SL Paper 1

Which statement is correct for a reversible reaction when $K_c \gg 1$?

A. The reaction almost goes to completion.

B. The reaction hardly occurs.

C. Equilibrium is reached in a very short time.

D. At equilibrium, the rate of the forward reaction is much higher than the rate of the backward reaction.

Markscheme

A

Examiners report

[N/A]

Which statement is always correct for a chemical reaction at equilibrium?

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

B. The amounts of reactants and products are equal.

C. The concentration of the reactants and products are constantly changing.

D. The forward reaction occurs to a greater extent than the reverse reaction.

Markscheme

A

Examiners report

[N/A]

Iron(III) ions, Fe^{3+}, react with thiocyanate ions, SCN^-, in a reversible reaction to form a red solution. Which changes to the equilibrium will make the solution go red?

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons [FeSCN]^{2+}(aq) \quad \Delta H^\ominus = +ve$$

Yellow Red

I. Increasing the temperature

II. Adding $\mathrm{FeCl_3}$

III. Adding a catalyst

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

A

Examiners report

[N/A]

Which statement about chemical equilibria implies they are dynamic?

A. The position of equilibrium constantly changes.

B. The rates of forward and backward reactions change.

C. The reactants and products continue to react.

D. The concentrations of the reactants and products continue to change.

Markscheme

C

Examiners report

[N/A]

What happens to the position of equilibrium and the value of K_c when the temperature is increased in the following reaction?

$$\mathrm{PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)} \quad \Delta H^\ominus = +87.9\ \mathrm{kJ\,mol^{-1}}$$

	Position of equilibrium	Value of K_c
A.	shifts towards reactants	decreases
B.	shifts towards reactants	increases
C.	shifts towards products	decreases
D.	shifts towards products	increases

Markscheme

D

Examiners report

[N/A]

Which factor does **not** affect the position of equilibrium in this reaction?

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H = -58 \text{ kJ mol}^{-1}$$

A. Change in volume of the container

B. Change in temperature

C. Addition of a catalyst

D. Change in pressure

Markscheme

C

Examiners report

[N/A]

Consider the reaction between gaseous iodine and gaseous hydrogen.

$$\mathrm{I_2(g) + H_2(g) \rightleftharpoons 2HI(g)} \quad \Delta H^{\ominus} = -9 \text{ kJ}$$

Why do some collisions between iodine and hydrogen **not** result in the formation of the product?

A. The $\mathrm{I_2}$ and $\mathrm{H_2}$ molecules do not have sufficient energy.

B. The system is in equilibrium.

C. The temperature of the system is too high.

D. The activation energy for this reaction is very low.

Markscheme

A

Examiners report

[N/A]

Consider the equilibrium between $N_2O_4(g)$ and $NO_2(g)$.

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

Which changes shift the position of equilibrium to the right?

I. Increasing the temperature
II. Decreasing the pressure
III. Adding a catalyst

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

A

Examiners report

[N/A]

The equilibrium constant for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is K.

What is the equilibrium constant for this equation?

$$2N_2(g) + 6H_2(g) \rightleftharpoons 4NH_3(g)$$

A. K

B. $2K$

C. K^2

D. $2K^2$

Markscheme

C

Examiners report

[N/A]

What is the equilibrium constant expression, K_c, for the following reaction?

$$2NH_3(g) + 2O_2(g) \rightleftharpoons N_2O(g) + 3H_2O(g)$$

A. $\frac{3[H_2O][N_2O]}{2[NH_3]2[O_2]}$

B. $\frac{[NH_3]^2[O_2]^2}{[N_2O][H_2O]^3}$

C. $\frac{2[NH_3]2[O_2]}{3[H_2O][N_2O]}$

D. $\frac{[N_2O][H_2O]^3}{[NH_3]^2[O_2]^2}$

Markscheme

D

Examiners report

[N/A]

The equilibrium between nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, is shown below.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \quad K_c = 0.01$$

What happens when the volume of a mixture at equilibrium is decreased at a constant temperature?

