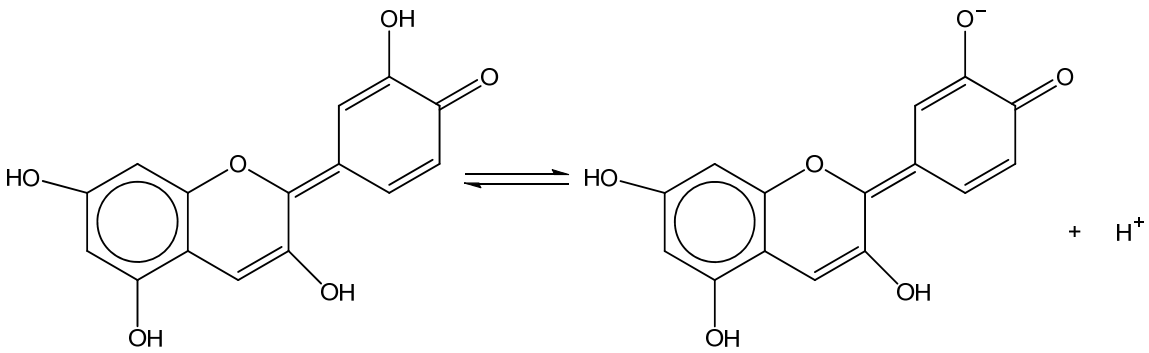
Victoria Junior College
2011 H2 Chemistry Prelim Exam 9647/3
Suggested Answers

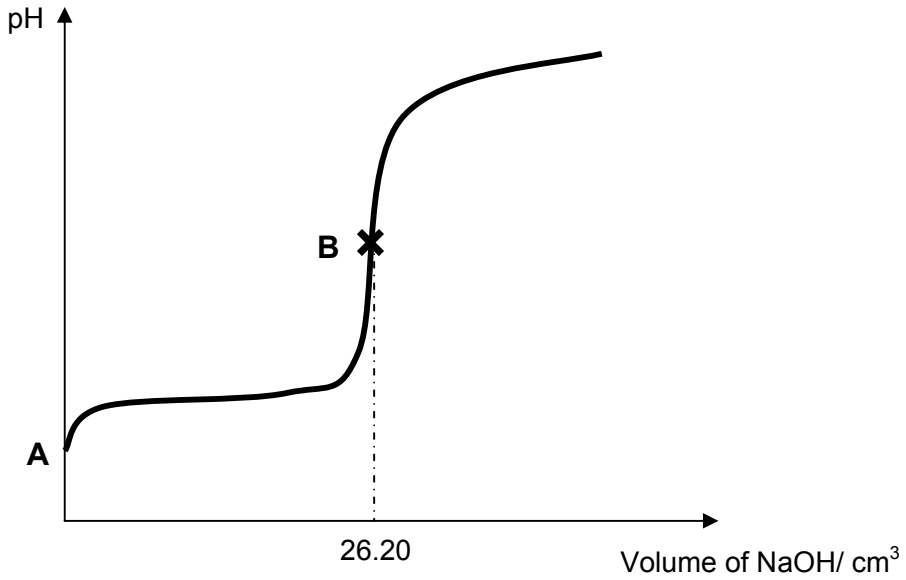
1 Use of the *Data Booklet* is relevant to this question.

Cyanidin is a natural pH indicator that can be found in many red berries, including grapes, blackberry and cherry. Aqueous solutions of cyanidin change colour with pH, appearing red at pH < 3, violet at pH 7-8, and blue at pH > 11. In addition, cyanidins are antioxidants that can scavenge free radicals and counteract ageing caused by oxidative damage in our body tissues and cells.



Cyanidin

Cyanidin (CyH) is a *weak monoprotic acid*. In one experiment, 25.0 cm^3 of cyanidin was titrated against 0.10 mol dm^{-3} of dilute NaOH at 25°C. The following titration curve was obtained using a data logger.



(a)(i) Explain what is meant by a *weak monoprotic acid*, with reference to CyH. [1]

A weak monoprotic acid is an acid that dissociates partially to donate only one proton per acid molecule.

i.e.

$CyH \rightleftharpoons Cy^- + H^+$

(ii) Calculate the molar concentration of the cyanidin solution. [1]

Since $n_{CyH} = n_{NaOH}$,

Conc. of cyanidin = $\frac{0.10 \times 26.20}{25.0}$ = 0.105 mol dm^{-3}

(iii) Given that the solution of cyanidin is only 0.8% dissociated into ions, calculate the value of K_a for cyanidin, stating clearly its units. [2]

$[H^+] = [Cy^-] = 0.008 \times 0.105 = 8.40 \times 10^{-4}$ mol dm^{-3}

$K_a = \frac{[Cy^-][H^+]}{[CyH]}$

$K_a = \frac{(8.40 \times 10^{-4})^2}{0.105}$ = 6.72 x 10^{-6} mol dm^{-3}

[OR 6.77 x 10^{-6} if dissociation of CyH is considered]

(iv) Explain, with the aid of an appropriate equation, why the pH at end-point **B** is greater than 7. [2]

At end-point B, only the conjugate base of the weak acid, Cy^- is present.
$Cy^- + H_2O \rightleftharpoons CyH + OH^-$
Cy^- hydrolyses in water to produce excess OH^- ions. Hence, pH > 7.

