A-Level Chemistry

Equilibria and Kc
(Multiple Choice)

Question Paper

Time available: 31 minutes
Marks available: 30 marks

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1. Which statement about the use of a catalyst in a reversible reaction is correct?

A The activation energy for the reverse reaction is increased.

B The equilibrium constant increases.

C The rate of the reverse reaction increases.

D The enthalpy change for the forward reaction decreases.

(Total 1 mark)

2. Which statement about the addition of a catalyst to an equilibrium mixture is correct?

A The activation energy for the reverse reaction increases.

B The equilibrium constant for the forward reaction increases.

C The rate of the reverse reaction increases.

D The enthalpy change for the forward reaction decreases.

(Total 1 mark)

3. Which statement is **not** always correct for a reaction at equilibrium?

reactants $\rightleftharpoons$ products

A The concentrations of the reactants and products are equal.

B The equilibrium can be achieved starting from the reactants.

C The equilibrium can be achieved starting from the products.

D The rate of the forward reaction is equal to the rate of the reverse reaction.

(Total 1 mark)

4. When one mole of ammonia is heated to a given temperature, 50 % of it dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$$

What is the total amount, in moles, of gas in this equilibrium mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)

5. Which change leads to a higher concentration of SO_3 in this equilibrium mixture?

$$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -188\ \text{kJ mol}^{-1}$$

A higher concentration of O_2

B higher temperature

C lower pressure

D use of a catalyst

(Total 1 mark)

6. Which statement is **not** correct about the industrial preparation of ethanol by the hydration of ethene at 300 °C?

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)\ \Delta H = -46\ \text{kJ mol}^{-1}$$

A The reaction is catalysed by an acid.

B The higher the pressure, the higher the equilibrium yield of ethanol.

C The higher the temperature, the higher the equilibrium yield of ethanol.

D A low equilibrium yield of ethanol is acceptable because unreacted ethene is recycled.

(Total 1 mark)

7. For this reaction at equilibrium, which combination of temperature and pressure would give the greatest equilibrium yield of products?

$$W(g) + X(g) \rightleftharpoons 2Y(g) + Z(g) \qquad \Delta H = +47 \text{ kJ mol}^{-1}$$

A High pressure and high temperature ⬭

B High pressure and low temperature ⬭

C Low pressure and high temperature ⬭

D Low pressure and low temperature ⬭

(Total 1 mark)

8. The forward reaction in this equilibrium is endothermic

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

Which statement is correct?

A If the total pressure is increased at constant temperature, the proportion of $COCl_2$ in the equilibrium mixture will decrease ⬭

B Use of a catalyst will increase the proportion of $COCl_2$ in the equilibrium mixture at constant temperature and pressure ⬭

C Reducing the equilibrium concentration of CO will increase the value of the equilibrium constant ⬭

D Raising the temperature from 373 K to 473 K will increase the value of the equilibrium constant ⬭

(Total 1 mark)

9. Hydrogen can be produced by this reaction.

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

In an experiment 4.20 mol of carbon monoxide were mixed with 2.00 mol of steam. When the reaction reached equilibrium, 1.60 mol of hydrogen had been formed.

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

A 0.30

B 0.41

C 1.54

D 2.46

(Total 1 mark)

10. The following equilibrium was established in a container with volume V cm^3 at 393 K and 200 kPa.

$$M_2(g) + R(g) \rightleftharpoons RM_2(g) \qquad \Delta H = +150 \text{ kJ mol}^{-1}$$

Which change would increase the yield of RM_2?

A change the pressure to 150 kPa

B change the temperature to 293 K

C remove RM_2 as it is formed

D change the volume of the vessel to 2V cm^3

(Total 1 mark)

11. When one mole of ammonia is heated to a given temperature, 50% of the compound dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g)$$

What is the total number of moles of gas present in this equilibrium mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)

12. A pale brown mixture of NO_2 and N_2O_4 is allowed to reach equilibrium in a sealed gas syringe according to the following equation.

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

When the plunger is pushed further into the syringe the pressure increases and the mixture becomes paler in colour.

When the syringe is placed in a hot oven the mixture becomes darker in colour.

Which of the following statements is correct?

A NO_2 is brown and the forward reaction is exothermic.

B NO_2 is brown and the forward reaction is endothermic.

C NO_2 is colourless and the forward reaction is exothermic.

D NO_2 is colourless and the forward reaction is endothermic.

(Total 1 mark)

13. **A** and **B** react together in this reversible reaction.

$$\mathbf{A} + \mathbf{3B} \rightleftharpoons \mathbf{C} + \mathbf{2D}$$

A mixture of 10 mol of **A** and 10 mol of **B** were left to reach equilibrium. The equilibrium mixture contained 4 mol of **B**.

