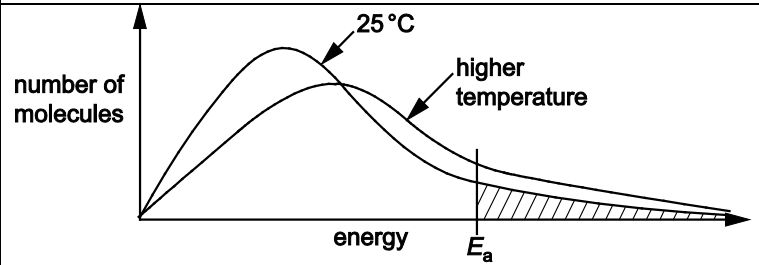
Mark Scheme

Question	Answer	Marks	Guidance
1	C	**1**	
2	D	**1**	

Mark Scheme

Question			Answer	Marks	Guidance
3	(a)	(i)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 0.163 $dm^3\ mol^{-1}\ s^{-1}$ **OR** 0.1632 $dm^3\ mol^{-1}\ s^{-1}$ award 4 marks **IF** answer = 0.163 **OR** 0.1632 with incorrect units award 3 marks Order w.r.t. IC*l* = 1 and order w.r.t H_2 = 1 ✓ rate = k[IC*l*][H_2] ✓ $k = \frac{2.04 \times 10^{-2}}{0.250 \times 0.500}$ = 0.163 **OR** 0.1632 ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	4	**If there is an alternative answer, check to see if there is any ECF credit possible using working below** Both orders = 1 mark Correct rate equation or rearranged form = 1 mark Candidates may use experimental data from experiments 2 or 3 to calculate the rate constant **DO NOT ALLOW** 0.16
		(ii)	rate = k[IC*l*][H_2] (from **(i)**) = $0.163 \times 3 \times 10^{-3} \times 2 \times 10^{-3} = 9.78 \times 10^{-7}$ (mol $dm^{-3}\ s^{-1}$) ✓	1	**ALLOW ECF** from **(i)** Note use of 0.1632 from **(i)** gives $9.79(2) \times 10^{-7}$

Mark Scheme

Question			Answer	Marks	Guidance
	(b)		 Correct curve for higher temperature ✓ Activation energy shown on diagram **AND** graph shows that at higher temperature (*owtte*) more molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	**2**	Boltzmann distribution – must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis at high energy Maximum of curve to right **AND** lower than maximum of lower temperature curve **AND** above lower temp line at higher energy as shown in diagram link to graph required for mark
			Total	**7**	

Mark Scheme

Question			Answer	Marks	Guidance
4	(a)		Measure reduction of colour of bromine ✓	1	
	(b)		Measure volume of CO_2 (produced) ✓	1	
	(c)		Concentration of HCOOH would be constant ✓	1	
	(d)*		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive conclusion which uses quantitative data from the graph to correctly identify and calculate initial rate **AND** half lives and reasoned order of Br_2 **AND** determination of *k* with units *There is a well-developed conclusion showing a line of reasoning which is clear and logically structured. The working for initial rate, half life and order are clearly shown. Determination of k is clear and correct.* **Level 2 (3–4 marks)** Reaches a sound, but not comprehensive, conclusion based on quantitative data from the graph. Correctly identifies and calculates initial rate **AND** half lives and reasoned order of Br_2 *The conclusion has a line of reasoning presented with some structure. The initial rate and order is relevant and supported by correct evidence from the graph. There may be errors in the calculations which prevent the correct determination of k.*	6	**Indicative scientific points may include:** **Initial rate** • Evidence of tangent on graph drawn to line at t = 0 s **AND** gradient determined in range $4 \pm 1 \times 10^{-5}$ • *initial rate* expressed as gradient value with units of mol dm^{-3} s^{-1}, e.g. *initial rate* = 4×10^{-5} mol dm^{-3} s^{-1} **Half lives and reasoned order of Br_2** • Half life measured on graph **OR** within text **OR** stated in range 180–200 s • Constant half life **OR** two stated half lives within ±20 s **AND** conclusion that Br_2 is 1st order **Determination of *k* with units** • Rate constant *k* clearly linked to initial rate **OR** half-life: $k = \frac{rate}{[Br_2]}$ **OR** $k = \frac{\ln 2}{t_{1/2}}$ • *k* determined correctly from measured initial rate or measured half life with units of s^{-1}, e.g. $k = 4 \times 10^{-3}$ s^{-1} from initial rate of 4×10^{-5} mol dm^{-3} s^{-1} **OR** $t_{1/2}$ of 175 s