(v) Calculate the pH value at end-point **B**. Hence, state the colour change observed at the end-point. [4]

Conc. of salt = $\frac{0.10 \times 26.20}{25.0 + 26.20}$ = 0.0512 mol dm^{-3}

$K_b = \frac{[CyH][OH^-]}{[Cy^-]} = \frac{K_w}{K_a} = \frac{10^{-14}}{6.72 \times 10^{-6}}$ = 1.49 x 10^{-9} mol dm^{-3}

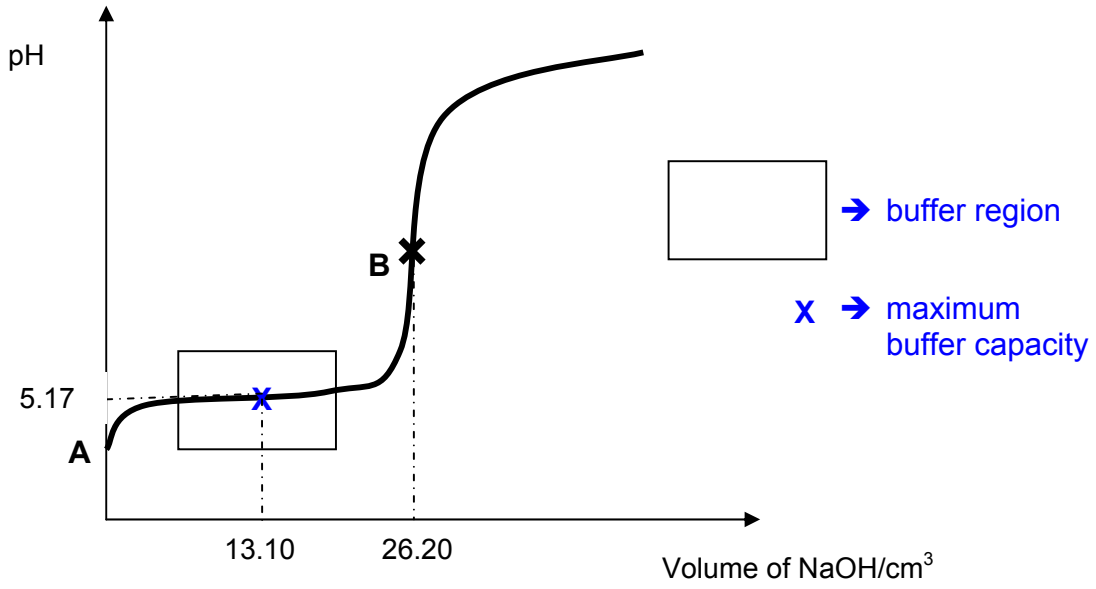
$$\frac{[OH^-]^2}{[Cy^-]} = \frac{[OH^-]^2}{0.0512} = 1.49 \times 10^{-9}$$

$[OH^-] = 8.73 \times 10^{-6}$
pOH = - $\log_{10}$ $[OH^-]$ = 5.06
pH = 14 – pOH = 8.94
Colour change at end-point: violet to blue.

(b) An aqueous solution of cyanidin CyH and Cy^- can act as a buffer.

(i) Copy the titration curve onto your answer script and label
I – the buffer region
II – the point corresponding to maximum buffer capacity by indicating the pH and volume of NaOH added.

[1]



(ii) Explain, with the help of equations, how an aqueous mixture of CyH^+ and Cy can control pH when relatively small amounts of acid or base is added to the solution.

[3]

When a small amount of acid is added,

$$Cy^-(aq) + H^+(aq) \rightarrow CyH(aq)$$

Large reservoir of Cy^- ions from the salt in the buffer remove the additional H^+ ions and the pH of the solution remains almost constant.

When a small amount of base is added,

$$CyH(aq) + OH^-(aq) \rightarrow Cy^-(aq) + H_2O(l)$$

Large reservoir of CyH molecules in the buffer remove the additional OH^- ions and the pH of the solution remains almost constant.

(iii) In a sample of cherry juice at 25°C, the concentration ratio of Cy^- to CyH was found to be 3 to 1. Using the K_a value determined above, calculate the pH value of the cherry juice.

[1]

$$pH = pK_a + \lg \frac{[Cy^-]}{[CyH]}$$

$$= -\lg (6.72 \times 10^{-6}) + \lg \frac{3}{1}$$

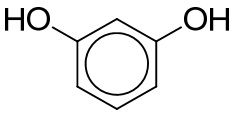
$$= 5.65$$

(iv) Sam tried to dilute the same cherry juice sample by adding 100 cm^3 of deionized water at 25°C. Predict the pH of the resulting sample. [1]

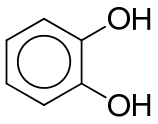
Dilution has no effect on $\frac{[Cy^-]}{[CyH]}$ and K_a.

Thus, pH remains the same at 5.65.

(c) Cyanidin can be synthesized via a number of steps from either of the two molecules shown below:



Molecule P



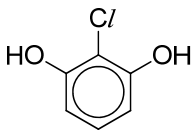
Molecule Q

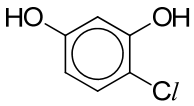
(i) Which molecule **P** or **Q** will have a higher boiling point? Explain your answer. [2]

P will have a higher boiling point as more energy will be required to overcome the stronger inter-molecular hydrogen bonding in P. On the other hand, due to the proximity of the –OH groups in molecule Q, intra-molecular hydrogen bonding predominates. As such, less energy is required to break the weaker dipole-dipole interactions in Q.

