

**Q1.**

- 2 (a) (i)  $K_{sp} = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$  [1] units:  $\text{mol}^2\text{dm}^{-6}$  [1] ecf
- (ii)  $[\text{Ba}^{2+}] = \sqrt{(1.3 \times 10^{-10})} = 1.14 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$  [1]
- (iii)  $\text{BaCO}_3$  can react with/dissolve in the acid/HCl in the stomach [1]  
 (or unbalanced equation showing, e.g.  $\text{BaCO}_3 + \text{HCl} \rightarrow$ )

4

- (b) (i)  $K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$  [1] units:  $\text{mol}^3\text{dm}^{-9}$  [1] ecf
- (ii) calling  $[\text{Mg}^{2+}] = x$ , then  $K_{sp} = x(2x)^2 = 4x^3 \Rightarrow x = \sqrt[3]{(K_{sp}/4)}$  [1]  
 $\therefore [\text{Mg}^{2+}] = \sqrt[3]{(2 \times 10^{-11}/4)} = 1.7 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$  [1]  
 allow ecf for use of  $\sqrt[3]{}$
- (iii) % left =  $100 \times (1.7 \times 10^{-4})/(0.054) = 0.32\%$   
 $\therefore$  % extracted = **99.7** (%) [1]

5

- (c) (i)  $\Delta H_r = \Delta H_f^\circ(\text{Mg}^{2+}) + 2\Delta H_f^\circ(\text{Cl}^-) - \Delta H_f^\circ(\text{MgCl}_2)$   
 $= -467 + 2(-167) - (-641)$   
 $= -160 \text{ (kJ mol}^{-1}\text{)}$  [1]
- (ii) highly exothermic enthalpy change of solution  
 or  $\Delta H_{sol}$  is very negative [1]

2

- (d) mention of hydration enthalpy and lattice enthalpy [1]  
 hydration enthalpy decreases more than does lattice enthalpy  
 or  
 enthalpy change of solution or  $\Delta H_{sol}$  becomes  
 less negative/more positive [1]

2

**Total: 13, max 12**

**Q2.**

5 (a)  $K_a = \frac{[\text{RCO}_2^-][\text{H}^+]}{[\text{RCO}_2\text{H}]}$  [1]

Part (a): [1]

(b) (i) The more chlorine atoms in the molecule, the stronger the acid, [1]

due to the electron-withdrawing (inductive) effect of Cl... [1]

**either**...stabilising the anion, **or** spreading (-) charge more,  
**or**...weakening the O-H bond in the acid, **or**...increasing ionisation,  
**or**...facilitates  $\text{H}^+$  donation

**or**...causing the equilibrium  $\text{RCO}_2\text{H} = \text{RCO}_2^- + \text{H}^+$  to lie further to the right.

Mark is conditional on reference to the effect of presence of chlorine. [1]

(ii)  $[\text{H}^+] = \sqrt{(0.1 \times 1.4 \times 10^{-3})} = 0.0118 \text{ (mol dm}^{-3}\text{)}$  allow 0.012 [1]

$\therefore \text{pH} = -\log_{10}(0.0118) = 1.93$  Allow 1.9 or 1.92 e.c.f. [1]

(iii)  $\text{p}K_a = -\log_{10}(5.5 \times 10^{-2}) = 1.26$  Allow 1.3 [1]

Part (b): [6]

### Q3.

2 (a) (i)  $K_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}]$  [1]

units are:  $\text{mol}^2\text{dm}^{-6}$  ecf [1]

(ii)  $[\text{CaSO}_4] = \sqrt{K_{sp}} = 5.5 \times 10^{-3} \text{ (5.477} \times 10^{-3}\text{)} \text{ (mol dm}^{-3}\text{)}$  ecf [1]

(iii)  $n(\text{CaSO}_4) \text{ in } 100 \text{ dm}^3 = 5.5 \times 10^{-3} \times 100 = 0.55 \text{ moles}$  ecf from (ii) [1]

$M_r(\text{CaSO}_4) = 136.1$

Thus  $\text{mass}(\text{CaSO}_4) = 0.55 \times 136.1 = 74.8 \text{ g}$  (0.55  $\times M_r$ ) [1]  
(if the accurate  $[\text{CaSO}_4]$  is held throughout the calculation, ans = 74.5g)

[5]

(b) (i) down the group: the  $\Delta H_{\text{solution}}$  becomes more endothermic;  
**both** lattice energy **and**  $\Delta H_{\text{hydration}}$  become less (exothermic);  
due to **ionic** radius (of  $\text{M}^{2+}$ ) increasing;  
but  $\Delta H_{\text{hydration}}$  changes more than lattice energy *any three points* [3]

(ii)  $K_{sp} = [\text{Ba}^{2+}][\text{SO}_4^{2-}] = (9 \times 10^{-6})^2 = 8.1 \times 10^{-11}$  **NO** ecf [1]

[4]

(c) (i) LE is the energy change when **1 mole** of (ionic) solid [1]

is formed from its **gaseous ions** [1]

