IB Chemistry – SL

Topic 7 Questions

1. $I_2(g) + 3Cl_2(g) \rightleftharpoons 2ICl_3(g)$

What is the equilibrium constant expression for the reaction above?

A. $K_c = \dfrac{[ICl_3]}{[I_2][Cl_2]}$

B. $K_c = \dfrac{2[ICl_3]}{3[I_2][Cl_2]}$

C. $K_c = \dfrac{2[ICl_3]}{[I_2] + 3[Cl_2]}$

D. $K_c = \dfrac{2[ICl_3]^2}{[I_2][Cl_2]^3}$

2. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H^{\ominus} = -200\ kJ$

According to the above information, what temperature and pressure conditions produce the greatest amount of SO_3?

	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	high
D.	high	low

3. Which statement(s) is/are true for a mixture of ice and water at equilibrium?

I. The rates of melting and freezing are equal.

II. The amounts of ice and water are equal.

III. The same position of equilibrium can be reached by cooling water and heating ice.

A. I only

B. I and III only

C. II only

D. III only

4. What will happen to the position of equilibrium and the value of the equilibrium constant when the temperature is increased in the following reaction?

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad \Delta H = +14 \text{ kJ}$$

	Position of equilibrium	Value of equilibrium constant
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

5. Which statement concerning a chemical reaction at equilibrium is **not** correct?

A. The concentrations of reactants and products remain constant.

B. Equilibrium can be approached from both directions.

C. The rate of the forward reaction equals the rate of the reverse reaction.

D. All reaction stops.

6. In the reaction below

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ}$$

which of the following changes will increase the amount of ammonia at equilibrium?

I. Increasing the pressure

II. Increasing the temperature

III. Adding a catalyst

A. I only

B. II only

C. I and II only

D. II and III only

7. In the Haber process for the synthesis of ammonia, what effects does the catalyst have?

	Rate of formation of $NH_3(g)$	Amount of $NH_3(g)$ formed
A.	Increases	Increases
B.	Increases	Decreases
C.	Increases	No change
D.	No change	Increases

8. What will happen if $CO_2(g)$ is allowed to escape from the following reaction mixture at equilibrium?

$$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

A. The pH will decrease.

B. The pH will increase.

C. The pH will remain constant.

D. The pH will become zero.

9. Which statements are correct for a reaction at equilibrium?

I. The forward and reverse reactions both continue.

II. The rates of the forward and reverse reactions are equal.

III. The concentrations of reactants and products are equal.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

10. The manufacture of sulfur trioxide can be represented by the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^\ominus = -197 \text{ kJ mol}^{-1}$$

What happens when a catalyst is added to an equilibrium mixture from this reaction?

A. The rate of the forward reaction increases and that of the reverse reaction decreases.

B. The rates of both forward and reverse reactions increase.

C. The value of $\Delta H^\ominus$ increases.

D. The yield of sulfur trioxide increases.

11. Which changes will shift the position of equilibrium to the right in the following reaction?

$$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$$

I. adding a catalyst

II. decreasing the oxygen concentration

III. increasing the volume of the container

A. I and II only B. I and III only

C. II and III only D. I, II and III

12. Which statement is always true for a chemical reaction that has reached equilibrium?

A. The yield of product(s) is greater than 50%.

B. The rate of the forward reaction is greater than the rate of the reverse reaction.

C. The amounts of reactants and products do not change.

D. Both forward and reverse reactions have stopped.

13. The equation for a reversible reaction used in industry to convert methane to hydrogen is shown below.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H^{\ominus} = +210 \text{ kJ}$$

Which statement is always correct about this reaction when equilibrium has been reached?

A. The concentrations of methane and carbon monoxide are equal.

B. The rate of the forward reaction is greater than the rate of the reverse reaction.

C. The amount of hydrogen is three times the amount of methane.

D. The value of $\Delta H^{\ominus}$ for the reverse reaction is –210 kJ.

14. The equation for a reaction used in the manufacture of nitric acid is

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^{\ominus} = -900 \text{ kJ}$$

Which changes occur when the temperature of the reaction is increased?