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Reaches a simple conclusion using at least one piece of quantitative data from the graph. Attempts calculation of initial rate **OR** half lives and reasoned order of Br_2. *The information selected from the graph is basic and communicated in an unstructured way. The calculations may not be clear and the evidence used from the graph may not be clearly shown.* **0 marks** No response or no response worthy of credit.		
			Total	**9**	

Mark Scheme

Question	Answer	Marks	Guidance
5	A	1	

Mark Scheme

Question			Answer	Marks	Guidance
6	(a)		$n(H_2O_2) = 2.30 \times \frac{25.0}{1000}$ **OR** = 0.0575 (mol) ✓ vol $O_2 = \frac{0.0575}{2} \times 24000 = 690$ **cm^3** ✓ Collect in 1000 cm^3/1 dm^3 measuring cylinder ✓	3	**ALLOW** 0.69(0) **dm^3** 2nd mark subsumes 1st mark **ALLOW** 1000 cm^3/1 dm^3 syringe Needs a **name** of actual apparatus, not just 'container' 'measuring cylinder' without volume is insufficient **DO NOT ALLOW** burette For other possible apparatus, contact Team Leader **ALLOW** volumes from 700–1000 cm^3 but should be realistic apparatus, e.g. 700, 750, 800, 850, 900, 950.
	(b)		Measure mass (loss) ✓	1	**ALLOW** weight for mass **ALLOW** take samples and titrate (remaining H_2O_2)

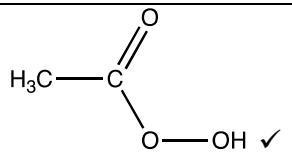
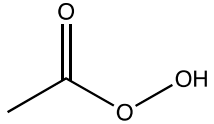
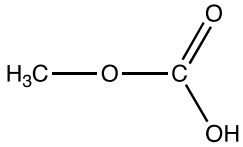
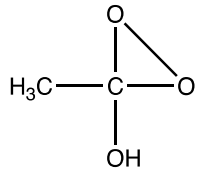
Mark Scheme

Question	Answer	Marks	Guidance
(c)*	*Please refer to the marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** A comprehensive conclusion using quantitative data from the graph to correctly determine initial rate **AND** half lives/gradient with 1st order conclusion for H_2O_2 **AND** determination of *k*. *There is a well-developed line of reasoning which is clear and logically structured.* *Clear working for initial rate, half life*/gradient *and order and k.* *Units mostly correct throughout.* **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 structure and supported by some evidence. The scientific points are supported by evidence from the graph.* **Level 1 (1–2 marks)** Reaches a simple conclusion using at least one piece of quantitative data from the graph. Attempts to calculate initial rate **OR** half life. *There is an attempt at a logical structure with a reasoned conclusion from the evidence.* **0 marks** *No response worthy of credit.*	6	**Indicative scientific points may include:** **Initial rate** • Tangent shown on graph as line at t = 0 s • Gradient determined in range: $1.5 – 2.0 \times 10^{-3}$ e.g. $\frac{2.3}{1300} = 1.77 \times 10^{-3}$ • *initial rate* as gradient value with units: mol dm^{-3} s^{-1}, *For other methods contact TL* **Evidence for 1st order 2 methods** • 1st order clearly linked to half-life **OR** 2 gradients: **1. Half life** • Half life shown on graph • Half life range 800–1000 s • Two 'constant' half lives ±50 s **2. Two gradients → two rates** • 2 tangents shown on graph at *c* and *c*/2 • Gradient at *c*/2 is half gradient at *c* e.g. *c* = 2.3 mol dm^{-3}, gradient = 1.6×10^{-3} **AND** *c* = 1.15 mol dm^{-3}, gradient = 0.8×10^{-3} • For chosen method, conclusion: H_2O_2 is 1st order **Determination of *k* 2 methods** • *k* clearly linked to rate **OR** half-life: $k = \frac{rate}{[H_2O_2]}$ e.g. $k = \frac{1.6 \times 10^{-3}}{2.3} = 7 \times 10^{-4}$ s^{-1} **OR** $k = \frac{\ln 2}{t_{1/2}}$ e.g. $k = \frac{0.693}{950} = 7.3 \times 10^{-4}$ s^{-1}
	Total	**10**	