(ii)  $\text{LE}(\text{BaSO}_4) < \text{LE}(\text{MgSO}_4)$ , due to larger radius of  $\text{Ba}^{2+}$  both points [1]

[3]

[Total: 12]

## Q4.

- 2 (a) (i)  $\Delta H = 4 \times 278 - 244 - 2 \times 496$  [1]  
 $= -124 \text{ (kJ mol}^{-1}\text{)}$  [1]  
 (correct ans [2])
- (ii) shape is bent/V-shaped/non-linear (or diagram) [1]  
 due to (one) lone pair and/or (1) odd/unpaired electron (or shown on diag) [1]  
 (assume electrons are on chlorine unless explicitly stated otherwise, in which case award no mark)
- (iii)  $3\text{KClO}_3 + \text{H}_2\text{SO}_4 \longrightarrow \text{K}_2\text{SO}_4 + \text{KClO}_4 + \text{H}_2\text{O} + 2\text{ClO}_2$  [1] [5]
- (b) (i) coal-fired power stations; fuel in cars; car exhausts/gas emissions; other named use of a fossil fuel; contact process; cement manufacture; brick manufacture; roasting of sulphide ores; burning tyres (any 2) [1]  
 (NOT volcanoes etc; NOT burning of natural gas)  
 (no marks for only 1 correct source)
- (ii) causes acid rain [1]  
 which lower pH of lakes; leaches aluminium from soils; kills fish/plants/rainforests; dissolves/corrodes/damages buildings (any 1) [1]  
 (NOT asthma etc – since this is not environmental) [3]
- (c) (i)  $\text{CO}_2$ : simple + molecular/covalent or weak intermolecular forces  
 $\text{SiO}_2$ : giant/macro + molecular/covalent  
 $\text{SnO}_2$ : ionic/electrovalent (ignore "giant") (all 3 correct) [2]  
 (2 correct = [1], 1 correct = [0])
- (ii)  $\text{SnO}_2$  is stable,  $\text{PbO}_2$  is not or  $\text{SnO}_2$  is the more stable [1]  
 $\text{PbO}_2 \longrightarrow \text{PbO} + \frac{1}{2} \text{O}_2$  [1]
- (iii)  $\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$  [1]  
 $K_c = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{O}][\text{CO}_2]}$  or  $[\text{H}^+][\text{HCO}_3^-]/[\text{CO}_2]$  ecf [1]
- (iv)  $\text{HCO}_3^- + \text{H}^+ \longrightarrow \text{H}_2\text{CO}_3$  or  $\text{H}_2\text{O} + \text{CO}_2$  (or equation with  $\text{H}_3\text{O}^+$ ) [1]  
 $\text{HCO}_3^- + \text{OH}^- \longrightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$  (NB NOT  $\text{H}_2\text{CO}_3 + \text{OH}^- \rightarrow$ ) [1]
- (words can substitute for one of the equations but not both. If two correct word descriptions are given, in the absence of at least one correct equation, award [1] mark only) [8]

[Total: 16 max 15]

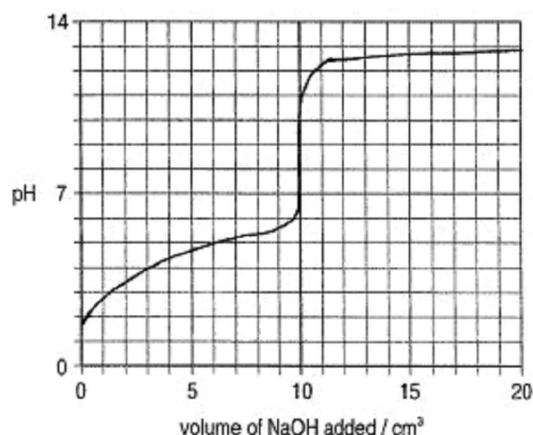
## Q5.

- 1 (a) acids are proton/ $H^+$  donors [1]  
 bases are proton/ $H^+$  acceptors [1] [2]

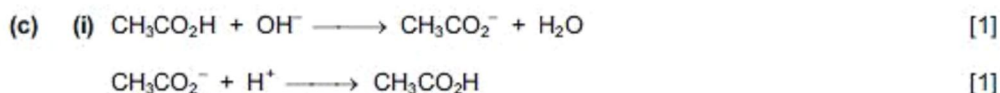
- (b) (i) more *Cl* atoms produce a **stronger acid** or the larger the  $K_a$  the **stronger the acid** [1]  
 (NOT just "the more *Cl* atoms, the larger the  $K_a$ " – must refer to acid strength) [1]  
 because the anion/ $RCO_2^-$  is more stable or the O-H bond is weaker/polarised [1]  
 due to the electronegativity/electron-withdrawing effect of *Cl* [1]

- (ii)  $[H^+] = \sqrt{K_a \cdot c} = 0.0114 \text{ (mol dm}^{-3}\text{)}$  [1]  
 pH = **1.94** (allow 1.9) ecf from  $[H^+]$  [1]  
 (correct answer = [2])

(iii)



- start at pH = 1.94 (ecf from (ii) and goes up > 2 pH units before steep portion) [1]  
 steep portion (over at least 3 pH units) at  $V = 10 \text{ cm}^3$  [1]  
 flattens off at pH 12–13 [1] [8]



- (ii)  $pK_a = -\log_{10}(1.7 \times 10^{-5}) = 4.77$  or  $[H^+] = 8.5 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$  [1]  
 pH =  $pK_a + \log_{10}(0.2/0.1) = 5.07$  (allow 5.1) [1]  
 (correct answer = [2]) [4]

[Total: 14]

Q6.

