F325: Equilibria, Energetics and Elements
5.1.1 How Fast? / 71

1. (i) O_3: Exp 2 has 4 times [H_2] as Exp 1
and rate increases by 4 **(1)**,

so order = 1 with respect to O_3 **(1)**

C_2H_4: Exp 3 has 2 × [C_2H_4] and 2 × [O_3] as Exp 2;
and rate has increased by 4 **(1)**,

so order = 1 with respect to C_2H_4 **(1)**

rate = k [O_3] [C_2H_4] **(1)** 5

(ii) use of k = rate / [O_3] [C_2H_4] = $1.0 \times 10^{-12} / (0.5 \times 10^{-7} \times 1.0 \times 10^{-8})$
to obtain a calculated value **(1)**
$k = 2 \times 10^3$ **(1)**
units: $dm^3\ mol^{-1}\ s^{-1}$ **(1)** 3

(iii) rate = $1.0 \times 10^{-12} /4 = 2.5 \times 10^{-13}$ ($mol\ dm^{-3}\ s^{-1}$) **(1)** 1

(iv) rate increases and k increases **(1)** 1

[10]

2. $1\frac{1}{2}O_2(g) \rightarrow O_3(g)$/
$O_2(g) + \frac{1}{2}O_2(g) \rightarrow O_3(g)$ **(1)**

NO is a catalyst **(1)** as it is (used up in step 1 and) regenerated in step 2/
not used up in the overall reaction**(1)**
allow 1 mark for 'O/NO_2 with explanation of regeneration.'

[3]

3. (i) H_2: Exp 2 has 2.5 times [H_2] as Exp 1
and rate increases by 2.5 **(1)**,

so order = 1 with respect to H_2 **(1)** 2

NO: Exp 3 has 3 x [NO] as Exp 2;
and rate has increased by $9 = 3^2$ **(1)**,

so order = 2 with respect to NO **(1)** 2

QWC At least two complete sentences where the meaning is clear. 1

(ii) rate = k[NO]^2 [H_2] **(1)** 1

(iii) $k = \dfrac{\text{rate}}{[NO]^2[H_2]} / \dfrac{2.6}{0.10^2 \times 0.20}$ **(1)**

$= 1300$ **(1)** units: $dm^6\ mol^{-2}\ s^{-1}$ **(1)**

allow 1 mark for 7.69×10^{-4} or 1.3×10^x (x not 3) 3

[9]

4. (i) $1\frac{1}{2}O_2(g) \rightarrow O_3(g)$/

$O_2(g) + \frac{1}{2}O_2(g) \rightarrow O_3(g)$ **(1)**

NO is a catalyst **(1)** as it is (used up in step 1 and) regenerated in step 2/
not used up in the overall reaction**(1)**
allow 1 mark for 'O/NO_2 with explanation of regeneration.' 3

(ii) Rate = $k[NO]\ [O_3]$ **(1)**
Species in rate equation match those reactants in the slow step / rate determining step **(1)** 2

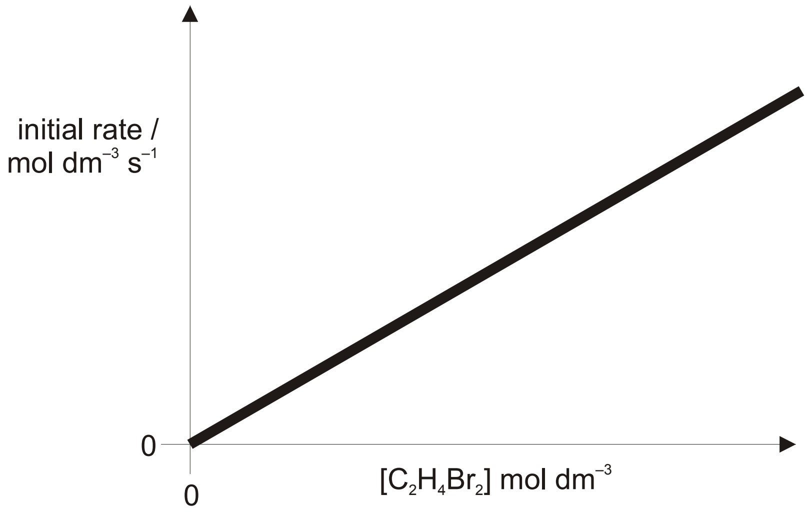
[5]

