ANDERSON SERANGOON JUNIOR COLLEGE

H2 Chemistry 9729 **2019 JC2 Prelim Exam Paper 2 Solutions**

1 (a) Reducing power of Group 2 elements increases [1] down the group.

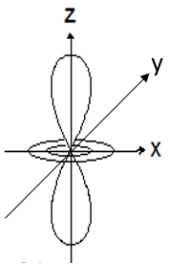
Number of (principal) quantum shell / electronic shell increases and valence electrons are further away and more shielded from the nucleus. Valence electrons are less strongly attracted to the nucleus and smaller amount of energy is needed to remove the valence electron so it is more easily oxidised. [1]

(b) (i) Copper can give up both 3d and 4s electrons for delocalisation whereas calcium can only give up 2 electrons. [1] Electrons act as mobile charge carriers [1] to conduct electricity.

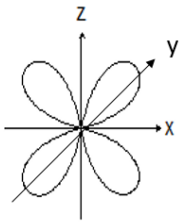
(ii) Cu has smaller atomic radius and higher atomic mass [1] compared to Ca.
Also, Cu has a more closely packed structure due to stronger metallic bonding as compared to Ca. [1]
Hence, Cu has a much higher density than Ca.

(c) (i) A
Each orbital can hold a maximum of 2 electrons of opposite spin.
Diagram B has a pair of electrons having the same spin.
[1] with explanation

(ii)



$3d_{z^2}$ [1]



$3d_{xz}$ [1]

Alternative answers: $3d_{x^2-y^2}$, $3d_{xy}$, $3d_{yz}$

(d) (i) Both silicon and silica have a giant molecular structure. [1]

(ii)
- From the data booklet:
  Si–Si BE: 222 kJ mol^{-1}
  Si–O BE: 460 kJ mol^{-1} [1]

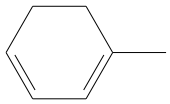
- Size of valence orbitals: Si > O
- Valence orbitals of Si are more diffused than that of O
- Overlap of orbitals is less effective in Si–Si than in Si–O

- The Si–O bond in silica is stronger than the Si–Si bond in silicon.
- Hence, bond energy: Si–Si < Si–O and more energy is required to break the Si–O bond than the Si–Si bond. [1]

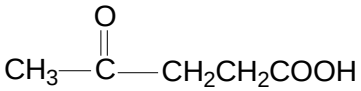
2 (a) (i) presence of <u>carboxylic acid</u> or <u>–COOH</u> group
presence of <u>$CH_3CO–$</u> or <u>methyl ketone</u>
<u>absence</u> of <u>chiral carbon</u>

any 2 for [2]

(ii)



C



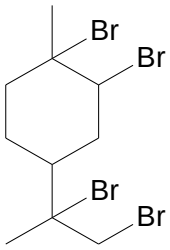
D

[1] each

(iii) **E**: $(CH_3)_2CO$; **F**: CH_3CH_2CHO [1] each

(iv) **G**: $CH_3CH=CHCH(CH_3)_2$ [1]

(b) (i)

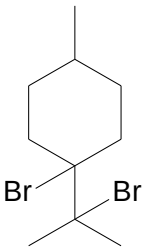


[1]

<u>Orange–red</u> / red–brown Br_2 <u>decolourises / turns colourless</u>. [1]

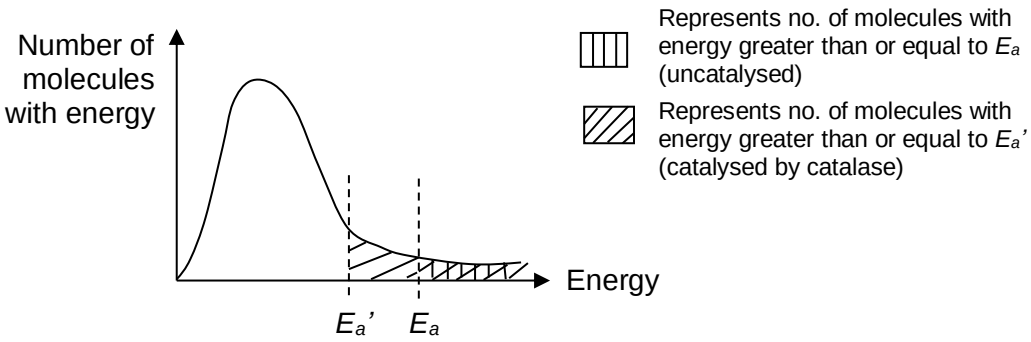
(ii) NaOH in ethanol, heat (under reflux) [1]

(iii)



[1]