	Position of equilibrium	Value of K_c
A.	shifts to the left	increases
B.	shifts to the left	decreases
C.	shifts to the right	increases
D.	shifts to the right	decreases

15. Which changes cause an increase in the equilibrium yield of $SO_3(g)$ in this reaction?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -196 \text{ kJ}$$

I. increasing the pressure

II. decreasing the temperature

III. adding oxygen

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Iron(III) ions react with thiocyanate ions as follows.

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

What are the units of the equilibrium constant, K_c, for the reaction?

A. $mol\ dm^{-3}$

B. $mol^2\ dm^{-6}$

C. $mol^{-1}\ dm^3$

D. $mol^{-2}\ dm^6$

17. Consider the following equilibrium reaction in a closed container at 350°C.

$$SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g) \qquad \Delta H^{\ominus} = -85\ kJ$$

Which statement is correct?

A. Decreasing the temperature will increase the amount of $SO_2Cl_2(g)$.

B. Increasing the volume of the container will increase the amount of $SO_2Cl_2(g)$.

C. Increasing the temperature will increase the amount of $SO_2Cl_2(g)$.

D. Adding a catalyst will increase the amount of $SO_2Cl_2(g)$.

18. Which of the following equilibria would **not** be affected by pressure changes at constant temperature?

A. $4HCl(g) + O_2(g) \rightleftharpoons 2H_2O(g) + 2Cl_2(g)$

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

C. $C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$

D. $PF_3Cl_2(g) \rightleftharpoons PF_3(g) + Cl_2(g)$

19. Consider the following equilibrium reaction in a closed container at 350°C

$$SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g) \qquad \Delta H^{\ominus} = -85\ kJ$$

Which statement is correct?

A. Decreasing the temperature will increase the amount of $SO_2Cl_2(g)$.

B. Increasing the volume of the container will increase the amount of $SO_2Cl_2(g)$.

C. Increasing the temperature will increase the amount of $SO_2Cl_2(g)$.

D. Adding a catalyst will increase the amount of $SO_2Cl_2(g)$.

20. What is the equilibrium constant expression, K_c, for the reaction below?

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$$

A. $K_c = \dfrac{[NO_2]}{[N_2][O_2]}$

B. $K_c = \dfrac{2[NO_2]}{3[N_2][O_2]}$

C. $K_c = \dfrac{[NO_2]^2}{[N_2][O_2]^2}$

D. $K_c = \dfrac{[NO_2]^2}{[N_2]+[O_2]^2}$

21. Sulfur dioxide and oxygen react to form sulfur trioxide according to the equilibrium.

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

How is the amount of SO_2 and the value of the equilibrium constant for the reaction affected by an increase in pressure?

A. The amount of SO_3 and the value of the equilibrium constant both increase.

B. The amount of SO_3 and the value of the equilibrium constant both decrease.

C. The amount of SO_3 increases but the value of the equilibrium constant decreases.

D. The amount of SO_3 increases but the value of the equilibrium constant does not change.

22. The equation for the Haber process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92.2 \text{ kJ}$$

Which conditions will favour the production of the greatest amount of ammonia at equilibrium?

