

1. (i) O<sub>3</sub>: Exp 2 has 4 times [H<sub>2</sub>] as Exp 1  
and rate increases by 4 (1),  
so order = 1 with respect to O<sub>3</sub> (1)  
C<sub>2</sub>H<sub>4</sub>: Exp 3 has 2 × [C<sub>2</sub>H<sub>4</sub>] and 2 × [O<sub>3</sub>] as Exp 2;  
and rate has increased by 4 (1),  
so order = 1 with respect to C<sub>2</sub>H<sub>4</sub> (1)  
rate =  $k [\text{O}_3] [\text{C}_2\text{H}_4]$  (1) 5
- (ii) use of  $k = \text{rate} / [\text{O}_3] [\text{C}_2\text{H}_4] = 1.0 \times 10^{-12} / (0.5 \times 10^{-7} \times 1.0 \times 10^{-8})$   
to obtain a calculated value (1)  
 $k = 2 \times 10^3$  (1)  
units:  $\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$  (1) 3
- (iii) rate =  $1.0 \times 10^{-12} / 4 = 2.5 \times 10^{-13} (\text{mol dm}^{-3} \text{s}^{-1})$  (1) 1
- (iv) rate increases and  $k$  increases (1) 1
- [10]**
2.  $1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{O}_3(\text{g})/$   
 $\text{O}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{O}_3(\text{g})$  (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<sub>2</sub> with explanation of regeneration.' 3
- [3]**
3. (i) H<sup>+</sup>/proton donor (1) 1  
(ii) partially dissociates/ionises (1) 1
- [2]**
4.  $\text{C}_6\text{H}_5\text{OH}(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{C}_6\text{H}_5\text{O}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
acid 1 base 2 base 1 acid 2 (1) 1
- [1]**

5. (i)  $K_a = [\text{C}_6\text{H}_5\text{O}^-(\text{aq})] [\text{H}^+(\text{aq})] / [\text{C}_6\text{H}_5\text{OH}(\text{aq})]$  (1) 1
- (ii)  $M_r \text{C}_6\text{H}_5\text{OH} = 94$  (1)  
 $[\text{C}_6\text{H}_5\text{OH}(\text{aq})] 4.7/94 = 0.050 \text{ mol dm}^{-3}$  (1)  
 $1.3 \times 10^{-10} \approx [\text{H}^+(\text{aq})]^2 / 0.050 \text{ mol dm}^{-3}$  (1) ('=' sign is acceptable)  
 $[\text{H}^+] = \sqrt{\{(1.3 \times 10^{-10}) \times (0.050)\}} = 2.55 \times 10^{-6} \text{ mol dm}^{-3}$  (1)  
 $\text{pH} = -\log[\text{H}^+] = -\log 2.55 \times 10^{-6} = 5.59$  (1)  
 3 marks:  $[\text{H}^+]$ ; pH expression ; calc of pH from  $[\text{H}^+]$  5

[6]

6.  $[\text{H}^+(\text{aq})] = 1.99 \times 10^{-9} \text{ mol dm}^{-3}$  (1)  
 $[\text{C}_6\text{H}_5\text{O}^-(\text{aq})] = K_a [\text{C}_6\text{H}_5\text{OH}(\text{aq})] / [\text{H}^+(\text{aq})]$  (1)  
 $[\text{C}_6\text{H}_5\text{O}^-(\text{aq})] = 0.13 \text{ mol dm}^{-3}$  (1) 3

*Calculation should use half the original concentration of phenol to find the concentration of sodium phenoxide in the buffer. This should then be doubled back up again.*

*Do **not** penalise an approach that uses the original concentration of phenol in the expression above.*

[3]

