OCR A-Level Chemistry A

Equilibrium constants K_c and K_p mark scheme · goes with “Equilibrium constants K_c and K_p” · whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/

Mark schemes

Equilibrium constants K_c and K_p · 7 questions

Q1 · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q13 · [1 mark]

Answer: **B**

OCR MARK SCHEME

0.426

EXAMINER GUIDANCE

ALLOW *0.426 in the box*

Q2 · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q9 · [1 mark]

Answer: **B**

25 atm

Q3 · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q20 · [8 marks]

OCR MARK SCHEME

20(a)

Level 3 (5–6 marks)

Uses correct method to calculate K_c

AND explains why most operational condition is different with few omissions in the explanation.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Uses correct method to calculate K_c with few errors

OR

Derives a correct expression for K_c with an attempt at the K_c calculation **AND** explains why an operational condition is different with some omissions.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

EXAMINER GUIDANCE

Indicative scientific points may include:

IGNORE trailing zeroes

Equilibrium amounts

$n(N_2)$: 1.20 – 0.08 = 1.12, $n(H_2)$: 3.60 – 0.24 = 3.36

Equilibrium concentrations

$$[N_2] = \frac{1.12}{8.00} = 0.140 \text{ (mol dm}^{-3}\text{)}$$

$$[H_2] = \frac{3.36}{8.00} = 0.420 \text{ (mol dm}^{-3}\text{)}$$

$$[NH_3] = \frac{0.160}{8.00} = 0.0200 \text{ (mol dm}^{-3}\text{)}$$

Equilibrium expression and K_c value wih units

$$K_c = \frac{[NH_3]^2}{([N_2] \times [H_2]^3)}$$

Derives a correct expression for K_c **AND** explains why one operational condition is different with some omissions.

OR

explains why most operational conditions are different

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

$$K_c = \frac{0.0200^2}{0.140 \times 0.420^3} = 0.0386$$

Calculator: 0.03856417851 Units: $dm^6\ mol^{-2}$

Explanation for operational differences.

Temperature

- Low temperature for maximum yield: (ΔH –ve \ exothermic)
- High temperature to increase rate

Pressure

- High pressure for maximum yield (fewer (gaseous) moles/molecules of products)
- High pressure expensive to generate **OR** high pressure is a safety hazard

Catalyst

- Allows a lower temperature to be used for maximum yield.
- Reducing fuel expense **OR** increasing rate

20(b)(i)

Equilibrium (position) shifts to the left (as T is decreased)

AND

(forward) reaction is endothermic ✓

[1 mark]

ALLOW *'favours backward reaction'*

Implies shift to left

ALLOW *'shifts in exothermic direction' BUT only if (forward) reaction stated as endothermic*

20(b)(ii)

Student 2 is correct

AND

same number of gas particles/ gas(eous) molecules/moles of gas on each side (of equation) ✓

[1 mark]

ALLOW *AW that suggests student 2 is correct*

Q4 · June 2025 · Paper 3 (Unified chemistry) · Q3 · [11 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

3(a)

Conditions of pressure and temperature 2 marks

Pressure:

Right-hand side has fewer (gaseous) moles/

3 (gaseous) moles form 1 (gaseous) moles

AND

High pressure ✓

Temperature:

(Forward reaction) is exothermic/ gives out heat/ ΔH –ve

AND

Low temperature ✓

For moles, **ALLOW** molecules/particles

ORA for *reverse reaction*

DO NOT ALLOW *gaseous atoms*

ALLOW increase *pressure*

ALLOW *Reverse reaction is endothermic/ takes in heat/ ΔH +ve*

ALLOW decrease *temperature*

Calculation 3 marks

FIRST CHECK ANSWER

IF $[H_2]$ = 0.48 (mol dm^{-3}) award all 3 marks for calc

IF $[H_2]$ = 0.476 (mol dm^{-3}) award 2 marks for calc

K_c expression

$$K_c = \frac{[CH_3OH]}{[CO]\,[H_2]^2}$$

OR $1.8 = \dfrac{0.11}{0.27 \times [H_2]^2}$ **OR** $1.8 = \dfrac{0.11}{0.27 \times x^2}$ ✓

Calculation of $[H_2]$

$[H_2] = \sqrt{\left(\dfrac{0.11}{0.27 \times 1.8}\right)}$ **OR** 0.476 ✓

Calculator: 0.4757493548

= 0.48 (mol dm^{-3}) **AND 2 SF** ✓

2 SF is 'appropriate' with 2 SF values in question

NOTE: 0.48 subsumes mark for 0.476

Square brackets required in K_c expression

DO NOT ALLOW inverted K_c:

$$\frac{[CO]\,[H_2]^2}{[CH_3OH]}$$

ALLOW ECF *for calculation from inverted K_c expression*

i.e. $[H_2] = \sqrt{\left(\dfrac{0.11 \times 1.8}{0.27}\right)}$ **OR** 0.856..... ✓

= 0.86 to 2 SF ✓

IF *no square root,*

$[H_2] = \dfrac{0.11}{0.27 \times 1.8}$ = 0.226337.... ✗

= 0.23 to 2 SF ✓ **ECF**

NO other ECFs

[5 marks]

3(b)

Level 3 (5–6 marks)

All three student's results are used to determine ALL correct orders

AND correct rate equation **AND** correct rate constant, *k*

Indicative scientific points may include:

Order from Experiment 1

- CH_3COCH_3 is 1st order
- $[CH_3COCH_3] \times 3$, rate × 3

Order from Experiment 2

AND explanation for why the mechanism has more than one step.