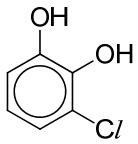
(ii) Draw the structures of all the possible organic products when **P** and **Q** react separately with chlorine in trichloromethane. [2]

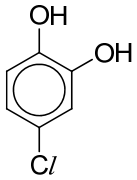
Products formed from P:





Products formed from Q:





[Total: 20]

2

(a) The elements in Period 3 range from metals on the left of the Periodic Table to non-metals on the right. By describing one **physical** property of the element and one **chemical** property of its chloride, explain why phosphorus can be regarded as a non-metal. Write equation(s) where relevant.

Physical property of phosphorus:

Phosphorus does not conduct electricity due to absence of delocalised electrons in its simple molecular structure.
(OR It has low melting point due to weak dispersion forces to be overcome in its simple molecular solid structure.)

Chemical property of PCl_3 *or* PCl_5:

It undergoes hydrolysis to form an acidic solution due to its covalent nature.

$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ *or* $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

[2]

(b)(i) The element aluminium and its compounds have some properties characteristic of metals, and some of non-metals. Aluminium hydroxide, for example, is known to be *amphoteric*. Explain the meaning of the word in italics.

An amphoteric compound is one which reacts with both acids and bases.

Aluminium sulfate and calcium oxide are sometimes added to water supplies to co-precipitate suspended solids and bacteria. A small amount of aluminium-containing ions remains in solution and its presence in drinking water may contribute to the mental illness known as Alzheimer's disease.

(b)(ii) Write a balanced equation for the reaction that occurs when aluminium sulfate and calcium oxide is added to water, given that aluminium hydroxide is one of the products formed.

$Al_2(SO_4)_3 + 3CaO + 3H_2O \rightarrow 2Al(OH)_3 + 3CaSO_4$

(b)(iii) Explain why adding too much calcium oxide would increase the probability of contracting Alzheimer's disease. Write equations for all reactions that occur.

CaO dissolves slightly to form an alkaline solution of $Ca(OH)_2$.
$CaO + H_2O \rightarrow Ca(OH)_2$

OH^- thus formed reacts with $Al(OH)_3$ to form soluble $Al(OH)_4^-$.
$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$

[4]

(c) Explain each of the following as fully as you can. Justify your answers with relevant data from the *Data Booklet*. Write balanced equations, including state symbols, for any reaction that occurs.

(i) HC*l* can be prepared by adding concentrated sulfuric acid to solid sodium chloride. However the yield of HI is very low when concentrated sulfuric acid is added to solid sodium iodide.

$NaCl\,(s) + H_2SO_4(l) \rightarrow NaHSO_4\,(s) + HCl\,(g)$
$NaI\,(s) + H_2SO_4(l) \rightarrow NaHSO_4\,(s) + HI\,(g)$
$8\,HI\,(g) + H_2SO_4(l) \rightarrow 4I_2\,(g) + H_2S\,(g) + 4H_2O\,(l)$

$Cl_2 + 2e \rightleftharpoons 2\,Cl^-$ $E^\theta = +1.36V$
$I_2 + 2e \rightleftharpoons 2\,I^-$ $E^\theta = +0.54V$

I^- is a stronger reducing agent compared to Cl^- (as shown by the less positive E^θ value hence able to reduce H_2SO_4 to H_2S. Hence very little of HI is left behind.

[3]

(ii) When a hot glass rod is plunged into a gas jar of gaseous HI, some violet vapour is seen. On repeating the experiment with HBr, no change is observed.

Hot glass rod able to decompose HI to H_2 and I_2. Purple apour is iodine.

$$2HI\,(g) \rightarrow H_2(g) + I_2\,(g)$$

Reaction involves breaking of H-I bond (BE= 299 $kJmol^{-1}$) which is weaker than the H-Br bond (BE= 366 $kJ\,mol^{-1}$).

[Or HI is easier to decompose as the bond is weaker due to the larger I atom, hence bond length is longer.]

[2]

(d) Tetraethyl-lead (IV), $Pb(C_2H_5)_4$, is an example of an organometallic compound. It can be used as an antiknock agent in petrol. At the high temperature in a car engine, the Pb-C bond in $Pb(C_2H_5)_4$, breaks to yield lead atoms and ethyl radicals.

(i) By using VSEPR theory, predict the shape of the $Pb(C_2H_5)_4$ molecule.

Tetrahedral (4 bp & no l lp, equal repulsion between the 4 bp)

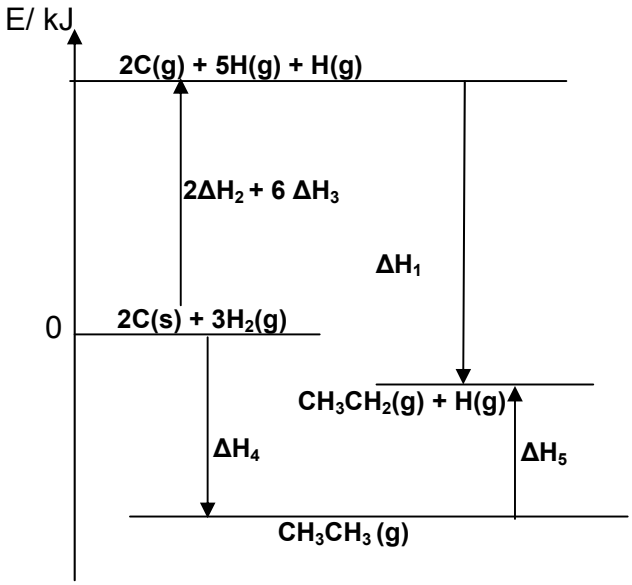
[1]