I. The value of K_c increases

II. More N_2O_4 is formed

III. The ratio of $\frac{[NO_2]}{[N_2O_4]}$ decreases

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

C

Examiners report

[N/A]

What effect will an increase in temperature have on the K_c value and the position of equilibrium in the following reaction?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\ kJ$$

	K_c	Equilibrium position
A.	increases	shifts to the right
B.	decreases	shifts to the left
C.	increases	shifts to the left
D.	decreases	shifts to the right

Markscheme

B

Examiners report

The difficulty index for this question was 58%, with incorrect responses distributed quite evenly over the distracters. It did however prove to be the best discriminator on the paper with a discrimination index of 0.64.

Hydrogen and iodine react in a closed vessel to form hydrogen iodide.

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

At 350 °C $\quad K_c = 60$

At 445 °C $\quad K_c = 47$

Which statement is correct when the system is at equilibrium at 350 °C?

A. The concentrations of all reactants and products are equal.

B. The concentrations of the reactants are greater than the concentration of the product.

C. The reaction, as written, barely proceeds at this temperature.

D. The reaction, as written, goes almost to completion at this temperature.

Markscheme

D

Examiners report

A comment was made that “barely” in answer C may have been difficult for those working in their second language. We acknowledge this, and will avoid its use.

What is the equilibrium constant expression, K_c, for the following reaction?

$$2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$$

A. $K_c = \frac{[H_2S]^2}{[H_2]^2[S_2]}$

B. $K_c = \frac{[H_2][S_2]}{[H_2S]}$

C. $K_c = \frac{2[H_2]+[S_2]}{2[H_2S]}$

D. $K_c = \frac{[H_2]^2[S_2]}{[H_2S]^2}$

Markscheme

D

Examiners report

[N/A]

Consider the following reaction:

$$2A \rightleftharpoons C \quad K_c = 1.1$$

Which statement is correct when the reaction is at equilibrium?

A. $[A] \gg [C]$

B. $[A] > [C]$

C. $[A] = [C]$

D. $[A] < [C]$

Markscheme

D

Examiners report

One respondent felt that this question required too much mathematical analysis. 61.21% of the candidates, however, gave the correct answer. It is not too much of a step from [C] / $[\mathrm{A}]^2 = 1.1$ (Assessment statement 7.2.1) to realizing that [C] must be larger than [A] – and then there is only one possible answer.

Which is **always** correct for a reaction at equilibrium?

	Concentrations of reactants and products	Rates of forward and reverse reactions
A.	continue to change	equal
B.	remain constant	equal
C.	continue to change	different
D.	remain constant	different

Markscheme

B

Examiners report

[N/A]

The value of the equilibrium constant, K_c, for a reaction is 1.0×10^{-10}. Which statement about the extent of the reaction is correct?

A. The reaction hardly proceeds.

B. The reaction goes almost to completion.

C. The products have a higher concentration than the reactants.

D. The concentrations of reactants and products are the same.

Markscheme

A

Examiners report

[N/A]

What happens to the position of equilibrium and the value of K_c in the following reaction when the temperature is decreased?

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^\ominus = +57.2\ kJ$$

	Position of equilibrium	Value of K_c
A.	shifts towards reactants	decreases
B.	shifts towards reactants	increases
C.	shifts towards products	decreases
D.	shifts towards products	increases

Markscheme

A

Examiners report

[N/A]

What will happen if the pressure is increased in the following reaction mixture at equilibrium?

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

A. The equilibrium will shift to the right and pH will decrease.

B. The equilibrium will shift to the right and pH will increase.

C. The equilibrium will shift to the left and pH will increase.

D. The equilibrium will shift to the left and pH will decrease.

Markscheme

A

Examiners report

[N/A]

The reaction below represents the Haber process for the industrial production of ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H^\ominus = -92\ kJ$$

The optimum conditions of temperature and pressure are chosen as a compromise between those that favour a high yield of ammonia and those that favour a fast rate of production. Economic considerations are also important.