7. (a) rate of forward reaction = rate of reverse reaction (1)  
 concentrations of reactants and products are constant but they are constantly interchanging (1) 2
- (b) (i)  $K_c = [\text{CH}_3\text{OH}] / [\text{CO}] [\text{H}_2]^2$  (1) 1
- (ii) use of  $K_c = [\text{CH}_3\text{OH}] / [\text{CO}] [\text{H}_2]^2$  and moles to obtain a calculated value (1)  
 convert moles to concentration by +2:  $[\text{CO}] = 3.10 \times 10^{-3} \text{ mol dm}^{-3}$ ;  
 $[\text{H}_2] = 2.60 \times 10^{-5} \text{ mol dm}^{-3}$ ;  $[\text{CH}_3\text{OH}] = 2.40 \times 10^{-2} \text{ mol dm}^{-3}$  (1)  
 $K_c = [2.60 \times 10^{-5}] / [3.10 \times 10^{-3}] [2.40 \times 10^{-2}]^2 = 14.6 / 14.56$  (1)  
 If moles not converted to concentration, calculated  $K_c$  value = 3.64  
 (scores 1st and 3rd marks)  
 units:  $\text{dm}^6 \text{ mol}^{-2}$  (1) 4
- (c) (i) fewer moles of gas on right hand side (1) 1
- (ii) None (1) 1

- (d) (i) moved to left hand side/reactants increase/less products (1) 1  
(ii)  $\Delta H$  negative because high temperature favours the endothermic direction (1) 1
- (e) (i)  $\text{CH}_3\text{OH} + 1\frac{1}{2} \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ (1) 1  
(ii) adds oxygen/oxygenated (1) 1
- [13]**
8. (i)  $\text{H}_2$ : Exp 2 has 2.5 times  $[\text{H}_2]$  as Exp 1 and rate increases by 2.5 (1),  
so order = 1 with respect to  $\text{H}_2$  (1) 2  
NO: Exp 3 has 3 x  $[\text{NO}]$  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 =  $k[\text{NO}]^2 [\text{H}_2]$  (1) 1
- (iii)  $k = \frac{\text{rate}}{[\text{NO}]^2 [\text{H}_2]} / \frac{2.6}{0.10^2 \times 0.20}$  (1)  
= 1300 (1) units:  $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$  (1)  
allow 1 mark for  $7.69 \times 10^{-4}$  or  $1.3 \times 10^x$  (x not 3) 3
- [9]**
9. (i)  $1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{O}_3(\text{g})/$   
 $\text{O}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{O}_3(\text{g})$  (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<sub>2</sub> with explanation of regeneration.' 3
- (ii) Rate =  $k[\text{NO}] [\text{O}_3]$  (1)  
Species in rate equation match those reactants in the slow step / rate determining step (1) 2
- [5]**
10. (a)  $K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$  (1) 1

- (b) (i)  $\text{PCl}_5 > 0.3 \text{ mol dm}^{-3}$  ;  $\text{PCl}_3$  and  $\text{Cl}_2 < 0.3 \text{ mol dm}^{-3}$  (1) 1
- (ii) At start, system is out of equilibrium with too much  $\text{PCl}_3$  and  $\text{Cl}_2$  and not enough  $\text{PCl}_5$  /  
 $\frac{0.3 \times 0.3}{0.3} = 0.3$  is greater than  $K_c = 0.245 \text{ mol dm}^{-3}$  (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  $\rightarrow$  left to oppose increase in energy/  
 because  $K_c$  decreases (1) 2

[9]

11. (a) (i) Ionic product (1) 1
- (ii)  $K_w = [\text{H}^+(\text{aq})] [\text{OH}^-(\text{aq})]$  (1) *state symbols not needed* 1
- (b) moles of  $\text{HCl} = \frac{5 \times 10^{-3} \times 21.35}{1000} = 1.067 \times 10^{-4} \text{ mol}$  (1)
- moles of  $\text{Ca}(\text{OH})_2 = \frac{1.067 \times 10^{-4}}{2} = 5.34 \times 10^{-5} \text{ mol}$  (1)
- concentration of  $\text{Ca}(\text{OH})_2 = 40 \times 5.34 \times 10^{-5}$   
 $= 2.136 \times 10^{-3} \text{ mol dm}^{-3}$  (1)
- 2 marks for  $4.27 \times 10^{-3} / 8.54 \times 10^{-3} \text{ mol dm}^{-3}$   
 (no factor of 4) 3

(c)  $[\text{OH}^-] = 2 \times 2.7 \times 10^{-3} = 5.4 \times 10^{-3} \text{ mol dm}^{-3}$  (1)

$$[\text{H}^+(\text{aq})] = \frac{K_w}{[\text{OH}^-(\text{aq})]} = \frac{1.0 \times 10^{-14}}{5.4 \times 10^{-3}} = 1.85 \times 10^{-12} \text{ mol dm}^{-3}$$
 (1)

$\text{pH} = -\log(1.85 \times 10^{-12}) = 11.73/11.7$  (1) 3

ecf is possible for pH mark providing that the  $[\text{H}^+]$  value has been derived from  $K_w/[\text{OH}^-]$

If pOH method is used, pOH = 2.27. would get 1<sup>st</sup> mark,

pH = 14 - 2.27 = 11.73 gets 2<sup>nd</sup> mark.