- 2 (a) (i) One that can go in either direction. [1]
- (ii) both forward & reverse reactions are going on at the same time, but the concentrations of all species do not change (owtte) or rate of forward = rate of backward reaction [1]
- (b) (i)  $K_c = \frac{[H^+][OH^-]}{[H_2O]}$  [1]
- (ii)  $K_w = [H^+][OH^-]$  [1]  
 rearrangement of equation in (i) gives  $K_c[H_2O] = [H^+][OH^-]$  &  $K_w = K_c[H_2O]$  (owtte) or the  $[H_2O]$  is contained within  $K_w$  [1]
- (iii)  $K_w$  will be higher in hot water **because** reaction is endothermic [1]
- (c) (i)  $[OH^-] = 5 \times 10^{-2}$ ;  $[H^+] = (1 \times 10^{-14}) / 5 \times 10^{-2} = 2 \times 10^{-13}$  [1]  
 $pH = -\log_{10}[H^+] = 12.7$  (correct ans = [2]) ecf [1]
- (ii)  $[NH_4^+] = [OH^-] (= x)$  [1]  
 $x^2 = 1.8 \times 10^{-6} \times 0.05 \Rightarrow x (= [OH^-]) = 9.49 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$  (correct ans = [2]) [1]
- (iii)  $[H^+] = K_w / [OH^-] = (1 \times 10^{-14}) / 9.49 \times 10^{-4} = 1.05 \times 10^{-11} \text{ (mol dm}^{-3}\text{)}$  ecf [1]
- (iv)  $pH = 11.0$  ecf [1]

[Total: 12 max 11]

## Q7.

- 1 (a)  $[H^+] = \sqrt{(0.05 \times 5.6 \times 10^{-4})} = 5.29 \times 10^{-3} \text{ mol dm}^{-3}$  [1]  
 $pH = -\log_{10}(5.29 \times 10^{-3}) = 2.3$  [1]  
 [2]
- (b) (i) (Brønsted-Lowry) acid-base/proton transfer/neutralisation/exothermic/reversible/equilibrium [1]
- (ii)
- $$\begin{array}{c} \text{H} \text{ : } \text{N} \text{ : } \text{H} \\ \text{..} \\ \text{..} \\ \text{H} \end{array}$$

[1]

$$\text{H} \text{ : } \text{F} \text{ :}$$

[1]

$$\left[ \begin{array}{c} \text{H} \text{ : } \text{N} \text{ : } \text{H} \\ \text{..} \\ \text{..} \\ \text{H} \end{array} \right]^{\oplus} \left[ \text{: } \text{F} \text{ :} \right]^{\ominus}$$

[1]

3 x [1]
- (iii) (in  $NH_4F$ ):  
 covalent: between N & H [1]  
 dative: between N & H [1]  
 ionic: between  $NH_4^+$  &  $F^-$  or  $N^+$  &  $F^-$  or ammonium and fluoride (i.e. in words) or between (oppositely charge) ions [1]
- (iv) (**reverse** reaction, remember)  
 high temperature, because reverse reaction is endothermic [1]  
 low pressure, because reverse reaction causes an increase in no. of gaseous molecules or an increase in partial pressure/volume. [1]  
 [9]