Which statement is correct?

A. A higher temperature would ensure higher yield and a faster rate.

B. A lower pressure would ensure a higher yield at a lower cost.

C. A lower temperature would ensure a higher yield and a faster rate.

D. A higher pressure would ensure a higher yield at a higher cost.

Markscheme

D

Examiners report

[N/A]

Which changes occur when the temperature is decreased in the following equilibrium?

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

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

Markscheme

B

Examiners report

[N/A]

Which change will favour the **reverse** reaction in the equilibrium?

$$2\mathrm{CrO_4^{2-}(aq)} + 2\mathrm{H^+(aq)} \rightleftharpoons \mathrm{Cr_2O_7^{2-}(aq)} + \mathrm{H_2O(l)} \qquad \Delta H = -42\ \mathrm{kJ}$$

A. Adding $\mathrm{OH^-(aq)}$

B. Adding $\mathrm{H^+(aq)}$

C. Increasing the concentration of $\mathrm{CrO_4^{2-}(aq)}$

D. Decreasing the temperature of the solution

Markscheme

A

Examiners report

[N/A]

Consider the following equilibrium reaction.

$$2\mathrm{SO_2(g)} + \mathrm{O_2(g)} \rightleftharpoons 2\mathrm{SO_3(g)} \quad \Delta H^{\ominus} = -197\ \mathrm{kJ}$$

Which change in conditions will increase the amount of $\mathrm{SO_3}$ present when equilibrium is re-established?

A. Decreasing the concentration of $\mathrm{SO_2}$

B. Increasing the volume

C. Decreasing the temperature

D. Adding a catalyst

Markscheme

C

Examiners report

[N/A]

The following are K_c values for a reaction, with the same starting conditions carried out at different temperatures. Which equilibrium mixture has the highest concentration of products?

A. 1×10^{-2}

B. 1

C. 1×10^{1}

D. 1×10^{2}

Markscheme

D

Examiners report

[N/A]

What is the equilibrium constant expression, K_c, for the following reaction?

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

A. $K_c = \frac{[NO][Br_2]}{[NOBr]}$

B. $K_c = \frac{[NO]^2[Br_2]}{[NOBr]^2}$

C. $K_c = \frac{2[NO]+[Br_2]}{[2NOBr]}$

D. $K_c = \frac{[NOBr]^2}{[NO]^2[Br_2]}$

Markscheme

B

Examiners report

[N/A]

An increase in temperature increases the amount of chlorine present in the following equilibrium.

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

What is the best explanation for this?

A. The higher temperature increases the rate of the forward reaction only.

B. The higher temperature increases the rate of the reverse reaction only.

C. The higher temperature increases the rate of both reactions but the forward reaction is affected more than the reverse.

D. The higher temperature increases the rate of both reactions but the reverse reaction is affected more than the forward.

Markscheme

C

Examiners report

[N/A]

What is the equilibrium constant expression for the reaction below?

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

A. $K_c = \frac{[NO_2]^2}{[N_2O_4]}$

B. $K_c = \frac{[N_2O_4]}{[NO_2]}$

C. $K_c = \frac{[N_2O_4]}{2[NO_2]}$

D. $K_c = \frac{[N_2O_4]}{[NO_2]^2}$

Markscheme

D

Examiners report

[N/A]

Which equilibrium reaction shifts to the product side when the temperature is increased at constant pressure **and** to the reactant side when the total pressure is increased at constant temperature?

A. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H^\ominus < 0$

B. $N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^\ominus > 0$

C. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \Delta H^\ominus < 0$

D. $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad \Delta H^\ominus > 0$

Markscheme

B

Examiners report

[N/A]

For the following reaction $K_c = 1.0 \times 10^{-5}$ at 30 °C.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Which relationship is correct at equilibrium at this temperature?

