Equilibria – 2023 AS Chemistry 9701

1. Nov/2023/Paper_ 9701/11/No.12

Nitrogen dioxide, NO_2, exists in equilibrium with dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57\,kJ\,mol^{-1}$$

Which conditions give the greatest percentage of $N_2O_4(g)$ at equilibrium?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

2. Nov/2023/Paper_ 9701/11/No.13

When an equimolar mixture of H_2 and I_2 react, the mole fraction of HI in the final mixture is x.

What is the equilibrium constant, K_p, for the reaction?

A $\dfrac{x^2}{(1-x)^2}$

B $\dfrac{x^2}{(1-2x)^2}$

C $\dfrac{4x^2}{(1-x)^2}$

D $\dfrac{4x^2}{(1-2x)^2}$

3. Nov/2023/Paper_ 9701/12/No.14

A mixture of the three gases, oxygen, nitrogen and argon, is at a total pressure of 500 kPa. There is a total of 1.2 moles of gas in the mixture.

If the oxygen gas alone occupied the entire volume of the mixture, it would exert a pressure of 150 kPa.

At room conditions the amount of nitrogen gas in the mixture would occupy a volume of 5.76 dm^3.

What is the partial pressure of the argon gas in the mixture?

A 150 kPa

B 200 kPa

C 250 kPa

D 300 kPa

4. Nov/2023/Paper_ 9701/12/No.15

0.200 mol of sulfur dioxide and 0.200 mol of oxygen are placed in a 1.00 dm^3 sealed container. The gases are allowed to react until equilibrium is reached.

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

At equilibrium there is 0.100 mol of SO_3 in the container.

What is the value of K_c?

A 0.150 mol dm^{-3}

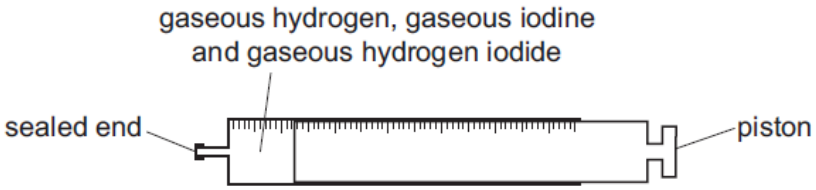
B 0.800 mol dm^{-3}

C 1.25 mol^{-1} dm^3

D 6.67 mol^{-1} dm^3

5. Nov/2023/Paper_ 9701/12/No.17

The diagram shows a gas syringe with a free-moving piston. The syringe contains gaseous hydrogen, gaseous iodine and gaseous hydrogen iodide at equilibrium.



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

Three changes are listed.

1 increasing the total pressure by adding an inert gas and keeping the volume constant

2 increasing the pressure by adding more gaseous hydrogen iodide and keeping the volume constant

3 decreasing the volume by pushing the piston to the left

Which changes will result in an equilibrium position at which the rate of the forward reaction has increased?

A 2 only **B** 1 and 2 **C** 1 and 3 **D** 2 and 3

6. Nov/2023/Paper_ 9701/22/No.2(a, b, c)

NO and NO_2 react at 25 °C to give N_2O_3 as shown in the equation.

$$NO(g) + NO_2(g) \rightleftharpoons N_2O_3(g) \qquad \Delta H = -7.2\,kJ\,mol^{-1}$$

The reaction is reversible and reaches equilibrium in a closed system.

(a) Fig. 2.1 shows how the rate of the forward reaction changes with time.

Initially, the rate of the reverse reaction is zero.

Complete Fig. 2.1 to sketch how the rate of the **reverse** reaction changes with time.

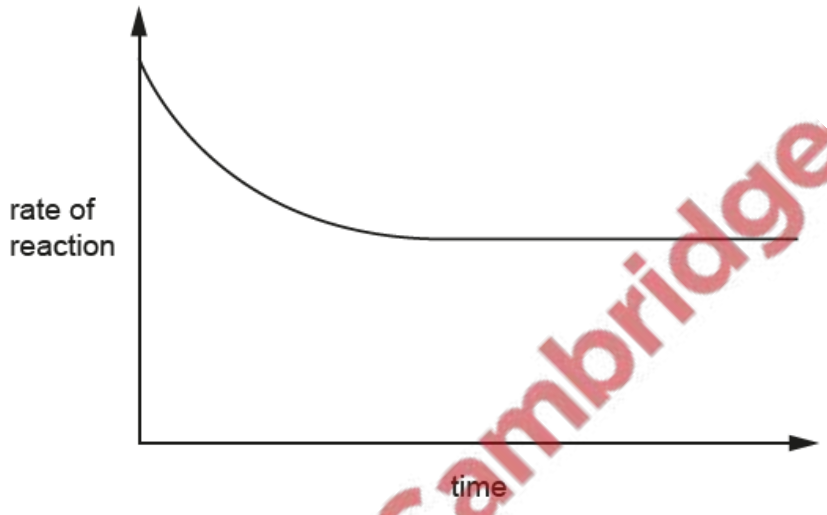


Fig. 2.1

[1]

(b) State how the position of equilibrium changes, if at all, when the reaction takes place at 100 °C.

Explain your answer.

Assume the pressure remains constant.

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.....

.....

..... [2]

(c) Table 2.1 shows the composition of an equilibrium mixture of NO(g), NO_2(g) and N_2O_3(g) at 101 kPa.

Table 2.1

gas	number of moles at equilibrium / mol
NO	0.605
NO_2	0.605
N_2O_3	0.390

Calculate K_p, the equilibrium constant with respect to partial pressures.

