OCR A-Level Chemistry A

Module 5: Physical chemistry and transition elements mark scheme · goes with "Module 5: Physical chemistry and transition elements" · whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/

Mark schemes

6 topics · 105 questions

Q1 · Acids, bases and buffers · [12 marks]

OCR MARK SCHEME

21(a)

FIRST, CHECK THE ANSWER ON ANSWER LINE

***IF** answer = 0.753, award 3 marks*

$[H^+] = 10^{-pH} = 10^{-2.440} = 3.63 \times 10^{-3}$ (mol dm^{-3}) ✓

$[CH_3COOH] = \dfrac{[H^+]^2}{K_a}$ **OR** $\dfrac{(3.63 \times 10^{-3})^2}{1.75 \times 10^{-5}}$ ✓

= 0.753 (mol dm^{-3}) ✓

[3 marks]

EXAMINER GUIDANCE

***ALLOW** use of HA and A^-*

***ALLOW 3 SF** up to calculator value of $3.630780548 \times 10^{-3}$ correctly rounded*

***NOTE**: Answer is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value*

***ALLOW** 0.749 if $[H^+]$ has been subtracted from $[CH_3COOH]$ for greater accuracy at end*

21(b)

CH_3COOH	+	FCH_2COOH	⇌	$CH_3COOH_2^+$	+	FCH_2COO^- ✓
B2		**A1**		**A2**		**B1**
OR						
B1		**A2**		**A1**		**B2** ✓

i.e. labels other way round

[2 marks]

Watch for opposite order on RHS, i.e.:

$FCH_2COO^- + CH_3COOH_2^+$

Take great care matching labels

ALLOW ECF** for incorrect proton transfer as below. This is the **ONLY ECF

CH_3COOH	+	FCH_2COOH	⇌	CH_3COO^-
A1		**B2**		**B1**
OR				
A2		**B1**		**B2**

i.e. labels other way round

21(c)(i)

$[CH_3COO^-]$

$n(CH_3COONa) = \dfrac{9.08}{82.0}$ **OR** 0.111 ✓ (Calc: 0.1107317073)

$[CH_3COO^-] = \dfrac{9.08}{82.0} \times \dfrac{1000}{250}$ = 0.443 (mol dm^{-3})

OR $n(CH_3COOH) = \dfrac{0.800 \times 250}{1000}$ = 0.200 (mol) ✓

$[H^+]$

$[H^+] = \dfrac{K_a \times [CH_3COOH]}{[CH_3COO^-]}$ **OR** $\dfrac{K_a \times n(CH_3COOH)}{n(CH_3COO^-)}$

$= \dfrac{1.75 \times 10^{-5} \times 0.800}{0.443}$ **OR** $\dfrac{1.75 \times 10^{-5} \times 0.200}{0.111}$ ✓

= 3.16×10^{-5} (mol dm^{-3}) ✓

pH (must come from calculated $[H^+]$)

pH = –log (3.16×10^{-5}) = 4.50 ✓

***ALLOW** 2 sig fig*

***ALLOW** use of HA and A^-*

Mark by **ECF**

Alternative method

(If both methods are attempted, mark the method which produces the higher mark)

$[H^+]$

$[H^+] = 10^{-pH} = 10^{-4.50}$

= 3.16×10^{-5} (mol dm^{-3}) ✓

$[CH_3COO^-]$

$[CH_3COO^-] = \dfrac{K_a \times [CH_3COOH]}{[H^+]}$

OR $\dfrac{1.75 \times 10^{-5} \times 0.800}{(3.16 \times 10^{-5})}$ ✓

= 0.443 (mol dm^{-3}) ✓

LAST 3 marks are **NOT** available using

- K_a square root approach (weak acid pH)
- K_w /10^{-14} approach (strong base pH)

Henderson–Hasselbalch (HH) alternative

$pK_a = -\log 1.75 \times 10^{-5} = 4.757$ (or 4.756961951..)

$pH = pK_a + \log\left(\frac{[CH_3COO^-]}{[CH_3COOH]}\right)$ **OR** $= pK_a - \log\left(\frac{[CH_3COOH]}{[CH_3COO^-]}\right)$

OR $pK_a + \log\left(\frac{0.443}{0.800}\right)$ **OR** $= pK_a - \log\left(\frac{0.800}{0.443}\right)$ ✓

$= pK_a - 0.257$ ✓

$= 4.757 - 0.257 = 4.50$ ✓

[5 marks]

mass of CH_3COONa

mass $CH_3COONa = \frac{0.443 \times 250}{1000}$

OR 0.111 ✓

$0.111 \times 82.0 = 9.08$ (g) ✓

Common errors

4.64	Use of $M(CH_3COONa) = 60$	4 marks
2.40	Use of K_a of FCH_2COOH	4 marks

21(c)(ii)

pH is the same/constant ✓

ratio/proportion $[HA]/[A^-]$ is the same ✓

[2 marks]

M2 is dependent upon M1

ALLOW *Change in [HA] and $[A^-]$ is proportional*

Q2 · Acids, bases and buffers · [1 mark]

Answer: **C**

5.06

Q3 · Acids, bases and buffers · [11 marks]

OCR MARK SCHEME

19(a)(i)

$K_a = \dfrac{[H^+]\,[CH_3COO^-]}{[CH_3COOH]}$ ✓

[1 mark]

EXAMINER GUIDANCE

IGNORE *state symbols*

Must be square brackets

IGNORE *expressions with HA or with* $[H^+]^2$

19(a)(ii)

FIRST, CHECK ANSWER ON ANSWER LINE

IF answer = 4.76 award 3 marks

$[H^+] = 10^{-pH}$

$= 10^{-2.41} = 3.89 \times 10^{-3}$ (mol dm^{-3}) ✓

K_a

$= \dfrac{[H^+]^2}{[CH_3COOH]} = \dfrac{(3.89 \times 10^{-3})^2}{0.870}$

$= 1.74 \times 10^{-5}$ (mol dm^{-3}) ✓

pK_a

$= -\log K_a = -\log 1.74 \times 10^{-5} = 4.76$ ✓

[3 marks]

ALLOW *use of HA and* A^-

ALLOW 3 SF *up to calculator value of:*

$3.89045145 \times 10^{-3}$ correctly rounded

K_a $1.739725573 \times 10^{-3}$

NOTE*:* 1.74×10^{-5} *is same from unrounded* $[H^+]$ *calculator value and 3 SF* $[H^+]$ *value*

2 DP required

19(a)(iii)

$\%\ \text{dissociation} = \dfrac{[H^+]}{[CH_3COOH]} \times 100$

$= \dfrac{3.89 \times 10^{-3}}{0.870} \times 100 = 0.447(\%)$ ✓

[1 mark]

3 SF required

19(b)

FIRST, CHECK ANSWER ON ANSWER LINE

IF answer = 95.9(%) award 4 marks

$[H^+] = 10^{-pH}$

$= 10^{-13.48} = 3.31 \times 10^{-14}$ (mol dm^{-3}) ✓

$[OH^-]$ from K_w

$= \dfrac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302$ (mol dm^{-3}) ✓

Mass of (NaOH)

$= \dfrac{0.302 \times 100}{1000} \times 40.0 = 1.21$ (g) ✓

% of NaOH to 3 SF

$= \dfrac{1.21}{1.26} \times 100 = 95.9$ (%) ✓

[4 marks]

ALLOW ECF *throughout*

IGNORE *rounding errors beyond 3rd SF throughout*

ALLOW 3.3×10^{-14} (mol dm^{-3})

ALLOW *0.30*

ALLOW *0.303 if* 3.3×10^{-14} *used in the first marking point*

ALLOW *pOH method:,*

pOH = 14 – 13.48 = 0.52

$[OH^-] = 10^{-0.52} = 0.302$ (mol dm^{-3})

ALLOW $[OH^-] \times 0.1 \times 40$

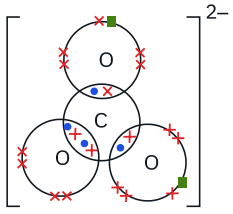
Rounding $[OH^-]$ to 0.3(0) gives $\dfrac{1.2}{1.26} = 95.2\%$

Award 4 marks

Rounding $[OH^-]$ to 0.303 gives $\dfrac{1.212}{1.26} = 96.2\%$

Award 4 marks

19(c)



NOT REQUIRED

- Charge ('2–') **IGNORE** incorrect charges
- Brackets
- Circles

IGNORE *inner shells*

ALLOW *rotated diagram*

Global rules

- C and O electrons must be shown differently, e.g. • for C and × for O
- Na electrons shown with different symbol

MARKING

Bonding around central C atom ✓

- 4 electrons for C shown as • **OR** ×
- 4 electrons for O, different from C as • **OR** ×
- C=O bond with 2 C electrons **AND** 2 O electrons
- Two C–O bonds with 1 C electron **AND** 1 O electron

Non-bonded (nb) electrons around 3 O atoms ✓

- C=O oxygen has 4 nb 'O' electrons
- Each C–O oxygen has 5 nb 'O' electrons **AND** 1 'extra' electron with different symbol

[2 marks]

ALLOW *diagram with missing C or O symbols.*

In C=O bond, ALLOW sequence × × • •

In C–O bond, ALLOW 'extra' electron with different symbol for O electron

ALLOW *non-bonding electrons unpaired*

ALLOW *'extra' electron as* • ***OR*** × *if it has been labelled 'extra electron' or similar*

Q4 · Acids, bases and buffers · [1 mark]

Answer: **D**

H_3O^+ and H_2O

Q5 · Acids, bases and buffers · [9 marks]

OCR MARK SCHEME

17(a)

Level 3 (5–6 mark)

Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

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)

Detailed explanation of equilibrium and the action of the buffer.

OR

Detailed explanation of equilibrium and correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

OR

Detailed explanation of the action of the buffer and correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

OR

Partial explanations of equilibrium, and the action of the buffer and attempt calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

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)

Detailed explanation of equilibrium.

OR

Correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

OR

Detailed explanation of the action of the buffer.

OR

Partial explanations of equilibrium and the action of the buffer.'

OR

EXAMINER GUIDANCE

Indicative scientific points may include:

(State symbols not required in equations)

Equilibrium and equilibrium shifts

- $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$
- Addition of H^+ causes ⇌ to shift to left
- Addition of OH^- causes ⇌ to shift to right

Action of buffer

- Increase in H^+ / addition of acid leads to:

$H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$

OR HCO_3^- reacts with added acid

- Increase in OH^- / addition of alkali leads to:

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

OR

$H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$

OR

H_2CO_3 reacts with added alkali

Calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio

- $K_a = 10^{-6.38}$ **OR** 4.17×10^{-7} (mol dm^{-3})
- $[H^+] = 10^{-7.40}$ **OR** 3.98×10^{-8} (mol dm^{-3})
- $\frac{[HCO_3^-]}{[H_2CO_3]}$ **OR** $\frac{(4.17 \times 10^{-7})}{(3.98 \times 10^{-8})}$
- ratio = 10.47(:1) OR 10.48(:1)

ALLOW *10.5 OR 10(:1) (after working shown)*

ALLOW $\frac{(4.2 \times 10^{-7})}{(4.0 \times 10^{-8})}$

Partial explanation of equilibrium and attempt at calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.'

OR

Partial explanation of the action of the buffer and attempt at calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.

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]

And ratio = 10.5 **OR** 11 (after working shown)

ALLOW $\frac{[H_2CO_3]}{[HCO_3^-]}$ ***OR*** $\frac{3.98 \times 10^{-}}{4.17 \times 10^{-7}}$

And ratio = 1 : 0.095 ..

17(b)

Coordinate bond mark

O_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron ✓

Ligand substitution mark

(When required) O_2 is replaced by H_2O **OR** CO_2

OR O_2 is replaced by CO

OR H_2O **OR** CO_2 is replaced by O_2 ✓

Ligand strength mark

CO forms strong(er) bonds (than O_2) ✓

[3 marks]

ALLOW *names or symbols of ligands*

ALLOW *H_2O/CO/CO_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron*

ALLOW *oxygen donates electron pair to* ***OR*** *binds with Fe^{2+}/Fe(II)/Fe/Iron*

DO NOT ALLOW *Fe^{3+}*

ALLOW *other words for replaced*

ALLOW *K_{stab} for CO (much) higher (than for O_2)*

ALLOW *CO bonds irreversibly* ***OR*** *CO is a strong(er) ligand*

IGNORE *affinity*

Q6 · Acids, bases and buffers · [14 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

20(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 2.98 award 2 marks

$[H^+] = \sqrt{(Ka \times [C_2H_5COOH])} = 1.039 \times 10^{-3}$ (mol dm^{-3}) ✓

pH = –log 1.039×10^{-3} = 2.98 (Must be to 2 DP) ✓

[2 marks]

ALLOW ECF *throughout*

ONLY ALLOW pH mark by **ECF** if K_a **AND** 0.080 used and **AND** pH <7

Common errors (Must be to 2 DP)

One mark for pH = 5.97 (No square root):

One mark for pH = 0.92 **OR** pH = 5.15 (Using incorrect K_a values)

20(b)(i)

$n(C_2H_5COOH) = (\frac{0.0800 \times 25.0}{1000}) =) 0.002$ (mol)

AND

$V(NaOH) = \frac{0.002}{0.100} \times 1000 = (= 20(.0)\ cm^3)$ ✓

[1 mark]

ALLOW *0.02 dm^3 if unit given*

Mark is for WORKING which could all be shown as 1 step

ALLOW *method showing 20cm^3 NaOH contains the same moles as acid*

$n(C_2H_5COOH)$ = 0.08(00) x 0.025(0) = 0.002 (mol)

and

n(NaOH) = 0.02(00) x 0.1 = 0.002(00) (mol)

20(b)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 12.55 award 4 marks

Excess mol of NaOH:

$n(OH^-)_{excess} = n(OH^-) - n(C_2H_5COOH)$

$= (\frac{0.100 \times 45.0}{1000}) - (\frac{0.0800 \times 25.0}{1000})$

= 0.0045 – 0.002 = 0.0025 (mol) ✓

ALLOW ECF *throughout*

For first mark **ALLOW**

(Excess volume of NaOH = 25(.0) cm^3)

$n(OH^-)_{excess} = \frac{0.100 \times 25.0}{1000} = 0.0025$ (mol)

Common errors

If initial V(NaOH) = 45 cm^3

$[OH^-] = 0.0643$ (mol)

$[H^+] = 1.56 \times 10^{-13}$ (mol dm^{-3})

Concentration of OH^-:

$[OH^-] = \left(\frac{0.0025}{70.0 \times 10^{-3}}\right) = 0.0357$ (mol dm^{-3}) ✓

Concentration of H^+:

$[H^+] = \left(\frac{1.00 \times 10^{-14}}{0.0357}\right) = 2.8 \times 10^{-13}$ (mol dm^{-3}) ✓

Conversion to pH:

pH = $(-\log 2.8 \times 10^{-13}) = 12.55$ ✓

[4 marks]

pH = 12.81 award three marks (no 1st mark)

If $n(OH^-)_{excess}$ is used in $[H^+]$ calculation

$n(OH^-)_{excess} = 0.0025$ (mol)

$[H^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12}$ (mol dm^{-3})

pH = 11.40 award three marks (no 2nd mark)

ALLOW *pOH method for last two marks*

pOH = $-\log[OH^-] = 1.447$

pH = $14 - 1.447 = 12.55$

ALLOW *ECF for conversion from $[H^+]$ to pH provided value calculated is above 7 and from derived $[H^+]$*

20(b)(iii)

Shape

Slight rise/flat, **AND** (near) vertical, **AND** then slight rise/flat ✓

pH

Vertical section within the extremes of pH 5 to 12 and a minimum range of three pH units

AND middle of vertical section (equivalence point) needs to be above pH 7 ✓

End point

Vertical section at ~ 20 cm^3 NaOH ✓

[3 marks]

If pH curves wrong way round (i.e. adding acid to alkali),

ONLY award mark for End point (~ 20 cm^3)

20(b)(iv)

cresol purple

AND

pH range matches vertical section/rapid pH change

OR

end point/colour change matches vertical section/rapid pH change ✓

[1 mark]

ALLOW *pH range (of the indicator) matches equivalence point*

ALLOW *end point/colour change matches equivalence point*

IGNORE *colour change matches end point*

Colour change is the same as end point

20(b)(v)

similarity: end point / volume (20 cm^3) of NaOH needed to neutralise

OR

final pH / shape of curve after end point ✓

difference: HCN higher starting pH

OR

HCN shorter vertical section ✓

[2 marks]

End point must not refer to same pH

ALLOW *different equivalence point*

IGNORE *different starting pH*

20(c)

HIO_3 dissociation is not negligible / dissociates to a significant extent

OR

Large K_a and HIO_3 is 'stronger' (weak) acid

OR

$[HIO_3]_{eqm}$ is significantly lower than $[HIO_3]_{initial/undissociated}$ ✓

[1 mark]

ALLOW *use of HA*

Ignore $[HIO_3]_{equilibrium} < [HIO_3]_{initial/undissociated}$

ALLOW

$[HIO_3]_{equilibrium} \sim [HIO_3]_{undissociated}$ is no longer a valid assumption

ALLOW

$[HIO_3]$ has a larger K_a so the assumption that $[HIO_3]$ at equilibrium = $[HIO_3]$ initially so assumption is not valid

Q7 · Acids, bases and buffers · [1 mark]

Answer: **D**

Colour stays yellow.

Q8 · Acids, bases and buffers · [1 mark]

Answer: **C**

NH_4^+ and H_2O

Q9 · Acids, bases and buffers · [14 marks]

OCR MARK SCHEME

19(a)(i)

Titres

22.75	22.45	**22.70**	22.55

✓

Mean titre

$\frac{22.45 + 22.55}{2}$ = 22.5(0) (cm^3) ✓

[2 marks]

EXAMINER GUIDANCE

2 DP essential

i.e. last 0 for 22.70

DO NOT ALLOW *use of trial titre.*

19(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 498 mg award 5 marks

Number of moles of KOH in titre

= $\frac{0.0600 \times 22.50}{1000}$ **OR** 1.35×10^{-3} (mol) ✓

Number of moles of acid in 10 cm^3

= $\frac{1.35 \times 10^{-3}}{2}$ **OR** 6.75×10^{-4} (mol) ✓

Number of moles of acid in 250 cm^3

= $6.75 \times 10^{-4} \times 25$ **OR** 0.016875 (mol) ✓

Mass of acid in 4 tablets

= 0.016875 × 118 **OR** 1.99125 (g) ✓

Mass in one tablet AND mg conversion

(i.e. divide by 4 **AND** x 1000)

= $\frac{1.99 \times 10^3}{4}$ = 498 (mg) ✓

Answer must be to 3SF

[5 marks]

ALLOW ECF *from incorrect titre in 19 (a) (i)*

ALLOW ECF *throughout*

TAKE CARE: values shown may be truncated calculator values.

Steps can be calculated in any order which will change the intermediate answers. Marks are for the processing of the data.

ALLOW *3SF up to calculated value throughout BUT ignore trailing zeros on intermediate values*

IGNORE *rounding errors past 3SF*

Common errors

5 marks

503 mg	(use of 22.725 cm^3)

4 marks

996mg	(no divided by 2)
19.9mg	(no volume conversion i.e. x 25)

19(b)(i)

(Glycolic) acid is in excess/partially neutralised

AND

glycolate/potassium glycolate (ions) are present/produced ✓

[1 mark]

ALLOW *some acid remains*

ALLOW *conjugate base for glycolate ions/salt of weak acid*

ALLOW *$HOCH_2COO^-$*

19(b)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 3.93 award 4 marks

Initial amounts

ALLOW ECF *throughout*

ALLOW use of moles for *concentration*

$[H^+] = \frac{1.479 \ldots \times 10^{-4} \times 0.0200}{0.0250}$

Common errors

$n(HOCH_2COOH) = \frac{0.750 \times 60.0}{1000}$ **OR** 0.045(0) (mol)

AND $n(KOH) = \frac{0.625 \times 40.0}{1000}$ **OR** 0.025(0) ✓

Amounts in the buffer solution

$n(HOCH_2COOH) = 0.0450 - 0.0250$ **OR** 0.02(00) (mol)

AND $n(HOCH_2COO^-)$ 0.025(0) (mol) ✓

pH

$K_a = 10^{-3.83}$ **OR** $1.479 \ldots \times 10^{-4}$ ✓

$[H^+] = \frac{1.479 \ldots \times 10^{-4} \times 0.200}{0.250}$ **OR** 1.183×10^{-4} (mol dm^{-3})

pH = 3.93 (2 DP) ✓

[4 marks]

3 marks

pH = 3.57

not using n(HA) remaining

2 marks

pH = 3.75

using HA and KOH concentrations within question

19(b)(iii)

NH_3 / OH^- reacts with H^+ / $HOCH_2COOH$ / (Glycolic) acid ✓

$HOCH_2COOH \rightleftharpoons H^+ + HOCH_2COO^-$

AND Equilibrium shifts to the right ✓

[2 marks]

ALLOW *NH_3 will act as a base (and form NH_4^+)*

ALLOW *NH_3 decreases $[H^+]$*

ALLOW *$HA \rightleftharpoons H^+ + A^-$*

Equilibrium needs to be shown.

Q10 · Acids, bases and buffers · [21 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

20(a)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

if answer = 6.77 award 2 marks

$K_w = [H^+][OH^-]$ **OR** $K_w = [H^+]^2$ **OR** $[H^+] = \sqrt{K_w}$ ✓

($[H^+] = \sqrt{(2.92 \times 10^{-14})}$)

pH = $-\log(1.71 \times 10^{-7}) = 6.77$ ✓

[2 marks]

DO NOT ALLOW *use of A^- or X^-*

20(a)(ii)

(In pure water), $[H^+]$ (always) equals $[OH^-]$

[1 mark]

ALLOW *moles/number of H^+ is (always) equal to moles/number of OH^-.*

DO NOT ALLOW *ratio $[H^+] : [OH^-]$ doesn't change*

20(b)

- Equation $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓

CHECK THE ANSWER ON ANSWER LINE

if answer = 11.51 award 4 calculation marks

- $n(Sr(OH)_2) = \frac{0.145}{121.6} = 1.1924\ldots \times 10^{-3}$ ✓
- $[OH^-] = 2 \times \frac{1.1924 \times 10^{-3}}{0.25} = 9.539\ldots \times 10^{-3}$ ✓
- $[H^+] = \frac{K_w}{[OH^-]} = \frac{2.92 \times 10^{-14}}{9.539.. \times 10^{-3}} = 3.061\ldots \times 10^{-12}$ ✓
- pH = $-\log(3.061\ldots \times 10^{-12}) = 11.51$ ✓

2 DP required

[5 marks]

IGNORE *state symbols (even if wrong)*

ALLOW *multiples*

ALLOW *$Sr^{2+} + 2OH^-$ for $Sr(OH)_2$*

ALLOW *3 SF up to the calculated value.*

Ignore RE after 3SF.

ALLOW *ECF throughout but final answer must be pH>7*

Final answer must be from calculated values.

Common errors for 3 calculation marks

11.98 (Use of $K_w = 1 \times 10^{-14}$)

11.21 (no × 2)

10.91 (÷ by 2)

Common error for 2 calculation marks

pH = 11.67 (no × 2 and wrong K_w)

Alternative method for:-

pH = pK_w – pOH

- $n(Sr(OH)_2) = \frac{0.145}{121.6} = 1.1924... \times 10^{-3}$
- $[OH^-] = 2 \times (\frac{1.1924 \times 10^{-3}}{0.25}) = 9.539... \times 10^{-3}$
- pH = pK_w - pOH = (-log 2.92×10^{-14}) - (-log $9.539.. \times 10^{-3}$)
- pH = 13.53(46) - 2.02(05) = 11.51

20(c)(i)

$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + H_2O + CO_2$ ✓

[1 mark]

IGNORE *state symbols*

DO NOT ALLOW *H_2CO_3 for $H_2O + CO_2$ (question states that a gas was produced)*

ALLOW *multiples*

20(c)(ii)

M_r of $SrCO_3$ is different to M_r $CaCO_3$ /

moles $SrCO_3$ are different to moles $CaCO_3$ ✓

M_r of $SrCO_3$ > M_r $CaCO_3$ /moles $SrCO_3$ < moles $CaCO_3$

AND

More moles/volume gas (from $CaCO_3$) ✓

[2 marks]

ALLOW *ORA*

ALLOW

$n(SrCO_3) = (\frac{1.00}{147.6}) = 6.78 \times 10^{-3}$ (mol)

AND

$n(CaCO_3) = (\frac{1.00}{100.1}) = 9.99 \times 10^{-3}$ (mol)

For the 2nd mark, we are assessing the idea of the greater moles of carbonate produces more gas.

Subsumes first mark

ALLOW

$n(SrCO_3) = (\frac{1.00}{147.6}) = 6.78 \times 10^{-3}$ (mol)

AND

$n(CaCO_3) = (\frac{1.00}{100.1}) = 9.99 \times 10^{-3}$ (mol)

AND

Calculated values (CO_2) 163 cm^3 **AND** 240 cm^3

20(d)(i)

$Mg + 2H^+ \rightarrow Mg^{2+} + H_2$ ✓

[1 mark]

ALLOW *multiples*

ALLOW *Mg^{+2}*

IGNORE *state symbols*

20(d)(ii)

HCl is a strong acid/completely dissociates

AND

CH_3COOH is a weak acid/partially dissociates ✓

Greater H^+ concentration in HCl

AND

More frequent collisions / faster rate of reaction ✓

More CH_3COOH dissociates until same number of moles of H^+ released

OR

same total moles H^+ produced (by the end)

OR

(Both acids are monobasic) and have the same number of moles of acid ✓

[3 marks]

IGNORE *HCl is a stronger acid than ethanoic acid.*

ALLOW *ORA*

DO NOT ALLOW *dibasic/tribasic*

20(e)(i)

ALLOW *One molecule of (butanoic) acid*

One mole of (butanoic) acid donates/dissociates to form one mole of protons/H^+ ✓

[1 mark]

donates/dissociates to form one proton/H^+

ALLOW *only one hydrogen ion in the acid can be replaced per molecule (in an acid-base reaction)*

20(e)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

IF *ANSWER = 1.5(3) x 10^{-5} award 4 marks*

- $[H^+] = 10^{-pH}$ **OR** $10^{-5.07}$ **OR** 8.51×10^{-6} ✓
- $(\frac{3.39}{56.1})$ **OR** 0.0604 (0.06042781)

(nA^- in buffer) = (n(KOH))

OR

0.0604 x 4 **OR** 0.242 ✓

([A^-] in buffer)

- nHA in buffer = (0.376 x 0.25) – 0.0604 = (0.094) – 0.0604 **OR** 0.0336 (0.03357219...)

OR

[HA] in buffer = (0.376 – 0.242) **OR** 0.0336 x 4 **OR** 0.134 (0.13428877) ✓

- $K_a = \frac{[H^+][A^-]}{[HA]} = \frac{8.51 \times 10^{-6} \times 0.242}{0.134}$ = 1.5..... × 10^{-5} (1.5319942 × 10^{-5}) ✓

[4 marks]

ALLOW ECF *throughout*

ALLOW 2 SF *for [H^+] (use of pH)*

ALLOW *3 SF up to the calculated value.*

Ignore RE after 3SF for moles and concentration values

Mark use of 2SF in working as incorrect once and then allow ECF

ALLOW *full marks for use of moles (volumes cancel)*

$K_a = \frac{8.51 \times 10^{-6} \times 0.0604}{0.0336} = 1.53 \times 10^{-5}$

ALLOW *final answer to 2SF*

Common errors for 3 marks

5.47(1731026) x 10^{-6} (not subtracting moles of KOH from HA)

20(f)

ratio/proportion [HA]/[A^-] is the same

[1 mark]

ALLOW *Change in [HA] and [A^-] is proportional*

ALLOW *the concentrations of the weak acid and conjugate base change by same amount*

Q11 · Acids, bases and buffers · [1 mark]

Answer: **A**

$CH_3COONa(aq)$

Q12 · Acids, bases and buffers · [11 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

19(a)(i)

$(K_a) = \frac{[H^+]\,[ClCH_2COO^-]}{[ClCH_2COOH]}$ ✓

[1 mark]

DO NOT ALLOW *without square brackets*

DO NOT ALLOW $\frac{[H^+]^2}{[ClCH_2COOH]}$

DO NOT ALLOW $\frac{[H^+][A^-]}{[HA]}$

19(a)(ii)

[H^+] = [A^-]

OR [H^+] from water is negligible

OR dissociation of water is negligible ✓

[1 mark]

Answer must be in terms of concentration

ALLOW *[H^+] ≈ [A^-]*

IGNORE *HA ⇌ H^+ + A^- is a 1:1 mole ratio.*

19(a)(iii)

FIRST CHECK ANSWER ON ANSWER LINE

If answer = 2.85 OR 2.86 OR 2.87 award 3 marks

([H^+] =) $10^{-1.95}$

OR = 1.1(22...) × 10^{-2} ✓

ALLOW ECF *throughout*

ALLOW *[H^+] =1.1 × 10^{-2} up to calculator value*

ALLOW *2 sig figs up to calculator value.*

ALLOW *calculations based on finding the $[HA]_{equ}$*

$(K_a) = \left(\frac{[H^+]^2}{[ClCH_2COOH]} \right)$

$= \frac{(1.122...\ x10^{-2})^2}{(0.090)}$ **OR** $\frac{(1.12\ x10^{-2})^2}{(0.090)}$ **OR** $\frac{(1.1\ x10^{-2})^2}{(0.090)}$

$=1.4(0) \times 10^{-3}$ **OR** $=1.39 \times 10^{-3}$ **OR** $= 1.34 \times 10^{-3}$ ✓

$(pK_a = -\log_{10}(K_a) =)$ 2.85, 2.86 OR 2.87 (2DP) ✓

[3 marks]

$\frac{(1.122...\ x10^{-2})^2}{(0.079)}$ **OR** $\frac{(1.12\ x10^{-2})^2}{(0.079)}$ **OR** $\frac{(1.1\ x10^{-2})^2}{(0.079)}$

$=1.59 \times 10^{-3}$ **OR** $=1.59 \times 10^{-3}$ **OR** $= 1.53 \times 10^{-3}$ ✓

$(pK_a = -\log_{10}(K_a) =)$ 2.80 **OR** 2.80 **OR** 2.81 (2DP) ✓

Must be 2DP

Common error:

2 marks

0.90 (not using $[H^+]^2$)

19(b)(i)

Smooth s-shaped curve using a best fit line that goes through the majority of points. ✓

Reading off x-axis at 12.5 cm^3 ✓

$n(Ba(OH)_2) =) \frac{0.0560 \times 12.5}{1000}$

$= 7.00 \times 10^{-4}$ ✓

$n(CH_3COOH =) 2 \times$ (moles $Ba(OH)_2$)

$= 1.40 \times 10^{-3}$ ✓

(concentration =) $\frac{1.4 \times 10^{-3}}{\left(\frac{10}{1000} \right)}$

$= 0.14(0)$ (mol dm^{-3}) ✓

Alternative method based on calculating pK_a from the half neutralisation point.

pH and $[H^+]$ reading will come from the candidates graph and the data points provided.

e.g.

pH at half neutralisation

6.25 cm^3 = pH 4.7 = pK_a ✓

$K_a = 10^{-4.7}$

$= 1.995 \times 10^{-5}$ ✓

$[H^+]$ at pH 3.3 (obtained from data on the graph provided)

$10^{-3.3} = 5.012 \times 10^{-4}$ (mol dm^{-3}) ✓

$[HA] = \frac{[H^+]^2}{[K_a]}$

$= \frac{(5.012 \times 10^{-4})^2}{(1.995 \times 10^{-5})}$

$= 0.0126$ (mol dm^{-3}) ✓

[5 marks]

DO NOT ALLOW *point to point*

DO NOT ALLOW *tram/feather lines.*

ALLOW *Reading off x-axis from 12.4 – 12.6 cm^3*

ALLOW *ECF throughout*

ALLOW *3SF or more unless there is a trailing zero*

Alternative answers:

0.139 (mol dm^{-3}) (from reading off x-axis at 12.4 cm^3)

0.141 (mol dm^{-3}) (from reading off x-axis at 12.6 cm^3)

Common errors:

3 Marks

0.134 (Use of 12 cm^3)

0.202 (use of 18 cm^3)

ALLOW *MP2 for K_a = 1.7 x 10^{-5} to 1.8 x 10^{-5} (knowledge of actual K_a value)*

ALLOW *ECF from any quoted K_a*

19(b)(ii)

Phenol red

OR

Phenolphthalein ✓

[1 mark]

Both indicators can change colour on the sharp vertical section of the candidates curve.

