OCR A-Level Chemistry A

Module 3: Periodic table and energy mark scheme · goes with “Module 3: Periodic table and energy” · whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/

Mark schemes

Enthalpy changes, Group 2 and the halogens, Periodicity and Reaction rates and equilibrium · 142 questions

Q1 · Enthalpy changes · [1 mark]

Answer: **B**

–129 kJ mol^{-1}

Q2 · Enthalpy changes · [7 marks]

OCR MARK SCHEME

24(a)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF $\Delta_r H$ = –58.5 (kJ mol^{-1}) award 4 marks

Energy released in J OR kJ

= 100.0 × 4.18 × 10.5 = 4389 (J) **OR** 4.389 (kJ) ✓

Correctly calculates $n(Pb(NO_3)_2)$

$= 1.50 \times \frac{50}{1000} = 0.075(0)$ (mol) ✓

Δ*H* value in J OR kJ

Answer MUST divide energy by $n(Pb(NO_3)_2)$

$(–)\ \frac{4389}{0.0750}$ **OR** (–)58520 (J)

OR

$(–)\ \frac{4.389}{0.0750}$ **OR** (–)58.52 (kJ) ✓

(Sign ignored and/or more than 3 SF)

Correct $\Delta_r H$ in kJ **AND** – sign **AND** 3 SF = –58.5 (kJ mol^{-1}) ✓

[4 marks]

EXAMINER GUIDANCE

ALLOW *4390 J; 4.39 kJ*

DO NOT ALLOW *less than 3 SF*

IGNORE *units*

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

ALLOW ECF *from $n(Pb(NO_3)_2)$*

AND/OR *Energy*

ALLOW *58500 (from 4390)*

IGNORE *absence of – sign and 3 SF requirement*

Final mark requires – sign, kJ **AND** 3 SF

Note: From 4390 J, $\Delta_r H$ = –58.5 (kJ mol^{-1}) (SAME)

Common error

–29.3	3 marks (50 g instead of 100 g in $mc\Delta T$)

24(b)

$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$ ✓

State symbols required

[1 mark]

ALLOW *$Pb^{+2}(aq)$*

IGNORE *spectator ions, $K^+(aq)$ and $2NO_3^-(aq)$ on both sides*

24(c)

FIRST, CHECK ANSWER ON ANSWER LINE

IF [KI(aq)] rounds to 3.3 mol dm^{-3}

e.g. 3.30, 3.33, 3.3 recurring

Method 1

[KI(aq)] for complete reaction

$= 2 \times 0.0750 = 0.150$ mol $\times \frac{1000}{50} = 3$ (mol dm^{-3}) ✓

10% greater gives 3 × 1.1 = 3.3(0) ✓

OR---

Method 2

n(KI(aq)) required = 2.2 × 0.0750 = 0.165 mol ✓

ALLOW ECF *from incorrect $n(Pb(NO_3)_2)$ from 24(a) BUT if (a) is incorrect but 0.0750 used here, treat as a fresh start and **IGNORE** response from 24(a)*

ALLOW *2 marks for 3.3/3.3 recurring*

Attempt at increasing concentration by 10%

$= 2 \times 0.0750 = 0.150$ mol

$\times \frac{1000}{45} = 3.33$ (mol dm^{-3})

ALLOW ECF *from incorrect n(KI)*

Common errors

$[KI(aq)] = 0.165 \times \frac{1000}{50} = 3.3(0)$ (mol dm^{-3}) ✓

[2 marks]

3	1 mark (Correct for KI with no extra 10%)
1.65	1 mark (no factor of 2 used for KI)
2.7	1 mark (10% less rather than 10% more)
2.73/2.72	1 mark (10% increase in volume: 55 cm^3)

Q3 · Enthalpy changes · [1 mark]

Answer: **C**

6.0 °C

Q4 · Enthalpy changes · [1 mark]

Answer: **B**

–126.5 kJ mol^{-1}

Q5 · Enthalpy changes · [13 marks]

OCR MARK SCHEME

3(a)(i)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF answer = –2510 (kJ mol^{-1}) award 4 marks

IF answer = 2508/2507 (kJ mol^{-1}) award 3 marks

(not rounded to 3SF, ignore sign)

IF answer = +2510 (kJ mol^{-1}) award 3 marks

(incorrect sign)

IF answer = –2510000 (kJ mol^{-1}) award 3 marks

(used J instead of kJ)

Moles

$n(C_6H_{14})$ = 0.0150 mol ✓

Energy

q calculated correctly = 37620 (J) **OR** 37.620 (kJ) ✓

Calculating ΔH

EXAMINER GUIDANCE

$\text{moles} = \frac{1.29}{86.0}$

IGNORE *trailing zeros*

$q = 200 \times 4.18 \times 45.0$

ALLOW *correctly rounded to 3 sig figs: 37.6 kJ*

ALLOW *ECF from incorrect q*

ALLOW ECF *from incorrect molar mass or incorrect moles of hexane to 3 SF or more correctly rounded*

IGNORE *sign at this intermediate stage*

IGNORE *working*

$\Delta H = \frac{37.62}{0.015} = 2508$ (kJ mol^{-1})

Correctly calculates ΔH in kJ mol^{-1}

AND to 3 or more SF ✓

Rounding **AND** sign

calculated value of ΔH rounded to 3 SF

AND '–'sign ✓

$\Delta H = \frac{37.6}{0.015} = 2507$ (kJ mol^{-1})

$\Delta H = -2510$ (kJ mol^{-1})

Final answer must have '–' sign and 3 SF

[4 marks]

3(a)(ii)

Any two from the following: ✓✓

- Heat released to the surroundings
- Incomplete combustion
- Non-standard conditions

ALLOW *heat loss*

ALLOW *incomplete reaction* ***OR*** *not everything burns*

IGNORE *reference to evaporation*

[2 marks]

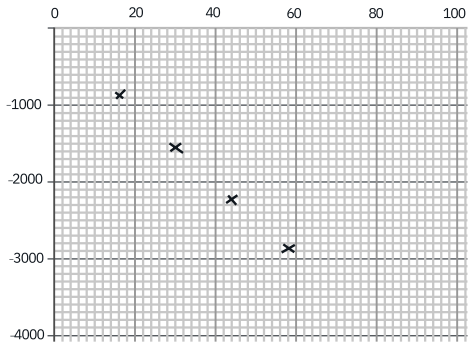
3(b)(i)

Value for butane plotted accurately on the graph ✓

[1 mark]

relative molecular mass = 58

$\Delta_c H^{\ominus} = -2877$ kJ mol^{-1}



Check accuracy:

- There must be a visible point
- Vertically: touching the 58 line
- Horizontally: between 2800 and 2900

3(b)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF energy released = 87.5 (minimum) to 90 (maximum) AND line is extrapolated to 72 (molar mass) award 3 marks

IF energy released <87.5 OR > 90.0 check the estimated value of $\Delta_c H^{\ominus}$ from the graph

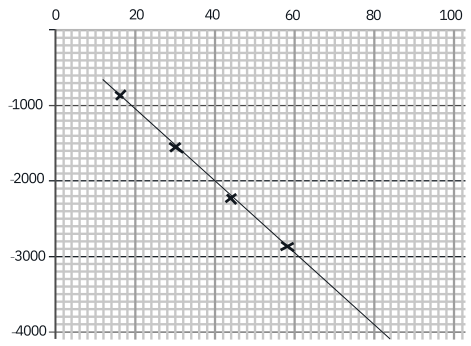
Estimation of $\Delta_c H^{\ominus}$

extrapolated (straight) line of best fit (see graph)

AND

relative molecular mass = 72

$\Delta_c H^{\ominus} = -3509$ kJ mol^{-1}



correctly estimated value $\Delta_c H^{\ominus}$ from graph ✓

Calculation of energy released

$n(C_5H_{12})$ = 0.0250 mol ✓

energy released

= 0.0250 × correctly estimated value of $\Delta_c H^{\ominus}$ ✓

[3 marks]

Expected value within range:

(–)3500 to (–)3600 (kJ mol^{-1})

moles = $\frac{1.80}{72.0}$

***IGNORE** sign*

***ALLOW ECF** from incorrectly calculated moles of pentane **OR** incorrectly estimated $\Delta_c H^{\ominus}$*

3(c)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF enthalpy change = –3919.5 (kJ mol^{-1}) award 3 marks

IF enthalpy change = (+)3919.5 (kJ mol^{-1}) award 2 marks

Working for CO_2 **AND** H_2O seen anywhere (1 mark)

6 × (–)393.5 **AND** 6 × (–)285.8

OR (–)2361 **AND** (–)1714.8

OR (–)4075.8 ✓

Calculates $\Delta_c H$

A further 2 marks for correct answer

AND correct sign

= (6 × –393.5) + (6 × –285.8) – (–156.3)

= –3919.5 (kJ mol^{-1}) ✓✓

[3 marks]

IF there is an alternative answer, check to see if there is any ECF credit possible

***ALLOW 3 marks for** $\Delta_c H$ = –3920*

FINAL answer rounded to 3 SF

Common incorrect answers are shown below

***ALLOW 2 marks for** $\Delta_c H$ = –3924*

From $\Delta_c H$ = (6 × –394 + 6 × –286) – (–156)

Data rounded to 3 sig figs

***ALLOW 2 marks for** $\Delta_c H$ = –4232.1*

All data added together

(6 × –393.5) + (6 × –285.8) + (–156.3)

***ALLOW 1 mark for** $\Delta_c H$ = (+)4232.1*

Q6 · Enthalpy changes · [1 mark]

Answer: **C**

+298

Q7 · Enthalpy changes · [14 marks]

OCR MARK SCHEME

2(a)

Level 3 (5–6 marks)

A comprehensive conclusion, using all quantitative data, to calculate the energy change and ΔH values for reactions 3.1 and 3.2

AND linking ΔH data using Hess' Law

EXAMINER GUIDANCE

Indicative scientific points may include:

1. Masses and ΔT from raw results

- $m(Na_2O)$ = 1.24 (g)
- m(solution) = 25.75 (g)
- ΔT = 35.0 (°C)

Energy change from $mc\Delta T$

There is a well-developed line of reasoning which is clear and logically structured. The working throughout is clearly shown. All values calculated with reasonable numbers of SF and correct signs mostly shown, allowing for ECF.

Level 2 (3–4 marks)

Attempts to describe all three scientific points but explanations may be incomplete.

OR Explains two scientific points thoroughly with few omissions.

There is a line of reasoning with some logical structure. There may be minor errors in energy change and errors in the calculations of ΔH for reaction 3.1 or reaction 3.2.

Level 1 (1–2 marks)

Processes raw mass and temperature data and obtains a calculated value for the energy change using $mc\Delta T$

OR attempts to obtain values for two scientific points but explanations may be incomplete

There is an attempt at a logical structure with a line of reasoning to obtain a value for energy change. There may be minor errors in calculation of energy change.

0 marks – No response or no response worthy of credit.

[6 marks]

2(b)

% uncertainties to at least 1 SF, rounded or truncated

ONE correct % uncertainty ✓

BOTH correct % uncertainties ✓

mass: $\frac{0.005 \times 2}{1.24} \times 100$ = 0.8/0.81 **OR** 0.80 (truncated)

ΔT: $\frac{0.1 \times 2}{35.0} \times 100$ = 0.6 / 0.57 (%) ✓

Calculator values:

mass: 0.8064516129

- energy released in J **OR** kJ

= 25.75 × 4.18 × 35.0

= 3767 (J) **OR** 3.767 (kJ)

(3.767225 unrounded)

2. $\Delta_r H$ for reaction 3.2

- $n(Na_2O) = \frac{1.24}{62.0}$ = 0.0200 (mol)
- $\Delta_r H$ value $\frac{-3767}{0.0200}$ = –188 (kJ mol^{-1})

(–188.36125 unrounded)

3. $\Delta_r H$ for reaction 3.1

- ΔH value for reaction 3.1 clearly linked to ΔH for reaction 3.2 and reaction 3.3 in energy cycle or an expression:

$\Delta H(3.1) = \Delta H(3.2) + 2\Delta H(3.3)$

- $\Delta H(3.1)$ = –188 + (2 × –57.6)

= –188 – 115.2 = –303(.2) (kJ mol^{-1})

(–303.56125 unrounded)

Note

Throughout, **ALLOW ECF** from previous value

ALLOW omission of trailing zeroes

ALLOW error for uncertainty

***ALLOW ECF** from mass and ΔT in 2(a)*

***IGNORE** % uncertainty of mass of solution*

ALLOW one mark for:

- 2 calculations with both ×2 factors missing i.e. mass 0.3% **AND** ΔT 0.4%
- Not converting to %s using ×2 factors i.e. 0.008 **AND** 0.006

ΔT: 0.5714285714

[2 marks]

2(c)

*ALLOW uncertainty **OR** error throughout*

Greater mass of Na_2O **OR** more Na_2O ✓

For mass, ALLOW amount/moles/quantity

larger ΔT

OR reduces % uncertainty in ΔT ✓

[2 marks]

ALLOW up to 2 marks based on a single mass measurement:

one mass measurement

OR measure mass directly ✓

e.g. tare balance

% uncertainty reduced by half ✓

IGNORE

- repeat and take average
- read to more figures (same apparatus)
- increase volume (reduces mass error but increases ΔT error)
- use a cooling curve
- use a lid

2(d)(i)

sodium nitrate(III)

[1 mark]

*ALLOW sodium nitrite **OR** sodium nitrite(III)*

2(d)(ii)

Sodium/Na oxidised from 0 to +1 ✓

Nitrogen/N reduced from +3 to 0 ✓

[2 marks]

ALLOW 1+ for +1 and 3+ for +3

ALLOW N_2 for nitrogen

*ALLOW 1 mark for elements **AND** all oxidation numbers correct, but N on oxidised line and Na on reduced line*

'+' is required in +3 and +1 oxidation numbers

2(d)(iii)

$2NaNO_2 + 6Na \rightarrow 4Na_2O + N_2$ ✓

***IGNORE** state symbols*

[1 mark]

ALLOW multiples, e.g.

$NaNO_2 + 3Na \rightarrow 2Na_2O + ½N_2$

Q8 · Enthalpy changes · [1 mark]

Answer: **B**

−1842.3

Q9 · Enthalpy changes · [1 mark]

Answer: **B**

In the calculation, the student used the molar mass of ethanol instead of methanol.

Q10 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

23(a)(i)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF $\Delta_f H$ = –457 OR –458 (kJ mol^{-1}) award 4 marks

IF $\Delta_f H$ = ±229 OR 457 (kJ mol^{-1}) award 3 marks

Energy released in J OR kJ

= 25.0 × 4.18 × 28.0 = 2926 (J) **OR** 2.926 (kJ) ✓

Correctly calculates $n(AgNO_3)$

$= 0.512 \times \frac{25.0}{1000} = 1.28 \times 10^{-2}$ (mol) ✓

ΔH per mole $AgNO_3$ in kJ AND 3 SF

Answer MUST divide energy by $n(AgNO_3)$

$\pm \frac{2.926}{1.28 \times 10^{-2}} = \pm 228.59375$

= ±229 (kJ) ✓

3 SF needed Sign **NOT** needed

ΔH for 2 mol $AgNO_3$ AND – sign AND 3 SF

$\Delta H_r = 2 \times -228.59375 = -457$ (kJ mol^{-1})

OR 2 × –229 = –458 (kJ mol^{-1}) ✓

[4 marks]

EXAMINER GUIDANCE

***ALLOW ECF** throughout*

***ALLOW** 2930 J **OR** 2.93 kJ*

***DO NOT ALLOW** < 3 SF*

***IGNORE** any sign and units*

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

Alternative approach using 1 mol Mg

Energy released = 2926 (J) **OR** 2.926 (kJ) ✓

$n(AgNO_3) = 1.28 \times 10^{-2}$ (mol) ✓

$n(Mg) = \frac{1.28 \times 10^{-2}}{2} = 6.4 \times 10^{-3}$ (mol) ✓

$\Delta H_r = \frac{2.926}{6.4 \times 10^{-3}} = -457$ (kJ mol^{-1}) ✓

– **sign AND** 3 SF needed

23(a)(ii)

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓

State symbols required

White precipitate **AND** $AgNO_3/Ag^+$ **NOT ALL** reacted

OR

NO white precipitate **AND** $AgNO_3/Ag^+$ ALL reacted ✓

[2 marks]

***ALLOW** $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$*

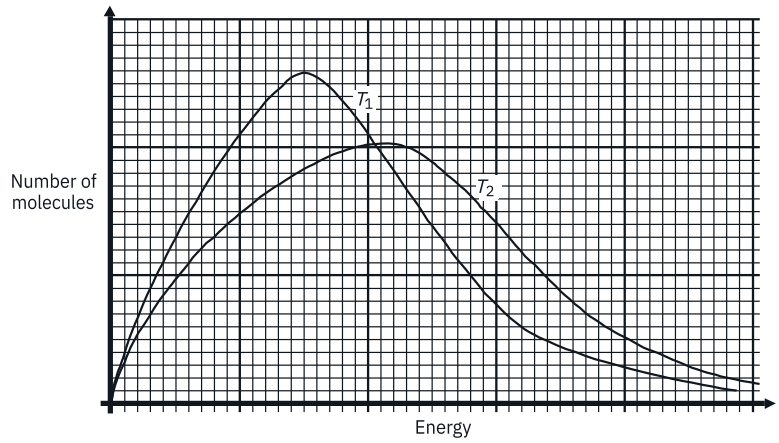
Observation needs to be linked to conclusion

23(b)

Boltzmann distribution 3 marks

***NOTE**: Look for marking criteria within annotations on Boltzmann distribution diagram*

***IGNORE** slight inflexion on the curve*



Curve

Curve starts within one small square of origin

AND curve does not touch x axis at high energy

AND curve does not increase by more than one small square at higher energy ✓

Labels

Axes labels correct:

- Number of molecules **AND** Energy ✓

Curves for two temperatures

Drawing of two curves with higher and lower temperature clearly identified in diagram or text

AND higher *T* maximum to right **AND** at least one small square lower than lower *T* max ✓

Explanation 1 mark

More molecules have energy greater than E_a

OR

Greater area under curve above E_a ✓

Could be in diagram

[4 marks]

For labels,

ALLOW *number of particles*

ALLOW *amount of molecules/particles*

IGNORE *number of atoms*

ALLOW *kinetic energy*

IGNORE *enthalpy for energy*

IGNORE *curves meeting at higher energy BUT*

DO NOT ALLOW *crossing over by more than one small square*

ALLOW *more molecules have the energy to react*

IGNORE *more successful collisions*

OR collide more frequently

DO NOT ALLOW *explanation is in terms of two activation energies (i.e. 'catalyst explanation')*

Q11 · Enthalpy changes · [1 mark]

Answer: **B**

Only 1 and 2

Q12 · Enthalpy changes · [1 mark]

Answer: **B**

The activation energy of the reverse reaction is 270 kJ mol^{-1}.

Q13 · Enthalpy changes · [1 mark]

Answer: **B**

The enthalpy change for the reverse equation is +184.6 kJ mol^{-1}.

Q14 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

24(a)(i)

Pressure:

Right-hand side has fewer (gaseous) moles

OR 4 (gaseous) moles form 2 (gaseous) moles ✓

High pressure ✓

Temperature:

(Forward) reaction is exothermic/Δ*H* is negative

OR (Forward) reaction gives out heat ✓

Low temperature ✓

[4 marks]

24(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

IF answer = 2.86 × 10^{-2} award 2 marks

K_c expression

$(K_c =)\ \dfrac{[NH_3]^2}{[N_2]\,[H_2]^3}$ **OR** $\dfrac{0.862^2}{1.25 \times 2.75^3}$

OR 0.02858 ..... ✓

Answer to 3 SF and in standard form

$K_c = 2.86 \times 10^{-2}$ ✓

[2 marks]

24(b)(i)

298 K/25°C

AND

100 kPa ✓

[1 mark]

24(b)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF answer = (+)90 (kJ mol^{-1}) award 3 marks

IF answer = –90 (kJ mol^{-1}) award 2 marks

EXAMINER GUIDANCE

ALLOW *suitable alternatives for right-hand side,*

e.g.: towards NH_3/products

OR forward direction

OR increases yield

For moles, **ALLOW** molecules/particles

ALLOW reverse *reaction is endothermic /ΔH is positive/takes in heat*

ORA for *reverse reaction*

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

ALLOW *calculated value 0.02858291 correctly rounded to 3 or more SF for 1st marking point*

ALLOW ECF to 3 SF and standard form *ONLY from inverted K_c expression → 3.50 × 10^1*

DO NOT ALLOW

$\dfrac{[NH_3]^2}{[N_2] + [H_2]^3}$ *= 0.0337 (no marks)*

IGNORE *attempts at units*

ALLOW *'a stated temperature'*

To accept that other standard temperatures can be used and 298 should strictly be added as $\Delta H_{298}^{\ominus}$

ALLOW *1 × 10^5 Pa, 101 kPa, 1.01 × 10^5 Pa, 1 atm, 1 bar*

ALLOW ECF if common errors not seen

IF ΔH of –908 has NOT been used, *ONLY award 1st mark*

IF answer = (+)360 (kJ mol^{-1}) award 2 marks

Use of $\Delta_f H$ values and balancing numbers

± (4 × –46) **OR** ± 184

AND

± (6 × –242) **OR** ± 1452 seen anywhere ✓

Correct subtraction using ΔH = –908

4 × $\Delta_f H$(NO)

= (4 × –46) – (6 × –242) – 908

= –184 + 1452 – 908

= (+)360 (kJ mol^{-1}) ✓

Calculation of $\Delta_f H$(NO) formation by ÷4

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

[3 marks]

COMMON ERRORS

1 mark

Incorrect signs(s) **AND** missing ÷4

±2544 from ± (184 + 1452 + 908)

±728 from ± (184 + 1452 – 908)

±2176 from ± (–184 + 1452 + 908)

–360 from – (–184 + 1452 – 908)

2 marks

Incorrect signs(s)

±636 from ± (184 + 1452 + 908) = ± 2544÷4

±182 from ± (184 + 1452 – 908) = ± 728÷4

±544 from ± (–184 + 1452 + 908) = ± 2176÷4

–90 from – (–184 + 1452 – 908) = –360÷4

Q15 · Enthalpy changes · [1 mark]

Answer: **A**

56.8

Q16 · Enthalpy changes · [13 marks]

OCR MARK SCHEME

5(a)(i)

Level 3 (5–6 marks)

Calculates CORRECT enthalpy change with correct – signs for $\Delta_{sol}H$ ($CuSO_4$(s)) for reaction 5.2

AND

$\Delta_r H$, for reaction 5.1.

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)

Calculates a value of $\Delta_{sol}H$ ($CuSO_4$(s)) for reaction 5.2 from the:

Energy change

AND

Amount in mol of $CuSO_4$.

There is a line of reasoning presented with some structure.

EXAMINER GUIDANCE

Indicative scientific points may include:

1. Processing experimental data

Energy change from $mc\Delta T$

- Energy in J **OR** kJ

Using 50.70 g, 50.0 g

= 50.70 × 4.18 × 13.5 = 2861 (J) **OR** 2.861 (kJ)

3SF or more (2.861001 unrounded)

OR 50.0 × 4.18 × 13.5 = 2821.5 (J) **OR** 2.8215 (kJ)

Amount in mol of $CuSO_4$

- $n(CuSO_4)$ = $\frac{7.98}{159.6}$ = 0.0500 (mol)

The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Processes experimental data to obtain the:

Energy change from $mc\Delta T$

OR

Amount in mol of $CuSO_4$.

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]

2. ± value of $\Delta_{sol}H(CuSO_4(s))$ for reaction 5.2

From $m = 50.70$ g = ± $\frac{2.861}{0.0500}$ = ±57.22 (kJ mol^{-1})

(–57.22002 unrounded)

From $m = 50.0$ g = ± $\frac{2.8215}{0.0500}$ = ±56.43 (kJ mol^{-1})

3. CORRECT enthalpy changes for reactions 5.2 and 5.1 with signs (using 50.70 g ONLY)

Reaction 5.2 = –57.22 (kJ mol^{-1})

3SF or more with correct – sign

Reaction 5.1

$\Delta_rH = \Delta_{sol}H(CuSO_4(s)) - \Delta_{sol}H(CuSO_4 \cdot 5H_2O(s))$

= –57.22 – 8.43 = –65.65 (kJ mol^{-1})

3SF or more with correct – sign

***NOTE**: A clear and logically structured response would include an energy cycle*

***ALLOW** omission of trailing zeroes*

***ALLOW** minor slips*

5(a)(ii)

Temperature change = $\frac{0.2 \times 100}{20}$ = 1(.0)°C ✓

[1 mark]

***IGNORE** direction of temperature change*

Working **NOT** required

5(b)

FIRST CHECK THE ANSWER IN ON ANSWER LINE

If answer = (+)156 (J K^{-1} mol^{-1}) award 4 marks

Part 1: Calc of Δ_rS

Use of 298 K (seen anywhere) 1 mark ✓

- e.g. –16.1 = –55.8 – 298 × ΔS

CORRECT use of Gibbs' equation 1 mark

- using candidate's temperature (e.g. 298)
- with –16.1 **AND** –55.8

Using 298 K, ΔS

= $\frac{-55.8 - (-16.1)}{298} = \frac{-39.7}{298}$

= –0.133...(kJ K^{-1}mol^{-1})

OR –133... (J K^{-1}mol^{-1})

Sign required **IGNORE** units

Calculator:

–0.133221 (kJ K^{-1} mol^{-1})

–133.221 (J K^{-1} mol^{-1})

- to calculate ΔS in kJ **OR** J ✓

Part 2: Calc of $S(Na_2S_2O_3)$ 1 mark

CORRECT use of standard S data in question ✓

Seen anywhere (could be within an expression) e.g.

- $372.4 – [\ S(Na_2S_2O_3) + (5 \times 69.9)\ ]$
- **OR** $372.4 – (5 \times 69.9)$
- **OR** $372.4 – 349.5$
- **OR** 22.9

IGNORE *sign, i.e.* ***ALLOW*** *–22.9, etc*

CORRECT calculation of $S(Na_2S_2O_3)$ using candidate's calculated ΔS in Part 1 to 3 SF 1 mark ✓

[4 marks]

ALLOW ECF *from incorrect temperature.*

Using –133:

$S(Na_2S_2O_3) = 372.4 – 349.5 – (–133)$

$= 22.9 + 133$

$= (+)156\ (J\ K^{-1}\ mol^{-1})$

3 SF required

ALLOW ECF *from incorrect* $\Delta_f S$ *(Part 1)*

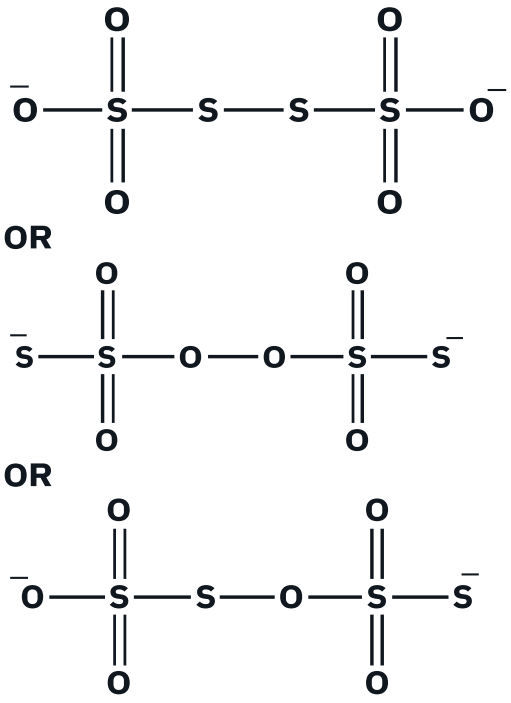
5(c)(i)

109.5(º) **AND** tetrahedral ✓

[1 mark]

ALLOW *109–110(º)*

5(c)(ii)



OR

OR

✓

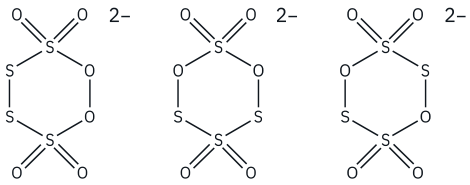
IGNORE *absence of charges* ***OR*** *incorrect charges*

[1 mark]

IGNORE *charges*

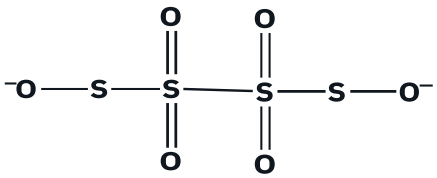
ALLOW *cyclic structures.*

Three 6-ring structures possible, e.g.



