Mark schemes

1 (a) **Method 1**

Allow working throughout to 2sf

M1 Moles of Mg = 0.396/24.3 = 0.0163

1

M2 Moles of CH_3COOH = 0.600 × 30.0/1000 = 0.018

1

M3 Mark for showing Mg is in excess: either
0.018 mol of CH_3COOH reacts with 0.009 mol of Mg OR
0.0163 mol of Mg reacts with 0.0326 mol of CH_3COOH OR
0.0073 mol of Mg is in excess

1

*If candidate gets 16.3 mol (as not converted mg to g) in method 1 or
3 then can only score 1 mark maximum (M2)*

Accept other valid calculations that show the Mg is in excess

Method 2

M1 Moles of CH_3COOH = 0.600 × 30.0/1000 = 0.018

M2 Moles of Mg that would react with this = 0.009

M3 Mass of Mg needed = 24.3 × 0.009 = 0.219 g which is less
than 0.396 g OR
Moles of Mg = 0.0163 which is more than 0.009 required

Method 3

M1 Moles of Mg = 0.396/24.3 = 0.0163

M2 Moles of CH_3COOH that would react with this = 0.0326

M3 Volume of CH_3COOH needed = 0.0326 / 0.60 = 0.0543 dm^3
(54.3 cm^3) which is more than 0.030 dm^3 (30 cm^3)

(b) M1 Line starts at origin and is steeper

1

M2 (moles CH_3COOH = 0.800 × 20/1000 = 0.016) line levels out
on 8th line up (line below the original 9th line)

*M2 for line on 8th line on grid (original on 9th line) – allow some
leniency so long as clear it ends at (or very close to) the 8th line;
and line does not significantly wobble*

1

[5]

2 C

[1]

3 (a) (i) Curve drawn from origin with peak clearly lower and to right.

*New curve crosses original once only, finishes above original and does **not** clearly curve up*

IGNORE relative areas

1

(ii) (Relative areas under curves indicate) <u>many</u> (owtte) more molecules with E greater than or equal to Ea (at higher T) or reverse argument

ALLOW *'particles'*

IGNORE *'atoms'*

1

(Large) increase in (number of) <u>successful</u> (owtte) <u>collisions per unit</u> time

OR *'<u>frequency</u> of successful <u>collisions</u>'*

1

(b) (i) Yield increases

Yield decreases/stays the same CE = 0

If not answered mark on

1

More moles/molecules (of gas) on left/fewer on right/3 on left 1 on right

1

<u>Equilibrium shifts/moves</u> (to right) to reduce pressure/oppose higher pressure

No M3 if 'more moles on right' in M2

IGNORE *'favours'*

NOT *just 'oppose the change'*

QoL means that M3 is only awarded if these ideas are clearly linked in one statement

1

(ii) Higher T would increase rate but decrease yield/make less methanol

OR

Lower T decreases rate but increases yield;

*If no mention of both rate **AND** (idea of) yield max 1*

1

Chosen T is a compromise/balance (between rate and yield) owtte

1

[8]

4 C

[1]

5 B

[1]

6 A

[1]

7 C

[1]

8 (a) Consider experiments 1 and 2: [B constant]

[A] increases × 3: rate increases by 3^2 therefore 2nd order with respect to A

1

Consider experiments 2 and 3:

[A] increases × 2: rate should increase × 2^2 but only increases × 2

Therefore, halving [B] halves rate and so 1st order with respect to B

1

Rate equation: rate = $k[A]^2[B]$

1

(b) rate = $k[C]^2[D]$ therefore k = rate / $[C]^2[D]$

1

$$k = \frac{7.2 \times 10^{-4}}{\left(1.9 \times 10^{-2}\right)^2 \times \left(3.5 \times 10^{-2}\right)} = 57.0$$

Allow consequential marking on incorrect transcription

1

mol^{-2} dm^{+6} s^{-1}

Any order

1

(c) rate = $57.0 \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2} = 3.99 \times 10^{-3}$ (mol dm^{-3} s^{-1})