Q13 · Acids, bases and buffers · [10 marks]

OCR MARK SCHEME

1(a)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *pH = 13.6(0), award 2 marks*

EXAMINER GUIDANCE

ALLOW ECF *from incorrect $[H^+]$ calculated from $[OH^-]$ AND K_w*

$K_w = [H^+] \times 0.400$ **OR** $1.00 \times 10^{-14} = [H^+] \times 0.400$

OR $[H^+] = \dfrac{K_w}{0.400}$ **OR** $[H^+] = \dfrac{1.00 \times 10^{-14}}{0.400}$ **OR** $[H^+] = 2.5 \times 10^{-14}$ ✓

pH = $-\log 2.5 \times 10^{-14} = 13.6(0)$ ✓

ALLOW *13.6..... up to calculator value of 13.60205999 correctly rounded*

[2 marks]

.....for pH > 7 ONLY

ALLOW *method based on pOH:*

pOH = –log 0.400 = 0.40 ✓

Calculator: 0.39794...

pH = 14 – 0.40 = 13.6(0) ✓

1(b)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *pH = 1.12, award 1 mark*

pH = –log 0.075 = 1.12 ✓

2 DP required

[1 mark]

1(c)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *pH = 4.28, award 2 marks*

$1.75 \times 10^{-5} = \dfrac{[H^+] \times 0.100}{0.300}$

OR $[H^+] = \dfrac{1.75 \times 10^{-5} \times 0.300}{0.100}$

OR $[H^+] = 5.25 \times 10^{-5}$ (mol dm^{-3}) ✓

pH = $-\log 5.25 \times 10^{-5} = 4.28$ ✓

2 DP required

[2 marks]

COMMON ERRORS

1 mark for 5.23 inverted [HA] and [A$^-$]

$[H^+] = \dfrac{1.75 \times 10^{-5} \times 0.100}{0.300}$

OR $5.83.... \times 10^{-6}$ ✗

pH = $-\log 5.83.... \times 10^{-6} = 5.23$ ✓ **ECF**

1 mark for 4.46 [HA] = 0.2 instead of 0.3

$[H^+] = \dfrac{1.75 \times 10^{-5} \times 0.200}{0.100}$

OR 3.5×10^{-5} ✗

pH = $-\log 3.5 \times 10^{-5} = 4.46$ ✓ **ECF**

Other **ECF** available from ONE transcription error ONLY, e.g. 1.57×10^{-5} for $K_a = 1.75 \times 10^{-5}$

Zero marks for square root approach

e.g. via $K_a = \dfrac{[H^+]^2}{0.300}$

Zero marks for [A$^-$] : [HA] = 0.1 : 0.1

i.e. $[H^+] = \dfrac{1.75 \times 10^{-5} \times 0.100}{0.100} = 1.75 \times 10^{-5}$ ✗

pH = 4.76 ✗

ALLOW *Henderson-Hasselbalch for both marks:*

e.g. pH = $4.76 + \log \dfrac{0.100}{0.300}$

OR pH = $-\log(1.75 \times 10^{-5}) + \log \dfrac{0.100}{0.300}$ ✓

OR pH = $-\log(1.75 \times 10^{-5}) - \log \dfrac{0.300}{0.100}$

pH = 4.28 ✓

1(d)

Calculation 2 marks

$n(Cu(NO_3)_2 \cdot 3H_2O) = \dfrac{0.200 \times 100}{1000}$

ALLOW ECF *throughout*

ALLOW ECF *from incorrect n($Cu(NO_3)_2 \cdot 3H_2O$)*

4.83 g subsumes 1st mark

OR 2(.00) × 10^{-2} (mol) **OR** 0.02(00) ✓

Mass $Cu(NO_3)_2•3H_2O$ = 2.00 × 10^{-2} × 241.5 = 4.83 (g) ✓

2 or more DP to match balances

Method 3 marks

Dissolve solid in (distilled) water (less than 100 cm^3) (in beaker) ✓

Transfer (solution) to volumetric flask

AND

Wash/rinse (from beaker to flask) ✓

Make up to mark/up to 100 cm^3 with (distilled water)

AND

Invert flask (several times to ensure mixing) ✓

[5 marks]

ALLOW *small amount/some*

DO NOT ALLOW *100 cm^3 or more of water*

IGNORE *solvent*

ALLOW *graduated flask*

ASSUME that wash/rinse is to a volumetric flask

ALLOW *swirl/shake*

ALLOW *preparation of solutions > 100 cm^3 4 marks*

e.g. for 250 cm^3

$n(Cu(NO_3)_2•3H_2O) = \frac{0.200 \times 250}{1000}$ **OR** 0.05 (mol) ✗

Mass $Cu(NO_3)_2•3H_2O$ = 0.05 × 241.5 = 12.075 (g) ✓

Then method adapted for 250 cm^3 volumetric flask

e.g. Make up to 250 cm^3 with water

Q14 · Acids, bases and buffers · [1 mark]

Answer: **C**

pH range of the indicator: 9.4 –10.6

Q15 · Acids, bases and buffers · [12 marks]

OCR MARK SCHEME

19(a)

0.82 ✓

[1 mark]

EXAMINER GUIDANCE

(pH = –log(0.15)) =0.82

2 DP required

19(b)(i)

Higher (pH) **AND**

(Nitric acid fully ionises and) nitrous acid partially dissociates/ionises ✓

Lower <u>concentration</u> of H^+ ions (in nitrous acid) ✓

[2 marks]

DO NOT ALLOW *nitric acid is a stronger acid (in the question)*

IGNORE *easily dissociates*

IGNORE *does not fully dissociate/dissociates less*

ASSUME "It" refers to HNO_2

19(b)(ii)

(Simultaneous) oxidation and reduction of (the same) <u>element</u> ✓

N from +3 (in HNO_2) to +5 (in HNO_3)

AND

N from +3 (in HNO_2) to +2 (in NO) ✓

N is oxidised to HNO_3

AND

N is reduced to NO ✓

[3 marks]

ALLOW *N / nitrogen for element*

IGNORE *species for element*

+ required

ALLOW *3+, 5+, and 2+*

DO NOT ALLOW *N^{3+}, N^{5+} and N^{2+}*

ALLOW *clearly assigned oxidation numbers above the equation if not quoted on the answer line*

19(c)

Level 3 (5–6 marks)

Correct method for the calculation of $[H^+]$

AND correct method for the calculation of $[CH_3CH_2COO^-]$ **AND** correct mass of CH_3CH_2COONa **AND** explains how pH changes in a buffer when OH^- is added with reference to an equilibrium equation

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)

Correct method for the calculation of $[H^+]$

ALLOW *use of 2 SF up to calculator value*

ALLOW *use of HA and A^-*

Calculation of concentrations

$[H^+] = 10^{-pH} = 10^{-4.85}$

= 1.4(125375...) × 10^{-5} mol dm^{-3}

$[CH_3CH_2COO^-] = \frac{K_a \times [CH_3CH_2COOH]}{[H^+]}$

$= \frac{1.32 \times 10^{-5} \times 0.180}{1.4(125) \times 10^{-5}}$

= 0.168(208) mol dm^{-3}

AND correct method for the calculation of [$CH_3CH_2COO^-$]

AND

attempt at a method for calculation of mass of CH_3CH_2COONa **OR** an attempt at an explanation of how pH changes in a buffer when OH^- is added

OR

Correct method for the calculation [H^+]

AND attempt of method for calculating [$CH_3CH_2COO^-$]

AND

correct method for calculation of mass of CH_3CH_2COONa **OR** an attempt at an explanation of how pH changes in a buffer when OH^- is added

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)

Method for the calculation of [H^+]

AND

[$CH_3CH_2COO^-$] **OR** correct method for calculation of mass of CH_3CH_2COONa

OR

Explanation of how pH changes in a buffer when OH^- is added

OR

Method for the calculation of [H^+] and a simplistic explanation of how pH changes in a buffer when OH^- is added

OR

Attempts the calculation of concentration and mass with a simplistic explanation

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]

OR 0.16971... mol dm^{-3} if 1.4 x 10^{-5} used

This method could be contained within the working for the mass calculation

Calculation of mass

$n(CH_3CH_2COO^-) = 0.168 \times 0.125$

$= 0.0210(26)$ (mol)

$n(CH_3CH_2COONa) = n(CH_3CH_2COO^-)$

$M_r = 96.0$

$m(CH_3CH_2COO^-) = 0.0210(26) \times 96.0$

= 2.02 g **OR** 2.018 g

ALLOW *range 2.00 g to 2.04 g*

ALLOW *alternative methods that lead to correct mass.*

Action of buffer

OH^- from addition of alkali:

$H^+ + OH^- \rightarrow H_2O$

OR

$CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$

OR

OH^- reacts with H^+ / CH_3CH_2COOH / (propanoic) acid

$CH_3CH_2COOH \rightleftharpoons H^+ + CH_3CH_2COO^-$

ALLOW $HA \rightleftharpoons H^+ + A^-$

equilibrium shifts to the right / (acid) further dissociates restoring [H^+] therefore only a small change in [H^+]

minimising change in [CH_3CH_2COOH] / [$CH_3CH_2COO^-$]

Examples of the communication statement for all levels being met could typically include:

- clear mathematical working and appropriate units for calculated values
- use of full chemical formulae in equilibrium rather than HA / A^-

Alternative approach

Henderson–Hasselbalch (HH)

ALLOW *use of 2 SF up to calculator value*

$$pH = pK_a + \log \frac{[CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$$

OR $$= pK_a - \log \frac{[CH_3CH_2COOH]}{[CH_3CH_2COO^-]}$$

e.g.

$$4.85 = 4.879426069 + \log \frac{[CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$$

$$-0.029426069 = \log \frac{[CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$$

$$\frac{[CH_3CH_2COO^-]}{[CH_3CH_2COOH]} = 0.934884354$$

$n(CH_3CH_2COO^-)$ = 0.934(884354) x 0.125 x 0.18

= 0.0210259898

$m(CH_3CH_2COO^-)$ = 0.0210259898 x 96

= 2.01849502

= 2.02 g

Q16 · Acids, bases and buffers · [1 mark]

Answer: **D**

1.48

Q17 · Acids, bases and buffers · [11 marks]

OCR MARK SCHEME

18(a)

Equation: $Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$ ✓

Oxidation: Mg from 0 to +2 ✓

Reduction: H from +1 to 0 ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW *$Mg(CH_3COO)_2$*

ALLOW *multiples*

IGNORE *Oxidation numbers in formulae*

IGNORE *state symbols*

Mark independently from equation

ALLOW *1 mark for correct oxidation numbers but incorrectly linked to redox.*

18(b)

$HCOOH + CH_3COOH \rightleftharpoons HCOO^- + CH_3COOH_2^+$ ✓

A1 B2 B1 A2

OR

A2 B1 B2 A1 ✓

CARE:

Both + and – charges required for products in equilibrium

DO NOT AWARD *the 2nd mark from an equilibrium expression that omits either charge*

[2 marks]

IGNORE *state symbols (even if wrong)*

IF *proton transfer is wrong way around*

ALLOW *2nd mark for idea of acid–base pairs, i.e.*

$HCOOH + CH_3COOH \rightleftharpoons HCOOH_2^+ + CH_3COO^-$

B2 A1 A2 B1

NOTE For the 2nd marking point (acid–base pairs), this is the ONLY acceptable **ECF**

i.e. NO ECF from impossible chemistry

18(c)(i)

$[H^+] = 10^{-2.72}$ **OR** 1.905×10^{-3} (mol dm^{-3}) ✓

$[CH_3COOH] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}}$ ✓

(= 0.204 mol dm^{-3})

[2 marks]

ALLOW *2SF up to calculator value of $1.905460718 \times 10^{-3}$*

ALLOW *use of [HA]*

Mark is for working.

18(c)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 2.4×10^{-2} (mol dm^{-3}) award 4 marks

Calculation of H^+ in buffer

$[H^+]_{buffer} = 10^{-4.00}$ **OR** 1×10^{-4} (mol dm^{-3}) ✓

Calculation of CH_3COOH in buffer

$n(CH_3COOH)$ **OR** $[CH_3COOH]_{buffer}$

$= \frac{0.204}{1000} \times 400$ **OR** 8.16×10^{-2} ✓

Calculation of $[CH_3COO^-]$ in buffer (in 1 dm^3)

$[CH_3COO^-]_{buffer} = \frac{1.78 \times 10^{-5} \times (8.16 \times 10^{-2})}{(1 \times 10^{-4})}$

OR 1.5×10^{-2} (mol dm^{-3}) ✓

ALLOW ECF

ALLOW *[HA] and $[A^-]$ in working*

ALLOW *1.5×10^{-2} up to calculator value 1.45248×10^{-2} (mol dm^{-3})*

ALLOW *2.4×10^{-2} up to calculator value 2.4208×10^{-2} (mol dm^{-3})*

COMMON ERRORS BUT CHECK WORKING

Calculation of original $[CH_3COO^-]$ (in 600 cm^3)

$[CH_3COO^-]_{initial} = (\frac{1.45248 \times 10^{-2} \times 1000}{600})$

$= 2.4 \times 10^{-2}$ (mol dm^{-3}) ✓

ALLOW *alternative approach based on Henderson–Hasselbalch equation (**ALLOW** –logK_a for pK_a) e.g.*

$pH = pK_a + \log \frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $pK_a - \log \frac{[CH_3COO^-]}{[CH_3COOH]}$ **OR**

$4 = 4.75 + \log \frac{8.16 \times 10^{-2}}{[CH_3COO^-]}$ **OR** $4.75 - \log \frac{[CH_3COO^-]}{8.16 \times 10^{-2}}$ ✓

$\log[CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84$ ✓

$[CH_3COO^-]_{buffer} = 1.5 \times 10^{-2}$ ✓

$[CH_3COO^-]_{initial} = 2.4 \times 10^{-2}$ ✓

[4 marks]

$[CH_3COO^-]_{initial} = 8.7 \times 10^{-3}$	600 and 1000 inverted	3 marks
$[CH_3COO^-]_{initial} = 3.6 \times 10^{-6}$	$[CH_3COOH]$: $[H^+]$ inverted	3 marks
$[CH_3COO^-]_{initial} = 1.3 \times 10^{-6}$	$[CH_3COOH]$: $[H^+]$ inverted AND 600 and 1000 inverted	2 marks
No volumes used = 3.6×10^{-2}		2 marks

ALLOW *–logK_a for pK_a*

Q18 · Acids, bases and buffers · [10 marks]

OCR MARK SCHEME

6(a)

Bond angle	Name of shape
120(°)	Trigonal planar
104–105(°)	Non-linear

Mark by row **OR** by column to give higher mark

i.e. 2 bond angles correct ✓

2 shapes correct ✓

OR

i.e. bond angle **AND** shape correct in 1st row ✓

bond angle **AND** shape correct in 2nd row ✓

[2 marks]

EXAMINER GUIDANCE

For non-linear,

ALLOW *bent, v-shaped, angular*

IGNORE *planar, 'not straight'*

6(b)

CH_3SO_2OH	+	H_2O	⇌	$CH_3SO_2O^-$	+	H_3O^+ ✓
A1		**B2**		**B1**		**A2** ✓

For an equilibrium shown using CH_3COOH instead of H_2O, mark acid–base pairs by **ECF**, i.e.

CH_3SO_2OH	+	CH_3COOH	⇌	$CH_3SO_2O^-$	+	$CH_3COOH_2^+$ ✗
A1		**B2**		**B1**		**A2** **ECF** ✓

CH_3SO_2OH dissociates more (than CH_3COOH)

OR CH_3SO_2OH is a stronger acid ✓

ORA *in terms of CH_3COOH being a weaker acid*

ALLOW → *for* ⇌

ALLOW *acid–base pairs labelled other way round.*

i.e.

CH_3SO_2OH	+	H_2O	⇌	$CH_3SO_2O^-$	+
A2		**B1**		**B2**	

ALLOW *small slip*

If ONE charge is missing from equilibrium.

ALLOW ECF *for acid–base pairs mark*

IGNORE *'more acidic'*

Response needs strength/dissociation

ALLOW *maths explanation for final 2 marks, e.g.*

$K_a(CH_3COOH) = 10^{-(4.76)} = 1.74 \times 10^{-5}$

$[H^+] = \sqrt{(1.74 \times 10^{-5}) \times 1)} = 4.17 \times 10^{-3}$

$pH = -\log 4.17 \times 10^{-3} = 2.38$ ✓

Student is correct

AND

(sulfonic acid has) lower pK_a/higher K_a **OR** greater $[H^+]$

ORA ✓

[4 marks]

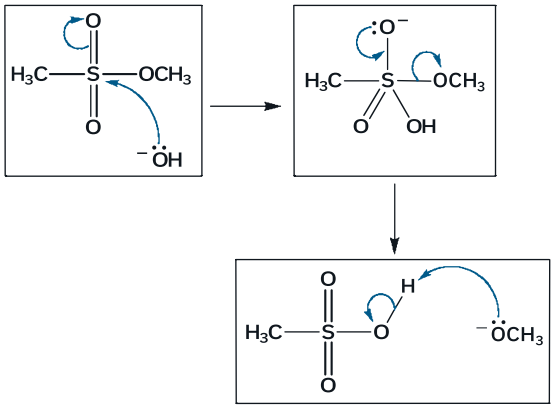
$K_a(CH_3SO_2OH) = 10^{-(-1.90)} = 79.4$

$[H^+] = \sqrt{(79.4) \times 1} = 8.91$

pH = –log 8.91 = –0.95 ✓

BOTH pH calcs subsumes 'Student is correct'

6(c)



6 curly arrows correct ✓✓✓✓

5 curly arrows correct ✓✓✓

4 curly arrows correct ✓✓

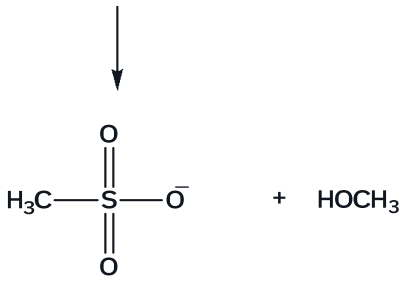
3 curly arrows correct ✓

[4 marks]

IGNORE *any added charges* ***OR*** *dipoles.*

Marks solely for curly arrows

IGNORE *any curly arrows on bottom structures (not in boxes):*



Q19 · Acids, bases and buffers · [16 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

22(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 13.15 award 2 marks

$[H^+] = \dfrac{1.00 \times 10^{-14}}{0.140} = 7.14..... \times 10^{-14}$ (mol) ✓

pH = –log $(7.14..... \times 10^{-14})$ = 13.15 ✓

2 DP required

[2 marks]

ALLOW ECF *providing pH>7*

Calculator: $7.142857143 \times 10^{-14}$

ALLOW *pOH method*

pOH = –log(0.14) = 0.85..... ✓

pH = 14.00 – (0.85.....) = 13.15 ✓

22(b)(i)

$n(H_2SO_4) = \dfrac{1.60 \times 25.0}{1000} = 0.04(00)$ (mol)

AND

$n(NaOH) = \dfrac{1.50 \times 55.0}{1000} = 0.0825$ (mol) ✓

0.04(00) mol H_2SO_4 reacts with 0.08(00) mol NaOH

OR

1 mol H_2SO_4 reacts with 2 mol NaOH ✓

[2 marks]

ALLOW *0.0825>0.08*

22(b)(ii)

$q = mc\Delta T = 80.0 \times 4.18 \times 13.0$

= 4347.2 (J) **OR** 4.3472 (kJ) ✓

$\Delta H_1 = \dfrac{(-)\ 4.3472}{0.0400} = (-)108.68$ kJ mol^{-1} ✓

ALLOW *3 SF up to calculated answer throughout*

ALLOW ECF *from q*

DO NOT ALLOW *division by n(NaOH)*

ALLOW $\Delta_{neut}H$ *from* $\Delta H_1/2$

ALLOW *alternative methods*

$\Delta_{neut}H = \frac{(-)\ 108.68}{2} = (-)54.34$ kJ mol^{-1} ✓

– sign for ΔH value(s) ✓

[4 marks]

22(b)(iii)

The same **OR** 13°C ✓

(Double the moles so) double the energy is spread over double the volume

ALLOW *explanation that uses a calculation based on moles, volumes*

ALLOW *mass for volume*

[2 marks]

22(c)

Level 3 (5–6 marks)

Reaches a comprehensive conclusion with most detail and few errors for the formation of the buffer

AND Calculation of the correct buffer pH

AND Correct mass of N_2O_3.

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)

Reaches a sound conclusion with some detail and some errors for

Formation of buffer **AND** Calculation of the buffer pH

OR

Formation of buffer **AND** Mass of N_2O_3.

OR

Calculation of the buffer pH **AND** Mass of N_2O_3.

OR

Partial explanations of formation of the buffer

AND buffer pH **AND** Mass of N_2O_3.

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)

Attempts, with some success, to:

Describe formation of buffer **OR** Calculate buffer pH

OR Obtain mass of N_2O_3.

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]

Indicative scientific points may include:

1. Formation of buffer

- Acid / HNO_2 is in excess
- $HNO_2 + NaOH \rightarrow NaNO_2 + H_2O$
- Partial neutralisation of $HNO_2 \rightarrow$ formation of NO_2^-/ $NaNO_2$
- Buffer contains HNO_2 **AND** NO_2^-/$NaNO_2$

2. Calculation of buffer pH

- $n(HNO_2)$ added = 0.0500 (mol)
- n(NaOH) added = 0.0150 (mol)
- $n(NO_2^-)$ formed = 0.0150 (mol)
- $n(HNO_2)$ remaining = 0.0500 – 0.0150 = 0.0350 (mol)
- $K_a = 10^{-3.34} = 4.57... \times 10^{-4}$ (mol dm^{-3})
- Concentrations = mol (volume 1 dm^3)
- $[H^+] = \frac{4.57... \times 10^{-4} \times 0.0350}{0.0150} = 1.0665.... \times 10^{-3}$ (mol dm^{-3})
- pH = 2.97
- pH to 2 dec places

3. Calculation of mass of N_2O_3

- 1 mol $N_2O_3 \rightarrow$ 2 mol HNO_2 **OR** $N_2O_3 + H_2O \rightarrow 2HNO_2$
- $n(HNO_2)$ = 0.0500 (mol)
- $n(N_2O_3) = \frac{0.0500}{2} = 0.0250$ (mol)
- $m(N_2O_3) = 0.0250 \times 76 = 1.9(0)$ g

Q20 · Equilibrium constants Kc and Kp · [1 mark]

Answer: **B**

OCR MARK SCHEME

0.426

EXAMINER GUIDANCE

ALLOW *0.426 in the box*

Q21 · Equilibrium constants Kc and Kp · [10 marks]

OCR MARK SCHEME

20(a)

Conditions

Low/decreased pressure

EXAMINER GUIDANCE

DO NOT ALLOW *more atoms on right-hand side* ***OR*** *fewer atoms on left-hand side.*

DO NOT ALLOW *incorrect shift direction*

AND high/increased temperature ✓

Pressure:

Right-hand/product side has more (gaseous) moles/molecules

OR left-hand side/reactant side has fewer (gaseous) moles/molecules ✓

Temperature:

(Forward) reaction is endothermic / takes in heat

OR reverse reaction is exothermic / gives out heat ✓

Low pressure gives a slow rate

OR

High temperature uses a large amount of energy/fuel ✓

[4 marks]

ORA

IGNORE *'expensive'*

IGNORE *use of catalyst*

20(b)(i)

$(K_c =)\ \dfrac{[SO_3]^2}{[SO_2]^2\,[O_2]}$ ✓

Units: $dm^3\ mol^{-1}$ ✓

[2 marks]

IGNORE *state symbols in K_c expression, even if wrong.*

For units, **ALLOW** $mol^{-1}\ dm^3$

DO NOT ALLOW *dm^3/mol*

NOTE*: If K_c upside down, units become mol dm^{-3} by* ***ECF***

No other **ECF** allowed for units.

20(b)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *answer = 2.45, Award 4 marks.*

Equilibrium concentrations (moles × 2.5) 1 MARK

$SO_2 = 0.135$ (mol dm^{-3})

AND $O_2 = 0.0675$ (mol dm^{-3}) ✓

Calculation of $[SO_3(g)]$ 2 MARKS

$[SO_3] = \sqrt{(K_c \times [SO_2]^2 \times O_2)}$

OR $\sqrt{(\ (3.045 \times 10^4) \times 0.135^2 \times 0.0675)}$ ✓

$= 6.12039291$ (mol dm^{-3}) ✓

Answer scores both $[SO_3]$ marks automatically

Calculation of $n(SO_3)$ in 400 cm^3 1 MARK

$n(SO_3) = \dfrac{6.12039291}{2.5} = 2.45$ (mol) ✓

3SF required (Appropriate number)

[4 marks]

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

ALLOW ECF *from incorrect concentrations of SO_2 and/or O_2*

ALLOW ECF *from incorrect $[SO_3]$*

ALLOW 3 SF*, 6.12, up to calculator value of 6.12039291 correctly rounded.*

Common errors		
37.5	**1 mark**	No √ for $[SO_3]^2$ and no scaling by 1/2.5
15.0	**2 marks**	No √ for $[SO_3]^2$
0.619	**3 marks**	Use of mol of SO_2 and O_2
1.55	**2 marks**	No conc used and Use of mol of SO_2 and O_2

Q22 · Equilibrium constants Kc and Kp · [10 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

18(a)

$K_c = \dfrac{[NO_2]^2}{[NO]^2\,[O_2]}$ ✓

Units = $dm^3\ mol^{-1}$ ✓

[2 marks]

Must be square brackets

IGNORE *state symbols*

ALLOW *$mol^{-1}\ dm^3$*

ALLOW *$mol\ dm^{-3}$ as ECF from inverted K_c expression*

18(b)

FIRST CHECK THE ANSWER ON THE ANSWER LINE **IF answer = 1.2 (mol) award 4 marks**

Unless otherwise stated, marks are for correctly calculated values. Working shows how values have been derived.

$[NO] = \dfrac{0.40}{4.0} = 0.1(0)\ (mol\ dm^{-3})$

AND

$[O_2] = \dfrac{0.80}{4.0} = 0.2(0)\ (mol\ dm^{-3})$ ✓

$[NO_2]^2 = 45 \times 0.10^2 \times 0.20$ **OR** = 0.09(0) ✓

$[NO_2] = \sqrt{(45 \times 0.10^2 \times 0.20)}$ **OR** = 0.3(0) $(mol\ dm^{-3})$ ✓

amount $NO_2 = 0.30 \times 4 = 1.2$ (mol) ✓

[4 marks]

For all parts, **ALLOW** numerical answers from 2 significant figures up to the calculator value

Ignore rounding errors after second significant figure

1st mark is for realising that concentrations need to be calculated.