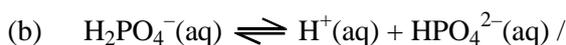
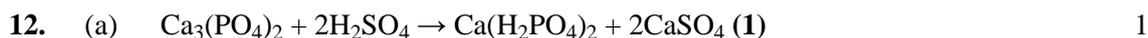
Commonest mistake will be to not double  $\text{OH}^-$  and to use  $2.7 \times 10^{-3}$

This gives ecf answer of 11.43/11.4, worth 2 marks.

pH = 11.13 from dividing by 2: worth 2 marks

(d) 8 (1) 1

[9]



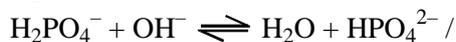
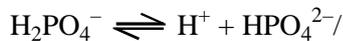
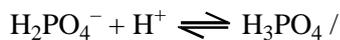
(or equivalent with  $\text{H}_2\text{O}$  forming  $\text{H}_3\text{O}^+$ ) 1



(iii)  $\text{H}_2\text{PO}_4^-$  produced  $\text{Ca}(\text{H}_2\text{PO}_4)_2$  or on LHS of an attempted equilibrium equation (1)

2 equations/equilibria to shown action of buffer (1)(1)

from:



[7]



[3]

14. (a) partial dissociation:  $\text{HCOOH} \rightleftharpoons \text{H}^+ + \text{HCOO}^-$  (1) 1
- (b) (i)  $\text{pH} = -\log(1.55 \times 10^{-3}) = 2.81/2.8$  (1)  
 $[\text{H}^+]$  deals with negative indices over a very wide range/  
 pH makes numbers manageable  
 /removes very small numbers (1) 2
- (ii)  $K_a = \frac{[\text{H}^+(\text{aq})][\text{HCOO}^-(\text{aq})]}{[\text{HCOOH}(\text{aq})]}$  (1) (state symbols not needed) 1
- (iii)  $K_a = \frac{[\text{H}^+(\text{aq})]^2}{[\text{HCOOH}(\text{aq})]} = \frac{(1.55 \times 10^{-3})^2}{0.015}$  (1)  
 $= 1.60 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}(1)$   
 $\text{p}K_a = -\log K_a = -\log(1.60 \times 10^{-4}) = 3.80$  (1) 3
- (iv) Percentage dissociating =  $\frac{(1.55 \times 10^{-3}) \times 100}{0.015} = 10.3\%$  /  
 10% (1) 1  
*(working not required)*

[8]

15. (i)  $\text{HCOOH} + \text{NaOH} \rightarrow \text{HCOONa} + \text{H}_2\text{O}$  (1) 1  
*state symbols not needed*
- (ii)  $n(\text{HCOOH}) = 0.0150 \times 25.00/1000 = 3.75 \times 10^{-4}$  (1)  
 volume of  $\text{NaOH}(\text{aq})$  that reacts is  $30 \text{ cm}^3$  (1)  
 so  $[\text{NaOH}] = 3.75 \times 10^{-4} \times 1000/30 = 0.0125 \text{ mol dm}^{-3}$  (1) 2
- (iii)  $K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$  (1)  
 $\text{pH} = -\log(1 \times 10^{-14}/0.0125) = 12.10/12.1$  (1)  
 (calc 12.09691001) 3
- (iv) metacresol purple (1)  
 pH range coincides with pH change **during sharp rise** OR  
 pH 6-10 /coincides with equivalence point/end point (1) 2

[8]

16. (a)  $K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$  (1) 1

- (b) (i) 

$\text{H}_2$	$\text{I}_2$	$\text{HI}$
0.30	0.20	0

$$\begin{array}{ccc} 0.14 & 0.04 & 0.32 \\ & \text{(1)} & \text{(1)} \end{array} \quad 2$$

