

- (iii) The decomposition of HBr is endothermic.

State the effect of increasing temperature on the **percentage** of HBr that decomposes. Use Le Chatelier's principle to explain your answer.

.....

 [3]

- (ii) Calculate the mole fraction of each gas in the equilibrium mixture.

mole fraction of HCl =

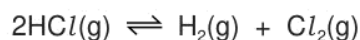
mole fraction of H₂ =

mole fraction of Cl₂ = [1]

- (d) In another experiment under different conditions, an equilibrium mixture was produced with mole fractions for each species as shown.

species	mole fraction
HCl	0.88
H ₂	0.06
Cl ₂	0.06

- (i) Write the expression for the equilibrium constant,
- K_p
- , for the decomposition of HCl.



$$K_p =$$

[1]

(iii) Calculate the value of K_p for this experiment.

$K_p = \dots\dots\dots$ [1]

[Total: 18]

- (d) In another equilibrium mixture formed from different starting amounts of SO_2 and O_2 , the partial pressures of SO_2 , O_2 and SO_3 were as shown.

$$p\text{SO}_2 = 8.42 \times 10^2 \text{ Pa}$$

$$p\text{O}_2 = 6.00 \times 10^4 \text{ Pa}$$

$$p\text{SO}_3 = 9.10 \times 10^4 \text{ Pa}$$

- (i) Write the expression for the equilibrium constant, K_p , for the production of SO_3 from SO_2 and O_2 .

$$K_p =$$

[1]

- (ii) Calculate the value of K_p for this reaction and state the units.

$$K_p = \dots\dots\dots$$

$$\text{units} = \dots\dots\dots$$

[2]

[Total: 17]

May/June 2017 9701/23 · Q3 (d)(i), (d)(ii)

(ii) State the meaning of the term *strong Brønsted-Lowry acid*.

.....

.....

..... [2]

May/June 2018 9701/21 · Q1 (f)(ii)

(c) In aqueous solution the ammonium ion acts as a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

.....

.....

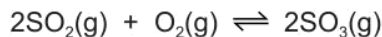
.....

..... [2]

May/June 2018 9701/22 · Q2 (c)(i)

- (d) 2.00 moles of $\text{SO}_2(\text{g})$ and 2.00 moles of $\text{O}_2(\text{g})$ are sealed in a container with a suitable catalyst, at constant temperature and pressure. The resulting equilibrium mixture contains 1.98 moles of $\text{SO}_3(\text{g})$.

The total volume of the equilibrium mixture is 40.0 dm^3 .



- (i) Write the expression for the equilibrium constant, K_c , for the reaction between $\text{SO}_2(\text{g})$ and $\text{O}_2(\text{g})$ to produce $\text{SO}_3(\text{g})$.

$K_c =$

[1]

- (iii) Use your answers to (d)(i) and (d)(ii) to calculate the value of K_c for this equilibrium mixture. Give the units of K_c .