ALLOW ECF

Correct numerical answer with no working would score all previous calculation marks

Making point 2 subsumes point 1

Making point 3 subsumes points 2 and 1

Common errors

9.6 = 3 marks mol of NO and O_2 used

0.36 = 3 marks mol of NO_2 calculated from $[NO_2]^2$

2.4 = 2 marks mol of NO and O_2 used and no mol of NO_2 calculated

18(c)(i)

Exothermic

AND

K_p decreases as temperature increases ✓

[1 mark]

ALLOW *K_c for K_p*

ALLOW *Equilibrium shifts to left hand side as temperature increases*

18(c)(ii)

Equilibrium shift

(Equilibrium position) shifts to right / forward / towards products ✓

Effect of increased pressure on K_p expression

Ratio (in K_p expression) decreases

OR

Denominator/bottom of K_p expression increases more (than numerator/top) ✓

Equilibrium shift (K_p expression)

Ratio (in K_p expression) increases to restore K_p

OR

Numerator/top of K_p expression increases to restore K_p ✓

[3 marks]

ALLOW *K_c for K_p throughout the response.*

ALLOW *K_p (initially) decreases for second marking point **IF** K_p is seen to be restored later in the process.*

ALLOW *more NO_2 / product formed to restore K_p*

ALLOW *ratio adjusts to restore K_p*

Q23 · Equilibrium constants Kc and Kp · [1 mark]

Answer: **B**

25 atm

Q24 · Equilibrium constants Kc and Kp · [11 marks]

OCR MARK SCHEME

5(a)

TAKE CARE: Correct final answer of –52.3 OR –52.25 can be obtained from two cancelling errors:

- Use of 50 for energy released (no ×2 of 50 for two solutions mixed)

EXAMINER GUIDANCE

ALLOW ECF throughout

DO NOT ALLOW *less than 3 SF*

IGNORE *units*

- No ÷ 2 in final step

–52.3 OR –52.25 would then be awarded 2 marks out of 4

Correctly calculates *n*(succinic acid)

$= \frac{0.400 \times 50.0}{1000} = 0.02(00)$ (mol) ✓

Energy released in J OR kJ

$= 100.00 \times 4.18 \times 5.0 = 2090$ (J) **OR** 2.090 (kJ) ✓

Energy released, in kJ or J, for formation of 2 mol H_2O

$\pm \frac{2090}{0.0200} = \pm 104500$ (J)

OR

$\pm \frac{2.090}{0.0200} = \pm 104.5$ **OR** ± 105 (kJ) ✓

$\Delta_{neut}H$ to 3 or more SF AND correct – sign

$= -\frac{104.5}{2} = -52.3$ **OR** – 52.25 kJ mol^{-1} ✓

[4 marks]

ALTERNATIVE METHOD

***n*(succinic acid)** = 0.02(00) (mol) ✓

Energy released = 2090 (J) **OR** 2.090 (kJ) ✓

***n*(H_2O) formed** = 2 × 0.02(00) = 0.04(00) (mol) ✓

$\Delta_{neut}H = -\frac{2.090}{0.0400} = -52.3$ **OR** – 52.25 kJ mol^{-1} ✓

5(b)(i)

Titration ✓

[1 mark]

IGNORE *type of titration*

5(b)(ii)

$(CH_2COOH)_2 + 2C_2H_5OH \rightleftharpoons (CH_2COOC_2H_5)_2 + 2H_2O$ ✓

[1 mark]

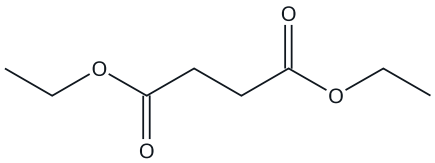
ALLOW → *instead of* ⇌ *sign*

ALLOW *molecular formulae or hybrid formulae*

Structures provided on QP

e.g. $C_4H_6O_4 + 2C_2H_6O \rightleftharpoons C_8H_{14}O_4 + 2H_2O$

5(b)(iii)



✓

[1 mark]

IGNORE *displayed formulae*

5(b)(iv)

Volume cancels

OR

Same number of moles on each side of equation ✓

[1 mark]

ALLOW *units cancel*

ALLOW *(sum of) balancing numbers/coefficients on each side of equation are the same*

OR same number of (moles of) reactants and products

IGNORE *volume is the same; K_c has no units*

5(b)(v)

Moles of equilibrium products 1 mark

$n((CH_2COOC_2H_5)_2) = 0.0300$ (mol)

AND

$n(H_2O) = 0.0600$ (mol) ✓

Moles of C_2H_5OH 1 mark

$n(\mathbf{C_2H_5OH}) = 0.150 - 0.060 = 0.0900$ (mol) ✓

K_c calculated 1 mark

ALLOW ECF

ALLOW *0.66, 0.666, etc. (**2 SF** and more)*

Treated as meaning 0.6 recurring

ALLOW *2/3*

IGNORE *any units*

$= \frac{0.03 \times 0.06^2}{0.02 \times 0.09^2} = 0.667$ **OR** 0.67 ✓

NOTE: *0.02 must be used for n(succinic acid)*

[3 marks]

Q25 · Equilibrium constants Kc and Kp · [23 marks]

OCR MARK SCHEME

19(a)(i)

More energy is released by forming bonds than energy required when breaking bonds

OR

bond enthalpy of bonds being made is higher than bond enthalpy of bonds being broken ✓

[1 mark]

EXAMINER GUIDANCE

Response needs link between energy, breaking and making bonds

Eg 'bond breaking is endothermic' **AND** 'bond making is exothermic' **AND** 'exothermic change outweighs endothermic change'

IGNORE *more bonds made than broken*

19(a)(ii)

FIRST CHECK ΔG

If $\Delta G = -1010$ (kJ mol^{-1}) award first 3 marks

$\Delta S = (2 \times 248 + 2 \times 70) - (2 \times 206 + 3 \times 205)$

$= -391$ (J K^{-1} mol^{-1}) **OR** -0.391 (kJ K^{-1} mol^{-1}) ✓

$\Delta G = \Delta H - T\Delta S = -1125 - (293 \times -0.391)$ ✓

$= -1010$ (kJ mol^{-1}) ✓

Feasible **AND** $\Delta G < 0$ **OR** ΔG is negative ✓

[4 marks]

ALLOW *ecf*

ALLOW *–1010000 (J mol^{-1})*

ALLOW *3 SF up to calculator value –1010.437*

Common errors

ALLOW:

Two calculation marks for:

–1117 to 3 SF up to calculator value of –1117.179865

(use of 20 instead of 293)

(+)113438 (kJ mol^{-1}) or 113000, 113400, 113440

(mix of J and kJ)

–1008 up to calculator value of –1008.482

(use of T = 298)

–1018 up to calculator value of –1018.257

(use of T = 273)

ALLOW ECF *for from incorrect ΔG,*

eg Non feasible **AND** $\Delta G > 0$ **OR** ΔG is +ve

19(a)(iii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –20 (kJ mol^{-1}) award 3 marks

Using Both $\Delta_c H^{\ominus}$ values multiplied by 2

$2 \times (-296.8)$ or -593.6

AND

$2 \times (-285.8)$ or -571.6 $(= -1165.2)$ ✓

Use of –1125 and correctly processed:

$2\Delta_f H(H_2S) = [2 \times (-296.8) + 2 \times (-285.8)] - (-1125)$

$= -40.2$ (kJ mol^{-1}) ✓

Division by 2

$\Delta_f H(H_2S) = -20$ (kJ mol^{-1}) ✓

[3 marks]

First mark may be awarded from data on a cycle

ALLOW *– 20.1(0)*

ALLOW ECF: *third mark is for dividing by 2 and use of all three values*

Common errors

Two marks for (+)20(.1)

ALLOW *ecf if no multiplication by two occurred*

[(–296.8)+(–285.8)]–(–)1125 = (+)542.4 for 2nd mark

Leading to $\Delta_f H(H_2S)$ = (+) 271(.2) for 3rd mark

ALLOW *–296.8 –285.8 = –582.6 for 1st mark if* $-\frac{1125}{2}$ ***OR*** *– 562.5 is seen in 2nd mark*

19(b)(i)

$(K_p) = \frac{p(SO_3)^2(g)}{p(SO_2(g))^2 \times p(O_2(g))}$ ✓

atm^{-1} ✓

ALLOW *species without state symbols and without brackets.*

e.g., pSO_3^2, $ppSO_3^2$, PSO_3^2, $p(SO_3)^2$ $(pSO_3)^2$etc.

DO NOT ALLOW *square brackets*

ALLOW *atm as* ***ECF*** *if K_p is upside down*

[2 marks]

ALLOW *use of any pressure unit*

eg Pa^{-1} or kPa^{-1}

19(b)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

if answer = 27.2 award 5 marks

Initial amounts

$n(SO_2) = (\frac{10.2}{24.0} =) 0.425$ (mol) **AND**

$n(O_2) = (\frac{12}{32.0} =) 0.375$ (mol) ✓

Equilibrium amounts in moles

$n(SO_2) = (0.425 - 0.350 =) 0.075$ (mol) **AND**

$n(O_2) = (0.375 - \frac{0.350}{2} =) 0.200$ (mol) ✓

Total moles

$n_{tot} = 0.625$ (mol) ✓

Partial pressures

$pSO_2 = (\frac{0.075}{0.625} \times 2.50 =) 0.3$ (atm) **AND**

$pO_2 = (\frac{0.2}{0.625} \times 2.50 =) 0.8$ (atm) **AND**

$pSO_3 = (\frac{0.350}{0.625} \times 2.50 =) 1.4$ (atm) ✓

K_p to 3 SF

$(K_p = \frac{1.4^2}{(0.3^2 \times 0.8)} =) 27.2$ (atm^{-1}) ✓

[5 marks]

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

Common errors

Allow 4 marks for 1.45/1.46 (depending upon rounding)

Initial amounts

$n(SO_2) = 2 \times n(O_2)$

$n(O_2) = 0.375$ and $n(SO_2) = 0.75(0)$

Equilibrium moles

$n(SO_2)$ $0.75 - 0.350 = 0.4(0)$

$n(O_2) = 0.2(0)$

total moles

$n_{tot} = 0.95$

partial pressures

$pSO_2 = 1.05$

$pO_2 = 0.526$

pSO3 = 0.921

Allow 4 marks for 15.1/15.0

Initial amounts

$n(O_2) = \frac{12}{16} = 0.75$

Equilibrium moles

$n(O_2) = 0.575$

total moles

$n_{tot} = 1.00$

partial pressures

$pSO_2 = 0.188$

$pO_2 = 1.438$

pSO3 = 0.88

IGNORE *units*

19(b)(iii)

(greater K_p value means) equilibrium position shifted to right/RHS ✓

Lower temperature because (forward) reaction is exothermic ✓

[2 marks]

ALLOW *greater/higher amount of SO_3/product*

ALLOW *greater K_p means larger numerator*

19(b)(iv)

equilibrium position (far) to the right ✓

[1 mark]

ALLOW *(very) high yield of products or of SO_3*

ALLOW *reaction is nearly complete / irreversible*

ALLOW *Forward reaction is (greatly) favored*

ALLOW *(far) more product(s) than reactant(s) or*

ALLOW *equilibrium (greatly) favours product*

19(c)(i)

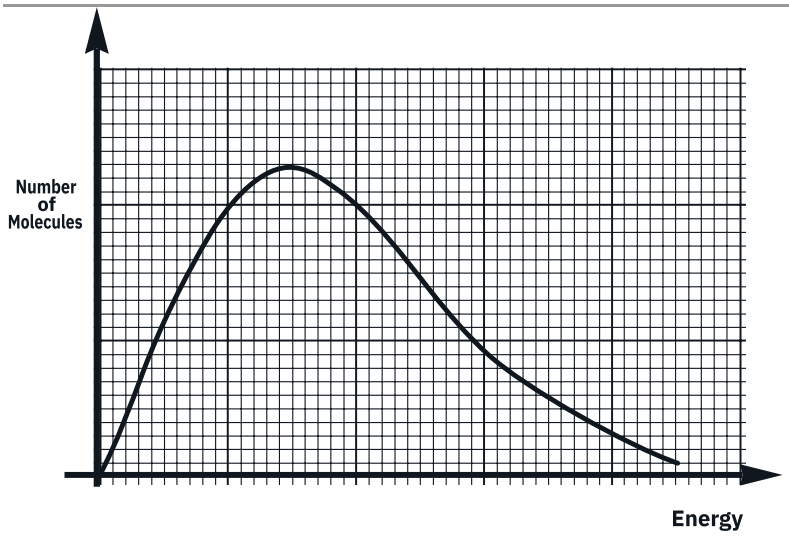
DO NOT ALLOW *two curves*

Confusion with effect of temperature

DO NOT ALLOW *'enthalpy' for x-axis label*

DO NOT ALLOW *'atoms' as y-axis label*

ALLOW ECF *for atoms (instead of molecules/particles) if y axis labelled as 'atoms'*



IGNORE *(more) successful collisions*

IGNORE *response implying 'more collisions'*

(confusion with effect of greater temperature)

Correct drawing of Boltzmann distribution

Curve starts within one small square of origin

AND not touching the x axis at high energy ✓

Axes labels:

y: (number of) molecules/particles

AND x: (kinetic) energy ✓

Catalyst and activation energy

Catalyst provides a lower activation energy **OR** E_c shown to the left of E_a on Boltzmann distribution ✓

Particles with $E > E_a$

more or a greater proportion of molecules / particles / collisions have (energy above) activation energy (with catalyst) **OR** more molecules have enough energy to react **OR** greater area under curve above activation energy ✓

[4 marks]

19(c)(ii)

heterogeneous (catalyst) **AND**

catalyst in a different phase/state (from other substances) ✓

ALLOW *catalyst is a solid* ***AND*** *not a gas / everything else is a gas*

[1 mark]

Q26 · Equilibrium constants Kc and Kp · [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.

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

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

Level 1 (1–2 marks)

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*

Q27 · Equilibrium constants Kc and Kp · [11 marks]

OCR MARK SCHEME

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 ✓

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

EXAMINER GUIDANCE

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*

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. $[H_2] = \sqrt{(\frac{0.11 \times 1.8}{0.27})}$ **OR** 0.856..... ✓

= 0.86 to 2 SF ✓

IF *no square root,*

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

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

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

Calculation of $[H_2]$

$[H_2] = \sqrt{\left(\frac{0.11}{0.27 \times 1.8}\right)}$ **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

= 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*

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]

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

- 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* $[Br_2]^0\,[CH_3COCH_3]^1[H^+]^1$

- $k = \frac{\text{rate}}{[CH_3COCH_3][H^+]}$ **OR** $\frac{1.70 \times 10^{-7}}{1.50 \times 10^{-3} \times 2.50 \times 10^{-1}}$
- $k = 4.53 \times 10^{-4}$
- **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*

Q28 · Equilibrium constants Kc and Kp · [1 mark]

Answer: **B**

0.048

Q29 · Equilibrium constants Kc and Kp · [9 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

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

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 ✓

ALLOW *'favours reverse reaction'*

Implies shift to left

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

[1 mark]

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)

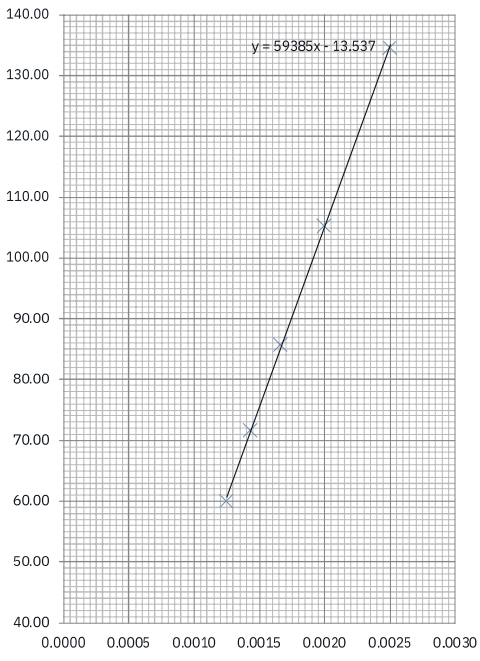
ΔH in kJ mol^{-1}

ΔH correct in kJ mol^{-1}

AND 3SF

AND – sign ✓

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



ALLOW *4 points on graph*

Tolerance 1 small square

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

This mark subsumes gradient mark

[4 marks]

5(d)

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

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

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

From provided values and gradient = 60000:

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]

$\frac{\Delta S}{R} = \ln K_p$ – gradient × $\frac{1}{T}$

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

Q30 · Equilibrium constants Kc and Kp · [11 marks]

OCR MARK SCHEME

20(a)

rate of forwards reaction = rate of backwards reaction

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

[1 mark]

EXAMINER GUIDANCE

***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)

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]

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)*

20(c)(ii)

Mark by **COLUMN**

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
	✓	✓	✓

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

[3 marks]

Q31 · Equilibrium constants Kc and Kp · [18 marks]

OCR MARK SCHEME

1(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 20 award 2 marks

$n(CO_2) = \frac{110}{44}$ **OR** 2.5 (mol)

AND

$n(O_2) = \frac{120}{32}$ **OR** 3.75 (mol) ✓

$p(CO_2) = \frac{2.5}{6.25} \times 50.0$ **OR** $0.4 \times 50.0 = 20(.0)$ (atm) ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW ECF

from incorrect Σ ($n(CO_2) + n(O_2)$) ONLY

1(b)

FIRST CHECK THE ANSWER ON ANSWER LINES

If $[PCl_3] = [Cl_2] = 0.02(00)$ award 2 marks

$K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}$ **OR** with number(s), e.g. $K_c = \frac{[PCl_3]\,[Cl_2]}{0.05(00)}$ ✓

$[PCl_3] = [Cl_2] = \sqrt{(K_c \times [PCl_5])}$

$= \sqrt{(8.00 \times 10^{-3} \times 0.0500)}$

$= \sqrt{(4.00 \times 10^{-4})}$

$= 2.00 \times 10^{-2}$ (mol dm^{-3}) ✓

[2 marks]

Square brackets required

Common errors

2.00×10^{-4}	from $K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}$	1 mark
÷2 instead of √		
2.5	from $K_c = \frac{[PCl_5]}{[PCl_3]\,[Cl_2]}$	1 mark
Inverse K_c expression		

1(c)

Electronegativity and boiling point

Boiling point/Energy increases with increased electronegativity (difference) ✓

Type of intermolecular force

HF **AND** NH_3 have hydrogen bonding

AND

CH_4 has London forces/induced (dipole–)dipole interactions ✓

Comparison between strength of intermolecular forces

HF has stronger hydrogen bonding than NH_3

OR hydrogen bonding is stronger than London forces ✓

ALLOW ORA *throughout*

ORA

IGNORE *permanent dipole interactions*

IGNORE *IDID*

IGNORE *HF and NH_3 are polar/CH_4 is non-polar*

IGNORE *strength of ionic and covalent bonds*

[3 marks]

1(d)

A: Ca_3N_2 (formula required) ✓

B: NH_3 **OR** ammonia ✓

C: $Ca(OH)_2$ **OR** calcium hydroxide ✓

Equation:

$Ca_3N_2 + 6H_2O \rightarrow 2NH_3 + 3Ca(OH)_2$ ✓

[4 marks]

IGNORE *working*

If B and C labels are the wrong way round ***OR*** *missing, award 1/2 for B and C labels,*

i.e. for B $Ca(OH)_2$ C NH_3 1/2 marks

ALLOW CaO_2H_2

ALLOW *multiples for equation*

IF C *= CaO,* ***ALLOW ECF*** *for:*

$Ca_3N_2 + 3H_2O \rightarrow 2NH_3 + 3CaO$

1(e)

$2CH_3CH(OH)COOH + Na_2CO_3 \rightarrow 2CH_3CH(OH)COONa + CO_2 + H_2O$

CO_2 and H_2O **OR** $CH_3CH(OH)COONa$ as product(s) ✓

Balanced equation correct ✓

$3CH_3CH(OH)COOH + Al \rightarrow (CH_3CH(OH)COO)_3Al + 1½\ H_2$

H_2 **OR** $(CH_3CH(OH)COO)_3Al$ as product ✓

Balanced equation correct ✓

[4 marks]

ALLOW *multiples*

IGNORE *state symbols*

ALLOW *ions shown separately*

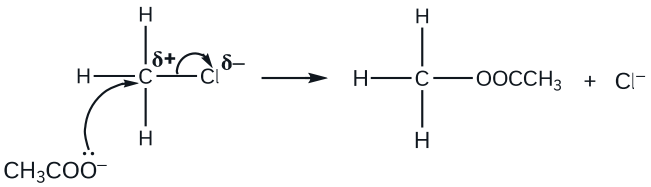
For CO_2 AND H_2O, **ALLOW** H_2CO_3

ALLOW *....COONa$^+$ (i.e. one of charges missing)*

ALLOW *....COO)$_3$Al^{3+} (i.e. one of charges missing)*

1(f)

Mechanism:



NOTE*: Can be any C–X bond, e.g. C–Cl, C–Br, C–I but must be consistent.*

Curly arrow on C–X

Dipole shown on C–X bond of CH_3X, $C^{\delta+}$ and $X^{\delta-}$

AND

curly arrow from C–X bond to X atom ✓

Curly arrow from CH_3COO^-

Curly arrow from CH_3COO^- to C atom of C–X bond ✓

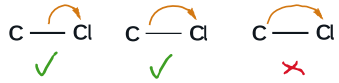
Products

Correct organic product **AND** X^- ✓

[3 marks]

NOTE*: Curly arrows can be straight, snake-like, etc. but* ***NOT*** *double headed or half headed arrows*

1st curly arrow must start from, **OR** be traced back to, any part of C–Cl bond and go to Cl

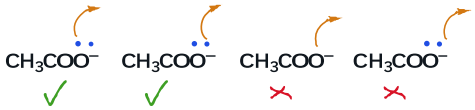


2nd curly arrow must

- go to the C of C–Cl

AND

- start from, **OR** be traced back to any point across width of lone pair on O of CH_3COO^-



- **OR** start from '–' on O of CH_3COO^- ion



(Lone pair **NOT** needed if curly arrow from O^-)

If CH_3COOH used instead of CH_3COO^-,

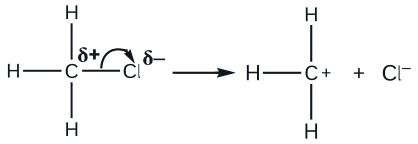
ALLOW *X^-* ***OR*** *HX as 2nd product*

ALLOW *S_N1 mechanism*

First mark

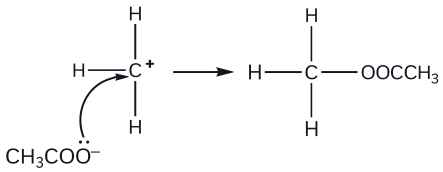
Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$,

AND curly arrow from C–Cl bond to Cl atom ✓



Second mark

Correct carbocation **AND** curly arrow from CH_3COO^- to carbocation



Curly arrow must be from lone pair on O of CH_3COO^-

OR from minus on O of CH_3COO^- ion (no need to show lone pair if curly came from – charge) ✓

Third mark

Correct organic product **AND** Cl^- ✓

Q32 · Lattice enthalpy, entropy and free energy · [12 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

18(a)

$\Delta G = \Delta H - T\Delta S$

linked to $y = mx + c$ (somewhere) ✓

gradient = $-\Delta S$ ✓

P: ΔH / enthalpy change ✓

Q: (temperature) for reaction to be feasible/unfeasible

OR

(temperature) at which feasibility changes ✓

[4 marks]

Could be:

$\Delta G = -\Delta S\, T + \Delta H$

– sign required

ALLOW ΔS = –gradient

***ALLOW** 'point of feasibility'*

For Feasibility:

***ALLOW** can take place/happen **OR** is spontaneous*

***IGNORE** 'minimum/maximum temperature'*

18(b)(i)

(Species have) different states/phases ✓

[1 mark]

18(b)(ii)

(K_p =) $p(CO(g))^4$ ✓

[1 mark]

Allow species without state symbols and without brackets, e.g. $p_{CO}{}^4$, $ppCO^4$, PCO^4, $p(CO^4)$ etc.

***DO NOT ALLOW** square brackets*

18(b)(iii)

ΔG at 25 C

$\Delta G = \Delta H - T\Delta S = 676.4 - (298 \times 0.7031)$

= (+) 467 (kJ mol^{-1}) **OR** (+) 466876 (J mol^{-1}) ✓

Non-feasibility statement

Non-feasible when $\Delta G > 0$

OR $\Delta G > 0$ **OR** $\Delta H > T\Delta S$ ✓

Minimum temperature

$$\text{minimum temperature} = \frac{\Delta H}{\Delta S} = \frac{676.4}{0.7031}$$

= 962(.0) K ✓

[3 marks]

***IGNORE** units*

***ALLOW** (+) 467 up to calculator value of 466.8762 correctly rounded*

ECF for any positive value determined in M1

***ALLOW** 962 up to calculator value of 962.0253165 correctly rounded*

18(b)(iv)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF answer = –110.5, Award 3 marks.

Correct expression

$-13.5 = (4 \times -393.5) - (-1118.5 + 4 \times \Delta_f H(CO))$ ✓

Correct subtraction using ΔH and $\Delta_f H(Fe_3O_4)$

$4 \times \Delta_f H(CO) = (4 \times -393.5) - (-1118.5) + 13.5$

= –442(.0) (kJ mol^{-1}) ✓

Calculation of $\Delta_f H$(CO) formation

$$\Delta_f H(CO) = \frac{-442}{4} = -110.5 \text{ (kJ mol}^{-1}\text{)}$$ ✓

[3 marks]

For answer,

ALLOW –111 (kJ mol^{-1})

***NOTE**: IF any values are omitted, DO **NOT** AWARD any marks. e.g. –393.5 OR –13.5 may be missing*

Common errors

(+)110.5	wrong/omitted sign	**2 marks**
(+)184.625 / 184.63 / 184.6 / 185	No $4CO_2$	**2 marks**
(+)738.5 / 739	No $4CO_2$ and no CO/4	**1 mark**
–117.25 / –117.3 / –117	Wrong cycle	**2 marks**
–469	Wrong cycle, no CO/4	**1 mark**
(+)177.875 / 177.88 / 177.9 / 178	Wrong cycle, no $4CO_2$	**1 mark**
–360.5	Used 118.5	**2 marks**

Any other number: CHECK for **ECF** from 1st marking point for expressions using ALL values with ONE error only e.g. one transcription error:, e.g.395.3 for 393.5

Q33 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **A**

–219.1

Q34 · Lattice enthalpy, entropy and free energy · [15 marks]

OCR MARK SCHEME

16(a)(i)

(enthalpy change when)

1 mole of gaseous ions react

OR 1 mole of hydrated/aqueous ions are formed ✓

gaseous ions dissolve in water

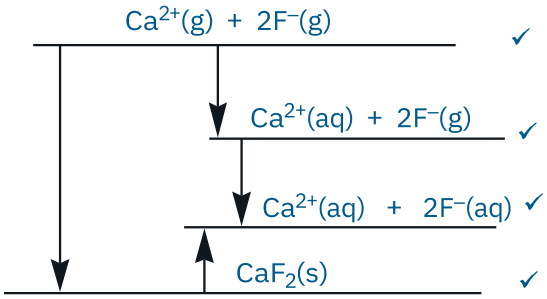
OR gaseous ions form aqueous/hydrated ions ✓

[2 marks]

EXAMINER GUIDANCE

IGNORE *'energy released'* ***OR*** *'energy required'*

16(a)(ii)



[4 marks]

Correct species **AND** state symbols required for each mark. (mark independently)

On 2nd line, **ALLOW** $Ca^{2+}(g) + 2F^{-}(aq)$

(i.e. F^- hydrated before Ca^{2+})

On 3rd line, **ALLOW** $CaF_2(aq)$

DO NOT ALLOW *when first seen but* ***ALLOW ECF*** *for '2' missing and for use of the following ions*

Fl^-

F_2^-

$Ca^{+/3+}$

16(a)(iii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF answer = –504 (kJ mol^{-1}) award 2 marks

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

'–' sign is needed.

IF answer = –1008 (kJ mol^{-1}) award 1 mark

$2 \times \Delta_{hyd}H(F^-)$

$= [-2630 + 13] - (-1609)$

OR $-2617 + 1609$

OR -1008 (kJ mol^{-1}) ✓

$\Delta_{hyd}H(F^-) = \frac{-1008}{2} = -504$ ✓ (kJ mol^{-1})

[2 marks]

COMMON ERRORS for 1 mark:

(+)2694: signs all reversed

–2113: sign wrong for –1609

–2126: sign wrong for 2630

–517: sign wrong for 13

+504: sign wrong

IF ALL 3 relevant values from the information at the start of Q16a(iii) have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF

16(a)(iv)

Correct comparison of Δ_{hyd} linked to sizes

$\Delta_{hyd}H(F^-)$ more negative/exothermic (than $\Delta_{hyd}H(Cl^-)$)

AND

F^- has smaller size (than Cl^-) ✓

Comparison of attraction between ions and water

F^- OR smaller sized ion linked to greater attraction to H_2O ✓

[2 marks]

ORA

IGNORE *'atomic' before radius when comparing size of ions*

IGNORE *charge density*

IGNORE *electronegativity*

IGNORE *nuclear attraction*

DO NOT ALLOW *'forms stronger hydrogen bonds with water'* ***OR*** *'forms stronger van der Waals' forces with water'*

ALLOW *'forms bonds' for attraction'*

DO NOT ALLOW *F^- greater attraction to H_2O if given as larger ion*

Assume 'F' / 'Fluorine' means 'ions' but ***DO NOT ALLOW*** *'F molecules'*

16(b)(i)

Average bond enthalpy

Breaking of one mole of bonds ✓

In gaseous molecules ✓

[2 marks]

IGNORE *energy required* ***OR*** *energy released*

IGNORE *heterolytic / homolytic*

DO NOT ALLOW *bonds formed*

DO NOT ALLOW *ionic bonds*

IGNORE *species for molecules*

16(b)(ii)

FIRST, CHECK ANSWER ON ANSWER LINE

IF answer = (+) 158 award 3 marks

Bond enthalpy of F–F

(ΔH for (O–H) bonds broken =)

1856 **OR** 4×464 (kJ mol^{-1}) ✓

(ΔH for bonds made =) 2770 (kJ mol^{-1})

OR 498 **AND** 2272 (kJ mol^{-1})

OR 498 **AND** 4×568 (kJ mol^{-1}) ✓

(bond enthalpy) F–F = $\frac{2770 - 1856 - 598}{2}$

$= (+)158$ (kJ mol^{-1}) ✓

[3 marks]

IGNORE *sign*

IGNORE *sign*

ALLOW ECF

Common errors

Award 2 marks for;

–158 (Wrong sign)

(±)316 (No ÷ 2)

(+) 622 (use of 2 x 464)

(+) 457 (omitting – 598)

(+) 756 (use of +598)

Award 1 mark for;

(+) 970 (use of 2 x 464 and +598)

Q35 · Lattice enthalpy, entropy and free energy · [15 marks]

OCR MARK SCHEME

16(a)

s-block

AND highest energy or outer electron is in a s orbital or s sub–shell ✓

EXAMINER GUIDANCE

ALLOW *'outer' or 'valence' for 'highest energy'*

IGNORE *electron configurations*

DO NOT ALLOW *s shell / energy level*

[1 mark]

16(b)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 25.982 award 2 marks

$$\frac{78.99 \times 23.985 + 10.00 \times 24.986 + 11.01 \times m}{100} = 24.305 \checkmark$$

Relative isotopic mass = 25.982 (must be 5 SF) ✓

[2 marks]

ALLOW *any correct rearrangement of this sum for first mark*

eg 11.01 x m = 2430.5 – 1894.575 – 249.86

ALLOW *ecf for transcription errors in first sum but answer must be 5 sf*

16(c)(i)

$CaO + H_2O \rightarrow Ca(OH)_2$ ✓

[1 mark]

ALLOW *multiples*

IGNORE *state symbols*

ALLOW *$CaO + 2H_2O \rightarrow Ca(OH)_2 + H_2O$*

AND $CaO + H_2O \rightarrow Ca^{2+} + 2OH^-$

16(c)(ii)

both pH values > 7 **AND** ≤ 14

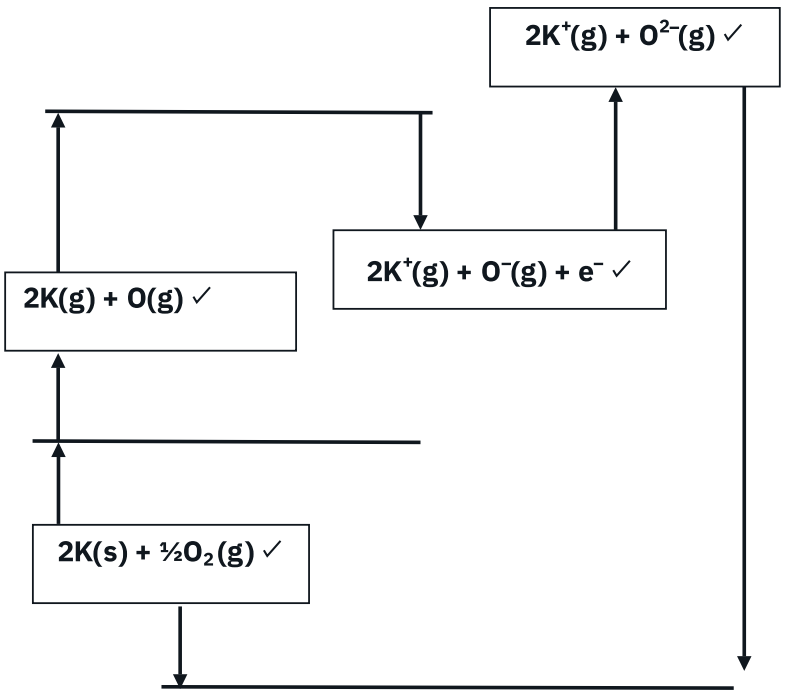
AND

pH with SrO > pH with CaO ✓

[1 mark]

ALLOW *ranges within these values but ranges must not overlap*

16(d)(i)



[4 marks]

Mark each marking point independently

Correct species **AND** state symbols required for each mark

For e^-, **ALLOW** e

For e^- only, **IGNORE** any state symbols added

16(d)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –2277 (kJ mol^{-1}) award 2 marks

–363 – (2 × +89 +249 + 2 × 419 – 141 + 790) ✓

–363 – 1914

= –2277 ✓ (kJ mol^{-1})

[2 marks]

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

See list below for marking of answers from common errors

ALLOW *for 1 mark ONE mistake with sign* ***OR*** *use of 2 x:*

+2277 (wrong sign)

–601 (2 × –419 instead of 2 × +419)

–697 (–790 instead of +790)

–1551 (+363 instead of –363)