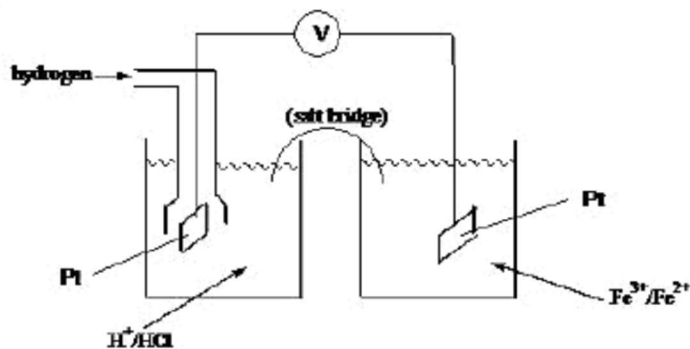
- (c) (i)  $4\text{NH}_3 + \text{CuS} + 2\text{O}_2 \rightarrow [\text{Cu}(\text{NH}_3)_4]\text{SO}_4$  [1]
- (ii) deep/dark/royal blue or purple [NOT violet] [1]
- (iii) deep blue colour would change to light blue [NOT intensity of colour decreases] [1]  
 $\Rightarrow$  hexaquocopper(II) ion or  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  or  $[\text{Cu}(\text{H}_2\text{O})_n(\text{NH}_3)_{6-n}]^{2+}$ , where a = 4 or 6  
 or ligand exchange (of  $\text{NH}_3$ ) by  $\text{H}_2\text{O}$  [1]  
**[4]**
- (d) ligand exchange/substitution/displacement/replacement [IN WORDS] [1]  
 (use of named ligands are OK instead of 'ligand'. e.g. "water is displaced by chloride")
- formula of anion (see below for possibilities) [1]  
 balanced equation. e.g.  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + n\text{Cl}^- \rightarrow [\text{Cu}(\text{H}_2\text{O})_{6-n}\text{Cl}_n]^{2-n} + n\text{H}_2\text{O}$  [1]
- (Allow  $n=1$  up to  $n=6$ . Also allow  $[\text{CuCl}_n]^{2-n}$  as product. Examples from many possible are:  
 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{Cl}^- \rightarrow [\text{Cu}(\text{H}_2\text{O})_4\text{Cl}_2] + 2\text{H}_2\text{O}$   
 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$   
 equation could include  $\text{HCl}$  on the LHS, for example:  
 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow \text{H}_2\text{CuCl}_4 + 2\text{H}^+ + 6\text{H}_2\text{O}$  or  $\rightarrow \text{CuCl}_4^{2-} + 4\text{H}^+ + 6\text{H}_2\text{O}$  [3])

**[Total: 18 max 17]**

## Q8.

- 1 (a) The potential of an **electrode** compared to that of a standard hydrogen electrode (SHE)  
 or  
 the EMF of a **cell** composed of the test electrode and the SHE [1]  
 all measurement concentrations of  $1 \text{ mol dm}^{-3}$  and  $298\text{K}$  /  $1 \text{ atm}$  pressure [1]  
**[2]**

(b)



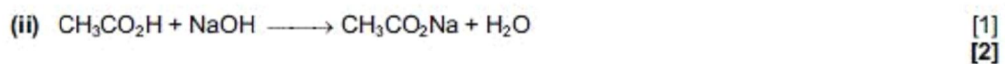
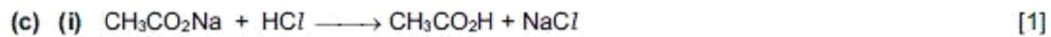
- $\text{H}_2$  and good delivery system [1]  
 $\text{Fe}^{2+}/\text{Fe}^{3+}$  solution labelled [1]  
 platinum electrodes (both) [1]  
 salt bridge and voltmeter [1]  
 $\text{H}^+$  or  $\text{HCl}$  or  $\text{H}_2\text{SO}_4$  [1]  
 (acid is not sufficient)  
**[5]**

- (c) (i)  $E^{\ominus} = 0.77 - 0.54 = 0.23$  (V) [1]
- (ii) Since  $E^{\ominus}$  is positive/  $E^{\ominus} > 0$
- So more products / the equilibrium will be over to the right / forward reaction is favoured  
ecf from (c)(i) [1]
- (iii)  $K_c = [\text{Fe}^{2+}]^2[\text{I}_2]/[\text{Fe}^{3+}]^2[\text{I}^-]^2$  [1]
- units are  $\text{mol}^{-1} \text{dm}^3$  ecf on expression [1]
- (iv) ( $[\text{Fe}^{2+}]$  must always be twice  $[\text{I}_2]$ , so  $[\text{Fe}^{2+}] = 0.02$  ( $\text{mol dm}^{-3}$ ) [1]
- ( $[\text{I}^-]$  must always be equal to  $[\text{Fe}^{3+}]$ , so  $[\text{I}^-] = 2 \times 10^{-4}$  ( $\text{mol dm}^{-3}$ ) [1]
- (v)  $K_c = \{(0.02)^2 \times 0.01\} / \{(2 \times 10^{-4})^2 \times (2 \times 10^{-4})^2\}$  correct expression [1]  
(allow ecf from incorrect expression in (c)(iii))  
(allow ecf from (c)(iv))  
 $= (4 \times 10^{-6}) / (1.6 \times 10^{-15}) = 2.5 \times 10^9$  ( $\text{mol}^{-1} \text{dm}^3$ ) [1]

[Total: 15]

## Q9.

- (b) there are two ways of calculating the ratio:
- $\text{p}K_a = -\log_{10}(K_a) = -\log_{10}(1.79 \times 10^{-5}) = 4.747$  (4.75) or  $[\text{H}^+] = 10^{-5.5} = 3.16 \times 10^{-6}$  [1]
- $\log_{10}([\text{B}] / [\text{A}]) = \text{pH} - \text{p}K_a = 0.753$  (0.75) or  $[\text{salt}] / [\text{acid}] = K_a / [\text{H}^+]$  [1]
- $\therefore [\text{B}] / [\text{A}] = 10^{0.753} = 5.66$   
or  $= 1.79 \times 10^{-5} / 3.16 \times 10^{-6} = 5.66$   
(or  $[\text{A}] / [\text{B}] = 0.177$ ) [1]
- (correct ratio = [3] marks)
- since  $\text{B} + \text{A} = 100$ ,  $\therefore (100 - \text{A}) / \text{A} = 5.66 \Rightarrow$
- |   |     |
|---|-----|
| $\frac{\text{vol of acid} = 15 \text{ cm}^3}{\text{vol of salt} = 85 \text{ cm}^3}$ | [1] |
|   | [4] |



