Suggested Answers for 9729 H2 CM 2019 JC 2 Prelim

Paper 2

1 **(a)** Barium has a larger nuclear charge and larger shielding effect than beryllium. Although there is an increase in nuclear charge in barium, it is cancelled out by the simultaneous increase in shielding effect by inner shells of electrons. Barium has a bigger atomic radius than beryllium. **[3]**

Hence the valence electrons become increasingly less attracted by the positive nucleus and less energy is required to remove the valence electrons. Therefore 1st IE of Ba is lower than the 1st IE of beryllium.

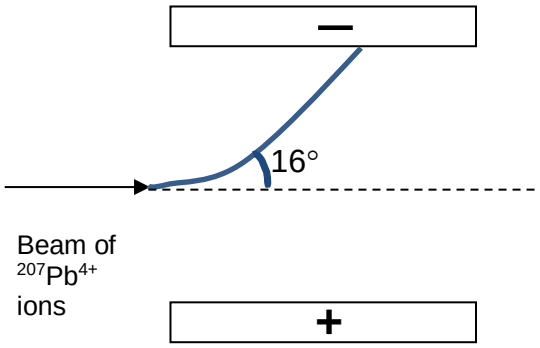
(b) **(i)** $Ca(NO_3)_2\ (s) \rightarrow CaO\ (s) + 2NO_2\ (g) + \frac{1}{2}O_2\ (g)$ **[1]**

(ii) **[3]**

cations	Ionic radius/nm
Pb^{2+}	0.120
Zn^{2+}	0.074
Ca^{2+}	0.099

The ionic radius of the metal cation increases from Zn^{2+} to Ca^{2+} to Pb^{2+} and its charge density decreases. As a result, the ability of M^{2+} to polarise the electron cloud of the large NO_3^- anion decreases and the N–O bonds are weakened to a smaller extent. Hence $Zn(NO_3)_2$ decomposes at the lowest temperature followed by $Ca(NO_3)_2$ and lastly $Pb(NO_3)_2$.

(c) **[2]**



$\frac{charge}{mass}$ for $Pb^{2+} = \frac{+2}{207.2} = 0.00965$

$\frac{charge}{mass}$ for $Pb^{4+} = \frac{+4}{207.2} = 0.01930$

Angle of deflection $= \frac{0.01930}{0.00965} \times 8 = 16°C$

[Total: 9]

2 **(a)** $K_{a1} = X^2 / (0.300 - X)$; assuming x is very small and 0.300 - X = 0.300

$X = 0.0207 \text{mol dm}^{-3}$

pH = -lg 0.0207 = 1.68 **[1]**

(b) $[Na_3C_6H_5O_7] = 46 / (23.0 \times 3 + 12.0 \times 6 + 16.0 \times 7 + 1.0 \times 5)$

$= 0.178 \text{ mol dm}^{-3}$

$K_b = K_w / K_a = 10^{-14} / (3.98 \times 10^{-7}) = 2.51 \times 10^{-8} \text{ mol dm}^{-3}$

$K_b = [OH^-]^2 / 0.178 = 2.51 \times 10^{-8}$

$[OH^-] = 6.69 \times 10^{-5} \text{ mol dm}^{-3}$

pH = 14 – pOH

pH = 9.82 **[3]**

(c) **(i)** [salt] = [acid] / Amount of acid = Amount of salt / Larger volume of buffer

Amounts of salt and acid are relatively higher than the amount of acid or alkali added. **[2]**

(ii) $pH = 6.40 = pK_{a3}$

buffer consist of $HC_6H_5O_7^{2-}$ and $C_6H_5O_7^{3-}$

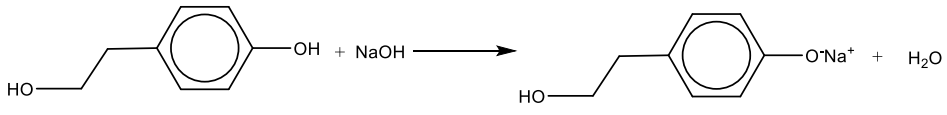
Amt of of citric acid = 0.300 x 0.05 = 0.0150 mol