NOTE*: There MUST be 2 atoms in centre between 6-bonded S atoms.*

e.g. **DO NOT ALLOW**



Q17 · Enthalpy changes · [1 mark]

Answer: **A**

−555.8

Q18 · Enthalpy changes · [9 marks]

OCR MARK SCHEME

25(a)(i)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *$\Delta_r H$ = –116 (kJ mol^{-1}) award 4 marks*

IF *$\Delta_r H$ = +116 (kJ mol^{-1}) award 3 marks*

Energy released in J OR kJ

= 75.0 × 4.18 × 18.5 = 5799.75 (J) OR 5.79975 (kJ) ✓

Correctly calculates $n(Ba(OH)_2)$ OR $n(HNO_3)$

$$n(Ba(OH)_2) = 2 \times \frac{25.0}{1000} = 0.05(00) \text{ (mol)}$$

OR

$$n(HNO_3) = 2 \times \frac{50.0}{1000} = 0.1(00) \text{ (mol)} \checkmark$$

ΔH per mole $Ba(OH)_2$ in J OR kJ

Answer MUST divide energy by $n(Ba(OH)_2$ OR $2 \times n(HNO_3))$

$$\pm \frac{5799.75}{0.05} \text{ OR } \pm 2 \times \frac{5799.75}{0.1} = \pm 115995 \text{ (J)}$$

OR

$$\pm \frac{5.79975}{0.05} \text{ OR } \pm 2 \times \frac{5.79975}{0.1} = \pm 115.995 \text{ (kJ)} \checkmark$$

ΔH in kJ mol^{-1} to 3 SF AND – sign

$\Delta_r H$ = –116 (kJ mol^{-1}) ✓

[4 marks]

25(a)(ii)

Reason for incorrect conclusion

neutralisation forms 1 mol H_2O

OR $\Delta_r H$ forms 2 mol H_2O ✓

Value for $\Delta_{neut} H = \pm \frac{\text{answer to 25a(i)}}{2}$ (kJ mol^{-1}) ✓

2 SF or more

[2 marks]

25(b)

EXAMINER GUIDANCE

ALLOW *5799.8 OR 5800 J OR 5.7998 OR 5.8 kJ*

DO NOT ALLOW *< 3 SF EXCEPT 5.8 (trailing zeroes)*

IGNORE *any sign*

IGNORE *units i.e.* ***ALLOW*** *correctly calculated number in J OR kJ OR no units*

ALLOW *3SF or more OR use of 5800 J OR 5.8 kJ*

Sign **NOT** needed

3 SF needed

Common errors

3 marks

$\frac{5799.75}{0.1}$ → –58.0 no 2 × using 0.1

$\frac{5799.75}{0.15}$ → –38.7 ÷ by 0.05 + 0.10

$2 \times \frac{5799.75}{0.15}$ → –77.3

2 marks for answers above with wrong sign or not to 3 SF

Other multiples by using *m* as 50 or 25:

Mark using same principle

Use of 50 → –77.3 3 marks

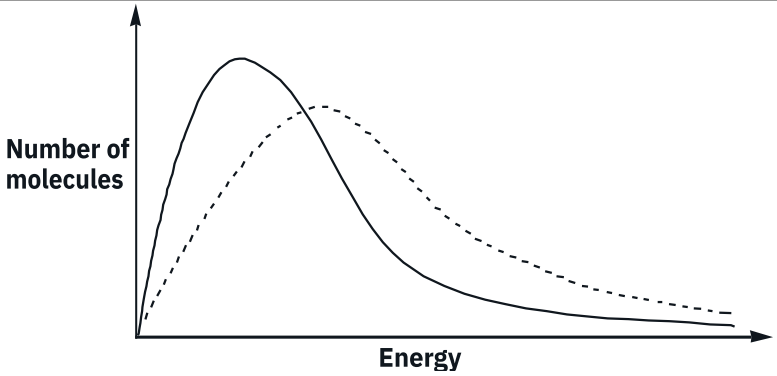
Use of 25 → –38.7 3 marks

H_2O essential

IGNORE *sign, even if wrong*

ALLOW *2 SF, e.g. 58*

NOTE*: Look for marking criteria within annotations on Boltzmann distribution*



Curve at higher temperature 1 mark

Curve starts close to zero

AND

does not touch x axis at high energy

AND

maximum to right AND lower than provided curve

AND

finishing higher than provided curve ✓

Labels 1 mark

Axes labels correct:

- Number of molecules AND Energy ✓

Explanation 1 mark

More molecules have energy greater than E_a

OR

Greater area under curve above E_a ✓

Could be in diagram

If not stated, assume higher temperature

diagram

IGNORE *slight inflexion on the curve*

For labels,

ALLOW *number of particles*

ALLOW *amount of molecules/particles*

IGNORE *number of atoms*

ALLOW *kinetic energy*

IGNORE *enthalpy for energy*

ORA *at lower temperature*

ALLOW *more molecules have the energy to react*

more molecules can overcome/reach E_a

IGNORE *atoms*

IGNORE *more successful collisions*

OR collide more frequently

DO NOT ALLOW *explanation is in terms of two activation energies (i.e. 'catalyst explanation)*

[3 marks]

Q19 · Enthalpy changes · [1 mark]

Answer: **A**

–730

Q20 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

5(a)

Level 3 (5–6 marks)

Calculates correct enthalpy change with correct – sign for $\Delta_{hy}H$ (Ca^{2+}), allowing for acceptable errors.

EXAMINER GUIDANCE

Indicative scientific points may include:

1. Processing experimental data

Energy change from $mc\Delta T$

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)

Calculates a value of $\Delta_{sol}H$ ($CaCl_2$(s)) from the:

Energy change

AND

Amount in mol of $CaCl_2$.

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)

Processes experimental data to obtain the:

Energy change from $mc\Delta T$

OR

Amount in mol of $CaCl_2$.

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]

- Energy in J **OR** kJ = 106.6 × 4.18 × 18.5 = 8243.378 (J) **OR** 8.243378 (kJ)

3SF or more

Amount in mol of $CaCl_2$

- $n(CaCl_2) = \frac{9.28}{111.1} = 0.0835.....$ (mol)

0.08352835284 unrounded

---

2. ± value of $\Delta_{sol}H(CaCl_2(s))$

$= \pm \frac{8.24.....}{0.0835....} = \pm$

98.68957929 (kJ mol^{-1})

3 SF or more. From 3 SF:

$\frac{8.24}{0.0835} = 98.7$

---

3. CORRECT $\Delta_{hy}H(Ca^{2+})$ calculated with signs

$\Delta_{hy}H(Ca^{2+}) = L.E. + \Delta_{sol}H(CaCl_2) - 2\Delta_{hy}H(Cl^-)$

$= -2223 + (-98.7) - (2 \times -378)$

$= -1566$ (kJ mol^{-1})

3SF or more with correct – sign

From unrounded values, –1565.689579

See next page for examples of acceptable errors

Acceptable errors

ALLOW *omission of trailing zeroes*

ALLOW *minor slips in rounding, transcription errors, etc throughout*

ALLOW *one small error,*

e.g. subtracting mass of $CaCl_2$ for m

$m = 106.60 - 9.28 = 97.32$

$q = 7.5257556$ (kJ)

$\Delta_{sol}H = 90.09821629$ (kJ mol^{-1})

5(b)(i)

$C_8H_{18} + C_2H_5OH + 15½\ O_2 \rightarrow 10CO_2 + 12H_2O$ ✓

[1 mark]

5(b)(ii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 341850 to 2 SF or more award 3 marks

$M(C_8H_{18}) = 114$ **AND** $M(C_2H_5OH) = 46$

OR

1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓

50 mol C_8H_{18} **OR** 50 mol C_2H_5OH

OR

50 mol (C_8H_{18} + C_2H_5OH)

OR

8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓

Energy = (50 × 5470) + (50 × 1367)

OR 50 × (5470 + 1367) **OR** 50 × 6837

OR 273500 + 68350

= 341850 (kJ) ✓

[3 marks]

$\Delta_{hy}H(Ca^{2+}) = -1557$ (kJ mol^{-1})

OR adding mass of $CaCl_2$ for *m*

m = 106.60 + 9.28 = 115.88

q = 8.9610004 kJ

$\Delta_{sol}H = 107.2809423$ (kJ mol^{-1})

$\Delta_{hy}H(Ca^{2+}) = -1574$ (kJ mol^{-1})

ALLOW *multiples*

e.g.

$2C_8H_{18} + 2C_2H_5OH + 31\ O_2 \rightarrow 20CO_2 + 24\ H_2O$

ALLOW $C_{10}H_{24}O$ *for* $C_8H_{18} + C_2H_5OH$

Combining ethanol and octane!

IGNORE *sign throughout*

ALLOW *approach based on mass for 2nd mark*

$m(C_8H_{18}) = (\frac{114}{160}) \times 8000 = 5700$ g

AND

$m(C_2H_5OH) = (\frac{46}{160}) \times 8000 =$ 2300 g

$\text{Energy} = \frac{5700}{114} \times 5470 + \frac{2300}{46} \times 1367$

= 341850 (kJ)

ALLOW 2 SF or more *correctly rounded*

Common errors

310800 → 2 marks

Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)

Example

energy released when 4kg of C_8H_{18} burnt–

$\frac{4000}{114}$ = 35 moles . . .

5470 × 35 = 191929.8246 KJ released

$\frac{4000}{46}$ = 87.0 . . . .

87 × ~~54~~ 1367 = 118869.5652

~~191929+~~

191929.8246 + 118869.5652 = 310800

energy released = ... kJ [3]

Q21 · Enthalpy changes · [1 mark]

Answer: **D**

The standard enthalpy change of combustion of hydrogen is –286 kJ mol^{-1}.

Q22 · Enthalpy changes · [1 mark]

Answer: **D**

The enthalpy change for the condensation of a gas to a liquid is a negative value.

Q23 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

23(a)(i)

$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$

Correct species ✓

Balanced ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW multiples

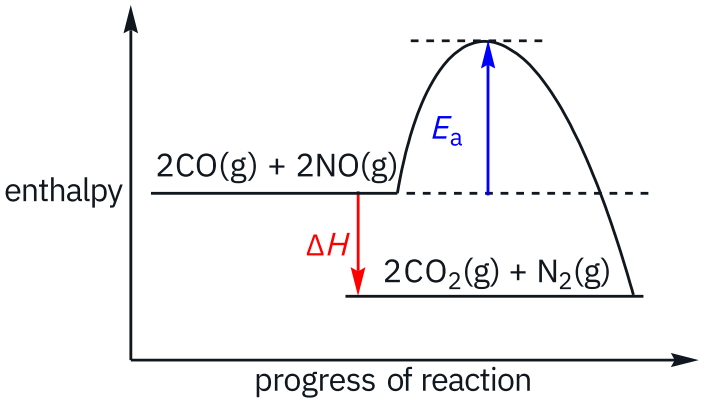
IGNORE state symbols

For heptane formula, ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

*ALLOW 1 mark for balanced combustion equation for a different alkane (**ECF**)*

e.g. $C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$

23(a)(ii)



Reactants, products and Δ*H*

2CO + 2NO on LHS

AND

IGNORE state symbols

Δ*H* DO NOT ALLOW –Δ*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.

ALLOW –746 for ΔH

E_a ALLOW AE **OR** A_E

ALLOW 2 arrowheads at each end of E_a line

OR no arrowhead

BUT DO NOT ALLOW arrowhead down

$2CO_2 + N_2$ on RHS

AND

ΔH labelled with products below reactants

AND

Arrow downwards ✓

E_a (independent of ΔH)

curve with arrow from reactants to top of curve

AND

E_a labelled ✓

IF *endothermic diagram shown,*

ALLOW ECF *for* E_a *using MS criteria*

[2 marks]

E_a line must reach maximum (or near to maximum) on curve

23(a)(iii)

Catalyst lowers activation energy

OR

Catalyst increases rate without itself changing ✓

Reaction proceeds via a different route/pathway

OR

More molecules/particles exceed activation energy ✓

[2 marks]

ALLOW 2nd labelled curve on profile diagram in 23(a)(ii) with lower activation energy/E_c *with catalyst*

ALLOW E_c *needs less energy to start reaction*

ALLOW E_c *curve is lower than* E_a *curve*

IGNORE 'shorter route' for alternative route

IGNORE more successful collisions

23(b)(i)

298 K/25°C

AND

100 kPa ✓

[1 mark]

ALLOW 'a stated temperature'

To accept that other standard temperatures can be used and 298 should strictly be added as $\Delta H_{298}^{\ominus}$

IF *a temperature is seen, it must be 298/25°C*

ALLOW 1×10^5 *Pa, 101 kPa,* 1.01×10^5 *Pa, 1 atm, 1 bar*

23(b)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –394 (kJ mol^{-1}*) award 3 marks*

Use of $\Delta_f H$ values and balancing numbers

± (–824) seen anywhere

AND

± (3 × –111) **OR** ± (333) **OR** ±1157 seen anywhere ✓

ALLOW ECF *throughout*

COMMON ERRORS

Correct subtraction for $3\Delta_f H(CO)$ using ΔH

(–25) + (–1157)

–1157 = 824 + (3 × –111)

= –1182 (kJ mol^{-1}) ✓

Calculation of $\Delta_f H(CO_2)$ formation

$$\Delta_f H(CO_2) = \frac{-1182}{3} = -394 \text{ (kJ mol}^{-1}\text{)} \checkmark$$

[3 marks]

–1182	omission of ÷3 for $\Delta_f H(CO_2)$	**2 marks**
(+)394	Incorrect subtraction	**2 marks**
(+)1182	Incorrect subtraction **&** no ÷3	**1 mark**
–320	no ×3 for –111	**2 marks**
–960	no ×3 for –111 **AND** no ÷3	**1 mark**
–377.3 / –377	incorrect subtraction	**2 mark**
–1132	incorrect subtraction **AND** no ÷3	**1 mark**
–303.3 / –303	no ×3 for –111 **AND** incorrect subtraction	**1 mark**
–385.66... / –385.7	no ΔH (25) and ÷3	**2 marks**
(+)385.66... / (+)385.7	no ΔH (25) and ÷3 and wrong sign	**1 mark**

Q24 · Enthalpy changes · [16 marks]

OCR MARK SCHEME

4(a)

(The enthalpy change) for complete combustion ✓

of 1 mol (of substance) ✓

[2 marks]

EXAMINER GUIDANCE

DO NOT ALLOW *energy required*

IGNORE *energy released*

ALLOW *combustion in excess oxygen/air*

OR reacts in excess oxygen

OR reacts completely in oxygen

ALLOW *element* ***OR*** *compound* ***OR*** *reactant*

DO NOT ALLOW *atoms*

IGNORE *standard states/conditions*

4(b)(i)

$\frac{2 \times 0.25}{31} \times 100 = 1.6\ \%$ ✓

ALLOW *1 d.p. up to calculator value of 1.612903226 correctly rounded*

[1 mark]

4(b)(ii)

Level 3 (5–6 marks)

Calculates an acceptable value for $\Delta_c H$

AND

Evaluates at least two differences from data book value AND suggests at least two suitable improvements.

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)

Use of results to calculate moles of butan-1-ol AND an attempt to calculate *q*

AND

Evaluate at least one difference from data book value AND suggests at least one suitable improvement.

OR

Calculates an acceptable value for $\Delta_c H$

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 to calculate moles of butan-1-ol **OR** attempts to calculate *q*

AND

Evaluate at least one difference from data book value **OR** suggests at least one suitable improvement.

OR

Correct use of results to calculate moles of butan-1-ol AND an attempt to calculate *q*

OR

Indicative scientific points may include:

Calculation of *q* and *n*

- mass butan-1-ol burnt = 1.31 g
- $\Delta T = 31$ °C
- $q = mc\Delta T = 200 \times 4.18 \times 31 =$ 259(16) J **OR** 25.9(16) (kJ)
- *n*(butan-1-ol) $= \frac{1.31}{74} = 0.0177(017...)$ (mol)

Calculation of $\Delta_c H$

- $\Delta H = \frac{q}{0.0177017..}$
- ΔH = (–)1460 to (–)1464 (kJ mol^{-1})

ALLOW *answer in J* mol^{-1} *if units are given*

ALLOW *a single slip/rounding errors e.g.* $M_r = 73$

IF *no calculation seen check 4(b)(i) /page 10 for any working.*

Difference from data book value

- Heat losses
- Incomplete combustion
- Data book uses standard values
- Evaporation of alcohol from wick
- Evaporation of water from beaker

Examples of improvements

- Burn in plentiful oxygen
- Draft shield

Evaluate at least one difference from data book value AND suggests at least one suitable improvement.

The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

0 marks

No response or no response worthy of credit.

[6 marks]

- Copper can in place of beaker
- Use a bomb calorimeter
- Add lid to beaker
- Place cap over wick when not burning
- Reduce gap between burner and beaker
- Use standard conditions
- Use 3 DP balance **OR** digital thermometer
- Heat for longer to reduce % uncertainty in mass/temperature measurements

4(b)(iii)

Mass burnt = 0.9825 (g) ✓

[1 mark]

ALLOW *any value from 0.98 to 0.99 g*

ALLOW ECF *from b(ii)*

i.e. 0.75 × mass change calculated

OR

q = 150 x 4.18 x 31 = 19437 J = 19.4(37) kJ

$$\text{Mass burnt} = \frac{19.4(37)}{\text{calculated } \Delta H} \times 74$$

4(c)(i)

FIRST, CHECK ANSWER ON ANSWER LINE

IF *bond enthalpy = (+)805 (kJ mol^{-1}) award 4 marks*

IF *bond enthalpy = (+)3220 (kJ mol^{-1}) award 3 marks*

Energy for bonds made: (6O–*H*)

6 × 464

OR 2784 (kJ) ✓

Energy for bonds broken:

(1 C–C + 5C–*H* + 1C–O + 1O–*H* + 3O=O)

347 + (5 × 413) + 358 + 464 + (3 × 498)

OR 347 + 2065 + 358 + 464 + 1494

OR 4728 (kJ) ✓

4C=O bond enthalpy correctly calculated

–1276 = 4728 – (4C=O + 2784)

4C=O bond enthalpy = 4728 – 2784 + 1276

ALLOW ECF *throughout*

IGNORE *signs for first 3 marking points*

Alternative method

ALLOW *(5O–H) from bonds made if O-H is omitted from bonds broken.*

Made: 5 x 464 **OR** 2320 (kJ) ✓

Broken: 347 + (5 × 413) + 358 +(3 × 498)

OR 4264 (kJ) ✓

4C=O bond enthalpy = 4264 – 2320 + 1276

= (+)3220 (kJ mol^{-1}) ✓

DO NOT ALLOW *– sign*

COMMON ERRORS for 3 marks

OR (+)3220 (kJ mol^{-1}) ✓

C=O bond enthalpy correctly calculated

C=O bond enthalpy = $\frac{3220}{4}$ = (+)805 kJ mol^{-1} ✓

[4 marks]

-805	(Wrong Sign)
(+)718(.25)	(Missing C-C)
(+)431.5	(Missing 3 x O=O)
(+)167	(Incorrect rearrangement)

4(c)(ii)

Less energy is required to break bonds in methoxymethane ✓

Energy released in bond forming is same ✓

[2 marks]

ORA

ALLOW *bonds in methoxymethane are weaker (than in ethanol)*

IGNORE *calculations*

ALLOW *Same bonds being formed*

Q25 · Enthalpy changes · [11 marks]

OCR MARK SCHEME

2(a)(i)

Rubidium chlorate(VII) ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW Rubidium(I) chlorate(VII)

Rubidium chloroate(VII)

IGNORE Rubidium (VII)chlorate

Rubidium chlorate(IIV)

Rubidium chlorate (7)

Rubidium perchlorate

2(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 54.0 ***OR*** *54.1* ***OR*** *54.2 (kJ mol^{-1}) award 3 marks*

Energy change from $mc\Delta T$

Energy in J **OR** kJ

= 102 × 4.18 × 1.5 **OR** 639.54 (J) **OR** 0.63954 (kJ) ✓

Amount in mol of $RbClO_3$

$n(RbClO_3)$ = $\frac{2.00}{169}$ **OR** 0.0118..... (mol) ✓

$\Delta_{sol}H(RbClO_3)$

= $\frac{0.63954}{0.0118.....}$ = (+) 54.0 ✓

From unrounded values, ΔH = 54.04113

ALLOW ECF *throughout*

IGNORE sign

IGNORE RE and SF in 1st 2 marks

0.01183431953 unrounded

ALLOW 54 (from 54.0)

CARE 54.00 is a rounding error

COMMON ERRORS

52.98 **OR** 53.14 2 marks

100 instead of 102:

Energy = 100 × 4.18 × 1.5 = 627 J

From unrounded *n*,

ΔH = $\frac{0.627}{0.0118.....}$ = 52.98 kJ mol^{-1}

OR 53.0 (3SF) **OR** 53

Examples of mixed acceptable intermediate rounding, e.g.

$\frac{0.640}{0.0118}$ $\Delta H = 54.237 \rightarrow 54.2$

$\frac{0.63954}{0.01183}$ $\Delta H = 54.06 \rightarrow 54.1$

[3 marks]

2(b)

FIRST CHECK THE ANSWER ON ANSWER LINE

If range = 4.4 × 10^{-5} – 4.5 × 10^{-5} (kJ mol^{-1}) award 3 marks

$[H^+] = 10^{-1.50}$ **OR** 0.0316 ... **OR** 0.032 mol dm^{-3} ✓ 1 mark

THEN 2 APPROACHES:

From rounded 0.0118,

$\Delta H = \frac{0.627}{0.0118} = 53.14$ **OR** 53.1

0.02078 **OR** 0.0208 1 mark

102 and 2 swapped:

Energy = 2 × 4.18 × 1.5 = 12.54 J

$n = \frac{102}{169} = 0.60355.....$

ECF $\Delta H = \frac{0.01254}{0.60355.....} = 0.0208$ *kJ* mol^{-1}

1.06 2 marks

102 for *n* instead of 2.00:

$n = \frac{102}{169} = 0.60355.....$

$\Delta H = \frac{0.63954}{0.60355.....} = 1.06$ kJ mol^{-1}

OR

2 for energy instead of 102

Energy = 2 × 4.18 × 1.5 = 12.54 J

$\Delta H = \frac{0.01254}{0.0118.....} = 1.06$ kJ mol^{-1}

107.4 – 107.7 2 marks

8.314 for c instead of 4.18:

Energy = 102 × 8.314 × 1.5 = 1272 J

Energy = 102 × 8.31 × 1.5 = 1271.4 J

ΔH = 107.4 – 107.7 kJ mol^{-1}

depends on intermediate rounding

CHECK

Apply ECF for any other comparable responses.

Calculator: 0.0316227766

ALLOW $10^{-1.5}$

ECF possible from incorrect $[H^+]$

From unrounded $[H^+]$,

Calculator: 0.04650408324

EITHER:

Factor that concentration changes by 1 mark

Factor = $\frac{0.0316.....}{0.680}$ = 0.0465... times

OR $\frac{0.680}{0.0316.....}$ = 21.5..... times ✓

Initial rate with diluted acid 1 mark

= 0.0465... × 9.52×10^{-4} **OR** $\frac{9.52 \times 10^{-4}}{21.5.....}$

= 4.43×10^{-5} (mol dm^{-3} s^{-1}) ✓

OR:

Rate α concentration (1st order) 1 mark

$k = \frac{\text{rate}}{[HCl]} = \frac{9.52 \times 10^{-4}}{0.680} = 1.4(0) \times 10^{-3}$

OR Constant = $\frac{0.680}{9.52 \times 10^{-4}}$ = 714.2857... ✓

Initial rate with diluted acid

= $1.4(0) \times 10^{-3} \times 0.0316$ ... **OR** $\frac{0.0316...}{714.2857...}$

= 4.43×10^{-5} (mol dm^{-3} s^{-1}) ✓

SUMMARY

M1	**$[H^+]$**	**0.0316.... OR 0.032**	**1 mark**
M2	**Working**	**0.0465 OR 21.5 OR 1.4×10^{-3} OR 714**	**1 mark**
M3	**Initial rate**	**Range: $4.4 \times 10^{-5} - 4.5 \times 10^{-5}$ 2 SF or more** *depends on intermediate rounding CHECK*	**1 mark**

[3 marks]

From $[H^+]$ = 0.032, Factor = 21.25

From unrounded $[H^+]$,

Calculator = $4.427188724 \times 10^{-5}$

From $[H^+]$ = 0.032, rate = 4.48×10^{-5}

ECF possible from incorrect $[H^+]$

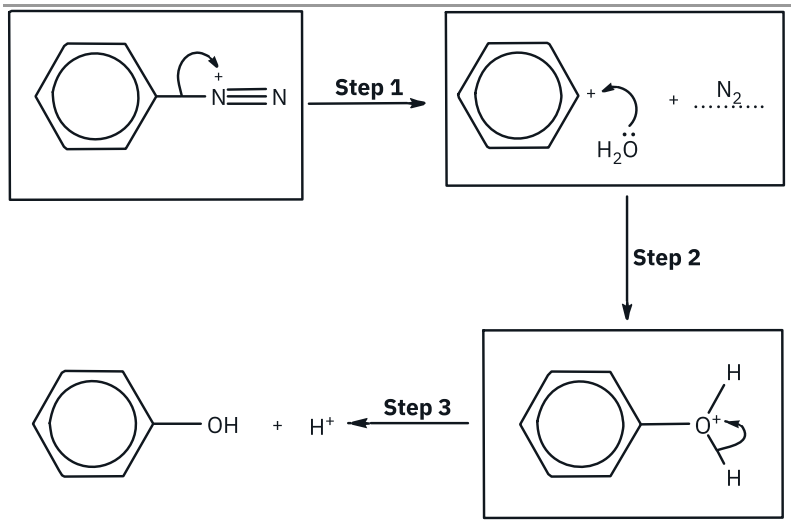
DO NOT ALLOW ECF unless derived from concentration and rate

2(c)

Mechanism:

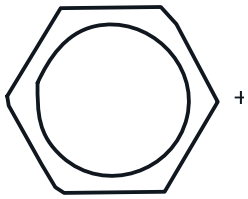
***NOTE**: Curly arrows can be straight, snake-like, etc. but **NOT** half arrows*

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



M1: Curly arrow from C–N bond to N^+ ✓

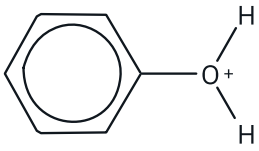
M2:



AND N_2 ✓

M3: Curly arrow from lone pair of O of H_2O to C^+ ✓

M4:



AND Curly arrow from O–H bond to O^+ ✓

For all marks, treat additional curly arrows as CON

ALLOW M3 shown in bottom box

IGNORE partial charges

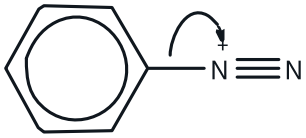
*ALLOW M3 **AND** M4 combined*

e.g.