5. (a) (i) Curve downwards starting at t = 0 ✓ 2
with slope gradually levelling off with no increase ✓
(don't worry about hitting the *x* axis)

(ii) Tangent shown at start ✓ 1

(iii) Half-life is constant 1
OR: draw tangents and then plot a 2nd graph of tangent or rate against concentration, which is a straight line through the origin. ✓

(iv) Straight line through origin ✓ 1



(b) 4 times [KI], rate increases by 4 ✓,
so order = 1 with respect to KI ✓ independent marks 2

(c) (i) rate/r = $k[C_2H_4Br_2]$ [KI] ✓ or ecf from **(b)** 1

(ii) $k = \dfrac{\text{rate}}{[C_2H_4Br_2][KI]} / \dfrac{0.027}{0.50 \times 0.18}$ ✓

= 0.3(0) ✓ units: dm^3 mol^{-1} s^{-1} ✓

units dependent on rate equation in (i).

Mark independently. 3

[11]

6. From graph, constant half-life **(1)**
Therefore 1st order w.r.t. [CH_3COCH_3] **(1)** 2

From table, rate doubles when [H^+] doubles **(1)**
Therefore 1st order w.r.t. [H^+] **(1)** 2

From table, rate stays same when [I_2] doubles **(1)**
Therefore zero order w.r.t. [I_2] **(1)**
Order with no justification does **not** score. 2

rate = $k[H^+][CH_3COCH_3]$ **(1)**
(from all three pieces of evidence)

$k = \dfrac{\text{rate}}{[H^+][CH_3COCH_3]} / \dfrac{2.1 \times 10^{-9}}{0.02 \times 1.5 \times 10^{-3}}$ **(1)**
= 7.0×10^{-5} **(1)** dm^3 mol^{-1} s^{-1} **(1)** 4
accept 7×10^{-5}

rate determining step involves species in rate equation **(1)**

two steps that add up to give the overall equation **(1)**

The left hand side of a step that contains the species in rate-determining step **(1)**
i.e., for marking points 2 and 3:
$CH_3COCH_3 + H^+ \rightarrow [CH_3COHCH_3]^+$
$[CH_3COHCH_3{}^+] + I_2 \rightarrow CH_3COCH_2I + HI + H^+$ 3

organises relevant information clearly and coherently,
using specialist vocabulary where appropriate
Use of the following four words/phrases:
constant, half-life, order, doubles/x2 **(1)** 1

[14]

7. (i) The slowest step **(1)** 1

(ii) $2NO_2 \rightarrow NO + NO_3$ **(1)**
$NO_3 + CO \rightarrow NO_2 + CO_2$ **(1)** 2
(or similar stage involving intermediates)

[3]

8. HCl and CH_3COOH have same number of moles/
release same number of moles H^+ /
1 mole of each acid produce ½ mol of H_2 **(1)**

$[H^+]$ in CH_3COOH < $[H^+]$ in HCl/
CH_3COOH is a weaker acid than HCl (ora) **(1)**

$Mg + 2HCl \rightarrow MgCl_2 + H_2$ **(1)**
$Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$ **(1)**

or
$Mg + 2H^+ \rightarrow Mg^{2+} + H_2$ **(1)(1)** 4

[4]

9. (i) constant half-life **(1)** 1

(ii) rate = $k[N_2O_5]$ **(1)** 1

Common error will be to use '2' from equation.

(iii) curve downwards getting less steep **(1)**
curve goes through 1200,0.30; 2400,0.15; 3600,0.075 **(1)** 2

(iv) tangent shown on graph at t = 1200 s **(1)** 1

(v)	$3.7(2) \times 10^{-4}$ **(1)** mol dm^{-3} s^{-1} **(1)** ecf possible from (ii) using $[N_2O_5]^x$ (2^{nd} order answer: $2.2(3) \times 10^{-4}$)	2	
			[7]

10.	(i)	slow step **(1)**	1	
	(ii)	$(CH_3)_2C{=}CH_2 + H_2O \rightarrow (CH_3)_3COH$ **(1)**	1	
	(iii)	H^+ is a catalyst **(1)** H^+ used in first step **and** formed in second step/ regenerated/ not used up **(1)**	2	
	(iv)	rate = k $[(CH_3)_2C{=}CH_2]$ $[H^+]$ **(1)** common error will be use of H_2O instead of H^+	1	
				[5]