3.2.3 Equilibria

Industrial processes

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193 minutes

189 marks

M1. (a) (i) *Rates:* Rates are equal, forward and backward **(1)**
Concentrations: Concentrations are constant **(1)**

Q of L mark

(ii) *Equilibrium yield:* Decreases **(1)**

if wrong allow max 1 for a correct moles statement

Explanation: More moles / molecules of product (or 2 → 4) **(1)**
Reaction / equilibrium moves to left / reduce constraint **(1)**

NOT "volume" answers

Allow one for "Reaction favours fewer molecules"

(iii) Enthalpy of reaction is positive / endothermic **(1)**

(iv) Both forward and backward rates changed / increased **(1)**
by equal amount (same proportion) **(1)**

allow one for "Ea of forward and backward reactions reduced by an equal amount"

8

(b) (i) The reaction is exothermic **(1)**
High temperature gives a low equilibrium yield **(1)**
Rate of reaction higher at higher temperature **(1)**

An "equilibrium statement" needed e.g. low temp favours the reaction
Do not allow answers based on cost of higher temperature etc

(ii) Higher pressure gives a higher yield **(1)**
4 moles of gaseous reactant form 2 moles of gaseous product **(1)**
Higher pressure generation or equipment is expensive to produce **(1)**

Equilibrium statement required
Cost factor
N.B. NOT a safety answer

6

[14]

M2. (a) rate forward reaction = rate backward reaction **(1)**
concentration remains constant **(1)**

NOT 'Equal',
Allow 'The same' if clear that means constant

2

(b) fewer moles (of gas) on R.H.S **(1) (or converse)**
(methanol favoured) by reducing applied pressure **(1)**

Or removing constraint

2

(c) Power / energy required to provide high pressure / pumping **(1)**
Strong pressure vessel / or equipment **(1)**

*High maintenance costs **(1)***
*High insurance costs **(1)***
Any two

2

(d) Effect: decreases **(1)**
Explanation: reaction exothermic (or reverse reaction endothermic) **(1)**
system tries to lower T or remove constraint or
oppose the change
or endothermic reaction favoured

3

(e) to speed up reaction **(1)**

or otherwise to slow
or takes too long
or to give more molecules $E > E_A$

1

[10]

M3. (a) An equilibrium opposes change **(1)**

1

(b) (i) *Effect on yield of hydrogen:* decreases **(1)**

Note C.E. if not decrease, but mark on if no answer

Explanation: pressure lowered (or increase opposed) **(1)**
by favouring fewer moles (of gas) **(1)**

(ii) *Effect on yield of hydrogen*: increase **(1)**

CE if wrong as above

Explanation: pressure / concentration / reactants / steam reduced **(1)**
by shifting to right **(1)**
or steam removed or forward reaction favoured

6

(c) *Reason 1*: cost of high temperature / energy **(1)**

Reason 2: cost of plant (to resist high T) too high **(1)**
OR plant could not contain high T

2

[9]

M4. (a) Same

1

(b) (i) Decreases

1

More moles on left hand side

1

Equilibrium moves to increase the pressure

(Or to oppose the change or to compensate for low pressure)

1

(ii) Cost of producing high pressure **(1)**
Cost of plant to resist high pressure **(1)**
Correct safety factor with reason **(1)**

max 2

(c) No change

1

Catalyst has no effect on equilibrium position

(Or catalyst affects rate of forward and backwards reactions equally)

1

(d) Negative

1

Reaction *(or equilibrium)* moves in the exothermic direction *(or to the right)*

1

In order to oppose the change *(or to raise the temperature)*

1

(e) Recycled (*or re-used or 'put back in'*)

1

[12]

M5. (a) mark labelled **X** on curve **A** where curve **C** joins **A**;

1

(b) equilibrium opposes a change;

(Q of L mark)

1

(c) **B**

1

more ammonia is produced (or yield increases);

1

fewer moles (of gas) on right (or 4 mol goes to 2 mol);

1

equilibrium moves to oppose increase in pressure (or oppose change);

1

(d) **C**

1

amount of ammonia (or yield or equilibrium) unchanged;

