## Mark schemes

**1** A

**[1]**

**2** (a) M1 $(K_c =) \frac{[CH_3CH_2OH]}{[CH_2 = CH_2][H_2O]}$

*Penalise missing brackets or use of (); allow correct molecular formulae in correct expression (and allow $CH_2CH_2$); ignore powers shown as 1*

**1**

M2 $mol^{-1}$ $dm^3$

*Units must be in simplest form on one line (or $dm^3$ $mol^{-1}$)*

*Units are consequential on expression in M1 ($mol^{-1}$ $dm^3$ only scores if it is the units for the expression in M1)*

**1**

(b) M1 $\frac{[\frac{4.40}{2.00}]}{[\frac{0.70}{2.00}]\times[\frac{1.20}{2.00}]}$ or $\frac{2.20}{0.35\times0.60}$ or $\frac{4.40}{0.70\times1.20}\times2.20$

*10.5 (3sf) scores both marks;*

*Correct value to 2sf (10) or 4sf or more (10.476...) scores 1 mark*

*Volume not used is CE=0*

*If use incorrect expression for $K_c$ in part (b) then no marks in part (b)*

**1**

M2 10.5 (must be 3sf)

*If a value from the question is copied incorrectly into the expression, could still score M2 if then used correctly in calculation (AE -1)*

*Ignore units*

**1**

**[4]**

**3** C

**[1]**

**4** C

**[1]**

**5** (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) many (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) successful (owtte) collisions per unit time

*OR 'frequency of successful collisions'*

**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**

Equilibrium shifts/moves (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]**

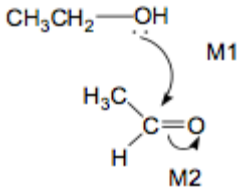
**6** (a) (i) Nucleophilic addition

*Any extra loses the mark*

*Allow minor spelling errors e.g. nucleophyllic*

**1**

(ii)




*M1 for arrow from lone pair on oxygen in ethanol to C of C=O (or to space half way between O and C)*

*M2 for arrow from C=O bond to oxygen in ethanal*

*Do not allow M2 as first step without nucleophilic attack, but can allow M1 for attack on C+ produced*

*+ rather than δ+ on C=O loses M2*

*Ignore any further steps*

*Mark independently*

**1**

**1**

(b) (i) Equal mixture of enantiomers/optical isomers OWTTE

**1**

(ii) (Non-superimposable) mirror images

*Ignore rotates light in opposite directions*

*Ignore stereoisomers*

**1**

(c) (i) Ethan**al** 0.33

**1**

Ethan**ol** 4.16

*Allow 4.2 for ethanol*

**1**

(ii) $K_c = \dfrac{[acetal][H_2O]}{[CH_3CHO][CH_3CH_2OH]^2}$ or with names

$\dfrac{(0.37/0.31)(0.65/0.31)}{(0.58/0.31)(3.76/0.31)^2}$ **OR** $\dfrac{(0.37)(0.65)}{(0.58)(3.76)^2} \times 0.31$

*Ignore slips in acetal structure or formula $C_6H_{14}O_2$*

*If $K_c$ wrong, allow M4 only for units conseq to their $K_c$*

*If volume omitted (gives $2.93 \times 10^{-2}$) may only score M1 and M4*

*If volume used = 310 $cm^3$ allow M2 then award M3 for 9.08 – 9.23 only and M4 for $mol^{-1}$ $cm^3$ only*

*Treat error in converting 310 $cm^3$ to $dm^3$ as AE*

**M1**
**M2**

$9.1 \times 10^{-3}$

*Allow range $9.08 \times 10^{-3}$ – $9.23 \times 10^{-3}$*

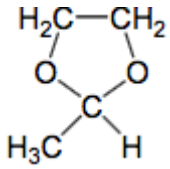
**M3**

$mol^{-1}dm^3$

*Not $moles^{-1}dm^3$*

**M4**

(d)



**1**

**[12]**

**7** (a) $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$

*State symbols essential*

*Do not allow this equation with $H_2O$ on the LHS*

*Ignore + aq on the LHS*

*Allow $H_2O$ written over the arrow / allow equation written as an equilibrium*

*Allow correct equations to form $[Mg(H_2O)_6]^{2+}$ ions*

**1**

(b) $\Delta H_{soln}\ MgCl_2 = LE + (\Delta H_{hyd}Mg^{2+}) + 2(\Delta H_{hyd}Cl^-)$

$\Delta H_{soln}\ MgCl_2 = 2493 - 1920 + (2 \times -364)$

$= -155$ (kJ mol-1)