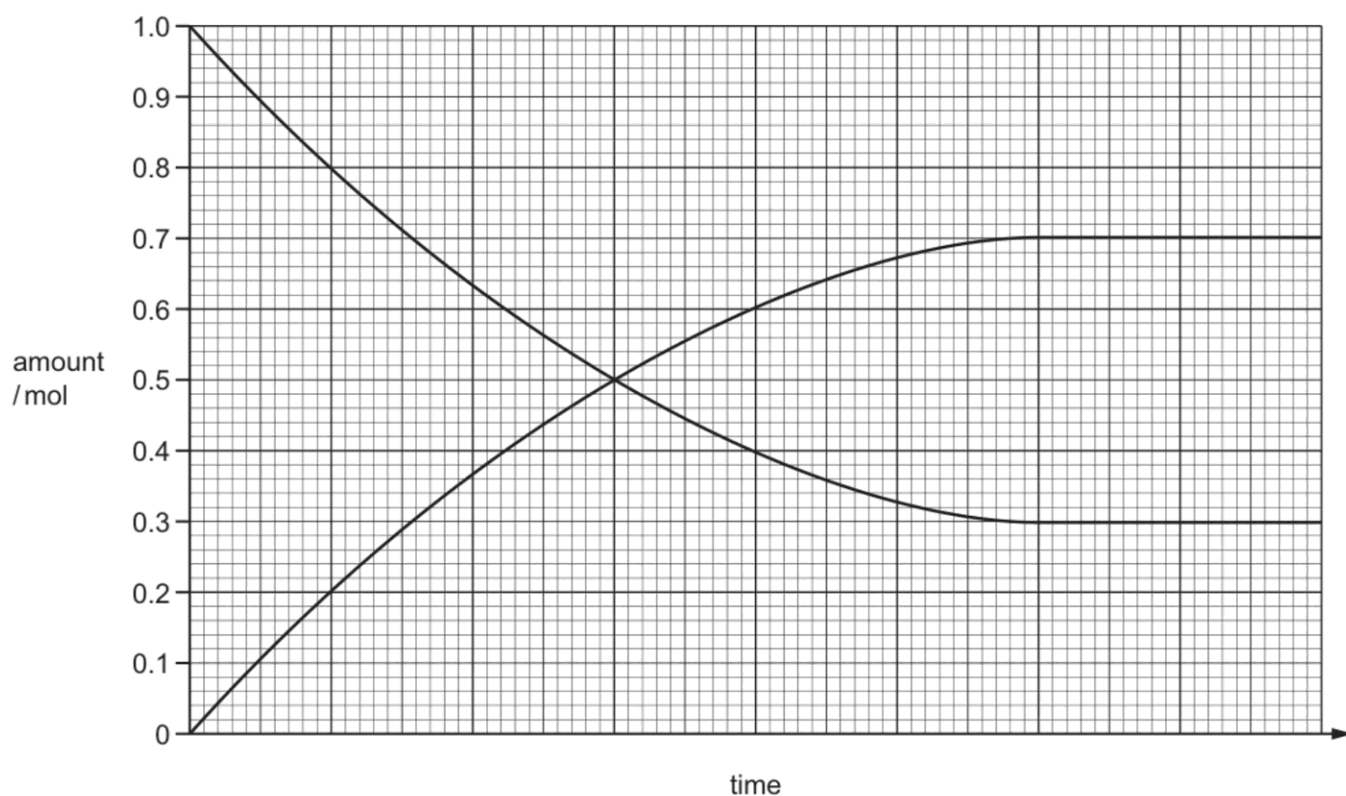
$K_c =$

units =

[3]

[Total: 22]

- (c) 1 mole of butane gas was added to a 1 dm³ closed system, at a constant temperature and pressure. The amount of butane and methylpropane was measured at regular time intervals.

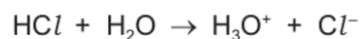


- (i) Label the graph with a t to show the time taken to reach dynamic equilibrium. [1]
- (iv) Calculate a value for K_c and state its units.

$K_c = \dots\dots\dots$ units = $\dots\dots\dots$ [2]

[Total: 10]

(c) Hydrogen chloride reacts with water.



(i) In this reaction, one of the reactants behaves as a Brønsted-Lowry acid.

What is meant by the term *Brønsted-Lowry acid*?

.....
..... [1]

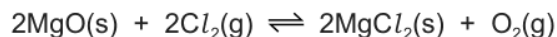
(ii) Identify the reactant behaving as an acid and its conjugate base.

acid

conjugate base [1]

May/June 2019 9701/22 · Q2 (c)(i), (c)(ii)

- (f) Magnesium oxide reacts reversibly with chlorine according to the following equation.



Under certain conditions, a dynamic equilibrium is established.

- (i) State **two** features of a reaction that is in dynamic equilibrium.

1

2 [2]

- (ii) The equilibrium constant, K_p , is given by the following expression.

$$K_p = \frac{p_{\text{O}_2}}{p_{\text{Cl}_2}^2}$$

At $1.00 \times 10^5 \text{ Pa}$ and 500 K , 70% of the initial amount of $\text{Cl}_2\text{(g)}$ has reacted.

Calculate K_p and state its units.

$K_p = \dots\dots\dots$

units = [3]

(a) Explain why ammonia is described as a Brønsted-Lowry base in this reaction.

..... [1]

The product mixture can then be added to soil.

(b) State **two** reasons why this mixture of products is added to some soils.

1

2 [2]

May/June 2020 9701/21 · Q4 (a), (b)

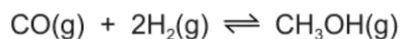
(ii) NCl_3 reacts with water to form HOCl , a weak Brønsted-Lowry acid.

Explain fully what is meant by the term *weak Brønsted-Lowry acid*.

.....
.....
..... [2]

Oct/Nov 2020 9701/22 · Q3 (d)(ii)

- (c) Methanol is made by reacting carbon monoxide with hydrogen.