(ii)  $K_c = \frac{0.32^2}{0.14 \times 0.04} = 18.28571429$  (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]

17. (i)  $I_2(aq) + H_2S(g) \rightarrow 2HI(aq) + S(s)$   
 species and balance (1)  
 state symbols: accept (s) for  $I_2$ ; (aq) for  $H_2S$  (1) 2

(ii) amount  $I_2$  reacted = 1.89 mol / HI formed = 3.44 mol (1)  
 theoretical amount HI produced = 3.78 mol/484 g (1)  
 $\% \text{ yield} = \frac{3.44 \times 100}{3.78}$  or  $\frac{440 \times 100}{484} = 91.0 \%$  (1) 3

(iii)  $[HI] = \frac{3.44 \times 1000}{750} = 4.58/4.59 \text{ mol dm}^{-3}$  (1)  
 $\text{pH} = -\log 4.59 = -0.66$  (1) 2

[7]

18. From graph, constant half-life (1)  
 Therefore 1<sup>st</sup> order w.r.t.  $[CH_3COCH_3]$  (1) 2

From table, rate doubles when  $[H^+]$  doubles (1)  
 Therefore 1<sup>st</sup> 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)

$$k = \frac{\text{rate}}{[H^+][CH_3COCH_3]} = \frac{2.1 \times 10^{-9}}{0.02 \times 1.5 \times 10^{-3}} \text{ (1)}$$

$$= 7.0 \times 10^{-5} \text{ (1) dm}^3 \text{ mol}^{-1} \text{ s}^{-1} \text{ (1)} \quad 4$$

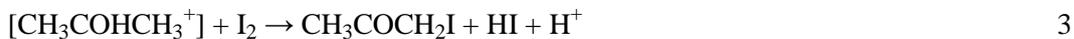
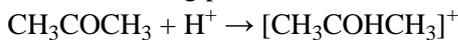
*accept  $7 \times 10^{-5}$*

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:



organises relevant information clearly and coherently,

using specialist vocabulary where appropriate

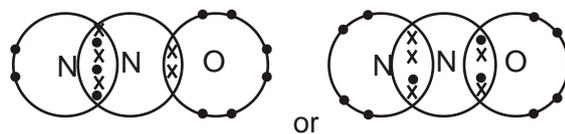
Use of the following four words/phrases:

constant, half-life, order, doubles/x2 (1) 1

[14]

19. (a) (i) (+)1 (1) 1

(ii)



Look for atoms bonded together.  
AND other lone pairs. 1

(b) (i)  $\text{C}_{13}\text{H}_{18}\text{O}_2$  (1)

(ii) any chemical that reacts to produce gas:  
e.g. carbonate and  $\text{CO}_2$  (1)

*accept: metal more reactive than Pb and  $\text{H}_2$*

balanced equation to match chemical added (1) 3

(c)  $M_r(\text{Lidocaine}) = 236$  (1)

Moles Novocaine =  $100 \times 10^{-3} / 236 = 4.24 \times 10^{-4}$  (1)

Concentration of Novocaine =  $4.24 \times 10^{-4} \times (1000/5)$   
=  $0.0847/0.0848/0.085 \text{ mol dm}^{-3}$  (1) 3

- (d) mass C =  $12 \times \frac{3.74}{44.0} = 1.02 \text{ g}$  /  
 moles CO<sub>2</sub> =  $\frac{3.74}{44} = 0.085 \text{ mol}$  (1)  
 mass H =  $\frac{2}{18} \times 0.918 = 0.102 \text{ g}$  /  
 moles H<sub>2</sub>O =  $\frac{0.918}{18} = 0.051 \text{ mol}$  (1) 2  
 ratio C : H =  $\frac{1.02}{12} : \frac{0.102}{1} = 0.0850 : 0.102 = 5 : 6 / 10 : 12 /$   
 ratio CO<sub>2</sub> : H<sub>2</sub>O = 5 : 3 / 10 : 6 (1)  
 mass O = 1.394 – (1.020 + 0.102) = 0.272 g  
 / using 1.394 g eugenol and M<sub>r</sub> = 164, shows that 1  
 molecule contains 2 atoms of O (1) 2  
 ∴ molecular formula = C<sub>10</sub>H<sub>12</sub>O<sub>2</sub> (1) 1