Mark Scheme

Question			Answer	Marks		Guidance
7	(a)	(i)	*(rate =)* $k\,[H_2O_2]\,[I^-]$ ✓ $k = \frac{rate}{[H_2O_2]\,[I^-]} = \frac{2.00 \times 10^{-6}}{0.0100 \times 0.0100} = 0.02(00)$ ✓ units: $dm^3\ mol^{-1}\ s^{-1}$ ✓	**3**		**Square brackets required** **IGNORE** any state symbols **IGNORE** $[H^+]^0$ **ALLOW ECF** from incorrect rate equation **BUT** units must fit with rate equation used **ALLOW** $mol^{-1}\ dm^3\ s^{-1}$ **OR** in any order **NOTE** K_c expression with calculation and units **0 marks**
	(a)	(ii)	Plot graph using ln k **AND** $1/T$ ✓ (Measure) gradient ✓ *Independent mark* $E_a = (-)R \times$ gradient **OR** $(-)8.314 \times$ gradient ✓ • *Independent mark, even if variables for graph are incorrect* • *Subsumes 'gradient' mark*	**3**		**Unless otherwise stated, assume, that ln *k* is on y axis and 1/*T* is on x axis** **IGNORE** intercept **ALLOW** gradient = $(-)\frac{E_a}{R}$ --- **NOTE: ALLOW 'Inverse graph' (special case)** Plot graph of $1/T$ against ln k ✓ (Measure) gradient ✓ *Independent mark* $E_a = (-)\frac{R}{\text{gradient}}$ **OR** $(-)\frac{8.314}{\text{gradient}}$ **OR** gradient = $(-)\frac{R}{E_a}$ ✓ *Subsumes 'gradient' mark*

Mark Scheme

Question			Answer	Marks		Guidance
	(b)		**ALLOW** equilibrium sign in equations provided reactants on left **Reaction of H_2O_2 with MnO_2:** $H_2O_2 + MnO_2 + 2H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ ✓ **Reaction of H_2O_2 with Mn^{2+}:** $H_2O_2 + Mn^{2+} \rightarrow MnO_2 + 2H^+$ ✓ **Use of *E* data** Use of *E* data to support equation(s) above or half direction of provided half equations (one including MnO_2) ✓ *Also look for evidence around half equations* MnO_2 regenerated/reformed ✓ *Must be linked to an equation showing MnO_2 as reactant and an equation showing MnO_2 as product*	**4**		**ALLOW** correct multiples **IGNORE** state symbols --- **ALLOW** uncancelled H_2O and H^+ $H_2O_2 + MnO_2 + \mathbf{4}H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ **+ $2H^+$** $H_2O_2 + Mn^{2+}$ **+ $2H_2O$ + $2H^+$** $\rightarrow MnO_2 + \mathbf{4}H^+$ **+ $2H_2O$** ***Examples*** • More negative *E* moves to left **ORA** • Reduction half equation to the right **ORA** • Most positive *E* is reduced **ORA** • Calculated *E* cell = +0.81 V (*from top 2*) **OR** *+0.27 V (from bottom 2)* **ALLOW** combining of equations above to show that MnO_2 is used and reformed
	(c)	**(i)**	 ✓ **ALLOW** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous, e.g. 	**1**		**ALLOW**  **OR**  Structure must include OH as part of COOOH group **ALLOW** $-O^- H^+$ in structure