–1858 (2 × +419 not used for K)

–1921 (2 × –89 instead of 2 × +89)

–2152.5 or –2153 (+249 ÷ 2)

–2188 (2 × +89 not used for K)

–2280 (rounded to 3SF)

–2559 (+141 instead of –141)

For other answers, check for a single transcription error or calculator error which could merit 1 mark

16(e)(i)

For sodium

atomic radius smaller

OR

fewer shells ✓

nuclear attraction increases

OR

(outer) electron(s) experience more attraction ✓

[2 marks]

ALLOW *'Na/sodium is smaller'*

IGNORE *smaller radius / fewer shells / less shielding if applied to ions but* ***DO NOT ALLOW*** *responses which refer to ions losing electrons*

DO NOT ALLOW *molecules*

ALLOW *energy levels for shells*

IGNORE *fewer orbitals* ***OR*** *fewer sub–shells*

ALLOW less *(electron) shielding* ***OR*** *electron repulsion between shells*

IGNORE *just 'shielding'*

ALLOW *more/stronger/bigger nuclear attraction etc*

IGNORE *'pull' for attraction*

IGNORE *electrons more tightly held*

IGNORE *'nuclear charge' for 'nuclear attraction'*

IGNORE *more energy (in question)*

ALLOW *reverse argument for potassium throughout*

16(e)(ii)

Comparison of size of cations

For sodium ions

ionic radius of sodium / Na^+ is smaller ✓

Comparison of attraction of cation and anion

Na^+ has stronger attraction to O^{2-} ✓

[2 marks]

comparison of IONS is essential

ALLOW *Na^+ has a larger charge density*

IGNORE *'Na has smaller atomic radius' but* ***DO NOT ALLOW*** *contradictory sentences eg 'Na$^+$ ions have smaller atomic radius'*

IGNORE *pull for attraction*

ALLOW *'sodium ion' and 'oxygen ion'*

IGNORE *just 'oxygen' or just 'O' for oxygen ion*

ALLOW *stronger attraction between oppositely charged ions*

Q36 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **A**

ΔH –ve · ΔS –ve

Q37 · Lattice enthalpy, entropy and free energy · [14 marks]

OCR MARK SCHEME

17(a)(i)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF T = 52.4 °C OR 52.5 °C award 4 marks

IF T = 32.4 (°C) award 3 marks

Correctly calculates n($AgNO_3$)

$= \frac{0.400 \times 100.0}{1000}$ **OR** 0.04(00) (mol) ✓

Energy released per mole of $AgNO_3$ in J OR kJ

EXAMINER GUIDANCE

ALLOW ECF *throughout*

ALLOW *13.6 kJ* ***OR*** *13600 J (to 3SF)*

DO NOT ALLOW *< 3 SF*

IGNORE *any sign and units*

i.e. **ALLOW** correctly calculated value in J **OR** kJ

ALLOW ECF ONLY *from calculated ΔT +20 °C*

Common errors

3 marks

$= \frac{678 \times 0.0400}{2}$ **OR** 13.56 (kJ) **OR** 13560 (J) ✓

Correctly calculates ΔT

$\Delta T = \frac{13560}{100 \times 4.18}$ **OR** 32.4 (°C) ✓

Maximum temperature reached

= 32.4... + 20.0 = 52.4 °C ✓

3 SF required

84.9 °C (not divided ΔH / 2)

[4 marks]

17(a)(ii)

Maximum temperature is the same

AND

Half the energy/ moles **AND** half the mass/volume

ALLOW *response that links the same proportionality/ratio of volume/mass and energy/moles*

ALLOW *if seen by a calculation*

[1 mark]

17(b)(i)

(Enthalpy change) when 1 mole of a compound is formed from its elements ✓

ALLOW *energy required* ***OR*** *energy released*

ALLOW *one mole of product/substance*

DO NOT ALLOW *1 mole of element*

DO NOT ALLOW

is formed from its gaseous elements

when 1 mole of a solid compound

when 1 mole of a gaseous compound

[1 mark]

17(b)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

If answer = (+)90 award 2 marks

$4(\Delta_f H^{\ominus}.NO) = -1172 - 6(-286) + 4(-46)$

$= -1172 + 1716 - 184$

$= (+)360$ (kJ mol^{-1}) ✓

$\Delta_f H^{\ominus}.NO = \frac{360}{4} = (+)90$ (kJ mol^{-1}) ✓

ALLOW ECF *providing all values are used*

ALLOW one *transcription error in the values used for M2*

Common error

1 mark

-90 (wrong sign)

[2 marks]

17(c)(i)

a measure of the dispersal of energy (in a system) ✓

ALLOW *a measure/degree of the disorder (of a system) ORA*

[1 mark]

17(c)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –2587 (kJ mol^{-1}) award 3 marks

$\Delta S^{\ominus}$

$\Delta S^{\ominus} = 256 + 4(214) + 8(192) - 4(151) - 8(220)$

$= (+)284$ (J K^{-1} mol^{-1})

OR $(+)0.284$ (kJ K^{-1} mol^{-1}) ✓

Use of

T = 298 (K)

AND

$\Delta S = 0.284$ (kJ K^{-1} mol^{-1}) ✓

$\Delta H = (\Delta G + T\Delta S)$

$= -2587$ (kJ mol^{-1}) ✓

ALLOW ECF *throughout*

M2 is for unit conversions seen anywhere.

ALLOW 3SF *up to the calculator value -2587.368 (kJ mol^{-1})*

ALLOW ECF *from incorrect unit conversions or incorrect ΔS.*

Common errors

2 marks

[3 marks]

-2664.9 (kJ mol^{-1})	(Use of 25°C)
81960 (kJ mol^{-1})	(Use of ΔS 284)
4428 (kJ mol^{-1})	(Use of 25°C and ΔS 284)
-2756.632 (kJ mol^{-1})	(Use of ΔS = -0.284)

17(c)(iii)

ΔS is positive/ + **AND** ΔH is negative/ – ✓

ΔG is negative (– at all temperatures)

OR ΔG is (always) negative/ – ✓

[2 marks]

ALLOW *ΔH is exothermic*

ALLOW *'-TΔS' is negative'*

ΔG comment is dependent on on the signs assigned to ΔS **AND** ΔH (either in answer or from 17 cii).

ALLOW ECF *from incorrect signs for ΔS and/or ΔH from c(ii)*

i.e.

ΔS is positive/ + **AND** ΔH is positive/ +

Reaction is feasible only at high temperatures

ΔS is negative/ - **AND** ΔH is negative/ -

Reaction is feasible only at low temperatures

IGNORE *ΔS is negative/ -* ***AND*** *ΔH is positive/ + (-ΔG given in 17 cii)*

Alternative Approach

ALLOW *use of ΔG=0 for 2 marks*

i.e. calculates T = -9109K ✓

It is always feasible above - 9109K / calculated -ve value and all temperatures are above this ✓

Q38 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **A**

½ Br_2(l) → Br(g)

Q39 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **B**

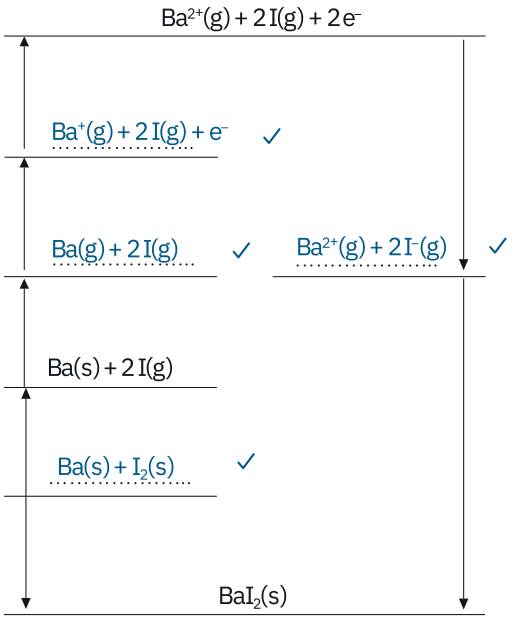
Only 1 and 2

Q40 · Lattice enthalpy, entropy and free energy · [10 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

16(a)(i)



[4 marks]

16(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –1872 award 2 marks

ΔH lattice = 2(+296) – 965 – 503 – 180 + 2(–107)– 602 ✓

ΔH lattice = –1872 (kJ mol^{-1}) ✓

[2 marks]

***ALLOW** for 1 mark +1872 (wrong sign on answer)*

Common errors for 1 mark

–3056 (–296 x 2 instead of 296 x2)

–2168 (296 x 1 instead of 296 x2)

–1765 (–107 x 1 instead of –107 x 2)

–1512 (180 instead of –180)

–1444 (107 x 2 instead of –107 x 2)

–866 (503 instead of –503)

–668 (602 instead of –602)

+58 (965 instead of -965)

For other answers, check for a single transcription error or calculation error which could merit 1 mark if all values have been used.

***DO NOT ALLOW** any answer which involves two errors*

16(b)

Ist IE of Mg and Sr

(Mg) removes electron from shell closer to the nucleus / smaller atomic radius ✓

Greater nuclear attraction (between atom and outer electron) ✓

2nd/1st IE of Sr

2nd electron removed from cation/positively charged ion

OR

proton:electron ratio (in (1)+ ion) is greater (than in atom) ✓

Greater nuclear attraction / attraction between ion (and outer electron) ✓

[4 marks]

ORA throughout

***ALLOW** going down the group for comparison of Mg/Sr*

Assume 'it' means Mg

***ALLOW** (Mg) fewer shells*

***ALLOW** less shielding*

***ALLOW** removal of electron from 3s rather than 5s*

***ALLOW** Greater attraction between nucleus (and outer electron)*

***ALLOW** Sr^+ ion smaller (than Sr atom)*

***ALLOW same** number of protons/nuclear charge attracting one fewer electron*

***IGNORE** repulsion between electrons in the s orbital*

***IGNORE** shielding*

Q41 · Lattice enthalpy, entropy and free energy · [11 marks]

OCR MARK SCHEME

18(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –4950 award 3 marks

- $q = mc\Delta T$ = 150 x 4.18 x 10.5 = 6583.5 (J) **OR** 6.5835 (kJ) ✓
- $n(C_7H_{16}) = \frac{0.133}{100} = 1.33 \times 10^{-3}$ ✓
- $\Delta_c H = \frac{q}{n} = \frac{6.5835}{1.33 \times 10^{-3}} = -4950$ kJ mol^{-1}

– sign required ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW *3 SF up to the calculated value*

Ignore RE after 3SF

IGNORE *sign*

ALLOW ECF *from incorrect q and/or n*

Common errors for 2 marks

+4950 kJ mol^{-1} (wrong sign)

-5077 (use of 0.0013 and 6.6 2SF)

-5064 (use of 0.0013 2SF)

-4962 (use of 6.6kJ use of 2SF)

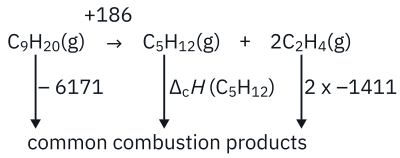
18(b)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –3535 award 2 marks

186 = $\Delta_c H(C_9H_{20}) - \Delta_c H(C_5H_{12}) - 2\,\Delta_c H(C_2H_4)$

OR From Hess cycle with all numerical values used and correct multiples used/labelled



✓

$\Delta_c H(C_5H_{12})$ = (–6171) – 2(–1411) -186 = –3535 kJ mol^{-1} ✓

[2 marks]

IGNORE *any incorrect combustion products on bottom line.*

Common errors for 1 mark

+3535 (wrong sign for final answer)

+8807 (use of +6171)

-9179 (use of +1411)

-4946 (use of 1 x -1411)

-3163 (use of +186)

For other answers, check for a single transcription error or calculation error using all values which could merit 1 mark

18(c)(i)

(ΔS) is positive

AND

more molecules / moles of (gaseous) product /produced ✓

[1 mark]

ALLOW *reaction produces more (gaseous) molecules /moles of products than reactants*

IGNORE *explanations based on ΔG*

18(c)(ii)

Best fit line drawn ✓

(–)ΔS = correct gradient from graph

OR (–)0.127 (kJ K^{-1} mol^{-1}) ✓

ΔS = gradient × –1000 = (+)127 (J K^{-1} mol^{-1}) ✓

Minimum T (ΔG = 0) = 370 (K) ✓

ΔH (y-intercept) = (+)46 (kJ mol^{-1}) ✓

[5 marks]

Allow ***ECF*** *throughout*

Place tick for line of best fit on the graph

Allow lines that will extrapolate to y axis at 43-47 and x axis at 820-840

DO NOT ALLOW *outside ranges*

ALLOW *rounding to 2SF*

e.g. (–)$\Delta S = \frac{105}{830}$ = (–)0.127

ALLOW *(–)0.122 to (–)0.131*

ALLOW *122 to 131*

This mark subsumes gradient mark

ALLOW *340 to 370*

ALLOW *67 to 97* ***AND*** *°C*

DO NOT ALLOW *-ve T in K*

ALLOW *43 to 47*

Candidates can receive full credit for calculating ΔS, T and/or ΔH from previously determined values

e.g

$$T = \frac{\Delta H}{\Delta S} = \frac{46}{0.127} = 362K$$

Q42 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **B**

–254

Q43 · Lattice enthalpy, entropy and free energy · [17 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

16(a)(i)

FIRST CHECK ANSWER ON ANSWER LINE

If answer = –117 kJ mol^{-1}, award 4 marks.

ΔH = –286– (–188)

= –98 kJ mol^{-1} ✓

ΔS = 70 + ½(205) – 110 = 62.5 (J K^{-1} mol^{-1})

or 0.0625 (kJ K^{-1} mol^{-1}) ✓

$\Delta G = \Delta H - T\Delta S$

= –98 – (298 × 0.0625) ✓

ΔG = –117 kJ mol^{-1} (3SF) ✓

[4 marks]

ALLOW ECF *throughout*

ALLOW *–98000 – (298 × 62.5)*

Common Errors for ΔG

3 marks

–18700 (ΔS not converted to kJ)

–493 (ΔH = –286 + (–188) = –474)

–147 (ΔS = 165: not halving 205)

–99.6 (T not converted to K)

–18.7 (ΔH not converted J but ΔS J K^{-1} mol^{-1})

(+)79.4 (–188 – (–286) = +98)

2 marks

(+) 117 (incorrect signs for ΔH and ΔS)

Final Answer MUST BE 3 SF

16(a)(ii)

(Rate of reaction) slow

OR Activation energy high ✓

[1 mark]

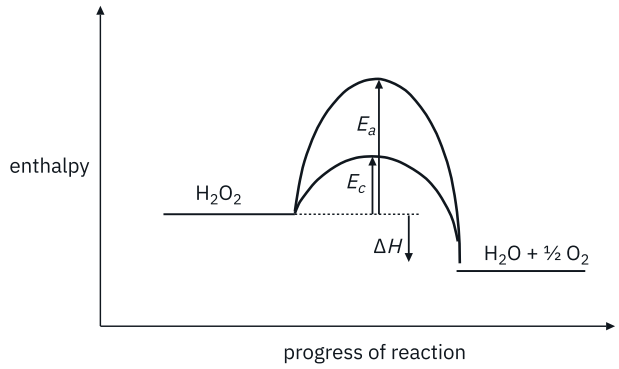
ALLOW *ΔG takes no account of rate of reaction*

ALLOW *molecules do not have sufficient energy to equal or exceed the activation energy.*

IGNORE *molecules do not have sufficient energy to react.*

DO NOT ALLOW *there is not enough activation energy*

16(b)(i)



H_2O_2 on LHS **AND** $H_2O + ½ O_2$ on RHS

AND

ΔH labelled with product line below reactant line

AND

Arrow downwards ✓

E_a correctly labelled ✓

E_c correctly labelled with $E_c < E_a$ ✓

[3 marks]

Care enthalpy profile must match ΔH sign in16 a) i) – check calculation

ALLOW *endothermic profile as* ***ECF*** *from + ΔH calculated in 16 a) i) for all three marks*

State symbols not required

ΔH DO NOT ALLOW $-\Delta H$

DO NOT ALLOW *double headed arrow on ΔH*

ALLOW *ΔH arrow even with small gap at the top and bottom,*

i.e. line does not quite reach reactant or product line.

E_a and E_c

ALLOW *no arrowhead or arrowheads at both end of E_a or E_c lines*

E_a or E_c lines must reach maximum (or near to maximum) on curve

ALLOW *overlapping lines* ***OR*** *lines on side reaching maximum*

For E_a, **ALLOW** AE **OR** A_E **OR** Eact **OR** suitable alternatives

ALLOW ECF *marks for E_a and E_c for correctly labelled endothermic diagram from a –ΔH value (from16 a) i))*

16(b)(ii)

(MnO_2) is in different phase/state (to the reactant / H_2O_2)

OR

catalyst is a solid **AND** reactant is liquid ✓

[1 mark]

ASSUME 'it' is MnO_2

ALLOW *'species in the reaction'*

IGNORE *references to products*

16(b)(iii)

Mn is +2 **AND** +3

OR

+ required

ALLOW *2+ and 3+*

Mn is +1 **AND** +6 ✓

[1 mark]

DO NOT ALLOW *Mn^{2+} Mn^{3+}*

DO NOT ALLOW *+ 4 (this is the oxidation state in MnO_2)*

16(c)(i)

(Enthalpy / heat energy change / released when) 1 mol of (ionic lattice) ✓

Is formed from its gaseous ions ✓

[2 marks]

ALLOW *1 mol of (ionic) compound/product/substance*

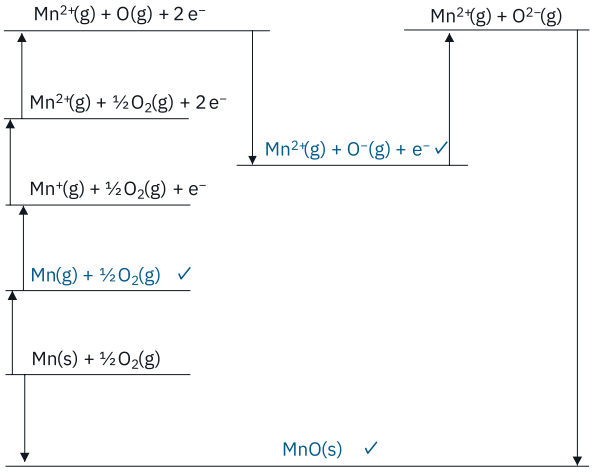
IGNORE *energy released/required*

ALLOW *$M^+(g) + X^-(g) \rightarrow MX(s)$*

DO NOT ALLOW *one mole of gaseous ions*

16(c)(ii)

Care: State symbols are required



[3 marks]

16(c)(iii)

FIRST CHECK ANSWER ON ANSWER LINE

If answer = –3798 award 2 marks

Common errors for 1 mark

-4080 (use of -141)

-3674 (use of +249/2 and correctly rounded)

-3673.5 (use of +249/2)

-3236 (use of +281)

-3300 (use of +249)

-3028 (use of -385)

-2364 (use of +717)

-2202 (use of +798)

-780 (use of +1509)

+3798 (wrong sign on answer)

For other answers, check for a single transcription error or calculation error which could merit 1 mark

ΔH lattice

= –281 – 249 – 717 – 1509 – (–141) – 798 + (–385) ✓

ΔH lattice = –3798 (kJ mol^{-1}) ✓

[2 marks]

Q44 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **B**

An electron is added to a negative ion.

Q45 · Lattice enthalpy, entropy and free energy · [13 marks]

OCR MARK SCHEME

17(a)

High pressure **AND** low temperature ✓

Right-hand side has fewer (gaseous) moles/molecules

OR

left-hand side has more (gaseous) moles/molecules ✓

(Forward) reaction is exothermic/gives out heat

EXAMINER GUIDANCE

Marks are independent

ORA *throughout*

ALLOW *RHS*

ALLOW *suitable alternatives for RHS*

e.g. product side

OR reverse reaction is endothermic/takes in heat ✓

[3 marks]

17(b)

(Reaction can be carried out at) lower temperatures / lower energy demand ✓

Less (fossil) fuels burnt / less CO_2 emissions ✓

[2 marks]

ALLOW *lower pressures as alternative to lower temperature*

ALLOW *reduced carbon footprint as alternative to less fuels burnt*

ALLOW *different reactions can be used with greater atom economy / less waste*

ALLOW *can reduce use of toxic substances*

17(c)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 25.55 kJ mol^{-1} ***OR*** *25550 J mol^{-1} award first 4 marks*

$\Delta S = 238 - (198 + 2 \times 131)$ ✓

$= -222$ (J K^{-1} mol^{-1}) **OR** -0.222 (kJ K^{-1} mol^{-1}) ✓

$\Delta G = \Delta H - T\Delta S$

OR

$\Delta G = -91 - (525 \times -0.222)$

OR

$\Delta G = -91000 - (525 \times -222)$ ✓

$= 25.55$ kJ mol^{-1} **OR** 25550 J mol^{-1} ✓

(Reaction is) not feasible **AND** $\Delta G > 0$ ✓

[5 marks]

ALLOW ECF

IGNORE *units at this stage*

Units for ΔG required

ALLOW *26 kJ mol^{-1}* ***OR*** *26000 J mol^{-1} up to calculator value.*

17(d)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 2.22 × 10^4 award first 2 marks

$$\ln K_p = \frac{-\Delta G}{RT} = \frac{2.48 \times 10^4}{8.314 \times 298} = 10.01$$ ✓

$K_p = 2.22 \times 10^4$ (3SF required) ✓

Units = atm^{-2} ✓

[3 marks]

ALLOW ECF *for transcription errors in first sum*

ALLOW *10 up to calculator value of 10.00979992*

ALLOW *22200*

ALLOW *2.20 × 10^4* ***OR*** *22000 (use of 10)*

ALLOW *alternatives (k)Pa^{-2}* ***OR*** *N^{-2} m^4* ***OR*** *mmHg^{-2}* ***OR*** *PSI^{-2}* ***OR*** *bar^{-2}*

Common errors for 1 mark:

22400 (use of 8.31)

4.50 x 10^{-5} (use of -10.01)

Q46 · Lattice enthalpy, entropy and free energy · [1 mark]

Answer: **A**

ΔH: + · ΔS: +

Q47 · Lattice enthalpy, entropy and free energy · [14 marks]

OCR MARK SCHEME

16(a)

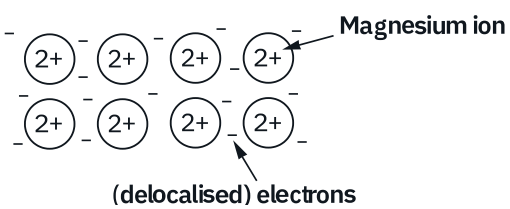


Diagram with regular arrangement of labelled 'Mg^{2+} ions' **OR** '2+ ions'

AND attempt to show electrons ✓

Labelled electrons between other species

EXAMINER GUIDANCE

Regular arrangement must have at least two rows of correctly charged ions and a minimum of two ions per row

ALLOW *as label: +2 ions* ***OR*** *+ 2 cations* ***OR*** *+2/2+ seen within circle*

ALLOW *e$^-$ or 'e' as a label for electron*

IGNORE *"–" for electron label*

ALLOW *mobile/flow for move*

IGNORE *'carry charge'*

AND

statement anywhere of delocalised electrons (can be in text or in diagram)

Electrons move ✓

[3 marks]

16(b)(i)

$Mg^{3+}(g) \rightarrow Mg^{4+}(g) + e^{-}$ ✓

[1 mark]

State symbols required

(ignore states on electrons)

ALLOW *$Mg^{3+}(g) - e^{-} \rightarrow Mg^{4+}(g)$*

ALLOW *$Mg^{+3}(g)$*

ALLOW *e for e^{-}*

16(b)(ii)

Big jump/larger difference between 2 and 3 ✓

[1 mark]

IGNORE *big jump between 10 and 11*

DO NOT ALLOW *other combinations.*

16(b)(iii)

1st **AND** 3rd **AND** 4th **AND** 5th **AND** 9th **AND** 11th ✓

i.e.

1	2	3	4	5	6	7	8	9	10	11	12
✓		✓	✓	✓				✓		✓	

[1 mark]

16(c)(i)

(enthalpy change for) 1 mole of a compound/substance/solid/solute dissolving ✓

[1 mark]

IGNORE *'energy released'* ***OR*** *'energy required'*

For dissolving, **ALLOW** forms aqueous/hydrated ions

IGNORE *ionic* ***OR*** *covalent*

DO NOT ALLOW *dissolving elements*

DO NOT ALLOW *response that implies formation of 1 mole of aqueous ions*

16(c)(ii)

$Mg^{2+}(aq) + 2F^{-}(g)$ ✓

$Mg^{2+}(aq) + 2F^{-}(aq)$ ✓

[2 marks]

ALLOW *$Mg^{2+}(g) + 2F^{-}(aq)$*

ALLOW *$MgF_2(aq)$*

16(c)(iii)

-6 (kJ mol^{-1}) ✓

$\Delta_{sol}H(MgF_2) = -(-2926) + (2 \times -506) + (-1920)$

[1 mark]

1 mark ONLY

16(c)(iv)

Ionic radius

Halide ion gets larger down the group ✓

Lattice enthalpy

Lattice enthalpy is less exothermic down group

OR halide ion has less attraction for Mg^{2+} ✓

Hydration enthalpy

Hydration enthalpy is less exothermic down group

OR halide ion has less attraction for H_2O ✓

Enthalpy of solution

Difficult to predict whether lattice enthalpy or hydration enthalpy has bigger effect ✓

ALLOW ORA *throughout*

ALLOW *ions closer together in MgF_2*

OR further apart in MgI_2

DO NOT ALLOW *atomic radius*

ALLOW *MgI_2 is less exothermic than MgF_2 for LE and hydration enthalpy -as trend 'down the group'.*

ALLOW *less negative/more positive*

BUT

IGNORE *is smaller/less*

[4 marks]

Q48 · Rate equations · [1 mark]

Answer: **A**

Q49 · Rate equations · [14 marks]

OCR MARK SCHEME

3(a)(i)

(rate =) k $[H_2O_2]$ $[I^-]$ ✓

$$k = \frac{\text{rate}}{[H_2O_2]\,[I^-]} = \frac{2.00 \times 10^{-6}}{0.0100 \times 0.0100} = 0.02(00)$$ ✓

units: $dm^3\ mol^{-1}\ s^{-1}$ ✓

[3 marks]

EXAMINER GUIDANCE

Square brackets required

IGNORE *any state symbols*

IGNORE $[H^+]^0$

ALLOW ECF *from incorrect rate equation*

BUT units must fit with rate equation used

ALLOW $mol^{-1}\ dm^3\ s^{-1}$ *OR in any order*

NOTE

K_c expression with calculation and units 0 marks

3(a)(ii)

Plot graph using ln k AND $\frac{1}{T}$ ✓

(Measure) gradient ✓

Independent mark

$E_a = (-)R \times$ gradient OR $(-)8.314 \times$ gradient ✓

- Independent mark, even if variables for graph are incorrect
- Subsumes 'gradient' mark

[3 marks]

Unless otherwise stated, assume, that ln k is on y axis and $1/T$ is on x axis

IGNORE *intercept*

ALLOW *gradient* $= \frac{(-)E_a}{R}$

NOTE: ALLOW *'Inverse graph' (special case)*

Plot graph of $1/T$ against ln k ✓

(Measure) gradient ✓

Independent mark

$E_a = \frac{(-)R}{\text{gradient}}$ OR $\frac{(-)8.314}{\text{gradient}}$

OR gradient $= \frac{(-)R}{E_a}$ ✓

Subsumes 'gradient' mark

3(b)

ALLOW *equilibrium sign in equations provided reactants on left*

Reaction of H_2O_2 with MnO_2:

$H_2O_2 + MnO_2 + 2H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ ✓

Reaction of H_2O_2 with Mn^{2+}:

$H_2O_2 + Mn^{2+} \rightarrow MnO_2 + 2H^+$ ✓

Use of E data

Use of E data to support equation(s) above or half direction of provided half equations (one including MnO_2) ✓

Also look for evidence around half equations

MnO_2 regenerated/reformed ✓

Must be linked to an equation showing MnO_2 as reactant and an equation showing MnO_2 as product

[4 marks]

ALLOW *correct multiples*

IGNORE *state symbols*

ALLOW *uncancelled* H_2O *and* H^+

$H_2O_2 + MnO_2 + 4H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O + 2H^+$

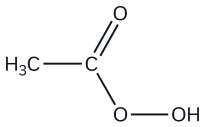
$H_2O_2 + Mn^{2+} + 2H_2O + 2H^+ \rightarrow MnO_2 + 4H^+ + 2H_2O$

Examples

- More negative E moves to left **ORA**
- Reduction half equation to the right **ORA**
- Most positive E is reduced **ORA**
- Calculated E cell = +0.81 V (from top 2) OR +0.27 V (from bottom 2)

ALLOW *combining of equations above to show that* MnO_2 *is used and reformed*

3(c)(i)

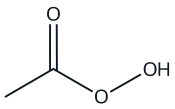


ALLOW

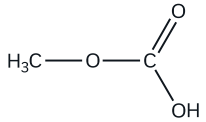
✓

ALLOW *skeletal OR displayed formula*

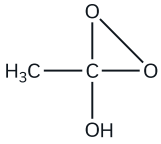
OR mixture of the above as long as non-ambiguous, e.g.



[1 mark]



OR



Structure must include OH as part of COOOH group

ALLOW *$-O^- H^+$ in structure*

3(c)(ii)

FIRST CHECK THE ANSWER ON THE ANSWER LINE

IF *answer = 0.023(125) (mol) award 3 marks for calculation*

If there is an alternative answer, check for any ***ECF*** *credit*

K_c expression

$(K_c =) \dfrac{[CH_3COOOH]}{[H_2O_2]\,[CH_3COOH]}$ ✓

$[CH_3COOOH]$

$= 0.37 \times 0.500 \times 0.500 = 0.0925$ (mol dm^{-3}) ✓

Subsumes K_c expression

$n(CH_3COOOH)$

$= \dfrac{0.0925 \times 250}{1000} = 0.023(125)$ (mol) ✓

[3 marks]

ALLOW *0.37 =* $\dfrac{[CH_3COOOH]}{0.500 \times 0.500}$

ALLOW ECF *but ONLY if 0.37 AND 0.5 × 0.5 have been used*

Common errors

0.076	**2 marks**	Use of $[CH_3COOOH]^2$
0.675	**2 marks**	Use of 0.5 for $[H_2O]$ on K_c
0.169	**2 marks**	Inverted K_c
0.338	**1 mark**	Inverted K_c AND 0.5 for $[H_2O]$
5.78×10^{-3}	**2 marks**	× 250 / 1000 before $[CH_3COOOH]$

Q50 · Rate equations · [11 marks]

OCR MARK SCHEME

17(a)

Level 3 (5–6 marks)

A comprehensive conclusion which uses quantitative results for determination of the reaction orders.

AND

Determines *k* from correct rate equation.

AND

Proposes the two-step mechanism which adds up to overall equation with no intermediate electrons.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated. The working for the scientific content is clearly linked to the experimental evidence.

Level 2 (3–4 marks)

EXAMINER GUIDANCE

Indicative scientific points may include:

Orders and rate equation

- Fe^{3+} 1st order **AND** I^- 2nd order

OR rate = $k[Fe^{3+}]\,[I^-]^2$

- Supported by experimental results

Calculation of *k*, including units

- *k* correctly calculated **AND** correct units, e.g.