OR

Their $k \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2}$

1

(d) Reaction occurs when molecules have $E \geq E_a$

1

Doubling T by 10 °C causes <u>many</u> more molecules to have this E

1

Whereas doubling [**E**] only doubles the number with this E

1

(e) $E_a = RT(\ln A - \ln k) / 1000$

Mark is for rearrangement of equation and factor of 1000 used correctly to convert J into kJ

1

$E_a = 8.31 \times 300 \, (23.97 - (-5.03)) / 1000 = 72.3$ (kJ mol^{-1})

1

[12]

9 (a) (i) **M1**
High (temperature) OR Increase (the temperature)

> *If **M1** is incorrect **CE = 0** for the clip*
>
> *If **M1** is blank, mark on and seek to **credit the correct information in the text***

M2
The (forward) reaction / to the right is <u>endothermic</u> or <u>takes in / absorbs heat</u>
OR
The reverse reaction / to the left is <u>exothermic</u> or <u>gives out / releases heat</u>

M3 depends on correct M2 and must refer to temperature / heat

> ***M3** depends on a correct statement for **M2***

At high temperature, the (position of) <u>equilibrium shifts / moves</u> left to right to <u>oppose the increase in temperature</u>

> *For **M3**, the position of equilibrium shifts / moves*
>
> *to <u>absorb heat</u> OR*
>
> *to <u>lower the temperature</u> OR*
>
> *to <u>cool down the reaction</u>*

3

(ii) **M1**
The reaction <u>gets to equilibrium faster / in less time</u>
OR
Produces a small yield <u>faster / in less time</u>
OR
<u>Increases the rate</u> (of reaction / of attainment of equilibrium)

> *Mark independently*

M2
High pressure leads to **one** of the following
- <u>more particles / molecules in a given volume</u>
- <u>particles / they are closer together</u>
- <u>higher concentration of particles / molecules</u>

<u>**AND**</u>
- <u>more collisions in a given time</u> / <u>increased collision frequency</u>

> *Penalise **M2** for reference to <u>increased</u> energy of the particles*

2

(iii) **M1** <u>Increase in / more / large(r) / big(ger) surface area / surface sites</u>

> *Mark independently*
>
> *For **M1** accept "an increase in surface"*

M2 <u>increase in / more successful / productive / effective collisions</u> (in a given time) (on the surface of the catalyst / with the nickel)

> *For **M2** not simply "more collisions"*
>
> *Ignore "the chance or likelihood" of collisions*

2

(b) **M1**

No effect / None

> *If **M1** is incorrect **CE = 0** for the clip*
>
> *If **M1** is blank, mark on and seek to **credit the correct information in the text***

M2 requires a correct M1

<u>Equal / same</u> <u>number / amount</u> of <u>moles / molecules / particles</u> on either side of the equation

OR

2 <u>moles / molecules / particles</u> on the left and 2 <u>moles / molecules / particles</u> on the right

> ***M2** depends on a correct statement for **M1***
>
> *In **M2 not** "atoms"*

2

[9]

10 (a) (i) Uses sensible scales.

> *Lose this mark if the **plotted points** do not cover half of the paper.*
>
> *Lose this mark if the graph plot goes off the squared paper*
>
> *Lose this mark if volume is plotted on the <u>x</u>-axis*

1

All points plotted correctly

> *Allow ± one small square.*

1

Smooth curve from 0 seconds to at least 135 seconds − the line must pass through or close to all points (± one small square).

> *Make some allowance for the difficulties of drawing a curve but do not allow very thick or doubled lines.*

1

(ii) Any value in the range 91 to 105 s

> *Allow a range of times within this but not if 90 quoted.*

1

(b) (i) Using pV = nRT

This mark can be gained in a correctly substituted equation.

1

$100\ 000 \times 570 \times 10^{-6} = n \times 8.31 \times 293$

Correct answer with no working scores one mark only.

1

n = 0.0234 mol

Do not penalise precision of answer but must have a minimum of 2 significant figures.