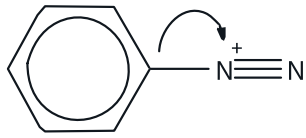


✓ ✓

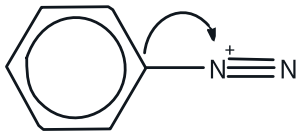
For



✓



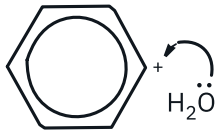
✓



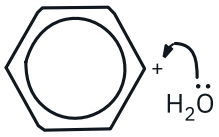
✗

2nd curly arrow must

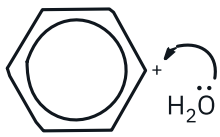
- start from, **OR** be traced back to any point across width of lone pair on O of H_2O
- go to the C or + of C^+ of $C_6H_5^+$



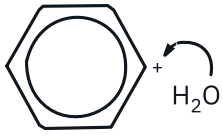
✓



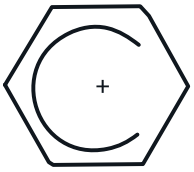
✓



✗



✗



DO NOT ALLOW M2 for carbocation

BUT

ALLOW for M3 and/or M4 by ECF, e.g.

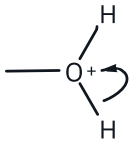


✓ ✓

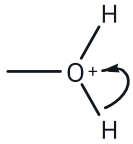
[4 marks]

3rd curly arrow must

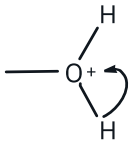
- start from '–' of O–H of $-OH_2^+$
- go to O or + of O^+



✓

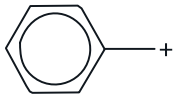


✓



✗

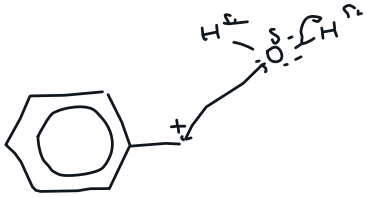
For



DO NOT ALLOW M2 for carbocation

BUT

ALLOW for M3 and/or M4 by ECF, e.g.



✗✓ ECF

Q26 · Enthalpy changes · [1 mark]

Answer: **C**

–110

Q27 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

23(a)(i)

Two (✓✓) from:

- rate of forward reaction = rate of reverse reaction
- Concentrations (of reactants and products) do not change/are constant
- In a closed system/environment

IGNORE *reactions take place together/reversible reaction*

ALLOW backward for reverse

DO NOT ALLOW *concentration of reactants = concentration of products*

ALLOW 'nothing can leave/enter'

[2 marks]

23(a)(ii)

Temperature:

(Forward) reaction is exothermic/ΔH is negative/ (Forward) reaction gives out heat

AND

Low temperature ✓

ALLOW reverse reaction is endothermic / ΔH is positive

OR reverse reaction takes in heat

ALLOW decrease temperature for low temperature

Pressure:

Right-hand side has fewer (gaseous) moles/ 4 (gaseous) moles form 2 (gaseous) moles

AND

High pressure ✓

For moles, ALLOW molecules/particles

ORA *for reverse reaction*

DO NOT ALLOW *gaseous atoms*

ALLOW increase pressure for high pressure

Equilibrium shift:

Equilibrium/system/equation shift expressed correctly seen at least once ✓

For shifts,

ALLOW 'shifts/moves/pushes' towards right'/NH_3/products

OR in favours the forward direction

OR favours the right

[3 marks]

23(b)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *bond enthalpy = (+)391 (kJ mol^{-1}) award 3 marks*

ALLOW ECF *Throughout*

Energy for bonds made (N≡N + 4 × O–H)

= 945 + 4 × 464

OR 945 + 1856

OR 2801 ✓

IGNORE *sign*

4 N–H bond enthalpy correctly calculated

4 × N–H = 2801 – 581–158 –498 = 1564 ✓

N–H bond enthalpy

ONLY ALLOW from use of at least 4 ΔH values

N–H bond enthalpy = $\frac{1564}{4}$ = (+)391 kJ mol^{-1} ✓

COMMON ERRORS (allow rounding down to whole number)

–391 → 2 marks Wrong sign for N–*H* bond enthalpy

159 → 2 marks 2 × O–*H* instead of 4 × O–*H*

945 + 2 × 464 = 1873 ✗

1873 – 581 – 158 – 498 = 636 ✓

Then $\frac{636}{4}$ = 159 ✓

681.5 → 2 marks Wrong sign for –581

945 + 4 × 464 = 2801 ✓

2801 – –581 – 158 – 498 = 2726 ✗

Then $\frac{2726}{4}$ = 681.5 ✓

536.25 → 2 marks (ΔH, –581 omitted)

ALLOW ECF *throughout, where calculation shown*

See common errors

For other answer, work on:

x = Energy for bonds made (N≡N + 4 × O–H)

4 N–H = x – 1237 **OR** x – 581 – 158 – 498

656

$$\text{N–H} = \frac{x - 1237}{4}$$

233.75 → 1 mark

158 instead of 945 and 158 omitted from N_2H_4

158 + 4 × 464 = 2014 ✗

2014 – 581 – 0 – 498 = 935 ✗

Then $\frac{935}{4}$ = 233.75 ✓

155.83 → 0 marks

As above but ÷6 instead of ÷4

Then $\frac{935}{6}$ = 155.83 ✗

194.25 → 2 marks 158 instead of 945

158 + 4 × 464 = 2014 ✗

2014 – 581 – 158 – 498 = 777 ✓

Then $\frac{777}{4}$ = 194.25 ✓

129.5 → 1 mark

As above but ÷6 instead of ÷4

Then $\frac{777}{6}$ = 129.5 ✗

484.75 → 2 marks

158 instead of 945. Then wrong sign for –581

158 + (4 × 464) = 2014 ✗

2014 – – 581 – 158 – 498 = 1939 ✓

Then $\frac{1939}{4}$ = 484.75 ✓

721 → 2 marks

–158 omitted and wrong signs for 581 and 498

945 + (4 × 464) = 2801 ✓

2801 – –581 – 0 – –498 = 2884 ✗

Then $\frac{2884}{4}$ = 721 ✓

945 + 4 × 464 = 2801 ✓

2801 – 0 – 158 – 498 = 2145 ✗

Then $\frac{2145}{4}$ = 536.25 ✓

154.75 → 2 marks 945 omitted

0 + (4 × 464) = 1856 ✗

1856 – 581 – 158 – 498 = 619 ✓

Then $\frac{619}{4}$ = 154.75 ✓

194.25 → 2 marks 158 instead of 945

158 + (4 × 464) = 2014 ✗

2014 – 581 – 158 – 498 = 777 ✓

$\frac{777}{4}$ = 194.25 ✓

–37.75 → 2 marks 158 used instead of 945 and 2 × O–*H*

158 + (2 × 464) = 1086 ✗

1086 – 581 – 158 – 498 = –151 ✓

$\frac{-151}{4}$ = –37.75 ✓

–1009.5 → 2 marks Wrong sign for 2801

945 + 4 × 464 = 945 + 1856 = 2801 ✓

–2801 – 581 – 158 – 498 = –4035 ✗

Then $\frac{-4035}{4}$ = –1009.5 ✓

430.5 → 2 marks (–158 omitted)

945 + (4 × 464) = 2801 ✓

2801 – 581 – 0 – 498 = 1722 ✗

$\frac{1722}{4}$ = 430.5 ✓

536.25 → 2 marks (Δ*H*, –581 omitted)

945 + 4 × 464 = 945 + 1856 = 2801 ✓

2801 – 0 – 158 – 498 = 2145 ✗

Then $\frac{2145}{4}$ = 536.25 ✓

719 → 2 marks Wrong signs for 158 and 498

945 + 4 × 464 = 945 + 1856 = 2801 ✓

2801 – 581 + 158 + 498 = 2876 ✗

[3 marks]

Then $\frac{2876}{4} = 719$ ✓

449.5 → 1 mark Wrong sign for –581 and 2 × O–*H*

945 + 2 × 464 = 945 + 928 = 1873 ✗

1873 – –581 – 158 – 498 = 1798 ✗

Then $\frac{1798}{4} = 449.5$ ✓

489 → 1 mark 2 × O–*H* instead of 4 × O–*H*

Wrong sign for –581 and –158 omitted

945 + 2 × 464 = 945 + 928 = 1873 ✗

1873 – –581 – 0 – 498 = 1956 ✗

Then $\frac{1956}{4} = 489$ ✓

43 → 2 marks No 4 × O–*H*

945 + 1 × 464 = 1409 ✗

1409 – 581 – 158 – 498 = 172 ✓

Then $\frac{172}{4} = 43$ ✓

23(c)



‘Dot and cross’ of triple bond correct ✓

Complete ‘dot and cross’ correct ✓

[2 marks]

ALLOW vertical arrangement:

x•••xx

as long as there are 3 electrons of each type

ALLOW 2 different symbols, provided that it is clear to which atom the electrons belong, i.e.

- 5 N electrons
- 4 C electrons
- 1 H electron

The H electron could look the same as the N electrons.

Dots could be open or filled.

Q28 · Enthalpy changes · [9 marks]

OCR MARK SCHEME

3(a)

(The enthalpy change) for the stated equation ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *reaction in molar quantities/stoichiometric ratio as shown/stated/given/in equation*

IGNORE *standard states or conditions*

DO NOT ALLOW *Energy released (can't assume reaction is exothermic)*

3(b)

Level 3 (5–6 marks)

Calculates CORRECT enthalpy change

AND

states multiple assumptions **AND** improvements

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)

Calculates CORRECT enthalpy change

OR

Correctly calculates the moles **AND** attempts the calculation of q

AND states multiple assumptions **OR** improvements.

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 any part of the calculation

AND

states an assumption **OR** an improvement.

OR

Correctly calculates the moles **AND** attempts calculation of q

OR

States multiple assumptions **OR** improvements

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

Energy change from $mc\Delta T$

Energy in J **OR** kJ

$q = 100.0 \times 4.18 \times 18.6 = 7774.8$(J) **OR** 7.7748 (kJ)

ΔH in kJ mol^{-1}

$n(Cu(NO_3)_2) = 0.05$ (mol)

$$\Delta H = -\frac{q}{n} = \frac{7.7748}{0.05} = -155 \text{ kJ}$$

mol^{-1} (3 SF)

ALLOW *-156 kJ mol^{-1} (use of 7.775 kJ)*

ALLOW *answer in J mol^{-1} if units are given*

ALLOW *a single slip/rounding errors*

Assumptions and Improvements (**NOT** INCLUSIVE)

Assumptions

- density of solution is 1 g cm^{-3}/same as water
- c of solution is same as water
- ignore the mass and c of zinc
- no heat escapes the system/lost to surroundings
- mass of solution remains constant
- no water lost/evaporated
- reaction goes to completion
- reaction completed under standard conditions
- measurements recorded are accurate

Improvements

- polystyrene cup /thermos flask
- use a lid
- more precise thermometer
- more precise balance

- measure mass of solution
- use burette to measure volume
- use a cooling curve
- use standard conditions

Aspects of the communication statement might typically have been met when calculations have been completed in a logical order, and for L3 or L2 (where level awarded for calculation only) the use of the correct sign with the final answer given to 3 or 4 significant figures.

3(c)

Half the energy/q **OR** volume/mass of solution

AND

half the moles ✓

Temperature change would be same ✓

[2 marks]

ALLOW *response that links the same proportionality/ratio of energy/volume/mass of solution to number of moles*

ALLOW *same amount of energy (released) per mole*

ALLOW *both marks if seen by a calculation i.e.*

$q = 50.0 \times 4.18 \times 18.6 = 3887.4$(J) **OR** 3.8874(kJ)

$n(Cu(NO_3)_2) = 0.025$ (mol)

$\Delta H = (-)\frac{q}{n} = \frac{3.8874}{0.025} = (-)155$ kJ mol^{-1} ✓

Use of same temperature ✓

May need to check answer in 3b to compare

IGNORE *Sign*

Q29 · Enthalpy changes · [1 mark]

Answer: **A**

OCR MARK SCHEME

−56

EXAMINER GUIDANCE

ALLOW *-56 (correct numerical answer)*

Q30 · Enthalpy changes · [14 marks]

OCR MARK SCHEME

2(a)(i)

Bonds are breaking

EXAMINER GUIDANCE

IGNORE *'more energy needed to break bonds than released in making bonds'*

AND

endothermic OR energy is required/needed ✓

IGNORE *'overcome' for 'break'*

[1 mark]

Unclear whether response refers to bond breaking or overall enthalpy change

2(a)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *bond enthalpy = (+)413 (kJ mol^{-1}) award 3 marks*

Energy for bonds made (3 × *H*–*H* + 1 × C≡O) 1 mark

3 × 436 + 1 × 1077

OR 1308 + 1077

OR 2385 (kJ) ✓

IGNORE *sign*

4C–*H* bond enthalpy correctly calculated 1 mark

4 × C–H bond enthalpy = 195 + 2385 – (2 × O–H)

= 195 + 2385 – 2 × 464

= 195 + 2385 – 928

= 1652 (kJ mol^{-1}) ✓

IGNORE *sign*

C–*H* bond enthalpy correctly calculated 1 mark

This mark is **NOT available from TWO previous errors OR from Δ*H* = 195 not being used **

C–H bond enthalpy = $\frac{1652}{4}$

= (+)413 kJ mol^{-1} ✓

For the final answer,

DO NOT ALLOW *value with a negative sign*

COMMON ERRORS

COMMON ERRORS	ECF for other numbers		
315.5 OR 316 → 2 marks	Wrong sign for 195		
Bonds made = 2385		✓	
–195 + 2385 – 928 = 1262		✗	
$\frac{1262}{4}$ = **315.5 OR 316**		✓	**ECI**
877 → 2 marks	Wrong sign for 928		
Bonds made = 2385		✓	
195 + 2385 + 928 = 3508		✗	
$\frac{3508}{4}$ = **877**		✓	**ECI**
364 → 1 mark	Missing Δ*H*, (195)		
Potentially 2 errors: missing 195			

–413 → 2 marks	Wrong sign for answer	
304 → 2 marks	2 mol of H_2 instead of 3 mol:	
2 × 436 + 1 × 1077 = 872 + 1077 = 1949		✗
195 + 1949 – 928 = 1216		ECF ✓
$\frac{1216}{4}$ = **304**		ECF ✓

[3 marks]

COMMON ERRORS	**ECF for other numbers**		
and sign for 195			
Bonds made = 2385		✓	
2385 – 928 = 1457		✗	
$\frac{1457}{4}$ = **364/ 364.3 /364.25**		✗	**NO ECI**
779.5 OR 780 → 1 mark	Wrong sign for 928 **AND** 195		
Bonds made = 2385		✓	
–195 + 2385 + 928 = 3118		✗	
$\frac{3118}{4}$ = **779.5**		✗	**NO ECI**
529 → 2 marks	1 O–*H* instead of 2 O–*H*:		
Bonds made = 2385		✓	
195 + 2385 – 464 = 2116		✗	

COMMON ERRORS	ECF for other numbers		
$\frac{2116}{4}$ = **529**		✓	**ECI**
181 → 2 marks	4 O–*H* instead of 2 O–*H*:		
Bonds made = 2385		✓	
195 + 2385 – 1856 = 724		✗	
$\frac{724}{4}$ = **181**		✓	**ECI**

2(a)(iii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *energy released = 7.15 × 10^5 kJ, award 2 marks*

$n(H_2) = \frac{60.0 \times 10^3}{24.0}$ = 2500 (mol) ✓

Energy released = 2500 × 285.8 = 7.15 × 10^5 kJ ✓

3SF **AND** standard form required

IGNORE *sign i.e. ALLOW + OR – OR no sign*

[2 marks]

ALLOW ECF *ONLY from incorrect n(H_2) based on with incorrect unit conversion from m^3*

e.g.

$n(H_2) = \frac{60.0 \times 10^2}{24.0}$ = 250 (mol) ✗

250 × 285.8 = 7.15 × 10^4 kJ ECF ✓

So ALLOW 1 mark for:

±7.15 × 10^x (unit conversion)

7.145 × 10^5 *(not 3SF)*

715000 *(not standard form)*

ALLOW use of ideal gas equation with a sensible temperature (290–298K) and pressure (100/101/101325 kPa)

e.g.

e.g. At 293K and 100 kPa,

$n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 293} = 2463...$ (mol)

→ $2463 \times 285.8 = 7.04 \times 10^5$ kJ

e.g. At 298K and 100 kPa,

$n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 298} = 2421.7...$ (mol)

→ $2421.7 \times 285.8 = 6.92 \times 10^5$ kJ

ALLOW use of 8.31 for R (same answers)

293K → $2464.24 \times 285.8 = 7.04 \times 10^5$ kJ

298K → $2422.89 \times 285.8 = 6.92 \times 10^5$ kJ

2(b)(i)

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓

ALL 3 state symbols required

[1 mark]

2(b)(ii)

$n(AgNO_3)$ 1 mark

$= \frac{2.50 \times 10^{-2} \times 60.0}{1000} = 1.5(0) \times 10^{-3}$ (mol) ✓

Essential mark

Formula 2 marks

Ratio

5.00×10^{-4} mol A contains $1.5(0) \times 10^{-3}$ mol Cl

OR

ratio A : Cl = $\frac{1.5(0) \times 10^{-3}}{5.00 \times 10^{-4}} = 1 : 3$ ✓

Formula

= $AlCl_3$ ✓

Automatically subsumes 1:3 ratio mark

ALLOW Al_2Cl_6

ALLOW PCl_3

Check equation from 2b(i) at top of response

ALLOW 1:3 or 3:1 ratio seen anywhere, e.g. XCl_3

***ALLOW ECF** from formula of silver chloride in 2b(i)*

e.g. From $AgCl_2$

$n(Cl) = 2 \times 1.5(0) \times 10^{-3} = 3.(00) \times 10^{-3}$ (mol)

ratio = 1 : 6

Formula = SCl_6

[3 marks]

2(c)(i)

$C_{13}H_{19}N_3O_7$ ✓

ALLOW elements in formula in any order

[1 mark]

e.g. $C_{13}H_{19}O_7N_3$

2(c)(ii)

4 ✓

[1 mark]

2(c)(iii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

***IF** difference = 61.7, award 2 marks*

M_r of C = 380 OR M_r of D = 441.7 ✓

Correct difference = 441.7 – 380 = 61.7 ✓

AWARD mark for correct answer of 61.7 only

[2 marks]

ALLOW other approaches based on different atoms in C and D,

e.g. Difference = 7 × (32.1 – 16) – 3 × (31 – 14)

= 112.7 – 51 = 61.7 ✓

Check answer from 2c(i) at top of response for ECF

***ALLOW ECF** from incorrect formula from 2c(i)*

e.g. From $C_{12}H_{16}N_3O_6$

M_r of C = 349 OR M_r of D = 394.6 ✓ ECF

difference = 394.6 – 349 = 45.6 ✓ ECF

Q31 · Enthalpy changes · [1 mark]

Answer: **D**

–726

Q32 · Enthalpy changes · [8 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

1(a)

releases OH^-/hydroxide (ions in aqueous solution) ✓

[1 mark]

***ALLOW** containing/forms OH^- (ions)*

***ALLOW** ionises to give OH^- (ions)*

***IGNORE** mention of pH*

1(b)

$H^+ + OH^- \rightarrow H_2O$ ✓

[1 mark]

***IGNORE** state symbols*

1(c)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

***IF** $\Delta H = -56.1$ (kJ mol^{-1}) award 4 marks*

***IF** $\Delta H = (+)56.1$ (kJ mol^{-1}) award 3 marks*

Energy released in J **OR** kJ

Q = mcΔT = 80 × 4.18 × 9.4

= 3143.36 (J) **OR** 3.14336 (kJ) ✓

ALLOW ECF throughout

***ALLOW** 3140 (J) **OR** 3.14 (kJ)*

***DO NOT ALLOW** < 3 SF*

***IGNORE** any sign*

***IGNORE** units i.e. **ALLOW** correctly calculated number in J **OR** kJ **OR** no units*

Calculates nH_2O/nHCl/nNaOH

$\frac{40 \times 1.4}{1000}$ = 0.056(0) (mol) ✓

ΔH per mole H_2O

$\frac{3.14336}{0.056}$ = ± 56.131428....(kJ mol^{-1})

OR

$\frac{3143.36}{0.056}$ = ± 56,131.428.... (J mol^{-1}) ✓

Δ*H* in kJ mol^{-1} to 3 SF **AND** – sign

ΔH = –56.1 (kJ mol^{-1}) ✓

[4 marks]

IGNORE *trailing zeroes e.g* ***ALLOW*** *0.056*

Sign **NOT** needed

Common Errors

-28.1	3 marks	Use of 40g instead of 80g or 2 x 0.056 mol
-1690	3 marks	+273 for temp change

Final answer must have 3 SF **AND** – sign

1(c)(ii)

Same number of moles (of HCl / H_2O) ✓

Same q/ energy/heat (released)

AND

(spread over a) smaller (total) volume / mass ✓

[2 marks]

IGNORE *responses related to changes in rate of reaction*

ALLOW *calculation which shows number of moles is same i.e. 0.02 x 2.8 = 0.056 (ALLOW ECF from (i) for this calculation)*

ALLOW *ΔH or Enthalpy change for 'heat'*

ALLOW *calculation to give ΔT = 12.5°C (using mass = 60 and same q value) (ALLOW ECF from (i) for this calculation)*

Q33 · Enthalpy changes · [16 marks]

OCR MARK SCHEME

17(a)(i)

Iron is an <u>element</u> (in its standard state) ✓

[1 mark]

EXAMINER GUIDANCE

Takes no energy to make an <u>element</u> from an <u>element</u> (under standard conditions)

17(a)(ii)

(Δ*H* =) 3(–394) + 0 – (–824) – 3(–111) ✓

(Δ*H* =) –25 kJ mol^{-1} ✓

[2 marks]

ALLOW ECF *for one transcriptional error*

Common Errors

1 mark

(+) 763	(no 3 x –394)
(+) 25	(incorrect sign)
–247	(no 3 x –111)
–2339	(+ for – (–824 + 3 x –111))

ALLOW ORA

17(a)(iii)

Fe_2O_3 is a solid and CO_2 is a gas ✓

So CO_2 / gas more disordered

OR greater number of ways a system can be arranged / energy can be dispersed in CO_2 / gas ✓

[2 marks]

17(a)(iv)

15 = 3(214) + 2x – 87 – 3(198)

OR 54 ✓

(2x = 54 so) S = 27 (J K^{-1} mol^{-1}) ✓

[2 marks]

ALLOW ECF *for a calculated value using all numerical values*

Common Errors

1 mark

241	(No 3 *x* 214)
12	(Subtraction backwards)
–171	(No 3 x198)

17(b)

Δ*G* at 100°C

(Δ*G* = Δ*H* –TΔ*S* =

491 – (373 × 0.543) / 491000 – (373 × 543))

= (+) 288 (kJ mol^{-1}) **OR** (+) 288461 (J mol^{-1}) ✓

Feasibility statement

Not feasible when Δ*G* > 0 ✓

Minimum Temperature

whole number required

$(T = \frac{\Delta H}{\Delta S} = \frac{491000}{543})$

= 904 **OR** 905 K ✓

ALLOW 3 SF *up to calculator value*

IGNORE *units*

ALLOW ECF *for any positive value determined in M1*

Alternative approach for first two marks

Δ*H* and *T*Δ*S* at 100°C

*T*Δ*S* = 373 × 0.543

= 202.539

Feasibility statement

(Δ*H* > *T*Δ*S*)

[3 marks]

491 > 202.539 **OR** 491000 > 202539 so not feasible

Alternative approach for first two marks

ΔS_{total} at 100°C

$\Delta S_{total} = \Delta S_{surroundings} + \Delta S_{system}$

$= \frac{-\Delta H}{T} + \Delta S_{system}$

$= \frac{-491}{373} + 0.543$

$= -0.773(3538874)$

Feasibility statement

Not feasible when $\Delta S_{total} < 0$

ALLOW *equal number of terms in numerator and denominator*

ALLOW *units cancelling as shown in an equation*

DO NOT ALLOW *references to concentration*

IGNORE *same number of reactants and products (need moles/molecules)*

17(c)(i)

Equal number of (gaseous) reactant and product molecules/moles

OR (pressure) units cancel ✓

[1 mark]

17(c)(ii)

FIRST CHECK ANSWERS ON THE ANSWER LINES

IF answer = 74(kPa) <u>for both</u> award 3 marks

$p(H_2O)\ p(CO) = \frac{p(H_2) \times p(CO_2)}{K_p}$

$= \frac{211 \times 211}{8.13}$

= 5476.(137761) ✓

(At equilibrium) $p(H_2O) = p(CO)$

/ the same value on both partial pressure answer lines ✓

$p(H_2O)$ **AND** $p(CO) = \sqrt{}$ 5476.(137761)

= 74(.0) (kPa) ✓

ALLOW ECF *from incorrect x^2*

ALLOW *$p(H_2O) = p(CO) = x$*

So $x^2 = \frac{p(H_2) \times p(CO_2)}{K_p} = 5476.138$

scores first 2 marks

[3 marks]

17(c)(iii)

Lower temperature

AND

ALLOW ORA

ALLOW *shifts to the products/increases yield or AW*

(forward reaction) is exothermic / reverse reaction is endothermic ✓

K_p (has increased and) equilibrium position shifted to the right ✓

[2 marks]

ALLOW *value of $p(H_2O)$ $p(CO)$ decreased / $p(H_2)$ $p(CO_2)$ increased*

Q34 · Enthalpy changes · [1 mark]

Answer: **C**

+435

Q35 · Enthalpy changes · [6 marks]

OCR MARK SCHEME

6

Level 3 (5–6 marks)

Calculates CORRECT enthalpy change ΔH_2 using m = 33.5 g in reaction 6.2.

AND

CORRECT enthalpy change ΔH_1 in reaction 6.1

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)

Using m = 30 – 33.5 g, c = 4.18/4.2 and ΔT = 4 calculates a value for **energy change per mole of Na_2CO_3 OR energy change per mole of HNO_3**

AND

the CORRECT amount in mol of Na_2CO_3 **OR** HNO_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)

Processes experimental data to obtain:

Calculates energy change correctly from $mc\Delta T$

OR

Attempts to calculate energy change from $mc\Delta T$ with two of m (30–33.5g), c (4.18/4.2) and ΔT (4) correct

AND amount in mol of Na_2CO_3 **OR** HNO_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.

EXAMINER GUIDANCE

TWO APPROACHES: from $n(Na_2CO_3)$ and from $n(HNO_3)$

SEE NEXT DOUBLE PAGE FOR GUIDANCE.

ALLOW *omission of trailing zeroes*

ALLOW *minor slips*

3 SF or more throughout

A: APPROACH based on $n(Na_2CO_3)$

Indicative scientific points may include:

1. Energy change from $mc\Delta T$

33.50 × 4.18 × 4.0 = 560.12 (J) **OR** 0.56012 (kJ)

OR 30.0 – 33.15, e.g.

30 × 4.18 × 4.0 = 501.6 (J) **OR** 0.5016 (kJ)

Amount of Na_2CO_3

$n(Na_2CO_3) = \frac{1.97}{106} = 0.01858....$ (mol)

2. Energy change per mole of Na_2CO_3 in kJ mol^{-1}

From m = 33.50 g = $\pm\frac{0.56012}{0.01858....} = \pm 30.138...$

ALLOW *30.11 → 30.15*

[6 marks]

From $m = 30$ g = $\pm \frac{0.5016}{0.01858....}$ = ±26.9896...