$k = \dfrac{8.10 \times 10^{-4}}{((4.00 \times 10^{-2}) \times (3.00 \times 10^{-2})^2)} = 22.5$

- $dm^6\ mol^{-2}\ s^{-1}$ **OR** $mol^{-2}\ dm^6\ s^{-1}$

Two-step mechanism

- Two steps add up to give overall equation

Reaches a sound, but not comprehensive, conclusion based on the quantitative results.

AND

Correctly identifies the orders and rate equation.

AND

Calculates the rate constant

OR

Proposes the two-step mechanism with reactants of first step matching rate equation or matches orders

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. The working for the scientific content is clearly linked to the experimental evidence.

Level 1 (1–2 marks)

Attempts to reach a simple conclusion for orders

AND

Attempts a relevant rate equation.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant The working for the scientific content is clearly linked to the experimental evidence.

0 marks

No response or no response worthy of credit.

- Slow step/ rate-determining step matches stoichiometry of rate equation.
- Each step balances by species and charge

e.g.

$Fe^{3+}(aq) + 2I^-(aq) \rightarrow [FeI_2]^+$ SLOW

$Fe^{3+}(aq) + [FeI_2]^+ \rightarrow 2Fe^{2+}(aq) + I_2(aq)$ FAST

$Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^{2+}(aq) + I_2^-(aq)$ SLOW

$Fe^{3+}(aq) + I_2^-(aq) \rightarrow Fe^{2+}(aq) + I_2(aq)$ FAST

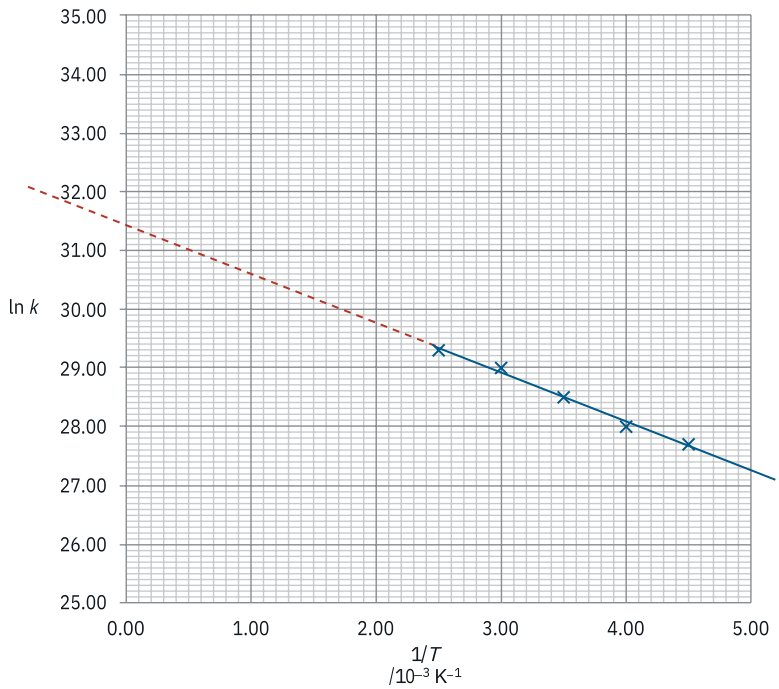
$Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^{+} + I_2$ SLOW

$Fe^{3+}(aq) + Fe^{+} \rightarrow 2Fe^{2+}(aq)$ FAST

There may be other feasible possibilities

[6 marks]

17(b)(i)



Gradient

Correct gradient calculated from best-fit straight line drawn within the range ±800 → ±1040 ✓

E_a calculation

E_a = (–) gradient × 8.314 ✓

e.g. from ±820, E_a = (+)6817.48 (J mol^{-1})

***E_a* to 3 SF AND** use of 10^{-3} for gradient ✓

e.g. from ±820, E_a = (+)6820 (J mol^{-1})

ALLOW *lines which do not intercept y-axis*

ALLOW *mark for gradient if correct working shown within E_a calculation without gradient being calculated separately*

ALLOW *±0.8(00) → ±1.04(0)*

(omission of 10^{-3})

ALLOW *ECF for calculated gradient x 8.314*

If value of gradient not shown separately,

ALLOW *E_a in range: 6650 → 8650*

OR 6.65 → 8.65 (omission of 10^{-3})

This mark subsumes gradient mark

NOTE: Omission of 10^{-3} can get 1st 2 marks

[3 marks]

17(b)(ii)

Intercept shown on graph

could be by extrapolation of line, or label on y axis

AND ln A linked to intercept value

e.g. ln $A = 31.4$ ✓

Calculation of $A = e^{\text{intercept}}$ ✓

e.g. $A = e^{31.4} = 4.33 \times 10^{13}$

[2 marks]

ALLOW *y = 31.4*

ALLOW *substitution of correct values of ln k and 1/T into* $\ln k = \frac{-E_a}{R} \times \frac{1}{T} + \ln A$ *to give a value of ln A which approximately matches the intercept if given*

$\ln A = \ln k + (\frac{E_a}{R} \times \frac{1}{T})$

Calculation of $A = e^{\ln A}$

OR

$e^{\ln k + (Ea/R \times 1/T)}$

ALLOW *ECF from incorrect ln A*

$e^{31.2} = 3.55 \times 10^{13}$

$e^{31.3} = 3.92 \times 10^{13}$

$e^{31.35} = 4.12 \times 10^{13}$

$e^{31.45} = 4.56 \times 10^{13}$

$e^{31.5} = 4.79 \times 10^{13}$

$e^{31.6} = 5.29 \times 10^{13}$

$e^{31.7} = 5.85 \times 10^{13}$

$e^{31.8} = 6.46 \times 10^{13}$

$e^{31.9} = 7.14 \times 10^{13}$

$e^{32.0} = 7.9(0) \times 10^{13}$

$e^{32.1} = 8.73 \times 10^{13}$

IF 2 DP answer given, check rounding from calculator value, not 3 DP values given

Eg $e^{31.7} = 5.8497 \times 10^{13}$ and $= 5.8 \times 10^{13}$(2SF)

Q51 · Rate equations · [1 mark]

Answer: **A**

Q52 · Rate equations · [1 mark]

Answer: **C**

+36.7

Q53 · Rate equations · [6 marks]

OCR MARK SCHEME

21

Level 3 (5–6 marks)

Most evidence used to determine the correct orders **AND** rate equation **AND** rate constant.

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)

Some evidence used to determine two orders correctly **AND** rate equation **AND** rate constant consistent with orders.

OR

Little evidence used to determine all three orders correctly **AND** rate equation **AND** rate constant.

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

EXAMINER GUIDANCE

Indicative scientific points may include:

Orders

Student 1

- zero order wrt Br_2

Student 2

- 1st order wrt CH_3COCH_3

Student 3

- 1st order wrt H^+

Explanations

Student 1

- constant gradient **OR** linear negative gradient **OR** constant rate **OR** rate independent of concentration **OR** decreasing half-life

Level 1 (1–2 marks)

Little evidence used to determine two orders correctly

OR

One order correct, with attempt to determine the rate equation **AND** rate constant.

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]

Student 2

- straight line through 0,0
- **OR** rate directly proportional to $[CH_3COCH_3]$ **OR** $[CH_3COCH_3] \times 2$, rate × 2

Student 3

- $[H^+] \times 2$, rate × 2

Rate equation, rate constant and units

- 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** $\dfrac{(1.25 \times 10^{-5})}{(1.6 \times 0.2)}$
- $k = 3.9... \times 10^{-5}$
- units: $dm^3\ mol^{-1}\ s^{-1}$ (Any order, e.g. $mol^{-1}\ dm^3\ s^{-1}$)

Q54 · Rate equations · [1 mark]

Answer: **A**

8.66×10^{-3}

Q55 · Rate equations · [8 marks]

OCR MARK SCHEME

4(a)

At 90 °C/higher temperature

- Faster rate **AND** more frequent collisions ✓
- More particles have the activation energy/E_a or greater ✓
- $[Co(H_2O)_6]^{2+}$ is lower ✓
- (forward reaction) ΔH –ve **OR** exothermic ✓

[4 marks]

EXAMINER GUIDANCE

ORA for 50 °C

IGNORE *more successful collisions*

ALLOW *more molecules have enough energy to react*

ALLOW *atoms/molecules/ions*

ALLOW *decreases*

4(b)(i)

Cl^- /It/They react with $AgNO_3$ / Ag^+ /silver ions

OR

AgCl formed

OR

$Ag^+ + Cl^- \rightarrow AgCl$ ✓

[1 mark]

IGNORE *chlorine/Cl for chloride ion*

IGNORE *$AgCl_2$*

4(b)(ii)

$[CoCl_4^{2-}]$ decreases **AND** $[Co(H_2O)_6]^{2+}$ increases ✓

Cl^- increase is 4 × change in $[CoCl_4^{2-}]$ / $[Co(H_2O)_6]^{2+}$ ✓

Equilibrium shifts to right ✓

[3 marks]

IGNORE *missing charges and small slips in formulae, e.g. $CoCl_4$ missing bracket, etc*

IGNORE *Cl^- for changes in concentration*

ALLOW *suitable alternatives for 'shifts to right', e.g. towards products*

OR in forward direction **OR** 'favours the right'

Q56 · Rate equations · [6 marks]

OCR MARK SCHEME

17

Level 3 (5–6 marks)

EXAMINER GUIDANCE

Indicative scientific points may include

Orders

ALL 3 correct orders linked to explanations

AND rate equation **AND** rate constant

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

Level 2 (3–4 marks)

Three correct orders

AND two out of:

some evidence of an explanation linked to an order

rate equation

rate constant

OR

Three correct orders

with an attempt at:

Some evidence of an explanation link to an order

rate equation

rate constant

OR

Two correct orders linked to explanations

AND rate equation

AND rate constant consistent with the candidate's orders

There is a line of reasoning with some structure and supported by some evidence.

Level 1 (1–2 marks)

Two correct orders

OR

One correct order

AND attempts to determine rate equation **OR** rate constant.

OR

One correct order

AND attempts an explanation.

There is an attempt at a logical structure with a reasoned conclusion from the evidence.

0 marks No response worthy of credit.

[6 marks]

- 1st order wrt Br^-
- 1st order wrt BrO_3^-
- 2nd order wrt H^+

Rate equation

- rate = $k\,[Br^-]\,[BrO_3^-]\,[H^+]^2$

Calculation of k from any row of data, e.g.

$$k = \frac{\text{Rate}}{[Br^-][BrO_3^-][H^+]^2}$$

$$k = \frac{2.52 \times 10^{-4}}{0.020 \times 0.120 \times (0.080)^2} = 16.4(0625)$$

Explanations from results e.g.

Br^-	$[Br^-] \times 3$	rate × 3	Expts 1 and 2
BrO_3^-	$[Br^-] \times 2$ **AND** $[BrO_3^-] \div 2$	rate: no change	Expts 1 and 3
	OR		
	$[Br^-] \times 2/3$ **AND** $[BrO_3^-] \div 2$	rate: × 1/3	Expts 2 and 3
H^+	$[BrO_3^-] \div 2$ **AND** $[H^+] \times 5$	rate × 12.5	Expts 1 and 4
	OR		
	$[Br^-] \div 3$ and $[BrO_3^-] \div 2$ and $[H^+] \times 5$	rate × 4.17	Expts 2 and 4
	OR		
	$[Br^-] \div 2$ and $[H^+] \times 5$	rate × 12.5	Expts 3 and 4

ALLOW *a sequential approach where they apply known orders first*

ALLOW *minor slips as we are looking for an holistic approach to LoR marking*

NOTE: *A clear and logically structured response would link orders to the experiment and experimental results provided. They could provide units*

Units

$dm^9\ mol^{-3}\ s^{-1}$

ALLOW *any order, e.g.* $mol^{-3}\ dm^9\ s^{-1}$

Q57 · Rate equations · [1 mark]

Answer: **D**

Q58 · Rate equations · [7 marks]

OCR MARK SCHEME

17(a)

(Over time) concentration decreases **AND** collisions are less frequent ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *less moles/particles per unit volume.*

ALLOW *fewer collisions per second/per unit time*

IGNORE *(over time) fewer reacting particles*

IGNORE *...chance of..*

IGNORE *amount decreases*

IGNORE *successful*

IGNORE *particles more spread out/further apart*

DO NOT ALLOW *particles have less energy in terms of energy distribution.*

17(b)

Level 3 (5–6 marks)

A comprehensive conclusion using quantitative data from graph to correctly determine

1st order conclusion for CV using half lives/gradients

AND rate at 3 minutes

AND determination of *k*

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

Level 2 (3–4 marks)

Reaches a conclusion using quantitative data from graph to correctly determine rate at 3 minutes **AND** determination of *k*.

OR

Half- lives/gradient with 1st order conclusion for CV

AND determination of *k*

OR

determined rate **AND** half-life/first order for CV

OR

Attempts to determine rate, *k* and order for CV

There is a line of reasoning with some structure and supported by some evidence.

Level 1 (1–2 marks)

Reaches a simple conclusion using at least one piece of quantitative data from the graph, i.e.

Attempts to calculate rate at three minutes **OR** *k* **OR** links half lives to 1st order.3

There is an attempt at a logical structure with a reasoned conclusion from the evidence.

0 marks No response worthy of credit

[6 marks]

Indicative scientific points may include:

Care: ALLOW the use of **ECF** for values obtained from a previously, incorrectly, calculated value.

ALLOW *minor slips as we are looking for a holistic approach to LoR marking.*

	Minutes	**Seconds**
Half life values	2.4 to 2.6 min	144 to 156 s
Rate at three minutes	(-) (1.5 to 1.8) $\times 10^{-8}$ mol dm^{-3} min^{-1}	(-) (2.5 to 3.0)$\times 10^{-10}$ mol dm^{-3} s^{-1}
Value of *k*	0.24 to 0.30 min^{-1}	(4.0 to 5.0) x 10^{-3} s^{-1}
Units of *k*	min^{-1}	s^{-1}

Examples of the communication statement being met would typically include:

- For L1 and L2: full working on the graph and/or appropriate units for calculated values.
- For L3: full working on the graph and appropriate units for calculated values.

If time has been measured in minutes

(see below for values using seconds).

Indicative scientific points may include:

Evidence for 1st order

1st order clearly linked to half-life **OR** 2 gradients:

Half life

Half- life shown on graph

Half- life range 2.4 to 2.6 min

Two 'constant' half lives

OR Two gradients → two rates

2 tangents shown on graph at *c* and *c*/2

This could include $c = 0.61 \times 10^{-7}$ mol dm^{-3} (t = 3 min)

Gradient at $c/2$ is half gradient at c

e.g. $c = 0.8 \times 10^{-7}$ mol dm^{-3}, gradient = 2.2×10^{-8} (mol dm^{-3} min^{-1})

AND $c = 0.4 \times 10^{-7}$ mol dm^{-3}, gradient = 1.1×10^{-8} (mol dm^{-3} min^{-1})

For chosen method, conclude that the reaction is 1st order wrt CV.

Rate at three minutes

Tangent shown on graph as line at $t = 3$ min

Gradient in range: $(1.5 - 1.8) \times 10^{-8}$

rate as gradient with units: mol dm^{-3} min^{-1}

OR $k = \frac{\ln 2}{t½} = 0.28 \text{min}^{-1}$

And k substituted into rate equation.

e.g.

Rate = k [CV]

Rate = 0.277 x 0.61 x10^{-7}

= 1.7 x10^{-8} mol dm^{-3} min^{-1}

Determination of k

k clearly linked to rate **OR** half-life:

e.g. $k = \frac{\text{rate}}{[\text{CV}]} = \frac{1.75 \times 10^{-8}}{0.62 \times 10^{-7}} = 0.28$

k in range: 0.24 - 0.30 min^{-1}

OR e.g. $k = \frac{\ln 2}{t½} = 0.28$ min^{-1}

Units of k: min^{-1}

If time has been measured in seconds:

Evidence for 1st order

1st order clearly linked to half-life **OR** 2 gradients:

Half life

Half- life shown on graph

Half- life range 144 to 156 s

Two 'constant' half lives

OR Two gradients → two rates

2 tangents shown on graph at c and $c/2$

This could include $c = 0.6 \times 10^{-8}$ mol dm^{-3} (t = 3 min)

Gradient at $c/2$ is half gradient at c

e.g. $c = 0.8 \times 10^{-7}$ mol dm^{-3},

gradient = 3.7×10^{-10} mol dm^{-3} s^{-1}

AND $c = 0.4 \times 10^{-7}$ mol dm^{-3},

gradient = 1.8×10^{-10} mol dm^{-3} s^{-1}

For chosen method, conclude that the reaction is 1st order wrt CV.

Rate at 180 seconds

Gradient in range (2.5 to 3.0) $\times 10^{-10}$

rate as gradient with units: mol dm^{-3} s^{-1}

OR $k = \frac{\ln 2}{t½} = 4.6 \times 10^{-3}$ s^{-1}

And k substituted into rate equation.

e.g.

Rate = k [CV]

Rate = 0.00462 x 0.61 x10^{-7}

= 2.8 x 10^{-10} mol dm^{-3} s^{-1}

Determination of k

k clearly linked to rate **OR** half-life:

e.g. $k = \frac{\text{rate}}{[CV]} = \frac{2.75 \times 10^{-10}}{0.62 \times 10^{-7}} = 4.4 \times 10^{-3}\ s^{-1}$

k in range (4.0 to 4.8) x 10^{-3} s^{-1}

OR e.g. $k = \frac{\ln 2}{t_{½}} = 0.28\ min^{-1}$ **OR** 4.6 x 10^{-3} s^{-1}

Units of k: s^{-1}

Q59 · Rate equations · [1 mark]

Answer: **B**

OCR MARK SCHEME

+133

EXAMINER GUIDANCE

ALLOW *+133 (correct numerical answer)*

Q60 · Rate equations · [1 mark]

Answer: **C**

112

Q61 · Rate equations · [1 mark]

Answer: **B**

rate = k[H_2] [ICl]

Q62 · Rate equations · [1 mark]

Answer: **C**

OCR MARK SCHEME

2

EXAMINER GUIDANCE

ALLOW *2 in the answer box*

Q63 · Rate equations · [9 marks]

OCR MARK SCHEME

20(a)(i)

To keep [CH_3OH] (effectively) constant

OR

Zero order with respect to CH_3OH

OR

To ensure equilibrium is far to the right ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *Change in [CH_3OH] is negligible*

ALLOW *rate is independent of [CH_3OH]*

IGNORE *Methanol doesn't run out/is not limiting reagent.*

20(a)(ii)

One half-life $t_{½}$ between 102 and 110 (mins)

Two half-lives calculated **OR** evidence on the graph of two half-lives

AND

constant half-life/values (means first order) ✓

[2 marks]

ALLOW *any two combinations of positions, e.g. 5 and 2.5* ***AND*** *4 and 2* ***AND*** *3 and 1.5*

20(a)(iii)

Using gradients

Evidence of tangent at t = 0 and intercept between 100 -140 (min) ✓

ALLOW ECF *from value of $t_{½}$ in (a)(ii)*

Correctly calculated gradient in the range of 2.9×10^{-5} to 4.0×10^{-5} (mol dm^{-3} min^{-1}) ✓

OR

Using half-life

For $t_{½}$ = 106 min, $k = \frac{\ln 2}{t_{½}} = 0.00654$ (min^{-1}) ✓

rate = $0.00654 \times 5 \times 10^{-3} = 3.27 \times 10^{-5}$ (mol dm^{-3} min^{-1}) ✓

[2 marks]

20(b)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 7.4 award 4 marks

Initial moles of reactants 1 mark

$n(CH_3OH)_{initial} = \frac{9.6}{32} = 0.3$ (mol)

AND

$n(CH_3COOH)_{initial} = \frac{12}{60} = 0.2$ (mol) ✓

Equilibrium moles 2 marks

$n(CH_3COOH)$ reacted = 0.2 – 0.03 = 0.17 (mol)

AND

$n(CH_3OH)_{equil}$ = 0.3 – 0.17 = 0.13 (mol) ✓

$n(CH_3COOCH_3)_{equil}$ = 0.17 (mol)

AND

$n(H_2O)_{equil}$ = 0.17 (mol) ✓

K_c calculation 1 mark

$$K_c = \frac{\frac{0.17}{V} \times \frac{0.17}{V}}{\frac{0.13}{V} \times \frac{0.03}{V}} = 7.4$$ ✓

[4 marks]

ALLOW *minimum of 2SF throughout*

ALLOW ECF *from initial moles*

ALLOW ECF *from equilibrium moles*

Use of V not required but K_c expression must be correct

ALLOW *up to calculator answer of 7.41025641*

Q64 · Rate equations · [1 mark]

Answer: **D**

+457

Q65 · Rate equations · [10 marks]

OCR MARK SCHEME

21(a)(i)

(Expt 1 and 2)

$[S_2O_3^{2-}]$ halves, ($[H^+]$ constant),

AND rate halves

AND first order (with respect to $[S_2O_3^{2-}]$) ✓

(Expt 2 and 3)

$[S_2O_3^{2-}]$ quarter **AND** $[H^+]$ halves,

AND rate quarters

AND zero order (with respect to $[H^+]$) ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW ORA i.e.

(Expt 2 and 1)

$[S_2O_3^{2-}]$ doubles, ($[H^+]$ constant),

AND rate doubles

AND first order with respect to $[S_2O_3^{2-}]$

ALLOW *comparison of Expt 1 and 3:*

$[S_2O_3^{2-}] \times 1/8$ **AND** $[H^+]$ halves,

AND rate × 1/8

AND zero order with respect to $[H^+]$

21(a)(ii)

$S_2O_3^{2-}$ as only reactant species in step 1 ✓

Step 1: $S_2O_3^{2-} \rightarrow S + SO_3^{2-}$

Rest of mechanism correct ✓

[2 marks]

Step 2 $SO_3^{2-} + 2H^+ \rightarrow SO_2 + H_2O$

OR

Step 1 $S_2O_3^{2-} \rightarrow SO_2 + SO^{2-}$

Step 2 $SO^{2-} + 2H^+ \rightarrow S + H_2O$

21(b)(i)

Gradient

gradient in range of –5700 to –6100 ✓

E_a calculation

E_a = (–) gradient × 8.314

e.g. from –5900, E_a = (+) 49052.6 (J mol^{-1}) ✓

E_a to 3SF and in kJ mol^{-1} ✓

e.g. 49.1 (kJ mol^{-1})

[3 marks]

Marks are for intermediate calculations

ALLOW ECF *from an incorrect gradient*

ALLOW ECF *on missing × 10^{-3},*

e.g. **ALLOW** 2 marks for:

gradient = –5.9,

leading to E_a = 49.0526 (J mol^{-1})

AND 0.0491 (kJ mol^{-1})

DO NOT ALLOW *a negative E_a*

21(b)(ii)

ln *A* is intercept at 0 when $\frac{1}{T}$ **OR** x axis is 0 ✓

[1 mark]

21(b)(iii)

ln k

ln k = –2.59 ✓

Temperature

$\frac{1}{T}$ = 3.10 × 10^{-3} (s^{-1})

T = 49.6 °C ✓

[2 marks]

Correct T scores 2 marks

ALLOW ECF *for 1/T from incorrect lnK shown on the graph*

ALLOW in the range

1/*T* = 3.09 – 3.11 (× 10^{-3} s^{-1})

T = 48.5 to 50.6 °C

ALLOW *T = 50 °C*

Q66 · Rate equations · [11 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

4(a)

(Large) excess of pent-1-ene

OR

There is a (large) excess ✓

[1 mark]

ALLOW

pent-1-ene concentration is (much) greater

OR

pent-1-ene has a high concentration

4(b)

Level 3 (5–6 marks)

Obtains a comprehensive conclusion to determine

initial rate AND order AND rate constant *k*

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)

Obtains a sound, but not comprehensive conclusion, to determine

initial rate AND order

OR order AND rate constant *k*

OR initial rate AND rate constant *k*

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)

Indicative scientific points may include:

Initial rate

- Evidence of tangent on graph drawn to line at *t* = 0 s **AND** gradient determined in range 4.5 – 6.5 × 10^{-6}
- initial rate expressed as gradient value with units of mol dm^{-3} s^{-1}, e.g. initial rate = 5.5 × 10^{-6} mol dm^{-3} s^{-1}

Reasoned order of I_2

Half lives

- Half life measured on graph **OR** within text **OR** stated in range 2500 ±10 s
- Constant half life **OR** two stated half lives within ±10 s **AND** conclusion that I_2 is 1st order

OR

Obtains a simple conclusion to determine

initial rate OR order

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]

Comparison of rates from gradients

- Rate measured as gradient at a concentration, *c*
- Rate measured at *c*/2
- *c* halves and rate halves
- so order 1

e.g. initial rate at c = 0.02 = 5.5×10^{-6} mol dm^{-3} s^{-1}

rate at c = 0.01 = 2.58×10^{-6} mol dm^{-3} s^{-1}

Determination of *k* with units

- Rate constant *k* clearly linked to initial rate **OR** half-life:

$k = \frac{\text{rate}}{[I_2]}$ **OR** $k = \frac{\ln 2}{t_{1/2}}$

- *k* determined correctly from measured initial rate or measured half life with units of s^{-1},

e.g. $k = \frac{5.5 \times 10^{-6}}{0.02} = 2.75 \times 10^{-4}\ s^{-1}$

from initial rate of 5.5×10^{-6} mol dm^{-3} s^{-1} **OR** from $t_{1/2}$ of 2500 s

- Typical range $2.25–3.25 \times 10^{-4}$

4(c)(i)

Reactants for 1st step: $CH_3CH_2CH_2CH{=}CH_2 + I_2$ ✓

2 steps that add up to overall equation:

$CH_2CH_2CH{=}CH_2 + I_2 \rightarrow CH_3CH_2CH_2CHICH_2I$ ✓

e.g.

$CH_3CH_2CH_2CH{=}CH_2 + I_2 \rightarrow CH_3CH_2CH_2CHICH_2^+ + I^-$

$CH_3CH_2CH_2CHICH_2^+ + I^- \rightarrow CH_3CH_2CH_2CHICH_2I$

[2 marks]

ALLOW *mechanism for electrophilic addition shown.*

IGNORE *state symbols*

Must be based on slow step, i.e. 2nd mark dependent on correct slow step:

$CH_3CH_2CH_2CH{=}CH_2 + I_2$

IGNORE *actual positioning of + charge*

ALLOW

$\rightarrow CH_3CH_2CH_2CHICH_2 + I$ (no charge)

$CH_3CH_2CH_2CHICH_2 + I \rightarrow$

4(c)(ii)

Repeat experiment with $[I_2]$ constant/kept the same

OR use (large) excess of I_2 ✓

Monitor/measure/plot $[CH_3CH_2CH_2CH{=}CH_2]$ over time

OR

Monitor/measure how $[CH_3CH_2CH_2CH{=}CH_2]$ affects rate ✓

[2 marks]

ALLOW *I_2 in (great) excess*

ALLOW *initial rates approach of running several experiments with different concentrations of $CH_3CH_2CH_2CH{=}CH_2$*

i.e. Measure initial rates for each experiment

AND double concentration → rate doubles

Q67 · Redox and electrode potentials · [1 mark]

Answer: **C**

Only 2 and 3

Q68 · Redox and electrode potentials · [9 marks]

OCR MARK SCHEME

22(a)(i)

Circuit: complete circuit **AND** voltmeter

AND labelled salt bridge linking two half-cells ✓

Half cells: Pt **AND** Fe^{2+} **AND** Fe^{3+} ✓

Zn **AND** Zn^{2+} ✓

EXAMINER GUIDANCE

Electrodes / salt bridge must at least touch the surface

ALLOW *small gaps in circuit wires*

ALLOW *half cells drawn either way around*

ALLOW *1 mol/dm^3* ***OR*** *1 M*

Standard conditions:

1 mol dm^{-3} (solution(s))

AND 298 K / 25°C ✓

[4 marks]

ALLOW *1 mol dm^{-3}/1M if omitted here but shown for just one solution in diagram*

IGNORE *pressure*

DO NOT ALLOW *1 mol(e) for concentration*

22(a)(ii)

1.53 (V) ✓

[1 mark]

IGNORE *sign*

22(b)

strongest reducing agent: Zn ✓

strongest oxidising agent: MnO_4^- ✓

[2 marks]

NOTE: *H^+ has been ignored*

22(c)

AWARD 2 marks for correct balancing **AND** all species cancelled on both sides of equation:

$2MnO_4^- + 6H^+ + 5SO_3^{2-} \rightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$ ✓ ✓

AWARD 1 mark for correct balancing but not all species (H_2O, H^+) cancelled on both sides of equation ✓

e.g. $2MnO_4^- + 16H^+ + 5SO_3^{2-} + 5H_2O \rightarrow 2Mn^{2+} + 8H_2O + 5SO_4^{2-} + 10H^+$

[2 marks]

ALLOW *correct multiples*

e.g. $MnO_4^- + 3H^+ + 2½SO_3^{2-} \rightarrow Mn^{2+} + 1½H_2O + 2½SO_4^{2-}$

IGNORE *state symbols*

e.g.

$MnO_4^- + 8H^+ + 2½SO_3^{2-} + 2½H_2O \rightarrow Mn^{2+} + 4H_2O + 2½SO_4^{2-} + 5H^+$

Q69 · Redox and electrode potentials · [1 mark]

Answer: **D**

$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$

Q70 · Redox and electrode potentials · [20 marks]

OCR MARK SCHEME

20(a)

ASSUME trend is down the group

(unless stated otherwise)

Forces

London forces increase

OR induced dipole(–dipole) interactions increase ✓

Reason

(Number of) electrons increases ✓

Link to energy and particles

More energy to break intermolecular forces

OR

to break London forces

OR

to break induced dipole(–dipole) interactions ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW *reverse argument throughout*

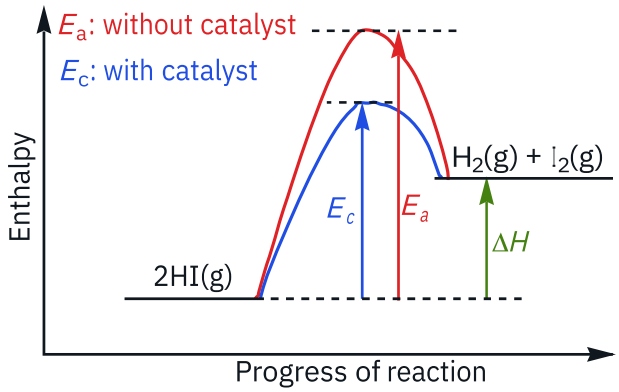
IGNORE *van der Waals'/vdW forces*

DO NOT ALLOW *hydrogen bonds* ***OR*** *permanent dipole(-dipole) interactions for first and third marking points*

ALLOW *more (electron) shells*

DO NOT ALLOW *covalent bonds break*

20(b)



2HI(g) on LHS **AND** $H_2(g) + I_2(g)$ on RHS ✓

ΔH labelled with product above reactant

AND arrow upwards ✓

E_a **AND** E_c correctly labelled with E_c below E_a ✓

[3 marks]

Mark each point independently

IGNORE *state symbols.*

ΔH: DO NOT ALLOW $-\Delta H$.