Carbon monoxide and hydrogen react at $1.0 \times 10^7 \text{ Pa}$ and 200°C . Eventually the reaction mixture reaches dynamic equilibrium.

The table shows the amounts of each species present in the mixture.

	CO(g)	H ₂ (g)	CH ₃ OH(g)
initial amount/mol	1.0	2.0	0
equilibrium amount/mol	0.030	0.060	0.97

- (i) Explain what is meant by *dynamic equilibrium*.

.....

 [2]

- (ii) Calculate the partial pressure of methanol vapour at equilibrium under these conditions. Show your working.

..... Pa [2]

- (iii) Write an expression for the equilibrium constant, K_p , for this reaction. State the units in your answer.

$K_p =$

units = [2]

[Total: 14]

6

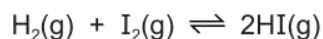
May/June 2021 9701/23 · Q2 (c)(i), (c)(ii), (c)(iii) (cont.)

- (ii) Give the formula of the conjugate base of H_2S .

..... [1]

Oct/Nov 2021 9701/21 · Q1 (c)(ii)

- (c) HI(g) can be formed by reacting $\text{H}_2\text{(g)}$ with $\text{I}_2\text{(g)}$. The reaction is reversible, and an equilibrium forms quickly at high temperatures.



- (i) Construct an expression for the equilibrium constant, K_p , for the reaction of $\text{H}_2\text{(g)}$ and $\text{I}_2\text{(g)}$ to form HI(g) .

$$K_p =$$

[1]

- (ii) The equilibrium partial pressures of the gases at 200°C are as follows.

$$p_{\text{H}_2\text{(g)}} = 895 \text{ Pa}$$

$$p_{\text{I}_2\text{(g)}} = 895 \text{ Pa}$$

$$p_{\text{HI(g)}} = 4800 \text{ Pa}$$

Calculate K_p for this reaction.

$$K_p = \dots\dots\dots [1]$$

Oct/Nov 2021 9701/22 · Q1 (c)(i), (c)(ii)

- 3 (a) 0.025 mol of HI(g) is added to a closed vessel and left to reach dynamic equilibrium. The total pressure of the vessel is 100 kPa.



- (i) Explain what is meant by dynamic equilibrium.

.....
.....
..... [2]

- (ii) Describe **one** difference in the initial appearance of the reaction mixture compared to the mixture at equilibrium.

..... [1]

- (iii) Write an expression for K_p for the reaction described in equation 1.

$K_p =$

[1]

- (iv) At equilibrium the partial pressure of HI(g) is 86.4 kPa.

Calculate the amount of HI(g) present in the mixture at equilibrium. Show your working.

amount of HI(g) = mol [2]

7

- (c) Describe the effect of increasing pressure on the value of K_p for the decomposition of HI(g).

..... [1]

- (d) HCl(g) is prepared by adding NaCl(s) to concentrated H₂SO₄.

HI(g) is **not** prepared by adding NaI(s) to concentrated H₂SO₄ because the HI(g) produced also reacts with concentrated H₂SO₄.

- (i) Identify the type of reaction that occurs when NaI(s) reacts with concentrated H₂SO₄ to form HI(g).

..... [1]

- (ii) Write an equation for the reaction of HI(g) and concentrated H₂SO₄.

..... [1]

- (iii) Explain why HI(g) reacts with concentrated H₂SO₄ whereas HCl does not.

..... [1]

[Total: 12]

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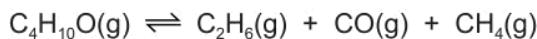
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May/June 2022 9701/22 · Q3 (a)(i), (a)(ii), (a)(iii), (a)(iv), (c), (d)(i), (d)(ii), (d)(iii) (cont.)

- (iii) When **G**, C₄H₁₀O, is heated in a sealed container, an equilibrium mixture is produced.



Complete the expression for the equilibrium constant, K_c , for this reaction.
State the units of K_c .

$K_c =$

units =

[2]

May/June 2022 9701/23 · Q3 (a)(iii)

(c) NH_4^+ is a Brønsted–Lowry acid.

(i) Define Brønsted–Lowry acid.

.....
..... [1]

Oct/Nov 2022 9701/22 · Q1 (c)(i)

(b) Reaction 1 reaches equilibrium at constant temperature and pressure.

