

Chapter 7

# Equilibrium

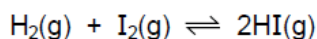


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- 1 In an experiment, 2.00 mol of hydrogen and 3.00 mol of iodine were heated together in a sealed container and allowed to reach equilibrium at a fixed temperature. The container had a fixed volume of  $1.00 \text{ dm}^3$ . At equilibrium, there were 2.40 mol of iodine present in the mixture.



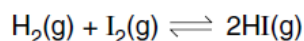
1

What is the value of the equilibrium constant,  $K_c$ ?

- A 0.107      B 0.357      C 0.429      D 2.33

- 2 When 0.20 mol of hydrogen gas and 0.15 mol of iodine gas are heated at 723 K until equilibrium is established, the equilibrium mixture is found to contain 0.26 mol of hydrogen iodide.

The equation for the reaction is as follows.



What is the correct expression for the equilibrium constant  $K_c$ ?

A  $\frac{2 \times 0.26}{0.20 \times 0.15}$

B  $\frac{(2 \times 0.26)^2}{0.20 \times 0.15}$

C  $\frac{(0.26)^2}{0.07 \times 0.02}$

D  $\frac{(0.26)^2}{0.13 \times 0.13}$

- 3 Why is ethanoic acid a stronger acid in liquid ammonia than in aqueous solution?

- A Ammonia is a stronger base than water.  
B Ammonium ethanoate is completely ionised in aqueous solution.  
C Ammonium ethanoate is strongly acidic in aqueous solution.  
D Liquid ammonia is a more polar solvent than water.

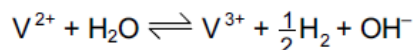
- 4 Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

- A aqueous bromine  
B dilute hydrochloric acid  
C limewater  
D acidified potassium dichromate(VI)

- 5 Which of these equations represents the reaction of sulphur dioxide with an excess of aqueous sodium hydroxide?

- A  $\text{SO}_2 + \text{NaOH} \rightarrow \text{NaHSO}_3$   
B  $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$   
C  $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$   
D  $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2$

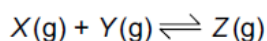
- 6 When vanadium(II) compounds are dissolved in water, the following equilibrium is established.



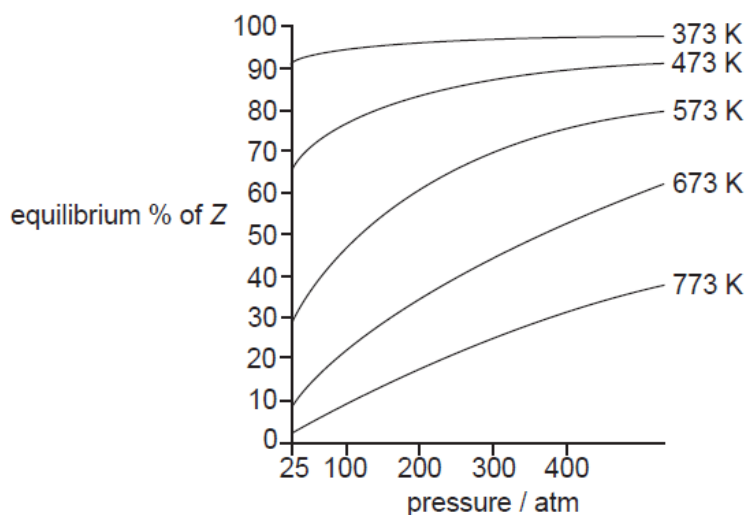
2

What would alter the composition of the equilibrium mixture in favour of the  $\text{V}^{2+}$  ions?

- A** adding an acid  
**B** adding a reagent that selectively precipitates  $\text{V}^{3+}$  ions  
**C** allowing the hydrogen to escape as it forms  
**D** making the solution more alkaline
- 7 In an industrial process, two gases X and Y react together to form a single gaseous product Z.



The percentage yield of product Z varies according to the pressure and the temperature as shown in the graphs.



Which statement about this equilibrium reaction is correct?

- A** Decreasing the temperature decreases the value of the equilibrium constant.  
**B** Decreasing the temperature increases the rate of this reaction.  
**C** Increasing the pressure increases the value of the equilibrium constant.  
**D** The reaction is exothermic in the forward direction.
- 8 At a total pressure of 1.0 atm, dinitrogen tetraoxide is 50% dissociated at a temperature of 60 °C, according to the following equation.



What is the value of the equilibrium constant,  $K_p$ , for this reaction at 60 °C?

- A**  $\frac{1}{3}\text{atm}$       **B**  $\frac{2}{3}\text{atm}$       **C**  $\frac{4}{3}\text{atm}$       **D** 2 atm
- 9 For the reaction



what are the correct units for the equilibrium constant  $K_c$ ?