Amt of NaOH needed = 0.0150 x 2.5 = 0.0375 mol

mass = 0.0375 x (23.0 + 16.0 + 1.0) = 1.50 g **[3]**

[Total: 9]

3 **(a)** **(i)**



[1]

(ii) Ion-dipole interactions **[2]**

Hydrogen bonding

Instantaneous dipole-induced dipole forces

(iii) Neutral $FeCl_3$. Violet colouration will be observed if tyrosol is present. There will be no violet colouration if tyrosol is not present. **[2]**

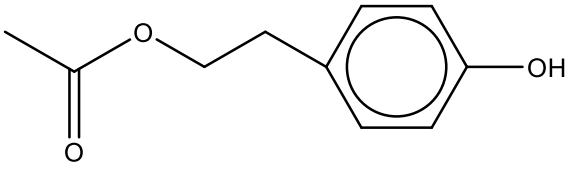
(iv) When the NaOH solution is changed, $[T]_{NaOH}$=0/ lowered. **[2]**

Equilibirum position shifts right to dissolve more tyrosol and counteract the change.

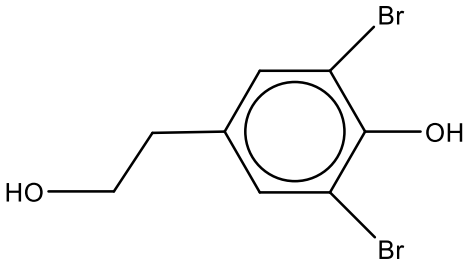
More tyrosol will be removed from the olives.

(b) **(i)** **[2]**

D:



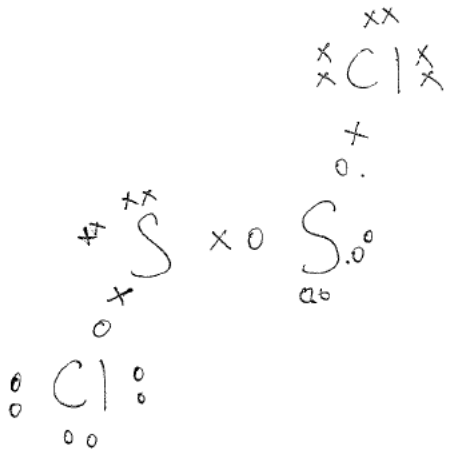
E:



(ii) The brominated tyrosol is a stronger acid than tyrosol. In the brominated phenoxide ion, the electron-withdrawing bromine atoms increase the delocalisation of the negative charge into the benzene ring, making the brominated phenoxide ion more stable than the phenoxide ion in tyrosol. **[1]**

[Total: 10]

4 **(a)**



Bond angle is 104.5^0 **[2]**

(b) All two compounds have simple covalent structures/ are simple covalent molecules.

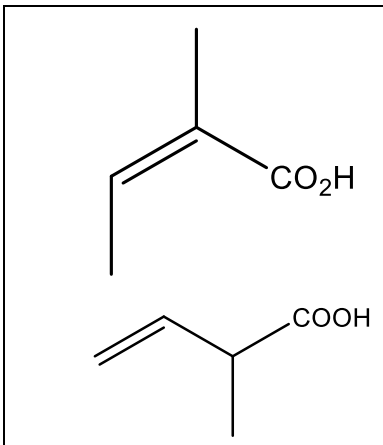
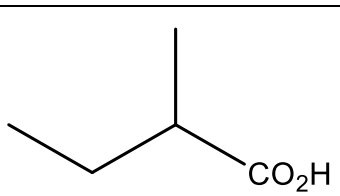
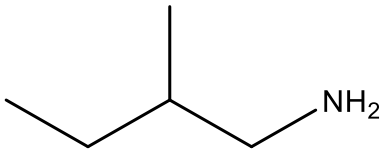
For $SOCl_2$ and S_2Cl_2, there exists permanent dipole-permanent dipole interactions and instantaneous dipole-induced dipole interactions between molecules. **[3]**

As S_2Cl_2 has a larger number of electrons/electron cloud and is more polar, more energy is required to overcome the stronger instantaneous dipole-induced dipole interactions and stronger permanent dipole-permanent dipole interactions between S_2Cl_2 molecules than $SOCl_2$ molecules. Therefore, S_2Cl_2 has a higher boiling point than $SOCl_2$.

