

APOLLO

How far? The extent of chemical change

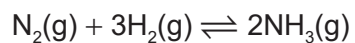
HL

Chemistry

First assessment 2025

14 questions | questions

29. Consider the following system at equilibrium:

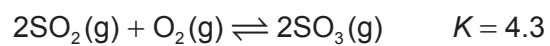


$$\Delta H_r^\ominus = -46 \text{ kJ mol}^{-1}$$

Which row correctly describes the initial effect of a change in pressure on the equilibrium position and the relationship between Q and K ?

	Change in pressure	Equilibrium shift	Relationship between Q and K
A.	decrease	to the left	$Q < K$
B.	increase	to the left	$Q > K$
C.	decrease	to the right	$Q > K$
D.	increase	to the right	$Q < K$

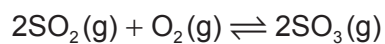
29. The following system is at equilibrium.



What is the value of the equilibrium constant, K , for the reverse reaction?

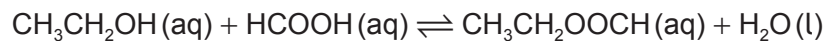
- A. $\sqrt{\frac{1}{4.3}}$
- B. 4.3
- C. $\frac{1}{4.3}$
- D. $\sqrt{4.3}$

30. What is the effect of doubling the pressure on the equilibrium? All other conditions remain unchanged.



	Effect on equilibrium position	Effect on equilibrium constant, K
A.	shifts right	no change
B.	shifts left	no change
C.	shifts right	increases
D.	shifts left	decreases

29. Which statement about this equilibrium reaction is correct?



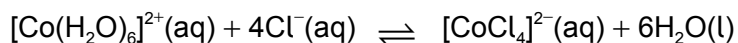
- A. Removing water from the reaction mixture has no effect on the position of equilibrium.
- B. Adding ethanol to the reaction mixture moves the position of equilibrium to the left.
- C. Removing ethanol from the reaction mixture moves the position of equilibrium to the left.
- D. Adding water to the reaction mixture moves the position of equilibrium to the right.

2. Cobalt ions form coloured compounds.(a) Deduce the electron configuration of the Co^{2+} ion.

[1]

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(b) An equilibrium is established when hydrated cobalt ions are mixed with concentrated hydrochloric acid.



Pink

Blue

(i) Predict the effect on the value of K and the equilibrium position when solid sodium chloride, $\text{NaCl}(\text{s})$, is added to the mixture at constant temperature.

[1]

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(ii) Heating an equilibrium mixture that is initially pink changes the colour to purplish-blue. Deduce, giving a reason, whether the formation of $[\text{CoCl}_4]^{2-}(\text{aq})$ is an exothermic or endothermic process.

[1]

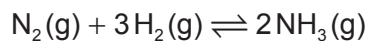
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3. Ammonia is produced industrially using the reversible reaction.



- (a) (i) Calculate the equilibrium constant, K , when 30.0 mol N_2 , 40.0 mol H_2 and 6.17 mol NH_3 are at equilibrium in a 55.0 dm³ reaction container at a temperature of 450 °C.

[3]