[13]

20. (a) (change in) concentration/mass/volume with time 1

- (b) (i) O<sub>2</sub>:  
 Exp 2 has 4 × [O<sub>2</sub>] as Exp. 1: rate increases by 4 (1),  
 so order = 1 with respect to O<sub>2</sub> (1)  
 NO:  
 Exp 3 has 3 × [NO] as Exp. 3: rate has increases by 9 (1),  
 so order = 2 with respect to NO (1) 4

- (ii) rate =  $k[\text{O}_2][\text{NO}]^2$  (1) 1

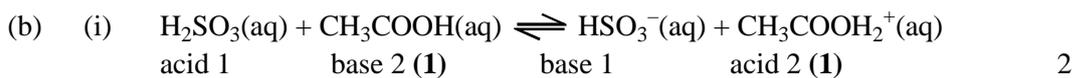
- (iii)  $k = \frac{\text{rate}}{[\text{O}_2][\text{NO}]^2} = \frac{7.10}{0.0010 \times 0.0010^2} = 7.10 \times 10^9$  (1)  
 units: dm<sup>6</sup> mol<sup>-2</sup> s<sup>-1</sup> (1) 2

[8]

21. (i) The slowest step (1) 1  
 (ii) 2NO<sub>2</sub> → NO + NO<sub>3</sub> (1)  
 NO<sub>3</sub> + CO → NO<sub>2</sub> + CO<sub>2</sub> (1) 2  
 (or similar stage involving intermediates)

[3]

22. (a) strength of acid/extent of dissociation/ionisation (1) 1



*1 mark for labels on each side of equation*

- (ii)  $\text{CH}_3\text{COOH}$  is the stronger acid/  
 $K_a$   $\text{CH}_3\text{COOH}$  is greater/  
 $\text{CH}_3\text{COOH}$  is more acidic ORA (1)



- (c) For  $\text{HCl}$ ,  $\text{pH} = -\log[\text{H}^+]$  (1) (or with values).  
 Could be awarded below  
 $= -\log 0.045 = 1.35$  (1) (accept 1.3)

For  $\text{CH}_3\text{COOH}$ ,  $[\text{H}^+] = \sqrt{(K_a \times [\text{CH}_3\text{COOH}]}$  /

$\sqrt{(1.70 \times 10^{-5} \times 0.045)}$  (1)

$[\text{H}^+] = 8.75 \times 10^{-4} \text{ mol dm}^{-3}$  (1)

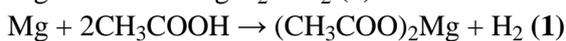
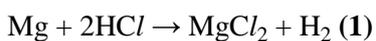
$\text{pH} = -\log 8.75 \times 10^{-4} = 3.058/3.06$  (1) (accept 3.1) 5

[10]

23.  $\text{HCl}$  and  $\text{CH}_3\text{COOH}$  have same number of moles/  
 release same number of moles  $\text{H}^+$  /  
 1 mole of each acid produce  $\frac{1}{2}$  mol of  $\text{H}_2$  (1)

$[\text{H}^+]$  in  $\text{CH}_3\text{COOH} < [\text{H}^+]$  in  $\text{HCl}$  /

$\text{CH}_3\text{COOH}$  is a weaker acid than  $\text{HCl}$  (ora) (1)



or



[4]

24. amount of NaOH in titration =  $0.175 \times 22.05/1000$   
 or  $3.86 \times 10^{-3}$  (1) (calc:  $3.85875 \times 10^{-3}$ )  
 amount of A in  $25.0 \text{ cm}^3 = 0.5 \times \text{mol NaOH}$   
 or  $1.93 \times 10^{-3}$  (1) (calc:  $1.929375 \times 10^{-3}$ )  
 amount of A in  $250 \text{ cm}^3 = 10 \times 1.93 \times 10^{-3}$  or  $1.93 \times 10^{-2}$  (1)  
 $1.93 \times 10^{-2}$  mol A has a mass of 2.82 g  
 molar mass of A =  $2.82/1.93 \times 10^{-2} = 146 \text{ g mol}^{-1}$  (1)  
 (or  $M_r$  of A is 146)  
 Therefore A is adipic acid /  $\text{HOOC}(\text{CH}_2)_4\text{COOH}$  (1) 5