Mark Scheme

Question			Answer	Marks		Guidance
	(c)	(ii)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 0.023(125) (mol) award 3 marks for calculation --- ***K_c expression*** $(K_c =) \frac{[CH_3COOOH]}{[H_2O_2]\,[CH_3COOH]}$ ✓ **$[CH_3COOOH]$** $= 0.37 \times 0.500 \times 0.500 = 0.0925$ (mol dm^{-3}) ✓ *Subsumes K_c expression* ***n*(CH_3COOOH)** $= 0.0925 \times \frac{250}{1000} = 0.023(125)$ (mol) ✓	**3**		**If there is an alternative answer, check for any ECF credit** --- **ALLOW** $0.37 = \frac{[CH_3COOOH]}{0.500 \times 0.500}$ **ALLOW ECF** but **ONLY** if 0.37 **AND** 0.5×0.5 have been used **Common errors** **0.076** **2 marks** *Use of $[CH_3COOOH]^2$* **0.675** **2 marks** *Use of 0.5 for $[H_2O]$ on K_c* **0.169** **2 marks** *Inverted K_c* **0.338** **1 mark** *Inverted K_c AND 0.5 for $[H_2O]$* **5.78×10^{-3}** **2 marks** $\times \frac{250}{1000}$ *before $[CH_3COOOH]$*
			Total	**14**		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
8	A	1	AO1.1	

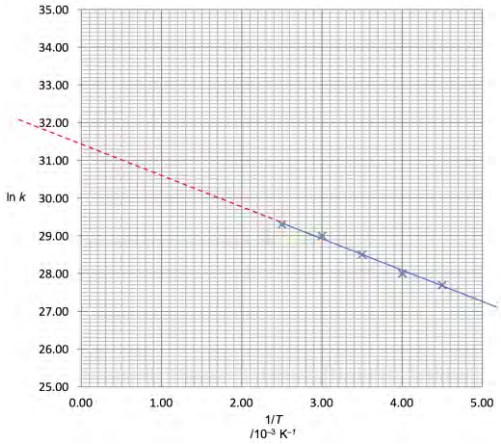
Mark Scheme

Question			Answer	Marks	Guidance
9	(a)*		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive conclusion which uses quantitative results for determination of the reaction orders. **AND** Determines *k* from correct rate equation. **AND** Proposes the two-step mechanism which adds up to overall equation *with no intermediate electrons*. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated. The working for the scientific content is clearly linked to the experimental evidence.* **Level 2 (3–4 marks)** Reaches a sound, but not comprehensive, conclusion based on the quantitative results. **AND** Correctly identifies the orders and rate equation. **AND** Calculates the rate constant **OR** Proposes the two-step mechanism with reactants of first step matching rate equation or matches orders *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. The working for the scientific content is clearly linked to the experimental evidence.*	6	**Indicative scientific points may include:** **Orders and rate equation** • Fe^{3+} 1st order **AND** I^- 2nd order **OR** *rate* = $k[Fe^{3+}]\,[I^-]^2$ • Supported by experimental results **Calculation of *k*, including units** • *k* correctly calculated **AND** correct units, e.g. $k = \frac{8.10 \times 10^{-4}}{(4.00 \times 10^{-2}) \times (3.00 \times 10^{-2})^2} = 22.5$ • $dm^6\,mol^{-2}\,s^{-1}$ **OR** $mol^{-2}\,dm^6\,s^{-1}$ **Two-step mechanism** • Two steps add up to give overall equation • Slow step/ rate-determining step matches stoichiometry of rate equation. • Each step balances by species and charge **e.g.** $Fe^{3+}(aq) + 2I^-(aq) \rightarrow [FeI_2]^+$ SLOW $Fe^{3+}(aq) + [FeI_2]^+ \rightarrow 2Fe^{2+}(aq) + I_2(aq)$ FAST $Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^{2+}(aq) + I_2^-(aq)$ SLOW $Fe^{3+}(aq) + I_2^-(aq) \rightarrow Fe^{2+}(aq) + I_2(aq)$ FAST $Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^+ + I_2$ SLOW $Fe^{3+}(aq) + Fe^+ \rightarrow 2Fe^{2+}(aq)$ FAST There may be other feasible possibilities