A. The concentration of NO equals the concentration of NOCl.

B. The concentration of NOCl is double the concentration of Cl_2.

C. The concentration of NOCl is much greater than the concentration of Cl_2.

D. The concentration of NO is much greater than the concentration of NOCl.

Markscheme

C

Examiners report

There were two G2 comments on this question, both stating that the question was demanding. The question was answered correctly by 54.51% of candidates.

What is the equilibrium constant expression, K_c, for this reaction?

$$2NO(g) + H_2(g) \rightleftharpoons N_2O(g) + H_2O(g)$$

A. $K_c = \frac{[N_2O]+[H_2O]}{2[NO]+[H_2]}$

B. $K_c = \frac{[NO]^2[H_2]}{[N_2O][H_2O]}$

C. $K_c = \frac{[2NO]+[H_2]}{[N_2O]+[H_2O]}$

D. $K_c = \frac{[N_2O][H_2O]}{[NO]^2[H_2]}$

Markscheme

D

Examiners report

[N/A]

Which are characteristics of a dynamic equilibrium?

I. Amounts of products and reactants are constant.

II. Amounts of products and reactants are equal.

III. The rate of the forward reaction is equal to the rate of the backward reaction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

B

Examiners report

[N/A]

What is the equilibrium constant expression, K_c, for the formation of hydrogen iodide from its elements?

$$\mathrm{H_2(g) + I_2(g) \rightleftharpoons 2HI(g)}$$

A. $K_c = \frac{[\mathrm{HI}]^2}{[\mathrm{H_2}] \times [\mathrm{I_2}]}$

B. $K_c = \frac{[\mathrm{2HI}]}{[\mathrm{H_2}] + [\mathrm{I_2}]}$

C. $K_c = \frac{2[\mathrm{HI}]^2}{[\mathrm{H_2}] + [\mathrm{I_2}]}$

D. $K_c = \frac{[\mathrm{2HI}]}{[\mathrm{H_2}] \times [\mathrm{I_2}]}$

Markscheme

A

Examiners report

K_c expressions often leave much to be desired so it was encouraging to see that this was the easiest question on the paper with 93% of answers correct.

Consider this reaction at equilibrium.

$$\mathrm{H_2S(aq) + Zn^{2+}(aq) \rightleftharpoons ZnS(s) + 2H^+(aq)} \quad \Delta H < 0$$

Which change shifts the equilibrium position to the right?

A. Adding sodium hydroxide

B. Decreasing pressure

C. Adding a catalyst

D. Increasing temperature

Markscheme

A

Examiners report

[N/A]

Which combination of temperature and pressure will give the greatest yield of sulfur trioxide?

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

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

Markscheme

B

Examiners report

[N/A]

Hydrogen and iodine react in a closed vessel to form hydrogen iodide.

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

At 350 °C $K_c = 60$

At 445 °C $K_c = 47$

Which statement describes and explains the conditions that favour the formation of hydrogen iodide?

A. Increased temperature as the forward reaction is exothermic, and increased pressure as there are two gaseous reactants and only one gaseous product

B. Increased temperature as the forward reaction is endothermic, and pressure has no effect as there are equal amounts, in mol, of gaseous reactants and products

C. Decreased temperature as the forward reaction is exothermic, and decreased pressure as there are two moles of gaseous product but only one mole of each gaseous reactant

D. Decreased temperature as the forward reaction is exothermic, and pressure has no effect as there are equal amounts, in mol, of gaseous reactants and products

Markscheme

D

Examiners report

[N/A]

The formation of nitric acid, $\mathrm{HNO_3(aq)}$, from nitrogen dioxide, $\mathrm{NO_2(g)}$, is exothermic and is a reversible reaction.

$$\mathrm{4NO_2(g) + O_2(g) + 2H_2O(l) \rightleftharpoons 4HNO_3(aq)}$$

What is the effect of a catalyst on this reaction?