1

reaction is faster;

1

[9]

M6. (a) Rate forward reaction = rate backward reaction (1)

Concentrations of reactants and products are constant (1)

2

(b) System opposes change (1)

Moves to the side with fewer moles (1)

In this case NH_3 (2 moles) on right side < N_2 + H_2 together (4 moles) on left side of equation (1)

3

(c) Too expensive to generate etc (1)

1

(d) (i) Yield of ammonia increases (1)

Exothermic reaction favoured (1)

System moves to raise temp / or oppose decrease in temp (1)

3

(ii) Faster reaction (1)

1

(iii) Balance between rate and yield (1)

1

[11]

M7. (a) Low temperature
Reaction is exothermic

1

Low T reduces effect of heat evolved
<u>or</u> heat evolved opposes the change in temperature

1

High pressure
3 mol gas → 1 mol gas

1

High p favours fewer moles by lowering p
<u>or</u> forward reaction reduces volume and lowers p

1

(b) High T gives a low yield

1

<u>but</u> Low T gives a low rate ∴ compromise

1

increases reaction rate/catalyst surface contact

1

[7]

M8. (a) **M1** <u>Concentrations</u> of reactants and products remain constant

For M1
NOT "equal concentrations"
NOT "amount"

1

M2 Forward <u>rate</u> = Reverse / backward <u>rate</u>

Credit the use of [ ] for concentration
Ignore dynamic, ignore closed system

1

(b) **M1** The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction.

1

M2 The equilibrium responds by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
Promotes the endothermic reaction by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
<u>Temperature increase is opposed</u> (by shift to the left)
OR
Change is opposed by <u>absorbing heat</u> / <u>lowering temperature</u>.

1

(c) (i) A substance that speeds up / alters the rate but is unchanged at the end / not used up.

<u>Both ideas needed</u>
Ignore references to activation energy and alternative route.

1

(ii) None OR no change OR no effect OR nothing OR Does not affect it / the position (of equilibrium) OR (The position is) the same or unchanged.

1

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

OR

There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere.

The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in

Ignore carbon monoxide

1

(ii) A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio.

$$2\,(CH_4 + H_2O \rightarrow CO + 3H_2)$$
$$CH_4 + CO_2 \rightarrow 2CO + 2H_2$$
$$3CH_4 + 2H_2O + CO_2 \rightarrow 4CO + 8H_2$$

Ratio = 1 : 2

1

[8]

M9. (a) (i) Oxidation

OR

Oxidised ONLY

1

(ii) Any one from

- to provide/overcome activation energy
- to provide the minimum energy to make the reaction go/start
  NOT simply to increase the (initial) reaction rate.

1

(iii) The reaction is exothermic OR releases heat (energy)

1

(iv) M1
Catalysts provide an alternative route/pathway OR an alternative mechanism

OR

(in this case) surface adsorption occurs (or a description of adsorption)

Ignore reference to "surface" alone

M2
Lowers the activation energy

OR

of lower activation energy

2

(b) M1
The (forward) reaction is exothermic OR the (forward) reaction releases heat

OR

The reverse reaction is endothermic or absorbs heat

M2 – Direction of change N.B. M2 depends on correct M1
At lower temperatures,

- the equilibrium yield of NO_2 is greater
- more NO_2 is formed
- equilibrium shifts (left) to right
- (equilibrium) favours the forward reaction

(***OR*** converse for higher temperatures)

2

(c) NO_2 (+) 4

NO_3^- (+) 5

HNO_2 (+) 3

3

[10]

M10. (a) (i) Reducing agent

OR

Reduce(s) (WO_3/tungsten oxide)

OR

electron donor

OR

to remove <u>oxygen</u> (from WO_3/tungsten oxide or to form water);

1

(ii) $WO_3 + \mathbf{3}H_2 \rightarrow W + \mathbf{3}H_2O$

Or multiples

1

(iii) *One from*

H_2 is

- explosive
- flammable or inflammable
- easily ignited

Ignore reference to pressure or temperature

1

(b) (i) Addition

Ignore "electrophilic"

Penalise "nucleophilic addition"

OR

(catalytic) hydrogenation

OR

Reduction

1

(ii) Geometric(al)

OR

cis/trans OR E Z OR E/Z

1

(c) (i) (If any factor is changed which affects an equilibrium), the position of equilibrium will shift/move/change/respond/act so as to oppose the change.