*M1 for expression in words or with correct numbers*

*Ignore units, but penalise incorrect units*

**1**
**1**

(c) M1: Solubility decreases (as temp increases)

M2: the enthalpy of solution is exothermic / reaction is exothermic / backwards reaction is endothermic

M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce temperature/oppose the increase in temperature (in the endothermic direction)

*If M1 is incorrect then CE=0/3*

*If answer to (b) is a +ve value, allow:*

*M1: Solubility increases (as temp increases)*

*M2: Enthalpy of solution is endothermic etc*

*M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce the temperature/oppose the increase in temperature (in the endothermic direction)*

**1**
**1**
**1**

**[6]**

**8** (a) amount of X = 0.50 – 0.20 = 0.30 (mol)

**1**

amount of Y = 0.50 – 2 × 0.20 = 0.10 (mol)

**1**

(b) Axes labelled with values, units and scales that use over half of each axis

*All three of values, units and scales are required for the mark*

**1**

Curve starts at origin

**1**

Then flattens at 30 seconds at 0.20 mol

**1**

(c) Expression = $K_c = \frac{[Z]}{[X][Y]^2}$

**1**

$[Y]^2 = \frac{[Z]}{[X]\,K_c}$

**1**

$[Y] = (0.35 / 0.40 \times 2.9)^{0.5} = 0.5493 = 0.55$ (mol $dm^{-3}$)

*Answer must be to 2 significant figures*

**1**

(d) Darkened / went more orange

**1**

The equilibrium moved to the right

**1**

To oppose the increased concentration of Y

**1**

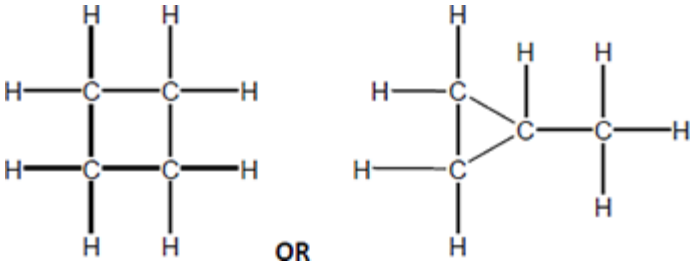
(e) The orange colour would fade

**1**

**[12]**

**9** (a) Alkenes

**1**




*Correctly drawn molecule of cyclobutane or methyl cyclopropane, need not be displayed formula*

**1**

(b) $C_6H_{14}$ (or correct alkane structure with 6 carbons)

*Allow hexane or any other correctly named alkane with 6 carbons*

**1**

(c) Poly(but-2-ene)

**1**

(d) High pressure

*Allow pressure ≥ MPa*

*Mention of catalyst loses the mark*

**1**

(e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

**Level 3**

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

**5–6 marks**

**Level 2**

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

**3–4 marks**

**Level 1**

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

**1–2 marks**

**Level 0**

Insufficient correct chemistry to gain a mark.

**0 marks**

***Indicative chemistry content***

***Stage 1****: consider effect of higher temperature on yield*

*(Or vice versa for lower temperature)*

- *Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature*
- *Exothermic reaction, so equilibrium shifts in endothermic direction / to the left*
- *So a Higher T will reduce yield*

***Stage 2****: consider effect of higher temperature on rate*

*(Or vice versa for lower temperature)*

- *At higher temperature, more high energy molecules*
- *more collisions have E>Ea*
- *So rate of reaction increases / time to reach equilibrium decreases*

***Stage 3****: conclusion*

*Industrial conditions chosen to achieve (cost-effective) balance of suitable yield at reasonable rate*

**[11]**

**10** (a) Bonds broken = 2(C=O) + 3(H–H) = 2 × 743 + 3 × H–H

Bonds formed = 3(C–H) +(C–O) + 3(O–H) = 3 × 412 + 360 + 3 × 463

*Both required*

**1**

–49 = [2 × 743 + 3 × (H–H)] – [3 × 412 + 360 + 3 × 463]

3(H–H) = –49 – 2 × 743 + [3 × 412 + 360 + 3 × 463] = 1450

*Both required*

**1**

H–H = 483 (kJ $mol^{-1}$)

*Allow 483.3(3)*

**1**

(b) Mean bond enthalpies are not the same as the actual bond enthalpies in $CO_2$ (and / or methanol and / or water)

**1**

(c) The carbon dioxide (produced on burning methanol) is used up in this reaction