ALLOW *±27.0* ***OR*** *±26.9*

3. ΔH_2 and ΔH_1 CORRECT with signs (From 33.50 ONLY)

Reaction 6.2:

$\Delta H_2 = -30.138$ (kJ mol^{-1})

ALLOW *–30.11 → –30.15*

Reaction 6.1

$\Delta H_1 = 2 \times \Delta H_3 - \Delta H_2$

$= 2 \times 19.8 - (-30.138....) = \Delta H_1 =$ (+)69.7 (kJ mol^{-1})

NOTE*: A clear and logically structured response might include an energy cycle and accurate use of SF, 4.18 and signs throughout*

B: APPROACH using $n(HNO_3)$

Indicative scientific points may include:

1. Energy change from $mc\Delta T$

$33.50 \times 4.18 \times 4.0 = 560.12$ (J) **OR** 0.56012 (kJ)

OR 30.0 – 33.15, e.g.

$30 \times 4.18 \times 4.0 = 501.6$ (J) **OR** 0.5016 (kJ)

Amount of HNO_3 and the Na_2CO_3

$n(HNO_3)$

$= \frac{1.00 \times 30.0}{1000} = 0.0300$ (mol)

Amount of Na_2CO_3

$n(Na_2CO_3) = \frac{0.0300}{2} = 0.0150$ (mol)

2. Energy change per mole of Na_2CO_3 in kJ mol^{-1}

From $m = 33.50$ g = $\pm \frac{0.56012}{0.0150} = \pm$ 37.34

From $m = 30$ g $= \pm \dfrac{0.5016}{0.0150} = \pm 33.44$

** Some may calculate energy change per mole of HNO_3 giving:

$\pm \dfrac{0.56012}{0.0300} = \pm 18.67$ and $\pm \dfrac{0.5016}{0.0300} = \pm 16.67$

3. ΔH_2 and ΔH_1 CORRECT with signs (From 33.50 ONLY)

Reaction 6.2: $\Delta H_2 = -37.34$ (kJ mol^{-1})

Reaction 6.1

$\Delta H_1 = 2 \times \Delta H_3 - \Delta H_2$

$= 2 \times 19.8 - (-37.34)$

$\Delta H_1 = (+)76.94$ (kJ mol^{-1})

***NOTE**: A clear and logically structured response might include an energy cycle and accurate use of SF, 4.18 and signs throughout*

Q36 · Enthalpy changes · [1 mark]

Answer: **C**

+464

Q37 · Enthalpy changes · [12 marks]

OCR MARK SCHEME

2(a)

(The enthalpy change) for complete combustion ✓

of 1 mol (of substance) ✓

[2 marks]

EXAMINER GUIDANCE

ALLOW *energy change for combustion in excess oxygen*

OR reacts in excess oxygen

OR reacts completely in oxygen

OR energy released during complete combustion

OR energy change for combustion in excess air

IGNORE *energy required*

ALLOW *element OR compound OR reactant*

DO NOT ALLOW *atoms*

2(b)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = –2680 (kJ mol^{-1}) award 4 marks

If answer = (+) 2680 (kJ mol^{-1}) award 3 marks

Energy released in J **OR** kJ = 200 × 4.18 × 20.0

= 16720 (J) **OR** 16.72 (kJ) ✓

$n(C_6H_{12}) = \frac{0.525}{84} = 0.00625$ (mol) ✓

Energy per mole = $\frac{16.72}{0.00625}$ **OR** (–)2675.2 (kJ mol^{-1}) ✓

$\Delta_c H$ = –2680 (kJ mol^{-1})

Value to 3SF

AND '–' sign ✓

[4 marks]

ALLOW *16700 J or 16.7 kJ up to calculator value of 16720 J (Must be at least 3 SF)*

ALLOW ECF *from incorrect M(C_6H_{12}) or energy change*

IF *energy released above rounded to 16700,*

Energy per mole = (–)2672 by ECF 3 marks

$\Delta_c H$ = –2670 to 3SF 4 marks

COMMON ERROR

-7.02 (kJ mol^{-1}) award 3 marks

2(c)(i)

% uncertainty in temp. rise = $\frac{1}{20} \times 100 = 5\%$ ✓

% uncertainty in volume = $\frac{2}{200} \times 100 = 1\%$

AND temp rise has greater % uncertainty ✓

[2 marks]

Award 1 mark if uncertainties are given as 0.05 AND 0.01 with correct statement

2(c)(ii)

Any two from:

Heat released to the surroundings ✓

ALLOW *heat loss*

IGNORE *reference to evaporation*

Incomplete combustion **OR** incomplete reaction **OR** not everything burns ✓

Non-standard conditions ✓

[2 marks]

2(c)(iii)

Less accurate due to greater heat losses ✓

More accurate due to smaller % uncertainty in temperature change **OR** mass of fuel burnt ✓

[2 marks]

ALLOW *less accurate due to evaporation of water*

ALLOW *error for uncertainty*

ALLOW *for both marks*

May not change as

increase in temperature change

OR increase in mass of fuel burned would decrease % uncertainty

BUT

may be outweighed by increased heat loss to surroundings

OWTTE

Q38 · Enthalpy changes · [1 mark]

Answer: **A**

−3914

Q39 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

3(a)(i)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF $\Delta_c H$ = −1860 OR −1850 (kJ mol^{-1}) with evidence of *working, award 3 marks*

IF $\Delta_c H$ = −1862, award 2 marks (not 3 SF)

Energy released in J OR kJ

= 100 × 4.18 × 24.5 = ±10241 (J) **OR** ±10.241 (kJ) ✓

3 SF minimum required

Calculates n(C_3H_8)

$= \frac{0.242}{44(.0)} = 0.0055(0)$ (mol) ✓

Calculates $\Delta_c H$ with − sign AND 3 SF (appropriate)

$\Delta_c H = \frac{10241}{0.0055 \times 1000}$ = −1862 No mark

= −1860 **OR** -1.86×10^3 (kJ mol^{-1}) ✓

EXAMINER GUIDANCE

ALLOW ECF *throughout*

DO NOT ALLOW *c = 4.2 → 10290*

Next 2 marks available by ECF → −1870

ALLOW *10240/10200 J* ***OR*** *10.24/10.2 kJ*

IGNORE *units*

ALLOW ECF *from initial 3 SF rounding to 10.2 kJ:*

$\pm \frac{10200}{0.0055 \times 1000}$ → ±1854.545455 ✓

→ 1850 ✓

Common errors

ΔH = **−54.6 OR −54.7 2 marks** by ECF from $mc\Delta T$

– sign AND 3 SF required

[3 marks]

m wrong as 0.242 and Δ*T* wrong as 297.5 K)

→ *mc*Δ*T* wrong as 300.9391 (J)

Δ*H* = –4.51 2 marks by ECF from *mc*Δ*T*

m wrong as 0.242 and Δ*T* correct as 24.5)

→ *mc*Δ*T* wrong as 24.78322 (J)

Δ*H* = –22600 2 marks by ECF from *mc*Δ*T*

m correct as 100 and Δ*T* wrong as 297.5)

→ *mc*Δ*T* wrong as 124355 (J)

IGNORE *incomplete 'reaction'*

3(a)(ii)

Any two from: 1 MARK ONLY ✓

- Heat loss/released to surroundings
- Incomplete combustion/reaction with oxygen or air **OR** not everything burns
- Evaporation of water

Needs link to combustion/burning/reaction with air/O_2

IGNORE *evaporation of* C_3H_8

[1 mark]

3(b)

Level 3 (5-6 marks)

Calculates $\Delta_r H$ for reaction 3.1 correctly with correct sign

AND

Calculates a value for $\Delta_c H^{\ominus}$ of propane using **$\Delta_r H$ AND ± 4 × $\Delta_{vap} H$**

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)

Calculates $\Delta_r H$ for reaction 3.1 correctly with correct sign

OR

Calculates bonds broken **OR** bonds made correctly to obtain a value of $\Delta_r H$ for reaction 3.1

AND attempts to link $\Delta_r H$ with $\Delta_{vap} H$ **OR** calculates 4 × $\Delta_{vap} H$

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:

Bond enthalpy calculation of $\Delta_r H$

Bonds broken

= (2 × 347) + (8 × 413) + (5 × 498)

= (694) + (3304) + (2490)

= ± 6488 kJ mol^{-1}

Bonds made

= (6 × 805) + (8 × 464)

= (4830) + (3712) = ± 8542 kJ mol^{-1}

$\Delta_r H$ = 6488 – 8542 = –2054 kJ mol^{-1}

NOTE*: 3 C–C → 6835 for bond broken:* *ΔH = –1707*

2 C–C omitted from bonds broken gives: Δ*H* = –2748

Determination of $\Delta_c H(C_3H_8)$

$\Delta_c H^{\ominus}$ of propane using $\Delta_r H$ AND ± 4 × $\Delta_{vap} H$

Uses bond enthalpies for bonds broken and bonds made but may contain errors or omissions **AND** obtains a value for $\Delta_r H$.

OR

Calculates bonds broken **OR** bonds made correctly.

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]

Correct

$\Delta_c H(C_3H_8) = \Delta_r H - 4 \times \Delta_{vap} H$

$= -2054 - (4 \times 40.65)$

$= -2054 - 162.6$

$= -2216.6 / -2217$ kJ mol^{-1}

Incorrect

$\Delta_c H(C_3H_8) = -2054 + (4 \times 40.65)$

$= -2054 + 162.6$

$= -1891.4 / -1891$ kJ mol^{-1}

***NOTE**: A clear and logically structured response would include a correct energy cycle for $\Delta_c H(C_3H_8)$ using $\Delta_r H$ **AND** $4 \times \Delta_{vap} H$ in energy cycle or expression:*

***ALLOW** trailing zeroes **OR** minor slips*

Q40 · Enthalpy changes · [1 mark]

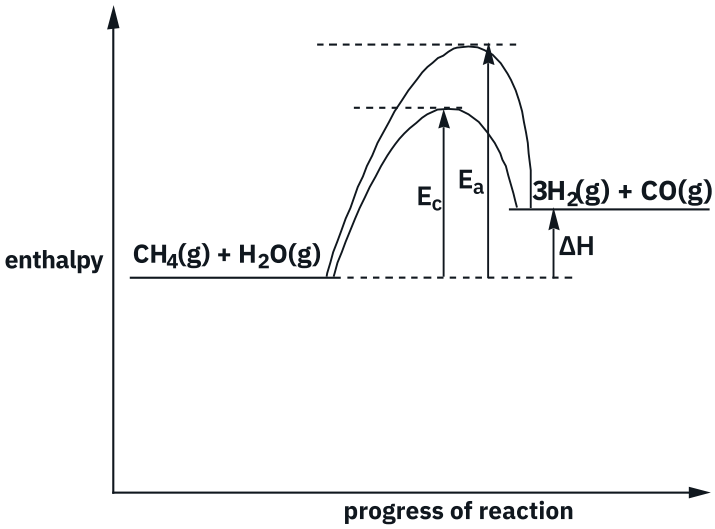
Answer: **A**

–2060

Q41 · Enthalpy changes · [10 marks]

OCR MARK SCHEME

22(a)



ΔH and products above reactants 1 mark

$3H_2(g) + CO(g)$ on RHS **IGNORE** state symbols

AND

ΔH labelled with product above reactant

AND

EXAMINER GUIDANCE

***IGNORE** state symbols.*

ΔH label

***ALLOW** arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line*

E_a and E_c labels

***ALLOW** no arrowhead(s) at both ends of activation energy line*

***ALLOW** double headed arrows*

BUT **DO NOT ALLOW** arrowhead down

E_a and E_c lines must point to maximum (or near to the maximum) on the curve

OR span approximately 80% of the distance between reactants and maximum regardless of position

ΔH arrow upwards ✓

E_a and E_c and curves 2 marks

ONE curve shown with arrow labelled E_a **OR** E_c from reactants to top of curve

→ 1 mark ✓

TWO curves shown with E_c arrow lower than E_a

AND each arrow from reactants to top of curve

→ 2 marks ✓

[3 marks]

22(b)

Pressure:

Right-hand side has more (gaseous) moles

OR 2 (gaseous) moles form 4 (gaseous) moles ✓

Low pressure **OR** decrease pressure ✓

Temperature:

(Forward) reaction is endothermic/ΔH is positive

OR (Forward) reaction takes in heat ✓

High temperature **OR** increase temperature ✓

ALLOW *suitable alternatives for right-hand side,*

e.g. towards H_2/products **OR** forward direction **OR** increases yield

For moles, **ALLOW** molecules/particles

ORA for *reverse reaction, e.g.*

ALLOW reverse *reaction is exothermic /ΔH is negative/gives out heat*

[4 marks]

22(c)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF bond enthalpy = (+)432 (kJ mol^{-1}) award 3 marks

Energy for bonds broken (4 × C–*H* + 2 × O–*H*)

4 × 413 + 2 × 464

OR 1652 + 928

OR 2580 (kJ) ✓

H–H bond enthalpy correctly calculated

3 × H–H bond enthalpy = 2580 – 1077 – 206

= 1297 (kJ mol^{-1}) ✓

H–H bond enthalpy = $\frac{1297}{3}$

= (+)432/432.3.... kJ mol^{-1} ✓

Mark is for answer

IGNORE *sign*

IGNORE *sign*

ALLOW ECF

DO NOT ALLOW *– sign*

COMMON ERRORS

570/569.66 (Allow 6 or 7 at end) → 2 marks

2580 – 1077 + 206 = 1709 ✓

Wrong sign for 206

Then $\frac{1709}{3}$ = 570 ✓

1150/1150.3... → 2 marks

2580 + 1077 – 206 = 3451 ✓

Wrong sign for 1077

$\frac{3451}{3}$ = 1150 ✓

501 → 2 marks

2580 – 1077 = 1503 ✓

[3 marks]

Missing 206

$\frac{1503}{3}$ = 501 ✓

Q42 · Enthalpy changes · [6 marks]

OCR MARK SCHEME

4(a)

Level 3 (5–6 marks)

Calculates CORRECT enthalpy change with correct signs for ΔH_2 for reaction 2

AND

ΔH_1 for reaction 1.

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)

Calculates a value of ΔH_2 for reaction 2 from the:

Energy change

AND

Amount in mol of $MgCO_3$.

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)

Processes experimental data to obtain the

Energy change from $mc\Delta T$

OR

Amount in moles of $MgCO_3$

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]

EXAMINER GUIDANCE

Indicative scientific points may include:

1. Processing experimental data

Energy change from $mc\Delta T$

- Energy in J **OR** kJ

Using 103.01 g or 100.0 g

= 103.01 × 4.18 × 5.0

= 2152.909 (J) **OR** 2.153 (kJ)

3SF or more (2.152909 unrounded)

OR 100.0 × 4.18 × 5.0

= 2090 (J) **OR** 2.09 (kJ)

Amount in mol of $MgCO_3$

$n(MgCO_3) = \frac{4.215}{84.3}$ = 0.0500 (mol)

2. ± value of ΔH_2 for reaction 2

From m = 103.01 g = ± $\frac{2.153}{0.0500}$ = ±43.06 (kJ mol^{-1})

(–43.05818 unrounded)

From m = 100.0 g = ± $\frac{2.09}{0.0500}$ = ±41.8 (kJ mol^{-1})

3. CORRECT enthalpy changes for Reaction 1 and Reaction 2 with signs (using 103.01 g ONLY)

Reaction 2 = –43.06 (kJ mol^{-1})

3SF or more with correct – sign

Reaction 1 $\Delta H_1 = \Delta H_2 - \Delta H_3$

= –43.06 – (–136.1) =

+93.04 (kJ mol^{-1})

3SF or more with correct – sign

ALLOW *omission of trailing zeroes, e.g. 93 for 93.0*

NOTE*: If 100 g used, ΔH is incorrect and L3 cannot be attained*

Q43 · Enthalpy changes · [1 mark]

Answer: **B**

–1102

Q44 · Group 2 and the halogens · [1 mark]

Answer: **D**

Aqueous sodium carbonate: effervescence · Aqueous silver nitrate: precipitate

Q45 · Group 2 and the halogens · [6 marks]

OCR MARK SCHEME

23(a)(i)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ ✓

Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

[1 mark]

EXAMINER GUIDANCE

ALLOW *3d after $4s^2$ or after $4p^6$,*

e.g. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

ALLOW *upper case D, etc and subscripts,*

e.g. .....$4S_2 3D_1$

DO NOT ALLOW *[Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$*

23(a)(ii)

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ ✓

Chlorine/Cl/Cl_2 is more reactive/stronger oxidising agent

OR reactivity decreases down group ✓

[2 marks]

ALLOW *multiples, e.g. $\frac{1}{2}Cl_2 + Br^- \rightarrow Cl^- + \frac{1}{2}Br_2$*

IGNORE *state symbols*

ALLOW *bromine is less reactive*

IGNORE *explanation in terms of electronegativity*

23(b)

Benefit **AND** risk required for mark

Benefits: kills **OR** removes bacteria

AND

Risk: toxic/poisonous

OR forms chlorinated hydrocarbons

OR forms carcinogens/toxic compounds ✓

[1 mark]

ALLOW *kills germs **OR** kills micro-organisms*

OR kills pathogens **OR** sterilises/disinfects

OR makes water potable/ safe to drink

OR purifies water

IGNORE *antiseptic, reduces risk of disease, cleans water*

ALLOW *reduces risk of water-born diseases, e.g. cholera/typhoid/dysentery*

IGNORE *'harmful'/'dangerous'*

IGNORE *chlorine is carcinogenic/ dangerous for health/causes breathing problems*

23(c)(i)

Silver nitrate **OR** $AgNO_3$ ✓

[1 mark]

ALLOW *Ag^+*

IF *name correct,* ***IGNORE*** *an incorrect formula*

IGNORE *acidified/HNO_3*

23(c)(ii)

Chloride: white (precipitate)

AND Bromide: cream (precipitate)

AND iodide: yellow (precipitate) ✓

[1 mark]

All three required for the mark

Q46 · Group 2 and the halogens · [12 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

1(a)(i)

$1s^2 2s^2 2p^6 3s^2$ ✓

[1 mark]

ALLOW *upper case S and P, and subscripts, e.g. .....$2S_2 3P_6$*

1(a)(ii)

(Mg) loses/transfers/donates two electrons ✓

[1 mark]

ALLOW *Mg loses the 3s electrons provided electronic configuration in (a)(i) is $3_s{}^2$*

ALLOW *$Mg \rightarrow Mg^{2+} + 2e^-$*

IGNORE *reference to oxidation numbers / states*

1(b)(i)

$Sr^+(g) \rightarrow Sr^{2+}(g) + e^-$ ✓

[1 mark]

ALLOW *$Sr^+(g) - e^- \rightarrow Sr^{2+}(g)$*

ALLOW *e for electron (i.e. charge omitted)*

IGNORE *states on the electron*

1(b)(ii)

Atomic radius

larger atomic radius

OR

more shells ✓

Effect of nuclear charge/shielding

Increased nuclear charge outweighed by increased distance/shielding

ALLOW ORA*: comparison needed for each mark.*

ALLOW *'more/higher energy levels'*

ALLOW *'electrons further from nucleus'*

ALLOW *'extra/new shell'*

IGNORE *more orbitals OR more sub-shells OR different shell*

OR

more/increased shielding ✓

Nuclear attraction

less nuclear attraction

OR

less attraction on electrons ✓

[3 marks]

ALLOW *more electron repulsion from inner shells*

IGNORE *responses with no comparison*

IGNORE *nuclear charge/effective nuclear charge*

ALLOW *'less nuclear pull' OR 'electrons held less tightly'*

1(c)(i)

Diagram of labelled reaction vessel for reaction ✓

Labelled (gas) syringe OR diagram of gas collection over water in a labelled measuring cylinder / inverted burette.

AND

closed system with a tube connecting reaction vessel to gas collection apparatus ✓

[2 marks]

ALLOW *(conical) flask, test-tube or boiling tube.*

DO NOT ALLOW *volumetric flask, beaker, measuring cylinder*

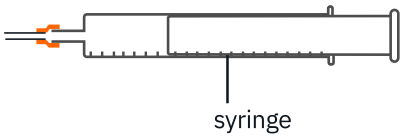
DO NOT ALLOW *delivery tube below reacting solution*

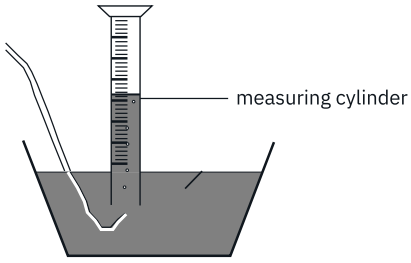
ALLOW *any of these diagrams.*



ALLOW *a single line for the tube*

IGNORE *Sealed end of delivery tube*





DO NOT ALLOW *measuring tube*

1(c)(ii)

FIRST CHECK CALCULATED VALUE FOR MOLAR / ATOMIC MASS OF CALCIUM

IF *answer = 40.1 OR 40.08 is seen anywhere award first two marks*

$n(H_2)$ OR n(Group 2 metal)

DO NOT ALLOW *pV = nRT for the calculation of the amount in moles for marking point 1.*

ALLOW *3 SF up to calculator value correctly rounded (0.004041666)*

ALLOW *3 SF up to calculator value correctly rounded (40.08247423)*

$= \frac{97.0}{24\,000} = 4.04 \times 10^{-3}$ (mol) ✓

molar mass/atomic mass of Group 2 metal

$= \frac{0.162}{0.00404} = 40.1$ (g mol^{-1}) ✓

Group 2 metal:

calcium/Ca ✓

[3 marks]

ALLOW ECF *from incorrectly calculated amount in moles*

DO NOT ALLOW *Calcium if no working*

ALLOW ECF *as element in Group 2 closest to the value calculated*

1(d)

Less (volume/products)

AND

Smaller amount/fewer moles/fewer atoms of the metal OR element reacting ✓

[1 mark]

IGNORE *higher relative atomic mass/molar mass*

ALLOW *a calculation showing that moles and volume are less*

$n(H_2) = \frac{0.162}{87.6} = 0.0018493156$

Volume = 0.0018493156 × 24000 = 44(.4) cm^3

Q47 · Group 2 and the halogens · [1 mark]

Answer: **D**

AgI

Q48 · Group 2 and the halogens · [1 mark]

Answer: **D**

The induced dipole–dipole interactions (London forces) increase.

Q49 · Group 2 and the halogens · [12 marks]

OCR MARK SCHEME

17(a)

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$ ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW multiples

IGNORE *state symbols (even if wrong)*

17(b)

Increasing size:

Atomic radius increases

OR

more shells

OR

more (electron) shielding ✓

Attraction

Nuclear attraction decreases

IGNORE *more orbitals* ***OR*** *more sub-shells*

Alternative must refer to shells

ALLOW *Energy levels for shells*

ALLOW *more electron repulsion between shells*

IGNORE *just 'shielding' (more/greater needed)*

IGNORE *'nuclear shielding'*

IGNORE *'pull' for attraction*

OR

(outer) electron(s) experience less attraction ✓

Ionisation energy

Ionisation energy decreases

OR

less energy needed to remove electron(s) ✓

IGNORE *'electrons less tightly held'*

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

IGNORE *'easier to remove electron'*

Energy is required

ALLOW *less energy to oxidise*

[3 marks]

17(c)(i)

Disproportionation:

oxidation and reduction of the same element ✓

Redox:

Cl is oxidised from +5 (in $KClO_3$) to +7 (in $KClO_4$) ✓

Cl is reduced from +5 (in $KClO_3$) to –1 (in KCl) ✓

ALLOW *'chlorine'* ***OR*** *'Cl' for same element*

IGNORE *'species' for 'element'*

ALLOW *after number, e.g. 5+*

IGNORE *ionic charges, e.g.* Cl^{5+}

IGNORE *'5' (signs required)*

IGNORE *any reference to electron loss/gain (even if wrong)*

ALLOW *one redox mark if oxidation numbers are correct but reduction/oxidation is incorrectly assigned*

[3 marks]

17(c)(ii)

potassium chlorate(VII) ✓

Brackets required

[1 mark]

17(d)(i)

Equation

$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ ✓

Entropy change and explanation

entropy decreases **OR** entropy change negative

AND

($BaSO_4$) solid/ppt has less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random particles/dispersal of energy ✓

ALLOW *multiples*

M2 is dependent on $BaSO_4(s)$ (even if formula is incorrect – eg $Ba(SO_4)_2(s)$) seen as a product in the attempted equation as long as reactants are not solid.

$BaSO_4$ solid/ppt may be assumed from $BaSO_4(s)$ seen in the attempted equation.

[2 marks]

17(d)(ii)

Equation

$\frac{1}{2}I_2(s) \rightarrow I(g)$ ✓

state symbols required

Entropy change and explanation

DO NOT ALLOW $I_2(s) \rightarrow 2I(g)$

DEPENDENT on $\frac{1}{2}I_2(s) \rightarrow I(g)$ **OR** $I_2(s) \rightarrow 2I(g)$

entropy increases **OR** entropy change positive

AND

gas has more disorder/ less order/ more ways of arranging energy/ more freedom/ more random particles / more dispersal of energy ✓

[2 marks]

Q50 · Group 2 and the halogens · [1 mark]

Answer: **D**

$Cr_2(SO_4)_3$(aq) and $BaCl_2$(aq)

Q51 · Group 2 and the halogens · [12 marks]

OCR MARK SCHEME

3(a)(i)

$Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *multiples*

IGNORE *state symbols*

3(a)(ii)

Iodine has a larger atomic radius ✓

Iodine has greater shielding / more shells ✓

Iodine has weaker / less nuclear attraction (on electron gained than bromine) ✓

[3 marks]

ORA

ALLOW *iodine is larger / bromine is smaller*

ALLOW *electron added to a shell further from the nucleus*

ALLOW *bromine has greater nuclear attraction*

IGNORE *'gained less easily' for 'weaker attraction'*

IGNORE *references to ionisation energy*

DO NOT ALLOW *mention of losing electrons for M3*

ALLOW *'pull' for 'attraction'*

IGNORE *just 'greater attraction'* ***OR*** *greater force*

3(b)(i)

Disproportionation

Oxidation AND reduction of same element/iodine

OR

Iodine has been oxidised and Iodine has been reduced ✓

Oxidation

from 0 to +1 in HIO ✓

ALLOW *I or* I_2 *for iodine*

IGNORE *numbers around equation for oxidation states*

ALLOW *1– for –1 AND 1+ for +1*

NOTE (for iodine/I_2) from 0 only needs to be seen once, does not need to be stated twice

Reduction

from 0 to –1 in HI ✓

[3 marks]

ALLOW *1 mark for 3 ox nos correct but no mention of words oxidation/reduction:*

0 in I_2 AND –1 in HI AND +1 in HIO

ALLOW *1 mark for species missing:*

Iodine oxidised (from 0) to +1

AND iodine reduced (from 0) to –1

3(b)(ii)

Chlorine is toxic/poisonous

OR

forms halogenated hydrocarbons

OR

forms carcinogens/toxic compounds ✓

[1 mark]

ALLOW *(reacts with hydrocarbons to) form carcinogens/toxic compounds*

IGNORE

- chlorine causes cancer
- harmful/dangerous
- chlorine causes breathing problems

3(c)

FIRST CHECK ON ANSWER LINE

If answer = (+) 431.5 (kJ mol^{-1}) award 2 marks

If answer = –431.5 (kJ mol^{-1}) award 1 mark (wrong sign)

2 × H–Cl bond enthalpy correctly calculated

= +436 +243 +184 = +863 (kJ mol^{-1}) ✓

H–Cl bond enthalpy correctly calculated

$\frac{+863}{2}$ = (+)431.5 (kJ mol^{-1}) ✓

[2 marks]

ALLOW *to 3 SF i.e. 432*

ALLOW *1 mark for (+)247.5 / 248 (wrong expression) i.e.* $\frac{436+243-184}{2}$

3(d)(i)

$Br_2(l) \rightarrow Br_2(g)$ ✓

[1 mark]

3(d)(ii)

Endothermic

AND

Energy required to overcome induced dipole–dipole forces/London forces ✓

[1 mark]

Mark independently of 3 (d) (i)

ALLOW *endo to break intermolecular forces/bonds*

ALLOW *bonds between molecules*

DO NOT ALLOW *van der Waals' forces*

Q52 · Group 2 and the halogens · [1 mark]

Answer: **C**

X_3Y_2

Q53 · Group 2 and the halogens · [8 marks]

OCR MARK SCHEME

23(a)

Electrons (down group)

number of electrons increases ✓

Type of intermolecular force (ANYWHERE)

induced dipole(–dipole) interactions

OR

London forces ✓

Link of energy with intermolecular forces (ANYWHERE)

(Down group,)

more energy to break/overcome intermolecular forces

OR

more/stronger intermolecular forces ✓

[3 marks]

23(b)

Test for Br^- (anion) 2 marks

Reagent **AND** observation

Silver nitrate/$AgNO_3$ **AND** cream (precipitate) ✓

Equation

$Ag^+ + Br^- \rightarrow AgBr$ ✓

State symbols not required

Test for NH_4^+ (cation) 3 marks

Reagent and conditions

(Heat with) NaOH/KOH/$Ca(OH)_2$/OH^-/hydroxide

BUT NOT ammonia ✓

Observation (Independent mark)

pH/indicator paper turns blue / purple / alkaline ✓

Equation

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ ✓

State symbols not required

EXAMINER GUIDANCE

ALLOW *more electron shells*

IGNORE *'more shells'*

OR more (electron) shielding

IGNORE *comments about nuclear attraction, ionisation energy, etc.*

IGNORE *van der Waals' forces, vdw*

IGNORE *abbreviations e.g. LDF, IDID*

IGNORE *less energy needed to break 'bonds'*

OR less energy needed to break 'London forces'

Too vague – needs idea of 'between molecules'

IGNORE *'covalent bonds' between atoms*

BUT response linking to breaking of covalent bonds is a CON for last marking point ONLY.