OR

(When a system/reaction in equilibrium is disturbed), the equilibrium shifts/moves in a direction which tends to reduce the disturbance

A variety of wording will be seen here and the key part is the last phrase and must refer to movement of the equilibrium.

QoL

1

(ii) **M1 – Statement of number of moles/molecules**
There are more moles/molecules (of gas) on the left/of reactants

OR

fewer moles/molecules (of gas) on the right./products

OR

there are 4 moles/molecules (of gas) on the left and 2 moles/molecules on the right.

Ignore "volumes" for M1

Mark independently

M2 – Explanation of response/movement in terms of pressure
Increase in pressure is opposed (or words to that effect)

OR

pressure is lowered by a shift in the equilibrium (from left) to right/favours forward reaction.

2

(d) ΣB(reactants) – ΣB(products) = Δ*H* (**M1**)

OR

Sum of bonds broken – Sum of bonds formed = ΔH (**M1**)

B(H–H) + ½B(O=O) – 2B(O–H) = – 242 (**M1**)

B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**)

B(H–H) = (+)436 (kJ mol^{-1}) (**M3**)

Award 1 mark for – 436

Candidates may use a cycle and gain full marks.

M1 could stand alone
Award full marks for correct answer.
Ignore units.
Two marks can score with an arithmetic error in the working.

3

[11]

M11. (a) **M1** The yield of zinc oxide increases/greater

If M1 is given as "decrease" OR "no effect" then CE= 0

M2 Removal of the carbon dioxide results in the **equilibrium**

Either

Shifting/moving/goes to the right
shifting/moving/goes L to R
favours the forward reaction/towards the products

M3 (By Le Chatelier's principle) the reaction/equilibrium will respond so as to replace the CO_2/lost product

OR to make more CO_2

OR to increase concentration of CO_2

For M3, not simply "to oppose the change/to oppose the loss of CO_2/to oppose the removal of carbon dioxide."

3

(b) **M1** Process 2 produces/releases SO_2

OR Process 2 produces/releases CO

M2 It/Process 3 avoids the release of SO_2 OR CO

OR It/Process 3 (captures and) converts SO_2 to H_2SO_4

M3 SO_2 causes acid rain OR is toxic/poisonous

OR CO is toxic/poisonous

3

Ignore "global warming" and "greenhouse gases" and "the ozone layer"
If both CO and SO_2 claimed to form acid rain, treat as contradiction

(c) **M1** Process 3 (is expensive because it) uses electrolysis
OR due to high electricity/electrical consumption

M2 this is justified because the product/zinc is pure

Ignore "energy"
Penalise "purer"

2

(d) **M1** $Zn^{2+} + 2e^- \longrightarrow Zn$

Ignore state symbols

M2 the negative electrode OR the cathode

Ignore absence of negative charge on electron
Accept electrons subtracted from RHS

2

(e) **M1** The reaction of ZnO with sulfuric acid
OR the second reaction in Extraction process 3

M2 neutralisation or acid-base

OR alternatively

M1 The reaction of zinc carbonate in Extraction process 1

M1 could be the equation written out in both cases

M2 (thermal) decomposition

M2 depends on correct M1

M3 It/carbon is oxidised/gains oxygen/changes oxidation state/number from 0 to +2/increase in oxidation state/number in Process 2

Do not forget to award this mark
Ignore reference to electron loss but penalise electron gain
Ignore "carbon is a reducing agent"

3

(f) **M1** $Zn + H_2O \longrightarrow ZnO + H_2$

M2 <u>Zinc oxide and hydrogen</u>

OR as an alternative

M1 $Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2$

M2 <u>Zinc hydroxide and hydrogen</u>

Mark independently

If ZnO_2 is given for zinc oxide in the equation, penalise M1 and mark on

If ZnOH is given for zinc hydroxide in the equation, penalise M1 and mark on

Ignore state symbols

Credit multiples of the equation

If M1 is blank, either of the M2 answers could score

To gain <u>both</u> marks, the names must match the correct equation given.

