IB Chemistry HL - R2.3

How far? The extent of chemical change

Exercises + Practice questions

Official answers appended at the end

Q2. Which statement is always true for a chemical reaction that has reached equilibrium at constant temperature?

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

B The rate of the reverse reaction is lower than that of the forward reaction.

C The amounts of reactants and products do not change.

D Both forward and reverse reactions have stopped.

Q3. Which statement is *not* true for a mixture of ice and water at equilibrium at constant temperature?

A The rates of melting and freezing are equal.

B The amounts of ice and water are equal.

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

D There is no observable change in the system.

Exercise

Q4. Write the equilibrium constant expression for the following reactions:

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

(b) $4NH_3(g) + 7O_2(g) \rightleftharpoons 4NO_2(g) + 6H_2O(g)$

(c) $CH_3Cl(aq) + OH^-(aq) \rightleftharpoons CH_3OH(aq) + Cl^-(aq)$

Q5. Write the equations for the reactions represented by the following equilibrium constant expressions:

(a) $K = \dfrac{[NO_2]^2}{[N_2O_4]}$ **(b)** $K = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$

Q6. Write the equilibrium constant expressions for the following chemical reactions:

(a) fluorine gas and chlorine gas combine to form $ClF_3(g)$

(b) NO dissociates into its elements

(c) methane, CH_4, and steam react to form carbon monoxide and hydrogen.

Q7. When the following reactions reach equilibrium at a given temperature, does the equilibrium mixture contain mostly reactants or mostly products? Assume that the values for K are applicable at the given temperature.

(a) $N_2(g) + 2H_2(g) \rightleftharpoons N_2H_4(g)$ $K = 7.4 \times 10^{-26}$

(b) $N_2(g) + O_2\ (g) \rightleftharpoons 2NO(g)$ $K = 2.7 \times 10^{-18}$

(c) $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $K = 6.0 \times 10^{13}$

Q8. At 298 K, the equilibrium concentrations in the reaction mixture:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

are $[N_2O_4] = 1.62\ mol\ dm^3$ and $[NO_2] = 1.80\ mol\ dm^{-3}$.

Determine the value of the equilibrium constant, K.

Q9. At a given temperature, the reaction

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

has a value of $K = 278$. Determine the value of K for the *reverse* reaction at this temperature.

Exercise

Q10. The manufacture of sulfur trioxide can be represented by the equation below:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -198\,kJ\,mol^{-1}$$

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 ΔH increases.

D The yield of sulfur trioxide increases.

Q11. What will happen to the position of equilibrium and the value of the equilibrium constant when the temperature is increased in the following reaction?

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

	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

Q12. 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

Q13. For each of the following reactions, predict in which direction the equilibrium will shift in response to an increase in pressure:

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

(b) $CO(g) + 2H_2 \rightleftharpoons CH_3OH(g)$

(c) $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

Q14. How will the equilibrium

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g) \quad \Delta H = +ve$$

respond to the following changes?

(a) addition of $H_2(g)$

(b) addition of $CH_4(g)$

(c) a decrease in the volume of the container

(d) removal of $CS_2(g)$

(e) increase in temperature

Q15. The reaction

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \quad \Delta H = -566\,kJ\,mol^{-1}$$

takes place in catalytic converters in cars. If this reaction is at equilibrium, will the amount of CO increase, decrease or stay the same when:

(a) the pressure is increased by decreasing the volume?

(b) the pressure is increased by adding $O_2(g)$?

(c) the temperature is increased?

(d) a platinum catalyst is added?

Q16. 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

Q17.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -200\,kJ\,mol^{-1}$$

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

Q18. Predict how you would expect the value of K for the exothermic Haber process to change as the temperature is increased. Explain the significance of this in terms of the reaction yield.

Exercise

Q19. The equilibrium constant, *K*, for the reaction:

$$H_2O(g) + Cl_2O(g) \rightleftharpoons 2HOCl(g)$$

is 0.0900 at 298 K.

Determine whether the following sets of conditions represent an equilibrium mixture for the reaction at this temperature.

	$[H_2O]$	$[Cl_2O]$	$[HOCl]$
(a)	0.100	0.100	1.00
(b)	0.49	0.040	0.042
(c)	0.19	0.00033	0.083

Q20. The equilibrium constant for the reaction:

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

is 1.00 at 298 K.

Determine the reaction quotient, *Q*, using the non-equilibrium concentrations below and determine the direction in which the reaction will proceed to reach equilibrium.

$[CO(g)] = 2.00\,mol\,dm^{-3}$

$[H_2O(g)] = 2.00\,mol\,dm^{-3}$

$[CO_2(g)] = 4.00\,mol\,dm^{-3}$

$[H_2(g)] = 4.00\,mol\,dm^{-3}$