1

(ii) Mol of $ZnCO_3$ = 0.0234

Mark consequentially on Q6

M1

1

Mass of $ZnCO_3$ = M1 × 125.4 = 2.9(3) or 2.9(4) g

If 0.0225 used then mass = 2.8(2) g

M2

1

(iii) Difference = (15.00 / 5) − Ans to b

If 2.87 g used then percentage is 4.3

M1

1

Percentage = (M1 / 3.00) × 100

Ignore precision beyond 2 significant figures in the final answer

If 2.82 g used from (ii) then percentage = 6.0

M2

1

(c) A reaction vessel which is clearly airtight round the bung

1

Gas collection over water or in a syringe

Collection vessel must be graduated by label or markings

Ignore any numbered volume markings.

1

[13]

11 (a) (i) Award mark for **X on the time axis** at the point where the lines just become **horizontal**

*Allow this mark if **X** is above the letters "sh" in the word "show" in part(ii) - in the range of lines 31 to 33.*

1

(ii)   They are equal / the same

OR

Forward (rate) = Reverse / backward (rate)
Allow the word 'speed' in this context.
Ignore reference to concentration.

1

(b)   Both **OR** forward and reverse reactions <u>occur at the same time</u>

OR both are <u>occurring at once</u>

OR both <u>occur all of the time</u>

OR both are ongoing

OR both never stop
Ignore 'at equal rates'.
Ignore reference to concentration or equilibrium.
The idea that both reactions occur <u>simultaneously</u> is essential.
The simple idea of 'both reactions occurring' is insufficient for the mark.

1

(c)   (i)   **M1** No effect / no change / none / stays the same

M2 requires correct **M1**
*In **M2**, ignore reference to particles or atoms.*

M2 Equal (number of) <u>moles / molecules</u> on both sides

2

(ii) **M1** Less time or it decreases or (equilibrium) <u>reached</u> faster (ie **M1** is a reference to time taken)

> *If **M1** is 'more time / it increases' or 'no effect', then* ***CE=0** for the clip.*
>
> *Reference to faster / increased rate / increased speed <u>alone</u> penalises **M1**, but mark on **M2** and **M3**.*

M2 <u>More</u> particles / molecules in a <u>given volume / space</u>

OR the particles / molecules are clos<u>er</u> together

> *If **M1** is blank, then look for all three marks in the text.*

M3 More <u>successful / productive</u> collisions <u>in a given time</u>

OR <u>more</u> collisions with <u>$E > E_{Act}$ in a given time</u>

OR <u>more frequent</u> <u>successful / productive</u> collisions

OR <u>increased / greater</u> <u>successful / productive</u> collision <u>frequency / rate</u>

> *Ignore reference to reactants / products.*
>
> *Penalise **M3** if an increase / decrease in the value of E_{Act} is stated.*

3

[8]

12 (a) <u>Amount / number / proportion / percentage / fraction / moles</u> of <u>molecules / particles</u>

> *Penalise an incorrect qualification of the number eg NOT number of molecules with E greater than Ea.*
>
> *Not 'atoms'.*

1

(b) There are no molecules / particles with zero energy

OR

All of the molecules / particles are moving / have some energy

> *Not 'atoms'.*
>
> *The answer should relate the energy to the molecules.*

1

(c) **C** (The most probable energy)

1

(d) **M1** The peak of the new curve is <u>displaced to the right</u> and <u>lower</u> than the original

M2 All of the following needed

- The new curve starts at the origin and should begin to separate from the original almost immediately

- <u>and</u> the new curve only crosses the original curve once

- <u>and</u> the total area under the new curve is <u>approximately</u> the same as the original

- <u>and</u> an attempt has been made to draw the new curve correctly towards the axis <u>above the original curve</u> but not to touch the original curve
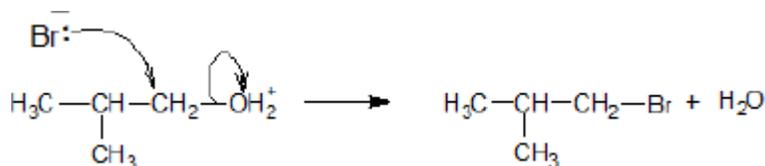
2

(e) None / no effect / stays the same

1

[6]

13 (a) (i) **M1** double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH_2

Penalise additional arrows.