2

[15]

M12. (a) **Three conditions <u>in any order</u> for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$

OR

$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

Penalise "bacteria" and "phosphoric acid" using the list principle

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up (to form glucose or in photosynthesis)

1

M3 6 (mol/molecules) CO_2/carbon dioxide given out due to **2** (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

(c) **M1 (could be scored by a correct mathematical expression)**

(Sum of) bonds broken – (Sum of) bonds made/formed = ΔH

OR

$(\Sigma)\ B_{reactants} - (\Sigma)\ B_{products} = \Delta H$

(where B = bond enthalpy/bond energy)

For M1 there must be a correct mathematical expression using ΔH or "enthalpy change"

M2 Reactants = (+) 4719
OR
Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.

Ignore units.

M2 is for either value underlined

M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are not specific for this reaction *OR* they are average values from many different compounds/molecules

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol
therefore ΔH = **– 669** kJ mol^{-1} OR – **670** $kJmol^{-1}$
OR **–668.8** kJ mol^{-1}

Award M1, M2 and M3 for correct answer to the calculation
Penalise M3 ONLY if correct answer but sign is incorrect
In M1, do not penalise incorrect cases in the formula
If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3
If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770
Ignore incorrect units in M2

M4 Incomplete combustion
Do not forget to award this mark. Mark independently

4

[15]

M13. (i) An activity which has no net/overall (annual) carbon emissions to the atmosphere/air

OR An activity which has no net/overall (annual) greenhouse gas emissions to the atmosphere/air.

OR There is no change in the total amount of carbon dioxide/carbon/greenhouse gas present in the atmosphere/air

The idea that the carbon/CO_2 given out equals the carbon/CO_2 that was taken in from the atmosphere/air
Answer must refer to the atmosphere or air

1

(ii) $Mg_3Si_2O_5(OH)_4 + \mathbf{3}CO_2 \longrightarrow \mathbf{3}MgCO_3 + \mathbf{2}SiO_2 + \mathbf{2}H_2O$

Allow multiples

1

[2]

M14. (i) More absorption/less transmittance of infrared radiation by it/water vapour

OR broader absorption by OH

OR less absorption/more transmittance of infrared radiation by carbon dioxide

Must be comparative

This may be described and must not be contradictory

Credit answers which refer correctly to "transmittance"

(more absorption = less transmittance)

1

(ii) **M1** CO_2 contains C=O (stated like this or in words or strongly implied) OR is O=C=O

M2 depends on correct M1

OR expected absorption/peak (for C=O) is missing

OR expected absorption/peak (for C=O) is shifted to 2300 (cm^{-1})

OR asymmetric stretching is occurring (due to C=O)

If M1 and M2 not scored, give one mark for either

No absorption/peak at 1700 (cm^{-1})/1715 (cm^{-1})

OR no absorption in the range 1680 – 1750 (cm^{-1})

Ignore "carbon-oxygen bonds", "C-O bonds"

Ignore reference to other absorptions

For M2

Allow "dip" OR "spike" OR "low transmittance" as alternatives for absorption.

2

[3]

M15. (a) **In either order**

For M1 accept [ ] for concentration

M1 Concentrations (of reactants and products) remain or stay constant / the same

NOT "equal concentrations" and NOT "concentration(s) is / are the same"

M2 Forward rate = Reverse / backward rate

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(b) **M1** Catalysts increase rate of / speed up both forward and reverse / backward reactions

If M1 is given as "no effect" / "no change" then CE= 0 for clip

M2 increase in rate / affect on rate / speed is equal / the same

Ignore references to "decrease in rate"

2

(c) (i) **M1** (The yield) increases / goes up / gets more

If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 There are more moles / molecules (of gas) on the left / of reactants

Ignore "volumes", "articles" "atoms" and "species" for M2

OR fewer moles / molecules (of gas) on the right / products

OR there are 4 moles / molecules (of gas) on the left and 2 moles / molecules on the right.