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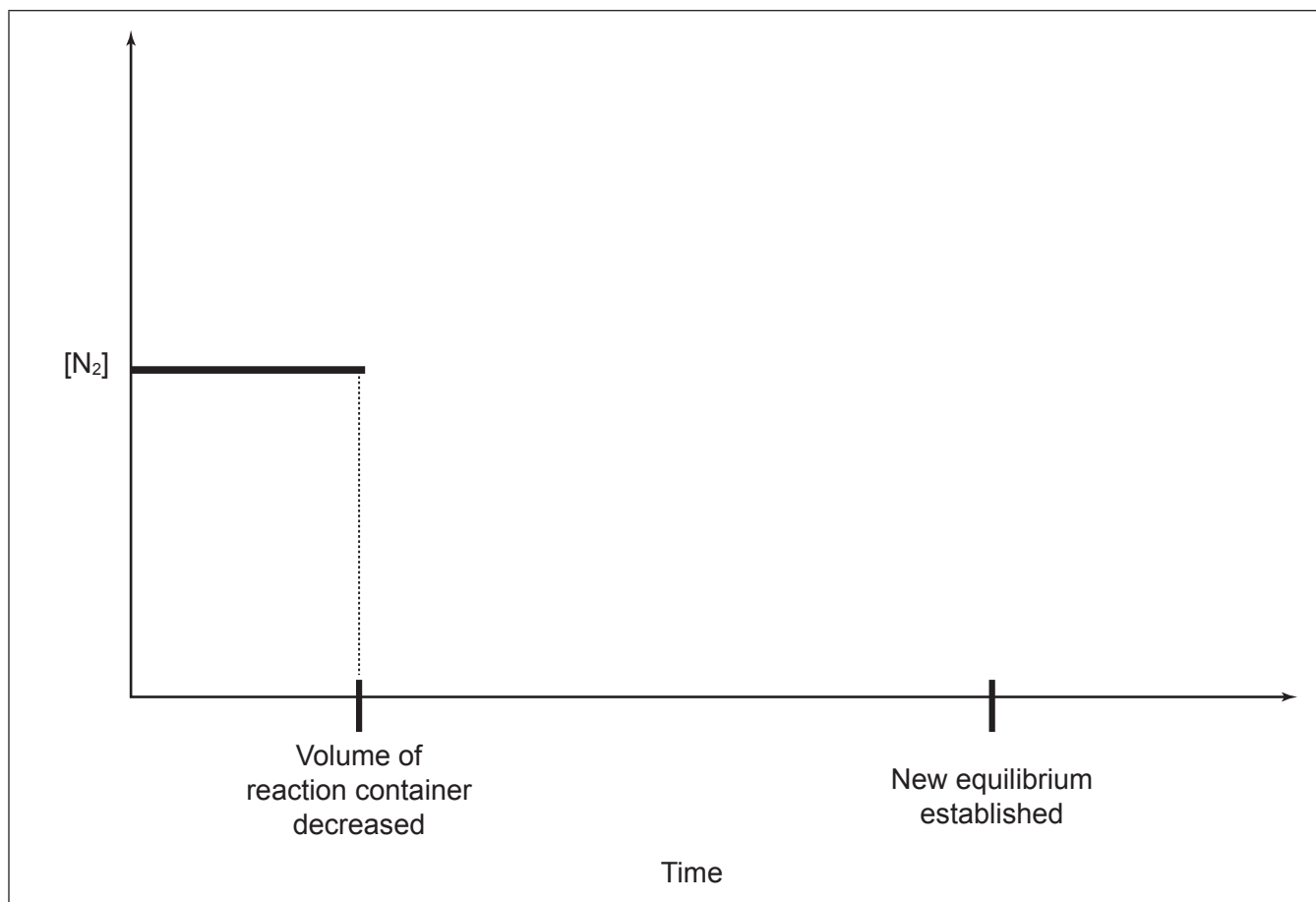
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- (ii) The volume of the reaction container of the mixture at equilibrium is suddenly decreased.

Sketch the graph of the concentration of nitrogen versus time on the axes below until after the new equilibrium is established at a constant temperature.

[3]



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(Question 3 continued)

- (iii) Calculate the standard change in Gibbs energy, $\Delta G^\ominus$, for this reaction at 450 °C, stating its units. Use your answer to part (a)(i) and section 1 of the data booklet. [2]

If you did not obtain an answer to part (a)(i) then use the value 0.200, although this is not the correct answer.

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- (b) (i) Outline how ammonia acts as a Lewis base when it forms the complex ion $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$. [1]

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- (ii) Determine the pH of a $0.350 \text{ mol dm}^{-3}$ solution of ammonia. Use section 1 of the data booklet. [3]

$$\text{p}K_{\text{b}}(\text{NH}_3) = 4.75$$

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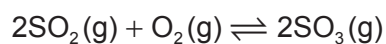
4440-0441

- 30.** Which statement regarding the chemical equilibrium explains why it is described as dynamic?
- A. There is a continuous shift in the equilibrium position.
 - B. The reactants and products continue to react.
 - C. The concentrations of reactants and products continue to change.
 - D. The rates of forward and reverse reactions continue to change.

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Turn over
0020-0207

31. SO_2 reacts with O_2 to produce SO_3 .



A mixture of 1.10 mol of $\text{SO}_2(\text{g})$ and 1.95 mol of $\text{O}_2(\text{g})$ was placed into a 1 dm^3 container at a certain temperature. When the equilibrium was reached, the mixture contained 0.18 mol of $\text{SO}_2(\text{g})$.

