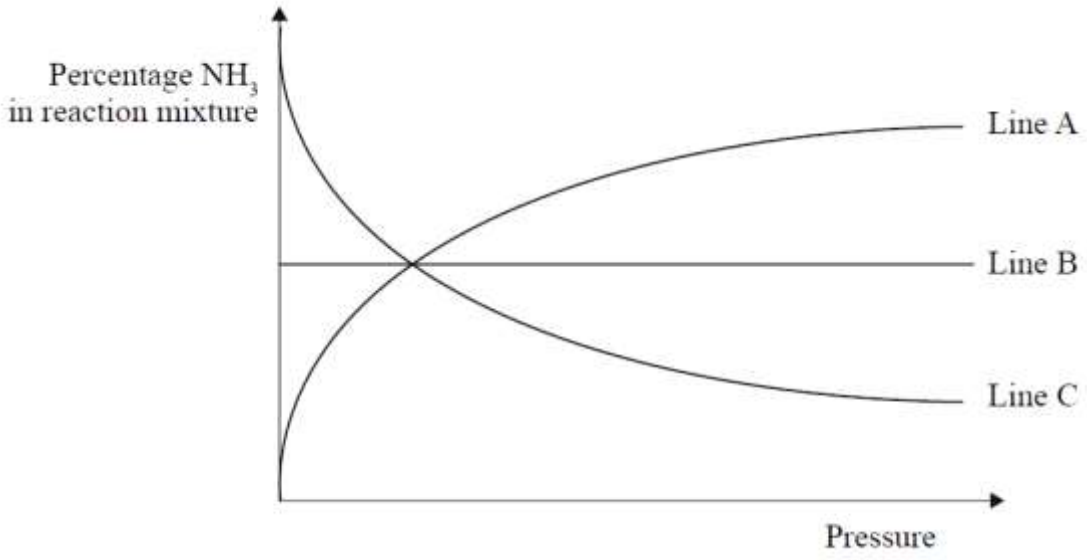

(b) On the above graph, identify the line that shows the correct relationship between the percentage of NH_3 in the reaction mixture, and increasing pressure.

Circle the correct answer below.

Line A Line B Line C

Explain your answer by applying knowledge of equilibrium principles.

QUESTION (2006:6)

An equilibrium system involving different species of cobalt(II) is shown in the equation below.

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

$[CoCl_4]^{2-}(aq)$ is blue and $[Co(H_2O)_6]^{2+}(aq)$ is pink.

At room temperature (25°C) the equilibrium mixture is pink.

(a) Describe the expected observation when solid sodium chloride (NaCl) is added to the equilibrium mixture. Explain your answer.

(b) The enthalpy change ($\Delta_r H$) for this reaction as written above, has a negative value. Circle the ion that would be present in the higher concentration when the equilibrium mixture is heated.

$[CoCl_4]^{2-}(aq)$ $[Co(H_2O)_6]^{2+}(aq)$

Explain your answer.

QUESTION (2005:2)

(a) Complete the equilibrium constant expression for the following reaction.

(i) $Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)^{2+}(aq)$. $K_C=$

(ii) At 25°C the value of *Kc* is 1.70 x 107. Circle the species that would be present in the higher concentration in the equilibrium mixture at this temperature.

$Ag^+(aq)$ or $Ag(NH_3)^{2+}(aq)$ Justify your choice.

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(b) Complete the equilibrium constant expression for the following reaction.

(i) $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$ $K_C =$

(ii) At 200°C the value of *Kc* is 1.10 × 10–5. Circle the species that would be present in the higher concentration in the equilibrium mixture at this temperature.

$NO_2(g)$ or $NO(g)$

Justify your choice.

QUESTION (2005:4)

The following reaction is exothermic: $2N_2O_5(g) \rightleftharpoons 4NO_2(g) + O_2(g)$ Both N_2O_5 and O_2 are colourless gases and NO_2 is a brown gas. A mixture of these gases exists at equilibrium and is observed as a brown colour.

(a) Complete the equilibrium constant expression for the reaction. $K_C =$

(b) For each of the following changes applied to the equilibrium system, describe the expected observation and explain why this occurs.

(i) The mixture of gases is heated (at constant pressure).

Expected observation:.

Explanation:

(ii) The pressure is increased, by decreasing the volume of the container.
Expected observation:

Explanation:

QUESTION (2004:4)

(a) The following equilibrium system is established when thiocyanate ions (SCN−) are added to iron (III) ions (Fe3+). The resulting aqueous solution is a dark red colour. The equation representing the equilibrium system and the colours of each species involved are given below.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

pale orange colourless dark red

(i) Complete the equilibrium constant expression for the above reaction. $K_C =$

(ii) When iron (III) ions (Fe^{3+}) are removed from the equilibrium mixture (by adding sodium fluoride), a colour change is observed. Describe the colour change you would expect to see and explain why it occurs.

(b) Ammonia is produced industrially according to the Haber Process as shown below:

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

(i) Complete the equilibrium constant expression for the above reaction. Kc =

(ii) The pressure of the system at equilibrium is increased (by decreasing the total volume of the system). Describe the effect of this change on the amount of NH_3 in the system. Explain your answer.

(iii) The percentage of NH_3 present in equilibrium mixtures at different temperatures and at constant pressure is shown in the table below.

Temperature (°C)	Percentage NH_3 present in equilibrium mixture
200	63.6
300	27.4
400	8.7
500	2.9

Justify whether the reaction in which NH_3 is formed, is endothermic or exothermic.