(d) e.g. hydrolysis of esters  $\text{RCO}_2\text{R}' (+ \text{H}_2\text{O}) \longrightarrow \text{RCO}_2\text{H} + \text{R}'\text{OH}$  or its reverse

or hydrolysis of amides:  $\text{RCONH}_2 (+ \text{H}_3\text{O}^+) \longrightarrow \text{RCO}_2\text{H} + \text{NH}_4^+$

hydrolysis of nitriles:  $\text{RCN} (+ \text{H}_3\text{O}^+ + \text{H}_2\text{O}) \longrightarrow \text{RCO}_2\text{H} + \text{NH}_4^+$

nitration of benzene (or any arene):  $\text{C}_6\text{H}_6 + \text{HNO}_3 \longrightarrow \text{C}_6\text{H}_5\text{NO}_2 (+ \text{H}_2\text{O})$

dehydration of alcohols, e.g. :  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 \longrightarrow \text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O}$   
(or the reverse)

halogenation of ketones, e.g. :  $\text{CH}_3\text{COCH}_3 + \text{X}_2 \longrightarrow \text{CH}_3\text{COCH}_2\text{X} (+ \text{HX})$

[3]

Q10.



- 2 (a) (i)  $K_a = [\text{HCO}_2^-][\text{H}^+]/\text{HCO}_2\text{H}$  (1)
- (ii)  $\sqrt{K_a[\text{HCO}_2\text{H}]} = \sqrt{1.77 \times 10^{-4} \times 0.05} = 2.97 \times 10^{-3}$  (1)  
(3.0 x 10<sup>-3</sup>)
- (iii)  $100 \times 2.97 \times 10^{-3} / 0.05 = 5.94\%$  (6%) (1)
- (iv)  $\text{pH} = -\log_{10}(2.97 \times 10^{-3}) = 2.5(2)$  (1) [4]
- (b)  $\text{pH} = -\log_{10}(0.05) = 1.30$  (1) [1]

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- (c) (i)  $2\text{HCO}_2\text{H} + \text{Mg} \rightarrow (\text{HCO}_2)_2\text{Mg} + \text{H}_2$  (1)  
(or  $2\text{H}^+ + \text{Mg} \rightarrow \text{Mg}^{2+} + \text{H}_2$ )
- (ii) moles of  $\text{H}^+ = 0.05 \times 20/1000 = 1 \times 10^{-3}$  (1)  
moles of  $\text{H}_2 = 1 \times 10^{-3}/2 = 0.5 \times 10^{-3}$
- volume of  $\text{H}_2 = 0.5 \times 10^{-3} \times 24,000 = 12 \text{ cm}^3$  (1)  
(or  $0.5 \times 10^{-3} \times 22400 = 12 \text{ cm}^3$ )
- (iii) (rate  $\propto [\text{H}^+]$ ) lower  $[\text{H}^+]$  in methanoic acid or  $\text{HCO}_2\text{H}$  dissociates slowly/partially (1)
- (iv) the equilibrium ( $\text{HCO}_2\text{H} \rightleftharpoons \text{HCO}_2^- + \text{H}^+$ ) continually shifts to the right as  $\text{H}^+$  is used up (1) [5]
- Total: 10**

Q11.

- 1 (a) (i) strong, because final pH is about 14 [1]
- (ii)  $(\text{pH} = 0.70) \Rightarrow [\text{H}^+] = 10^{-0.7} = 0.20 \text{ (mol dm}^{-3}\text{)}$  [1]
- $\therefore [\text{H}_2\text{SO}_4] = (0.10 \text{ mol dm}^{-3})$  ecf [1]
- (iii) (end point is at  $34.0 \text{ cm}^3 (\pm 0.5 \text{ cm}^3)$ , so)
- amount of  $\text{H}^+$  used =  $0.2 \times 25/1000 = 0.0050 \text{ mol}$  ecf from (ii) [1]
- moles of guanidine = moles of  $\text{H}^+$  =  $0.0050 \text{ mol}$
- [guanidine] =  $0.005 \times 1000/34.0 = 0.147 \text{ (mol dm}^{-3}\text{)}$  [1]
- allow range:  $0.145 - 0.149$  ecf in 0.005 or 34.0
- (iv)  $M_r = 8.68/0.147 = 59$  (allow range 58 – 60) ecf from (iii) [1] 6
- (b) (i)  $\longrightarrow 7 \text{ CaSO}_4 + 3 \text{ Ca(H}_2\text{PO}_4)_2 + 2 \text{ HF}$  [1]
- (ii)  $M_r$  values:  $\text{Ca(H}_2\text{PO}_4)_2 = 234.1$ ,  $\text{H}_2\text{SO}_4 = 98.0$  [1]
- $234.1 \times 3 = 702.3$   $98 \times 7 = 686$  both [1]
- ecf from ratios in equation, and from  $M_r$  values
- $\therefore$  mass of  $\text{H}_2\text{SO}_4$  needed =  $1.0 \times 686/702.3 = 0.98 \text{ kg}$  [1]
- (correct answer = [3] marks. accurate value is: 0.977 kg.  
Allow ecf from incorrect  $M_r$  or incorrect multipliers) 4
- (c) (i) A solution that **resists** changes in pH [NOT: results in **no** pH change] [1]
- when **small amounts** of  $\text{H}^+$  or  $\text{OH}^-$  are added [1]
- (ii)  $\text{pH} = -\log_{10}(6.3 \times 10^{-8}) + \log_{10}(0.1/0.2) = 6.9$  [1]
- or  $[\text{H}^+] = (6.3 \times 10^{-8}) \times 0.2/0.1 = 1.26 \times 10^{-7}$
- $\therefore \text{pH} = -\log_{10}(1.26 \times 10^{-7}) = 6.9$  3