(ii) Using only the data provided below, draw an *energy level* diagram to calculate ΔH_1, the enthalpy change of the following reaction:

$$2C(g) + 5H(g) \rightarrow CH_3CH_2\bullet(g)$$

Data:

Enthalpy change of atomization of C(s), ΔH_2	+717 kJ mol^{-1}
Enthalpy change of atomization of H_2(g), ΔH_3	+218 kJ mol^{-1}
Enthalpy change of formation of CH_3CH_3(g), ΔH_4	–85 kJ mol^{-1}
Bond dissociation energy of the first C-H bond in CH_3CH_3(g), ΔH_5	+435 kJ mol^{-1}



By Hess's Law,

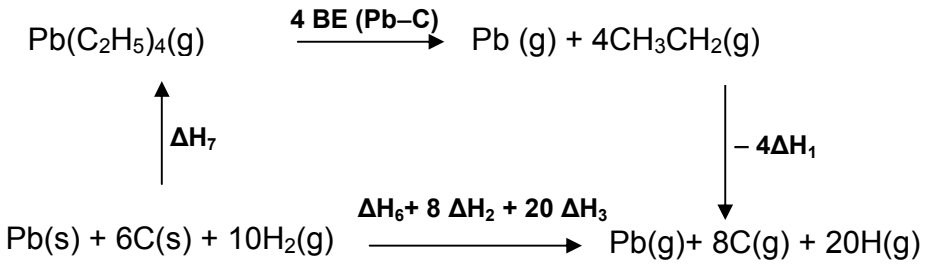
$$\Delta H_1 = \Delta H_4 + \Delta H_5 - 2\Delta H_2 - 6\Delta H_3$$
$$= 435 + (-85) - 2(717) - 6(218)$$
$$= -2392 \text{ kJ mol}^{-1}$$

[2 +1]

(iii) Hence, with the aid of the data in **(ii)** and additional data given below, draw an energy cycle to calculate the Pb-C bond energy in $Pb(C_2H_5)_4$.

Data:

Enthalpy change of atomization of Pb(s), ΔH_6	+195 kJ mol^{-1}
Enthalpy change of formation of $Pb(C_2H_5)_4(g)$, ΔH_7	+264 kJ mol^{-1}



By Hess's Law,

4 BE (Pb–C) $= 4\Delta H_1 + \Delta H_6 + 8\Delta H_2 + 20\Delta H_3 - \Delta H_7$
$= 4(-2392) + 195 + 8(717) + 20(218) - 264$
$= 459$ kJ
Mean Pb-C bond energy = 459/4 = 115 kJ mol^{-1}

[2+1]

(e) The ethyl radical formed in **(d)** reacts readily with chlorine gas to give chloroethane. Another possible product is 1, 2-dichloroethane.
Outline the steps in the mechanism to show the formation of 1, 2-dichloroethane, starting from chlorine gas and ethyl radical.

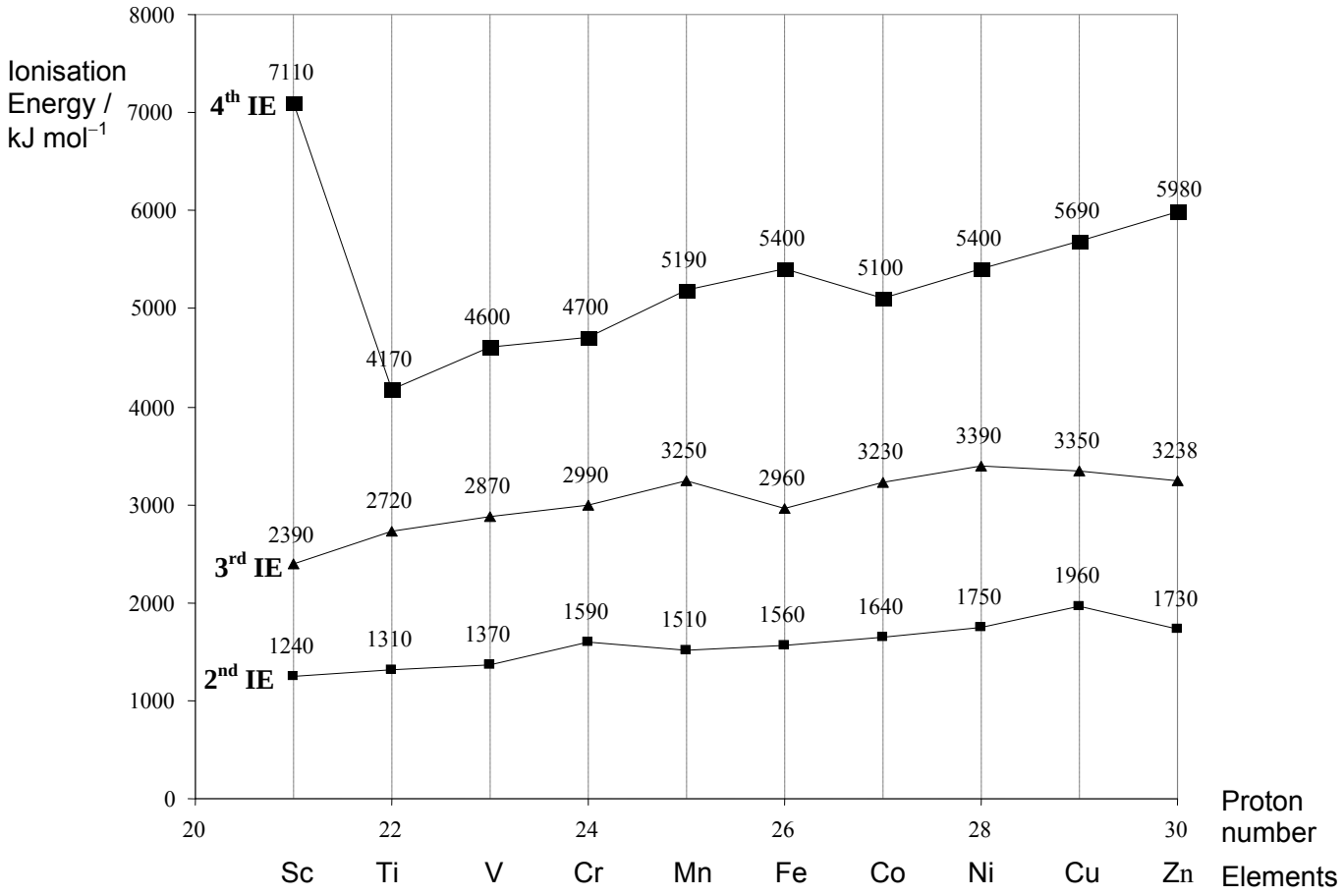
$CH_3CH_2\bullet + Cl_2 \rightarrow CH_3CH_2Cl + Cl\bullet$
$CH_3CH_2Cl + Cl\bullet \rightarrow \bullet CH_2CH_2Cl + HCl$
$\bullet CH_2CH_2Cl + Cl_2 \rightarrow ClCH_2CH_2Cl + Cl\bullet$