**1**

(d) 4 mol of gas form 2 mol

**1**

At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure

**1**

This increases the yield of methanol

**1**

(e) Impurities (or sulfur compounds) block the active sites

*Allow catalyst poisoned*

**1**

(f) Stage 1: moles of components in the equilibrium mixture

*Extended response question*

$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$

| | | | | |
|---|---|---|---|---|
| Initial moles | 1.0 | 3.0 | 0 | 0 |
| Eqm moles | (1–0.86) = 0.14 | (3–3×0.86) = 0.42 | 0.86 | 0.86 |

**1**

Stage 2: Partial pressure calculations

Total moles of gas = 2.28

Partial pressures = mol fraction × $p_{total}$

**1**

$p_{CO2}$ = mol fraction × $p_{total}$ = 0.14 × 500 / 2.28 = 30.7 kPa

$p_{H2}$ = mol fraction × $p_{total}$ = 0.42 × 500 / 2.28 = 92.1 kPa

*M3 is for partial pressures of both reactants*

*Alternative M3 =*

*$pp_{CO2}$ = 0.0614 × 500*

*$pp_{H2}$ = 0.1842 × 500*

**1**

$p_{CH3OH}$ = mol fraction × $p_{total}$ = 0.86 × 500 / 2.28 = 188.6 kPa

$p_{H2O}$ = mol fraction × $p_{total}$ = 0.86 × 500 / 2.28 = 188.6 kPa

*M4 is for partial pressures of both products*

*Alternative M4 =*

*$pp_{CH3OH}$ = 0.3772 × 500*

*$pp_{H2O}$ = 0.3772 × 500*

**1**

Stage 3: Equilibrium constant calculation

$K_p = p_{CH3OH} \times p_{H2O} / p_{CO2} \times (p_{H2})^3$

**1**

Hence $K_p$ = 188.6 × 188.6 / 30.7 × $(92.1)^3$ = $1.483 \times 10^{-3} = 1.5 \times 10^{-3}$

*Answer must be to 2 significant figures*

**1**

Units = $\underline{kPa}^{-2}$

**1**

**[16]**

**11** (a) Stage 1: Moles of acid at equilibrium

Moles of sodium hydroxide in each titration

= $(3.20 \times 2.00 \times 10^{-1}) / 1000 = 6.40 \times 10^{-4}$

*Extended response*

**1**

Sample = 10 $cm^3$ so moles of acid in 250 $cm^3$ of equilibrium mixture

= $25 \times 6.40 \times 10^{-4} = 1.60 \times 10^{-2}$

*M2 can only be scored if = answer to M1 × 25*

**1**

Stage 2: Moles of ester and water formed

Moles of acid reacted = $8.00 \times 10^{-2} - 1.60 \times 10^{-2} = 6.40 \times 10^{-2}$

= moles ester and water formed

*M3 is $8.00 \times 10^{-2}$ – M2*

**1**

Stage 3: Moles of ethanol at equilibrium

Moles of ethanol remaining = $1.20 \times 10^{-1} - 6.40 \times 10^{-2} = 5.60 \times 10^{-2}$

*M4 is $1.20 \times 10^{-1}$ – M3*

**1**

Stage 4: Calculation of equilibrium constant

$K_c = [CH_3COOCH_2CH_3]\,[H_2O] / [CH_3COOH]\,[CH_3CH_2OH]$

**1**

= $(6.40 \times 10^{-2})^2 / (1.60 \times 10^{-2})(5.60 \times 10^{-2})$

= 4.5714 = 4.57

*M6 is $M3^2$ / M2 × M4*

*Answer must be given to 3 significant figures*

**1**

(b)

| | **Rough** | **1** | **2** | **3** |
|---|---|---|---|---|
| **Final burette reading / $cm^3$** | 4.60 | 8.65 | 12.85 | 16.80 |
| **Initial burette reading / $cm^3$** | 0.10 | 4.65 | 8.65 | 12.85 |
| **Titre / $cm^3$** | 4.50 | 4.00 | 4.20 | 3.95 |

**1**

(c) Mean = 4.00 + 3.95 / 2 = 3.98 ($cm^3$)

*Allow 3.975 ($cm^3$)*

**1**

Titres 1 and 3 are concordant

*Allow titre 2 is not concordant*

**1**

(d) Thymol blue

**1**

(e) Percentage uncertainty: 0.15 / 3.98 × 100 = 3.77%

*Allow consequential marking on mean titre from 2.3*

**1**

(f) Use a lower concentration of NaOH

**1**

So that a larger titre is required (reduces percentage uncertainty in titre)

**1**

**[13]**

**12** A

**[1]**