Deduce what effect increasing the pressure will have on the amount of ethanol in the new equilibrium mixture. Use Le Chatelier's principle to explain your answer.

effect of increasing pressure

explanation

..... [2]

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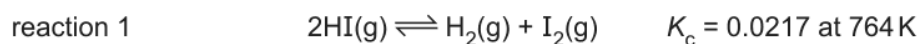
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8

May/June 2023 9701/22 · Q4 (b)

- (b) A sample of HI(g) is added to a 2.00 dm³ sealed vessel at 764 K and allowed to reach equilibrium.



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]

May/June 2023 9701/23 · Q4 (b)(i), (b)(ii), (c)(ii) (continued ·)

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

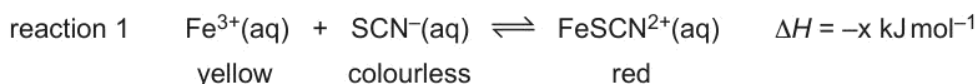
.....
.....
..... [1]

[Total: 10]

- 3 (a) Define Le Chatelier's principle.

.....
.....
..... [2]

- (b) Reaction 1 describes the reversible reaction between yellow $\text{Fe}^{3+}(\text{aq})$ and colourless $\text{SCN}^{-}(\text{aq})$ to produce red $\text{FeSCN}^{2+}(\text{aq})$.



A mixture of $\text{Fe}^{3+}(\text{aq})$, $\text{SCN}^{-}(\text{aq})$ and $\text{FeSCN}^{2+}(\text{aq})$ is at equilibrium at 20°C .

The temperature of this mixture is then increased to 50°C and allowed to reach equilibrium.

Deduce the changes that occur, if any, in the equilibrium mixture at 50°C compared to the equilibrium mixture at 20°C .

- change in appearance

.....

- change in relative concentration of $\text{FeSCN}^{2+}(\text{aq})$

.....

- change in value of the equilibrium constant, K_c

.....

[3]

- (c) In another experiment, equimolar amounts of $\text{Fe}^{3+}(\text{aq})$ and $\text{SCN}^{-}(\text{aq})$ are mixed together and allowed to reach equilibrium. The total volume of the mixture is 25.0 cm^3 .



At equilibrium the mixture contains:

- $[\text{SCN}^{-}] = 1.30 \times 10^{-3} \text{ mol dm}^{-3}$
- $[\text{FeSCN}^{2+}] = 0.300 \times 10^{-3} \text{ mol dm}^{-3}$.

- (i) Calculate the initial amount, in mol, of $\text{Fe}^{3+}(\text{aq})$ added to $\text{SCN}^{-}(\text{aq})$ to produce this mixture.

initial amount of $\text{Fe}^{3+}(\text{aq}) = \dots\dots\dots \text{ mol}$ [2]

- (ii) Calculate K_c for reaction 1 and state its units.

Show your working.

$K_c = \dots\dots\dots$

units $\dots\dots\dots$
[2]

[Total: 9]

May/June 2024 9701/21 · Q3 (a), (b), (c)(i), (c)(ii) (cont.)

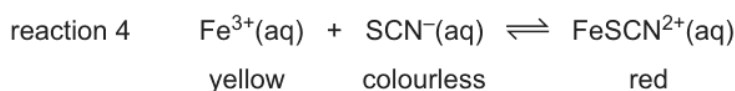
- 3 (a) Describe what is meant by dynamic equilibrium.

.....

.....

..... [2]

- (b) Reaction 4 describes the reversible reaction between yellow $\text{Fe}^{3+}(\text{aq})$ and colourless $\text{SCN}^{-}(\text{aq})$ to produce red $\text{FeSCN}^{2+}(\text{aq})$.



An equilibrium mixture contains $\text{Fe}^{3+}(\text{aq})$, $\text{SCN}^{-}(\text{aq})$ and $\text{FeSCN}^{2+}(\text{aq})$. A few colourless crystals of soluble $\text{KSCN}(\text{s})$ are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

- (i) Deduce the changes that occur, if any, in the equilibrium mixture after $\text{KSCN}(\text{s})$ is added compared to the original equilibrium mixture.

- change in appearance

.....

- change in relative concentration of $\text{Fe}^{3+}(\text{aq})$

.....

- change in value of the equilibrium constant, K_c

.....

[3]



- (ii) The expression for the equilibrium constant, K_c , for reaction 4 is shown.

$$K_c = \frac{[\text{FeSCN}^{2+}(\text{aq})]}{[\text{Fe}^{3+}(\text{aq})] \times [\text{SCN}^{-}(\text{aq})]}$$

5.00×10^{-5} mol of $\text{Fe}^{3+}(\text{aq})$ and 5.00×10^{-5} mol of $\text{SCN}^{-}(\text{aq})$ are added together and allowed to reach equilibrium. The total volume of the mixture is 25.0 cm^3 .