A. It increases the yield of nitric acid.

B. It increases the rate of the forward reaction only.

C. It increases the equilibrium constant.

D. It has no effect on the equilibrium position.

Markscheme

D

Examiners report

[N/A]

Which statement correctly describes the effect of a catalyst on the equilibrium below?

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

A. It increases the rates of both forward and reverse reactions equally.

B. It increases the rate of the forward reaction but decreases the rate of the reverse reaction.

C. It increases the value of the equilibrium constant.

D. It increases the yield of $\mathrm{NH_3}$.

Markscheme

A

Examiners report

[N/A]

What will happen when at a constant temperature, more iodide ions, $\mathrm{I^-}$, are added to the equilibrium below?

$$\mathrm{I_2(s) + I^-(aq) \rightleftharpoons I_3^-(aq)}$$

A. The amount of solid iodine decreases and the equilibrium constant increases.

B. The amount of solid iodine decreases and the equilibrium constant remains unchanged.

C. The amount of solid iodine increases and the equilibrium constant decreases.

D. The amount of solid iodine increases and the equilibrium constant remains unchanged.

Markscheme

B

Examiners report

One G2 comment stated that the SL syllabus only requires students to consider *Kc* from the equation for a homogeneous reaction as outlined in AS 7.2.1. The respondent stated that the equilibrium as written involves two phases, (s) and (aq), and hence this would have confused candidates. 52% of candidates however did get the question correct and the question proved to be a reasonably good discriminator also, with a discrimination index of 0.45.

What happens when the temperature of the following equilibrium system is increased?

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H^{\theta} = -91kJ$

	Position of equilibrium	Reaction rates of forward and reverse reactions
A.	shifts to the left	increase
B.	shifts to the left	decrease
C.	shifts to the right	decrease
D.	shifts to the right	increase

Markscheme

A

Examiners report

[N/A]

Consider the endothermic reaction below.

$$5CO(g) + I_2O_5(g) \rightleftharpoons 5CO_2(g) + I_2(g)$$

According to Le Chatelier's principle, which change would result in an increase in the amount of CO_2?

A. Increasing the temperature

B. Decreasing the temperature

C. Increasing the pressure

D. Decreasing the pressure

Markscheme

A

Examiners report

[N/A]

Carbon monoxide and water react together in the industrial production of hydrogen gas.

$$\mathrm{CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)}$$

What is the impact of decreasing the volume of the equilibrium mixture at a constant temperature?

A. The amount of $\mathrm{H_2(g)}$ remains the same but its concentration decreases.

B. The forward reaction is favoured.

C. The reverse reaction is favoured.

D. The value of K_c remains unchanged.

Markscheme

D

Examiners report

[N/A]

What is the equilibrium constant expression, K_c, for the following reaction?

$$\mathrm{N_2O_4(g) \rightleftharpoons 2NO_2(g)}$$

A. $K_\mathrm{c} = \frac{[\mathrm{NO_2}]}{[\mathrm{N_2O_4}]}$

B. $K_\mathrm{c} = \frac{[\mathrm{NO_2}]^2}{[\mathrm{N_2O_4}]}$

C. $K_\mathrm{c} = \frac{[\mathrm{NO_2}]}{[\mathrm{N_2O_4}]^2}$

D. $K_\mathrm{c} = [\mathrm{NO_2}][\mathrm{N_2O_4}]^2$

Markscheme

B

Examiners report

[N/A]

What is the effect of increasing temperature on the equilibrium?

$$ClNO_2(g) + NO(g) \rightleftharpoons ClNO(g) + NO_2(g) \qquad \Delta H^{\ominus} = -18.4\,kJ$$

	Position of equilibrium	K_c
A.	moves to left	decreases
B.	moves to left	no change
C.	moves to right	no change
D.	moves to right	increases

Markscheme

A

Examiners report

[N/A]