[5]

25. (a)  $K_p = \frac{p(\text{SO}_3)^2}{p(\text{SO}_2)^2 \times p(\text{O}_2)}$  (1)(1)  
 1 mark for correct powers but wrong way up.  
 1 mark for square brackets 2
- (b) An increase in pressure moves equilibrium to the right because there are less gaseous moles on the right hand side (1)  
 Increased pressures are expensive to generate/safety problems with walls of containers/enables gases to flow (1)  
 $K_p$  gets less with increasing temperature (1)  
 $\text{SO}_2$  and  $\text{O}_2$  increase/ $\text{SO}_3$  decreases (1)  
 Equilibrium  $\rightarrow$  left to oppose increase in temperature (1)  
 Forward reaction is exothermic or  $\Delta H$  is -ve /reverse reaction is endothermic or  $\Delta H$  is +ve because  $K_p$  gets less with increasing temperature (1) 6
- QoWC: organises relevant information clearly and coherently, using specialist vocabulary where appropriate (1) 1
- (c)  $3.0 \times 10^2 = \frac{p(\text{SO}_3)^2}{10^2 \times 50}$  (1)  
 $p(\text{SO}_3) = \sqrt{(3.0 \times 10^2 \times 10^2 \times 50)} = 1225 \text{ kPa}$  (1)  
 $\%(\text{SO}_3) = 100 \times 1225 / (1225 + 10 + 50) = 95\%$  (1) 3

- (d) (i)  $2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$  (1)(1)  
 ZnS, O<sub>2</sub> as reactants **and** SO<sub>2</sub> as a product: 1st mark.  
 ZnO **and** balance: 2<sup>nd</sup> mark 2
- (ii) ZnS is more available than S. (1) 1

[15]

26. (a) (i) O<sub>3</sub>: 1  
 and C<sub>2</sub>H<sub>4</sub> (1) 1
- (ii) 2 (1) 1
- (iii) rate = k[O<sub>3</sub>] [C<sub>2</sub>H<sub>4</sub>] (1) 1

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

(ii)  $k = \frac{\text{rate}}{[\text{O}_2][\text{C}_2\text{H}_4]}$  (1)

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

- (iii) 2 mol CH<sub>2</sub>O forms for every 0.5 mol O<sub>2</sub> /  
 stoichiometry of CH<sub>2</sub>O : O<sub>2</sub> is **not** 1:1 (1) 1

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

[11]

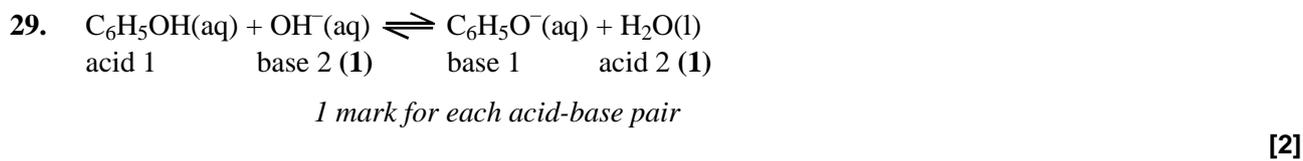
27. (i) each atom has two unpaired electrons (1) 1

- (ii) 2 oxygen atoms bonded by double bond (1)  
 third oxygen bonded by a covalent bond and outer shells correct (1)  
 For 2<sup>nd</sup> mark, all O atoms must have an octet.  
 A triangular molecule would have 3 single covalent bonds  
 for 1<sup>st</sup> mark but the origin of each electron must be clear for 2<sup>nd</sup> mark 2

- (iii) amount of O<sub>3</sub> in 150 kg =  $150 \times 10^3 / 48 = 3.13 \times 10^3$  mol (1)  
 amount of Cl radicals in 1 g =  $1 / 35.5 = 2.82 \times 10^{-2}$  mol (1)  
 1 mol Cl destroys  $3.13 \times 10^3 / 2.82 \times 10^{-2} = 1.11 \times 10^5$  mol O<sub>3</sub>  
 1 Cl radical destroys  $1.11 \times 10^5$  O<sub>3</sub> molecules (1)  
 (calculator: 110937) 3

[6]