What is the total amount, in moles, of substances in the equilibrium mixture?

A 14 ⬭

B 16 ⬭

C 18 ⬭

D 20 ⬭

(Total 1 mark)

14. Hydrogen is produced by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\ \text{kJ mol}^{-1}$$

Which of the following shows how the equilibrium yield of hydrogen and the value of the equilibrium constant are affected by the changes shown?

	Change	Effect on equilibrium yield of $H_2(g)$	Effect on value of K_c	
A	Increase pressure	decrease	decrease	⬭
B	Add a catalyst	increase	no effect	⬭
C	Increase temperature	increase	increase	⬭
D	Remove CO(g) as formed	increase	increase	⬭

(Total 1 mark)

15. The standard enthalpy of formation, ΔH_f for O_3(g) is + 142 kJ mol^{-1}. In which one of the following would both the changes shown increase the amount of O_2 gas in an equilibrium mixture containing only O_2(g) and O_3(g)?

A increasing the temperature and increasing the pressure

B increasing the temperature and decreasing the pressure

C decreasing the temperature and increasing the pressure

D decreasing the temperature and decreasing the pressure

(Total 1 mark)

16. Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Compared to the pH of solution **F**, the pH of solution **G** will be

A considerably lower.

B slightly lower.

C slightly higher.

D exactly the same.

(Total 1 mark)

17. Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Solution **G** was found to contain 0.5 mol of propanoic acid. Which one of the following is the value of the equilibrium constant (K_c) for the following equilibrium?

$$\text{propanoic acid + methanol} \rightleftharpoons \text{methyl propanoate + water}$$

A 0.2

B 1

C 5

D 10

(Total 1 mark)

18. Refer to the following reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^\ominus = -11 \text{ kJ mol}^{-1}, \qquad \Delta S^\ominus = +20 \text{ J K}^{-1} \text{ mol}^{-1}$$

Which one of the following statements is correct?

A This is a redox reaction.

B The reaction is **not** feasible below 298 K

C At equilibrium, the yield of hydrogen iodide is changed by increasing the pressure.

D At equilibrium, the yield of hydrogen iodide increases as the temperature is increased.

(Total 1 mark)

19. Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

The equilibrium constant for the reaction under these conditions is

A 0.20

B 0.23

C 3.9

C 4.3

(Total 1 mark)

20. Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

The percentage of ethanoic acid converted into the ester $CH_3COOC_2H_5$ in this reaction is

A 22.5%

B 30%

C 43%

C 90%

(Total 1 mark)

21. The data below refer to the industrial production of nitric acid from ammonia.

Reaction 1	$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$	$\Delta H^\ominus = -909\ kJ\ mol^{-1}$
Reaction 2	$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$	$\Delta H^\ominus = -115\ kJ\ mol^{-1}$
Reaction 3	$3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$	$\Delta H^\ominus = -117\ kJ\ mol^{-1}$

Possible units for the equilibrium constant, K_c, for *reaction 2* are

A $mol^{-2}\ m^6$

B $mol^{-1}\ dm^3$

C no units

D $mol\ dm^{-3}$

(Total 1 mark)

22. The data below refer to the industrial production of nitric acid from ammonia.

Reaction 1	$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$	$\Delta H^\ominus = -909\ kJ\ mol^{-1}$
Reaction 2	$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$	$\Delta H^\ominus = -115\ kJ\ mol^{-1}$
Reaction 3	$3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$	$\Delta H^\ominus = -117\ kJ\ mol^{-1}$

The equilibrium yield in **all three** reactions is increased when

A the pressure is increased.

B the pressure is decreased.

C the temperature is increased.

D the temperature is decreased.

(Total 1 mark)

23. Use the information below to answer this question.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

The equilibrium constant expression for the dissolving of magnesium hydroxide is $K = [Mg^{2+}]\,[OH^-]^2$. In a saturated solution of $Mg(OH)_2$ at a different temperature, the concentration of hydroxide ions is 1.0×10^{-3} mol dm^{-3}.

Which one of the following has the correct value and units for *K* under these conditions?

A 1.0×10^{-6} mol^2 dm^{-6}

B 5.0×10^{-7} mol^2 dm^{-6}

C 1.0×10^{-9} mol^3 dm^{-9}

D 5.0×10^{-10} mol^3 dm^{-9}

(Total 1 mark)

24. The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \quad \Delta H^\ominus = +3 \text{ kJ mol}^{-1}$$

The equilibrium yield of ethanoic acid could be increased by

A lowering the temperature.

B adding a catalyst.

C adding more water to the reaction mixture.

D adding more methanol to the reaction mixture.