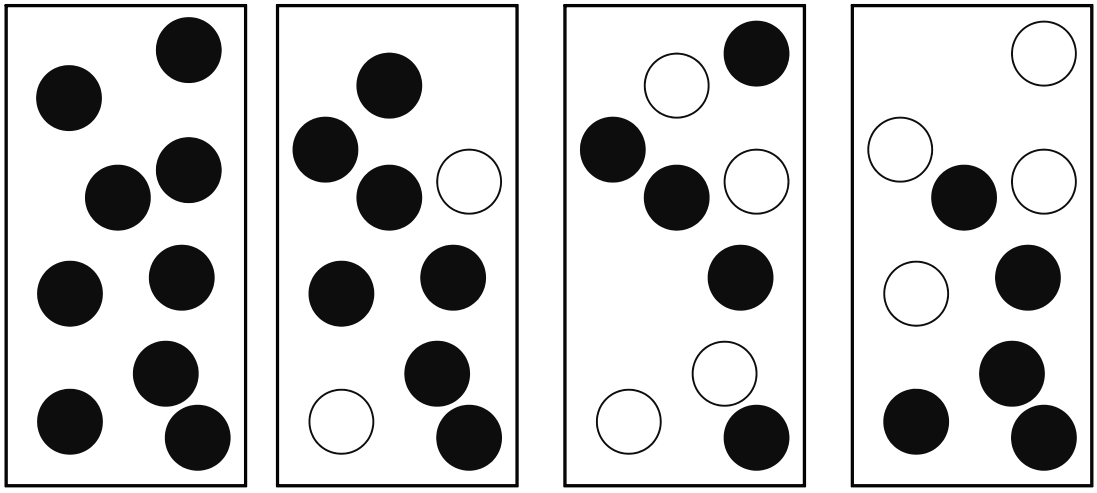
A. High temperature and high pressure

B. High temperature and low pressure

C. Low temperature and high pressure

D. Low temperature and low pressure

23. The sequence of diagrams represents the system as time passes for a gas phase reaction in which reactant **X** is converted to product **Y**.



X = ●

Y = ○

Which statement is correct?

A. At t = 5 days the rate of the forward reaction is greater than the rate of the backward reaction.

B. At t = 7 seconds the reaction has reached completion.

C. At t = 10 minutes the system has reached a state of equilibrium.

D. At t = 5 days the rate of the forward reaction is less than the rate of the backward reaction.

24. What changes occur when the temperature is increased in the following reaction at equilibrium?

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad \Delta H^{\ominus} = +14 \text{ kJ mol}^{-1}$$

	Position of equilibrium	Value of equilibrium constant
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

25. The table below gives information about the percentage yield of ammonia obtained in the Haber process under different conditions.

Pressure/ atmosphere	**Temperature/°C**			
	200	**300**	**400**	**500**
10	50.7	14.7	3.9	1.2
100	81.7	52.5	25.2	10.6
200	89.1	66.7	38.8	18.3
300	89.9	71.1	47.1	24.4
400	94.6	79.7	55.4	31.9
600	95.4	84.2	65.2	42.3

(a) From the table, identify which combination of temperature and pressure gives the highest yield of ammonia.

…….

(1)

(b) The equation for the main reaction in the Haber process is

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \text{ is negative}$$

Use this information to state and explain the effect on the yield of ammonia of increasing

(i) pressure: ……..……..

……..…….

……..

(2)

(ii) temperature: …….

……..….

……..

……..

(2)

(c) In practice, typical conditions used in the Haber process are a temperature of 500 °C and a pressure of 200 atmospheres. Explain why these conditions are used rather than those that give the highest yield.

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……..

(2)

(d) Write the equilibrium constant expression, K_c, for the production of ammonia.

……..

……..

(1)
(Total 8 marks)

26. Consider the following equilibrium reaction.

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

Using Le Chatelier's Principle, state and explain what will happen to the position of equilibrium if

(a) the temperature increases.

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(2)

(b) the pressure increases.

.....

.....

(2)
(Total 4 marks)

27. Ammonia is produced by the Haber process according to the following reaction.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H \text{ is negative}$$

(a) State the equilibrium constant expression for the above reaction.

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(1)

(b) Predict, giving a reason, the effect on the position of equilibrium when the pressure in the

reaction vessel is increased.

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.....

(2)

(c) State and explain the effect on the value of K_c when the temperature is increased.

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(2)

(d) Explain why a catalyst has no effect on the position of equilibrium.

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.....

(1)
(Total 6 marks)

28. (a) The following equilibrium is established at 1700°C.