3 (a) (i)



[1]: diagram

As shown on the diagram, in the presence of catalase, at a certain temperature T,

- Catalase provides a <u>different pathway</u> of a <u>lower activation energy</u> ($E_a' < E_a$).
- More molecules have <u>energies greater than or equal to the lowered activation energy E_a'.</u>
- This results in an <u>increase in the frequency of effective collisions</u>. [2]

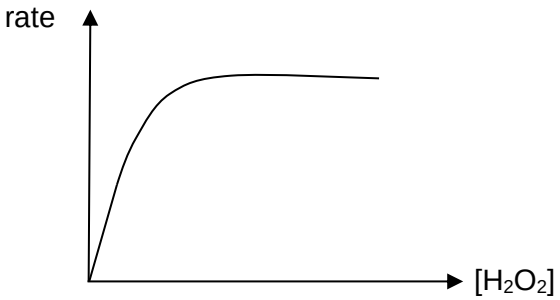
(ii) Repeat the experiment described but using varying volumes of H_2O_2 and topping it up with deionised water to keep the total volume constant at 50 cm^3 and add in 1 cm^3 of catalase. [1]

Record the time taken for 20 cm^3 of O_2 to form. [1]

As rate is inversely proportional to the time taken, plot a graph of 1/t against $[H_2O_2]$ / V_{H2O2}. [1]

Or find the product of $(V_{H2O2})^n t$ and determine the value of n when $(V_{H2O2})^n t$ becomes a constant.

(iii)



[1]: diagram

At low $[H_2O_2]$, rate is directly proportional to $[H_2O_2]$ (OR 1st order reaction) since active sites are not fully occupied.

At high $[H_2O_2]$, rate becomes constant (OR zero order reaction) since active sites are fully occupied. [1]

(b) **(i)** FeS is precipitated first.

(ii) When FeS is precipitates,
$[S^{2-}] = 3.7 \times 10^{-19} \div 0.100 = 3.70 \times 10^{-18}$ mol dm^{-3}

(iii) When MnS starts to precipitate,
$[S^{2-}] = 3.7 \times 10^{-13} \div 0.100 = 3.70 \times 10^{-12}$ mol dm^{-3} [1]
$[Fe^{2+}] = 3.7 \times 10^{-19} \div 3.7 \times 10^{-12} = 1.00 \times 10^{-7}$ mol dm^{-3}

(iv) % of Fe^{2+} remaining in solution = $1.00 \times 10^{-7} \div 0.1 \times 100\% = 0.0001\% << 1\%$
$\Rightarrow$ separation is effective

(v) As the pH increases, $[H^+]$ decreases, the positions of equilibrium (1) and (2) shift to the right, resulting in a higher $[S^{2-}]$.

For selective precipitation, the pH is increased such that the ionic product of FeS > K_{sp}(FeS) but ionic product of MnS < K_{sp}(MnS). Only FeS is precipitated.

[1] explain relationship between pH and $[S^{2-}]$ using LCP
[1] linking $[S^{2-}]$ to ionic product and hence K_{sp} to show sequence of precipitation

(c) **(i)** $2Cr_2O_3 + 3O_2 + 8OH^- \rightarrow 4CrO_4^{2-} + 4H_2O$ [1]

(ii) From yellow (CrO_4^{2-}) to orange ($Cr_2O_7^{2-}$) to green (Cr^{3+}) [1]

(iii) step **III**: acid–base reaction
complex ion in solution **P**: $[Cr(OH)_6]^{3-}$ (accept $[Cr(OH)_4]^-$ or $[Cr(OH)_4(H_2O)_2]^-$) [1]

(iv) $Na_3Fe(CN)_6$ [1]

4 **(a)** Ethylamine is a stronger base than phenylamine.

Ethylamine:
Ethyl group is electron–donating and increases the electron density around the N atom. This increases the availability of the lone pair of electrons on N atom to accept a proton. [1]

Phenylamine:
Lone pair of electrons on N atom in phenylamine is delocalised into the π electron cloud of the benzene ring. This decreases the availability of the lone pair of electrons on N atom to accept a proton. [1]

(b) **(i)** methyl orange
The working pH range of methyl orange lies within the range of rapid pH change of the titration curve which lies in the acidic pH region (equivalence pH < 7). [1]

(ii) At equivalence point:
$CH_3CH_2NH_2 + HCl \rightarrow CH_3CH_2NH_3^+Cl^-$
$CH_3CH_2NH_3^+ + H_2O \rightleftharpoons CH_3CH_2NH_2 + H_3O^+$

