

Question	Expected Answers	Marks
1 (a) (i)	rate at start (of reaction)/ t=0 ✓	[1]
	(ii) 0.048 (mol dm <sup>-3</sup> s <sup>-1</sup> ) ✓	[1]
(b) (i)	<p>C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>(aq):</p> <p>Exp 2 has twice [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> (aq)] as Exp 1 and rate x 2 ✓, so order = 1 with respect to C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> ✓</p> <p>HCl(aq):</p> <p>Exp 3 has 1.5 x [HCl] as Exp 1 and rate increases by 1.5 ✓, so order = 1 with respect to HCl(aq) ✓</p> <p><b>ORDER HAS TO BE CORRECT TO GET REASON MARK</b></p>	[4]
(ii)	2/second order ✓ This will be dependent on answer to (i)	[1]
(iii)	<p>rate = k[C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [HCl] ✓✓</p> <p>OR</p> <p>rate = 2.4 [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [HCl] ✓✓</p> <p><i>rate = k [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [H<sub>2</sub>O] scores 1 mark)</i>  <i>rate = [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [HCl] scores 1 mark)</i>  <i>k [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [HCl] scores 1 mark)</i>  <i>k = [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>] [HCl] scores zero</i>            Check for ecf from (i)</p>	[2]
(c)	increases ✓	[1]
(d) (i)	time for concentration (of a reactant) to fall to half the original value ✓	[1]
(ii)	<p>C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>: 0.05 mol dm<sup>-3</sup> ✓</p> <p>In one half life, [C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>], concentration halves 0.1/2 ✓</p> <p>HCl: 0.1 mol dm<sup>-3</sup> ✓</p> <p><i>Assume mol dm<sup>-3</sup> unless told otherwise</i>  <i>Assume 'mol dm<sup>3</sup> means mol dm<sup>-3</sup> but</i>  <i>Penalise wrong unit once only</i></p>	[3]
		<b>Total: 14</b>

Question	Expected Answers	Marks
2 (a) (i)	$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} \checkmark\checkmark$ <p style="text-align: center;"><i>award 1 mark if upside down</i> <i>K<sub>p</sub> expression worth 1 mark</i></p>	[2]
(ii)	Equil → left because $K_c$ is very small	[1]
(iii)	$[\text{O}_2(\text{g})] = \frac{[\text{NO}]^2}{[\text{N}_2] \times K_c} = \frac{(4.0 \times 10^{-16})^2}{1.1 \times 4.8 \times 10^{-31}} \checkmark$ <p>= 0.30 mol dm<sup>-3</sup> ✓ (calculator: 0.303030303)            answer given to 2 sig figs ✓            3.3 ✓✓ (upside down) calc: 3.3            7.6 x 10<sup>14</sup> ✓✓ (missing out 2) calc: 7.5757.....            0.37 ✓✓ (1.1 on top) calc: 0.366666..            5.2 x 10<sup>-46</sup> ✓✓ ('4' values swapped) calc: 5.236363. x 10<sup>-46</sup></p>	[3]
(b) (i)	$\Delta H$ is +ve ✓	
(ii)	equilibrium moves to the right to compensate for increase in temperature/to lower the temperature / to minimise the change ✓	
	increase in proportion of NO ✓ because $K_c$ increases <i>Can be linked to either increased proportion of NO or enthalpy change ✓</i>	[4]
(iii)	$2\text{NO} + \text{O}_2 \longrightarrow 2\text{NO}_2 \checkmark\checkmark$ <p><i>species correct for 1st mark</i>  <i>'simplest' balanced equation for 2nd mark</i>  <math>\text{NO} + \frac{1}{2}\text{O}_2 \longrightarrow \text{NO}_2</math> also gets both marks  <math>\text{N}_2\text{O}_4</math> is fine  <math>\text{NO}_2</math> for 1st mark</p>	[2]

(c)	<p>Optimum Pressure  low pressure ✓  fewer gaseous moles on left ✓</p> <p>Optimum Temperature  optimum: low temperature ✓  forward reaction is exothermic ✓</p> <p>Reason mark can only be awarded if the condition mark is correct.</p> <p>Condition mark is independent</p> <p>1000°C used to increase rate with more energetic collisions  OR so that a greater proportion of molecules exceed activation energy ✓</p> <p>10 atm used to increase rate by increasing concentration OR increasing collisions ✓</p> <p>Catalyst used to increase rate by lowering the activation energy/providing a lower energy route ✓  <i>NOT increase equilibrium yield</i></p> <p>Quality of written communication:  Recognition of a compromise between rate and equilibrium amount ✓</p>	<p>[7]</p> <p>[1]</p>
		<b>Total: 20</b>

