7.1 Equilibrium

Question Paper

Course	DP IB Chemistry
Section	7. Equilibrium
Topic	7.1 Equilibrium
Difficulty	Medium

Time allowed: 60

Score: /47

Percentage: /100

Question 1a

a) Ammonia gas can be synthesized by the direct combination of nitrogen gas and hydrogen gas. When the two gases are reacted together in a sealed container the following equilibrium reaction takes place:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g) \qquad \Delta H = -92.6\ kJ$$

Describe two characteristics of a reaction in a state of *dynamic equilibrium*.

[2 marks]

Question 1b

b) Write the equilibrium constant expression, K_c, for the reaction in part (a).

[1 mark]

Question 1c

c) Explain, with a reason, how each of the following changes can affect the position of equilibrium in part (a).

i) The volume of the container is increased.

ii) Ammonia is removed from the container.

[4 marks]

Question 1d

d) Ammonia is manufactured industrially by the Haber process in which iron is used as a catalyst. Explain the effect of a catalyst on the position of equilibrium and the value of K_c.

[1 mark]

Question 2a

a) Sulfuric acid is produced on an industrial scale in the Contact Process. The middle step of the process involves the following equilibrium reaction:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -198\ kJ$$

$K_c >> 1$ at 200 ^oC and 100 kPa

Outline what the information given about Kc tells you about the extent of the reaction at the conditions specified.

[1 mark]

Question 2b

b) The actual operating conditions of the Contact Process are 450 ^oC and 200 kPa. Explain the choice of using these operating conditions in terms of temperature and pressure.

[4 marks]

Question 2c

c) Suggest, with a reason, whether using pure oxygen instead of air would be an improvement to the Contact Process.

[1 mark]

Question 2d

d) Write the equilibrium constant expression for the **reverse** reaction of the Contact Process.

[1 mark]

Question 3a

a) A sample of chlorine gas is reacted with sulfur dioxide at 375 ^{o}C in a 1dm^{3} container. The equilibrium reaction produces colourless sulfuryl chloride, SO_2Cl_2, and the enthalpy change for the reaction is -84 kJ mol^{-1}.
Write the equation for the reaction and deduce the equilibrium constant expression.

[2 marks]

Question 3b

b) If the reaction in part (a) is carried out at 300 °C, predict what will happen to the equilibrium concentration of SO_2Cl_2 and the value of K_c. Explain your answer.

[3 marks]

Question 3c

c) If the reaction in (a) is now carried out in a 2.00 dm^3 container, predict, with a reason what will happen to the equilibrium concentration of SO_2Cl_2 and the value of K_c.

[3 marks]

Question 3d

d) If the same reaction is carried out in part (a) with a catalyst, explain how this will affect the equilibrium concentration of SO_2Cl_2.

[2 marks]

Question 4a

a) A reaction mixture was set up in a syringe containing dinitrogen tetraoxide gas and nitrogen dioxide gas as shown in the equation below:

$$N_2O_4\,(g) \leftrightharpoons 2NO_2\,(g) \qquad \Delta H = +58\ kJ\ mol^{-1}$$

The appearance of the gases is quite different; dinitrogen tetraoxide is a pale-yellow gas, whereas nitrogen dioxide is dark brown in colour.

State why this equilibrium reaction is considered homogeneous and deduce the equilibrium constant expression for the reaction.

[2 marks]

Question 4b

b) Explain why the reaction mixture turns darker in colour when it is heated.

[3 marks]

Question 4c

c) The reaction which takes place in part (a) has a K_c value of 3.21. A student claims that increasing the temperature of this reaction will increase the value of K_c.

Is the student correct? Justify your answer.

[3 marks]

Question 4d

d) Using Le Chatelier's principle, explain what would be seen if the plunger of the syringe was pressed and the gases within the syringe were compressed.

[3 marks]

Question 5a

a) During an esterification reaction, methanol and ethanoic acid react together to form the ester, methyl ethanoate, and water as shown below:

$CH_3OH\ (l) + CH_3COOH\ (l) \rightleftharpoons CH_3COOCH_3\ (l) + H_2O\ (l) \quad K_c = 7.21$ at 298K

A chemist sets up the reaction and allows it to reach *dynamic equilibrium* at a constant temperature.

(i) State the meaning of the term *dynamic equilibrium*.

(ii) Give one key condition which must be satisfied for a reversible reaction to reach dynamic equilibrium.

[3 marks]

Question 5b

b) Once the reaction in part (a) is set up, the chemist leaves it for 24 hours to make sure that it has reached equilibrium.

State how the chemist could check to make sure that the reaction mixture had reached equilibrium.

[2 marks]

Question 5c

c) When the chemist sampled the concentrations of the substances in the reaction mixture and calculated a value for the reaction quotient, she determined the value of Q to be 5.34.

(i) State the meaning of the term *reaction quotient*.

(ii) Deduce, with a reason, whether the reaction had reached equilibrium and what conclusion can be drawn from the value of Q.

[3 marks]

Question 5d

d) Adding more ethanoic acid to the reaction mixture will increase the yield of the ester produced.

Use Le Chatelier's principle to explain the above statement.

[3 marks]