$[H_3O^+]$ at equivalence point = $10^{-5.91}$ mol dm^{-3}

K_a of $CH_3CH_2NH_3^+ = 10^{-(14-3.35)} = 10^{-10.65}$

$$K_a = \frac{[H_3O^+][CH_3CH_2NH_2]}{[CH_3CH_2NH_3^+]} = \frac{[H_3O^+]^2}{[CH_3CH_2NH_3^+]}$$

$[CH_3CH_2NH_3^+]$ at equivalence point = $\frac{(10^{-5.91})^2}{(10^{-10.65})} = 0.0676$ mol dm^{-3} [1]

(iii) Let x cm^3 be the volume of HC*l* needed to neutralise ethylamine.

n(HC*l*) required to neutralise $CH_3CH_2NH_2$ = n($CH_3CH_2NH_3^+$)

$$= \frac{x}{1000} \times 0.2 = 0.0002x \text{ mol}$$

$[CH_3CH_2NH_3^+]$ at equivalence point = $\frac{\frac{0.0002x}{1000}}{\frac{x+20}{1000}} = 0.0676$ mol dm^{-3}

x = 10.2 cm^3 [1]

(iv) n($CH_3CH_2NH_2$) = 0.2 x 10.2/1000 = 0.00204 mol

$[CH_3CH_2NH_2] = \frac{0.00204}{\frac{20}{1000}} = 0.102$ mol dm^{-3} [1]

(v) $$K_b = \frac{[OH^-][CH_3CH_2NH_3^+]}{[CH_3CH_2NH_2]} = \frac{[OH^-]^2}{[CH_3CH_2NH_2]}$$

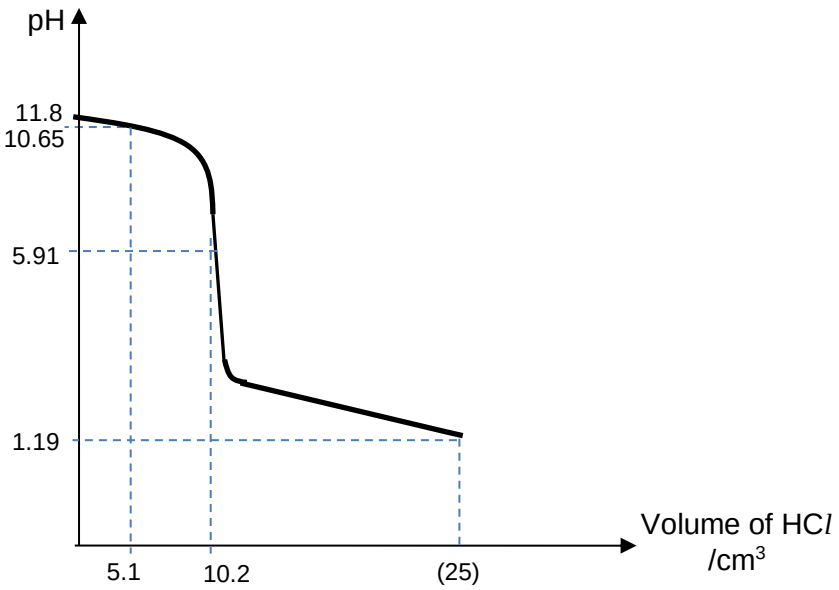
$[OH^-] = \sqrt{10^{-3.35} \text{ x } 0.102} = 0.0067499$ mol dm^{-3}
pOH = –log 0.0067499 = 2.17
pH = 14 – 2.17 = 11.8 [1]

(vi) n(HC*l*) unreacted = $\frac{25 - 10.2}{1000}$ x 0.2 = 0.00296 mol

[HC*l*] after 25.00 cm^3 has been added = $[H_3O^+] = \frac{\frac{0.00296}{20 + 25}}{1000} = 0.06577$ mol dm^{-3}

pH = –log 0.06577 = <u>1.18</u> [1]

(vii)



(c) **(i)** Initial amount of $C_6H_5NH_2 = \frac{200}{1000} \times 0.15 = 0.03$ mol

Initial amount of HC*l* = $\frac{100}{1000} \times 0.2 = 0.02$ mol

	$C_6H_5NH_2$ + HC*l* → $C_6H_5NH_3^+Cl^-$ + H_2O		
Initial mol	0.03	0.02	
Change in mol	–0.02	–0.02	+0.02
Final mol	0.01	0	0.02 [1]

$$K_b = \frac{[OH^-][C_6H_5NH_3^+]}{[C_6H_5NH_2]} = \frac{[OH^-](\frac{0.02}{0.3})}{(\frac{0.01}{0.3})} = 10^{-4.63}$$

$[OH^-] = 1.1721 \times 10^{-5}$ mol dm^{-3}
pOH = –log 1.1721×10^{-5} = 4.93
pH = 14 – 4.93 = <u>9.07</u> [1].