(c) (i) Step 2: NH_3, rtp **[2]**

Step 3: $LiAlH_4$ in dry ether..

(ii)

	
angelic acid	**T**
	
U	

[3]

(iii)

angelic acid cis – trans isomerism / enantiomerism

T enantiomerism

[2]

[Total: 12]

5 (a) (i) The difference in energies (ΔE) between these 2 sets of 3d orbitals is small and radiation from the visible region of the electromagnetic spectrum is absorbed when an electron is promoted from a lower energy d orbital to another unfilled/partially-filled d orbital of higher energy.

The colour observed (violet) corresponds to the complement of the absorbed colours (yellow). **[2]**

(ii) Vanadium(II) / V^{2+}(aq). Because V^{2+}(aq) is violet and V^{3+}(aq) is green, which means that for V^{2+} and V^{3+}, the complement colours, yellow and red respectively, are absorbed.

Since the energy of light is inversely proportional to its wavelength, the energy gap between the 2 sets of d orbitals in V^{2+} will be larger as the wavelength of yellow light is shorter than that of red light. **[2]**

(b) (i) V^{3+} : (3 , −2.7)

VO^{2+}: (4 , −2.3) **[1]**

(ii) E (VO_2^+/V^{2+}) = gradient of line joining VO_2^+ and V^{2+} points

$$= \frac{-2.40-(-1.32)}{2-5} = \mathbf{+0.36\ V}$$ **[1]**

(iii) $-\Delta G$ /F is the most negative here, hence ΔG for V^{3+} is the most positive. Thus V^{3+} is the most (thermodynamically) stable species of vanadium / +3 is the most stable oxidation state of vanadium.

Or V^{3+} will not undergo redox (i.e. oxidation (to VO^{2+}) and reduction (to V^{2+})) easily **[1]**

(c) **(i)** Catholyte chamber: $\underline{VO_2^+ / VO^{2+}}$

Anolyte chamber: $\underline{V^{3+} / V^{2+}}$ **[2]**

(ii) $V^{2+} + VO_2^+ + 2H^+ \rightarrow VO^{2+} + V^{3+} + H_2O$ **[1]**

(iii) From anolyte chamber towards catholyte chamber / Right to left **[1]**

(iv) Increase the concentration of VO_2^+ in the VO_2^+/VO^{2+} redox couple (i.e. catholyte) and/or increase the concentration of V^{2+} in the V^{3+}/V^{2+} redox couple (i.e. anolyte)

or

Attach a number of VRFB cells in series **[1]**

[Total: 12]

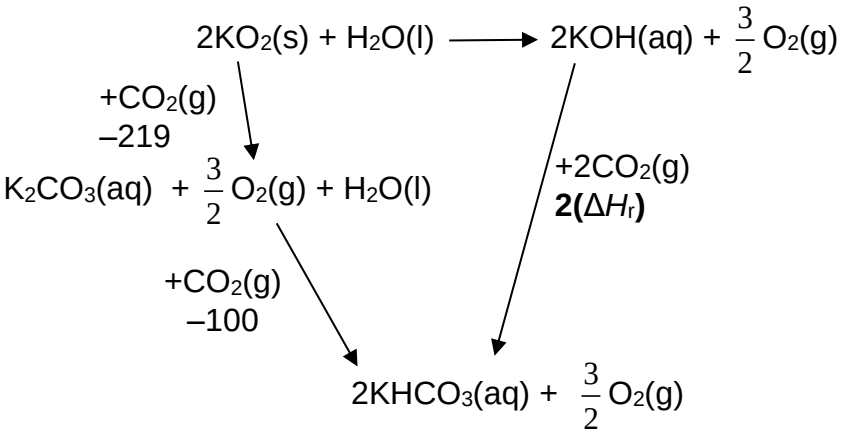
6 **(a)** **(i)** Energy is needed to <u>overcome the repulsion to add an electron to a negatively charged</u> O_2^-, hence the $\Delta H_f(O_2^{2-})$ is more positive than $\Delta H_f(O_2^-)$. **[2]**