M2 double-headed arrow from the bond to the O atom

As follows

2

(ii) **M1** <u>nucleophilic substitution</u>

M1 both words needed (allow phonetic spelling).

M2 1-bromo(-2-)methylpropane

M2 Require correct spelling in the name but ignore any hyphens or commas.

2

(b)　**M1**　hydrolysis

　　　　　　　*For **M1** give credit for 'hydration' on this occasion only.*

　　M2　C≡N with absorption range 2220–2260 (cm⁻¹)

　　　　　　　*Credit 1 mark from **M2** and **M3** for identifying C≡N **and** either*
　　　　　　　*O–H(acids) **or** C=O **or** C–O without reference to wavenumbers or*
　　　　　　　with incorrect wavenumbers.

　　M3　O–H(acids) with absorption range 2500–3000 (cm⁻¹)

　　　　OR

　　　　C=O with absorption range 1680–1750 (cm⁻¹)

　　　　OR

　　　　C–O with absorption range 1000–1300 (cm⁻¹)

　　　　　　　*Apply the list principle to **M3***

3

(c)　(i)　**M1** Yield / product **OR** ester increases / goes up / gets more

　　　　M2 (By Le Chatelier's principle) the position of equilibrium is driven / shifts /
　　　　moves to the right / L to R / in the forward direction / to the product(s)

　　　　M3 – requires a correct statement in M2

　　　　(The position of equilibrium moves)

　　　　to oppose the increased concentration of ethanol

　　　　to oppose the increased moles of ethanol

　　　　to lower the concentration of ethanol

　　　　to oppose the change and decrease the ethanol

　　　　　　　*If no reference to **M1**, marks **M2** and **M3** can still score BUT if **M1** is*
　　　　　　　incorrect CE=0
　　　　　　　*If there is reference to 'pressure' award   **M1** ONLY.*

3

(ii) **M1**

Catalysts provide an alternative route / pathway / mechanism

OR

surface adsorption / surface reaction occurs

> *For **M1**, not simply 'provides a surface' as the only statement.*
> ***M1** may be scored by reference to a specific example.*

M2

that has a lower / reduced activation energy

OR

lowers / reduces the activation energy

> *Penalise **M2** for reference to an increase in the energy of the molecules.*
> *For **M2**, the student may use a definition of activation energy without referring to the term.*
> *Reference to an increase in successful collisions in unit time alone is not sufficient for **M2** since it does not explain why this has occurred.*

2

[12]

14 (a) (Measure the) volume of gas / mass of the container + contents

1

Suitable named piece of equipment

> *Gas syringe (or inverted burette or measuring cylinder, as long as student has referred to the cylinder being filled with water) / balance.*
> *Equipment must be correct for the measurement stated.*

1

(b) Any **one** of:

- Mass of magnesium
   Allow amount of magnesium.

- Surface area of magnesium

1

(c) (i) Gravity: Conical flask or beaker and funnel /

Vacuum: Sealed container with a side arm and Buchner or Hirsch funnel

> *Must be either gravity filtration (with a V-shaped funnel) or vacuum filtration (with a side-arm conical flask) appropriately drawn.*

1

Filter paper

Must show filter paper as at least two sides of a triangle (V-shaped) for gravity filtration or horizontal filter paper for vacuum filtration.

1

(ii) Wash with / add (a small amount of cold) water

Ignore filtering.

1

[6]

15 (a) Sensible scales

Plotted points (including 0,0) must cover more than half the graph paper.

If axis wrong way round lose this mark but mark on consequentially.

Do not allow broken axis.

1

Plots points correctly

1

(b) Ring around the origin

1

(c) Line through points is smooth

Line must pass within ± 1 small square of each plotted point except the anomaly (allow one plot ± 2 small square – at 40 or 60s).

1

Line through points is best fit and ignores anomaly (allow one plot ± 2 small square)

Lose this mark if student's line is doubled.

Kinked line loses this mark.

Lose this mark if the line does not pass through the origin + / – 1 small square.

Lose this mark if the line deviates to anomaly.

1

(d) Draws suitable tangent

Must touch the curve at 30s and must not cross the curve.