Mark Scheme

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Attempts to reach a simple conclusion for orders **AND** Attempts a relevant rate equation. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant The working for the scientific content is clearly linked to the experimental evidence.* **0 marks** No response or no response worthy of credit.		

Mark Scheme

Question			Answer	Marks	Guidance
	(b)	(i)	 **Gradient** Correct gradient calculated from best-fit straight line drawn within the range ±800 → ±1040 ✓ **E_a calculation** E_a = (–) gradient × 8.314 ✓ *e.g. from ±820, E_a = (+)6817.48* (J mol^{-1}) **E_a to 3 SF AND** use of 10^{-3} for gradient ✓ *e.g. from ±820, E_a = (+)6820* (J mol^{-1})	3	**ALLOW** lines which do not intercept y-axis **ALLOW** mark for gradient if correct working shown within E_a calculation without gradient being calculated separately **ALLOW** ±0.8(00) → ±1.04(0) (*omission of 10^{-3}*) **ALLOW** ECF for calculated gradient x 8.314 If value of gradient not shown separately, **ALLOW** E_a in range: 6650 → 8650 **OR** 6.65 → 8.65 (*omission of 10^{-3}*) **This mark subsumes gradient mark** **NOTE: Omission of 10^{-3} can get 1st 2 marks**

Mark Scheme

Question			Answer	Marks	Guidance
		(ii)	Intercept shown on graph *could be by extrapolation of line, or label on y axis* **AND** ln A linked to intercept value *e.g. ln A = 31.4* ✓ Calculation of $A = e^{\text{intercept}}$ ✓ *e.g.* $A = e^{31.4} = 4.33 \times 10^{13}$	**2**	***ALLOW*** *y = 31.4* **ALLOW** substitution of correct values of ln k and 1/T into ln k = $-E_a/R$ x 1/T + ln A to give a value of ln A which approximately matches the intercept if given *ln A = ln k + (E_a/R x 1/T)* *Calculation of* $A = e^{lnA}$ ***OR*** $e^{ln\ k+\ (Ea/R\ \ x\ 1/T)}$ **ALLOW** ECF from incorrect ln *A* $e^{31.2} = 3.55 \times 10^{13}$ $e^{31.3} = 3.92 \times 10^{13}$ $e^{31.35} = 4.12 \times 10^{13}$ $e^{31.45} = 4.56 \times 10^{13}$ $e^{31.5} = 4.79 \times 10^{13}$ $e^{31.6} = 5.29 \times 10^{13}$ $e^{31.7} = 5.85 \times 10^{13}$ $e^{31.8} = 6.46 \times 10^{13}$ $e^{31.9} = 7.14 \times 10^{13}$ $e^{32.0} = 7.9(0) \times 10^{13}$ $e^{32.1} = 8.73 \times 10^{13}$ IF 2 DP answer given, check rounding from calculator value, not 3 DP values given Eg $e^{31.7} = 5.8497 \times 10^{13}$ *and* $= 5.8 \times 10^{13}$*(2SF)*
			Total	**11**	

