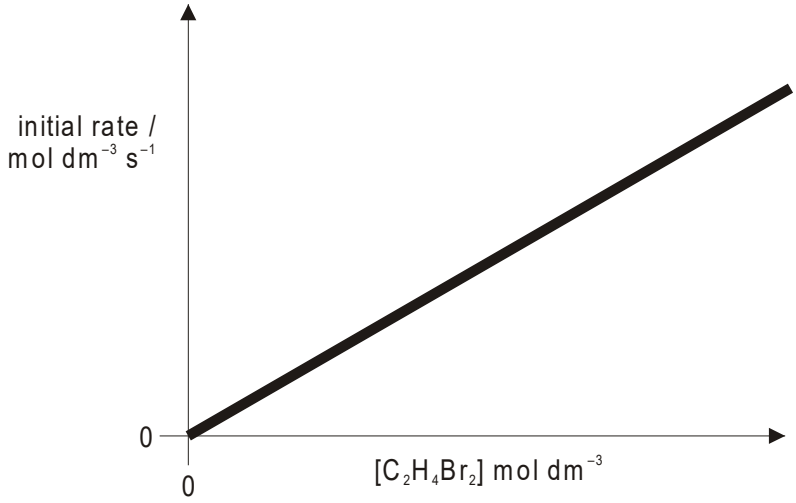
1. (a) (i) Curve downwards starting at t = 0 ✓ 2
with slope gradually levelling off with no increase ✓
(don't worry about hitting the *x* axis)

(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]

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

3. (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]

4. (a) (i) O_3: 1
and C_2H_4 **(1)** 1

(ii) 2 **(1)** 1

(iii) rate = $k[O_3]$ $[C_2H_4]$ **(1)** 1

(b) (i) measure gradient/tangent **(1)**
at t = 0/start of reaction **(1)** 2

(ii) $k = \frac{\text{rate}}{[O_2][C_2H_4]}$ **(1)**

$k = \frac{1.0\times10^{-12}}{0.5\times10^{-7}\times1.0\times10^{-8}} = 2 \times 10^3$ **(1)** $dm^3\ mol^{-1}\ s^{-1}$ **(1)** 3

(iii) 2 mol CH_2O forms for every 0.5 mol O_2 /
stoichiometry of $CH_2O : O_2$ is **not** 1:1 **(1)** 1

(iv) rate increases **(1)**
k increases **(1)** 2

[11]

5. (a) $K_c = \frac{[HI]^2}{[H_2][I_2]}$ **(1)** 1

(b) (i)

H_2	I_2	HI
0.30	0.20	0
0.14	0.04	0.32
(1)		**(1)**

2

(ii) $K_c = \frac{0.32^2}{0.14\times0.04} = 18.28571429$ **(1)**
= 18 (to 2 sig figs) **(1)**
no units **(1)**
(or ecf based on answers to (i) and/or (a)) 3

(c) K_c is constant **(1)**
Composition of mixture is the same **(1)** 2

[8]

6. (a) $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$ **(1)** 1

(b) (i) $PCl_5 > 0.3$ mol dm^{-3} ; PCl_3 and $Cl_2 < 0.3$ mol dm^{-3} **(1)** 1

(ii) At start, system is out of equilibrium with too much PCl_3 and Cl_2 and not enough PCL_5 /
$\frac{0.3 \times 0.3}{0.3}$ = 0.3 is greater than K_c = 0.245 mol dm^{-3} **(1)** 1

(c) (i) K_c does not change as temperature is the same **(1)** 1

(ii) Fewer moles on left hand side **(1)**
system moves to the left to compensate for increase in pressure by producing less molecules **(1)** 2

(d) (i) K_c decreases (as more reactants than products)**(1)** 1

(ii) Forward reaction is exothermic/
reverse reaction is endothermic **(1)**
equilibrium → left to oppose increase in energy/
because K_c decreases **(1)** 2

[9]