[2]

[Total: 20]

3 This question is about the transition elements and their compounds.

(a) The graph below shows the second to fourth ionisation energies for the first row d–block elements scandium to zinc.



(i) Explain what is meant by the term *transition element*. [1]

A transition element (or transition metal) is a d-block element that forms at least one ion with partially filled d orbitals.

(ii) Give an equation each to represent the second ionisation energy of chromium and the fourth ionisation energy of iron respectively. [1]

$Cr^{+}(g) \rightarrow Cr^{2+}(g) + e^{-}$

$Fe^{3+}(g) \rightarrow Fe^{4+}(g) + e^{-}$

***Must include state symbols in the equations to denote nth ionisation energy.**

(iii) Explain briefly why the second ionisation energy of chromium is higher than that of manganese. [2]

Cr^+ = $[Ar]3d^5$, Mn^+ = $[Ar]3d^54s^1$
The second electron removed from manganese is a 4s−electron while the second electron removed from chromium is a 3d−electron.
Since a 3d−electron is closer to the nucleus and has lower energy, more energy is required to remove it, causing second ionisation energy of Cr to be higher than that of Mn.

(iv) Explain briefly why the fourth ionisation energy of cobalt is lower than that of iron. [2]

Fe^{3+}= $[Ar]3d^5$, Co^{3+} =$[Ar]3d^6$
The 4th electron from Co is removed from one d orbital containing a pair of electrons while the 4th electron from Fe is removed from a singly occupied d orbital. Despite the higher effective nuclear charge of Co^{3+} as compared to Fe^{3+}, the removal of the 4th electron from Co is aided by inter-electronic repulsion. Hence, the 4th ionisation energy of Co is lower than that of Fe.

(b) *The use of the Data Booklet is relevant to this question.*

In one experiment, when aqueous iron(III) sulphate is boiled with an excess of potassium cyanide, a red solution **A** is obtained. In another experiment, when aqueous iron(III) sulphate is added to aqueous potassium iodide, a brown solution **B** is obtained.

Solution **B** is found to catalyse the reaction between iodide and peroxodisulphate, $S_2O_8^{2-}$, whereas solution **A** does not affect the rate of this reaction.

When aqueous sodium thiosulfate is added to solution **B** followed by aqueous sodium hydroxide, the brown colour is discharged and a green precipitate is observed. On standing, the green precipitate turns red-brown.

Explain these observations as fully as you can, with the aid of equations and reference to relevant $E^{\ominus}$ values. [9]

Solution A containing complex ion, $[Fe(CN)_6]^{3-}$, is formed between Fe^{3+} and excess CN^-. Ligand exchange reaction occurs to form a more stable complex.
$[Fe(H_2O)_6]^{3+} + 6CN^- \leftrightarrows [Fe(CN)_6]^{3-} + 6H_2O$
When Fe^{3+} is added to I^-, I^- is oxidised to brown iodine by Fe^{3+} while Fe^{3+} is reduced to Fe^{2+}. Hence, solution B contains iodine and Fe^{2+}. This redox reaction is feasible as E^o_{cell} = 0.77 – 0.54 = +0.23V > 0
$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

Solution B containing Fe^{2+} can act as a homogenous catalyst for the reaction between iodide and $S_2O_8^{2-}$ as its redox potential of 0.77V lies between that of $E^o(I_2|I^-)$= 0.54V and E^o ($S_2O_8^{2-}/SO_4^{2-}$)= 2.01V.

The activation energy for the reaction between iodide and peroxodisulphate, $S_2O_8^{2-}$ is lowered as reactions are now between oppositely charged ions and are not between two negatively charged ions.