28. (i) proton donor (1) 1  
 (ii) partially dissociates (1) 1  
 [2]



30. (i)  $K_a = \frac{[\text{C}_6\text{H}_5\text{O}^-][\text{H}^+]}{[\text{C}_6\text{H}_5\text{OH}]} \quad (1)$  1

(ii) concentration =  $38/94 \quad (1) = 0.40 \text{ mol dm}^{-3} \quad (1)$

*(first mark for  $M_r$  of phenol – incorrect answer here will give ecf for remainder of question)*

$$1.3 \times 10^{-10} \approx \frac{[\text{H}^+(\text{aq})]^2}{0.40} \quad (1)$$

*(‘=’ sign is acceptable)*

$$[\text{H}^+] = \sqrt{\{(1.3 \times 10^{-10}) \times (0.40)\}} = 7.2 \times 10^{-6} \text{ mol dm}^{-3} \quad (1)$$

$$\text{pH} = -\log[\text{H}^+] = -\log 7.2 \times 10^{-6} = 5.14 \quad (1) \quad 5$$

**3 marks:**  $[\text{H}^+] \quad (1)$ ; pH expression  $(1)$ ; calc of pH from  $[\text{H}^+] \quad (1)$

**Common errors:**

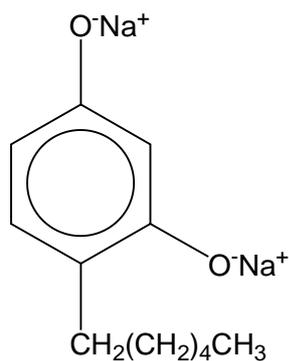
Without square root, answer = 10.28  $(1)(1)(0)$

Use of 38 as molar concentration does not score 1<sup>st</sup> 2 marks.

This gives an answer of 4.15 for 3 marks  $(1)(1)(1)$

[6]

31.



/ NaOH / Na (1)

weak acid/base pair mixture formed (1)

2

*On structure, 1 mark for O Na on either or both phenol groups.*

[2]

32. moles HCl in 23.2 cm<sup>3</sup> = 0.200 × 23.2/1000 = 4.64 × 10<sup>-3</sup> (1)moles B in 25 cm<sup>3</sup> = moles HCl = 4.64 × 10<sup>-3</sup> (1)moles B in 250 cm<sup>3</sup> = 4.64 × 10<sup>-3</sup> × 10 = 4.64 × 10<sup>-2</sup> (1)4.64 × 10<sup>-2</sup> mol B has a mass of 4.32 gmolar mass of B = 4.32/4.64 × 10<sup>-2</sup> = 93 g mol<sup>-1</sup> (1)

93 - 16 = 77 (1)

Therefore B is phenylamine / C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub> (1)

6

*There may be other valid structures that are amines. These can be credited provided that everything adds up to 93.**Answer could be a primary, secondary or tertiary amines.*

[6]

33. (a) (i) constant half-life (1)

1

(ii) rate = k[N<sub>2</sub>O<sub>5</sub>] (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) × 10<sup>-4</sup> (1) mol dm<sup>-3</sup> s<sup>-1</sup> (1)ecf possible from (ii) using [N<sub>2</sub>O<sub>5</sub>]<sup>x</sup>(2<sup>nd</sup> order answer: 2.2(3) × 10<sup>-4</sup>)

2

[7]

34. (i) slow step (1)

1

- (ii)  $(\text{CH}_3)_2\text{C}=\text{CH}_2 + \text{H}_2\text{O} \rightarrow (\text{CH}_3)_3\text{COH}$  (1) 1
- (iii)  $\text{H}^+$  is a catalyst (1)  
 $\text{H}^+$  used in first step **and** formed in second step/  
 regenerated/ not used up (1) 2
- (iv) rate =  $k [(\text{CH}_3)_2\text{C}=\text{CH}_2] [\text{H}^+]$  (1)  
 common error will be use of  $\text{H}_2\text{O}$  instead of  $\text{H}^+$  1

[5]

