1. (a) Log (1 / time) on the *y*-axis + log (vol) on *x*-axis

If axes unlabelled use data to decide that log (1 / time) is on the y-axis

1

Sensible scales

Lose this mark if the plotted points do not cover at least half of the paper

Lose this mark if the graph plot goes off the squared paper

Lose this mark if plots a non-linear / broken scale

Lose this mark if uses an ascending y-axis of negative numbers

1

Plots points correctly ± one square

1

Line through the points is smooth

Lose this mark if the candidate's line is doubled

1

Line through the points is best fit – ignores last point

Must recognise that point at 25 cm^3 is an anomaly

If wrong graph, mark consequentially on anomaly if correctly plotted.

*A kink on graph loses smooth **and** best fit marks*

1

(b) Uses appropriate *x* and *y* readings

Allow taken from table or taken or drawn on graph

Must show triangle on graph or such as $\frac{1.65-1.2}{1.4-0.9}$

1

Correctly calculates gradient 0.95 ± 0.02

Ignore positive or negative sign

Correct answer only with no working scores this mark

1

Answer given to 2 decimal places

1

(c) First order or order is 1

Allow consequential answer from candidate's results

1

(d) Thermostat the mixture / constant temperature / use a water bath
or Colorimeter / uv-visible spectrometer / light sensor to monitor colour change

1

Reaction / rate affected by temperature change
or Eliminates human error in timing / more accurate time of colour change

1

[11]

2. (a) (i) (Experiment 1 2) [A] doubled, ([B] constant,)
rate doubled **(1)**

stated or shown numerically

(ii) 2 **(1)**
or shown as ... $[B]^2$

2

(b) (i) $k = \frac{9.30 \times 10^{-5}}{(0.75)^2 \times (1.50)}$ $= 1.1(0) \times 10^{-4}$ **(1)** **(1)**

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

(ii) rate = $(1.10 \times 10^{-4}) \times (0.20)^2 \times (0.10)$
$= 4.4(1) \times 10^{-7}$ $(mol\ dm^{-3}\ s^{-1})$
(1) for the answer

Ignore units
Conseq on (i)
Upside down expression for k scores zero in (i)
for 9073
but rate = 9073 × (0.2)² × (0.1) = 36(.3)
conseq scores (1) in (ii)

4

[6]

3. (a) (i) Experiment 2: 0.4(0) × 10^{-3} **(1)**
Experiment 3: 0.15 **(1)**
Experiment 4: 0.28 **(1)**

(ii) $k = \frac{4.8 \times 10^{-3}}{(0.20)^2 \times (0.30)}$ $= 0.4(0)\ mol^{-2}\ dm^6\ s^{-1}$

(1) **(1)** **(1)**

(b) (change in) temperature **(1)**

1

[7]

4. (a) Power (or index or shown as *x* in $[\ ]^x$) of concentration term (in rate equation) **(1)**

1

(b) 2 **(1)**

1

(c) (i) *Order with respect to **A**:* 2 **(1)**
*Order with respect to **B**:* 0 **(1)**
(ii) *Rate equation:* (rate =) $k\ [A]^2$ **(1)**
Allow conseq on c(i)

Units for rate constant: $mol^{-1}\ dm^3\ s^{-1}$ **(1)**
conseq on rate equation

4

[6]

5. (a) order with respect to **P** is 2 **1**

order with respect to **Q** is 1 **1**

(b) (i) rate = k**[R][S]**^{2}

(if wrong expression, no further marks) **1**

rate = $(4.2 \times 10^{-4}) \times 0.16 \times 0.84^2$ **1**

$= 4.7 \times 10^{-5}$ (mol dm^{-3} s^{-1})

ignore units even if wrong **1**

(ii) $k = \frac{\text{rate}}{[R][S]^2} = \frac{8.1 \times 10^{-5}}{0.76 \times 0.98^2}$ **1**

$= 1.1 \times 10^{-4}$ **1**

(iii) T_1

If calculated value for $k > 4.2 \times 10^{-4}$, then answer to (iii) is T_2* **1

[8]

6. (a) (i) 2 **1**

(ii) 0 **1**

(b) (i) rate/$[NO_2]^2[O_2]$ **1**

13 **1**

mol^{-2}dm^{6}s^{-1} **1**

(ii) 1.9×10^{-3} **1**

(iii) Step 2

1 **[7]**

7. (a) (i) $(K_p) = (p_z)^2/(p_x)(p_y)^3$

(penalise use of square brackets, allow ())

1

(ii) **X** (22–6)/4 = 4 (MPa)

(mark is for value 4 only, ignore units)

1

Y obtained by multiplying value for **X** by 3

*(allow conseq on wrong value for **X**)*

1

Y 4.0 × 3 = 12 (MPa)

(mark is for value 12 only)

1

(iii) $K_p = 6.0^2/4.0 \times 12.0^3 = 5.21 \times 10^{-3}$

*(allow conseq on wrong values for **X** and **Y** e.g.$6^2/3 \times 9^3 = 0.165$)*

(if K_p wrong in (a)(i) CE)

1

MPa^{-2}

(allow any unit of P^{-2} provided ties to P used for K_p value)

1

(b) high pressure expensive (due to energy or plant costs)

1

(Rate is) slow (at lower temperatures)

1

[8]

8. (a) *M1* $K_p = ({}_PY)^3 . ({}_PZ)^2 / ({}_PW)^2 . ({}_PX)$ *NB [ ] wrong* **1**

M2 temperature **1**

M3 increase **1**

M4 particles have more energy or greater velocity/speed **1**

M5 more collisions with $E > E_a$ or more successful collisions **1**

M6 Reaction exothermic or converse **1**

M7 Equilibrium moves in the left **1**

Marks for other answers

Increase in pressure or concentration	*allow M1, M5, M6*	*Max 3*
Addition of a catalyst;	*allow M1, M5, M6*	*Max 3*
Decrease in temperature;	*allow M1, M2, M6*	*Max 3*
Two or more changes made;	*allow M1, M6*	*Max 2*

[7]

9. (a) 12 (kPa) **1**

pp = mole fraction × total pressure **or** mole fraction = 12/104 **1**

= 0.115

(allow 0.12) **1**

(b) 68 (kPa) **1**

(c) $K_p = \frac{(pSO_3)^2}{(pSO_2)^2 \times (pO_2)}$

(If K_p wrong, allow consequential units only)

(penalise square brackets in expression but then mark on)

1

$= \frac{68^2}{24^2 \times 12}$

1

= 0.669

(Allow 0.67)

(Allow full marks in calculation consequential on their values in (a) and (b))

1

kPa^{-1}

1

(d) T_2

(Must be correct to score any marks in this section)

1

Exothermic

1

Reduce T to shift equilibrium to the right
or forward reaction favoured by low T
or K_p increases for low T
or low T favours exothermic reaction

1

(e) Increase

1

None

1

[13]

10. D

[1]

11. C

[1]

12. A

[1]

13. D

14. B **[1]**

15. B **[1]**

16. D **[1]**