**Total 13**

**Q12.**

- 2 (a) (i) [one chiral centre only] (1)
- (ii)  $C_{13}H_{18}O_2$  (1)
- (iii)  $M_r = 206$  ecf (1)
- mass =  $0.15 \times (100/1000) \times 206 = 3.1$  g ecf (1)  
(correct ans = (2) marks)
- (iv)  $n(\text{NaOH}) = 0.1 \times 12/100 = 1.2 \times 10^{-3}$  moles (1)
- $n(\text{A}) = 0.6 \times 10^{-3}$ , so  $M_r = 0.1/(0.6 \times 10^{-3}) = 167$  (allow 166-170) (1)  
(correct ans = (2) marks)
- This fits with  $\text{HO}_2\text{C}-\text{C}_6\text{H}_4-\text{CO}_2\text{H}$  (which has  $M_r = 166$ ) (1) [7]
- (b) (i)  $(K_a =) [\text{H}^+][\text{A}^-]/[\text{HA}]$  (1)
- (ii)  $[\text{H}^+] = \sqrt{K_a \cdot c} = \sqrt{6.3 \times 10^{-6} \times 0.15} = 9.72 \times 10^{-4}$  (1)
- pH = 3.0 (1)  
(correct ans = (2) marks) [3]
- (c) (i) one that **resists/control/maintains** changes in pH (**NOT no** change in pH) (1)
- when **small amounts** of acid/ $\text{H}^+$  (or base/ $\text{OH}^-$ ) are added. (1)
- (ii)  $\text{HPO}_4^{2-} + \text{H}^+ \longrightarrow \text{H}_2\text{PO}_4^-$  (1)  
 $\text{H}_2\text{PO}_4^- + \text{OH}^- \longrightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$  (1)
- (iii) pH =  $\text{p}K_a + \log([\text{base}]/[\text{acid}])$   
=  $7.2 + \log(.002/.005) = 6.8$  (2)  
(correct ans = (2) marks: deduct (1) for each error,  
e.g. if ratio is upside down, hence pH = 7.6, answer is worth (1)) [6]
- [Total: 16 max 15]

### Q13.

- 1 (a) (i)  $K_a = [\text{H}^+][\text{RCO}_2^-]/[\text{RCO}_2\text{H}]$  [1]
- (ii)  $\text{p}K_a = -\log_{10}K_a$  or  $-\log K_a$  or  $\log [\text{H}^+]^2/[\text{RCO}_2\text{H}]$  NOT ln; [1]  
[2]
- (b) (i) acid strength increases from no. 1 to no. 3 or down the table or as Cls increase [1]  
due to the electron-withdrawing effect/electronegativity of chlorine (atoms) [1]  
stabilising the anion or weakening the O-H bond NOT  $\text{H}^+$  more available [1]
- (ii) chlorine atom is further away (from O-H) in no. 4, so has less influence [1]
- (iii) either: pH =  $\frac{1}{2}(\text{p}K_a - \log_{10}[\text{acid}])$  or  $K_a = 10^{-\text{p}K_a} = 1.259 \times 10^{-3}$  [1]  
=  $\frac{1}{2}(4.9 + 2)$   $[\text{H}^+] = \sqrt{(K_a \cdot c)} = 3.55 \times 10^{-4}$  [1]  
= 3.4 (allow 3.5) pH = 3.4 ecf [1]  
([1] for correct expression & values; [1] for correct working) [6]

## Q14.

- 2 (a) ethylamine > NH<sub>3</sub>, but phenylamine < NH<sub>3</sub> [1]

in ethylamine, the alkyl group donates electrons to the N, making lone pair more available [1]

in phenylamine, the lone pair is delocalised over the ring, so is less available [1]  
[3]