The catalysed pathway involves 2 steps with each step having a lower activation energy:

Step 1: $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $\quad E^o_{cell}$ = +1.24 V

Step 2: $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ $\quad E^o_{cell}$ = +0.23 V

However, solution A contains complex ion, $[Fe(CN)_6]^{3-}$. The redox potential of $E^o([Fe(CN)_6]^{3-}|[Fe(CN)_6]^{4-})$ is +0.36V, which is not within the required range. Furthermore, both $[Fe(CN)_6]^{3-}$ and I^- are negatively charged and the activation energy of such a reaction is still high.

When aq. $Na_2S_2O_3$ is added to solution B containing I_2, a redox reaction occurs in which I_2 is reduced to I^-, hence brown colour of I_2 is discharged.

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

When aq. NaOH is added to solution B containing Fe^{2+} ions, a green precipitate of $Fe(OH)_2$ is formed.

$Fe^{2+}(aq) + 2OH^-(aq) \leftrightarrows Fe(OH)_2(s)$

$4Fe(OH)_2(s) + O_2 + 2H_2O \rightarrow 4Fe(OH)_3(s)$

This redox reaction is feasible as E^o_{cell} = 0.40 – (–0.56) = +0.96V > 0

Hence $Fe(OH)_2$ is oxidised by air to red-brown $Fe(OH)_3$.

[Total: 10, Max: 9]

(c) Cobalt is one of the transition elements which is capable of complex ion formation.

(i) Ethylenediamine, $NH_2CH_2CH_2NH_2$, is a ligand that can form a complex with Co^{3+} ions in the mole ratio of 3:1. Deduce the formula of the cobalt-containing complex ion and state its shape. [3]

Since there is 1 lone pair electrons on each N atom in $NH_2CH_2CH_2NH_2$, one $NH_2CH_2CH_2NH_2$ molecule can form 2 dative bonds with central Co^{3+} in the complex. With 3 $NH_2CH_2CH_2NH_2$ bonded to 1 Co^{3+} in the complex, there will be a total of 6 dative bonds formed between the ligands and Co^{3+}. Hence, the formula of the complex is $[Co(NH_2CH_2CH_2NH_2)_3]^{3+}$ and the shape of the complex ion is octahedral.

(ii) $[Co(NH_3)_6]^{3+}$ appears yellow-brown while $[CoF_6]^{3-}$ appears blue. Explain the difference in colour. [2]

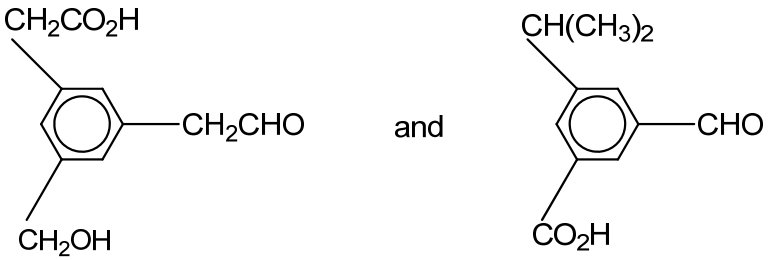
Different ligands have different ligand strength and thus the d orbitals are split to different extent/ energy gap, ΔE.
NH_3 ligand results in a larger ΔE and shorter λ absorbed. Thus, $[Co(NH_3)_6]^{3+}$ is yellow-brown. F^- ligand results in a smaller ΔE and longer λ absorbed. Thus, $[CoF_6]^{3-}$ appears blue.

[Total: 20]

4 (a) Suggest methods by which the following pairs of compounds could be distinguished from each other by simple chemical tests.

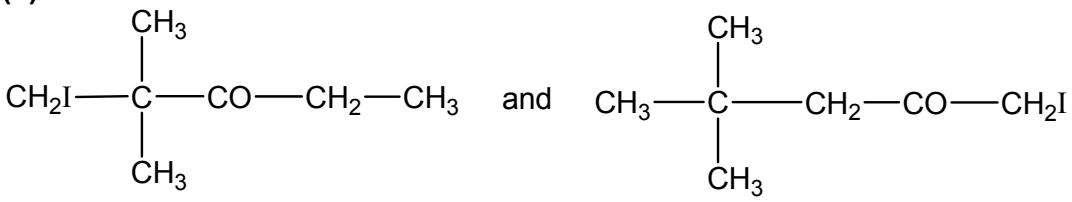
For each case, **no more than two steps** should be used.

(i)



Add Fehling's solution and warm.
The 1st compound gives a brick red ppt while the 2nd compound gives no ppt.

(ii)



Add aqueous I_2 and NaOH. Warm to <70°C.
2nd compound gives a pale yellow ppt while the 1st compound gives no ppt.

(iii) $CH_3CH_2CH{=}CHCH_2C(CH_2CH_3){=}CH_2$ and $CH_3CH_2CH_2CH{=}CHCH{=}CHCH_2CH_3$

Add acidified $KMnO_4$(aq) to each compound and heat
Add 2, 4–dinitrophenylhydrazine at room temperature to the resulting mixture.
1st compound gives an orange ppt while the 2nd compound gives no ppt.

[7]

(b) **D** ($C_{10}H_8O_2$) is a neutral compound. On heating with aqueous NaOH followed by acidification, **D** yields only one organic product, **E** ($C_{10}H_{10}O_3$), which is soluble in aqueous Na_2CO_3. When **E** is treated with H_2 and Ni, **F** ($C_{10}H_{12}O_3$) is formed. Unlike **E**, **F** does not display cis-trans isomerism.