Mark Schemes

Question	Answer	Marks	AO element	Guidance
10	C	1	AO2.6	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
11			***Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*** **Level 3 (5–6 marks)** Most evidence used to determine the correct orders **AND** rate equation **AND** rate constant. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some evidence used to determine two orders correctly **AND** rate equation **AND** rate constant consistent with orders. **OR** Little evidence used to determine all three orders correctly **AND** rate equation **AND** rate constant. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Little evidence used to determine two orders correctly **OR** One order correct, with attempt to determine the rate equation **AND** rate constant. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	**3.1 ×4** **3.2 ×2**	**Indicative scientific points may include:** **Orders** **Student 1** • zero order wrt Br_2 **Student 2** • 1st order wrt CH_3COCH_3 **Student 3** • 1st order wrt H^+ **Explanations** **Student 1** • constant gradient **OR** linear negative gradient **OR** constant rate **OR** rate independent of concentration **OR** decreasing half-life **Student 2** • straight line through 0,0 • **OR** rate directly proportional to $[CH_3COCH_3]$ **OR** $[CH_3COCH_3] \times 2$, rate $\times 2$ **Student 3** • $[H^+] \times 2$, rate $\times 2$ **Rate equation, rate constant and units** • rate = $k\,[CH_3COCH_3]\,[H^+]$ **ALLOW** rate = $k\,[Br_2]^0\,[CH_3COCH_3]^1\,[H^+]^1$ • $k = \frac{\text{rate}}{[CH_3COCH_3]\,[H^+]}$ **OR** $\frac{1.25 \times 10^{-5}}{1.6 \times 0.2}$ • $k = 3.9\ldots \times 10^{-5}$ • units: $dm^3\ mol^{-1}\ s^{-1}$ (Any order, e.g. $mol^{-1}\ dm^3\ s^{-1}$)
			Total	**6**		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
12	(a)		**Polar bonds** F (atom) is more electronegative (than C atom) **OR** F is very/the most electronegative ✓ **No overall dipole** (CF_4 is) symmetrical **OR** tetrahedral **OR dipoles** cancel **OR dipoles** act in opposite directions ✓	**2**	AO1.1 ×2	**Mark independently** **ALLOW** C and F have **different** electronegativities **OR** the atoms have different electronegativities **……BUT** **DO NOT ALLOW** C is more electronegative **ALLOW** C–F shown with correct dipole, i.e. $C^{\delta+}–F^{\delta–}$. **IGNORE** square planar **IGNORE** polar **bonds** cancel **BUT ALLOW** polarities cancel **IGNORE** charges cancel
	(b)		(Molecules) contain • ^2H **OR** deuterium/D • ^3H **OR** tritium/T **OR** O/H atoms have more neutrons (than ^1H) **OR** (different) O/H isotopes are present **OR** (Molecules are) D_2O ✓	**1**	AO1.2	**ALLOW** Molecules contain ^{18}O Idea of **isotopes** is critical **……..BUT** **DO NOT ALLOW** isotopes of elements different from H and O (e.g. C)
	(c)		$p(O_2) = 0.21 \times 1.00 \times 10^5$ = **21,000 / 2.1 × 10^4** (Pa) ✓	**1**	AO2.2	