(b)

halide	observation when AgNO <sub>3</sub> (aq) is added	observation when dilute NH <sub>3</sub> (aq) is added	observation when concentrated NH <sub>3</sub> (aq) is added	
chloride	<b>white ppt</b>	<b>dissolves</b>	<b>dissolves</b>	[1]
bromide	<b>cream ppt</b>	<b>no reaction / slightly dissolves</b>	<b>dissolves</b>	[1]
iodide	<b>(pale) yellow ppt</b>	<b>no reaction</b>	<b>no reaction</b>	[1] [3]

- (c) (i)  $[Ag^+(aq)] = \sqrt{K_{sp}} = \sqrt{(5 \times 10^{-13})} = 7.1 (7.07) \times 10^{-7} \text{ mol dm}^{-3}$  [1]

- (ii) AgBr will be **less soluble** in KBr, due to common ion effect or equilibrium is shifted to the left / or by Le Chatelier's principle [1]  
[2]

- (d) (i)  $K_c = \frac{[Ag(RNH_2)_2^+]}{[Ag^+][RNH_2]^2}$  [1]  
units are mol<sup>-2</sup> dm<sup>6</sup> [1]

- (ii) assume that most of the Ag<sup>+</sup>(aq) has gone to the complex, then

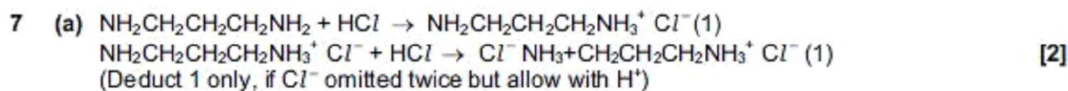
$$\begin{aligned} [Ag^+(aq)] &= 7.1 \times 10^{-7} \\ [Ag(NH_3)_2^+] &= 0.1 \end{aligned}$$

$$\begin{aligned} \text{and } [NH_3] &= \sqrt{\frac{[Ag(NH_3)_2^+]}{K_c[Ag^+]}} = \sqrt{\frac{0.1}{(1.7 \times 10^7 \times 7.1 \times 10^{-7})}} \\ &= 0.091 \text{ mol dm}^{-3} \end{aligned} \quad \begin{array}{l} [1] \\ [1] \end{array}$$

- (ii) When R = C<sub>2</sub>H<sub>5</sub>, K<sub>c</sub> is likely to be greater, since the ethyl group will cause the lone pair on N to be more available / nucleophilic / increases basicity [1]  
[5]

[Total: 13]

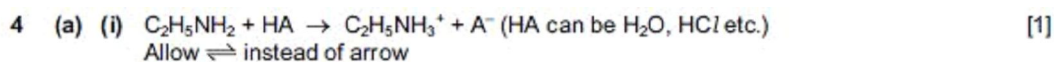
## Q15.



(b) starts at 11.3 and finished as 1.6 (1)  
 steep portions at 10  $\text{cm}^3$  and 20  $\text{cm}^3$  volume added (1) [2]

[Total: 4]

## Q16.



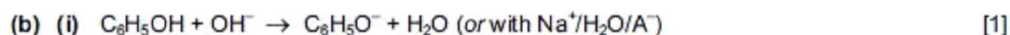
(ii)

most basic		least basic
<b>ethylamine</b>	<b>ammonia</b>	<b>phenylamine</b>

[1]

(iii) ethylamine >  $\text{NH}_3$  due to electron-donating ethyl/alkyl group [1]  
 phenylamine <  $\text{NH}_3$  due to delocalisation of lone pair over ring [1]

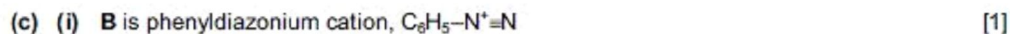
[4]



(ii)  $\text{pK}_a$  of nitrophenol is smaller/ $K_a$  is larger because it's a stronger acid/dissociates more than phenol [1]  
 stronger because the anionic charge is spread out moreover the  $\text{NO}_2$  group or  $\text{NO}_2$  is electron-withdrawing [1]

(iii)  $\text{pK}_a = 1.0$  [1]

(iv) Nitro group increases acidity / electron-withdrawing groups increase acidity [1]  
 [5]



(ii)

reaction	reagent(s)	conditions
Step 1	<b><math>\text{NaNO}_2 + \text{HCl}</math> or <math>\text{HNO}_2</math></b> [1]	<b><math>\text{T} &lt; 10^\circ\text{C}</math></b> [1]
Step 2	<b><math>\text{H}_2\text{O} / \text{aq}</math></b>	<b>heat/boil/<math>\text{T} &gt; 10^\circ</math></b> (both) [1]
Step 3	<b><math>\text{HNO}_3</math> NB <math>\text{HNO}_3(\text{aq})</math> OK for both</b>	<b>dilute</b> (both) [1]

[4]

[5]