IGNORE *confusion between cation and anion*

IGNORE *nitric acid*

ALLOW *'bromine' for bromide in text*

IGNORE *responses about solubility in NH_3*

ALLOW *full equation:*

e.g. $AgNO_3 + NH_4Br \rightarrow AgBr + NH_4NO_3$

ALLOW displacement by Cl_2

Reagent Cl_2/chlorine

AND

Observation Orange (solution) ✓

ALLOW *shade of orange*

DO NOT ALLOW *precipitate*

Equation

$2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$ ✓

[5 marks]

ALLOW *full equation, e.g. 2NaBr + Cl_2 → Br_2 + 2NaCl*

ALLOW *full equation:*

i.e. $NH_4Br + NaOH \rightarrow NaBr + NH_3 + H_2O$

ALLOW $NH_4Br + NaOH \rightarrow NaBr + NH_4OH$

Q54 · Group 2 and the halogens · [1 mark]

Answer: **C**

$Br^-(aq)$ can reduce $Cl_2(aq)$.

Q55 · Group 2 and the halogens · [1 mark]

Answer: **B**

calcium

Q56 · Group 2 and the halogens · [1 mark]

Answer: **B**

$Ca(OH)_2$ is used in agriculture to neutralise alkaline soils.

Q57 · Group 2 and the halogens · [1 mark]

Answer: **D**

London forces increase.

Q58 · Group 2 and the halogens · [9 marks]

OCR MARK SCHEME

24(a)(i)

Oxidation and reduction of the same element ✓

'Atom' is insufficient for element

[1 mark]

EXAMINER GUIDANCE

ALLOW 'chlorine' OR 'Cl' for same element

IGNORE *'species' for 'element'*

24(a)(ii)

Equation

$Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$ ✓

Redox:

Cl is oxidised from 0 (in Cl_2) to +1 in NaClO ✓

Cl is reduced from 0 (in Cl_2) to –1 in NaCl/HCl ✓

IGNORE *oxidation numbers shown in equation*

(treat as rough working)

DO NOT ALLOW

$Cl_2 + NaOH \rightarrow NaClO + HCl$

ALLOW ECF *from HCl in equation*

ALLOW 1 out of 2 redox marks if NaClO AND NaCl omitted, i.e.

Cl is oxidised from 0 to +1

AND

Cl is reduced from 0 to –1

BUT

If no oxidation numbers in explanation, look at equation for oxidation numbers

[3 marks]

24(b)

Identification of halide

Add (aqueous) silver nitrate OR $AgNO_3$

OR Ag^+/silver ions ✓

Observations – mark independently

Any 2 precipitate colours from

Chloride/Cl^- gives white precipitate

Bromide/Br^- gives cream precipitate

Iodide/I^- gives yellow precipitate ✓

Precipitate/solid seen at least once

Equation for at least one halide

e.g. $Ag^+ + Cl^- \rightarrow AgCl$

ALLOW $Ag^+ + X^- \rightarrow AgX$ ✓

IGNORE *state symbols (ppt already assessed)*

Identification of B and C

B: NaBr OR sodium bromide ✓

C: $CaCl_2$ OR calcium chloride ✓

[5 marks]

ALLOW 1 out of 2 redox marks if oxidation number changes are BOTH correct

...BUT reduction/oxidation is incorrectly assigned, i.e.

Cl is reduced from 0 (in Cl_2) to +1 in NaClO

Cl is oxidised from 0 (in Cl_2) to –1 in NaCl/HCl

General:

ALLOW number before sign in ox no,

i.e. 1+ for +1

1– for –1

IGNORE *ionic charges, e.g.* Cl^{1+}

IGNORE *'1' (signs required)*

IGNORE *references to electron loss/gain*

(even if wrong)

IGNORE *addition of* HNO_3 *but HCl CONs* $AgNO_3$

IGNORE *references to solubility in* NH_3 *(dil or conc), even if incorrect*

ALLOW chlorine for chloride, etc

ALLOW equation with Br^- *OR* I^-

e.g. $Ag^+ + Br^- \rightarrow AgBr$

ALLOW full/partial equations,

e.g. $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$

ALLOW explanation for identification: i.e.

B (Group 1):

Subtract molar/atomic mass of halide/Br from number in range 100–115/molar mass of B ✓

C (Group 2):

Subtract 2 × molar/atomic mass of halide/Cl from number in range 100–115/molar mass of C ✓

ALLOW displacement by addition of halogen ✓

2 correct colours in water or organic solvent ✓

Equation, e.g. $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓

Q59 · Group 2 and the halogens · [1 mark]

Answer: **D**

AgBr and AgI

Q60 · Group 2 and the halogens · [14 marks]

OCR MARK SCHEME

21(a)(i)

Ca fizzes faster

AND

Ca dissolves/disappears more quickly ✓

[1 mark]

EXAMINER GUIDANCE

CARE Both needed for 1 mark.

ORA

ALLOW AW

IGNORE *finishes first*

IGNORE *more bubbles (need idea of rate)*

IGNORE *exothermic*

21(a)(ii)

Oxidation $Mg \rightarrow Mg^{2+} + 2e^-$ ✓

Reduction $2H^+ + 2e^- \rightarrow H_2$

OR $H^+ + e^- \rightarrow \frac{1}{2}H_2$ ✓

[2 marks]

In half equations,

ALLOW *the use of e for* e^-

ALLOW *Mg - 2e⁻ → Mg²⁺*

IGNORE *state symbols even is wrong BUT half equations MUST only have species that change.*

For charges on half equations,

ALLOW *Mg⁺²* for *Mg²⁺*

OR H^{+1} for H^+

If BOTH half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations

21(b)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 2.53(g) award 5 marks

$[H^+] = 10^{-13.12}$ **OR** 7.58..... × 10^{-14} (mol dm^{-3}) ✓

ALLOW ECF *and 3SF throughout.*

ALLOW *calculation process in any order.*

IGNORE *rounding errors past 3SF*

Calculator: 7.58577575 × 10^{-14}

$[OH^-] = \dfrac{1 \times 10^{-14}}{7.58..... \times 10^{-14}}$ **OR** 0.1318 ..... (mol dm^{-3}) ✓

$n(OH^-)$ in 250 $cm^3 = \dfrac{0.1318.....}{4}$ **OR** 0.0329..... (mol) ✓

$n(Ba(OH)_2)$ or n(BaO) $= \dfrac{0.0329.....}{2}$ **OR** 0.0164..... (mol) ✓

Mass of BaO = 0.0164..... × 153.3 = 2.53 (g) 3SF ✓

[5 marks]

Calculator: 0.1318256739

ALLOW *alternative approach using pOH for first 2 marks.*

$p[OH^-] = 14 - 13.12 = 0.88$

$[OH^-] = 10^{-0.88} = 0.1318.....$

Calculator: 0.03295641846

0.033(0) comes from $[OH^-] = 0.132$

Calculator: 0.01647820923

Calculator: 2.526109475

Common errors

4 marks

5.05g	Not dividing by 2
2.82g	Use of M_r for $Ba(OH)_2$
5.06g	rounds to 0.132 in M2 then not dividing by 2

3 marks

5.65g	not dividing by 2 and using M_r for $Ba(OH)_2$

21(b)(ii)

$Ba^{2+}(aq) + 2H^+(aq) + SO_4^{2-}(aq) + 2OH^-(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$ ✓

[1 mark]

ALLOW *multiples*

ALLOW

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

OR

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

21(c)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 731(g) award 3 marks

$n(Z)$

$n(Ca_5NH_4(NO_3)_{11} \cdot 10H_2O) = \dfrac{1500}{1080.5}$ **OR** 1.388246... ✓

Mass of limestone

$n(CaCO_3)$ = 1.388246... × 5 **OR** 6.94123...

ALLOW ECF *throughout*

ALLOW *calculation process in any order.*

IGNORE *rounding errors past 3SF*

DO NOT ALLOW *100 for M_r of $CaCO_3$*

Common errors

2 marks

AND

mass $CaCO_3$ = 6.94123... × 100.1 **OR** 694.8 g ✓

mass limestone = $\frac{694.8 \times 100}{95.0}$ = 731 g (3SF) ✓

[3 marks]

146g	no x 5 for moles of $CaCO_3$
660g	use of 95.0/100
29.3g	divide by 5 rather than x5

21(c)(ii)

$Mg_3Ca(CO_3)_4(s) + 8HCl(aq) \rightarrow 3MgCl_2(aq) + CaCl_2(aq) + 4H_2O(l) + 4CO_2(g)$

Correct formulae ✓

Balanced **AND** state symbols ✓

[2 marks]

ALLOW *multiples*

M2 dependent on M1

IGNORE *incorrect state symbol for* $Mg_3Ca(CO_3)_4$

Q61 · Group 2 and the halogens · [1 mark]

Answer: **D**

Aqueous potassium carbonate: effervescence · Aqueous silver nitrate: precipitate

---

Q62 · Group 2 and the halogens · [1 mark]

Answer: **B**

carbonate, sulfate, halide

Q63 · Group 2 and the halogens · [1 mark]

Answer: **B**

$MgSO_4$

Q64 · Group 2 and the halogens · [1 mark]

Answer: **A**

$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$

Q65 · Group 2 and the halogens · [1 mark]

Answer: **B**

Hydroxides

Q66 · Group 2 and the halogens · [1 mark]

Answer: **D**

$4HCl + MnO_2 \rightarrow MnCl_2 + Cl_2 + 2H_2O$

Q67 · Group 2 and the halogens · [11 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

22(a)

Disproportionation

Oxidation and reduction of the same element/bromine

OR

Bromine has been oxidised and bromine has been reduced ✓

Oxidation numbers and redox

Br is oxidised from 0 (in Br_2) to +1 in NaBrO ✓

Br is reduced from 0 (in Br_2) to –1 in NaBr ✓

IGNORE *oxidation numbers shown in equation*

(treat as rough working)

BUT

If no oxidation numbers in explanation, or if oxidation numbers are not linked to substances, look at equation for annotations which may be worthy of credit

[3 marks]

'Atom' is insufficient for element

ALLOW *1 out of 2 redox marks if NaBrO AND NaBr omitted, i.e.*

Br is oxidised from 0 to +1 **AND**

Br is reduced from 0 to –1

ALLOW *1 out of 2 redox marks if oxidation number changes are BOTH correct*

...BUT reduction/oxidation is incorrectly assigned, i.e.

Br is reduced from 0 (in Br_2) to +1 in NaBrO

Br is oxidised from 0 (in Br_2) to –1 in NaBr

ALLOW *1 out of 2 redox marks for 3 oxidation numbers correct but no mention of words oxidation/reduction: e.g.*

0 in Br_2 **AND** –1 in NaBr **AND** +1 in NaBrO

General:

ALLOW *number before sign in ox no,*

i.e. 1+ for +1 1– for –1

IGNORE *ionic charges, e.g.* Br^{1+}

IGNORE *'1' (signs required)*

IGNORE *'+' and '-' (numbers required)*

IGNORE *references to electron loss/gain (even if wrong)*

22(b)(i)

Atomic radius

Cl has a smaller atomic radius (than Br)

OR Cl has fewer shells

OR Cl has less shielding ✓

Attraction

Nuclear attraction is more in Cl

OR (outer) electrons in Cl are more attracted (to nucleus)

OR Decreased distance / shielding in Cl outweighs decreased nuclear charge ✓

Ease of gaining electron

Comparison required throughout

ORA *throughout*

ALLOW *'down the group' if the group is clearly identified as group 7/halogens*

For fewer shells, **ALLOW** lower energy level

IGNORE *fewer orbitals* ***OR*** *fewer sub-shells*

IGNORE *'different shell'*

ALLOW *Cl has more nuclear pull*

IGNORE *more effective nuclear charge*

Easier to gain an electron in Cl ✓

[3 marks]

IGNORE *'nuclear charge' for nuclear attraction*

ALLOW *easier to reduce chlorine*

IGNORE *comments about energy/electronegativity*

22(b)(ii)

toxic/poisonous

OR

(forms) chlorinated/halogenated hydrocarbons

OR

(forms) carcinogenic compounds / toxic compounds ✓

[1 mark]

IGNORE *'harmful'/'dangerous'*

IGNORE *chlorine is carcinogenic/causes cancer dangerous for health/causes breathing problems*

IGNORE *forms HCl*

22(c)

Identification of halide

Add (aqueous) silver nitrate **OR** $AgNO_3$

OR Ag^+/silver ions ✓

Observations – mark independently

Any 2 precipitate colours from

Chloride/Cl^- gives white precipitate

Bromide/Br^- gives cream precipitate

Iodide/I^- gives yellow precipitate ✓

Precipitate/solid seen at least once

Correct equation for at least one halide

e.g. $Ag^+ + Cl^- \rightarrow AgCl$

ALLOW $Ag^+ + X^- \rightarrow AgX$ ✓

IGNORE *state symbols (ppt already assessed)*

Solubility

AgCl/precipitate dissolves in dilute $NH_3(aq)$

AND

AgBr/precipitate dissolves in concentrated $NH_3(aq)$,

AND

AgI/precipitate does not dissolve (in concentrated $NH_3(aq)$) ✓

[4 marks]

IGNORE *addition of HNO_3 but HCl/H_2SO_4 is a CON for $AgNO_3$*

IGNORE *addition of $Ba(NO_3)_2$ but $BaCl_2$ is a CON for $AgNO_3$*

ALLOW *Cl/chlorine for chloride, etc. (credit is for the colours and precipitate)*

ALLOW *ppt/ptte for precipitate*

ALLOW *equation with Br^-* ***OR*** *I^-*

e.g. $Ag^+ + Br^- \rightarrow AgBr$

ALLOW *'ammonia' or NH_3 for $NH_3(aq)$*

Answer needs to be clear it is the solid/AgX which is dissolving

---

Q68 · Group 2 and the halogens · [1 mark]

Answer: **B**

Only 1 and 2

Q69 · Group 2 and the halogens · [1 mark]

Answer: **A**

$BaSO_4$

Q70 · Group 2 and the halogens · [1 mark]

Answer: **D**

OCR MARK SCHEME

Only 1

EXAMINER GUIDANCE

ALLOW *1 in the answer box*

Q71 · Group 2 and the halogens · [9 marks]

OCR MARK SCHEME

23(a)

toxic/poisonous

OR

forms chlorinated hydrocarbons

OR

forms carcinogenic compounds / toxic compounds ✓

[1 mark]

EXAMINER GUIDANCE

IGNORE *'harmful'/'dangerous'*

IGNORE *chlorine is carcinogenic/causes cancer dangerous for health/causes breathing problems*

23(b)

Element oxidised: Chlorine/Cl

Change from: –1 to 0 ✓

Element reduced: Manganese/Mn

Change from +4 to +2 ✓

[2 marks]

MAX 1 mark if no '+' sign for oxidation number

ALLOW *Cl_2 for chlorine*

ALLOW *1–*

ALLOW *4+* ***AND*** *2+*

ALLOW *1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around*

IGNORE *numbers around equation i.e. treat as rough working*

23(c)

$3KClO_4 + 8Al \rightarrow 3KCl + 4Al_2O_3$ ✓

[1 mark]

ALLOW *multiples*

23(d)

Plan

Mix (solution of) halogen and (solution of) halide ✓

Observation with chlorine

bromide → orange/yellow ✓

Observation with bromine

IGNORE *additions of halogen to same halide e.g. Chlorine to chloride.*

ALLOW *within text if it is clear that halogen is added to halide*

Check observations in a presented table.

iodide → violet/purple/pink ✓

Observation with iodine

No colour change/no reaction ✓

Equation

$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$

OR

$Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$

OR

$Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓

Reactivity trend

$Cl_2 > Br_2 > I_2$ /decreases down the group ✓

[5 max]

ALLOW *multiples, e.g.* $½Cl_2 + Br^- \rightarrow ½Br_2 + Cl^-$

Q72 · Group 2 and the halogens · [1 mark]

Answer: **C**

Only 2 and 3

Q73 · Periodicity · [1 mark]

Answer: **B**

1st: 738 · 2nd: 1451 · 3rd: 7733 · 4th: 10543 · 5th: 13630

Q74 · Periodicity · [1 mark]

Answer: **D**

trigonal planar

Q75 · Periodicity · [1 mark]

Answer: **C**

$1s^2 2s^2 2p^6$

Q76 · Periodicity · [8 marks]

OCR MARK SCHEME

2(a)

Phosphorus has

more electrons ✓

Stronger London forces

OR

Stronger induced dipole(-dipole) interactions ✓

More energy required to break the intermolecular forces/bonds **OR** London forces ✓

EXAMINER GUIDANCE

ALLOW ORA *but comparison should be used for the all marks*

DO NOT ALLOW *Phosphorus has more electrons in the outer shell or larger electron cloud.*

IGNORE *Phosphorus molecules are bigger or have greater* M_r.

ALLOW *'more' for 'stronger'*

[3 marks]

ALLOW *stronger van der Waals'/vdW forces*

DO NOT ALLOW *attraction between atoms or that covalent bonds are broken*

2(b)

Magnesium

metallic (bonds) ✓

cations/positive ions/Mg^{2+}

AND

delocalised electrons ✓

ALLOW the (electrostatic) attraction between cations/positive ions and delocalised electrons for both Mg marks ✓ ✓

DO NOT ALLOW *molecules for second mark*

IGNORE *'sea of electrons'*

Silicon

covalent ✓

between atoms ✓

ALLOW the attraction between a shared pair of electrons and the nuclei of the (bonded) atoms for both marks ✓ ✓

DO NOT ALLOW *any intermolecular forces in marking points 2 and 4 or silicon molecules*

[4 marks]

2(c)

$Al_2S_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2S$ ✓

IGNORE *state symbols*

ALLOW *correct multiples*

[1 mark]

Q77 · Periodicity · [16 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

22(a)(i)

m/z	protons	neutrons	electrons
24	12	12	11
25	12	13	11
26	12	14	11

Mark vertically: protons **AND** neutrons ✓

electrons ✓

[2 marks]

22(a)(ii)

FIRST CHECK THE ANSWER ON THE ANSWER LINE

If answer = 24.32 award 2 marks

ALLOW ECF *for a correct calculation to 2 DP if:*

$$\frac{(24 \times 78.99) + (25 \times 10.00) + (26 \times 11.01)}{100}$$

OR 24.320 **OR** 24.3202 ✓

= 24.32 (to 2 DP) ✓

[2 marks]

- %s have been used with wrong isotopes ONCE

OR

- decimal places for ONE % have been transposed

22(b)

Observations linked to anion identifications

Bubbles/effervescence/fizzing/gas **AND** carbonate ✓

(white **OR** precipitate) **AND** sulfate ✓

Use of molar mass in reasoning

Molar mass used ONCE with carbonate **OR** sulfate ✓

Identification

B: K_2CO_3 ✓

C: Na_2SO_4 ✓

[5 marks]

For bubbles, **ALLOW** carbon dioxide/CO_2

BUT **DO NOT ALLOW** hydrogen/H_2

For carbonate, **ALLOW** CO_3

For sulfate, **ALLOW** SO_4

e.g. Carbonate: 140 – (12 + 48); 140 – 60

Sulfate: 140 – (32.1 + 64); 140 – 96.1

K_2CO_3 = 138.1

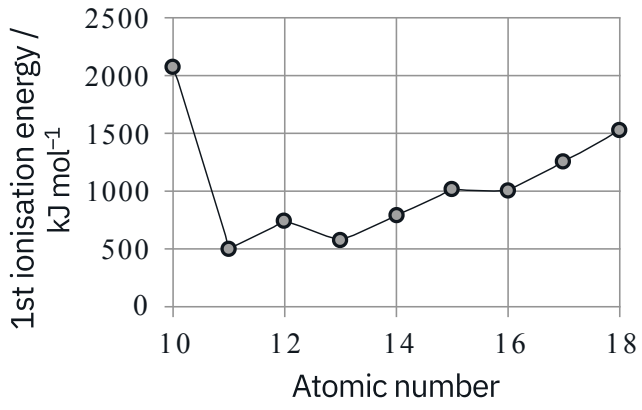
Na_2SO_4 = 142.1

***ALLOW ONE** of the two identification marks for:*

- Correct names: B potassium carbonate **AND C** sodium sulfate
- Incorrect formulae i.e. B KCO_3 **AND C** $NaSO_4$

Communicates the same as names

22(c)(i)



Ne (Z = 10) shown higher than 1500 (i.e. > Ar) ✓

[1 mark]

Look carefully for small dots on the y axis

***IGNORE** no straight line from Ne (10) to Na (11)*

22(c)(ii)

$$\frac{500}{6.02 \times 10^{23}} = 8.3 \times 10^{-22} \text{ (kJ)}$$ ✓

***ALLOW** use of IEs close to 500 giving a range:*

Answer MUST be to 2 SF **AND** in standard form.

[1 mark]

$8.0 \times 10^{-22} - 8.6 \times 10^{-22}$

i.e. $8.3 \pm 0.3 \times 10^{-22}$

22(c)(iii)

Nuclear charge

number of protons/proton number increases

OR

greater nuclear charge ✓

Distance/shielding

(Outer) electrons are in the same shell

OR

(Outer) electrons experience the same/similar shielding

OR

Atomic radius decreases ✓

Attraction

Greater nuclear attraction (on outer electrons)

OR

(outer) electrons are attracted more strongly (to the nucleus) ✓

[3 marks]

Comparison should be used for each mark

IGNORE *atomic number increases*

IGNORE *nucleus gets bigger*

IGNORE *'effective nuclear charge increases'*

IGNORE *same sub-shell* ***OR*** *same orbital*

IGNORE *'there is shielding'*

ALLOW *'greater repulsion from inner shells'*

ALLOW *'pull' for 'attraction'*

IGNORE *just 'greater attraction'* ***OR*** *greater force*

IGNORE *'held' for attracted,*

e.g. IGNORE 'held more strongly

22(c)(iv)

Sub-shells

Mg electron is removed from (3)s

AND

Al electron is removed from (3)p ✓

Energy levels

Al electron has a higher energy

OR (3)p has higher energy than (3)s ✓

[2 marks]

IGNORE *number before s and p*

e.g. ALLOW (2)s and (2)p

ALLOW *response implying that orbitals/sub-shell changes from s to p*

IGNORE *comments about distance from nucleus*

IGNORE *'less energy to remove'*

DO NOT ALLOW *unpaired electron removed more easily (****ORA****)*

Q78 · Periodicity · [1 mark]

Answer: **A**

silicon

Q79 · Periodicity · [1 mark]

Answer: **C**

number of protons in the nucleus

Q80 · Periodicity · [1 mark]

Answer: **A**

YCl

Q81 · Periodicity · [1 mark]

Answer: **A**

N atoms have less repulsion between p-orbital electrons than O atoms.

Q82 · Periodicity · [13 marks]

OCR MARK SCHEME

1(a)(i)

Hydrogen/H ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW H_2

1(a)(ii)

Helium/He ✓

[1 mark]

1(a)(iii)

Magnesium/Mg ✓

[1 mark]

1(a)(iv)

Sulfur/S ✓

[1 mark]

ALLOW *sulphur;* S_8

1(a)(v)

Chlorine/Cl **OR** fluorine/F ✓

[1 mark]

ALLOW Cl_2 *OR* F_2

1(a)(vi)

Phosphorus/P ✓

[1 mark]

ALLOW P_4

1(a)(vii)

Carbon/C ✓

[1 mark]

ALLOW *silicon/Si*

1(a)(viii)

Oxygen/O ✓

[1 mark]

ALLOW O_2

1(b)

NaCl OR $MgCl_2$ 2 marks

Giant **ionic OR ionic** lattice ✓

Ions are **mobile** in **liquid** state ✓

IGNORE *aqueous/dissolved ions are mobile*

IGNORE *'free ions'*

AND 'ions are free to carry current'

$SiCl_4$ OR PCl_3 OR SCl_2 2 marks

(Simple) molecular **OR** simple covalent (lattice) ✓

Induced dipole(–dipole) forces/interactions

OR London forces ✓

ALLOW *'are molecules'*

IGNORE

- permanent dipole(–dipole) forces
- IDID and LDF
- van der Waals

Comparison of bond strengths 1 mark

- Ionic bonds are stronger than London forces

OR

- Ionic bonds need more energy to break than London forces ✓

ALLOW *attraction between ions for ionic bonds*

ALLOW *intermolecular forces for London forces*

ALLOW *overcome for break*

ALLOW *indirect comparison, i.e.*

- Ionic bonds are strong **AND** London forces are weak

OR

- Ionic bonds need a large amount of energy to break **AND** London forces need little energy to break

[5 marks]

Q83 · Periodicity · [1 mark]

Answer: **D**

The elements in the halogen group increase in reactivity down the group.

Q84 · Periodicity · [1 mark]

Answer: **A**

S, Si, Al

Q85 · Periodicity · [1 mark]

Answer: **B**

silicon

Q86 · Periodicity · [1 mark]

Answer: **D**

OCR MARK SCHEME

Ar

EXAMINER GUIDANCE

ALLOW *Ar*

Q87 · Periodicity · [1 mark]

Answer: **B**

XCl_2

Q88 · Periodicity · [9 marks]

OCR MARK SCHEME

2(a)(i)

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

All formulae and balancing correct ✓

[1 mark]

EXAMINER GUIDANCE

IGNORE STATE SYMBOLS

ALLOW *multiples*

IGNORE *state symbols (even if wrong)*

2(a)(ii)

Oxidation

Sr from 0 to +2 ✓

Reduction

H from +1 to 0 ✓

[2 marks]

ALLOW *2+ for +2 and 1+ for +1*

'+' is required in +2 and +1 oxidation numbers

ALLOW *H_2 for hydrogen*

ALLOW *1 mark for elements* ***AND*** *all oxidation numbers correct but oxidation and reduction wrong way round* ***OR*** *not given.*

IGNORE *numbers around equation in (i)*

(treat as rough working)

2(a)(iii)

Atomic radius

Ca has smaller atomic radius

OR fewer shells ✓

Effect of nuclear charge/shielding

Ca has less/decreased shielding ✓

Nuclear attraction

Ca has greater nuclear attraction (for electrons)

OR Ca has a higher ionisation energy

OR more energy is required to lose the outer electrons ✓

[3 marks]

ORA in terms of Sr

Comparison needed for each mark.