1 mol of **F** is found to decolorize exactly 2 mol of aqueous Br_2. Upon reaction with $LiAlH_4$ in dry ether, **F** forms the compound **G**. **G** is no longer soluble in Na_2CO_3. When **G** is passed over hot Al_2O_3, **H** is produced.

H reacts with gaseous HCl to give the major product, **I**. **I** exists as optical isomers. On warming **I** with aqueous $AgNO_3$, a white precipitate is formed together with an organic product which does not change the colour of acidified $K_2Cr_2O_7$ solution.

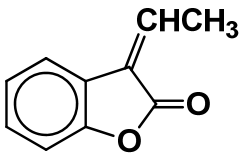
Deduce the structures of all the lettered compounds (**D** to **I**) and explain the reactions involved.

Evidence	Deduction
D ($C_{10}H_8O_2$)	**High C:H ratio shows that D has a benzene ring.**
D + aq NaOH → E	**D is hydrolysed.** **Since only E is formed, D is a cyclic ester.**
E soluble in Na_2CO_3.	**E undergoes acid-base reaction and contains $-CO_2H$.**
E displays cis-trans isomerism whereas F does not.	**E has C=C with 2 different groups attached to each C of the alkene group.** **Alkene in E is reduced to alkane in F.**
1 mol F reacts with 2 mol aq Br_2	**F contains phenol group which activates the benzene ring.** **Hence, it undergoes electrophilic substitution readily.** **2 mol of Br_2 are required since a cyclic phenolic ester forms a 1, 2-disubstituted ring.**
F + $LiAlH_4$ → G **G not soluble in Na_2CO_3**	**G does not contain $-CO_2H$.** **Hence $-CO_2H$ in F is reduced to give primary alcohol in G.**
G + Al_2O_3 → H	**Elimination / dehydration takes place.** **H is an alkene.**
H + HCl → I	**Electrophilic addition takes place.**
I – optical isomers	**I possesses a chiral centre.**

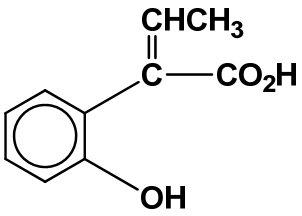
I + aq $AgNO_3$ → white ppt + org product	**White ppt is AgCl. I is confirmed to be a halogenoalkane.** **I undergoes nucleophilic substitution with water to form an alcohol.** **Since the organic product is not oxidized, alcohol formed is tertiary OR I is a tertiary halogenoalkane.**

Structures [1m each]

D



E



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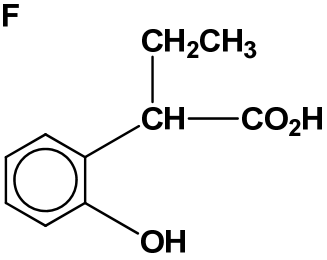

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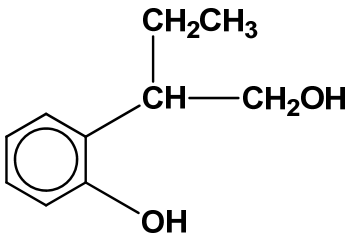

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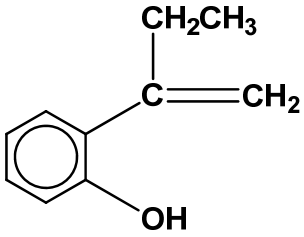

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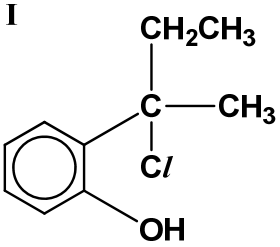


[Total 15, max 13]

[Total: 20]

5 (a) Sucrose is the most common natural food sweetener, often known as table sugar. In acidic solutions, sucrose is readily hydrolysed to a 1:1 mixture of glucose and fructose. The reaction is catalysed by aqueous H^+ ions.

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+(aq)} C_6H_{12}O_6 + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

A series of experiments was carried out at 25°C to investigate the kinetics of this reaction, using 0.79 mol dm^{-3} sucrose solution and 1.25 mol dm^{-3} hydrochloric acid.

The following data were obtained:

Expt	Volume of sucrose /cm^3	Volume of HC*l* /cm^3	Volume of water /cm^3	Initial rate of reaction /mol dm^{-3} min^{-1}
1	20	20	10	1.25×10^{-3}
2	20	30	0	1.88×10^{-3}
3	10	30	10	9.38×10^{-4}
4	40	20	10	**?**

(i) Using the data given above, determine the order of reaction with respect to sucrose and HC*l*.

Hence, determine the rate equation and calculate a value for the rate constant of the reaction, stating its units.

Compare Expts 1 and 2:
When V_{HCl} or [HC*l*] increases by 1.5 times ($V_{HCl} \propto$ [HC*l*] since total volume of solution is constant)
$\Rightarrow$ rate increases by $\frac{0.00188}{0.00125}$ = 1.5 times.
Hence reaction is first order with respect to HC*l*.