## Q17.

- 3 (a) (i)  $\text{NH}_3 + \text{HZ} \longrightarrow \text{NH}_4^+ + \text{Z}^-$  [1]  
 $\text{CH}_3\text{OH} + \text{HZ} \longrightarrow \text{CH}_3\text{OH}_2^+ + \text{Z}^-$  [1]
- (ii)  $\text{NH}_3 + \text{B}^- \longrightarrow \text{NH}_2^- + \text{BH}$  [1]  
 $\text{CH}_3\text{OH} + \text{B}^- \longrightarrow \text{CH}_3\text{O}^- + \text{BH}$  [1]
- [4]
- (b) (i) a reaction that can go in either direction [1]
- (ii) **rate** of forward = **rate** of backward reaction  
or forward/back reactions occurring but concentrations of all species do not change [1]
- [2]
- (c) (i) a solution that resists changes in pH [1]  
when small quantities of acid or base/alkali are added [1]
- (ii) in the equilibrium system  $\text{HZ} + \text{H}_2\text{O} = \text{Z}^- + \text{H}_3\text{O}^+$  [1]  
addition of acid: reaction moves to the left  
or  $\text{H}^+$  combines with  $\text{Z}^-$  **and** forms  $\text{HZ}$  [1]
- addition of base: the reaction moves to the right  
or  $\text{H}^+$  combines with  $\text{OH}^-$  **and** more  $\text{Z}^-$  formed [1]
- [5 max 4]
- (d) (i)  $[\text{H}^+] = \sqrt{0.5 \times 1.34 \times 10^{-5}} = 2.59 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$  [1]  
pH = **2.59/2.6** (min 1 d.p) ecf [1]
- (ii)  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H} + \text{NaOH} \longrightarrow \text{CH}_3\text{CH}_2\text{CO}_2\text{Na} + \text{H}_2\text{O}$  [1]
- (iii)  $n(\text{acid})$  in  $100 \text{ cm}^3 = 0.5 \times 100/1000 = 0.05 \text{ mol}$   
 $n(\text{acid})$  remaining =  $0.05 - 0.03 = 0.02 \text{ mol}$   
 $[\text{acid remaining}] = \mathbf{0.2} \text{ (mol dm}^{-3}\text{)}$  [1]
- likewise,  $n(\text{salt}) = 0.03 \text{ mol}$   
 $[\text{salt}] = \mathbf{0.3} \text{ (mol dm}^{-3}\text{)}$  [1]
- (iv)  $\text{pH} = 4.87 + \log(0.3/0.2) = \mathbf{5.04-5.05}$  ecf [1]
- [6]
- (e) **G** is  $\text{CH}_3\text{CH}_2\text{COCl}$   
**H** is  $\text{SOCl}_2$  or  $\text{PCl}_5$   
**J** is  $\text{NaCl}$  [2]  
(or corresponding Br compounds for **G**, **H** and **J**;  $\text{CH}_3\text{CH}_2\text{COBr}$ ,  $\text{SOBr}_2$ ,  $\text{NaBr}$ )
- [Total: 18]

Q18.

- 8 (a) (i) (nitrates are) soluble [1]
- (ii)  $\text{Ba}^{(2+)}$  and  $\text{Pb}^{(2+)}$  [1]
- $\text{SO}_4^{(2-)}$  [1]
- $\text{BaCO}_3/\text{PbCO}_3/\text{CaSO}_4$  are insoluble [1]
- [4]
- (b) (i) fertilisers/animal manure [1]
- (ii) washing powder/detergents/fertilisers/animal manure [1]
- (iii) growth/production of algae/weeds/plants  
or eutrophication [1]
- [3]
- (c) (i) *any one of:*
- $2\text{SO}_2 + \text{O}_2 \longrightarrow 2\text{SO}_3$  and  $\text{SO}_3 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_4$
- or  $\text{SO}_2 + \text{NO}_2 \longrightarrow \text{SO}_3 + \text{NO}$  and  $\text{SO}_3 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_4$
- or  $\text{SO}_2 + \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_4$  [1]
- (ii) roasting sulfide ores/extraction of metals from sulfide ores [1]
- [2]
- [Total: 9]

Q19.

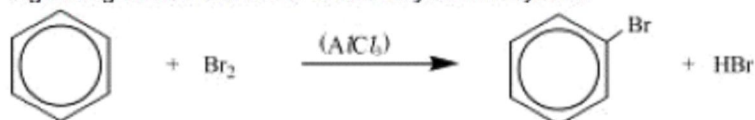
- 2 (a) *any two from:* molecules have negligible volume  
 negligible intermolecular forces *or* particles are not attracted to each other  
*or* to the walls of the container  
 random motion  
 no loss of **kinetic** energy during collisions *or* elastic collisions (NOT  
 elastic molecules) 2 × [1]  
[2]

- (b) (i) low temperature **and** high pressure both required [1]  
 (ii) (at low T) forces between particles are more important, [1]  
 (at high P) volume of molecules are significant [1]

**[3 max 2]**

- (c) (i) endothermic; because the equilibrium moves to the right on heating *or* with  
 increasing temperature *or* because bonds are broken during the reaction [1]

- (ii) e.g. halogenation *or* Friedel-Crafts alkylation / acylation



reactants [1]  
 products [1]

other possibilities: Cl<sub>2</sub>, I<sub>2</sub>, R-Cl, RCOCl etc.

**[3]**

**[Total: 7]**