(Total 1 mark)

25. The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \quad \Delta H^\ominus = +3 \text{ kJ mol}^{-1}$$

A 3 mol sample of methyl ethanoate was mixed with 3 mol of water and left to reach equilibrium at 298 K. The equilibrium yield of ethanoic acid was 2 mol. The value of K_c for this reaction at 298 K is

A $\frac{2}{3}$

B $\frac{4}{9}$

C 2

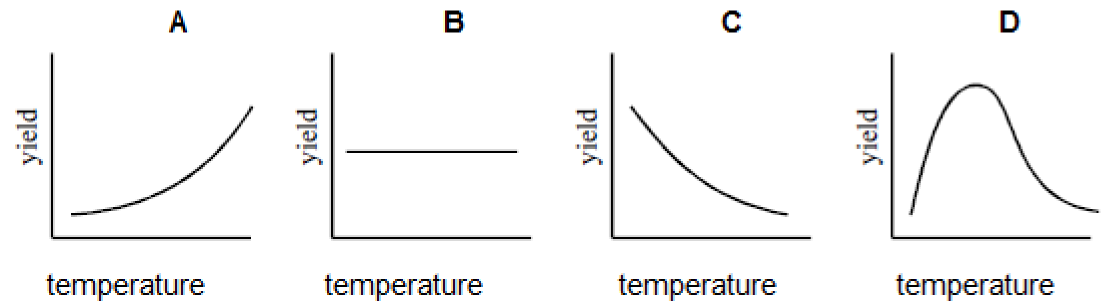
D 4

(Total 1 mark)

26. Normal water and heavy water react together to form isotopicaily mixed water according to the equation

$$H_2O(l) + D_2O(l) \rightleftharpoons 2HDO(l)$$

The standard enthalpy of formation of $H_2O(l)$ is -286 kJ mol^{-1}, that of $D_2O(l)$ is -294 kJ mol^{-1}, and that of HDO(l) is -290 kJ mol^{-1}. Which one of the following best represents the variation with temperature of the yield of HDO at equilibrium?



(Total 1 mark)

27. The equilibrium constant, K_c, for a reaction which leads to ozone (O_3) formation is

$$K_c = \frac{[N_2][O_3]^2}{[NO]^2[O_2]^2}$$

More ozone is formed as the temperature rises. Which one of the following is true at equilibrium?

A When ozone molecules collide with nitrogen they may form nitrogen monoxide.

B The enthalpy change for the reaction has a negative sign.

C Less ozone is formed at high pressure.

D At a fixed temperature, the magnitude of K_c increases as the concentration of NO decreases.

(Total 1 mark)

28. Methanol is synthesised from carbon monoxide and hydrogen according to the equation below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

Which one of the following changes would **not** affect the value of the equilibrium constant and would **not** increase the yield of methanol?

A increase in temperature

B decrease in temperature

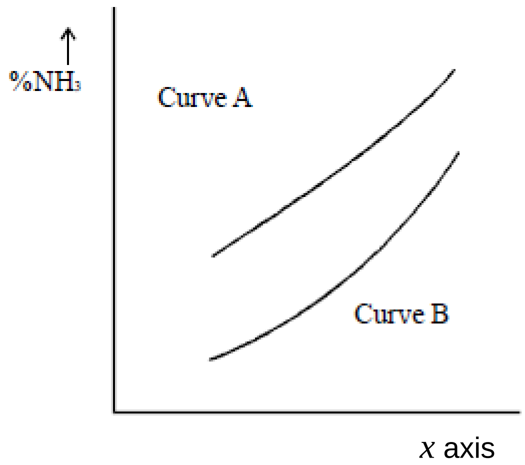
C increase in pressure

D decrease in pressure

(Total 1 mark)

29. The graph shows the equilibrium percentage of ammonia present during the formation of ammonia by the Haber process:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$



Which one of the following are correct labels for the graph?

	x axis	*Curve A*	*Curve B*
A	temperature	high pressure	low pressure
B	temperature	low pressure	high pressure
C	pressure	high temperature	low temperature
D	pressure	low temperature	high temperature

(Total 1 mark)

30. A sample of chlorine gas was sealed in a tube, heated and an equilibrium was established.

$Cl_2(g) \rightleftharpoons 2Cl(g)$

Which one of the following is **not** true?

A The concentration of chlorine atoms remains the same when a catalyst is added to the tube.

B Increase in temperature causes an increase in the concentration of chlorine atoms.

C Increase in pressure causes an increase in the concentration of chlorine atoms relative to chlorine molecules.

D Addition of more chlorine gas to the tube causes an increase in the concentration of chlorine atoms.

(Total 1 mark)