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

If only carbon dioxide gas and hydrogen gas are present initially, sketch on a graph a line representing rate against time for (i) the forward reaction **and** (ii) the reverse reaction until shortly after equilibrium is established. Explain the shape of each line.

(7)

(b) K_c for the equilibrium reaction is determined at two different temperatures. At 850°C, K_c = 1.1 whereas at 1700°C, K_c = 4.9.

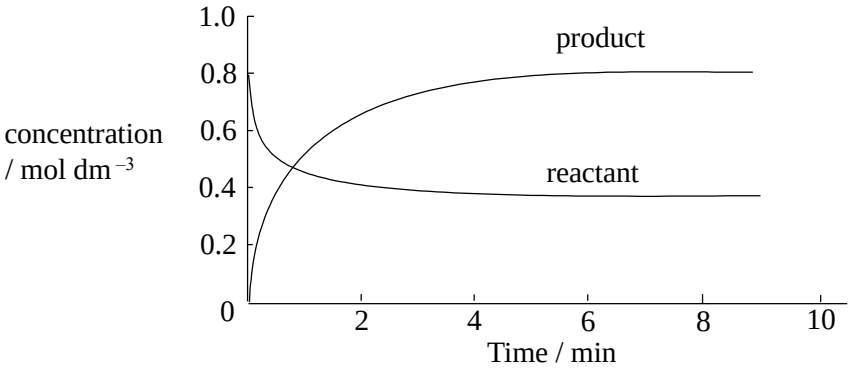
On the basis of these K_c values explain whether the reaction is exothermic or endothermic.

(3)
(Total 10 marks)

29. The equation for one reversible reaction involving oxides of nitrogen is shown below:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^{\ominus} = +58 \text{ kJ}$$

Experimental data for this reaction can be represented on the following graph:



(i) Write an expression for the equilibrium constant, K_c, for the reaction. Explain the significance of the horizontal parts of the lines on the graph. State what can be deduced about the magnitude of K_c for the reaction, giving a reason.

(4)

(ii) Use Le Chatelier's principle to predict and explain the effect of increasing the temperature on the position of equilibrium.

(2)

(iii) Use Le Chatelier's principle to predict and explain the effect of increasing the pressure on the position of equilibrium.

(2)

(iv) State and explain the effects of a catalyst on the forward and reverse reactions, on the position of equilibrium and on the value of K_c.

(6)
(Total 14 marks)

30. Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (d) in this question.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

(a) Write the equilibrium constant expression for the reaction.

(1)

(b) (i) State the catalyst used in this reaction of the Contact process.

(1)

(ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction.

(4)

(c) Use the collision theory to explain why increasing the temperature increases the rate of the reaction between sulfur dioxide and oxygen.

(2)

(d) Using Le Chatelier's principle state and explain the effect on the position of equilibrium of

(i) increasing the pressure at constant temperature.

(2)

(ii) removing of sulfur trioxide.

(2)

(iii) using a catalyst.

(2)

(Total 14 marks)

31. Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (c) in this question.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

(a) Write the equilibrium constant expression for the reaction.

(1)

(b) (i) State the catalyst used in this reaction of the Contact process.

(1)

(ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction.

(4)

(c) Using Le Chatelier's principle explain the effect on the position of equilibrium of

(i) increasing the pressure at constant temperature.

(2)

(ii) removing sulfur trioxide.

(2)

(Total 10 marks)

32. Many reversible reactions in industry use a catalyst. State and explain the effect of a catalyst on the position of equilibrium and on the value of K_c.

(Total 4 marks)

33. The equation for a reaction used in industry is

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \qquad \Delta H^{\ominus} = +210 \text{ kJ}$$

Deduce the equilibrium constant expression, K_c, for this reaction.

(Total 1 mark)

34. Consider the following reaction where colourless bromide ions react with colourless hydrogen peroxide to form a red-brown bromine solution.

$$2Br^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightleftharpoons Br_2(aq) + 2H_2O(l) \qquad \Delta H = \text{negative}$$

(a) Predict and explain the effect on the **position of equilibrium** when

(i) a small amount of sodium bromide solution is added.