Question	Expected Answers	Marks
3 (a) (i)	<p>pH = <math>-\log[\text{H}^+(\text{aq})]</math> ✓ <i>state symbols not needed</i></p> <p>(ii) HBr is stronger than <math>\text{CH}_3\text{COOH}</math> because pH is lower ✓ HBr dissociates more/more <math>\text{H}^+</math> ions..... for the same concentration ✓</p> <p>(iii) diluting by a factor of 10/ 10-fold dilution ✓</p> <p>pH = 3 ✓</p> <p>Credit a calculated pH for ecf from a wrong dilution with working shown</p>	[1]  [2]  [2]
(b) (i)	<p><math>K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]</math> ✓ <i>state symbols not needed</i></p> <p>(ii) <math>[\text{H}^+(\text{aq})] = \frac{K_w}{[\text{OH}^-(\text{aq})]} = \frac{1.0 \times 10^{-14}}{0.0200} = 5 \times 10^{-13} \text{ mol dm}^{-3}</math> ✓</p> <p>pH = <math>-\log(5 \times 10^{-13}) = 12.30</math> ✓ (accept calc value: 12.30103) ecf is possible for pH mark providing that the <math>[\text{H}^+]</math> value has been derived from <math>K_w/[\text{OH}^-]</math></p> <p>If pOH method is used, pOH = 1.7 would get 1st mark, pH = <math>14 - 1.7 = 12.3</math> gets 2nd mark.</p>	[1]    [2]
(c) (i)	<p>start at pH=3.4 (approx half way up 0-7 rise) ✓ sharp rise at 20 <math>\text{cm}^3</math> (must have a vertical part) ✓ finish higher above pH 7 than starting pH .....with line continued to 50 <math>\text{cm}^3</math> .....but finish pH is less than 14 ✓ NOTE that lines should not loop</p> <p>(ii) Indicator that has a pH range coinciding with steepest part of titration curve in (i). Likely to be thymol blue OR brilliant yellow ✓</p> <p>pH range coincides with .....pH change during sharp rise /equivalence point ✓</p>	[3]    [2]
		<b>Total: 13</b>

Question	Expected Answers	Marks
4 (a)	<p>P : O = 43.7/31 : 56.3/16 / 1.41 : 3.52 ✓</p> <p>Ratio P:O = 2 : 5 / Empirical formula = P<sub>2</sub>O<sub>5</sub> ✓</p> <p>Molecular formula = P<sub>4</sub>O<sub>10</sub> (from M<sub>r</sub> value) ✓</p> <p>Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> ✓</p> <p>Equations:  P<sub>4</sub> + 5O<sub>2</sub> → P<sub>4</sub>O<sub>10</sub> ✓  (or P<sub>4</sub> + 5O<sub>2</sub> → 2P<sub>2</sub>O<sub>5</sub>)</p> <p>P<sub>4</sub>O<sub>10</sub> + 6H<sub>2</sub>O → 4H<sub>3</sub>PO<sub>4</sub> ✓  (or P<sub>2</sub>O<sub>5</sub> + 3H<sub>2</sub>O → 2H<sub>3</sub>PO<sub>4</sub>)</p> <p>Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> + 3H<sub>2</sub>SO<sub>4</sub> → 2H<sub>3</sub>PO<sub>4</sub> + 3CaSO<sub>4</sub> ✓</p> <p>A candidate who writes an equation forming P<sub>4</sub>O<sub>6</sub> or P<sub>2</sub>O<sub>3</sub> can score the equation mark for oxidation of P<sub>4</sub>.</p>	<p>[3]</p> <p>[1]</p> <p>[3]</p>
(b) (i)	<p>H<sub>3</sub>PO<sub>4</sub> &gt; H<sub>2</sub>PO<sub>4</sub><sup>-</sup> &gt; HPO<sub>4</sub><sup>2-</sup></p> <p>Increased strengths with increasing K<sub>a</sub> values ✓</p>	[1]
(ii)	<p>Molar mass of Na<sub>2</sub>HPO<sub>4</sub> = 142 g mol<sup>-1</sup> ✓</p> <p>amount of Na<sub>2</sub>HPO<sub>4</sub> = 4.26/142 = 0.03 mol ✓  <i>e.c.f. mass/molar mass</i></p> <p>volume of H<sub>3</sub>PO<sub>4</sub> needed = 0.03 x 1000 / 0.5 = 60 cm<sup>3</sup> ✓  <i>e.c.f. moles Na<sub>2</sub>HPO<sub>4</sub> x 1000/0.5</i></p> <p>amount of NaOH = 2 x 0.03 = 0.06 mol ✓  <i>e.c.f. 2 x moles Na<sub>2</sub>HPO<sub>4</sub></i></p> <p>volume of NaOH needed = 0.06 x 1000 / 0.5 = 120 cm<sup>3</sup> ✓  <i>e.c.f. moles NaOH x 1000/0.5</i></p> <p>Penalise units once.</p>	[5]
		<b>Total: 13</b>