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

A.
$$\frac{0.92^2}{0.92^2 \times 0.46}$$

B.
$$\frac{0.46}{0.18 \times 1.03}$$

C.
$$\frac{0.92}{0.18 \times 1.49}$$

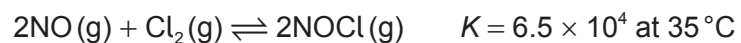
D.
$$\frac{0.92^2}{0.18^2 \times 1.49}$$

- 23.** A crystal of copper(II) sulfate is in equilibrium with a copper(II) sulfate solution in a stoppered flask at constant temperature.

Which observation is possible?

- A. The colour of the solution becomes darker.
- B. The volume of the liquid decreases.
- C. The shape of the crystal changes slowly over time.
- D. The size of the crystal decreases.

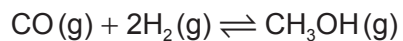
29. 2 mol of NO(g) and 1 mol of Cl₂(g) were mixed together, and the system was allowed to reach equilibrium at 35 °C:



Which relationship is correct for this equilibrium at 35 °C?

- A. [NOCl] = [NO]
- B. [NOCl] = 2[Cl₂]
- C. [NOCl] >> [NO]
- D. [NOCl] << [NO]

30. Consider the equilibrium reaction:



Under certain conditions, $K = 2.5$.

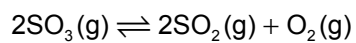
At the same temperature and pressure, a mixture has the following concentrations, in mol dm^{-3}

$$[\text{CO}] = 0.2 \quad [\text{H}_2] = 0.4 \quad [\text{CH}_3\text{OH}] = 0.32$$

Which statement is correct?

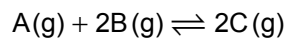
- A. Mixture is at equilibrium and no reactions are occurring.
- B. Forward and reverse reactions are occurring at the same rate.
- C. Forward reaction rate is favoured to establish equilibrium.
- D. Reverse reaction rate is favoured to establish equilibrium.

28. What is the equilibrium constant expression for the following reaction?



- A. $\frac{[\text{SO}_2]^2[\text{O}_2]}{[\text{SO}_3]^2}$
- B. $\frac{[\text{SO}_2]^2 + [\text{O}_2]}{[\text{SO}_3]^2}$
- C. $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$
- D. $\frac{2[\text{SO}_2][\text{O}_2]}{2[\text{SO}_3]}$

30. The equation for the reaction between two gases, A and B, is:



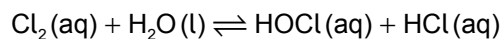
When the reaction is at equilibrium at 600 K, the concentrations of A, B, and C are 2, 1, and 2 mol dm⁻³ respectively. What is the value of the equilibrium constant at 600 K?

- A. 0.25
- B. 1
- C. 2
- D. 4

Section B

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Hypochlorous acid, HOCl, is a sterilizing agent used in swimming pools and is produced when chlorine reacts with water.



- (a) Deduce the oxidation states of chlorine in the reactants and products. [2]

Reactant: Cl_2 :

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Products: HOCl:

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HCl:

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- (b) Explain why more chlorine reacts with water when NaOH(aq) is added. [1]

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- (c) Researchers studying the solubility of chlorine in pure water at different temperatures compile the following data from different sources.

Source	Temperature / °C	Solubility of chlorine
A	0	1.46 g per 100 cm ³
B	10	310 cm ³ per 100 cm ³
C	20	0.70 g per 100 cm ³
D	25	6300 mg per 1000 cm ³
E	30	177 cm ³ per 100 cm ³
F	30	0.57 g per 100 cm ³

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12EP03

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(Question 1 continued)

- (i) Identify a problem in comparing the data from different sources. [1]

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- (ii) The units of solubility are converted to mol dm^{-3} .

Source	Temperature / °C	Solubility of chlorine	Solubility of chlorine / mol dm^{-3}
A	0	1.46 g per 100 cm^3	0.206
B	10	310 cm^3 per 100 cm^3	0.13
C	20	0.70 g per 100 cm^3	0.099
D	25	6300 mg per 1000 cm^3	0.089
E	30	177 cm^3 per 100 cm^3	
F	30	0.57 g per 100 cm^3	0.080

Complete the table by calculating the value for source E.