There is a well-developed line of reasoning which is clear and logically structured.

Level 2 (3–4 marks)

Three orders correct **AND** explanation for why the mechanism has more than one step.

OR

Two orders correct **AND** rate equation consistent with any incorrect orders

OR

One order correct **AND** attempts to calculate rate constant consistent with any incorrect orders **AND** explanation for why the mechanism has more than one step.

There is a line of reasoning presented with some structure.

Level 1 (1–2 marks)

One order correct **AND** rate equation consistent with any incorrect orders

OR two orders correct

The information is basic and communicated in an unstructured way.

0 marks

No response or no response worthy of credit.

[6 marks]

- Br_2 is zero order
- constant gradient **OR** constant rate **OR** rate independent of concentration **OR** linear negative gradient

Order from Experiment 3

- H^+ is 1st order
- straight line through 0,0 **OR** rate proportional to $[H^+]$ **OR** linear increase **OR** doubling $[H^+]$ leads to doubling of rate

Rate equation and rate constant

- rate = $k[CH_3COCH_3]\,[H^+]$

ALLOW *rate = k* $[Br_2]^0$ $[CH_3COCH_3]^1[H^+]^1$

- $k = \dfrac{\text{rate}}{[CH_3COCH_3][H^+]}$ **OR** $\dfrac{1.70 \times 10^{-7}}{1.50 \times 10^{-3} \times 2.50 \times 10^{-1}}$
- $k = 4.53 \times 10^{-4}$
- **IGNORE** units: ($dm^3\ mol^{-1}\ s^{-1}$) (Any order, e.g. $mol^{-1}\ dm^3\ s^{-1}$)

Communication

Aspects of the communication statement might typically have been met when:

there is a link between evidence and orders is clear for three students results.

Possible explanation of multi-step mechanism

e.g.

- Br_2 in overall equation; not in rate equation

OR

- H^+ in rate equation; not in overall equation
- **OR** $CH_3COCH_3 + H^+ \rightarrow$ slow /rate-determining step
- **OR** stoichiometry of overall equation different from rate equation

IGNORE *attempts at full mechanism*

Q5 · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q9 · [1 mark]

Answer: **B**

0.048

Q6 · November 2020 · Paper 3 (Unified chemistry) · Q5 · [9 marks]

OCR MARK SCHEME

5(a)

Shaded cells were given in the question.

T / K	500	600	700	800	
K_p	5.86×10^{45}	1.83×10^{37}	1.46×10^{31}	1.14×10^{26}	
$\frac{1}{T}$ / K^{-1}	2.00×10^{-3}	1.67×10^{-3}	1.43×10^{-3}	1.25×10^{-3}	✓
ln K_p	105	86	72	60	✓

Calculator values

$\frac{1}{T}$ /10^{-3}	2.00	1.66 recurring	1.428571429	1.25
ln K_p	105.3844788	85.79996441	71.75857432	59.99824068

EXAMINER GUIDANCE

Mark by row

ALLOW *2 SF or more for 1/T but ignore trailing zeroes*

ALLOW *whole numbers (±1) for ln K_p*

ALLOW *1 small slip in each row.*

e.g. 1.66 for 1.67; 71.7 for 71.8

Check with calculator values below table ✓

BUT DO NOT ALLOW whole number errors, e.g. 85 for 86 ✗

[2 marks]

5(b)

Equilibrium (position) shifts to the left

AND

(forward) reaction is exothermic ✓

[1 mark]

ALLOW *'favours reverse reaction'*

Implies shift to left

ALLOW *'shifts in endothermic direction' BUT only if (forward) reaction stated as exothermic*

5(c)

Plotting of graph

All points correctly plotted

AND best-fit straight line ✓

Gradient

Correct gradient of best-fit straight line within the range ±57000 → ±63000 ✓

ΔH calculation (subsumes mark for gradient)

ΔH = (–) gradient × 8.31(4) **OR** calculated value ✓

e.g. from ±60000, ΔH = (+)498840 (J) **OR** ±498.840 (kJ)