Lose this mark if the tangent is unsuitable but mark on.

1

Chooses appropriate x and y values from their graph

> *Mark consequentially if axes plotted the wrong way around.*
> *Allow information clearly shown on graph.*

1

Correctly calculates y / x

> *Difference in x values and y values must be at least 10 small squares in either direction.*

1

Gives answer with correct units (mol dm^{-3} s^{-1}) or correct variant

> *Lose this mark if answer not to minimum of 2 significant figures and no units or incorrect units are given.*
> *If student has used axis the wrong way round, the unit mark can be awarded for either the correct unit based on their graph or for the correct unit for rate.*

1

[9]

16 (a) M1 On the <u>energy axis</u> E_{mp} at the maximum of <u>the original peak</u>

> *M1 The limits for the horizontal position of E_{mp} are defined as above the word "the" in the sentence below the graph.*

M2 The peak of their new curve is <u>displaced to the left</u> and <u>higher</u> than the original.

M3 All of the following are required

- The new curve starts at the origin and should begin to separate from the original almost immediately

- <u>and</u> the new curve crosses the original curve <u>once</u>

- <u>and</u> an attempt has been made to draw the new curve correctly towards the energy axis <u>below the original curve</u> but not to touch the original curve or the axis

3

(b) **The rate of reaction decreases as the temperature decreases because**

M1 A decrease in the number / proportion of molecules with $E \geq E_a$
OR fewer molecules have $E \geq E_a$
OR fewer molecules have sufficient / enough energy to react / decompose

In M1
Ignore "molecules have less energy".
Ignore "less energetic collisions".
Ignore "molecules do not gain activation energy".
Ignore "fewer collisions".
Credit "particles" for "molecules" but NOT "atoms".

M2 Fewer effective / productive / successful collisions in a given time / given period
OR fewer frequent effective / productive / successful collisions
OR lower rate of effective / productive / successful collisions

Ignore "chance of collision"; this alone does not gain M2

2
[5]

17 (a) As concentration increases the amount of heat given out increases / temperature increases **(M1)**

Any order.

Ignore references to an exothermic reaction.

1

More successful collisions or reactions in a given time **OR** more particles have the activation energy **(M2)**

Allow could be a second / n^{th} order reaction.

1

(An increase in temperature or more heat given out) increases the rate of a reaction **(M3)**

1

(b) The magnesium is coated with an oxide / MgO **(M1)**

Allow magnesium hydroxide.

1

MgO / the coating / the corrosion product has to be removed before Mg will react
OR Mg and MgO / the coating / the corrosion product react at different rates
OR Initially MgO / the coating / the corrosion product reacts not Mg **(M2)**

Ignore inert coating.

1

(c) Any **two** from:

Any order.

Slower with hot water or faster with steam

The hot water produces $Mg(OH)_2$ / the hydroxide **OR** steam produces MgO / the oxide

(Slow) bubbling with hot water **OR** bright white light / flame / white solid with steam

2 max

(d) Magnesium sulfate is soluble <u>and</u> calcium sulfate is insoluble / slightly soluble / magnesium sulfate is more soluble / calcium sulfate is less soluble / correct trend in solubility **(M1)**

Any order.

***M1** requires a comparison of the two solubilities.*

<u>Calcium sulfate</u> coats the surface of the calcium **(M2)**

Coating prevents further contact with / reaction by the acid **(M3)**

*'Calcium sulfate forms a protective coating' scores   **M2** only.*

3

[10]

18 (a) Stoppered flask or similar with side arm

Allow gas outlet through stopper.

1

Calibrated container for collection eg gas syringe

Allow collection over water, but must use calibrated vessel for collection.

Lose 1 mark if apparatus is not gas tight.

1

(b) Plot a graph of 'volume (of gas)' against 'time'

1

Determine the <u>slope (gradient) at the beginning</u>

1

(c) Repeat with same volume **or** concentration of hydrogen peroxide <u>and</u> at the same temperature

Ignore references to results.

Do not allow 'keep everything the same' or words to that effect.

Must mention volume or concentration and temperature.

1

Add cobalt(II) chloride to one experiment

1

[6]