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(d)	**FIRST, CHECK ANSWER** **IF** answer = **231 000,** award **2 marks** --- **$n(C_3H_8)$** $n(C_3H_8) = \frac{42.0 \times 10^3}{24.0}$ **OR** $\frac{42.0 \times 10^6}{24\,000}$ **OR** 1750 (mol) ✓ **Mass of CO_2** mass CO_2 $= 3 \times 1750 \times 44$ $=$ **231 000 / 2.31×10^5** (g) ✓ **ALLOW 2 SF**, e.g. 230 000	**2**	AO2.2 AO2.6	**ALLOW** use of ideal gas equation with a sensible temperature (20–25ºC) and pressure (100/101 kPa) At 20ºC and 100 kPa, $n(C_3H_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 293} = 1724\ldots$ (mol) → ~ 227586 (g) (dependent on roundings) At 25ºC and 100 kPa, $n(C_3H_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 298} = 1695\ldots$ (mol) → ~ 223767 (g) (dependent on roundings) **ALLOW** use of 8.31 for *R* **ALLOW ECF** from $n(C_3H_8)$ --- **Common errors from 24.0 dm^3** 231 → 1 mark *No conversion of m^3 to dm^3* 0.231 → 1 mark *Confusion of cm^3 and dm^3* 77 000 → 1 mark *No 3 × for CO_2*
(e)	Initial rate $= 10^{-2} \times 2.4 \times 10^{-3}$ s^{-1} $=$ **2.4×10^{-5}** ($mol\ dm^{-3}\ s^{-1}$) ✓	**1**	AO2.2	
(f)	**FIRST, CHECK ANSWER** **IF** answer = **9.03×10^{22},** award **2 marks** --- $n(P_2O_5) = \frac{4.26}{142.0}$ **OR** 0.03(00) (mol) ✓ O atoms $= 5 \times 0.0300 \times 6.02 \times 10^{23}$ $=$ **9.03×10^{22}** ✓ Minimum 3 SF required	**2**	AO2.2	**Alternative approach** $n(\text{O atoms}) = \frac{4.26}{142.0} \times 5 = 0.15$ ✓ O atoms $= 0.15 \times 6.02 \times 10^{23} = 9.03 \times 10^{22}$ ✓ **ALLOW ECF** from incorrect $n(P_2O_5)$ **ALLOW** use of 6.022×10^{23} --- **Common error** 1.806×10^{22} **OR** 1.81×10^{22} → 1 mark No × 5
	Total	**9**		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
13	**D**	**1**	2.6	
14	**C**	**1**	1.2	**ALLOW** 2 in the answer box

Mark Scheme

Question			Answer	Marks	AO element	Guidance
15	(a)	(i)	To keep [CH_3OH] (effectively) constant **OR** Zero order with respect to CH_3OH **OR** To ensure equilibrium is far to the right ✓	1	3.3	**ALLOW** Change in [CH_3OH] is negligible **ALLOW** rate is independent of [CH_3OH] **IGNORE** Methanol doesn't run out/is not limiting reagent.
		(ii)	One half-life $t_{½}$ between 102 and 110 (mins) Two half-lives calculated **OR** evidence on the graph of two half-lives **AND** constant half-life/values (means first order) ✓	2	3.1 3.2	 **ALLOW** any two combinations of positions, e.g. 5 and 2.5 **AND** 4 and 2 **AND** 3 and 1.5
		(iii)	**Using gradients** Evidence of tangent at $t = 0$ and intercept between 100 -140 (min) ✓ Correctly calculated gradient in the range of 2.9×10^{-5} to 4.0×10^{-5} (mol dm^{-3} min^{-1}) ✓ **OR** **Using half-life** *For* $t_{½} = 106$ *min*, $k = \frac{\ln 2}{t_{½}} = 0.00654$ (min^{-1}) ✓ rate $= 0.00654 \times 5 \times 10^{-3}$ $= 3.27 \times 10^{-5}$ (mol dm^{-3} min^{-1}) ✓	2	3.1×1 3.2×1	 **ALLOW ECF** from value of $t_{½}$ in **(a)(ii)**

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(b)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 7.4 **award 4 marks** --- **Initial moles of reactants** **1 mark** $n(CH_3OH)_{initial} = \frac{9.6}{32} = 0.3$ (mol) **AND** $n(CH_3COOH)_{initial} = \frac{12}{60} = 0.2$ (mol) ✓ **Equilibrium moles** **2 marks** $n(CH_3COOH)$ reacted $= 0.2 - 0.03 = 0.17$ (mol) **AND** $n(CH_3OH)_{equil} = 0.3 - 0.17 = 0.13$ (mol) ✓ $n(CH_3COOCH_3)_{equil} = 0.17$ (mol) **AND** $n(H_2O)_{equil} = 0.17$ (mol) ✓ **K_c calculation** **1 mark** $K_c = \frac{0.17/V \times 0.17/V}{0.13/V \times 0.03/V} = 7.4$ ✓	**4**	1.2×1 2.8×3	**ALLOW** minimum of **2SF** throughout **ALLOW ECF** from initial moles **ALLOW ECF** from equilibrium moles Use of V not required but Kc expression must be correct **ALLOW** up to calculator answer of 7.41025641
			Total	**9**		