OR (equilibrium) shifts / moves to the side with less moles / molecules

M3 Can only score M3 if M2 is correct

The equilibrium shifts / moves (from left to right) to oppose the increase in pressure

For M3, not simply "to oppose the change"

For M3 credit the equilibrium shifts / moves to lower / decrease the pressure

(There must be a specific reference to the change that is opposed)

3

(ii) **M1** The yield decreases / goes down / gets less

If M1 is given as "increase" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 (Forward) reaction is exothermic ***OR*** gives out / releases heat

OR

reverse reaction is endothermic ***OR*** takes in / absorbs heat

Can only score M3 if M2 is correct

The equilibrium shifts / moves (from right to left) to oppose the increase in temperature

For M3, not simply "to oppose the change"

For M3 credit the equilibrium shifts / moves

to absorb the heat OR

to cool the reaction OR

to lower the temperature

(There must be a specific reference to the change that is opposed)

3

(d) (i) Must be comparative

Credit correct reference to rate being too (s)low / (s)lower at temperatures less than 600 K

Higher rate of reaction

OR increase / speed up the rate (of reaction)

Ignore statements about the "yield of ammonia"

OR Gets to equilibrium faster/ quicker

OR faster or quicker rate / speed of attainment of equilibrium

1

(ii) Less electrical pumping cost

Not just "less expensive" alone

OR

Not just "less energy or saves energy" alone

Use lower pressure equipment / valves / gaskets / piping etc.

Credit correct qualified references to higher pressures

OR

Uses less expensive equipment

Ignore references to safety

1

[12]

M16. (a) $\mathbf{2}Ca_5F(PO_4)_3 + 9SiO_2 + \mathbf{15}C \longrightarrow 9CaSiO_3 + CaF_2 + \mathbf{15}CO + \mathbf{6}P$

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)

= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

and

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)

= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH{=}CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

M17. (a) (i) M1 c(oncentrated) phosphoric acid / c(onc.) H_3PO_4

OR c(oncentrated) sulfuric acid / c(onc.) H_2SO_4

*In **M1**, the acid must be concentrated.*
Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants ***OR*** pass the gases over the catalyst several / many times

*In **M2**, ignore "remove the ethanol".*
Credit "re-use".

2

(ii) M1
(By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction

M2 depends on a correct statement of M1
The equilibrium moves / shifts to

- oppose the addition of / increased concentration of / increased moles / increased amount of water / steam
- to decrease the amount of steam / water

Mark M3 independently
M3 Yield of product / conversion increase ***OR*** ethanol increases / goes up / gets more

3

(iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

M2 At higher pressures
More / higher cost of electrical energy to pump / pumping cost
OR
Cost of higher pressure equipment / valves / gaskets / piping etc.
OR expensive equipment

*Credit all converse arguments for **M2***

2

(b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation

$2C(s / graphite) + 3H_2(g) + ½O_2(g) \longrightarrow CH_3CH_2OH(l)$
(C_2H_5OH)

Not multiples but credit correct state symbols in a correctly balanced equation.
Penalise C_2H_6O but credit correct state symbols in a correctly balanced equation.

2

(c) (i) M1 The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is burned / combusts / reacts completely in oxygen
OR burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states
OR (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K

*For **M3***
Ignore reference to 1 atmosphere

3

(ii) M1

Correct answer gains full marks

<u>ΣB(**reactants**) − ΣB(**products**) = *ΔH*</u>

Credit 1 mark for (+) 1279 (kJ mol^{-1})

OR
<u>Sum of bonds broken − Sum of bonds formed = ΔH</u>
OR
B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS)
− 4B(C=O) − 6B(O−H) (RHS) = <u>*ΔH*</u>

M2 (also scores **M1**)
348+360+463+5(412)+3(496) [LHS = **4719**]
(2060) (1488)
− 4(805) − 6(463) [RHS = **− 5998**] = *ΔH*
(3220) (2778)
OR using only bonds broken and formed (**4256** − **5535**)

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M3
ΔH= <u>− **1279**</u> (kJ mol^{-1})

*Allow a maximum of one mark if the only scoring point is LHS = 4719 **OR** RHS = 5998*

Award 1 mark for +1279

Candidates may use a cycle and gain full marks

3

(d) (i) <u>Reducing agent</u> ***OR*** <u>reductant</u> ***OR*** <u>electron donor</u>
OR to <u>reduce the copper oxide</u>

Not "reduction".