ALLOW *'fewer energy levels'*

ALLOW *'electrons closer to nucleus'*

IGNORE *fewer orbitals* ***OR*** *fewer sub-shells*

OR different shell

ALLOW more *electron repulsion from inner shells*

IGNORE *nuclear charge/effective nuclear charge*

ALLOW *'less nuclear pull'*

OR 'electrons held less tightly'

2(b)(i)

Any value in range: 8–14 ✓

[1 mark]

2(b)(ii)

White precipitate/white solid ✓

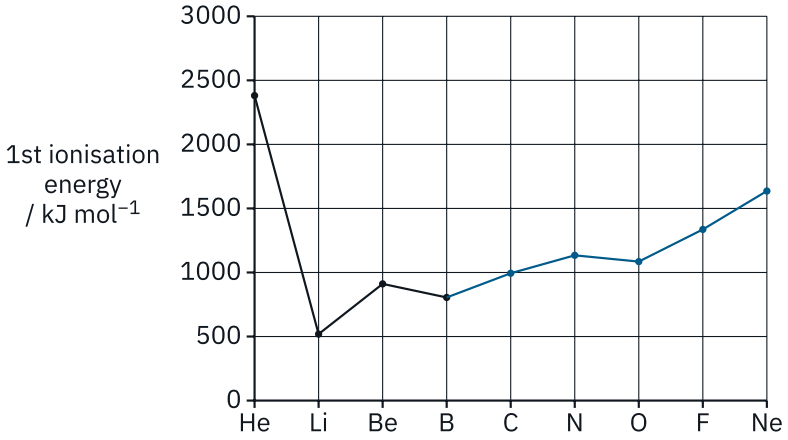
$BaSO_4$ ✓

[2 marks]

Q89 · Periodicity · [9 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

18(a)



All points show a general increase from B (i.e ignore O) **AND** Ne lower than He ✓

O lower than N **AND** O is higher than C **AND** F higher than O ✓

[2 marks]

18(b)

8.3×10^{-22} (kJ) ✓

From $\frac{500}{6.02 \times 10^{23}}$

Answer MUST be to 2 SF **AND** in standard form.

[1 mark]

ALLOW *use of IEs close to 500 giving a range:*

8.3×10^{-22} (from 500)

to 9.1×10^{-22} (from 550)

18(c)

Explanation for He

Distance/shielding

(Outer) electrons are in a lower energy/closer shell/smaller atomic radius/fewer shells ✓

Explanation for Be

Nuclear charge

number of protons/proton number increases

OR

greater nuclear charge ✓

Distance/shielding

(Outer) electrons are in the same shell **OR** sub-shell

OR

(Outer) electrons experience the same/similar shielding

OR

Atomic radius decreases ✓

For either Be or He

ORA *throughout*

Comparison needed for each mark

ALLOW *change of shell (i.e 2s and 1s)*

IGNORE *'different sub-shell'*

IGNORE *atomic number increases*

IGNORE *nucleus gets bigger*

IGNORE *'effective nuclear charge increases'*

ALLOW *same orbital*

IGNORE *'there is shielding'*

ALLOW *'greater repulsion from inner shells'*

IGNORE *just 'greater attraction'* ***OR*** *greater force*

IGNORE *'pull' for 'attraction'*

IGNORE *'held' for attracted,*

e.g. IGNORE 'held more strongly

Attraction

Greater nuclear attraction (on outer electrons)

OR

(outer) electrons attracted more strongly to the nucleus ✓

[4 marks]

18(d)

Sub-shells

Be electron is in (2)s

AND

B electron is in (2)p ✓

Energy levels

B / (2)p is higher energy (level)

OR Be / (2)s is lower energy (level) ✓

[2 marks]

IGNORE *number before s and p*

DO NOT ALLOW *"shell"*

IGNORE *block*

DO NOT ALLOW *unpaired electron removed more easily (**ORA**)*

IGNORE *'less energy to remove'*

IGNORE *comments about distance from nucleus*

IGNORE *2s shielding*

Q90 · Periodicity · [1 mark]

Answer: **C**

Al_2O_3

Q91 · Periodicity · [1 mark]

Answer: **A**

OCR MARK SCHEME

Li

EXAMINER GUIDANCE

ALLOW Li

Q92 · Periodicity · [9 marks]

OCR MARK SCHEME

ALLOW *upper case when it is obvious, e.g.* ***ALLOW*** *CR for Cr, AS for As*

ALLOW *names for elements*

EXAMINER GUIDANCE

1(a)

THREE from: N O F H ✓

[1 mark]

DO NOT ALLOW *ANY OTHER ELEMENTS (CON)*

1(b)

O ✓

[1 mark]

ALLOW *S*

BOD

1(c)

P **OR** S ✓

ALLOW *S_8, P_4*

ALLOW *As, Se*

[1 mark]

1(d)

Cr ✓

Mn ✓

[2 marks]

IGNORE *ions*

1(e)

Si ✓

[1 mark]

1(f)

S ✓

[1 mark]

ALLOW SF_6

1(g)

F ✓

[1 mark]

1(h)

As ✓

[1 mark]

Q93 · Periodicity · [17 marks]

OCR MARK SCHEME

2(a)(i)

Be: $1s^2 2s^2$ F: $1s^2 2s^2 2p^5$ ✓

Mg: $1s^2 2s^2 2p^6 3s^2$ Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$ ✓

Block: s p ✓

[3 marks]

EXAMINER GUIDANCE

1 mark per correct row

ALLOW upper case letter S and P, and subscripts, e.g. $2S_2 2P_5$

IGNORE *superscripts/numbers given on block (e.g.* s^2 *and* p^5*) if the letter is clear*

2(a)(ii)

Across period 2, the (2)s subshell fills first, followed by the (2)p ✓

same pattern or trend of filling (the subshells) repeated in other periods ✓

[2 marks]

ALLOW Elements in the same group have same number of electrons in their outer shells or subshell

e.g. s^2 in group 2/ s^2p^5 in group 17(7)

ALLOW Elements in the same period have the same number of energy levels/shells

ALLOW for both marks for indication that the pattern repeats across each period e.g

Across each period, elements repeat the pattern of electrons filling the s-subshell then p-subshell ✓✓

2(a)(iii)

Mg loses (2) electrons

AND

Cl gains an electron ✓

To gain a full/complete shell

OR

Noble gas configuration

OR

Stable/full octet ✓

*ALLOW Mg is oxidised **AND** Cl is reduced*

[2 marks]

2(a)(iv)

$2Mg + O_2 \rightarrow 2MgO$ ✓

ALLOW multiples

e.g. $Mg + ½O_2 \rightarrow MgO$

***IGNORE** state symbols even if wrong*

[1 mark]

2(b)(i)

Ca loses 2 electrons **AND** Oxidised ✓

H gains 1 electron (per atom) **AND** Reduced ✓

ALLOW H gains an electron OR gains electrons OR gains 2 electrons

*ALLOW 1 mark for Ca is oxidised **AND** H is reduced*

*ALLOW 1 mark for Ca loses electron(s) **AND** H gains electron(s)*

***IGNORE** oxidation numbers even if incorrect*

[2 marks]

2(b)(ii)

n(HCl) = 0.012 (mol) ✓

n(Ca) required to react with HCl = 0.006 (mol)

OR

0.0100 mol Ca would need 0.02 mol HCl to completely react ✓

Ca reacts with water ✓

Second mark must show recognition of the 2:1 ratio

e.g. ALLOW ratio is 1:2 but here only 1:1.2 so Ca is in excess

[3 marks]

2(c)(i)

B is below Be but above Li (about 800 kJ mol^{-1}) ✓

Mg is above Na but below Be (about 700 kJ mol^{-1}) ✓

***DO NOT ALLOW** if on the line of 900 kJ mol^{-1}. It must be clear that IE for Mg is less than Be as below it in group 2*

[2 marks]

2(c)(ii)

ALLOW $B^+(g) - e^- \rightarrow B^{2+}(g)$ for 2 marks

$B^+(g) \rightarrow B^{2+}(g) + e^-$

Equation correct ✓

Correct state symbols ✓

[2 marks]

The second mark is dependent upon the first mark except for the following close attempts:

ALLOW one mark for the following for state symbols

$B(g) \rightarrow B^{2+}(g) + 2e^-$

$B^+(g) + e^- \rightarrow B^{2+}(g) + 2e^-$

$B(g) \rightarrow B^+(g) + e^-$

ALLOW e for electron (i.e. charge omitted)

***IGNORE** states on the electron*

Q94 · Periodicity · [1 mark]

Answer: **C**

Only 2 and 3

Q95 · Periodicity · [11 marks]

OCR MARK SCHEME

20(a)(i)

killing bacteria ✓

[1 mark]

EXAMINER GUIDANCE

***ALLOW** killing microorganisms / microbes / sterilises water*

***IGNORE** 'removing' bacteria*

20(a)(ii)

$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓

Chlorine is more reactive than bromine

AND iodine is less reactive than bromine

OR

chlorine is a stronger oxidising agent than bromine **AND** iodine is a weaker oxidising agent than bromine. ✓

[2 marks]

***DO NOT ALLOW** full equation*

***IGNORE** state symbols*

CARE with endings (e.g. ide and ine)

***ALLOW** ORA*

***ALLOW** reactivity Cl > Br > I*

***ALLOW** bromide is a stronger reducing agent than chloride **AND** bromide is a weaker reducing agent than iodide*

***IGNORE** displacement*

***IGNORE** references to down the group.*

***IGNORE** all comparisons of electron structure/electron affinity*

20(b)

Equation for Step 1

$F_2 + NO_2 \rightarrow F + NO_2F$ ✓

Rate Equation

Rate = $k[F_2][NO_2]$ ✓

Mark independently

***ALLOW** rate = k $[NO_2][F_2]$*

Care – *k* must be included.

[2 marks]

20(c)

Level 3 (5–6 marks)

Describe the types of structure and bonding of all four elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles.

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)

Attempt to describe the types of bonding of three elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles.

OR

Describe in detail and bonding of two of the three types of structure **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles.

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)

Attempt to describe the bonding of two elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles.

OR

Describes in detail the bonding of one of the three types of structure **AND** explains the melting point in terms of the strength of the forces between the particles.

The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

0 marks

No response or no response worthy of credit.

[6 marks]

Indicative scientific points may include:

***ALLOW** minor omissions as we are looking for a holistic approach to LoR marking.*

Al (Giant metallic)

- Giant metallic structure/lattice
- Strong metallic bonding
- Electrostatic attraction between (positive) metal ions/cations and delocalised electrons
- A lot of energy needed to break bonds

Si (Giant covalent)

- Each Si atom forms 4 bonds / bonds with 4 other Si atoms
- Giant covalent structure/lattice
- Strong covalent bonds between atoms
- Between shared pair of electrons and adjacent nuclei.
- Most energy needed to break bonds

P, S (Simple covalent)

- Simple covalent / molecular structure/lattice
- Strong covalent bonds between atoms
- Weak induced dipole–dipole interactions between molecules*
- Least energy to overcome the forces
- Melting point of S_8 > P_4
- More electrons
- Stronger induced dipole–dipole interactions
- **DO NOT ALLOW** breaks BONDS
- **IGNORE** van der Waals' (VDW)

*__ALLOW__ London (dispersion) forces for induced dipole–dipole interactions.

Aspects of the communication statement might typically not have been met when irrelevant information (e.g. ionisation energies, ionic radius etc) have been included.

Q96 · Periodicity · [1 mark]

Answer: **A**

A shared pair of electrons and the nuclei of the bonded atoms

---

Q97 · Periodicity · [1 mark]

Answer: **C**

$Mg^{+}(g) \rightarrow Mg^{2+}(g) + e^{-}$

Q98 · Periodicity · [18 marks]

OCR MARK SCHEME

3(a)

Ca: metallic bonding **OR** giant metallic lattice ✓

Br_2: simple molecular **OR** simple covalent ✓

Induced dipole(–dipole) forces/interactions

OR London forces ✓

Conductivity linked to mobile electrons

In Ca electrons are mobile

OR electrons are delocalised

OR electrons can move

AND in Br_2 charge carriers/electrons are not mobile ✓

Melting point linked to bond strengths

Metallic bonds are strong

AND London forces are weak

OR

Metallic bonds need a large amount of energy to break

AND London forces need little energy to break ✓

[5 marks]

EXAMINER GUIDANCE

ALLOW *Metallic structure*

DO NOT ALLOW *reference to molecules or intermolecular forces for calcium*

ALLOW *'are molecules'*

IGNORE

- permanent dipole(–dipole) forces
- IDID and LDF
- van der Waals

DO NOT ALLOW *'free electrons' for mobile electrons*

ALLOW *comparison, e.g.*

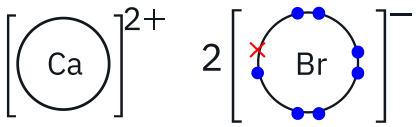
- Metallic bonds are stronger than London forces

OR

- Metallic bonds need more energy to break than London forces ✓

ALLOW *intermolecular forces instead of London forces for this mark*

3(b)(i)



Ca shown with either 8 or 0 electrons

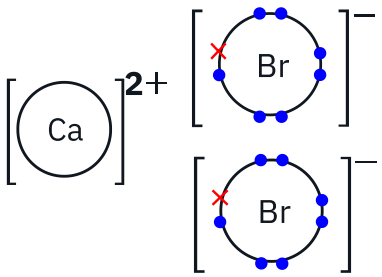
AND

Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓

Correct charges on both ions ✓

[2 marks]

ALLOW *separate Br^- ions, i.e.*



For first mark, if eight electrons are shown around Ca, the 'extra' electrons around Br must match the symbol chosen for the electrons for Ca.

IGNORE *inner shells*

Circles or brackets not required

3(b)(ii)

Atomic radius

Ba has a greater atomic radius than Ca

Comparison required throughout

ORA *throughout*

OR Ba has more shells

OR Ba has more shielding ✓

Attraction

Nuclear attraction is less in Ba

OR (outer) electrons in Ba are less attracted (to nucleus)

OR Increased distance / shielding in Ba outweighs increased nuclear charge ✓

Ionisation energy

Ionisation energy of Ba is less

OR easier to remove (outer) electrons in Ba ✓

[3 marks]

For more shells, **ALLOW** higher energy level

IGNORE *more orbitals* ***OR*** *more sub-shells*

IGNORE *'different shell' or 'new shell'*

ALLOW *'Ba has less nuclear pull'*

OR 'Ba electrons are less tightly held'

IGNORE *'less effective nuclear charge'*

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

ALLOW *easier to oxidise Ba*

3(c)(i)

$Al_2Se_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2Se$

[1 mark]

3(c)(ii)

H_2O has hydrogen/H-bonds (between molecules) ✓

H_2Se has induced dipole(-dipole) interactions

OR London forces ✓

H-bonds are stronger (than other intermolecular forces)

OR more energy needed to overcome H-bonds ✓

[3 marks]

ALLOW *permanent dipole-dipole interactions*

3(d)(i)

Sodium bromate(V) ✓

[1 mark]

3(d)(ii)

Br is oxidised **AND** reduced

OR Br oxidation number is increased and decreased ✓

Br is oxidised from 0 to +5 ✓

Br is reduced from 0 to –1 ✓

[3 marks]

ALLOW *same element is both oxidised and reduced*

ALLOW 1 mark *if all 3 oxidation numbers are correct (even if oxidation/reduction incorrectly assigned)*

Q99 · Periodicity · [9 marks]

OCR MARK SCHEME

21(a)

Interpretation of Results

Orange contains bromine **AND** no reaction

AND violet contains iodine ✓

EXAMINER GUIDANCE

Results can be interpreted anywhere in answer.

ALLOW *multiples, e.g.* $\frac{1}{2}Br_2 + I^- \rightarrow Br^- + \frac{1}{2}I_2$

Ionic equation

$Br_2 + 2I^- \rightarrow 2Br^- + I_2$ ✓

Reactivity (down the group)

Reactivity decreases

AND

oxidising power decreases

OR gains electrons less easily

OR forms negative ion/1– ion less easily

OR less energy released when electron gained ✓

OR more negative electron affinity

Size/shells/shielding (down the group)

Greater atomic radius

OR more shells

OR more shielding ✓

Attraction (down the group)

Less nuclear attraction down the group ✓

[5 marks]

IGNORE *other halogen/halide equations*

IGNORE *state symbols*

ALLOW *ORA*

DO NOT ALLOW *idea of losing electrons/ionisation energy*

IGNORE *chlorine is the most electronegative*

IGNORE *explanations in terms of displacement*

21(b)

Benefit **AND** risk required for ONE mark

Benefit: kills bacteria ✓

AND

Risk: toxic/poisonous

OR forms chlorinated hydrocarbons

OR forms carcinogens/toxic compounds ✓

[1 mark]

ALLOW *kills micro-organisms*

OR kills pathogens **OR** kills viruses **OR** sterilises/disinfects water

IGNORE *antiseptic, reduces risk of disease, cleans water*

IGNORE *'harmful'/'dangerous'*

IGNORE *chlorine is carcinogenic/ dangerous for health/causes breathing problems*

21(c)

$n(A) = \frac{0.209}{29} = 0.00721$ (mol) ✓

$M_r = \frac{1.26}{0.00721} = 174.8$ ✓

Molecular formula = BrF_5 ✓

Formula is dependent on M_r

[3 marks]

ALLOW ECF

ALLOW 2SF *0.0072 up to calculator value 0.0072068965517*

ALLOW *175 up to calculator value 174.8325359*

ALLOW F_5Br

ALLOW ECF *that matches calculated* M_r

Q100 · Periodicity · [1 mark]

Answer: **C**

Al < Si < P

Q101 · Periodicity · [1 mark]

Answer: **A**

Ca < Si < P < N

Q102 · Reaction rates and equilibrium · [9 marks]

OCR MARK SCHEME

25(a)

EQUILIBRIUM CONDITIONS 3 MAX

4 marking points → 3 max ✓✓✓

Mark first three CORRECT responses seen

Temperature:

(Forward) reaction is exothermic/Δ*H* is negative

OR (Forward) reaction gives out heat ✓

Pressure:

Right-hand side has fewer (gaseous) moles

OR 3 (gaseous) moles form 2 (gaseous) moles ✓

Equilibrium shift

Correct equilibrium shift in terms of temperature ✓

Correct equilibrium shift in terms of pressure ✓

INDUSTRIAL CONDITIONS

Low temperature gives a slow rate/slower reaction

OR high temperatures needed to increase rate ✓

(High) pressure provides a safety risk

OR

(High) pressure is expensive (to generate) /uses a lot of energy ✓

[5 marks]

EXAMINER GUIDANCE

ALLOW *suitable alternatives for 'towards right', e.g.: towards SO_3/products* ***OR*** *in forward direction* ***OR*** *'favours the right'*

ALLOW reverse *reaction is endothermic /ΔH is positive/takes in heat*

For moles, **ALLOW** molecules/particles

ORA for *reverse reaction*

IGNORE *responses in terms of activation energy*

ALLOW *high pressure is dangerous/explosive*

ALLOW *'These conditions are expensive'*

Statement subsumes pressure as 'these' will apply to pressure (required for this mark) and temperature

ALLOW ORA

e.g. Lower pressure → less danger/uses less energy

IGNORE *'It's expensive*

Link with pressure required

25(b)

Value of K_c 1 mark

K_c is small **OR** $K_c < 1$

AND equilibrium (position) is towards left ✓

Calculation: FIRST CHECK ANSWER

IF $[SO_3]$ = 0.876 OR 0.88 (mol dm^{-3})

award all 3 marks available for calculation

K_c expression 1 mark

ALLOW *suitable alternatives for 'towards left, e.g.: towards SO_2/O_2* ***OR*** *towards reactants* ***OR*** *in reverse direction* ***OR*** *'favours the left*

Square brackets required in K_c expression

ALLOW ECF *from* $\frac{[SO_3]}{[SO_2]^2[O_2]}$ *, i.e. no* $[SO_3]^2$

ALLOW 0.77 (2 SF)

$\frac{[SO_3]^2}{[SO_2]^2[O_2]}$ **OR** $\frac{[SO_3]^2}{2.00^2 \times 1.20}$ ✓

Evaluation of K_c $[SO_2]^2[O_2]$ 1 mark

K_c $[SO_2]^2[O_2] = 0.160 \times 2.00^2 \times 1.20$

$= 0.768$ ✓

Calculation of $[SO_3]$

ONLY available from correct evaluation for 2nd mark

$[SO_3] = \sqrt{(0.160 \times 2.00^2 \times 1.20)}$

$= 0.876$ (mol dm^{-3}) ✓

[4 marks]

ALLOW 0.88 *(2 SF) up to calculator value of 0.876356092 correctly rounded*

IF *K_c expression is inverted 2nd and 3rd marks are available by* ***ECF****:*

$[SO_3]^2 = \frac{2.00^2 \times 1.20}{0.160}$ **OR** 30 ✓

$[SO_3] = \sqrt{30} = 5.48$ **OR** 5.5 ✓

Any other K_c expression → NO MARKS,

e.g. $\frac{[SO_3]^2}{[SO_2]^2 + [O_2]}$ → $\sqrt{0.832}$ → 0.912

NO marks

Q103 · Reaction rates and equilibrium · [11 marks]

OCR MARK SCHEME

5(a)(i)

carbon dioxide lost/evolved/given off/or produced as a gas ✓

[1 mark]

EXAMINER GUIDANCE

DO NOT ALLOW *water or steam or CO_2 evaporates*

5(a)(ii)

FIRST CHECK ANSWER ON THE ANSWER LINE

IF *answer = 1.85* ***OR*** *1.845 g award 3 marks*

$n(HNO_3)$

$= 1.25 \times \frac{20.0}{1000} = 0.0250$ mol ✓

$n(SrCO_3)$

$= \frac{0.0250}{2} = 0.0125$ mol ✓

$m(SrCO_3)$

$= 0.0125 \times 147.6 = 1.845$ g **OR** 1.85 g ✓

[3 marks]

If there is an alternative answer, check to see if there is any ***ECF*** *credit possible*

ALLOW ECF *from incorrect $n(HNO_3)$*

molar mass of $SrCO_3 = 147.6$ (g mol^{-1})

ALLOW ECF *from incorrect $n(SrCO_3)$*

5(b)(i)

rate of reaction decreases

AND

concentration decreases/reactants are used up ✓

less frequent collisions ✓

[2 marks]

ALLOW *reaction slows down*

ALLOW *concentration of reactants decreases.*

ALLOW *fewer collisions per unit time*

OR collisions less often

OR decreased rate of collision

IGNORE *less successful collisions/ less collisions less chance of collisions*

5(b)(ii)

Attempted tangent on graph drawn to line at approximately t = 200 s ✓

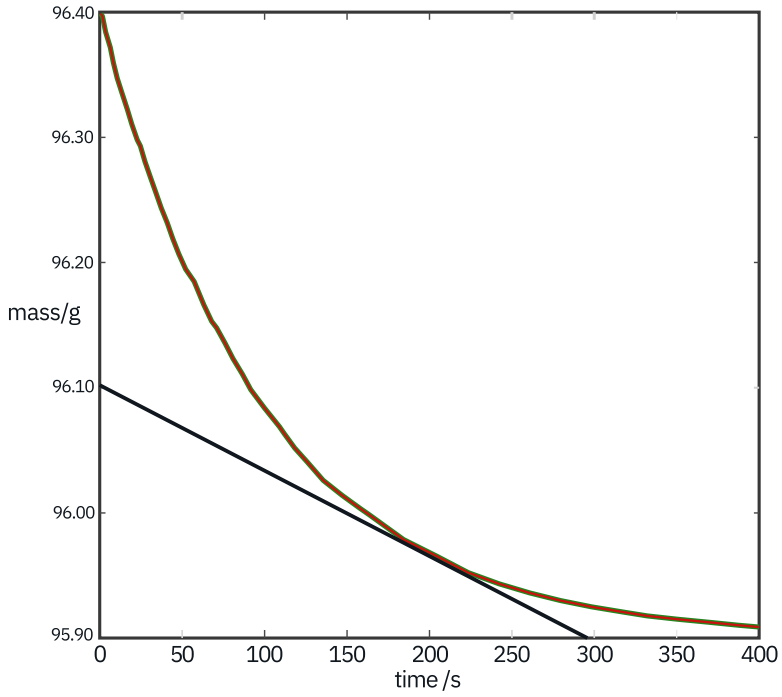
Gradient (y/x)

e.g. $\frac{0.20}{290} = 6.9 \times 10^{-4}$ ✓

ALLOW *1 SF up to calculator value, in range* 5×10^{-4} *to* 8×10^{-4}

IGNORE *units*

IGNORE *sign*



[2 marks]

5(c)

Flask **OR** beaker

AND

balance

AND

stopwatch **OR** stop clock **OR** other timing device ✓

Records mass at time intervals ✓

Time interval quoted between 10-50s ✓

DO NOT ALLOW *round-bottomed flask.*

IGNORE *weighing scales*

ALLOW *'weigh at time intervals'*

[3 marks]

Q104 · Reaction rates and equilibrium · [1 mark]

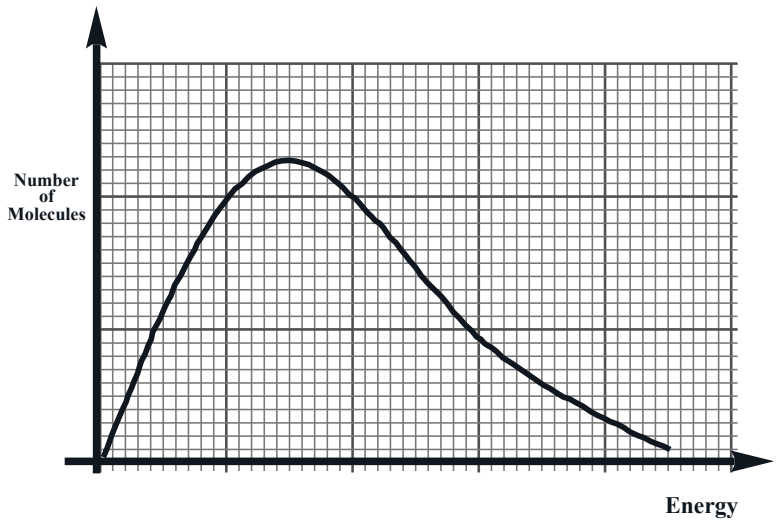
Answer: **B**

decrease the temperature

Q105 · Reaction rates and equilibrium · [8 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

23(a)



Correct drawing of Boltzmann distribution

Curve starts within two small squares 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 below E_a on Boltzmann distribution ✓

More molecules/particles/collisions have energy above activation energy (with catalyst)

OR

greater area under curve above activation energy ✓

[4 marks]

IGNORE *a slight inflexion on the curve*

DO NOT ALLOW *two curves*

Confusion with effect of temperature

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

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

ALLOW *'more molecules have enough energy to react'*

IF *y axis labelled as 'atoms'*

ALLOW ECF *for atoms (instead of molecules/particles)*

IGNORE *(more) successful collisions*

IGNORE *response implying 'more collisions'*

(confusion with effect of greater temperature)

23(b)

Two max ✓✓ from:

- Lower temperatures/less heat/less thermal energy
- Less fossil fuels/oil/coal/gas/non-renewable fuels
- Reduces CO_2 emissions

[2 marks]

IGNORE *lower pressures* ***OR*** *less energy (in question)*

IGNORE *just 'less fuel'*

IGNORE *less global warming*

IGNORE *less greenhouse gases, less CO, less NO*

CO_2 required

23(c)

IF *there is an alternative answer, check*

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF answer = 14.6 (dm^6 mol^{-2}) award 2 marks

K_c expression

$(K_c =)$ $\frac{[CH_3OH]}{[CO]\,[H_2]^2}$ **OR** $\frac{0.26}{0.31 \times 0.24^2}$

OR 14.56 ..... ✓

Answer to 3 SF

14.6 (dm^6 mol^{-2}) ✓

[2 marks]

*to see if there is any **ECF** credit possible using working below.*

***ALLOW** calculated value 14.5609319 correctly rounded to 3 or more SF for 1st marking point*

***ALLOW ECF to 3 SF ONLY** from inverted K_c expression → 0.0687*

DO NOT ALLOW

$\frac{[CH_3OH]}{[CO] + [H_2]^2}$ *= 0.707 (no marks)*

Q106 · Reaction rates and equilibrium · [6 marks]

OCR MARK SCHEME

2

Level 3 (5–6 marks)

All three scientific points are covered in detail and explained thoroughly.