Deduce the units of K_p.

K_p = ... units .....

[3]

7. June/2023/Paper_9701/11/No.4

For which equilibrium do both of the equilibrium constants K_c and K_p have no units?

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

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

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

D $SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$

8. June/2023/Paper_9701/11/No.8

The Contact process takes place at a pressure between 100 000 Pa and 200 000 Pa. A catalyst is used.

Which statement is correct?

A A V_2O_5 catalyst is added to increase the equilibrium yield of the reaction.

B Changes in pressure have no effect on the position of equilibrium.

C The equilibrium yield of the reaction is very high under the conditions used.

D An iron catalyst is added to increase the rate of reaction.

9. June/2023/Paper_9701/12/No.13

In which equilibrium will an increase in pressure at constant temperature increase the yield of the products on the right-hand side of the equation?

A $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

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

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

D $3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$

10. June/2023/Paper_9701/12/No.14

Hydrogen iodide is added to an evacuated reaction vessel. The vessel is sealed and warmed. A decomposition reaction occurs. Hydrogen and iodine are formed. Some hydrogen iodide remains.

When equilibrium is established, the total pressure is 1.20×10^5 Pa. The partial pressure of hydrogen is 4.00×10^3 Pa.

Hydrogen iodide, hydrogen and iodine are all gaseous under the conditions used.

What is the value of K_p for the equilibrium at this temperature, assuming the decomposition is the forward reaction?

A 1.19×10^{-3} **B** 1.28×10^{-3} **C** 1.38×10^{-3} **D** 1.43×10^{-3}

11. June/2023/Paper_9701/13/No.15

Sulfur dioxide reacts with oxygen as shown.

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

Which change will move the equilibrium position to the right side and change the value of the equilibrium constant, K_c?

A the addition of a catalyst

B increasing the pressure of the reaction

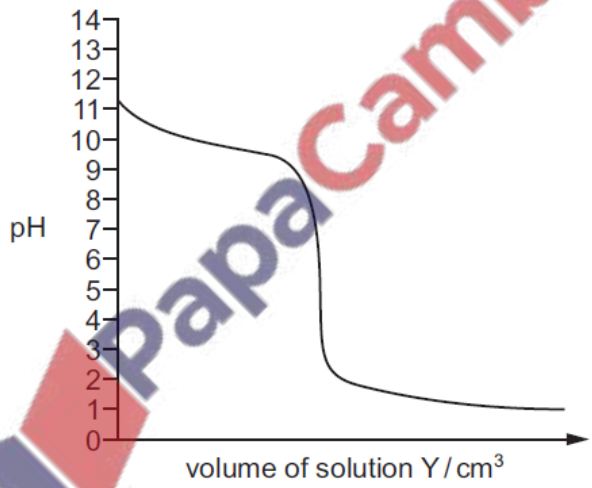
C decreasing the temperature of the reaction

D decreasing the concentration of product

12. June/2023/Paper_9701/13/No.16

Solutions X and Y both have a concentration of 0.10 mol dm^{-3}. A fixed volume of solution X is added to a conical flask, and solution Y is added from a burette to the conical flask. A titration is performed.

The diagram shows the pH titration curve for the acid–base reaction between the solutions.



What are solutions X and Y?

	solution X	solution Y
A	ammonia	nitric acid
B	ammonia	ethanoic acid
C	potassium hydroxide	nitric acid
D	potassium hydroxide	ethanoic acid

13. June/2023/Paper_9701/23/No.4

(a) Hydrogen chloride gas is made in the laboratory by adding concentrated sulfuric acid to potassium chloride.

(i) Construct an equation for this reaction.

..... [1]

(ii) Explain why hydrogen iodide is **not** prepared by adding concentrated sulfuric acid to sodium iodide.

.....

..... [2]

(b) A sample of HI(g) is added to a 2.00 dm^3 sealed vessel at 764 K and allowed to reach equilibrium.

reaction 1 $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $K_c = 0.0217$ at 764 K

At equilibrium the mixture contains 1.70 mol of HI(g).

(i) State **one** difference in the appearance of the initial reaction mixture compared to the mixture at equilibrium.

.....

..... [1]

(ii) Deduce the expression for equilibrium constant K_c for reaction 1.

K_c =

[1]

(iii) Calculate the concentration of I_2 present in the reaction mixture at equilibrium.
Show your working.

concentration of I_2 = ... mol dm^{-3} [3]

(c) The experiment is repeated at 500 K. The value of K_c under these conditions is 0.00625.

(i) Describe the difference in the composition of the equilibrium mixture at 500 K compared to 764 K.

.....

..... [1]

(ii) Use Le Chatelier's principle to deduce whether the decomposition of HI(g) is endothermic or exothermic. Explain your answer.

.....

.....

..... [1]

[Total: 10]

14. March/2023/Paper_9701/12/No.4

The table shows the partial pressures in an equilibrium mixture formed by the Haber process.

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

substance	partial pressure / kPa
nitrogen	7000
hydrogen	8000
ammonia	4000

What is the numerical value of the equilibrium constant, K_p, for this reaction?

A 4.46×10^{-9} **B** 4.76×10^{-5} **C** 7.14×10^{-5} **D** 2.24×10^{8}

15. March/2023/Paper_9701/12/No.5

A reversible reaction is shown.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H = +77.0 \text{ kJ mol}^{-1}$$

Which change in conditions will move the position of equilibrium to the right and increase the value of the equilibrium constant?

A a decrease in pressure

B a decrease in temperature

C an increase in pressure

D an increase in temperature