ΔH_f (O^{2-}) is highly endothermic/ requires a lot of energy as it involves the <u>breaking of a double bond</u> and the <u>addition of 2 electrons to a single atom/ single $^-O–O^-$ bond requires the addition of an electron to a negatively charged O^-.</u>

(ii) *Enthalpy change* when **1 mole of the solid ionic compound** is formed **from** its **constituent gaseous ions** under standard conditions. **[1]**

(iii) $LE \propto \left|\frac{q_1.q_2}{r_1 + r_2}\right|$. As the <u>charges of O^{2-} and O_2^{2-} are higher than O_2^-,</u> <u>the ionic size of O_2^{2-} is larger than that of O^{2-}</u>**,** the <u>magnitudes of LE of decreases in the order $K_2O > K_2O_2 > KO_2$</u>. **[2]**

(b) **[3]**



By Hess' Law, $2(\Delta H_r) = (-113) + (-219) + (-100)$

$\Delta H_r = -103$ kJ mol^{-1}

(c) **(i)** $\Delta H_{ppt} - T\Delta S_{ppt} = -RT \ln(K_{sp})$ **[1]**

$$\ln(K_{sp}) = \frac{\Delta H}{-RT} + \frac{\Delta S}{R}$$

From graph, gradient = $\frac{-5.3-(-6.3)}{0.0027-0.0035}$ = –1250 K

At (0.0027, –5.3), $-5.3 = -1250(0.0027) + \frac{\Delta S}{R}$

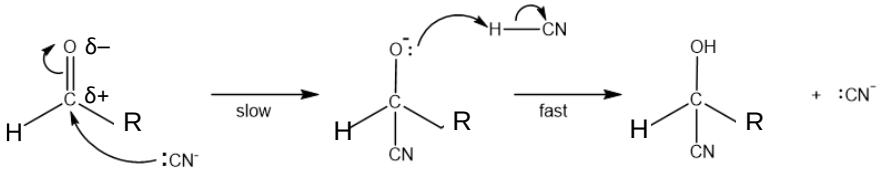
$$\frac{\Delta S}{R} = \frac{\Delta S}{8.31} = -1.925$$

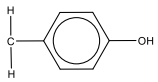
$$\Delta S = -1.925 \times 8.31 = -16.0 \text{ J mol}^{-1}\text{ K}^{-1}$$

(ii) Entropy/ Disorder decreases because there are less ways to distribute the energy/ arrange the ions/ particles as they have to take up fixed positions in the lattice structure. **[1]**

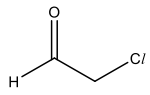
[Total: 10]

7 **(a)** **(i)** $NaCN \longrightarrow Na^+ + CN^-$ **[3]**



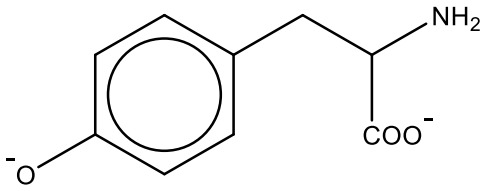
R is 

(ii) step 1

Anhydrous A*l*C*l*$_3$, 

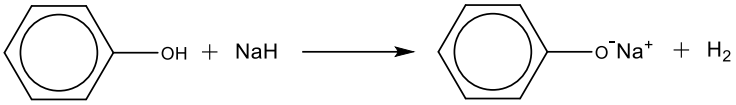
step 3 H_2SO_4 (aq), heat (under reflux) **[3]**

step 5 (excess) alcoholic NH_3, heat in a sealed tube

(b) **(i)** 

[1]

(ii) Use a longer gel plate / Apply a higher voltage / Change the pH / Run for a longer time. **[2]**

(c) **(i)** 

[1]

(ii)

Order of reaction with respect to iodomethane:	1
Justification:	[phenoxide] = 0.10 M, constant half life of 118.0 ± 5 min OR [phenoxide] = 0.15 M, constant half life of 80.0 ± 5 min
Order of reaction with respect to phenoxide:	1
Justification:	When concentration of phenoxide times 1.5, rate/ gradient times 1.5.

[4]

[Total: 15]