Assume the density of chlorine is 2.86 g dm^{-3} at 30°C . [2]

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- (iii) Suggest an explanation for the effect of temperature on solubility. [1]

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- (d) Suggest why chlorine is not often added to swimming pools directly. [1]

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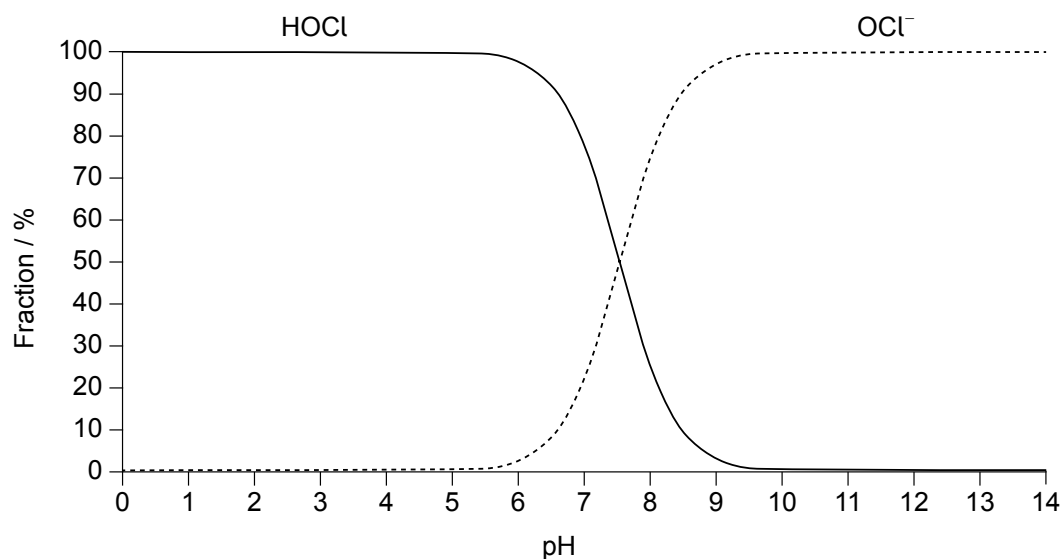


12EP04

(Question 1 continued)

- (e) HOCl ionizes to form the hypochlorite ion, OCl^- , which is a less effective disinfectant than the undissociated acid.

The graph shows the concentrations of HOCl(aq) and OCl^- (aq) at different pH values at 25°C.



- (i) Deduce the pH range where the water is most effectively sterilized. [1]

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- (ii) Determine, with reference to the graph in (e), the $\text{p}K_a$ of HOCl. [2]

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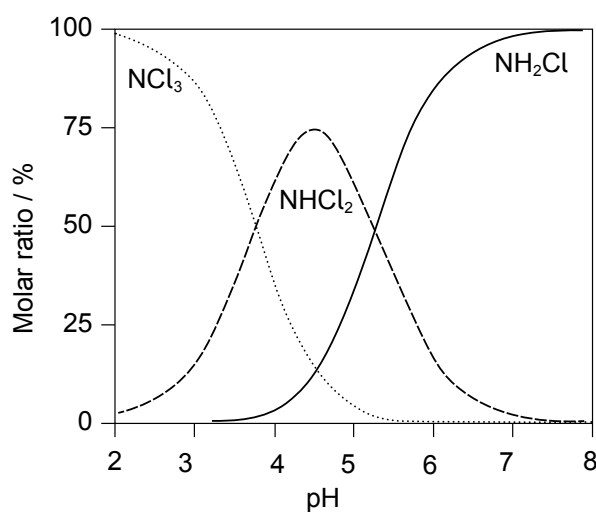
(Question 1 continued)

- (f) Ammonia released from sweat and urine reacts with HOCl to form a range of compounds including chloramines.
- (i) Deduce an equation for the formation of dichloramine, $\text{NHCl}_2(\text{aq})$, from ammonia and HOCl(aq). [1]

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- (ii) The graph shows the molar ratio of chloramines formed at different pH values at 25 °C. Trichloramine, NCl_3 , causes pool water to smell bad.



State **two** conditions needed to prevent the bad smell.

[2]

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- (g) Suggest **two** reasons why operating a swimming pool at a lower temperature is favourable for the environment.

[2]

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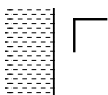
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12EP06



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