- A**  $\text{mol dm}^{-3}$       **B**  $\text{mol}^2 \text{dm}^{-6}$       **C**  $\text{mol}^{-1} \text{dm}^3$       **D**  $\text{mol}^{-2} \text{dm}^6$

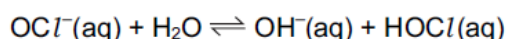
- 10 The dissociation of dinitrogen tetraoxide into nitrogen dioxide is represented by the equation below.



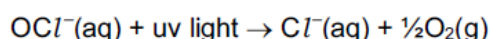
If the temperature of an equilibrium mixture of the gases is increased at constant pressure, will the volume of the mixture increase or decrease and why?

- A The volume will increase, but only because of a shift of equilibrium towards the right.
- B The volume will increase, both because of a shift of equilibrium towards the right and also because of thermal expansion.
- C The volume will stay the same, because any thermal expansion could be exactly counteracted by a shift of equilibrium towards the left.
- D The volume will decrease, because a shift of equilibrium towards the left would more than counteract any thermal expansion.

- 11 Swimming pool water can be kept free of harmful bacteria by adding aqueous sodium chlorate(I),  $\text{NaOCl}$ . This reacts with water to produce  $\text{HOCl}$  molecules which kill bacteria.

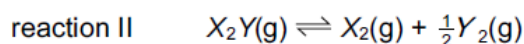
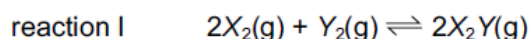


In bright sunshine, the  $\text{OCl}^-$  ion is broken down by ultra-violet light.



Which method would maintain the highest concentration of  $\text{HOCl}(\text{aq})$ ?

- A acidify the pool water
  - B add a solution of chloride ions
  - C add a solution of hydroxide ions
  - D bubble air through the water
- 12 Two equilibria are shown below.



The numerical value of  $K_c$  for reaction I is 2.

Under the same conditions, what is the numerical value of  $K_c$  for reaction II?

- A  $\frac{1}{\sqrt{2}}$       B  $\frac{1}{2}$       C  $\frac{1}{4}$       D -2

- 13 Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

- A aqueous bromine
- B dilute hydrochloric acid
- C limewater
- D acidified potassium dichromate(VI)

- 14 The table gives the concentrations and pH values of the aqueous solutions of two compounds, X and Y. Either compound could be an acid or a base.

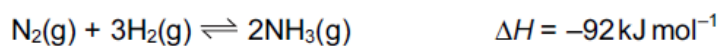
	X	Y
concentration	$2 \text{ mol dm}^{-3}$	$2 \text{ mol dm}^{-3}$
pH	6	9

Student P concluded that X is a strong acid.

Student Q concluded that the extent of dissociation is lower in X(aq) than in Y(aq).

Which of the students are correct?

- A both P and Q
  - B neither P nor Q
  - C P only
  - D Q only
- 15 The Haber process for the manufacture of ammonia is represented by the following equation.

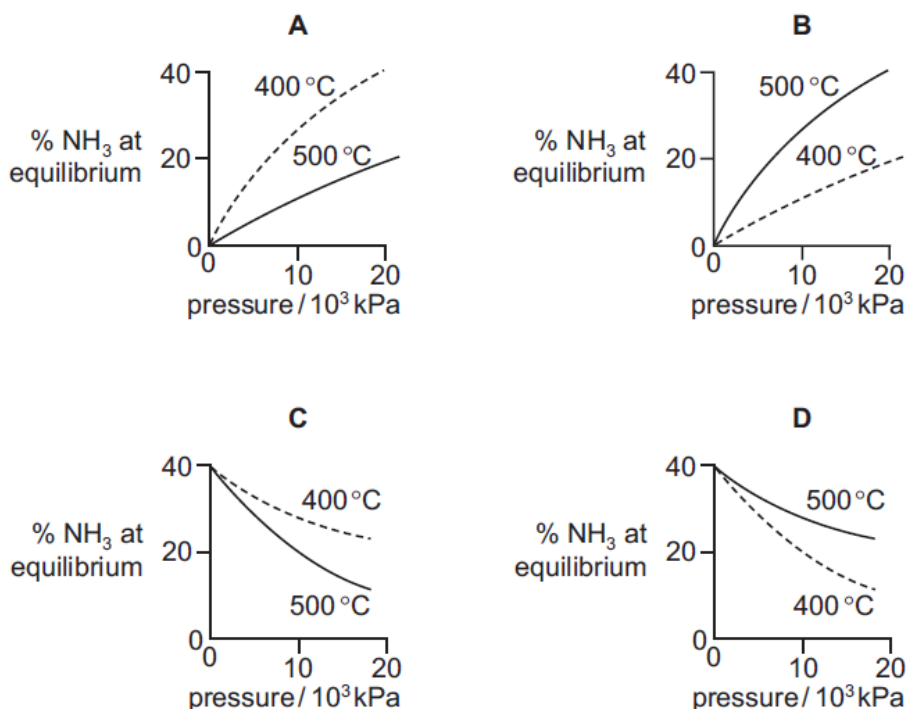


Which statement is correct about this reaction when the temperature is increased?