ΔH in kJ mol^{-1}

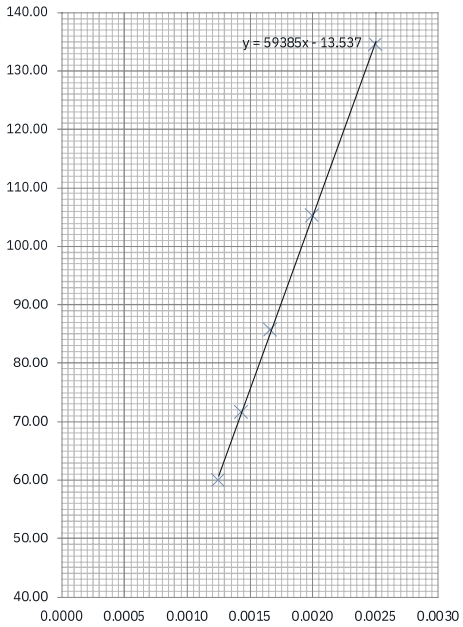
ΔH correct in kJ mol^{-1}

AND 3SF

AND – sign ✓

e.g. from ±498840, ΔH = –499 (kJ mol^{-1})

[4 marks]



ALLOW *4 points on graph*

Tolerance 1 small square

ALLOW *ΔH in range: –480 → –530 (kJ mol^{-1})*

This mark subsumes gradient mark

5(d)

Extrapolate line to (y) intercept **OR** Measure/Use (y) intercept ✓

Intercept = $\frac{\Delta S}{R}$ **OR** $\Delta S = R \times$ (y) intercept ✓

This statement automatically subsumes 1st mark

NOTE*: If 'x' intercept,* ***DO NOT ALLOW*** *1st mark but 2nd mark available for × R as BOD*

[2 marks]

ALLOW substitute values of ln K_p, $1/T$ and gradient into Equation 5.1 ✓

From provided values and gradient = 60000:

$\frac{\Delta S}{R} = \ln K_p - \text{gradient} \times \frac{1}{T}$

OR $135 - 60000 \times 2.50 \times 10^{-3} = -15$ ✓

Q7 · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q20 · [11 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

20(a)

rate of forwards reaction = rate of backwards reaction

OR concentrations/pressure/temperature are constant /do not change ✓

[1 mark]

DO NOT ALLOW *"are the same"*

20(b)(i)

$\Delta G = \Delta H - T\Delta S = -114 - (298 \times -0.147)$ ✓

$= -70.194$ (kJ mol^{-1})

AND

statement of $\Delta G < 0$ **OR** ΔG is –ve **OR** $\Delta H < T\Delta S$ ✓

[2 marks]

ALLOW *–114000 – (298 × –147)*

ALLOW *–70 up to calculator value of –70.194 correctly rounded,*

i.e. –70 **OR** –70.2 **OR** –70.19

ALLOW *-70000 up to -70194 (J mol^{-1})*

ALLOW ECF *for an incorrectly calculated negative value of ΔG linked to feasibility statement*

IGNORE *rounding after 3 SF*

ORA *for comment about – sign required for feasibility*

20(b)(ii)

776 (K) ✓

i.e. Maximum temperature = $\frac{\Delta H}{\Delta S} = \frac{-114}{-0.147}$ = 776 (K)

3 SF required (appropriate from supplied data)

[1 mark]

20(c)(i)

FIRST, CHECK FOR VALUE OF K_p.

IF *answer = 20.7 (MPa^{-1}), award 4 marks*

Equilibrium amounts

n(NO) = 0.4 (mol)

AND $n(O_2)$ = 0.9 (mol)

AND $n(NO_2)$ = 1.2 (mol) ✓

Total moles at equilibrium

n_{tot} = 2.5(mol) ✓

Partial pressures

$p(NO) = \frac{0.4}{2.5} \times 1.21 = 0.1936$ (MPa)

ALLOW ECF throughout

ALLOW *20.6 from 3 SF partial pressures, 0.194, 0.436 and 0.581*

IF *there is an alternative answer, check to see if there is any* ***ECF*** *credit possible using working below*

Look for values to 3 SF here: 0.194, 0.436 and 0.581

ALLOW 25.0 as ECF *(from omission of partial pressures for 3 marks)*

AND $p(O_2) = \frac{0.9}{2.5} \times 1.21 = 0.4356$ (MPa)

AND $p(NO_2) = \frac{1.2}{2.5} \times 1.21 = 0.5808$ (MPa) ✓

K_p value

$K_p = \frac{0.5808^2}{0.1936^2 \times 0.4356} = 20.7$ to 3 SF (MPa^{-1}) ✓

[4 marks]

20(c)(ii)

Change	K_p	Equilibrium amount of NO_2	Initial rate
Temperature increased	smaller	smaller	greater
Pressure increase	same	greater	greater
Catalyst added	same	same	greater
	✓	✓	✓

[3 marks]

Mark by **COLUMN**

ALLOW *obvious alternatives for greater/smaller/same, e.g. increases/decreases/ more/less*

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