At equilibrium the concentration of $\text{FeSCN}^{2+}(\text{aq})$ is $4.23 \times 10^{-4} \text{ mol dm}^{-3}$.

Calculate the equilibrium constant, K_c , for reaction 4.

Include the units in your answer.

$K_c = \dots\dots\dots$

units $\dots\dots\dots$

[4]

May/June 2024 9701/22 · Q3 (a), (b)(i), (b)(ii) (cont.)

- (c) (i) Write an expression for the equilibrium constant, K_p , for reaction 1. State the units.

$$K_p =$$

units [2]

- (ii) Equilibrium mixture **D** is made when 1.0 mol of $N_2(g)$ and 3.0 mol of $H_2(g)$ are added to a sealed container at 750 °C and 1000 atm and left to reach equilibrium. This mixture contains 1.16 mol of $NH_3(g)$.

Calculate the mole fraction of $NH_3(g)$ in **D**.

mole fraction of $NH_3(g)$ = [2]

- (iii) The mole fraction of $N_2(g)$ is 0.625 in a new equilibrium mixture, **E**.

Calculate the partial pressure of $N_2(g)$ in **E** when the total pressure is 1000 atm.

partial pressure of $N_2(g)$ = atm [1]

May/June 2024 9701/23 · Q2 (c)(ii), (c)(iii)

- (ii) Identify the sodium halide that **only** undergoes a Brønsted–Lowry acid–base reaction with concentrated H_2SO_4 .

..... [1]

March 2025 9701/22 · Q3 (c)(ii)

- (b) Define Le Chatelier's principle.

.....
.....
..... [2]

May/June 2025 9701/21 · Q3 (b)

- (d) State why ZnO is described as a Brønsted–Lowry base when it is added to $\text{H}_2\text{SO}_4(\text{aq})$.

..... [1]

May/June 2025 9701/23 · Q2 (d)

- (c) In experiment 3, 0.0772 mol of H_2 and 0.0986 mol of I_2 are present in an equilibrium mixture at 298 K.



Use the equilibrium constant, K_c , to calculate the amount, in mol, of HI present in the equilibrium mixture in experiment 3.

amount of HI in equilibrium mixture = mol [1]

- (d) The value of K_c for the dissociation of HCl at 298 K is 5.50×10^{-34} .



- (i) Define covalent bond.

.....
..... [1]

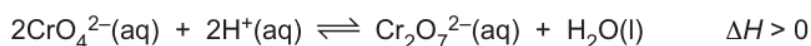
- (iii) Use the data given in (c) and (d) to suggest a value for the equilibrium constant for the **dissociation** of $\text{HBr}(\text{g})$ at 298 K.

..... [1]

[Total: 11]



- (d) In acidic conditions, a dynamic equilibrium is established between $\text{CrO}_4^{2-}(\text{aq})$ and $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$.



- (i) State what is meant by dynamic equilibrium.

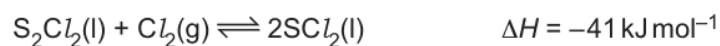
.....
..... [1]

- (ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

Oct/Nov 2025 9701/21 · Q1 (d)(i), (d)(ii)

- (e) $\text{S}_2\text{Cl}_2(\text{l})$ reacts with $\text{Cl}_2(\text{g})$ in a reversible reaction to form $\text{SCl}_2(\text{l})$. Under certain conditions, a dynamic equilibrium is established.



- (i) State what is meant by dynamic equilibrium.

.....
..... [1]

- (ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

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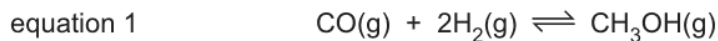
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Oct/Nov 2025 9701/22 · Q2 (e)(i), (e)(ii)

- (b) A 5.00 dm³ sealed flask contains 0.400 mol of CO(g) and 0.800 mol of H₂(g) and an Al₂O₃ catalyst. The flask is heated to a temperature of 290 °C and allowed to reach equilibrium. Equation 1 shows the reaction.



The equilibrium constant, K_c , of equation 1 is given.

$$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$

- (i) State the units of K_c .

..... [1]

- (ii) The equilibrium mixture contains 0.280 mol of CH₃OH(g).

Calculate the value of K_c .

Give your answer to **three** significant figures.

value of K_c = [3]

Oct/Nov 2025 9701/24 · Q2 (b)(i), (b)(ii)