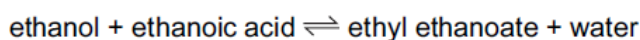
- A Both forward and backward rates increase.
- B The backward rate only increases.
- C The forward rate only increases.
- D There is no effect on the backward or forward rate.

- 16 The percentage of ammonia obtainable, if equilibrium were established during the Haber process, is plotted against the operating pressure for two temperatures, 400 °C and 500 °C.

Which diagram correctly represents the two graphs?



- 17 The esterification reaction

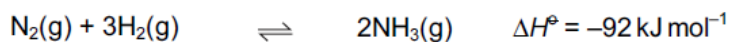


is an equilibrium. The forward reaction is exothermic.

How can the value of the equilibrium constant  $K_C$  be increased?

- A by adding a little concentrated sulfuric acid as a catalyst
  - B by increasing the initial concentration of ethanol
  - C by lowering the temperature
  - D by raising the temperature
- 18 Ammonia is manufactured on a large scale by the Haber process.

In a particular plant, conditions of 400 °C and 250 atm in the presence of an iron catalyst are used.



What could contribute most to increasing the equilibrium yield of ammonia?

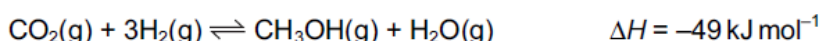
- A adding more catalyst
- B increasing the pressure to 400 atm
- C increasing the temperature to 1000 °C
- D using air rather than nitrogen

- 19 Two moles of compound P were placed in a vessel. The vessel was heated and compound P was partly decomposed to produce Q and R. A dynamic equilibrium between chemicals P, Q and R was established.

At equilibrium  $x$  moles of R were present and the total number of moles present was  $(2 + \frac{x}{2})$ .

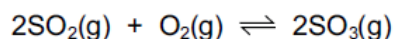
What is the equation for this equilibrium reaction?

- A  $P \rightleftharpoons 2Q + R$   
B  $2P \rightleftharpoons 2Q + R$   
C  $2P \rightleftharpoons Q + R$   
D  $2P \rightleftharpoons Q + 2R$
- 20 Methanol is manufactured by reacting carbon dioxide and hydrogen.



What would increase the equilibrium yield of methanol in this process?

- A adding a catalyst  
B adding an excess of steam  
C increasing the pressure  
D increasing the temperature
- 21 The reaction between sulfur dioxide and oxygen is a dynamic equilibrium.

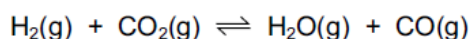


What happens when the pressure of the system is increased?

- A The rate of reaction will decrease and the position of the equilibrium will move to the left.  
B The rate of reaction will decrease and the position of the equilibrium will move to the right.  
C The rate of reaction will increase and the position of the equilibrium will move to the left.  
D The rate of reaction will increase and the position of the equilibrium will move to the right.
- 22 Sulfur trioxide is manufactured from sulfur dioxide and oxygen, using the Contact process.

Which condition affects the value of the equilibrium constant,  $K_c$ ?

- A adjusting the temperature  
B increasing the pressure  
C removing  $\text{SO}_3$  from the equilibrium mixture  
D using a catalyst
- 23 Hydrogen and carbon dioxide gases are mixed in equal molar amounts at 800 K. A reversible reaction takes place.

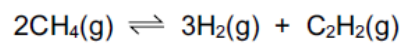


At equilibrium, the partial pressures of  $\text{H}_2$  and  $\text{CO}_2$  are both 10.0 kPa.  $K_p$  is 0.288 at 800 K.

What is the partial pressure of CO in the equilibrium mixture?

- A 5.37 kPa      B 18.6 kPa      C 28.8 kPa      D 347 kPa

24 The formation of hydrogen and ethyne,  $C_2H_2$ , from methane reaches dynamic equilibrium.



What are the units of  $K_c$ ?

- A  $\text{mol dm}^{-3}$       B  $\text{mol}^2 \text{dm}^{-6}$       C  $\text{mol}^3 \text{dm}^{-9}$       D  $\text{mol}^4 \text{dm}^{-12}$

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## Equilibrium

1	C	11	A	21	D	31	
2	C	12	A	22	A	32	
3	A	13	C	23	A	33	
4	C	14	D	24	B	34	
5	B	15	A	25		35	
6	D	16	A	26		36	
7	D	17	C	27		37	
8	C	18	B	28		38	
9	B	19	D	29		39	
10	B	20	C	30		40	