ALLOW *ΔH arrow even with a gap at the top and bottom, i.e. does not quite reach reactant or product line*

E_a: **ALLOW** no arrowhead or arrowheads at both ends of E_a line

E_a line must reach (near or not too far beyond) maximums regardless of position

ALLOW *AE or EA for E_a*

Exothermic diagram can access the first and third marks

20(c)

FIRST CHECK THE ANSWER ON THE ANSWER LINE

IF M = 183 AND Formula = Cl_2O_7 award 4 marks

IF M = 183 award 3 marks

Use of data and unit conversions

- (R = 8.314)
- T in K: 373K
- V in m^3: 76.0×10^{-6}
- (p in Pa: 1.00×10^5) ✓

Calculation of n

$$n = \frac{(1.00 \times 10^5) \times (76.0 \times 10^{-6})}{(8.314 \times 373)}$$

$n = 2.45 \times 10^{-3}$ (mol) ✓

Molar mass

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

Correct value of n subsumes first mark

ALLOW ECF *from incorrectly calculated n*

ALLOW ECF *from incorrect M if formula of Cl_xO_y is the closest to the with calculated value of M*

IGNORE *use of 24 000 cm^3 for calculation of n*

BUT then Mark molar mass and Molecular formula by **ECF** for two marks maximum.

$$n = \frac{76.0}{24000} = 3.17 \times 10^{-3} \text{ (mol)}$$

$$M = \frac{0.4485}{3.17 \times 10^{-3}} = 141.6/141.5 \text{ (g mol}^{-1}\text{)}$$ ✓

Molecular formula = Cl_3O_2 ✓

$M = \frac{m}{n} = \frac{0.4485}{2.45 \times 10^{-3}} = 183\ (g\ mol^{-1})$ ✓

Molecular formula

Cl_2O_7 ✓

[4 marks]

20(d)(i)

Titres correct and ALL recorded to 2 decimal places

Titre: 24.00 23.40 23.75 23.85 ✓

mean titre = 23.80 (cm^3) ✓

[2 marks]

ALLOW *23.8 cm^3*

20(d)(ii)

Percentage uncertainty = $\frac{0.05 \times 2}{23.40} \times 100 = 0.43$ (%) ✓

[1 mark]

ALLOW ECF *from incorrect subtraction in (i) or incorrect mean*

ALLOW *0.42% from titre values 2, 3 or 4 or mean titre or trial titre.*

2 DP required

20(d)(iii)

Add starch (near the end point) ✓

Blue to colourless ✓

[2 marks]

ALLOW *blue/black* ***OR*** *black* ***OR*** *purple for colour of mixture*

ALLOW *blue colour disappears (to colourless)*

IGNORE *'clear'*

IGNORE *'colorimetry'*

20(d)(iv)

FIRST CHECK THE ANSWER ON THE ANSWER LINE

IF B = $RbIO_3$ AND relative formula mass = 260.5 award 5 marks

IF relative formula mass = 260.5 award 4 marks

$n(S_2O_3^{2-})$ in titration

$= \frac{0.150 \times 23.80}{1000} = 3.57 \times 10^{-3}$ (mol) ✓

$n(IO_3^-)$ in titration

$= \frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4}$ (mol) ✓

$n(IO_3^-)$ in original 250 cm^3

$= 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3}$ (mol) ✓

Relative formula mass of B

$= \frac{1.55}{5.95 \times 10^{-3}} = 260.5\ (g\ mol^{-1})$ ✓

Formula of B (must be derived from relative formula mass)

Iodate of Group 1 metal that most closely matches calculated molar mass of B

Formula from 260.5 = $RbIO_3$ ✓

[5 marks]

ALLOW ECF *from incorrect mean titre in (a)(i)*

ECF *from $n(S_2O_3^{2-})$ in titration*

ALLOW *a two-step calculation*

$n(I_2) = \frac{n(S_2O_3^{2-})}{2}$ and $n(IO_3^-) = \frac{n(I_2)}{3}$

ECF *from $n(IO_3^-)$ in titration*

ECF *from $n(IO_3^-)$ in original 250 cm^3*

IF *scaling × 10 is omitted,*

ALLOW ECF *from $n(IO_3^-)$ in titration*

ALLOW ECF *from incorrect RFM of B provided metal is from Group 1*

ALLOW *$RbIO_3^-$*

DO NOT ALLOW *$RbIO_3$ without relative formula mass value.*

DO NOT ALLOW *260.4 (without working) and $RbIO_3$*

IF B *= $RbIO_3$ AND relative formula mass = 261 award 5 marks*

Q71 · Redox and electrode potentials · [10 marks]

OCR MARK SCHEME

3(a)

Overall 3– charge shown (outside brackets) for at least **ONE** isomer ✓

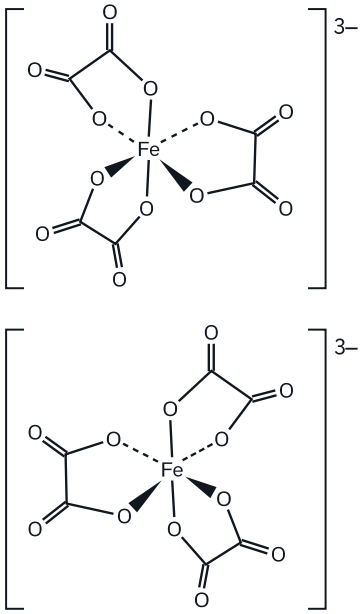
3– must apply to the overall charge of structures

EXAMINER GUIDANCE

ALLOW *–3 for 3–*

IGNORE *charges or dipoles on atoms within diagrams (even if wrong)*

Square brackets **NOT** required



1 mark for each isomer ✓✓

- Bonds **must** go to O ligand atoms on **EACH** structure
- **ALLOW** unambiguous structures; ethanedioate ions can include C atoms

[3 marks]

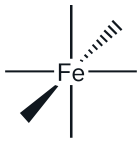
3D

Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':

For bond into paper, **ALLOW**:



ALLOW *following geometry throughout:*



NOT ALLOW *structures showing a simplified loop for ethanedioate ligands*

e.g.



3(b)(i)

Colourless to yellow ✓

[1 mark]

IGNORE *clear for colourless*

3(b)(ii)

Mean titre 1 mark

$= \frac{(23.15 + 23.25)}{2} = 23.2(0)\ (cm^3)$ ✓

Analysis of results 5 marks

$n(Ce^{4+}) = \frac{23.20 \times 0.0500}{1000} = 1.16 \times 10^{-3}$ (mol) ✓

$n((COOH)_2)$ in 25.0 $cm^3 = \frac{1.16 \times 10^{-3}}{2} = 5.8(0) \times 10^{-4}$ (mol) ✓

$n((COOH)_2)$ in 250 cm^3

$= 5.8(0) \times 10^{-4} \times 10 = 5.8(0) \times 10^{-3}$ (mol) ✓

Mass $(COOH)_2 = 5.8(0) \times 10^{-3} \times 90.0 = 0.522$ g ✓

% oxalic acid $= \frac{0.522 \times 100}{82.68} = 0.631\%$ ✓

Percentage **MUST** be expressed to **3 SF**

[6 marks]

Common error:

Incorrect mean from all 3 titres = 23.30 cm^3

Use ECF throughout

Intermediate values for working to **at least 3 SF.**

TAKE CARE as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited.

COMMON ERRORS:

Mean of 23.30 (use of all 3 titres)

→ 0.634%: 5 marks

TAKE CARE for final answer of 0.63 seen.

- No final mark as only 2 SF
- 0.63 may have been rounded from 0.631 (from correct mean)

OR from 0.634 (using mean from all 3 titres)

Check back to mean titre.

No ÷2 to obtain $n((COOH)_2)$

→ 1.26%: 5 marks from 23.20

→ 1.27% 4 marks from 23.30

Q72 · Redox and electrode potentials · [1 mark]

Answer: **C**

Only 2 and 3

Q73 · Redox and electrode potentials · [18 marks]

OCR MARK SCHEME

18(a)(i)

$[Cr(NH_3)_6]^{3+}(aq)$ ✓

[1 mark]

18(a)(ii)

$CrCl_3(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3NaCl(aq)$

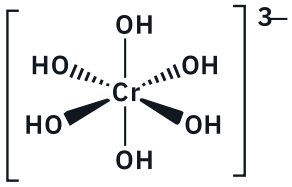
or

$Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ ✓

state symbols required

[1 mark]

18(a)(iii)



3-D diagram with all bonds through O in OH ✓

3– charge ✓

[2 marks]

18(a)(iv)

CrO_4^{2-} ✓

[1 mark]

18(a)(v)

orange ✓

[1 mark]

18(b)(i)

$(1s^2)2s^22p^63s^23p^63d^2$ ✓

[1 mark]

18(b)(ii)

Explanation of colours

VO^{2+} goes to V^{3+} (green) **AND** then V^{3+} goes to V^{2+} (violet) ✓

Explanation using $E^{\ominus}$ values

($E^{\ominus}$ of) system 4 (VO^{2+}/V^{3+}) is more positive / less negative than system 2 (Fe^{2+}/Fe)

OR

($E^{\ominus}$ of) system 3 (V^{3+}/V^{2+},) is more positive / less negative than system 2 (Fe^{2+}/Fe) ✓

Equilibrium shift related to $E^{\ominus}$ values

More positive/less negative system 4 (VO^{2+}/V^{3+}) shifts right

AND

EXAMINER GUIDANCE

IGNORE *state symbols*

IGNORE *square brackets around precipitate formulae*

ALLOW

$[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq)$
$\rightarrow Cr(OH)_3(H_2O)_3(s) + 3H_2O(l)$

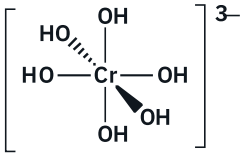
ALLOW *'hybrid' equations,*

Eg $Cr^{3+}(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3Na^+(aq)$

$[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s) + 6H_2O(l)$

$[Cr(H_2O)]_6^{3+}(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 6H_2O(l) + 3Na^+(aq)$

Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':



ALLOW *dotted line* ***OR*** *unfilled wedge as alternatives for dotted wedge*

IGNORE *charges inside brackets*

IGNORE *compounds e.g.* Na_2CrO_4

ALLOW *upper case D, etc. and subscripts, e.g.* $3D_2$

If included, ***ALLOW*** $4s^0$

IGNORE *'lower/higher'*

ALLOW *reverse argument System 2 more negative than system 4 etc*

E = (+)0.78 V for system 4 + system 2 reaction

OR

E = (+)0.18 V for system 3 + system 2 reaction

For shifts right'

ALLOW *(VO^{2+}) is reduced* ***OR*** *gains electrons (maybe seen as an equation)*

AND

'For shifts right'

More positive/less negative system 3 (V^{3+}/V^{2+}) shifts right

[3 marks]

ALLOW *(V^{3+}) is reduced* ***OR*** *gains electrons (maybe seen as an equation)*

IGNORE *Fe oxidised*

18(b)(iii)

$Fe + 4H^+ + 2VO^{2+} \rightarrow Fe^{2+} + 2H_2O + 2V^{3+}$

[1 mark]

IGNORE *state symbols*

ALLOW *multiples*

ALLOW *'⇌'*

18(c)(i)

(0.00200 mol dm^{-3} solution gives) a large titre which leads to a small (percentage) error / uncertainty ✓

[1 mark]

ALLOW *(0.0200 mol dm^{-3} solution gives) a small titre which leads to a large (percentage) error / uncertainty*

Assume 'it' means dilute solution

ALLOW *13.50 cm^3 gives a lower percentage error than 1.35 cm^3*

18(c)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 301 mg award 5 marks

$n(MnO_4^-) = \frac{13.50}{1000} \times 0.00200 = 2.7(0) \times 10^{-5}$ (mol) ✓

$n(Fe^{2+})$ (in.25.0 cm^3) = $2.7(0) \times 10^{-5} \times 5 = 1.35 \times 10^{-4}$ (mol) ✓

$n(Fe^{2+})$ (in 250 cm^3) = $1.35 \times 10^{-4} \times 10 = 1.35 \times 10^{-3}$ ✓

Mass $C_{12}H_{22}FeO_{14}$ in 2 tablets

= $1.35 \times 10^{-3} \times 445.8 = 0.6018$ (g) ✓

Mass $C_{12}H_{22}FeO_{14}$ in 1 tablet = 301 (mg)

AND to 3 SF ✓

[5 marks]

ALLOW ECF *throughout*

ALLOW *working to 3SF minimum throughout*

Common errors

602 (mg) (not dividing by 2) = 4 marks

37.7 (using 55.8 instead of 445.8) = 4 marks

Last mark involves dividing by two and converting g to mg. These steps may be seen earlier

18(c)(iii)

A: Mass Fe = $\frac{180 \times 55.8}{151.8}$ = 66 mg

B: Mass Fe = $\frac{210 \times 55.8}{169.8}$ = 69 mg

Iron supplement:

B provides more Fe per tablet ✓

[1 mark]

ALLOW *correct working if iron supplement is not named*

ALLOW *iron(II) fumarate or $C_4H_2FeO_4$*

Q74 · Redox and electrode potentials · [13 marks]

OCR MARK SCHEME

2(a)(i)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 2.19×10^{-3} award 3 marks

$n(Cl_2) = \frac{420}{24}$ = 17.5 (mol) ✓

$n(Ca(ClO)_2) = \frac{17.5}{2}$ = 8.75 (mol) ✓

Concentration $Ca(ClO)_2 = \frac{8.75}{4 \times 1000}$

= 2.19×10^{-3} (mol dm^{-3}) ✓

3SF AND standard form

[3 marks]

EXAMINER GUIDANCE

Use of ideal gas equation for all 3 marks provided 'sensible' *p* and *T* used:

e.g.

from 101 kPa and 298 K

→ *n* = 17.122 → 2.14×10^{-3}

from 100 kPa and 298 K

→ *n* = 16.952 → 2.12×10^{-3}

Examples of 'sensible'

p = 100 kPa, 101 kPa, 101,325 Pa

T = 273 – 298 K

ALLOW ECF

Common errors

4.38×10^{-3} (no ÷ 2) → 2 marks

2.19×10^{n} → 2 marks

4.38×10^{n} → 1 mark

2.2×10^{-3} → 2 marks

not appropriate SF

2(a)(ii)

Equation

$3Ca(ClO)_2 \rightarrow 2CaCl_2 + Ca(ClO_3)_2$ ✓

Reduction

Cl reduced from +1 to –1 ✓

Oxidation

Cl oxidised from +1 to +5 ✓

+1 starting oxidation number seen once

Cl required for both explanation marks

IGNORE *oxidation numbers shown below/above equation (treat as rough working)*

BUT

If no oxidation numbers in explanation, look at equation for oxidation numbers

[3 marks]

ALLOW *multiples*

ALLOW *$3ClO^- \rightarrow 2Cl^- + ClO_3^-$*

ALLOW *1 out of 2 redox marks if oxidation number changes are BOTH correct ...BUT reduction/oxidation is incorrectly assigned, i.e.*

Cl is oxidised from +1 to –1

Cl is reduced from +1 to +5

ALLOW *1 out of 2 redox marks if oxidation changes correct but red and ox not stated*

Cl changes from +1 to –1

Cl changes from +1 to +5

General:

ALLOW number before sign in ox no, e.g. *1– for –1*

IGNORE *ionic charges, e.g. Cl^{5+}*

IGNORE *'1' (signs required)*

IGNORE *references to electron loss/gain (even if wrong)*

2(b)

6 marking points → 5 MAX

ALLOW *labels 1, 2 and 3; A, B and C, etc, provided that meaning is clear*

ALLOW *reverse argument (**ORA**) throughout*

For equations, **ALLOW** multiples

In equations, **ALLOW** ⇌ for →

ALLOW *$Cr_2O_7^{2-}$ is oxidising agent if linked to C_2H_5OH as reactant in equation*

ALLOW *Cr^{6+} for $Cr_2O_7^{2-}$*

ALLOW *$Cr_2O_7^{2-}$ is reduced by C_2H_5OH*

In explanation,

look for CONs between '**OR**' statements

ALLOW *Cr^{3+} is reducing agent if clearly linked to FeO_4^{2-} as reactant in equation*

ALLOW *Fe^{6+} for FeO_4^{2-}*

ALLOW *Cr^{3+} is oxidised by FeO_4^{2-}*

In explanation,

look for CONs between '**OR**' statements

Oxidising agent AND equation

$Cr_2O_7^{2-}$ is oxidising agent with C_2H_5OH /oxidises C_2H_5OH ✓

$Cr_2O_7^{2-} + 8H^+ + 3C_2H_5OH \rightarrow 2Cr^{3+} + 7H_2O + 3CH_3CHO$ ✓

Explanation for $Cr_2O_7^{2-}/Cr^{3+}$ and CH_3CHO/C_2H_5OH

E for $Cr_2O_7^{2-}/Cr^{3+}$ is more +ve /higher /greater

OR

E_{cell} = (+)1.527 V *+ sign not required*

OR

$Cr_2O_7^{2-}/Cr^{3+}$ equilibrium shifts right ✓

Reducing agent AND equation

Cr^{3+} is reducing agent with FeO_4^{2-} /reduces FeO_4^{2-} ✓

$2Cr^{3+} + 2H^+ + 2FeO_4^{2-} \rightarrow Cr_2O_7^{2-} + H_2O + 2Fe^{3+}$ ✓

Explanation for $Cr_2O_7^{2-}/Cr^{3+}$ and FeO_4^{2-}/Fe^{3+}

E for $Cr_2O_7^{2-}/Cr^{3+}$ is less +ve (*E*) / lower /smaller

OR

E_{cell} = (+)0.87 V *+ sign not required*

OR

$Cr_2O_7^{2-}/Cr^{3+}$ equilibrium shifts left ✓

[5 marks]

Note on equations

There are 2 marks for the equations with H^+, H_2O and e^- cancelled down

ALLOW *1 mark for 2 'correct' equations where H^+, H_2O and e^- have **NOT** all been cancelled down.*

e.g. 1 mark from 2 uncancelled equations

$Cr_2O_7^{2-} + 14H^+ + 3C_2H_5OH \rightarrow 2Cr^{3+} + 6H^+ + 7H_2O + 3CH_3CHO$

2(c)

$5H_2S + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$

OR

$40\ H_2S + 16MnO_4^- + 48\ H^+ \rightarrow 16Mn^{2+} + 5S_8 + 64\ H_2O$

Any FIVE correct species ✓

Correct balanced equation ✓

[2 marks]

$2Cr^{3+} + 2H^+ + 2FeO_4^{2-} + 6e^- \rightarrow Cr_2O_7^{2-} + H_2O + 2Fe^{3+} + 6e^-$

ALLOW *multiples*

e.g.

$2½\ H_2S + MnO_4^- + 3H^+ \rightarrow Mn^{2+} + 2½\ S + 4H_2O$

$20H_2S + 8MnO_4^- + 24\ H^+ \rightarrow 8Mn^{2+} + 2½\ S_8 + 32\ H_2O$

IGNORE *extra species containing: Mn, H, S and O ONLY*

BUT ALLOW $KMnO_4$ on LHS, forming K^+ on RHS

IGNORE *electrons*

IGNORE *state symbols*

Q75 · Redox and electrode potentials · [1 mark]

Answer: **C**

The overall cell reaction is: $Li + CoO_2 \rightarrow LiCoO_2$

Q76 · Redox and electrode potentials · [15 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

21(a)

$2Ba + O_2 \rightarrow 2BaO$ ✓

$BaO + H_2O \rightarrow Ba(OH)_2$ ✓

Neutralisation

OR acid-base ✓

[3 marks]

ALLOW *multiples*

IGNORE *state symbols, even if incorrect*

ALLOW *$Ba + H_2O \rightarrow BaO + H_2$ (reaction with steam)*

ALLOW *other correct equations e.g. with less reactive metal oxide*

21(b)

FIRST CHECK ANSWER ON ANSWER LINE

If answer = 84 award 4 marks

$n(I^-) = \frac{26.2 \times 0.150}{1000} = 3.93 \times 10^{-3}$ ✓

$n(IO_3^-) = \frac{3.93 \times 10^{-3}}{5} = 7.86 \times 10^{-4}$ ✓

mass KIO_3 in 2 tablets = $7.86 \times 10^{-4} \times 214 = 0.168204$ g ✓

mass KIO_3 in 1 tablet = 0.084102 g = 84 mg (nearest whole number) ✓

[4 marks]

ALLOW *3 SF or more throughout*

ALLOW *ECF throughout*

Care – other sequence of calculations can be valid.

Alternative route

M3 mol (IO_3^-) in one tablet = $\frac{7.86 \times 10^{-4}}{2} = 3.93 \times 10^{-4}$

M4 Mass (KIO_3) in one tablet = $3.93 \times 10^{-4} \times 214 = 84$

Final answer must be a whole number

Common Errors

3 marks:

69 mg (using M_r of IO_3^-)

421mg (not divided by 5)

21(c)

Complete circuit **AND** voltmeter

AND labelled salt bridge linking two half-cells ✓

Pt **AND** Fe^{2+} **AND** Fe^{3+} ✓

Pt **AND** H_2 **AND** H^+ **AND** delivery system for H_2 gas ✓

Standard conditions

1 mol dm^{-3}

AND

Electrodes / salt bridge must at least touch the surface of solutions

ALLOW *small gaps in circuit wires*

ALLOW *half-cells drawn on either side*

ALLOW *a formula of a strong acid for H^+*

For standard conditions:

Can be awarded if all quoted on standard condition line or in labelled diagram.

ALLOW *1M*

Temperature: 298 K / 25 °C

AND

Pressure: 1 atm / 100 kPa/101 kPa ✓

[4 marks]

ALLOW *equimolar solutions for* Fe^{2+} ***AND*** Fe^{3+} *only.*

i.e. need 1 mol dm^{-3} for $[H^+]$

IGNORE H_2SO_4 *in diagram unless concentration is stated with a value other than 0.5 mol* dm^{-3}

DO NOT ALLOW *if any concentration is incorrect*

21(d)(i)

$Li + CoO_2 \rightarrow LiCoO_2$ ✓

[1 mark]

ALLOW ⇌

DO NOT ALLOW *uncancelled species*

21(d)(ii)

Cell potentials:

($E^{\ominus}$) = 1.23 - 0.00 **OR** 1.23 (V)

OR (redox system 6 – redox system 3) = 1.23 (V)

AND

($E^{\ominus}$) = 0.40 – (–0.83) = 1.23 (V)

OR (redox system 4 – redox system 2) = 1.23 (V) ✓

Acidic

Cell equation

(2×) $H_2 \rightleftharpoons 2H^+ + 2e^-$

AND

$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$

AND

$2H_2 + O_2 \rightarrow 2H_2O$ ✓

Alkaline

Cell equation

(2×) $H_2 + 2OH^- \rightleftharpoons 2H_2O + 2e^-$

AND

$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$

AND

$2H_2 + O_2 \rightarrow 2H_2O$ ✓

[3 marks]

IGNORE *state symbols throughout*

ALLOW *multiples*

ALLOW ⇌

Overall equation

AND

with evidence of working:

e.g. half-equations written out / combined but not cancelled / with crossings out **OR** System 6 goes forward / reduced **OR** system 3 goes backwards / oxidised

ALLOW *multiples*

Overall equation

AND

with evidence of working:

e.g. half-equations written out / combined but not cancelled / with crossings out **OR** System 4 goes forward / reduced **OR** system 2 goes backwards oxidised

ALLOW *1 mark for both equations with uncancelled species.*

ALLOW *1 mark for System 6 / reduced goes forward and system 3 goes backwards oxidised* ***AND*** *System 4 / goes forward / reduced and system 2 / goes backwards / oxidised*

Q77 · Redox and electrode potentials · [1 mark]

Answer: **C**

$½O_2(g) + H_2O(l) + 2e^- \rightarrow 2OH^-(aq)$

Q78 · Redox and electrode potentials · [1 mark]

Answer: **B**

Mg(s)

Q79 · Redox and electrode potentials · [9 marks]

OCR MARK SCHEME

20(a)(i)

Circuit: complete circuit **AND** voltmeter

AND labelled salt bridge linking two half-cells ✓

Half cells Pt **AND** V^{2+} **AND** V^{3+} ✓

Zn **AND** Zn^{2+} ✓

Standard conditions:

1 mol dm^{-3} seen anywhere in response

EXAMINER GUIDANCE

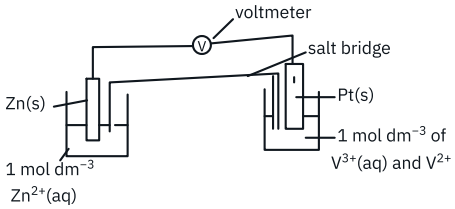
Electrodes / salt bridge must at least touch the surface

ALLOW *small gaps in circuit wires*

ALLOW *half cells drawn either way around*

AND 298 K / 25°C ✓

[4 marks]



ALLOW *1 M*

IGNORE *Equimolar for half cell 4*

IGNORE *1 mol / dm³*

IGNORE *pressure*

DO NOT ALLOW *1 mol(e) for concentration*

20(a)(ii)

(+)0.5(0) V ✓

[1 mark]

$E^{\ominus}_{cell}$ = −0.26 − (−0.76) = +0.5

DO NOT ALLOW *−0.5V*

20(b)

Equations

$Co + 2VO^{2+} + 4H^{+} \rightarrow Co^{2+} + 2V^{3+} + 2H_2O$ ✓

$Co + 2V^{3+} \rightarrow Co^{2+} + 2V^{2+}$ ✓

Comparison of *E* values

(*E* of) Co / system 3 is more negative/less positive than (*E* of) VO^{2+} / system 5

AND (*E* of) Co / system 3 is more negative/less positive than (*E* of) V^{3+} / system 4 ✓

Equilibrium shift related to *E* values (3/5 OR 3/4)

More negative/less positive (Co) / system 3 shifts left

AND

Less negative/more positive VO^{2+} / system 5 shifts right

OR Less negative/more positive V^{3+} / system 4 shifts right ✓

[4 marks]

ALLOW *multiples*

ALLOW ⇌

ALLOW *CO as Co*

IGNORE *state symbols even if wrong*

IGNORE *higher / lower electrode potential*

IGNORE *use of < / > for E comparison*

ALLOW E_{cell} *is (+)0.62V for Co / VO^{2+} cell*

AND E_{cell} is (+)0.02V for Co / V^{3+} cell

ALLOW *both half equations with <u>one</u> headed arrow (→) for each half equation in correct direction for systems 3/5* ***OR*** *systems 3/4*

e.g. $2H^{+} + VO^{2+} + e^{-} \rightarrow V^{3+} + H_2O$

AND

$Co \rightarrow Co^{2+} + 2e^{-}$

IGNORE *working on the table, treat as rough working*

Q80 · Redox and electrode potentials · [16 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

5(a)(i)

phenylmethanol ✓

[1 mark]

ALLOW *1-phenylmethanol, Phenylmethan-1-ol, 1-phenylmethan-1-ol*

DO NOT ALLOW

Hydroxymethylbenzene **OR** methylphenol

5(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If mass $LiAlH_4$ = 4.96 OR 4.97 g

AND % yield = 77.6 OR 77.5 (%) award 4 marks

Percentage yield 3 marks

Theoretical moles

$n(C_6H_5COOC_2H_5)$ **OR** $n(C_6H_5CH_2OH)$

$= \frac{7.50 \times 1.05}{150.0}$ **OR** 0.0525 (mol) ✓

Actual moles

$n(C_6H_5CH_2OH) = \frac{4.40}{108.0}$ **OR** 0.0407.... (mol) ✓

ALLOW ECF *for each step*

NOTE*: 7.50 × 1.05 = 7.875 g*

Alternative method using mass

1. Theoretical moles = 0.0525 mol

2. Mass = 0.0525 × 108.0 **OR** 5.67 g

3. % yield = $\frac{4.40}{5.67} \times 100 = 77.6\%$

Common errors

No density: $\frac{7.50}{150.0}$ = 0.0500 mol ✗

- % yield = 81.4 – 81.5% ✓✓ **ECF**
- $LiAlH_4$ mass = 4.74 g ✓ **ECF**

Calculator = 0.04074074074

% yield

$$\% \text{ yield} = \frac{0.0407....}{0.0525} \times 100 = 77.6\% \text{ (3 sig fig) ✓}$$

ALLOW *77.5 – 77.6 %*

taking into account rounding to 0.0407

÷ density: $\frac{7.50/1.05}{150.0} = 0.0476..$ ✗

- % yield = 85.5 – 85.6 % ✓✓ **ECF**
- $LiAlH_4$ mass = 4.46 g ✓ **ECF**

Mass of $LiAlH_4$ 1 mark

mass $LiAlH_4 = 0.0525 \times 2.5 \times 37.9 = 4.97$ ..... g ✓

Calculator = 4.974375 g

3SF

ALLOW *4.96 – 4.97 g*

3 SF

taking into account rounding to 0.131

[4 marks]

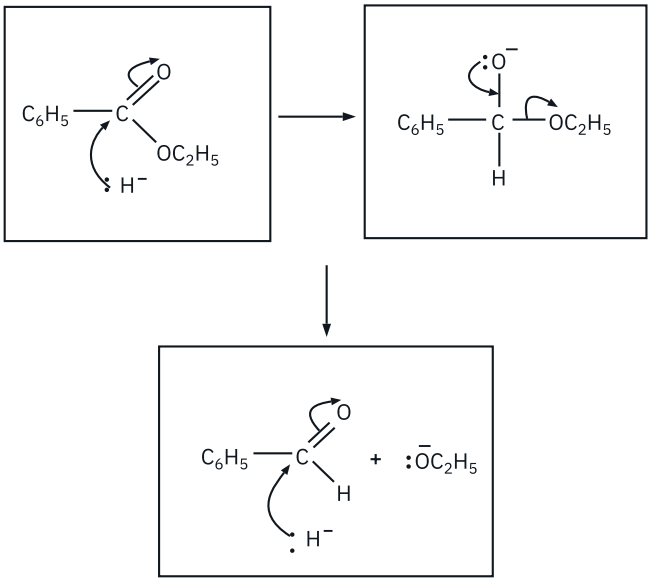
5(a)(iii)

Donates an electron pair (to another species) ✓

ALLOW *donates a lone pair*

[1 mark]

5(a)(iv)



IGNORE *any added charges* ***OR*** *dipoles.*

Marks solely for curly arrows

For each mark, an extra curly arrow is a CON

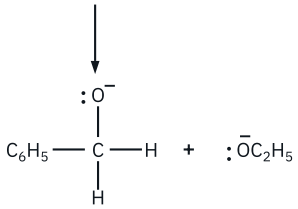
ALLOW *curly arrow from :*

OR from – charge on O^- or H^-

Curly arrow from a bond MUST go to O in C=O and in $-OC_2H_5$

IGNORE *any curly arrows on bottom structures (not in boxes):*

i.e.



6 curly arrows correct ✓✓✓✓

5 curly arrows correct ✓✓✓

4 curly arrows correct ✓✓

3 curly arrows correct ✓

Annotate incorrect or absent curly arrows first with x or ^

Helps to account for marks.

[4 marks]

5(a)(v)

H^+ adds to –ve ion/anion/O^-

OR

–ve ions are protonated

OR

Protonates the product (from Step 2)

OR

ALLOW *$O^- + H^+ \rightarrow OH$*

IGNORE *'to form an OH group/alcohol*

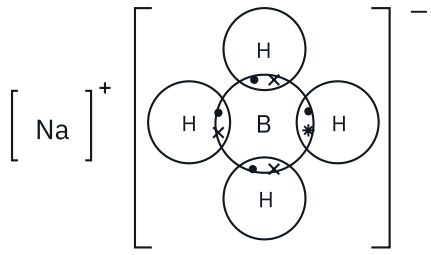
Must include idea of H^+ involved.