Not "oxidation".

Not "electron pair donor".

1

(ii) CH_3COOH

1

[17]

M18. (a) (i) M1 (Yield) increases / goes up / gets more

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

M2

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

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

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

The (position of) equilibrium shifts / moves left to right to oppose the decrease in temperature

*For **M3**, the equilibrium shifts / moves*
*to release heat **OR***
*to raise the temperature **OR***
to heat up the reaction.

3

(ii) M1 *Concentration(s)* (of reactants and products) remain or stay constant / the same

*For **M1** credit [ ] for concentration.*

M2 Forward rate = reverse / backward rate

Not "equal concentrations".
Not "concentrations is / are the same".
Not "amount".

Ignore "dynamic" and ignore "speed".

Ignore "closed system".

It is possible to score both marks under the heading of a single feature.

2

(b) $KBr + H_2SO_4 \longrightarrow KHSO_4 + HBr$

Credit this equation in its ionic form.

Ignore state symbols.

Credit multiples.

1

(c) M1 SO_2 identified

M2 correctly balanced equation (would also gain M1)

*Credit **M2** equation in its ionic form.*

Ignore state symbols.

$$\mathbf{2}HBr + H_2SO_4 \longrightarrow Br_2 + SO_2 + \mathbf{2}H_2O$$

Credit multiples.

Not H_2SO_3 on the right-hand side.

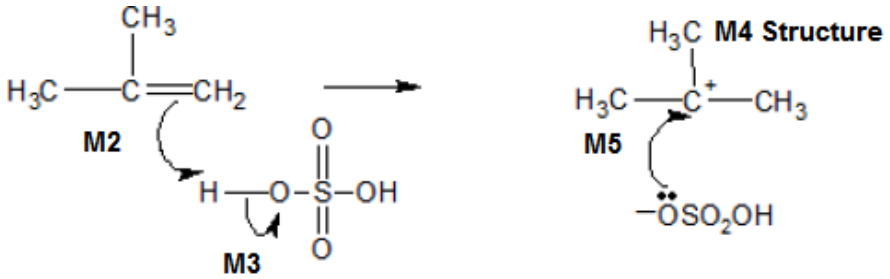
Mark M3 independently

M3 Oxidising agent ***OR*** electron acceptor ***OR*** oxidant ***OR*** to oxidise the bromide (ion) / HBr

M3 *Not "electron pair acceptor".*

3

(d) (i) **M1 Electrophilic addition**



M1 *both words required.*

For the mechanism

M3 *Penalise incorrect partial charges on O − H bond and penalise formal charges*

Ignore partial negative charge on the double bond.

M5 *Not* HSO_4^-

For ***M5****, credit* *as shown* *or* $^{-}OSO_3H$ *ONLY with the negative charge anywhere on this ion*

OR *correctly drawn out with the negative charge placed correctly on oxygen.*

M2 must show an arrow from the double bond towards the H atom of the H − O bond / HO on a compound with molecular formula for H_2SO_4

M2 could be to an H^+ ion and M3 an independent O − H bond break on a compound with molecular formula for H_2SO_4

Max any 3 of 4 marks ***for a correct mechanism*** *using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation.*

M3 must show the breaking of the O − H bond on H_2SO_4

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

M5 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom on their carbocation

Credit the correct use of "sticks".

For ***M5****, credit attack on a partially positively charged carbocation structure, but penalise* ***M4***

NB The arrows here are double-headed

5

(ii) Hydrolysis

Credit "(nucleophilic) substitution" but do not accept any other prefix.

Credit phonetic spelling.

1

(iii) Catalyst

1

[16]