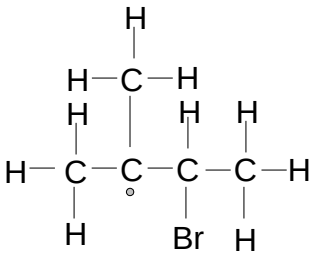
(ii) $C_6H_5NH_3^+ + OH^- \rightarrow C_6H_5NH_2 + H_2O$ [1]

5 **(a)** A highly reactive atom or group of atoms with an unpaired electron. [1]

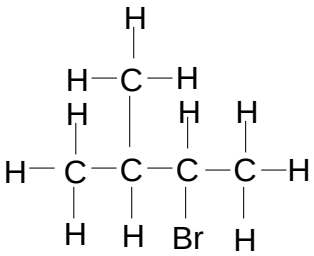
[1]

Break homolytically (shown in diagram with 2 half arrows) at the O–O single bond

(b)

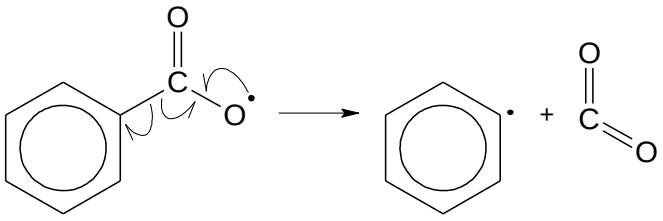


alkyl radical

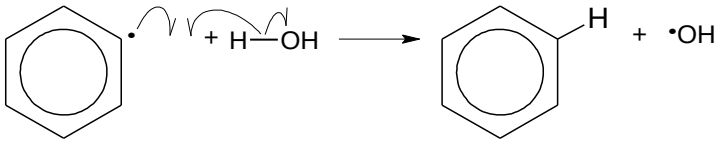


organic product [1] each

(c)



intermediate phenyl radical



6 half arrows [2]
Identity of the 2 radicals [1]

(d) **(i)** Total energy in the coffee = (4.5 x 38) + (20 x 17) + (15 x 17) = 766 kJ [1]
No. of minutes = 766 / 7 = 109 min [1]

(ii) M_r of $C_{55}H_{98}O_6$ = 854.0
x = 38 x 854.0 = 32452 kJ mol^{-1} or 32500 kJ mol^{-1} [1]

(e) **A:** $(CH_3)_3CCH_2CHO$ [1]
B: $CH_3COC(CH_3)_3$ [1]

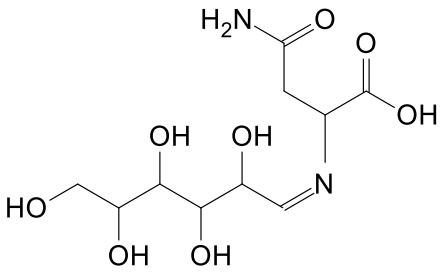
6 **(a)** **(i)** Since potatoes are boiled in water, the temperature is below 140 °C. Therefore, only a small amount of acrylamide is formed. [1]
(or words to the effect)

(ii) The Maillard reaction occurs largely on the surface of cooked food.
Since deep fried potato is cut into strips, there is an increased surface area to volume ratio for the formation of acrylamide compared to baked potato. [1]

(b) **(i)** At a lower pH, the amine group in asparagine is protonated. This prevents nucleophilic attack by the amine on the carbonyl group in glucose, preventing the formation of acrylamide. [1]

(ii) Glycine competes effectively with asparagine in the Maillard reaction, preventing the formation of the imine which leads to the formation of acrylamide. [1]
(or words to the effect)

(c)



imine [1]

(d) **(i)** The circled carbon atom is most susceptible to nucleophilic attack because it faces **less steric hindrance** than the other carbon atom in the epoxide group. [1]

(ii) This reaction **decreases the amount of guanine**, damaging the DNA structure such that it is not able to function normally, potentially leading to cancer. [1]

(iii) Since the **lone pair** on the N atoms in thymine is delocalised into the π bond of the adjacent C=O by resonance, it is **not available** to act as a nucleophile. [1]

(iv) The **C=C double bond** in phenylethene can be metabolised **into an epoxide** by the enzyme, just like the C=C double bond in acrylamide. [1]
This epoxide then follows the same mechanism as glycidamide, by reacting with guanine.
(or words to this effect)