The method is logically structured and clear calculations are shown for an appropriate mass of metal and suitable volume of acid. The drawing of a tangent and determination of the gradient is communicated well.

Level 2 (3–4 marks)

Candidates cover all three scientific points but explanations may be incomplete.

OR

Two of the scientific points are described thoroughly with no omissions.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. e.g. there are clear calculations to justify mass and acid volume supported by some working and units; a simple description for determining initial rate related to tangent but no detail of how to measure gradient..

Level 1 (1–2 marks)

There is a description based on at least two of the main scientific points

OR

The candidate explains one scientific point thoroughly with few omissions.

EXAMINER GUIDANCE

Indicative scientific points

1. Method

- measure mass of (excess) zinc

(using 2 decimal place balance)

- measure volume of hydrochloric acid

(using measuring cylinder)

- mix zinc and acid in flask
- measure gas volume at time intervals

2. Calculations

- moles of hydrogen

$\frac{72}{24000}$ = 0.00300 mol

- minimum mass of zinc

0.003 × 65.4 = 0.20 g

- moles of hydrochloric acid

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

0.00300 × 2 = 0.00600 mol

- volume/concentration of acid

If [HCl(aq)] = 0.1 mol dm^{-3} appropriate volume of acid

$= \frac{0.006 \times 1000}{0.1} = 60\ cm^3$

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. e.g. 'add zinc and acid and measure volume (no mass, volume or time intervals); calculations that have little structure, absent units and little working.

0 marks

No response or no response worthy of credit.

[6 marks]

If [HCl(aq)] ≥ 0.3 mol dm^{-3}, too low (≤ 20 cm^3)

If [HCl(aq)] ≤ 0.03 mol dm^{-3} too high (≥ 200 cm^3)

3. Processing results

- Plot a graph of volume against time
- Draw a tangent at $t = 0$
- Gradient of tangent = initial rate
- Gradient = $\frac{\text{volume}}{\text{time}}$

Q107 · Reaction rates and equilibrium · [1 mark]

Answer: **C**

Pressure: Increase · Temperature: Decrease

Q108 · Reaction rates and equilibrium · [1 mark]

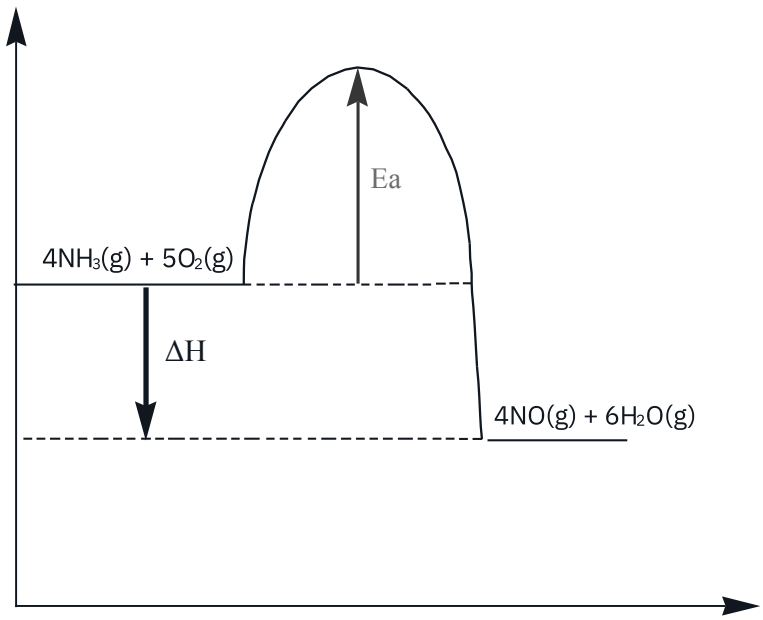
Answer: **B**

$$\frac{[NH_3(g)]^2}{[N_2(g)]\,[H_2(g)]^3}$$

Q109 · Reaction rates and equilibrium · [12 marks]

OCR MARK SCHEME

4(a)(i)



Reactants, products and E_a

Reactants on LHS $4NH_{3(g)} + 5O_{2(g)}$

EXAMINER GUIDANCE

IGNORE *state symbols*

ALLOW 1 mark for a correctly labelled endothermic diagram

E_a ALLOW no arrowhead or arrowheads at both ends of E_a line.

E_a line must reach maximum (or near to maximum) on curve

For E_a, ALLOW AE **OR** A_E

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.

ALLOW –905 for ΔH

AND

Products on RHS $4NO_{(g)} + 6H_2O_{(g)}$

AND

Activation energy correctly labelled / E_a ✓

ΔH

ΔH labelled with product below reactant

AND

Arrow downwards ✓

[2 marks]

4(a)(ii)

FIRST CHECK ON ANSWER LINE

If answer = 6.79×10^7 (kJ) award 4 marks

If answer = 2.72×10^8 (kJ) award 3 marks (no ÷ 4)

$n(NH_3)$

$= \frac{5.1 \times 10^6}{17} = 3.00 \times 10^5$ (mol) ✓

Stoichiometry and ΔH

1 mol NH_3 releases $\frac{905}{4}$ **OR** 226.25 (kJ) ✓

Energy released

$(3.00 \times 10^5) \times \frac{905}{4}$ **OR** 67875000 (kJ) ✓

Final answer to 3SF AND standard form

$= 6.79 \times 10^7$ (kJ) ✓

standard form AND 3 SF required

[4 marks]

IGNORE *(-) SIGN*

Throughout: **IGNORE** trailing zeroes in intermediate working,

e.g. For $n(NH_3)$ ALLOW 3×10^5 for 3.00×10^5

ALLOW ECF *from incorrect $n(NH_3)$* ***OR*** $\frac{905}{4}$

ALLOW 3 SF up to calc value correctly rounded.

Value will depend on intermediate rounding

Common Errors

1.09×10^9 (× 4 instead of ÷ 4)	3 marks
2.72×10^8 (no ÷ 4)	3 marks
6.79×10^1 (no tonnes → g)	3 marks

4(b)

$(K_c =) \frac{[NO(g)]^4 [H_2O(g)]^6}{[NH_3(g)]^4 [O_2(g)]^5}$ ✓

[1 mark]

Square brackets required

IGNORE *state symbols*

4(c)

EQUILIBRIUM CONDITIONS

ALLOW reverse arguments

Temperature: 1 mark

(Forward) reaction is exothermic/ΔH is negative

OR (Forward) reaction gives out heat ✓

Pressure: 1 mark

Left-hand side has fewer (gaseous) moles

OR 9 (gaseous) moles form 10 (gaseous) moles ✓

OPTIMUM EQUILIBRIUM CONDITIONS: 1 mark

(for maximum yield of NO)

Low temperature AND low pressure ✓

RATE: 1 mark

Low temperature/pressure gives a slow rate/slower reaction so high temperatures / higher pressure needed to increase rate **OR** frequency of collisions ✓

INDUSTRIAL CONDITIONS / OPERATIONAL FACTORS: 1 mark

High pressure provides a safety risk

OR

Higher temperatures increase energy costs / reduce yield / shift equilibrium to left

OR

(High) pressure is expensive (to generate) / uses a lot of energy ✓

[5 marks]

Answer MUST relate temp/pressure to rate / frequency of collisions

ALLOW Temperature / pressure not too high because yield reduced

IGNORE *stated temperatures and pressures*

IGNORE *catalyst*

Q110 · Reaction rates and equilibrium · [1 mark]

Answer: **C**

Only 2 and 3

Q111 · Reaction rates and equilibrium · [13 marks]

OCR MARK SCHEME

2(a)(i)

Graph

Graph of volume (y axis) against time (x axis)

AND Axes labelled with correct units

AND At least half graph paper in both directions

AND Linear scales ✓

Points

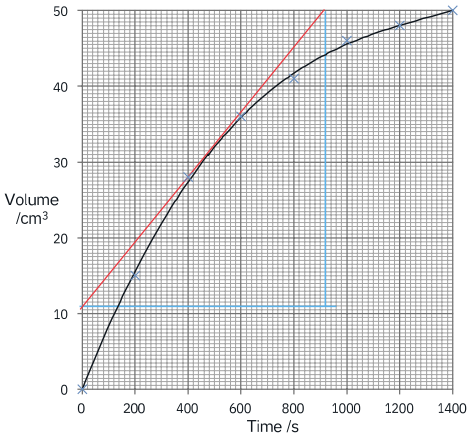
7 points from 200–1400 s plotted ✓

Point at 0,0 not required

Line

Curve drawn through origin (0,0) ✓

EXAMINER GUIDANCE



ALLOW *V* ***OR*** *Vol for volume*

AND

Curve not drawn with straight lines between points.

Rate

Attempted tangent on graph drawn to curve at $t = 500 \pm 100$ s ✓

Rate calculated in range 0.037–0.047 ($cm^3\ s^{-1}$) ✓

e.g. for graph in guidance: $\frac{50 - 11}{920 - 0} = 0.042$

For tangents not drawn at 500 ± 100 s,

- **ALLOW ECF ONLY** for a tangent drawn to the candidate's line.
- Then calculate the gradient from candidate's tangent.

For inverse graphs of time against volume,

- Graph mark will **not** be scored.
- All other marks are available.
- **BUT** rate = $\frac{1}{\text{gradient}}$ = 0.037–0.047 ($cm^3\ s^{-1}$)

ALLOW *t for time*

For 's', **ALLOW** sec, seconds, etc

CARE:

Use of *x* and *y* coordinates at $t = 500$ s scores zero,

e.g. For volume = 33 cm^3 and time = 500 s,

x and *y* coordinates gives

$\frac{33}{500} = 0.066$ ✗✗

[5 marks]

2(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 0.092 (mol dm^{-3}) award 3 marks

$n(O_2) = \frac{55}{24000} = 2.29 \times 10^{-3}$ (mol) ✓

$n(H_2O_2) = 2.29 \times 10^{-3} \times 2 = 4.58 \times 10^{-3}$ (mol) ✓

$[H_2O_2] = \frac{4.58 \times 10^{-3} \times 1000}{50.0} = 0.092$ (mol dm^{-3}) ✓

(**2 SF**)

[3 marks]

ALLOW ECF *throughout*

ALLOW *2 SF up to calculator value of* $2.291666667 \times 10^{-3}$

ALLOW *calculation using ideal gas equation provided that p = ~ 10^5 Pa and T in range 293–298 K.*

ALLOW *use of 8.31 for R (gives same answer)*

e.g. $n(O_2)$

$= \frac{(1 \times 10^5 \times 55 \times 10^{-6})}{(8.314 \times 298)} = 2.22 \times 10^{-3}$ (mol) ✓

$n(H_2O_2) = 2.22 \times 10^{-3} \times 2 = 4.44 \times 10^{-3}$ (mol) ✓

$[H_2O_2] = \frac{4.44 \times 10^{-3} \times 1000}{50.0} = 0.089$ (mol dm^{-3}) ✓

(2 SF)

NOTE*: 293 K gives 0.090 (mol dm^{-3})*

Common errors

0.046 → 2 marks	no × 2 for $n(H_2O_2)$

2(b)

$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

Correctly balanced equation for MnO_4^-/H_2O_2 reaction but no cancelling of H^+ and/or e^- ✓

Overall equation correct with all species cancelled ✓

[2 marks]

ALLOW *multiples*

ALLOW *⇌ instead of → sign*

ALLOW *1 mark for final equation with correct balancing numbers* ***AND***

ONE small slip in a formula **OR** charge

IGNORE *annotations around equations,*

i.e. treat as rough working

ALLOW *1 mark for:* $2H_2O_2 \rightarrow 2H_2O + O_2$

(H_2O_2 is acting as both reducing and oxidising agent)

2(c)(i)

Equation

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$

OR $[Co(H_2O)_6]^{2+} + 4HCl \rightleftharpoons [CoCl_4]^{2-} + 6H_2O + 4H^+$ ✓

[1 mark]

ALLOW *reverse equation:*

$[CoCl_4]^{2-} + 6H_2O \rightleftharpoons [Co(H_2O)_6]^{2+} + 4Cl^-$

but take care for subsequent explanations

IGNORE *state symbols (even if wrong)*

For $[CoCl_4]^{2-}$,

ALLOW $CoCl_4^{2-}$, $(CoCl_4)^{2-}$

2(c)(ii)

Equilibrium shift

- equilibrium (shifts) **to right** at high **temperature**/100°C

OR equilibrium shifts to left at low temperature/0°C ✓

CARE: Direction of shift depends on direction of equilibrium equation from 2c(i). Either look back or see the equation copied at bottom of 2c(ii) marking zone.

Enthalpy change

- Endothermic ✓

[2 marks]

Mark independently

ALLOW *suitable alternatives for 'to right' e.g. towards products* ***OR*** *in forward direction* ***OR*** *'favours the right'*

ORA *for 'to left'*

Temperature required but

ALLOW *'in ice for low temperature*

OR 'in boiling/hot water' for high temperature

IGNORE *shift to blue side or pink side*

Q112 · Reaction rates and equilibrium · [1 mark]

Answer: **C**

More molecules have an energy greater than the activation energy.

Q113 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

Both rates increase by the same factor.

Q114 · Reaction rates and equilibrium · [13 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

4(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 60 cm^3 award 3 marks

$n(HCl) = \frac{50.0}{1000} \times 0.100 = 5.00 \times 10^{-3}$ (mol) ✓

$n(H_2) = \frac{5.00 \times 10^{-3}}{2} = 2.50 \times 10^{-3}$ (mol) ✓

Volume = $2.5(0) \times 10^{-3} \times 24.0 \times 1000 = 60(.0)$ cm^3 ✓

[3 marks]

ALLOW *120 cm^3 for 2 marks (no ÷ 2)*

ALLOW *240 cm^3 for 2 marks (× 2 not ÷ 2)*

IGNORE *absence of trailing zeroes, e.g. for 0.100,* ***ALLOW*** *0.1*

ALLOW ECF *from n(HCl)*

ALLOW ECF *from n(HCl) and/or $n(H_2)$*

4(b)(i)

Use of graph paper

linear numerical scale chosen for x axis

AND

Time / s added as label

AND

ALL points plotted correctly ✓

[1 mark]

ALLOW *Time (s)* ***OR*** *Time in s*

ALLOW *seconds* ***OR*** *sec* ***OR*** *secs*

Tolerance ± 1 small square

Point at 0,0 **NOT** required

ALLOW *up to 3 plotting errors*

4(b)(ii)

Anomaly

point at 80 s circled ✓

[1 mark]

ALLOW *one more anomalous point* ***NOT*** *on the curve drawn in (iii)*

4(b)(iii)

Line

smooth curve using all points

EXCEPT point at 80 s ✓

[1 mark]

4(c)

Initial slope is steeper

AND curve levels off at an earlier time ✓

Same volume of gas produced (58 cm^3) ✓

[2 marks]

Tolerance ± 1 small square

4(d)

Rate

(Acid) concentration decreases. ✓

Collisions

Fewer collisions per second

IGNORE *amount of acid decreases, response must imply a volume and* ***NOT*** *area,*

e.g. fewer particles/molecules/ions in same space /volume

OR less frequent collisions ✓

[2 marks]

'fewer collisions' alone is not sufficient (no rate)

4(e)(i)

Catalyst lowers the activation energy (by providing an alternative route) ✓

A greater proportion of molecules have more energy greater than/equal to activation energy ✓

[2 marks]

ALLOW *'more' for 'greater proportion'*

ALLOW *more molecules have sufficient energy to react*

IGNORE *(more) successful collisions*

4(e)(ii)

Reactants have different physical states ✓

[1 mark]

ALLOW *idea that copper(II) sulfate solution is homogeneous in relation to the acid, but heterogeneous in relation to the zinc*

Q115 · Reaction rates and equilibrium · [1 mark]

Answer: **D**

The effect of concentration on the equilibrium position.

Q116 · Reaction rates and equilibrium · [1 mark]

Answer: **A**

$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$

Q117 · Reaction rates and equilibrium · [12 marks]

OCR MARK SCHEME

3(a)(i)

Rate

(Acid) concentration decreases ✓

Collisions

Fewer collisions per second

OR less frequent collisions ✓

Reaction stops

(Acid/reactant/limiting reagent) has reacted/been used up ✓

[3 marks]

EXAMINER GUIDANCE

IGNORE *amount of acid decreases*

Response MUST imply a volume and **NOT** area,

e.g. fewer particles/molecules/ions in same space /volume

IGNORE *responses not linked to rate, e.g.*

- 'fewer collisions'
- fewer successful collisions
- fewer collisions, less chance of collisions

No link to rate.

AW

3(a)(ii)

Tangent on graph

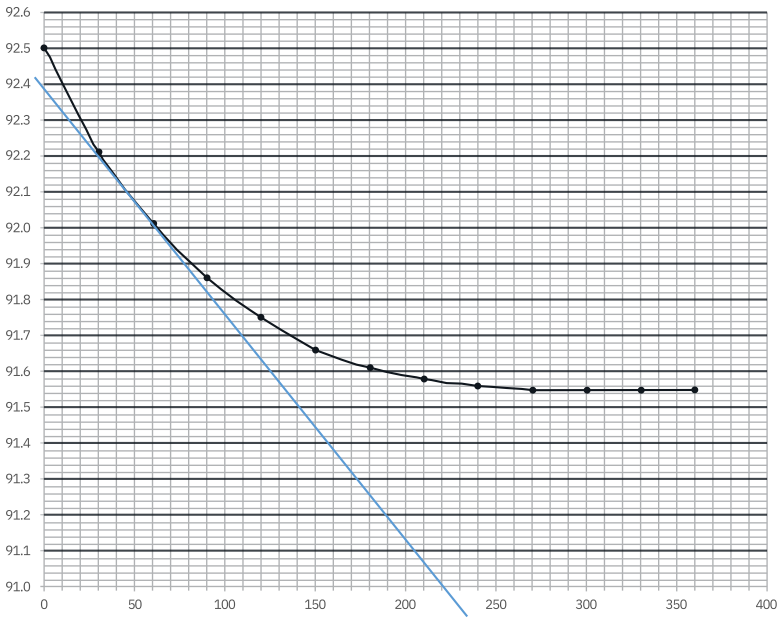
DO NOT ALLOW *interpolation (taking a direct reading from graph), answer must be derived from taking a gradient*

drawn at approximately t = 50 s (± 10 s) ✓

Calculation of rate

= Gradient (y/x) of tangent drawn

e.g. $\frac{92.4 - 91.0}{220} = \frac{1.4}{220} = 6.36 \times 10^{-3}$ (g s^{-1}) ✓



[2 marks]

ALLOW ECF from incorrectly drawn tangent

ALLOW *range of 5.7 x 10^{-3} to 6.9 x 10^{-3} in calculation of tangent (rounded to 1 d.p.)*

IGNORE *units*

IGNORE *sign*

Tolerance of readings:

y axis should be ± 0.02 g

(i.e. within 1 square)

x axis should be ± 5 s

(i.e. within 1 of a square)

3(a)(iii)

Slope is steeper

AND

levels off earlier ✓

Same loss in mass, i.e. levels off at ~91.55 g ✓

[2 marks]

Tolerance ± 1 small square

3(b)(i)

More vigorous bubbling ✓

Zinc dissolves/disappears more quickly ✓

[2 marks]

AW, e.g. bubbles/fizzes more quickly

For 1 alternative marking point **ALLOW** responses related to displacement of Cu from $CuSO_4$ by Zn:

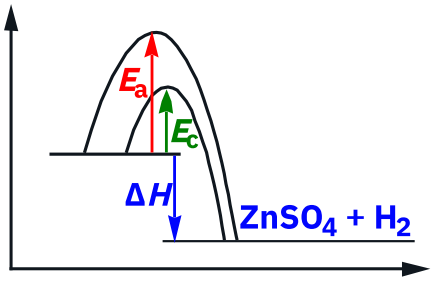
EITHER red/brown/black precipitate/solid formed **OR** (blue solution) turns colourless

3(b)(ii)

IGNORE *state symbols*

ΔH **DO NOT ALLOW** $-\Delta H$

DO NOT ALLOW *double headed arrow on ΔH*



ΔH ΔH labelled with product ($ZnSO_4$ + H_2) below reactant

AND

Arrow downwards ✓

E_a E_a correctly labelled ✓

E_c E_c correctly labelled with $E_c < E_a$ ✓

[3 marks]

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

For E_a, **ALLOW** AE **OR** A_E

ALLOW *marks for E_a and E_c for correctly labelled endothermic diagram (i.e.* ***ECF*** *from ΔH)*

Q118 · Reaction rates and equilibrium · [15 marks]

OCR MARK SCHEME

4(a)(i)

Level 3 (5-6 marks)

A comprehensive explanation of effect of temperature **AND** pressure on equilibrium is given with some details about rate **AND** operating conditions

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)

The candidate attempts three scientific points, but explanations are incomplete.

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)

A simple description based on at least two of the main scientific points.

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:

ALLOW *reverse arguments throughout*

Effect of Temperature on equilibrium position

- (Forward) reaction is endothermic/ΔH is +ve
- High temperature shifts equilibrium to right

Effect of Pressure on equilibrium position

- Left-hand side has fewer (gaseous) moles
- **OR** 2 (gaseous) moles form 4 (gaseous) moles
- Low pressure shifts equilibrium to right

Effect on rate of reaction

- High temp increases rate
- Low pressure reduces rate
- Catalyst increases rate
- Catalyst lowers activation energy

- Discussion using collision theory to support arguments

Operating conditions (not inclusive)

- Compromise conditions needed
- High temperatures increase energy demand/costs
- Slightly higher pressure used than optimum
- Higher pressures unsafe
- Catalyst reduces need for higher temperatures
- Catalyst doesn't effect the position of equilibrium
- Excess steam shifts equilibrium to right

4(a)(ii)

FIRST CHECK THE ANSWER ON ANSWER LINE

IF answer = *24.1, award 2 marks*

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

K_c expression

(K_c =) $\frac{[CO]\,[H_2]^3}{[CH_4][H_2O]}$ **OR** $\frac{(0.510)\,(1.53)^3}{(0.111)\,(0.682)}$

OR 24.12..... ✓

Answer to 3 SF

K_c = 24.1 ✓

ALLOW *calculated value 24.12887731 correctly rounded to 3 or more SF for 1st marking point*

ALLOW ECF to 3 SF

ONLY from inverted K_c expression → 0.0414

DO NOT ALLOW $\frac{[CO] + [H_2]^3}{[CH_4] + [H_2O]}$ *(no marks)*

IGNORE *attempts at units*

[2 marks]

4(b)

FIRST CHECK THE ANSWER ON ANSWER LINE

IF answer = *(+)198 award 3 marks*

IGNORE *sign*

IGNORE *sign*

Energy for bonds broken

(1 × C–C + 5 × C–*H* + 1 × C–O + 7 × O–*H*)

347 + 5(415) + 358 + 7(464)

OR 6028 (kJ) ✓

Energy for bonds made (6 × *H*–*H* + 4 × C=O)

6 × 435 + 4 × 805

ALLOW ECF

DO NOT ALLOW *– sign*

Common errors for 2 marks

–198 (incorrect cycle)

–149 (missed C-C from bonds broken)

–2586 (missing 6 x O-H from H_2O)

OR 2610 + 3220

OR 5830 (kJ) ✓

ΔH correctly calculated from above

$\Delta H = 6028 - 5830$

$= (+)198$ (kJ mol^{-1}) ✓

[3 marks]

4(c)

CO_2 bond angle = 180°

AND

H_2O bond angle = 104.5° ✓

CO_2 has 2 double bonds / 2 bonding regions ✓

H_2O has 2 bonded pairs **AND** 2 lone pairs ✓

Lone pairs repel more than bonding pairs ✓

[4 marks]

ALLOW *104–105*

IGNORE *Names of shapes even if incorrect*

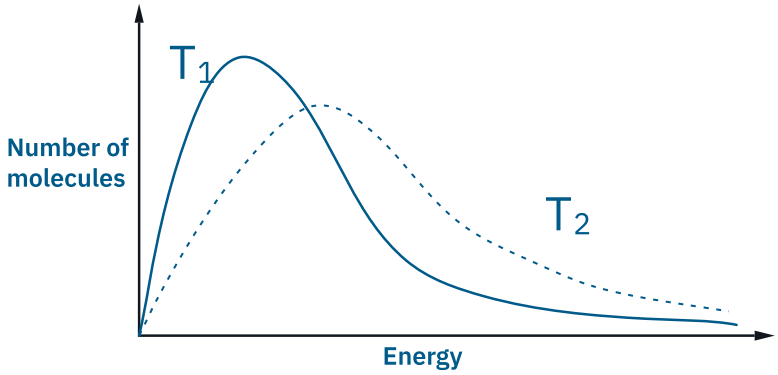
ALLOW *alternative phrases/words for repel e.g. 'push apart'*

DO NOT ALLOW *atoms repel*

Q119 · Reaction rates and equilibrium · [10 marks]

OCR MARK SCHEME

16(a)(i)



Axes labelled (number of) molecules

AND (kinetic) energy

AND correct drawing of a Boltzmann distribution

i.e. curve must start within the first small square nearest to the origin

AND must not touch the x-axis at high energy ✓

Drawing of correct Boltzmann distributions at two different temperatures with one termperature identified. ✓

(At higher temperature) more molecules/particles have energy above activation energy ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW *particles on the y-axis*

DO NOT ALLOW *atoms on y-axis*

DO NOT ALLOW *enthalpy on x-axis*

DO NOT ALLOW *an increase of more than one small square at the high energy end of the curve i.e. allow a small inflection*

ALLOW *T2 as 'higher termperature'*

Maximum of curve for higher temperature must be to the right **AND** lower than the maximum of the curve for lower temperature

Lines can only cross once

ALLOW ORA *if states the effect when the temperature is lower*

ALLOW *has enough energy to react*

ALLOW *E_a shown on graph* ***AND*** *greater area under the curve to the right of E_a*

DO NOT ALLOW *lowers E_a*

DO NOT ALLOW *atoms for molecules*

IGNORE *(more) successful collisions*

16(a)(ii)

Orders

(Expt 1+2)

When [NO] × 2, rate × 4

AND 2nd order with respect to NO ✓

(Expt 2+3)

When [NO] × 2 **AND** [CO] × 4, rate × 16

AND 1st order with respect to CO ✓

Rate Equation

rate = k $[NO]^2[CO]$ ✓

Value of k

$$(k = \frac{1.85 \times 10^{-4}}{((2.75 \times 10^{-4})^2 \times 7.25 \times 10^{-4})})$$

$= 3.37 \times 10^6$ ✓

Units of k

$dm^6\ mol^{-2}\ s^{-1}$ ✓

[5 marks]

***ALLOW ORA** throughout*

e.g. expt 2+1 [NO] halves, rate quarters etc.