Provides H^+ to form the alcohol ✓

Needs idea of H^+ being gained/donated

[1 mark]

5(b)



8 electrons around B

AND 4 covalent bonds between B and 4 H atoms

AND Na with no electrons **OR** 8 electrons ✓

3 covalent bonds containing x or o **AND**

1 covalent bond containing x **OR** o **AND** extra Na electron shown differently **AND** charges ✓

ALLOW *dot and cross labels swapped:*

i.e. • for B electrons and × for H electrons

[2 marks]

NOT REQUIRED

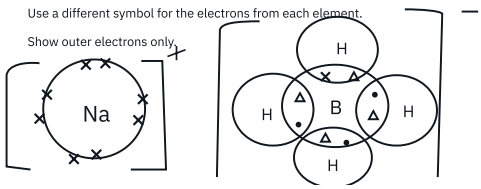
- Brackets
- Circles
- B and H symbols

IGNORE *inner shells*

DO NOT ALLOW ANY *marks for a covalent* $NaBH_4$

IF *8 electrons around Na, the 'extra' electron around B must match Na electrons*

ALLOW *other symbols than x and o provided that the origin of the electron is clear, e.g.*



5(c)(i)

–1.24 V ✓

[1 mark]

– sign required

5(c)(ii)

$NaBH_4 + OH^-$ on left-hand side

AND $NaBO_2 + H_2O$ on right-hand side ✓

Correct balanced equation with electrons ✓

$NaBH_4 + 8OH^- \rightarrow NaBO_2 + 6H_2O + 8e^-$

ALLOW 1 mark for 'correct equation' but wrong way *round, i.e.* $NaBO_2 + 6H_2O + 8e^- \rightarrow NaBH_4 + 8OH^-$

[2 marks]

ALLOW: $Na^+ + BH_4^-$ ***and*** Na^+ ***and*** BO_2^-

IGNORE O_2 *for the 1st mark only*

ALLOW *multiples*

IGNORE *state symbols*

For 2nd mark, any common species on both sides of equation needs to be cancelled

Q81 · Redox and electrode potentials · [1 mark]

Answer: **C**

1 : 1

Q82 · Redox and electrode potentials · [9 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

19(a)

Circuit

Complete circuit **AND** voltmeter

AND salt bridge linking two half-cells ✓

Half cells

Ag **AND** Ag^+ **AND** 1 mol dm^{-3} solution ✓

Pt **AND** H^+ **AND** MnO_4^- **AND** Mn^{2+}

AND 1 mol dm^{-3} /equimolar solution ✓

[3 marks]

Voltmeter must be shown **AND** salt bridge must be labelled

ALLOW *small gaps in circuit*

If species in BOTH half cells are correct but concentration of 1 mol dm^{-3} omitted,

ALLOW *1 mark for BOTH half cells.*

ALLOW *acidified as an alternative for H^+*

IGNORE *stated pressure*

Not relevant here as no gas

19(b)

Comparison of E values

E of redox system 4 (MnO_4^-/Mn^{2+}) is more positive/less negative than *E* of redox systems **2** (HCOOH/HCHO) **OR 1** (CO_2/HCOOH) ✓

Equilibrium shift related to *E* values

More negative/less positive/system 2 (HCOOH/HCHO) **OR** system 1 (CO_2/HCOOH) shifts left

OR

Less negative/more positive/system 4 (MnO_4^-/Mn^{2+}) shifts right ✓

- 2 and 4

$2MnO_4^- + 5HCHO + 6H^+ \rightarrow 2Mn^{2+} + 5HCOOH + 3H_2O$ ✓

- 1 and 4

$2MnO_4^- + 5HCOOH + 6H^+ \rightarrow 2Mn^{2+} + 5CO_2 + 8H_2O$ ✓

[4 marks]

IGNORE *higher/lower*

*ALLOW Overall $E_{reaction}$ = (+)1.54V **OR** (+)1.62V*

For 'shifts left', **ALLOW** 'is oxidised'

OR 'electrons are lost ' **OR** 'reducing agent'

For 'shifts right', **ALLOW** 'is reduced'

OR 'electrons are gained' **OR** 'oxidising agent'

IGNORE *state symbols*

ALLOW *multiples*

DO NOT ALLOW *un-cancelled species, e.g. H^+, on both sides*

ALLOW *for 1 mark two balanced equations with uncancelled species.*

ALLOW *combined equation for 2 marks:*

$4MnO_4^- + 5HCHO + 12H^+ \rightarrow 4Mn^{2+} + 5CO_2 + 11H_2O$

19(c)

$2H^+ + ½O_2 + 2e^- \rightarrow H_2O$ ✓

1.34 + (−0.11) = (+)1.23 (V) ✓

[2 marks]

IGNORE *state symbols*

ALLOW *multiples*

Q83 · Redox and electrode potentials · [1 mark]

Answer: **C**

$Cu^{2+}(aq)$

Q84 · Redox and electrode potentials · [11 marks]

OCR MARK SCHEME

19(a)(i)

Complete circuit with voltmeter

AND labelled salt bridge linking two half-cells ✓

EXAMINER GUIDANCE

Half cells can be drawn in either order

Half cells must show electrodes dipping into solutions

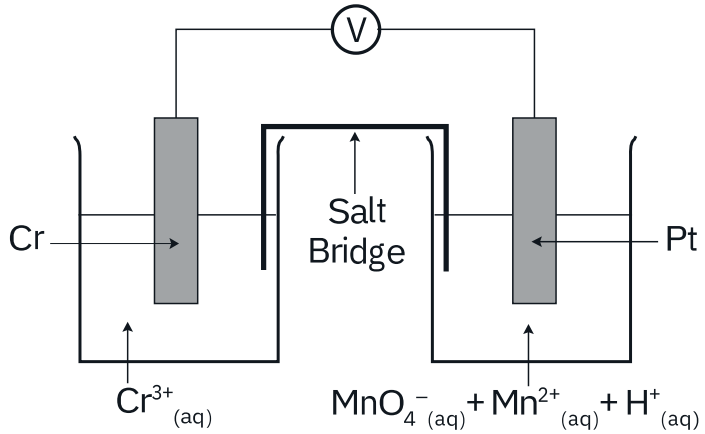
ALLOW *small gaps in circuit*

IGNORE *any stated concentrations*

IGNORE *state symbols*

In salt bridge, **ALLOW** any stated ion that may be present,

e.g. Cr^{3+}, MnO_4^-, Mn^{2+}, H^+



Cr electrode in Cr^{3+} ✓

Pt electrode in MnO_4^- **AND** H^+ **AND** Mn^{2+} ✓

[3 marks]

19(a)(ii)

$5Cr + 3MnO_4^- + 24H^+ \rightarrow 5Cr^{3+} + 3Mn^{2+} + 12H_2O$ ✓

[1 mark]

IGNORE *state symbols*

ALLOW *multiples*

19(b)(i)

Mn is oxidised from +6 (in MnO_4^{2-}) to +7 (in MnO_4^-) ✓

Mn is reduced from +6 (in MnO_4^{2-}) to +4 (in MnO_2) ✓

[2 marks]

IGNORE *'6' (signs required)*

ALLOW *after number, e.g. 5+*

ALLOW *1 mark for correct oxidation numbers but not linked to oxidation/reduction.*

IGNORE *any reference to electron loss/gain (even if wrong)*

19(b)(ii)

Explanation using $E^\ominus$ values

($E^\ominus$ of) system 3 (MnO_4^-/MnO_4^{2-}) is less positive / more negative than system 5 (MnO_4^{2-}/MnO_2) ✓

Equilibrium shift related to $E^\ominus$ values

system 3 (MnO_4^-/MnO_4^{2-}) shifts left

AND

system 5 (MnO_4^{2-}/MnO_2) shifts right ✓

[2 marks]

IGNORE *'lower/higher'*

ALLOW *reverse argument:*

System 5 more positive than system 3, etc

Must be comparative

ALLOW *response in terms of* E_{cell}

E = (+)1.14 V for system 5 – system 3

Shift dependent on systems 3 and 5 correctly identified

19(c)(i)

$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ ✓

[1 mark]

ALLOW *multiples*

ALLOW $H_2 + 2OH^- - 2e^- \rightarrow 2H_2O$

ALLOW *equation with equilibrium sign*

19(c)(ii)

(0.40 – 1.23 =) –0.83 (V) ✓

[1 mark]

19(c)(iii)

Fuel reacts with oxygen/oxidant to give electrical energy/voltage ✓

[1 mark]

ALLOW *named fuel. e.g. hydrogen/H_2; ethanol; methanol, etc*

ALLOW *fuel cell requires <u>continuous</u> supply of fuel* ***AND*** *oxygen/an oxidant*

OR

fuel cell operates <u>continuously</u> as long as a fuel **AND** oxygen/an oxidant are added

IGNORE *'reactants' 'products' and comments about pollution and efficiency*

Q85 · Transition elements · [1 mark]

Answer: **A**

$Cr(OH)_6^{3-}$

Q86 · Transition elements · [1 mark]

Answer: **D**

Dative covalent

Q87 · Transition elements · [13 marks]

OCR MARK SCHEME

23(a)(i)

$CuCl_4^{2-}$ **OR** $[CuCl_4]^{2-}$ ✓

yellow solution

$Cu(OH)_2$ ✓

pale blue precipitate

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓

deep blue solution

CuI ✓	I_2 ✓
white solid	brown solution

[5 marks]

EXAMINER GUIDANCE

ALLOW *$Cu(Cl)_4^{2-}$*

ALLOW *$Cu(OH)_2(H_2O)_4$*

Brackets required for $[Cu(NH_3)_4(H_2O)_2]^{2+}$

NOTE:

Take great care to check that subscripted numbers and brackets are correct

23(a)(ii)

Reaction 1: ligand substitution ✓

Reaction 2: redox ✓

[2 marks]

ALLOW *ligand exchange*

ALLOW *reduction* ***AND*** *oxidation*

ALLOW *precipitation*

23(b)

Level 3 (5–6 marks)

A comprehensive conclusion using all data to obtain correct formulae for A, B, C and D

AND optical isomers shown

There is a well-developed line of reasoning which is clear and logically structured with use of 3D structures for both optical isomers of C, use of wedges and bonding to N.

The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Reaches a sound conclusion for the formula of B

AND

obtains the correct formula of the hydrated complex A

OR a 3D diagram of one optical isomer of cation C

There is a line of reasoning and supported by some evidence.

Calculations are clear and can be followed to obtain correct conclusions. 3D diagram, if present, should use wedges mostly correctly.

Formula of *A* to show water separately or formula of *C* to show ligands separately, as appropriate.

Level 1 (1–2 marks)

Reaches a simple conclusion to obtain the correct formula of anhydrous complex **B** **OR** shows that A contains $2H_2O$

Indicative scientific points may include:

1. Formula of anhydrous complex B

$NiC_6N_6H_{24}Cl_2$

Example of working

Ni : C : N : H : Cl

$$= \frac{18.95}{58.7} : \frac{23.25}{12.0} : \frac{27.12}{14.0} : \frac{7.75}{1.00} : \frac{22.93}{35.5}$$

There may be other methods

2. Formula of hydrated complex A

$NiC_6N_6H_{24}Cl_2 \cdot 2H_2O$ **OR** $NiC_6N_6H_{24}Cl_2(H_2O)_2$

Example of working

$$n(\text{anhydrous salt}) = \frac{7.433}{309.7} = 0.02400 \text{ (mol)}$$

$$n(H_2O) = \frac{0.864}{18.0} = 0.04800 \text{ (mol)}$$ ✓

There may be other methods

3. Formula of cation C

$[NiC_6N_6H_{24}]^{2+}$ **OR** $[Ni(H_2NCH_2CH_2NH_2)_3)]^{2+}$

(could be in structures

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

Attempts more than one part of the problem.

0 marks No response or no response worthy of credit.

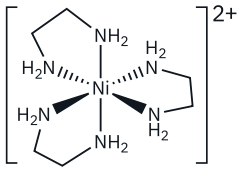
[6 marks]

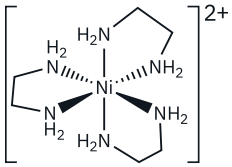
2+ charge can be shown on cation **OR** optical isomers (i.e. seen somewhere)

- Bidentate ligand D

$H_2NCH_2CH_2NH_2$ or displayed so that structure is clearly unambiguous.

- Optical isomers





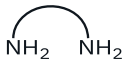
Accuracy of structures

Bonding shown from Ni to N of $H_2NCH_2CH_2NH_2$

ALLOW *$CH_3CH(NH_2)_2$ for ligand*

For $H_2NCH_2CH_2NH_2$ in optical isomers,

ALLOW *C–C without Hs and*

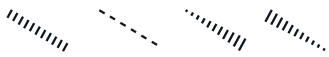


Each structure to contain

2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':



Bond into paper can be shown as:



Q88 · Transition elements · [1 mark]

Answer: **D**

Only 1

Q89 · Transition elements · [18 marks]

OCR MARK SCHEME

21(a)

Ni: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓

Ni^{2+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW *4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$*

ALLOW *$1s^2$ written after answer prompt (ie $1s^2$ twice)*

ALLOW *upper case D, etc and subscripts, e.g. .....$4S_2 3D_8$*

ALLOW *for Ni^{2+} .....$4s^0$*

DO NOT ALLOW *[Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$*

Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

21(b)(i)

Circuit : complete circuit **AND** voltmeter **AND** salt bridge linking two half-cells ✓

Half cells : Pt **AND** I^- **AND** I_2 ✓

Ni **AND** Ni^{2+} ✓

Standard conditions :

1 mol dm^{-3} solutions

AND 298 K / 25°C ✓

[4 marks]

Voltmeter must be shown **AND** salt bridge must be labelled

ALLOW *small gaps in circuit*

ALLOW *half cells drawn either way around*

IGNORE 2 *before* $I^-(aq)$

DO NOT ALLOW $I_2(g)$ ***OR*** $I_2(s)$ ***OR*** $I_2(l)$

ALL conditions required

BUT ALLOW 1 mol dm^{-3}/1M if omitted here but shown for just one solution in diagram

Look on diagram in addition to answer lines

IGNORE *pressure*

Not relevant for this cell

DO NOT ALLOW *1 mol for concentration*

21(b)(ii)

E = 0.79 (V) ✓

[1 mark]

IGNORE *sign*

21(c)(i)

$H_2O_2(aq) + 2H^+(aq) + 2Fe^{2+}(aq) \rightarrow 2Fe^{3+-}(aq) + 2H_2O(l)$ ✓

[1 mark]

ALLOW *multiples*

IGNORE *state symbols, even if wrong*

21(c)(ii)

Equations

$3Zn(s) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 3Zn^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ ✓

$Zn(s) + 2Cr^{3+}(aq) \rightarrow Zn^{2+}(aq) + 2Cr^{2+}(aq)$ ✓

Comparison of E values (seen once)

E of Zn is more negative/less positive than E of $Cr_2O_7^{2-}$

OR

E of Zn is more negative/less positive than E of Cr^{3+} ✓

Equilibrium shift related to E values

More negative/less positive **OR** Zn system shifts left

OR

Less negative/more positive $Cr_2O_7^{2-}$ system shifts right **OR** Less negative/more positive Cr^{3+} system shifts right ✓

[4 marks]

ALLOW *multiples*

IGNORE *state symbols, even if wrong*

ALLOW E_{cell} *is (+) 2.09V for* $Zn/Cr_2O_7^{2-}$ *cell*

OR

ALLOW E_{cell} *is (+) 0.34V for* Zn/Cr^{3+} *cell*

IGNORE *'lower/higher'*

For 'shifts left':

ALLOW *'(Zn) is oxidised'* ***OR*** *'electrons are lost (from Zn)'*

For 'shifts right',

ALLOW *'(Cr) is reduced'* ***OR*** *'electrons are gained'*

21(d)

Level 3 (5–6 marks)

All three reactions are covered in detail with C, D, E and F identified with clear explanations.

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

Level 2 (3–4 marks)

All three reactions are covered but explanations may be incomplete

OR

Two reactions are explained in detail.

Indicative scientific points may include:

REACTION 1 ($CuSO_4/NH_3$)

Product

C : $[Cu(NH_3)_4(H_2O)_2]^{2+}$

Equation

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

Structure of trans stereoisomer

There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.

Level 1 (1–2 marks)

Make two simple explanations from any one reaction.

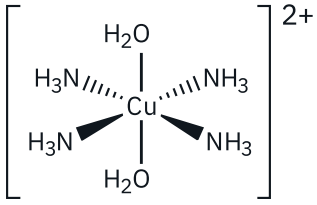
OR

Makes one simple explanation from each of two reactions

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 worthy of credit.

[6 marks]



Correct connectivity

REACTION 2 (Cu_2O/H_2SO_4)

Products

D : $CuSO_4$ **OR** $[Cu(H_2O)_6]^{2+}$

E: Cu

Equation

$Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$

Oxidation numbers

Cu(+1) → Cu(+2) + Cu(0)

REACTION 3 (CuO/HNO_3)

Equation

$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

Molar ratios

Cu : H : N : O

$= \frac{26.29}{63.5} : \frac{2.49}{1.0} : \frac{11.59}{14.0} : \frac{59.63}{16.0}$

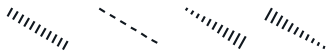
Formula of F

$CuH_6N_2O_9$

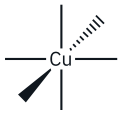
F: $Cu(NO_3)_2 \cdot 3H_2O$ (**OR** $Cu(NO_3)_2(H_2O)_3$)

Further guidance on use of wedges

- Must contain 2 ‘out wedges’, 2 ‘in wedges’ and 2 lines in plane of paper **OR** 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’:
- For bond into paper, **ALLOW**:



- **ALLOW** following geometry:



Q90 · Transition elements · [1 mark]

Answer: **C**

Only 2 and 3

Q91 · Transition elements · [1 mark]

Answer: **B**

Only 1 and 2

Q92 · Transition elements · [16 marks]

OCR MARK SCHEME

22(a)(i)

(N) donates two electron pairs (to a metal ion/metal/Fe^{3+}))

EXAMINER GUIDANCE

ALLOW *lone pairs for electron pairs*

TWO is only needed once if bonds are plural

AND

forms two coordinate / dative (covalent) bonds ✓

[1 mark]

e.g. donates 2 electron pairs to form co-ordinate bonds

OR donates electron pairs to form 2 coordinate bonds.

DO NOT ALLOW *$Fe(NH_2CH_2CH_2NH_2)Cl_2$ for empirical formula*

ALLOW *any order*

22(a)(ii)

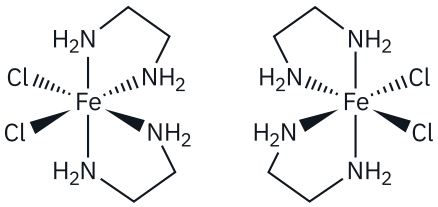
Empirical formula

$FeC_4H_{16}N_4Cl_2$ (any order)

AND charge = (1)+ ✓

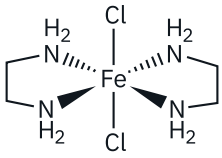
Structures

i.e. Optical isomers (*cis*)



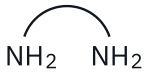
✓ ✓

i.e. trans isomer



✓

For $NH_2CH_2CH_2NH_2$, **ALLOW** skeletal, structural, displayed formula **AND** C-C without Hs and



IF *NH_2 shown with incorrect number of H, eg.*



, penalise first time ONLY

IF ALL *3 isomers are 'correct', but* ***2 x Cl AND*** *no Ns, e.g.*



AWARD 1 mark

TAKE CARE: structures may be in different orientations and in different order

IGNORE *charges (anywhere)*

IF *connectivity between Fe* ***AND*** *N of NH_2 is incorrect then penalise first time ONLY*

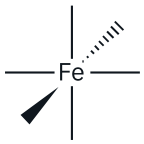
Each structure to contain

2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':

Bond into paper can be shown as:



ALLOW



[4 marks]

22(b)(i)

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ ✓

[1 mark]

IGNORE *state symbols, even if wrong*

ALLOW

$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2(H_2O)_4 + 2H_2O$

OR

$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$

22(b)(ii)

Explanation of the brown precipitate

The brown ppt is $Fe(OH)_3$

OR

$Fe(OH)_2$ loses electrons/ $Fe(OH)_2$ oxidised ✓

ORA

ALLOW *Fe^{2+} is oxidised to Fe^{3+}*

ALLOW *Fe*

ALLOW *E_{cell} is (+) 0.96V*

IGNORE *'lower/higher'*

Comparison of *E* values

(*E* of) Fe/Redox system 1 is more negative/less positive (than *E* of O_2/redox system 2)

OR

(*E* of) O_2/Redox system 2 is more positive/less negative (than *E* of Fe/redox system 1)

✓

Equilibrium shift

More negative/less positive **OR** Fe system **OR** Redox system 1 shifts left

OR

More Positive/less negative **OR** O_2 system **OR** Redox system 2 shifts right ✓

Equation

$4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ ✓

[4 marks]

For equilibrium shift

ALLOW *E_{cell} is +ve therefore the reaction is feasible.*

OR

Direction of half equation correctly written.

ALLOW *multiples*

ALLOW *equilibrium*

IGNORE *state symbols, even if wrong*

DO NOT ALLOW *uncancelled species*

22(c)

Level 3 (5–6 marks)

Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G.

AND

most correct equations and identifies some changes in oxidation number

AND

Calculation of M_r of the gas

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)

Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G.

AND EITHER

some correct equations

OR

Any one correct equation and a relevant change in oxidation number

OR

any one correct equation and a correct calculation of the M_r

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)

Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G

OR

The correct formulae for 1 of B, C, D, E, F and G with correct equation or calculation.

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]

Indicative scientific points may include

	Formula
B	$CuCl_4^{2-}$ **OR** $[CuCl_4]^{2-}$
C	$[Cu(H_2O)_6]^{2+}$ **OR** $CuSO_4$
D	SO_2
E	$Cu(NO_3)_2$ **OR** $[Cu(H_2O)_6]^{2+}$
F	CuI
G	I_2

Experiment 1

Equation

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$

Experiment 2

Evidence

$n(D) = \frac{45}{24000} = 1.875 \times 10^{-3}$

Molar mass (D) = $\frac{0.12}{1.875 \times 10^{-3}} = 64$

Equation

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

Oxidation numbers

Cu 0→ Cu +2; S +6 → S +4

Experiment 3

Equation

$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

OR

$2Cu(NO_3)_2 + 4KI \rightarrow 2CuI + I_2 + 4KNO_3$

Oxidation numbers

Cu +2→ Cu +1; I –1 to 0

Q93 · Transition elements · [1 mark]

Answer: **D**

Only 1

Q94 · Transition elements · [14 marks]

OCR MARK SCHEME

22(a)

Level 3 (5–6 marks)

Explains the terms 'd-block element' **AND** 'transition element'

AND

Explains why not all d-block are transition elements

AND

At least THREE correct electron configurations (need to be one electron configuration of d block atom, transition element ion and zinc (or scandium) ion

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)

Explains both the terms 'd-block element' and 'transition element'

AND

Explains why not all d-block are transition elements

OR

Explains both the terms 'd-block element' and 'transition element'

AND

Links terms to at least TWO correct electron configurations

OR

Explains the terms 'd-block element' **OR** 'transition element'

AND

Explains why not all d-block are transition elements

AND

Links terms to at least ONE correct electron configuration

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)

Explains the term 'd-block element' **OR** 'transition element'

AND

Attempts to link terms with ONE correct electron configuration

OR

Explains the term 'd-block element' **AND** 'transition element'

OR

Explains the term 'd-block element' **OR** 'transition element'

AND Explains why not all d-block are transition elements

OR

Any TWO out of THREE correct electron configurations (one element and one ion that is a transition element and one ion that is not a transition element)

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]

EXAMINER GUIDANCE

Indicative scientific points may include:

Terms

d-block element: element with highest energy/ valence electron in d-orbital/sub-shell **OR** d subshell is being filled

DO NOT ALLOW *d block for d-subshells*

Transition element: element forming one or more ions (allow atom and ion - IUPAC definition) with incomplete/partially filled d-subshell/d-orbitals

DO NOT ALLOW *d shell*

d-block element:

ALLOW *examples with an ion with an incomplete d-subshell, e.g.* Fe^{2+} *-* $[Ar]4s^0 3d^6$

ALLOW *examples with highest energy electrons in a d-subshell, e.g. Fe -* $[Ar]4s^2 3d^6$

Not all d-block are transition elements:

Sc and Zn form ions with complete or empty d-shells **ORA**

For Sc^{3+}, ALLOW Sc^{+3} OR Sc forms a 3+ ion

For Zn^{2+}, ALLOW Zn^{+2} OR Zn forms a 2+ ion

Sc^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6$

Sc^{3+} **AND** d subshell empty / d orbital(s) empty

Zn^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

Zn^{2+} **AND** d subshell full / ALL d orbitals full

ALLOW *minor slips on inner shell electron configurations*

NOTE*: A clear and logically structured response would link definitions to electron configurations to support the explanations. If stated, for the level, there should be clear indication that the d subshell is full/empty or partially full*

22(b)(i)

Cu

ALLOW *any one precipitation reaction*

Precipitation with OH^-/NH_3 2 marks

(Pale) Blue (precipitate) **AND** $Cu(OH)_2$ (can be seen in the equation) ✓

$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ ✓

OR

Precipitation with I^- 2 marks

White (precipitate) **AND** CuI ✓

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$ ✓

Cr

Precipitation with OH^-/NH_3 2 marks

(Dark) Grey-Green (precipitate) **AND** $Cr(OH)_3$ ✓

$Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ ✓

[2 marks]

any one ligand substitution

ALLOW *other correct equations linked to correct colour change*

IGNORE state symbols

DO NOT ALLOW dark/royal *blue (complex ion colour)*

ALLOW $Cu(H_2O)_4(OH)_2$

ALLOW

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O$

OR $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$

OR $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2(H_2O)_4 + 2NH_4^+$

ALLOW *Green*

ALLOW $Cr(H_2O)_3(OH)_3$

ALLOW

$[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3(H_2O)_3 + 3H_2O$

OR $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3(H_2O)_3 + 3NH_4^+$

OR $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$

22(b)(ii)

Cu

Ligand substitution with NH_3/Cl^- 2 marks

NH_3 Deep/dark/royal blue (solution)

AND $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓

OR

Cl^- yellow (solution)

AND $[CuCl_4]^{2-}$ ✓

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ ✓

Cr

Ligand substitution with NH_3 2 marks

NH_3

Purple (solution) **AND** $[Cr(NH_3)_6]^{3+}$ ✓

$[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ ✓

OR

Dark Green (solution) **AND** $[Cr(OH)_6]^{3-}$ ✓

$[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$ ✓

[2 marks]

ALLOW *other correct equations linked to correct colour change*

ALLOW ECF *on any incorrect charges of the complex ions when linked to colour via an equation.*

22(c)

Charge: –1 **OR** – **OR** 1– ✓

Coordination number: 6 ✓

[2 marks]

ALLOW $[Co(C_2O_4)_2(H_2O)_2]^-$

DO NOT ALLOW Co^-

IGNORE *sign*

22(d)

$3V^{3+} + Cr_2O_7^{2-} + 2H^+ \rightarrow 3VO_2^+ + 2Cr^{3+} + H_2O$

ALL reactant and product species correct ✓

Correct balancing (of correct equation) **AND** cancelling of species ✓

IGNORE *Balancing and electrons for first mark*

DO NOT ALLOW *electrons in final answer*

[2 marks]

Q95 · Transition elements · [10 marks]

OCR MARK SCHEME

4(a)

Any correct formula for $X_2Y(ZO_4)_2 \cdot 6H_2O$ ✓

with suitable elements for X, Y and Z using information in stem:

- X can be K, Rb, Cs, Fr ONLY
- Y can be Mg or a transition element in period 4: Ti → Ni
- Z must be Cr

Example: $K_2Mg(CrO_4)_2 \cdot 6H_2O$

[1 mark]

EXAMINER GUIDANCE

Suitable transition elements:

Ti, V, Cr, Mn, Fe, Co, Ni

- Cu in in the Tutton's salt in Q4
- Sc and Zn and not classified as transition elements

4(b)(i)

Mass $(NH_4)_2SO_4$ = 3.3025 g ✓

Mass $CuSO_4 \cdot 5H_2O$ = 6.24 g ✓

[2 marks]

ALLOW 3.3, 3.30. 3.303

ALLOW 6.2

4(b)(ii)

- Prevents water of crystallisation from being removed
- Anhydrous salt would form
- Prevents dehydration ✓

[1 mark]

***IGNORE** all the water would be removed*

water is the solvent

***IGNORE** prevents decomposition*

***IGNORE** increases the size of crystals*

4(c)(i)

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓

TAKE CARE with correct brackets, numbers and 2+ charge

[1 mark]

ALLOW +2 for charge

***IGNORE** $[Cu(NH_3)_4]^{2+}$*

H_2O and NH_3 can be in either order,

i.e. $[Cu(H_2O)_2(NH_3)_4]^{2+}$

4(c)(ii)

Formula of precipitate $Cu(OH)_2$ ✓

***IGNORE** name: copper(II) hydroxide*

Formula of gas NH_3 ✓

***IGNORE** name: ammonia*

Test for ammonia

Available only from a reasonable attempt for identifying the gas as NH_3, e.g. NH_4, NH_4^+, NH_2, ammonia, ammonium

(Moist/damp) indicator/litmus (paper) turns blue ✓

Moist/damp NOT required.

Initial colour of litmus NOT required but blue is CON

[3 marks]

ALLOW $Cu(OH)_2(H_2O)_4$

*ALLOW charges on Cu **AND** OH*

e.g. $Cu^{2+}(OH^-)_2$ ✓

DO NOT ALLOW unbalanced charges.

e.g. $Cu(OH^-)_2$ ✗

DO NOT ALLOW correct test for NH_3 based on incorrect ID of the gas

NO **ECF** for a test on the wrong gas (has to be test for NH_3)

DO NOT ALLOW bleaches indicator CON

4(c)(iii)

Reagent

$BaCl_2$ / barium chloride (solution)

OR $Ba(NO_3)_2$ / barium nitrate (solution)

OR Ba^{2+} (solution/aq) / barium ions ✓

Observation

white precipitate/ppt ✓

ALLOW $Ba(OH)_2$ or other soluble Ba^{2+} compounds

***IGNORE** test for other anions provided they do NOT interfere with SO_4^{2-} test*

e.g.