35. (a) **High Pressure**  
 Equilibrium  $\rightarrow$  right as fewer moles on right hand side  
 and the shift reduces number of molecules/compensates  
 for increasing pressure (1)  
 Rate increases/ more collisions (1) 2
- High temperature**  
 Equilibrium  $\rightarrow$  left as equilibrium goes to the left to  
 compensate for increased temperature/absorbs the  
 energy/in endothermic direction (ora) (1)  
 Rate increases/ more successful collisions (1) 2
- Other effect**  
 High pressures expensive/ high temperatures expensive  
 /high pressures cause safety problems (1) 1
- QWC: One correct statement followed by correct explanation (1) 1
- (b) (i)
- |                              |                          |                        |     |
|------------------------------|--------------------------|------------------------|-----|
| CO                           | $\text{H}_2$             | $\text{CH}_3\text{OH}$ |     |
| 1.0                          | 2.0                      | 0.0                    |     |
| 0.9                          | 1.8 (1)                  | 0.1 (1)                |     |
| 0.9/2.8 or 0.321 or 0.32/0.3 |                          | 1.8/2.8 or 0.643 or    |     |
| 0.64/0.6                     | 0.1/2.8 or 0.036 or 0.04 |                        | (1) |
| 3.21 (MPa)                   | 6.43 (MPa)               | 0.36 (MPa)             | (1) |
- In 3<sup>rd</sup> and 4<sup>th</sup> rows, ecf from previous row 4
- (ii)  $K_p = \frac{p(\text{CH}_3\text{OH})}{p(\text{CO}) \times p(\text{H}_2)^2}$  (1)(1)  
 1 mark for  $K_c$  / use of any [ ] /inverted/power missing. 2
- (iii)  $K_p$  stays the same (1)  
 Equilibrium position moves to the right/yield increases (1)  
 in response to increase in reactants (1)  

$$K_p = \frac{0.261}{3.70 \times 5.10^2} = 2.71 \times 10^{-3}$$
 (1)  $\text{MPa}^{-2}$  (1) 3
- (iv) calc value  $2.7120546 \times 10^{-3}$ ; answer and/or units ecf from (ii) 2
- (c)  $\text{CH}_3\text{OH} + 1.5\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$  (1) 1

[18]

36. (i) completely dissociates/ionised (1)  
proton donor (1) 2
- (ii)  $\text{NO}_3^-$  (1) 1 [3]
37. (i)  $\text{pH} = -\log[\text{H}^+] / -\log(0.015)$  (1) = 1.82 / 1.8 (1) (Not 2) 2
- (ii)  $[\text{H}^+] = 0.0075 \text{ mol dm}^{-3}$   
 $\text{pH} = -\log(0.0075) = 2.12 / 2.1$  (1) 1 [3]
38. (i)  $K_w = [\text{H}^+(\text{aq})] [\text{OH}^-(\text{aq})]$  (1) 1  
*state symbols not needed*
- (ii)  $[\text{H}^+(\text{aq})] = 10^{-\text{pH}} = 10^{-13.54} = 2.88/2.9 \times 10^{-14} \text{ mol dm}^{-3}$  (1)  
 $[\text{NaOH}] / [\text{OH}^-(\text{aq})] = \frac{K_w}{[\text{H}^+(\text{aq})]} = \frac{1.0 \times 10^{-14}}{2.88 \times 10^{-14}}$   
 $= 0.347 / 0.35 \text{ mol dm}^{-3}$  (1) 2 [3]
39. (i) a solution that minimises/resists/opposes pH changes (1) 1
- (ii) The buffer must contain both  $\text{CH}_3\text{COOH}$  and  $\text{CH}_3\text{COONa}$  /  
 $\text{CH}_3\text{COO}^-$  /weak acid and conjugate base(\*) (1)  
Solution A is a mixture of  $\text{CH}_3\text{COOH}$ (\*) and  $\text{CH}_3\text{COONa}$ (\*) /  
/ has an excess of acid /is acidic (1)  
Solution B, contains only  $\text{CH}_3\text{COONa}$ / only  $\text{CH}_3\text{COO}^-$   
/only the salt/ is neutral (1)  
 $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$  /  
acid/alkali has been neutralised/  
 $\text{CH}_3\text{COOH}(\text{aq})$  and  $\text{NaOH}$  react together (1) 4 [5]

40.  $[\text{H}^+]$  increases (1)  
 $\text{H}_2\text{O}$  ionises more /  
for  $\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$ , equilibrium moves to the right (1)

2

*exo/endo is 'noise'*

[2]