(2)

(ii) a small amount of sodium hydroxide solution is added.

(2)

(iii) a catalyst is added.

(2)

(b) State and explain the effect on the value of the **equilibrium constant** when the temperature of the reaction is increased.

(2)

(c) State and explain the colour change when hydrochloric acid is added to the reaction solution at equilibrium.

(3)
(Total 11 marks)

35. The equation for the exothermic reaction in the Contact process is given below:

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

(i) Write the equilibrium constant expression for the reaction.

(1)

(ii) State and explain qualitatively the pressure and temperature conditions that will give the highest yield of sulfur trioxide.

(4)

(iii) In practice, conditions used commercially in the Contact process are 450°C and 2 atmospheres of pressure. Explain why these conditions are used rather than those that give the highest yield.

(3)

(iv) Name a catalyst used in the Contact process. State and explain its effect on the value of the equilibrium constant.

(3)
(Total 11 marks)

36. In the gaseous state, methane and steam react to form hydrogen and carbon dioxide.

(i) Write an equation for the endothermic equilibrium reaction. Deduce the equilibrium expression for the reaction and state its units.

(4)

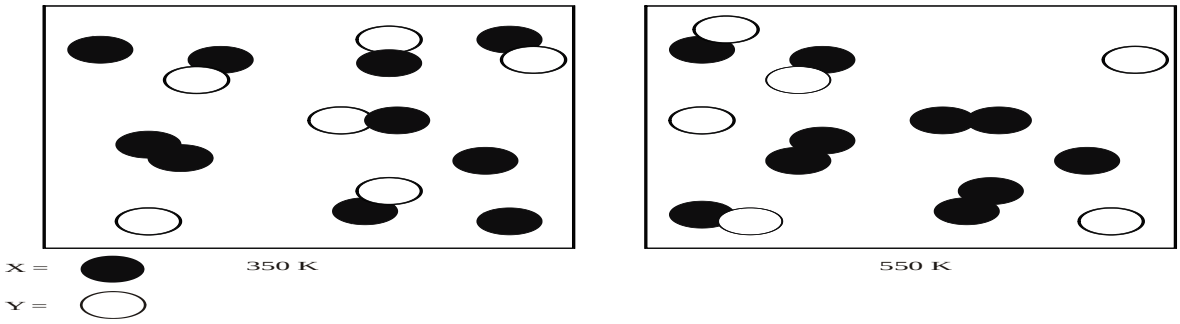
(ii) Deduce and explain the conditions of temperature and pressure under which the forward reaction is favoured.

(4)

(iii) Explain, at the molecular level, why the reaction is carried out at high pressure in industry.

(2)
(Total 10 marks)

37. The diagrams below represent equilibrium mixtures for the reaction $Y + X_2 \rightleftharpoons XY + X$ at 350 K and 550 K respectively. Deduce and explain whether the reaction is exothermic or endothermic.



(Total 2 marks)

38. The equation for the main reaction in the Haber process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \text{ is negative}$$

(i) Determine the equilibrium constant expression for this reaction.

(1)

(ii) State and explain the effect on the equilibrium yield of ammonia with increasing the pressure and the temperature.

(4)

(iii) In practice, typical conditions used in the Haber process involve a temperature of 500°C and a pressure of 200 atm. Explain why these conditions are used rather than those that give the highest yield.

(2)

(iv) At a certain temperature and pressure, 1.1 dm^3 of $N_2(g)$ reacts with 3.3 dm^3 of $H_2(g)$. Calculate the volume of $NH_3(g)$, that will be produced.

(1)

(v) Suggest why this reaction is important for humanity.

(1)

(vi) A chemist claims to have developed a new catalyst for the Haber process, which increases the yield of ammonia. State the catalyst normally used for the Haber process, and comment on the claim made by this chemist.

(2)

(Total 11 marks)