***IGNORE** addition of $HCl/HNO_3/H^+$*

BUT DO NOT ALLOW H_2SO_4

Only available from soluble Ba^{2+} reagent

ALLOW minor slips in formula of Ba^{2+} reagent,

e.g. $BaCl$, $BaNO_3$

[2 marks]

Interferes with SO_4^{2-} test

IGNORE *$Ag^+/AgNO_3$ after SO_4^{2-} test*

DO NOT ALLOW before SO_4^{2-} test

IGNORE *bubbling any gas through limewater*

IGNORE *responses linked to CrO_4^{2-}*

Not in Tutton's salt that student prepares

Q96 · Transition elements · [1 mark]

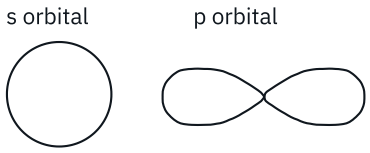
Answer: **D**

$FeSO_4$

Q97 · Transition elements · [12 marks]

OCR MARK SCHEME

22(a)



✓

Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$

AND

Fe^{2+} = $(1s^2)2s^22p^63s^23p^63d^6$ ✓

[2 marks]

EXAMINER GUIDANCE

IGNORE *shading*

IGNORE *axes directions x, y, z*

DO NOT ALLOW *multiple p orbitals*

For electron configuration,

ALLOW *$4s^2$ after $3d^6$*

i.e. $1s^22s^22p^63s^23p^63d^64s^2$

ALLOW *upper case D, etc and subscripts,*

e.g. .....$4S_23D_1$

ALLOW *$4s^0$*

IGNORE *$[Ar]3d^6$ $4s^2$*

22(b)(i)

(A =) $[Co(H_2O)_6]^{2+}$ ✓

(B =) $Co(OH)_2$ ✓

(C =) $[CoCl_4]^{2-}$ **OR** $CoCl_4^{2-}$ ✓

[3 marks]

IGNORE *state symbols even if incorrect*

[ ] essential

ALLOW *$[Co(OH)_2(H_2O)_4]$* **OR** *$Co(OH)_2(H_2O)_4$*

ALLOW *-2 for 2-*

i.e. $[CoCl_4]^{-2}$

22(b)(ii)

Complex : $[Co(NH_3)_4Cl_2]$ ✓

Charge +1 / + / 1+ ✓

[2 marks]

IGNORE *Any charges for 1st mark*

ALLOW *$[CoCl_2(NH_3)_4]$*

ALLOW *$[Co(Cl)_2(NH_3)_4]$*

DO NOT ALLOW *$[Co(Cl_2)(NH_3)_4]$*

DO NOT ALLOW *if charges shown in formula within brackets for 2nd mark*

22(c)

Oxygen (O lone pair) forms a coordinate/dative bond to Fe(II)/Fe/Iron/Fe^{2+} ✓

replaced by H_2O or CO_2

OR

O_2 bonds reversibly (with metal ion) ✓

FIRST CHECK ANSWER ON ANSWER LINE

If 7.3(0) AND not healthy / below 7.35 award three *calculation marks*

$$[H^+] = \frac{K_a \times [H_2CO_3]}{[HCO_3^-]}$$

OR

ALLOW *word equations using → and ⇌*

IGNORE *number of coordinate bonds*

ALLOW ORA

Check for alternative methods on mark scheme.

ALLOW ECF *throughout*

ALLOW *$[A^-]$ for $[HCO_3^-]$* **AND/OR** *$[HA]$ for $[H_2CO_3]$ (asked for in 19 a) ii))*

ALLOW $[H^+] = K_a \div (\frac{[HCO_3^-]}{[H_2CO_3]})$

ALLOW $\frac{[H_2CO_3]}{[HCO_3^-]} = \frac{[H^+]}{K_a}$

$[H^+]$ value subsumes MP3

$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$ ✓

$[H^+] = 5.02 \times 10^{-8}$ ✓

$pH = -\log(5.02 \times 10^{-8}) = 7.3(0)$

AND not healthy / below 7.35 ✓

Alternative method 1:

pH of healthy blood is between 7.35 and 7.45

pH 7.35		**pH 7.45**	
$[H^+] = 4.47 \times 10^{-8}$	**OR**	$[H^+] = 3.55 \times 10^{-8}$	✓
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$	✓
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$	
$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 12:03:1$	

8.5:1 does not lie in the range of 9.55:1 to 12.03:1 **AND** unhealthy ✓

Alternative method 2:

$pH = pK_a + \log \frac{[HCO_3^-]}{[H_2CO_3]}$ ✓

$pK_a = 6.37$ ✓

$6.37 + \log \frac{(8.5)}{(1)}$

7.3(0) **AND** not healthy / below 7.35 ✓

[5 marks]

ALLOW *$[H^+] = 5.02 \times 10^{-8}$ up to the calculator value ($5.023529412 \times 10^{-8}$)*

DO NOT ALLOW *a weak acid approach for marking points 3 and 5. i.e. $[H^+]$ can be awarded.*

ALLOW *7.3 up to calculator value (pH =7.298991951)*

ALLOW *$[H^+] = 3.98 \times 10^{-8}$ from average pH 7.40 used. 3*

Q98 · Transition elements · [17 marks]

OCR MARK SCHEME

3(a)(i)

species with two lone pairs (of electrons) ✓

forming dative (covalent)/co-ordinate bond(s)

OR

donates electrons to a (central) metal atom/ion ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW species with lone pairs that form two dative/coordinate bonds ✓✓

ALLOW non-bonding pair for lone pair

IGNORE LP for lone pair

IGNORE donates two pairs of electrons alone

3(a)(ii)

Charge

Overall 3– charge shown (outside brackets) on at least ONE optical isomer ✓

3– must apply to the overall charge of structures

3D structures

IGNORE charges or dipoles on atoms within diagrams (even if wrong)

Square brackets **NOT** required

ALLOW unambiguous structures

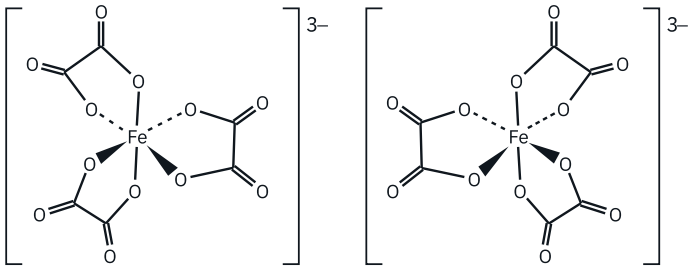
ALLOW –3 for 3–

3D: Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper

OR 4 lines, 1 'out wedge' and 1 'in wedge':

For bond into paper, ALLOW:

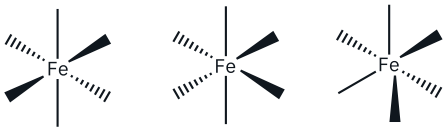




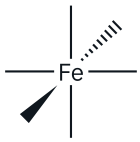
1 mark for each isomer ✓✓

- Bonds MUST go to O^- of $(COO^-)_2$ ligands

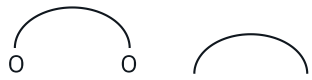
DO NOT ALLOW *impossible 3D diagrams, e.g.*



ALLOW following geometry throughout:



DO NOT ALLOW *3D structures simplified loop for oxalate, e.g.*



For incorrect element in centre, e.g. Cu,

AWARD 2 marks max

[3 marks]

3(b)(i)

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ ✓

OR $Fe^{2+} - e^- \rightarrow Fe^{3+}$

$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ ✓

OR $C_2O_4^{2-} - 2e^- \rightarrow 2CO_2$

[2 marks]

For both half-equations,

ALLOW multiples

ALLOW e for e^-

IGNORE state symbols.

ALLOW $C_2O_4^{2-} \rightarrow C_2O_4^- + e^-$

$C_2O_4^{2-} \rightarrow C_2O_4 + 2e^-$

$2H_2O + C_2O_4^{2-} \rightarrow 2CO_3^{2-} + 4H^+ + 2e^-$

ALLOW $2C_2O_4^{2-} \rightarrow C_4O_8^{2-} + 2e^-$

3(b)(ii)

	1	2	3
Final reading/cm^3	23.55	45.40	22.75
Initial reading/cm^3	1.90	23.55	1.20
Titre/cm^3	21.65	21.85	21.55

Readings recorded to accuracy of burette

All readings recorded to two decimal places with the last figure either 0 or 5

AND

Final and initial readings in correct rows ✓

Correct titres

All 3 titres correct to 2 DP: ✓✓

2 titres correct to 2 DP: ✓

[3 marks]

3(b)(iii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *% error = 0.46, award 1 mark*

$\frac{2 \times 0.05}{21.65} \times 100 = 0.46$ (%) ✓

2 DP minimum

Check Titres from 3b(ii) at top of response

ALLOW % error from ANY of the 3 titres from 3b(ii)
OR *from the mean titre*

DO NOT ALLOW *0.50%*

Calculator value: 0.46189...

[1 mark]

3(b)(iv)

Level 3 (5–6 marks)

Analyses the results to calculate the correct amount of MnO_4^- using the correct mean titre from the candidate's titres

AND

Obtains correct value of x as 2

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)

Analyses titration results to determine an amount of MnO_4^- from a mean titre of the candidate's titres

AND

amount of FeC_2O_4 in 25.0 cm^3 **OR** 250 cm^3

OR

uses a mass of FeC_2O_4 to obtain a value of x with few errors

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)

Analyses results to determine an amount of MnO_4^- from the candidate's titres

OR

Analyses the information to obtain values of $n(MnO_4^-)$ and $n(FeC_2O_4)$ with some errors.

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]

*For mean titre,

Check Titres from 3b(ii) at top of response*

Indicative scientific points may include:

Mean titre and $n(MnO_4^-)$

$$\text{Mean titre} = \frac{(21.65 + 21.55)}{2} = 21.6(0)\ (cm^3)$$

$$n(MnO_4^-) = \frac{0.0200 \times 21.6(0)}{1000} = 4.32 \times 10^{-4}\ (mol)$$

Amount of FeC_2O_4 in mol

$$n(FeC_2O_4) \text{ in } 25.0\ cm^3 = \frac{5}{3} \times n(MnO_4^-)$$

$$= 7.2(0) \times 10^{-4}\ (mol)$$

$$n(FeC_2O_4) \text{ in } 250\ cm^3 = 7.2(0) \times 10^{-3}\ (mol)$$

Value of x (final answer)

$$\text{Molar mass } FeC_2O_4 \cdot xH_2O = \frac{1.295}{7.2(0) \times 10^{-3}}$$

$$= 179.9$$

Molar mass of $xH_2O = 179.9 - 143.8 = 36.(....)$

$$x = \frac{36}{18} = 2$$

Credit other correct methods,

e.g. For value of x

Mass of $FeC_2O_4 = 7.2(0) \times 10^{-3} \times 143.8 = 1.03536$ g

Mass of $H_2O = 1.295 - 1.035 = 0.25964$ g

$$n(H_2O) = \frac{0.25964}{18} = 0.0144 \text{ mol}$$

$$x = \frac{0.0144}{7.2 \times 10^{-3}} = 2$$

Responses using 25.0 cm^3 rather than the titres are limited to Level 1

For communication, a typical 'logical structure' would label most calculation steps in response

e.g.

Communication strand met

$KMnO_4$ Meantitre: $\frac{21.65 + 21.55}{2} = 21.6\ cm^3$.

~~0.02~~ $n(KMnO_4) = 21.6 \times 10^{-3} \times 0.02$

$= 4.32 \times 10^{-4}$.

$n(FeC_2O_4 \cdot xH_2O) = \frac{4.32 \times 10^{-4}}{3} \times 5$

$= 7.2 \times 10^{-4}$ · in 25 cm^3

n $= 7.2 \times 10^{-3}$ in 250 cm^3

$n = \frac{mass}{mr.}$

$mr = \frac{mass}{n} = \frac{1.295}{7.2 \times 10^{-3}} = 179.86$

Communication strand not met

$\frac{21.60}{1000} \times 0.02 = 4.32 \times 10^{-4}$ mol

$\left(\frac{4.32 \times 10^{-4}}{3}\right) \times 5 = 7.2 \times 10^{-4}$ mol in 25 cm^3

$(7.2 \times 10^{-4}) \times 10 = 7.2 \times 10^{-3}$ mol in 250 cm^3

$\frac{1.295}{7.2 \times 10^{-3}} = 179.86$

Q99 · Transition elements · [1 mark]

Answer: **B**

Only 1 and 2

Q100 · Transition elements · [17 marks]

OCR MARK SCHEME

21(a)(i)

Fe $(1s^2)$ $2s^22p^63s^23p^63d^64s^2$ ✓

Cu^{2+} $(1s^2)$ $2s^22p^63s^23p^63d^9$ ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW *$(1s^2)$ $2s^22p^63s^23p^64s^23d^6$*

ALLOW *upper case letter S and P, and subscripts,*

e.g. $2S_22P_5$

IGNORE *$(4s^0)$*

IGNORE *electron configuration of copper under the line. Treat as working*

DO NOT ALLOW *[Ar] as shorthand for $(1s^2)$ $2s^22p^63s^23p^6$*

21(a)(ii)

Green precipitate ($FeSO_4$) ✓

(Pale) blue precipitate ($CuSO_4$) ✓

[2 marks]

ALLOW *1 mark for both correct colours stated without precipitate mentioned*

ALLOW *ppt / solid*

DO NOT ALLOW *dark blue for $CuSO_4$*

21(b)(i)

Donates one/an electron pair (to a metal ion)

AND forms one/a dative (covalent) / coordinate bond (to a metal ion) ✓

[1 mark]

ALLOW *lone pair for electron pair*

21(b)(ii)

Fe = $\frac{12.6}{55.8}$: C = $\frac{54.3}{12}$: H = $\frac{4.5}{1}$: N = $\frac{12.6}{14}$: Cl = $\frac{16.0}{35.5}$

= 0.226 : 4.525 : 4.5 : 0.900 : 0.451

1 : 20 : 20 : 4 : 2 ✓

$FeC_{20}H_{20}N_4Cl_2$ ✓

(pyridine ligands =) Four / 4 ✓

(coordination number =) Six / 6 ✓

[4 marks]

ALLOW *other methods*

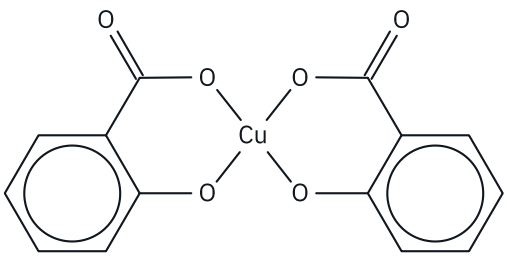
ALLOW *$FeC_{20}H_{20}N_4Cl_2$* ***OR*** *$Fe(C_5H_5N)_4Cl_2$ for ratio*

CORRECT empirical formulae subsumes ratio mark

DO NOT ALLOW *$Fe(C_5H_5N)_4Cl_2$ for $FeC_{20}H_{20}N_4Cl_2$ (not the empirical formulae)*

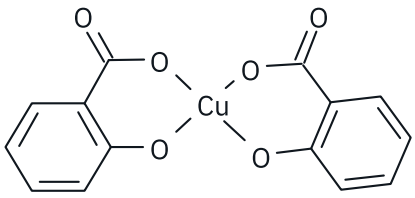
21(c)

Cis isomer



IGNORE *charge and brackets*

ALLOW



ALLOW *geometric*

Cis/trans ✓

ALLOW *E/Z*

[2 marks]

21(d)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 65.4% award 5 marks

$n(S_2O_3^{2-}) = \frac{31.15 \times 0.0800}{1000} = 2.492 \times 10^{-3}$ ✓

$n(Cu^{2+})$ in 25 $cm^3 = 2.492 \times 10^{-3}$

OR $n(I_2) = 1.246 \times 10^{-3}$ ✓

$n(Cu^{2+})$ in 250 $cm^3 = 2.492 \times 10^{-2}$ ✓

Mass $CuSO_4.5H_2O$ in mixture A = $2.492 \times 10^{-2} \times 249.6$

= 6.22(0032) g ✓

$\% = \frac{6.22 \times 100}{9.51} = 65.4$ % (3 SF required) ✓

ALLOW ECF *throughout*

ALLOW 3 SF *up to calculated value*

IGNORE *rounding errors after 3 SF*

Common Errors

4 marks

65.2%	(use of 249 rather than 249.6)
41.8%	(use of 159.6 ($CuSO_4$))
32.7%	(no use of second ratio)
6.54%	(no x 10)

[5 marks]

21(d)(ii)

Iron(III) / Fe^{3+} reacts with iodide ions (I^-) to form iodine (I_2)

OR

Iron(III) / Fe^{3+} oxidises I^- ✓

ALLOW ORA

ALLOW *(because) Iron(III) is reduced by /reacts with thiosulfate*

[1 mark]

Q101 · Transition elements · [15 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

4(a)(i)

sulfate(IV) (ion) ✓

IV essential

[1 mark]

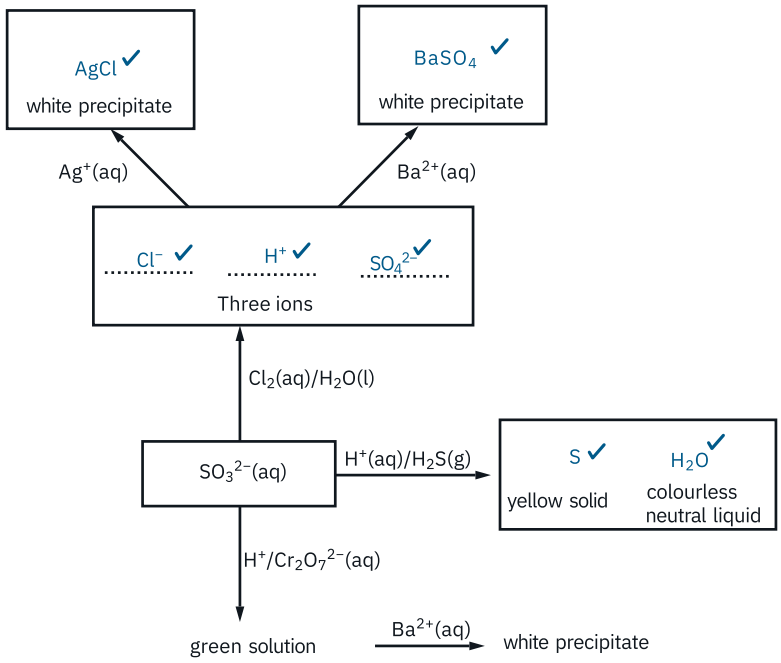
ALLOW *sulphate(IV)*

ALLOW *sulfite* ***OR*** *sulphite*

DO NOT ALLOW *'oxide' in name:*

e.g. sulfur trioxide **OR** sulfur(IV) oxide

4(a)(ii)



[7 marks]

For top left box, **ALLOW** Ag_2SO_4

All responses must be formulae.

DO NOT ALLOW *'sulfur' for S*

ALLOW *3 ions from the following 5 ions:*

H^+ **OR** H_3O^+, Cl^-, ClO^-, HSO_4^-, SO_4^{2-}

MUST be ions

ALLOW S_8

DO NOT ALLOW S_2

4(a)(iii)

$3SO_3^{2-} + Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$

SO_3^{2-} and $Cr_2O_7^{2-}$ on left-hand side

AND $Cr^{3+} + SO_4^{2-}$ on right hand side ✓

Correct balanced equation ✓

DO NOT ALLOW *additional incorrect Cr or S species in equation, e.g.* Cr^{2+}, $Cr(OH)_3$, $[Cr(OH)_6]^{3-}$

[2 marks]

ALLOW *multiples*

IGNORE *state symbols*

ALLOW $Cr_2(SO_4)_3$ *for* $2\ Cr^{3+} + 3\ SO_4^{2-}$

ALLOW $Cr^{3+} + H_2SO_4$ *on right-hand side*

ALLOW $[Cr(H_2O)_6]^{3+}$ *for* Cr^{3+}

DO NOT ALLOW $[Cr(OH)_6]^{3-}$

4(b)(i)

$C_6H_{16}N_2NiO_6$ ✓

Any order

Count: 5 elements in formula

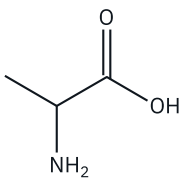
MUST be empirical formula

[1 mark]

DO NOT ALLOW $Ni(C_3H_6NO_2)_2(H_2O)_2$

ALLOW $C_6H_{16}N_2Ni_1O_6$ *i.e. 1 after Ni*

4(b)(ii)



Amino acid B

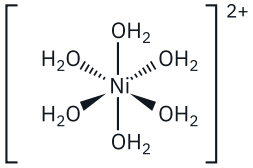
1 mark ✓

In amino acid

- **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
- **IGNORE** connectivity

In Complex ion C

- 3D: Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper
- **OR** 4 lines, 1 'out wedge' and 1 'in wedge':



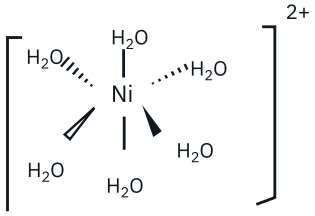
Complex ion C

2 marks

- Ni and 6 H_2O ligands in 3D structure (see guidance) ✓
- 2+ charge **AND** connectivity to 6 O in H_2O ligands ✓

'O' connectivity ONLY needed for 2nd complex ion mark

i.e. This response gets 1st mark point: Ni, $6H_2O$ and 3D



[3 marks]

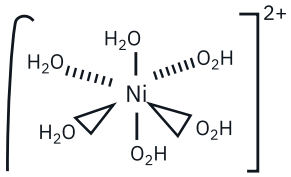
ALLOW *following geometry*



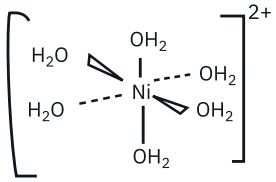
For bond into paper, **ALLOW**:



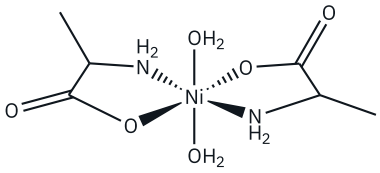
DO NOT ALLOW *–O_2H for 1st complex ion mark, e.g.*



DO NOT ALLOW *for 1st complex ion mark (impossible 3D)*



4(b)(iii)



✓

[1 mark]

IGNORE *connectivity to NH_2*

IGNORE *3D Optical isomer in amino acid*

Watch for adjacent Os

Q102 · Transition elements · [1 mark]

Answer: **C**

Only 2 and 3

Q103 · Transition elements · [15 marks]

OCR MARK SCHEME

22(a)

Level 3 (5–6 marks)

All three tests are covered in detail, with at least six of B to H identified correctly and equations mostly correct.

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)

All three tests are covered with at least four of B to H identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae.

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:

Identification of unknowns

Can be identified within labelled equation.

B is $FeSO_4$ **OR** Iron(II) sulfate

- Test 1: Fe^{2+} present
- Test 2: SO_4^{2-} present

D is $Fe(OH)_2$ **OR** $[Fe(H_2O)_4(OH)_2]$ **OR** iron(II) hydroxide

G is $BaSO_4$ OR barium sulfate

C is $CrCl_3$ **OR** chromium(III) chloride

- Test 1: Cr^{3+} present

Only two tests covered with at least two of B to H identified correctly, and little attempt at writing equations.

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]

- Test 3: Cl^- present

E is $Cr(OH)_3$ **OR** $[Cr(H_2O)_3(OH)_3]$ **OR** chromium(III) hydroxide

F is $[Cr(NH_3)_6]^{3+}$

H is silver chloride OR AgCl

Equations

D: $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **OR**

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ **OR**

$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(H_2O)_4(OH)_2] + 2H_2O$ **OR**

$[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$

OR

$[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(OH)_2 + 4H_2O + 2NH_4^+$

E: $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$ **OR**

$Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ **OR**

$[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(H_2O)_3(OH)_3] + 3H_2O$ **OR**

$[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow [Cr(H_2O)_3(OH)_3] + 3NH_4^+$ **OR**

$[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3 + 3H_2O + 3NH_4^+$

F: $[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$

OR

$Cr(OH)_3 + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3OH^-$ **OR**

$[Cr(H_2O)_3(OH)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3H_2O + 3OH^-$

G: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

H: $Ag^+ + Cl^- \rightarrow AgCl$

22(b)(i)

Ni : S : N = $\frac{16.26}{58.7} : \frac{35.36}{32.1} : \frac{31.0}{14}$ **OR** 0.277 : 1.10 : 2.21

OR 1 : 4 : 8 ✓

x = 4 ✓

2 + x + y = 8

y = 2 ✓

[3 marks]

ALLOW *any correct method*

ALLOW *NiS_4N_8 for ratio*

ALLOW ECF *for y from incorrect x*

22(b)(ii)

+2 ✓

[1 mark]

+ required

ALLOW *2+*

22(c)

$n(MnO_4^-)$ in titration

$= \frac{0.01 \times 12.6}{1000} = 1.26 \times 10^{-4}$ ✓

$n(SO_3^{2-})$ in 25.0 cm^3

$= 1.26 \times 10^{-4} \times 2.5 = 3.15 \times 10^{-4}$ (mol) ✓

$n(SO_3^{2-})$ in 250 cm^3

$= 10 \times 3.15 \times 10^{-3} = 3.15 \times 10^{-3}$ (mol) ✓

mass Na_2SO_3 in 525 g meat

$= 3.15 \times 10^{-3} \times 126.1 = 0.397$ (g) ✓

ALLOW *3 SF or more throughout*

ALLOW ECF *throughout*

Calculator = 0.397215 g

ALLOW *within range: 756 to 757 mg*

ALLOW *0.397 g<0.446 g per 525 g meat.*

mass Na_2SO_3 in 1 kg of meat

$= \frac{0.397215 \times 1000}{525} = 0.7566$ g **OR** 756.6 mg

AND less than the maximum permitted level **OR** AW ✓

[5 marks]

Q104 · Transition elements · [6 marks]

OCR MARK SCHEME

2

Level 3 (5-6 marks)

Comprehensive explanation of the terms, ligand and coordination number and ligand substitution

AND

3D diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes

AND

Ligand substitution illustrated with a balanced equation

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)

Explanation of the terms, ligand and coordination number and ligand substitution with some errors or omissions

AND:

Diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes

OR

A 3D wedged diagram of a suitable example of 6 **OR** 4 coordination

OR

A diagram of a suitable example of 6 **OR** 4 coordination

AND ligand substitution illustrated with an equation

OR

Ligand substitution illustrated with a balanced equation

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)

Explanation of some terms: ligand, coordination number and ligand substitution with some errors or omissions.

AND

A suitable example of a complex ion **OR** Ligand substitution illustrated with an equation with some errors

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.

EXAMINER GUIDANCE

Indicative scientific points may include:

Terms

- Ligand: Donates a lone pair to metal ion

Forms dative covalent (coordinate) bond with metal ion

- Coordination number: Number of coordinate bonds to metal ion. Could be implicit in annotated diagrams

NOTE: *For monodentate ligands, 'number of ligands' is the same as the number of coordination number*

- Ligand substitution: One ligand replacing another

Suitable examples of complex ions with different shapes

- Coordination no 6

Octahedral e.g. $[Cu(H_2O)_6]^{2+}$, $[Fe(H_2O)_6]^{3+}$

- Coordination no 4

Tetrahedral e.g. $CuCl_4^{2-}$, $CoCl_4^{2-}$

OR Square planar Pt complexes, e.g. $Pt(NH_3)_2Cl_2$

Diagrams and equations

- Diagrams of complex ions (may be 3D)
- Equation for ligand substitution

e.g. $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

NOTE: *A clear and logically structured response would link shapes with some of: coordination number, names of shapes, connectivity, involvement of lone pairs, bond angles, etc. (not inclusive)*

ALLOW *minor slips*

NOTE: Levels and the mark within a level is a 'best-fit', not perfection

[6 marks]

Q105 · Transition elements · [11 marks]

OCR MARK SCHEME

17(a)

Transition element:

Has an ion with an incomplete/partially-filled d sub-shell/d-orbital ✓

EXAMINER GUIDANCE

DO NOT ALLOW *d shell*

IGNORE *d block*

IGNORE *outer electron*

d-block

d sub-shell/d-orbital is being filled/has highest energy

OR

Electron configurations shown for

Sc: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$

AND

Zn:$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ ✓

Electron configurations of ions

Sc^{3+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

AND

d sub-shell empty / d orbital(s) empty ✓

Zn^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

AND

d sub-shell full / d-orbitals full ✓

[4 marks]

electron configurations

ALLOW *$4s^0$*

ALLOW *$4s^2$ before 3d, i.e. .....$4s^2 3d^1$; $4s^2 3d^{10}$*

IGNORE *other Sc and Zn ions*

ALLOW ECF *for short hand notation.*

For Sc^{3+}, **ALLOW** Sc^{+3} **OR** Sc forms a 3+ ion;

For Zn^{2+}, **ALLOW** Zn^{+2} **OR** Zn forms a 2+ ion;

17(b)(i)

Donates two electron pairs (to a metal ion)

AND

forms two coordinate bonds (to a metal ion) ✓

[1 mark]

ALLOW *lone pairs for electron pairs*

ALLOW *dative (covalent) bonds for coordinate bonds*

TWO is only needed once if bonds are plural, e.g.

Donates 2 electron pairs to form coordinate bonds

Donates electron pairs to form 2 coordinate bonds

17(b)(ii)

Level 3 (5–6 marks)

Reaches a comprehensive conclusion with most detail and few errors to obtain:

the formulae of A and B

AND ionic equation for ligand substitution

AND the 3D structures of B stereoisomers

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)

Reaches a sound conclusion with some detail and some errors for

the formula of **A OR B**

AND

ionic equation for ligand substitution

OR the 3D structures of B stereoisomers

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)

Obtains the correct formula of **A OR B OR** 3D structures of B stereoisomers which are mostly correct.

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]

Indicative scientific points:

1. Formula of the hydrated salt A

Formula of A:

$Cr_2H_{24}O_{24}S_3$

Example of working

Cr : H : O : S

$$\frac{17.10}{52.0} : \frac{3.94}{1.0} : \frac{63.13}{16.0} : \frac{15.83}{32.1}$$

There may be other methods

Detail Hydrated salt = $Cr_2(SO_4)_3 \cdot 12H_2O$

2. Formula of B and ionic equation

Formula of B:

$[Cr(H_2O)_2(C_2O_4)_2]^-$

Ionic equation

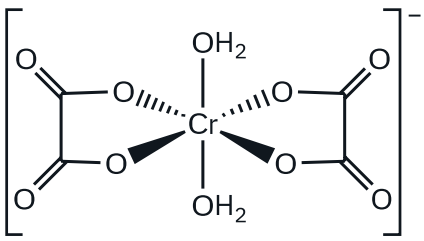
$[Cr(H_2O)_6]^{3+} + 2C_2O_4^{2-} \rightarrow [Cr(H_2O)_2(C_2O_4)_2]^- + 4H_2O$

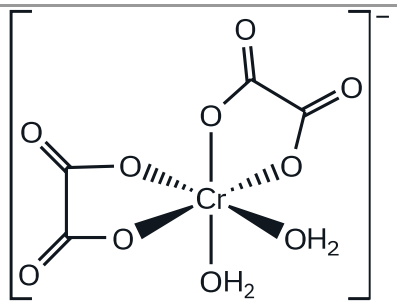
ALLOW *ligands in any order, e.g.*

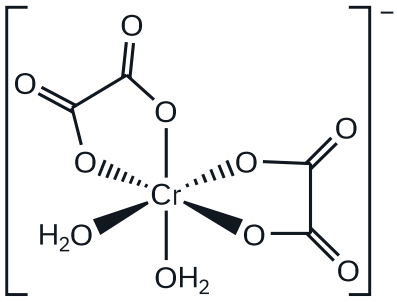
$[Cr(C_2O_4)_2(H_2O)_2]^-$

Detail Use of charges and brackets

3. 3D structures of B stereoisomers







- Consistent use of 2 ‘out wedges’, 2 ‘in wedges’, 2 lines in plane of paper **OR** 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’

ALLOW *following orientations*



Detail

- Most bonding shown from Cr to O of H_2O and O^- $C_2O_4^{2-}$

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