***IGNORE** [CO] constant*

***ALLOW** if working shown with the table.*

***ALLOW** if seen in 2 steps i.e.*

When [NO] × 2, rate x 4 AND

[CO] × 4, intermediate rate × 4.

***ALLOW** comparing Expt 1+3*

When [NO] × 4 AND [CO] × 4, rate × 64

AND 1st order with respect to CO

***ALLOW ECF** from incorrect orders*

***ALLOW** rate = k $[NO]^2[CO]^1$*

***ALLOW** rate equation with correct numbers substituted*

***ALLOW** 3.36 x 10^6 from the use of Expt 3*

***IGNORE** errors in working out – the mark is for the value*

***ALLOW** 3 SF upto the calculator value 3374180.678 OR 3.374180678 x10^6*

***IGNORE** rounding errors past 3SF*

***ALLOW** units in any order e.g. mol^{-2} dm^6 s^{-1}*

***ALLOW ECF** from incorrect rate equation.*

Common errors

4 marks (including units)

4.65 x 10^9 mol^{-3} dm^9 s^{-1} (use of 2nd order with respect to CO)

2446 mol^{-1} dm^3 s^{-1} (use of zero order wrt CO)

16(b)

$2NO_2$ only on LHS of step 1 ✓

Rest of mechanism ✓

[2 marks]

M2 dependent on M1

Examples:

Step 1: $2NO_2 \rightarrow NO + NO_3$

Step 2: $NO_3 + CO \rightarrow NO_2 + CO_2$

OR

Step 1: $2NO_2 \rightarrow N_2O_4$

Step 2: $N_2O_4 + CO \rightarrow NO + NO_2 + CO_2$

OR

Step 1: $2NO_2 \rightarrow N_2 + 2O_2$

Step 2: $N_2 + 2O_2 + CO \rightarrow NO + NO_2 + CO_2$

OR

Step 1: $2NO_2 \rightarrow 2NO + O_2$

Step 2: $NO + O_2 + CO \rightarrow NO_2 + CO_2$

Q120 · Reaction rates and equilibrium · [1 mark]

Answer: **A**

The activation energy shifts to the left.

Q121 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

2.8×10^{-4}

Q122 · Reaction rates and equilibrium · [9 marks]

OCR MARK SCHEME

24(a)

All reaction species have same state/phase

OR

Reactants AND products has same state ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *SO_2 AND O_2 AND SO_3 for all species*

OR reactants and products are gases

OR the molecules are all gases

IGNORE *reactants and catalyst have same state*

24(b)

Throughout,

ALLOW *suitable alternatives for right-hand side,*

e.g. towards SO_3/products

OR forward direction

Pressure 2 marks

Increased pressure shifts equilibrium to right

OR favours the right

OR increases yield (of SO_3) ✓

Right-hand side has fewer (gaseous) moles

OR 3 (gaseous) moles → 2 (gaseous) moles ✓

ORA *for reverse reaction*

e.g. decreased pressure shifts equilibrium to left

For moles, **ALLOW** molecules/particles

ORA *for reverse reaction*

e.g. decreased temperature shifts equilibrium to right

ALLOW *reverse reaction is endothermic /ΔH is positive/takes in heat*

ALLOW *rates of forward and reverse reaction increase by same amount*

IGNORE *'no increase in yield'*

Temperature 2 marks

Increased temperature shifts equilibrium to left

OR favours the left

OR decreases yield (of SO_3) ✓

(Forward) reaction is exothermic/ΔH is negative

OR (Forward) reaction gives out heat ✓

Catalyst 1 mark

No shift in equilibrium

OR no effect on yield (of SO_3) ✓

Yield could still decrease

[5 marks]

24(c)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

IF answer = 7.9×10^4 award 2 marks

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

K_c expression

$(K_c =)$ $\dfrac{[SO_3]^2}{[SO_2]^2\,[O_2]}$ **OR** $\dfrac{(5.0 \times 10^{-2})^2}{(3.0 \times 10^{-3})^2 \times (3.5 \times 10^{-3})}$

OR 79365. ..... ✓

Answer to 2 SF and in standard form

$K_c = 7.9 \times 10^4$ ✓

Square brackets required for K_c expression

ALLOW ECF to 2 SF and standard form

ONLY from inverted K_c expression → 1.3×10^{-5}

DO NOT ALLOW

$\dfrac{[SO_3]^2}{[SO_2]^2 + [O_2]}$ *= 0.71 (no marks)*

***IGNORE** attempts at units*

[2 marks]

24(c)(ii)

Equilibrium shifts to the right/towards products/SO_3 ✓

***ALLOW** equilibrium favours the right*

[1 mark]

Q123 · Reaction rates and equilibrium · [1 mark]

Answer: **A**

More molecules have an energy greater than the activation energy.

Q124 · Reaction rates and equilibrium · [1 mark]

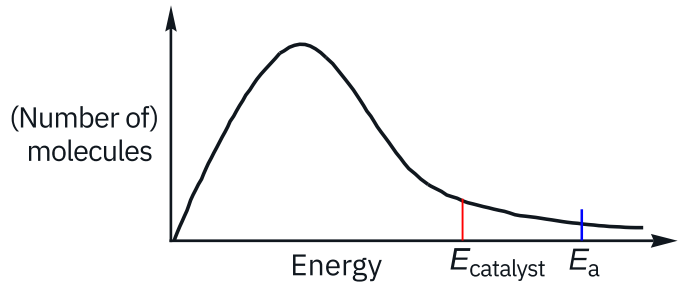
Answer: **B**

$$\frac{[SO_3(g)]^2}{[SO_2(g)]^2\,[O_2(g)]}$$

Q125 · Reaction rates and equilibrium · [13 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

4(a)



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 below E_a on Boltzmann distribution ✓

Particles with $E >$ Ea

More 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]

DO NOT ALLOW *two curves*

Confusion with effect of temperature

IGNORE *a slight inflexion on the curve if less than one small square*

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

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

IF *y axis labelled as 'atoms'*

ALLOW ECF *for atoms (instead of molecules/particles)*

IGNORE *(more) successful collisions*

IGNORE *response implying 'more collisions' (confusion with effect of greater temperature)*

4(b)(i)

Line

Smooth curve using all points

EXCEPT point at 100 s. ✓

Anomaly

Point at 100 s circled ✓

[2 marks]

ALLOW *flexibility around point at 120 s*

Graph should be seen to level off on or very near to 90 cm^3

4(b)(ii)

Tangent on graph

drawn at = 50 s (± 10 s) ✓

DO NOT ALLOW *interpolation (taking a direct reading from graph),*

Calculation of rate

= gradient (y/x) of tangent drawn

= 0.67 ± 0.2 $cm^3\ s^{-1}$ ✓

[2 marks]

Answer must be derived from taking a gradient

ALLOW ECF *from incorrectly drawn tangent or a straight line of best fit*

4(b)(iii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 0.15 (mol dm^{-3}) award 3 marks

$n(O_2) = \frac{90}{24000}$ **OR** $\frac{0.09}{24}$ **OR** 0.00375 (mol) ✓

$n(H_2O_2)$ = 2 × 0.00375 **OR** 0.0075 (mol) ✓

$c(H_2O_2) = 0.0075 \times \frac{1000}{50.0}$ = 0.15 mol dm^{-3} ✓

[3 marks]

ALLOW ECF

COMMON ERRORS

For 2 marks:

0.075 missing x 2

150 missing a cm^3 to dm^3 conversion

ALLOW *use of ideal gas equation using sensible p and T for first mark. e.g.*

from 100 kPa and 293 K

$n = \frac{pV}{RT}$

→ n

$= \frac{pV}{RT} = \frac{(100 \times 10^3) \times (90 \times 10^{-6})}{8.314 \times 293}$

= 0.00369...

(mol)

Examples of 'sensible' p and T:

p = 100 kPa, 101 kPa, 101,325 Pa

T = 273 – 298 K

4(c)

ANY two ✓✓

- Amount of catalyst/metal oxide (allow same mass **OR** same moles)
- Temperature
- Volume of H_2O_2
- Concentration of H_2O_2
- Moles/amount of H_2O_2
- Pressure
- Surface area of catalyst

[2 marks]

DO NOT ALLOW *concentration/volume of catalyst/metal oxide*

Q126 · Reaction rates and equilibrium · [1 mark]

Answer: **C**

Q127 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

How the activation energy changes: decreases · Proportion of molecules with energy > E_a: increases

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Q128 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

Rate of reaction: Increases · Equilibrium yield of HI: No effect

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Q129 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

The position of equilibrium moves towards the products.

Q130 · Reaction rates and equilibrium · [8 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

23(a)

Two (✓ ✓) from:

- rate of forward reaction = rate of reverse reaction
- Concentrations (of reactants and products) do not change/are constant
- In a closed system/environment

[2 marks]

IGNORE *reactions take place together/reversible reaction*

ALLOW *backward for reverse*

DO NOT ALLOW *concentration of reactants = concentration of products*

ALLOW *'nothing can leave/enter'*

23(b)

FIRST, CHECK THE ANSWER LINE, **IF bond** enthalpy = (+)463 (kJ mol^{-1}) award 3 marks

Energy for bonds broken (4 × S=O in SO_2) + 1 × O=O)

(4 × 522) + (1 × 494) **OR** 2088 + 494

OR 2582 (kJ) ✓

S=O bond enthalpy in 6 x SO_3 correctly calculated

6 × S=O bond enthalpy in SO_3 = 2582 + 196

= 2778 (kJ mol^{-1}) ✓

S=O bond enthalpy in SO_3 correctly calculated

S=O bond enthalpy in SO_3 = $\frac{2778}{6}$

= (+)463 kJ mol^{-1} ✓

Mark is for answer

[3 marks]

IGNORE *sign*

(rearranging assessed below)

ECF for MP2*: Ans to part 1 + 196*

ECF for MP3*: Ans to part 2/6;* ***IGNORE*** *significant figures and rounding errors.*

COMMON ERRORS

Use of 2 S=O (reactants) and 3 S=O (product)

+578 → 1 mark

Wrong sign for 196

+398 → 2 marks (ans: 397.6...)

Use of 2 S=O (reactants) and dividing by 2

+867 → 1 mark

Addition of S=O (product) bonds, not subtraction

-463 → 2 marks

23(c)

K_c expression

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

Calculation

(K_c =) $\frac{42.0^2}{25.0^2 \times 108}$ **OR** 0.02613..... ✓

= 2.61 × 10^{-2} to 3 SF and standard form ✓

[3 marks]

Square brackets required for K_c expression

IGNORE *state symbols, even if wrong*

DO NOT ALLOW

$K_c = \frac{[SO_3(g)]^2}{[SO_2(g)]^2 + [O_2(g)]}$ for first two marks

BUT ALLOW ECF to 3SF and standard form

i.e. 2.41 x 10^0

ALLOW *42^2 and 25^2 in substituted equation*

ALLOW ECF for Calculation *from inverted K_c expression ONLY i.e.*

3.83×10^{1} for two marks (to 3 SF and standard form)

DO NOT ALLOW *0.0261×10^{0}*

ALLOW ECF *from any incorrect K_c value for 3 SF and standard form*

IGNORE *attempts at units*

Q131 · Reaction rates and equilibrium · [14 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

18(a)(i)

(Pt has) different state / phase (to reactants) ✓

[1 mark]

ALLOW *Pt is a solid but reactants are gases*

IGNORE *products*

18(a)(ii)

Correct drawing of a Boltzmann distribution

curve must start within the first small square nearest to the origin

AND must not touch the x-axis at high energy

AND not be horizontal for more than 1 large square ✓

Catalyst (provides a reaction pathway with) lower activation energy **OR** E_a to the right of $E_{c/cat}$ marked on graph

AND

A greater proportion / more of molecules / particles have energy greater or equal to the activation energy / $E \geq E_a$ ✓

[2 marks]

DO NOT ALLOW *multiple curves*

IGNORE *a slight inflexion at the end of the curve less than one <u>small</u> square*

ALLOW *shading on the graph if linked to the idea of more molecules*

ALLOW *more molecules have (sufficient) energy to react for $E \geq E_a$*

IGNORE *more (frequent) successful collisions BUT*

DO NOT ALLOW *more frequent collisions*

IGNORE *more molecules have / meet / reach activation energy*

DO NOT ALLOW *molecules have more energy (confusion with temperature)*

18(a)(iii)

Lower temperature can be used (for the same yield)

OR less energy demand / required to heat reaction

OR less fossil fuels need to be burnt

OR reduction in CO_2

OR catalyst can be reused ✓

[1 mark]

18(b)

(Experiments 1 & 2)

As $[O_2]$ × 2, rate × 2

ALLOW ORA *throughout*

Check table for working if none shown

ALLOW *2 SF up to calculator value*

AND 1st order with respect to O_2 ✓

(Experiments 1 & 3)

As [NO] × 1.5, rate × 2.25

AND 2nd order with respect to NO

OR

(Experiments 2 & 3)

As [NO] × 1.5 and $[O_2] \div 2$, rate × 1.13

$(1.13 = \frac{1.5^2}{2})$

AND 2nd order with respect to NO ✓

rate = $k[NO]^2[O_2]$ ✓

$k = \frac{7.45 \times 10^{-4}}{0.04^2 \times 0.035} = 13(.30357...$

OR

$k = \frac{1.49 \times 10^{-3}}{0.04^2 \times 0.070} = 13(.30357...$

OR

$k = \frac{1.68 \times 10^{-3}}{0.06^2 \times 0.035} = 13(.33333...$ ✓

Units: $dm^6\ mol^{-2}\ s^{-1}$ ✓

[5 marks]

***ALLOW ECF** from incorrect orders*

***ALLOW** in any order*

***ALLOW ECF** from incorrect rate equation*

e.g. 1st order wrt NO

units $mol^{-1}\ dm^3\ s^{-1}$

zero order wrt NO

units: s^{-1}

18(c)(i)

11.4 / 11.35 ✓

[1 mark]

18(c)(ii)

Straight line of best fit ✓

Mark first two marking points independently

***ALLOW** rounding to 2SF*

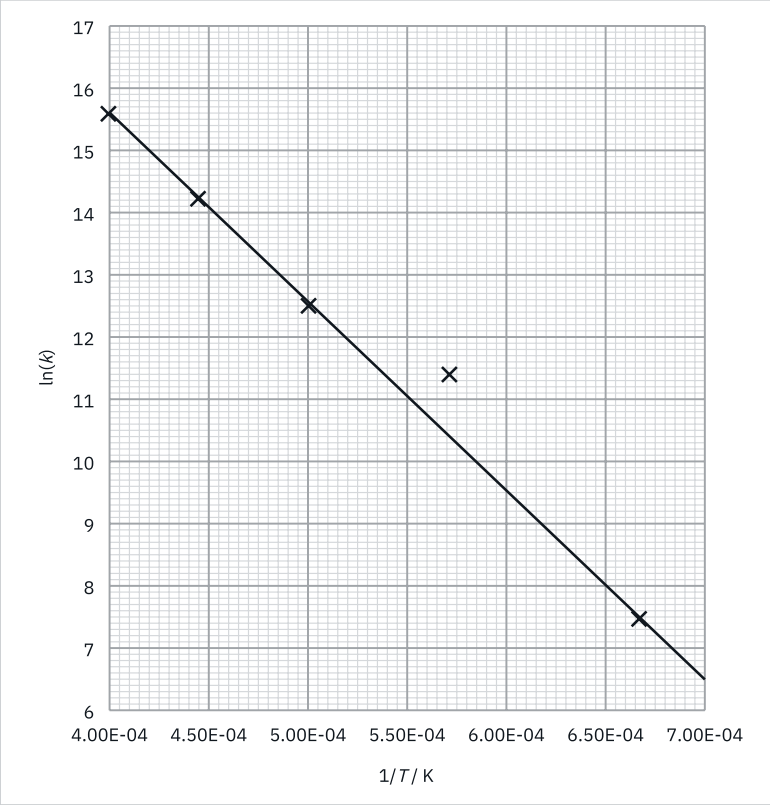
Best fit line judged from their points using the following guidance:

Line should go through ranges:

Top left	15.3 – 15.7
Bottom right	6.3 – 6.8

and exclude anomalous point at ln(*k*) = 11.4

Marks are for intermediate calculations



ALLOW ECF *from an incorrect gradient*

IGNORE *signs for both* E_a *calculation and gradient*

DO NOT ALLOW *a negative* E_a

Gradient

Gradient from a straight line in range of (–)28300 to (–)31300 ✓

CHECK THE ANSWER ON ANSWER LINE

If answer = 240 to 260 (kJ mol^{-1}) award last two marks

E_a calculation

Ea = (–) gradient × R (8.314) ✓

e.g. from –30000, E_a = (+)249420 (J mol^{-1})

Ea to 2 SF and in kJ mol^{-1} ✓

e.g. 250(kJ mol^{-1})

[4 marks]

Q132 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

1.2

Q133 · Reaction rates and equilibrium · [1 mark]

Answer: **D**

High temperature and low pressure

Q134 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

OCR MARK SCHEME EXAMINER GUIDANCE

0.0540

ALLOW *0.054(0)*

Q135 · Reaction rates and equilibrium · [8 marks]

OCR MARK SCHEME

24(a)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = –46 (kJ mol^{-1}) award 3 marks

Use of $\Delta_c H$ values and balancing numbers

± (+180 + (3 × –286)) **OR** ± 678

AND

± (2 × –293) **OR** ± 586 seen anywhere ✓

Correct subtraction using ΔH

(–678) – (–586)

= –92 (kJ mol^{-1}) ✓

Calculation of $\Delta_f H(NH_3)$ formation

$$\Delta_f H(NH_3) = \frac{-92}{2} = -46 \text{ (kJ mol}^{-1}\text{)} \checkmark$$

[3 marks]

EXAMINER GUIDANCE

ALLOW ECF *throughout*

COMMON ERRORS

–92 omission of ÷2 for $\Delta_f H(NH_3)$ 2 marks

(+)46 Incorrect subtraction 2 marks

(+)92 Incorrect subtraction & no ÷2 1 mark

–385 no ×2 for –293 and no ÷2 1 mark

–192.5 no ×2 for –293 2 marks

(+)480 no ×3 for –286 and no ÷2 1 mark

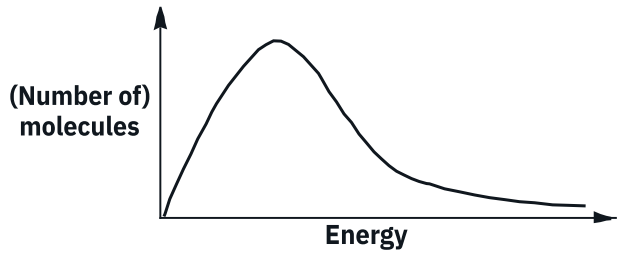
(+)240 no ×3 for –286 2 marks

(+)187 no ×3 for –286 **AND** no ×2 for –293 **AND** no ÷2 1 mark

(+)93.5 no ×3 for –286 **AND** no ×2 for –293 2 marks

24(b)

Boltzmann distribution (seen anywhere) 2 marks



Curve

Curve starts close to origin (**ALLOW** flexibility)

AND curve does not touch x axis at high energy ✓

Labels

(Number of) molecules/particles **AND** Energy ✓

Curves for two temperatures 1 mark ✓

NOTE*: Look for marking criteria within annotations on Boltzmann distribution diagram*

IGNORE *slight inflexion on the curve*

IGNORE *small increase at end of curve*

For labels,

ALLOW *kinetic energy*

IGNORE *number of atoms*

IGNORE *enthalpy for energy*

Temperature

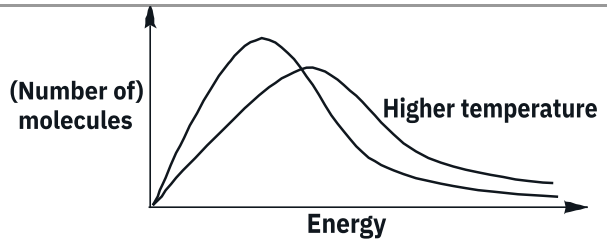
Drawing of two labelled curves

AND higher temperature peak at higher energy

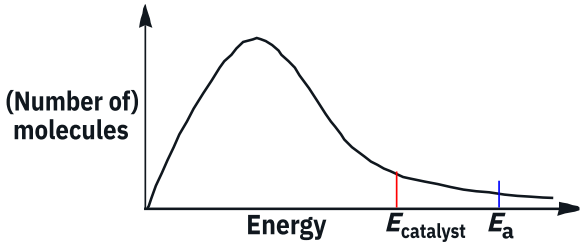
AND lower on molecules

IGNORE *curves meeting at higher energy*

Higher temperature curve must cross over



Catalyst and activation energy 1 mark ✓



Molecules and activation energy, E_a 1 mark

Explanation

At higher temperature **OR** in presence of catalyst

More molecules/particles/collisions

- have energy above activation energy

OR have enough energy to overcome E_a ✓

Could be shown on diagram(s) using shaded area with annotations

[5 marks]

ASSUME that T_2 is higher temperature than T_1

Catalyst

E_c shown at lower energy than E_a on Boltzmann distribution

***IGNORE** catalyst provides a lower activation energy*

Boltzmann distribution not used

***ALLOW** more molecules have energy to react*

***ALLOW** E_a for activation energy*

***ALLOW** E_c for activation energy with catalyst*

***IGNORE** more successful collisions*

OR collide more frequently

Q136 · Reaction rates and equilibrium · [9 marks]

OCR MARK SCHEME

4(a)

Bond angle

112–120° ✓

Explanation

Around N, there is a double bond, a single bond and a lone pair ✓

Electron pairs repel ✓

Seen anywhere

[3 marks]

EXAMINER GUIDANCE

***ALLOW** 3 bonding pairs and 1 lone pair*

OR 2 bonding region and 1 lone pair

***ALLOW** bonding pairs or lone pairs*

4(b)(i)

$(K_c =) \dfrac{[NO]^2[Cl_2]}{[NOCl]^2}$ ✓

[1 mark]

***DO NOT ALLOW** curved brackets*

4(b)(ii)

Response MUST refer to stoichiometry

From equation, $n(NO)$ is $2 \times n(Cl_2)$

OR

Ratio NO:Cl_2 is 2:1

of equation and compare molar ratio of both NO and Cl_2

[1 mark]

4(b)(iii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = √1.31 = 1.1 (mol dm^{-3}) award 2 marks

$[NOCl]^2 = \frac{[NO]^2[Cl_2]}{K_c}$ **OR** $\frac{0.34^2 \times 0.17}{0.015}$ **OR** 1.3 ✓

[NOCl] = √1.3 = 1.1 (mol dm^{-3}) ✓

ALLOW *1.1 up to calculator value of 1.144552314*

ALLOW ECF *from inverted K_c expression in b(ii)*

2.9(478) x 10^{-4} 1 mark

0.017(1691584) 2 marks

[2 marks]

4(b)(iv)

As *T* increases, equilibrium (position) shifts to right

AND (forward) reaction is endothermic ✓

Equilibrium concentration of NO increases ✓

ALLOW *'favours the right', for 'shifts to right'*

ALLOW *moves to right in endothermic direction*

[2 marks]

Q137 · Reaction rates and equilibrium · [1 mark]

Answer: **B**

Only 1 and 2

Q138 · Reaction rates and equilibrium · [1 mark]

Answer: **D**

The peak decreases in height and moves to the right.

Q139 · Reaction rates and equilibrium · [1 mark]

Answer: **A**

Q140 · Reaction rates and equilibrium · [1 mark]

Answer: **C**

The concentrations of the reactants and products are equal.

Q141 · Reaction rates and equilibrium · [10 marks]

OCR MARK SCHEME EXAMINER GUIDANCE

5(a)

$K_c = \dfrac{[CH_3OH]}{[CO] \times [H_2]^2}$ ✓

Multiplication sign is not required

DO NOT ALLOW *curved brackets*

[1 mark]

5(b)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 1.4..... (mol dm^{-3}) award 2 marks

$[CH_3OH] = 15.4 \times 0.57 \times 0.40^2$ ✓

$= 1.40448$ (mol dm^{-3}) ✓

ALLOW ECF *from incorrect expression in (a)*

ALLOW *1.4 up to calculator value of 1.40448*

[2 marks]

5(b)(ii)

To the right ✓

ALLOW *towards the product/CH_3OH*

[1 mark]

5(c)

Less fossil fuel used ✓

Reduction in CO_2 (emissions) ✓

ALLOW *Less energy used*

[2 marks]

5(d)(i)

d-block ✓

[1 mark]

5(d)(ii)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^1$ ✓

Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

ALLOW *4s* ***AND/OR*** *$4p^1$ before 3d,*

e.g. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$

ALLOW *$1s^2$ after answer prompt (ie $1s^2$ twice)*

ALLOW *upper case D, etc and subscripts,*

e.g. .....$4S_2 3D_8$

DO NOT ALLOW *[Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$*

[1 mark]

5(e)

Element A is silicon/Si ✓

AND

A large increase between the 4th and 5th IE

5th electron is removed from shell closer to the nucleus

ALLOW *an indication of a different shell (from removal of 5th electron)*

OR there are 4 electrons in the outer shell ✓

[2 marks]

Q142 · Reaction rates and equilibrium · [13 marks]

OCR MARK SCHEME

6(a)

Best fit curve ✓

Tangent drawn at approximately $t = 50$ s ✓

Gradient calculated: 0.44 ± 0.2 ($cm^3\ s^{-1}$) ✓

[3 marks]

EXAMINER GUIDANCE

DO NOT ALLOW *interpolation (taking a direct reading from graph), answer must be derived from taking a gradient*

ALLOW *ECF from incorrectly drawn tangent*

6(b)

Advantage: no loss of gas ✓

Disadvantage: small loss in mass ✓

[2 marks]

IGNORE *easier to set up*

6(c)(i)

FIRST CHECK THE ANSWER ON ANSWER LINE

If answer = 0.41 (g) award 2 marks

$n(\text{Ba}) = \frac{0.26}{87.6}$ **OR** 2.9..... × 10^{-3} **OR** 3 × 10^{-3} ✓

mass Ba = 137.3 × 2.9..... × 10^{-3}

= 0.41 g ✓ 2 DP required

[2 marks]

ALLOW *ECF from incorrect moles of Ba*

Calculator: 2.96803653 × 10^{-3}

NOTE 3 × 10^{-3} also gives 0.41 g

6(c)(ii)

Steeper initial gradient **AND** levels off earlier ✓

Same volume of gas produced ✓

[2 marks]

6(c)(iii)

Reactivity

Ba is more reactive (than Sr) ✓

Atomic radius

Ba has a greater atomic radius (than Sr)

OR Ba has more shells

OR Ba has more shielding ✓

Attraction

Nuclear attraction is less in Ba

OR (outer) electrons in Ba are less attracted (to nucleus)

Comparison required throughout

ORA *throughout*

For more shells, **ALLOW** higher energy level

IGNORE *more orbitals* ***OR*** *more sub-shells*

IGNORE *'different shell' or 'new shell'*

ALLOW *Ba has less nuclear pull'*

OR 'Ba electrons are less tightly held'

IGNORE *less effective nuclear charge'*

OR Increased distance / shielding in Ba outweighs increased nuclear charge ✓

Ionisation energy

Ionisation energy of Ba is less

OR easier to remove (outer) electrons in Ba ✓

[4 marks]

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

ALLOW *easier to oxidise Ba*

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