Compare Expts 2 and 3:
When $V_{sucrose}$ or [sucrose] decreases by 0.5 times ($V_{sucrose} \propto$ [sucrose] since total vol of solution is constant)
$\Rightarrow$ rate decreases by ($\frac{0.000938}{0.00188} = 0.499$ ≈ 0.5 times.
Hence reaction is first order with respect to sucrose.

rate = *k*[sucrose][HC*l*]

From Expt 1,
[sucrose] = 0.79 × 20/50 = 0.316 mol dm^{-3}
[HC*l*] = 1.25 × 20/50 = 0.500 mol dm^{-3}

$\therefore k = \dfrac{0.00125}{0.316 \times 0.500}$ = **7.91 x 10^{-3} mol^{-1} dm^3 min^{-1}**

OR

From Expt 2,
[sucrose] = 0.79 × 20/50 = 0.316 mol dm^{-3}
[HC*l*] = 1.25 × 30/50 = 0.750 mol dm^{-3}

$\therefore k = \dfrac{0.00188}{0.316 \times 0.750}$ = **7.93 x 10^{-3} mol^{-1} dm^3 min^{-1}**

OR

From Expt 3,
[sucrose] = 0.79 × 10/50 = 0.158 mol dm^{-3}
[HC*l*] = 1.25 × 30/50 = 0.750 mol dm^{-3}

$\therefore k = \dfrac{0.000938}{0.158 \times 0.750}$ = **7.92 x 10^{-3} mol^{-1} dm^3 min^{-1}**

(ii) Using your answer in **(i)**, deduce the initial rate of reaction for Experiment **4**.

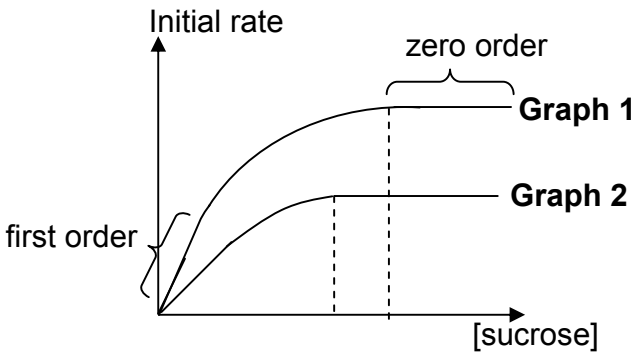
From Expt 4,
[sucrose] = 0.79 × 40/70 = 0.451 mol dm^{-3}
[HC*l*] = 1.25 × 20/70 = 0.357 mol dm^{-3}

$\therefore$ Initial rate = 7.91 x 10^{-3} × 0.451 × 0.357
= 1.27 x 10^{-3} mol dm^{-3} min^{-1}

[6]

(b) In bacteria, sucrose is broken down into glucose and fructose by the enzyme, *invertase*. A few experiments were carried out to measure the initial rate of the enzyme-catalysed hydrolysis reaction for different concentrations of sucrose.

(i) Sketch a graph to show how the initial rate of this enzyme-catalysed hydrolysis reaction varies with different concentration of sucrose. Label your graph as **Graph 1**.



(ii) Explain the shape of **Graph 1**, making reference to the order of reaction with respect to sucrose.

At low [sucrose], reaction is first order wrt sucrose due to availability of active sites on enzyme for binding.

As [sucrose] increases, more active sites on enzyme molecules are occupied by sucrose molecules. Hence, reaction is no longer first order wrt sucrose (mixed order).

At high [sucrose], all active sites of enzyme molecules will be occupied by sucrose molecules and become saturated. Further increase in [sucrose] will no longer increase the reaction rate. Hence, reaction is zero order wrt to sucrose.

(iii) On the same axes in **(b)(i)**, sketch another graph to show how the initial rate will vary with the concentration of sucrose if the reaction mixtures were contaminated with *trace* amounts of Ag^+ ions. Label this graph as **Graph 2**.

[See graph above]

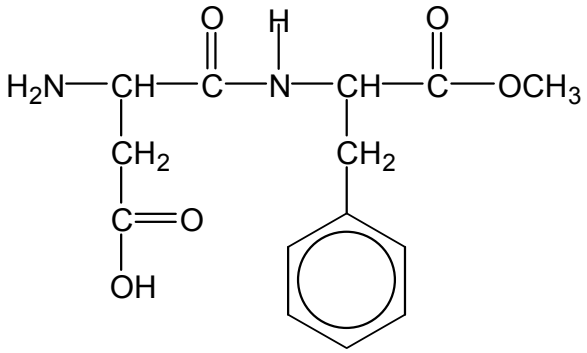
(iv) What causes the shape of **Graph 2** to be different from **Graph 1**? Explain your answer.

Trace amounts of Ag^+ disrupt some ionic bonds in the enzyme as they combine with anionic R groups such as $-COO^-$.
[OR Ag^+ form bonds with S thus disrupting disulphide bonds between cysteine residues.]
This causes part of the enzyme to uncoil resulting in enzyme denaturation which causes a reduction in the number of active sites.

[7]

(c) Aspartame, an artificial sweetener, is about 200 times sweeter than sucrose.

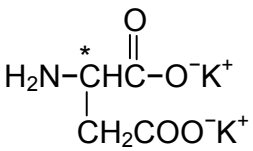
The structure of aspartame is as follows:

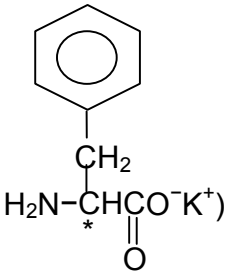


(i) Predict and explain whether aspartame is soluble in water, making reference to its structure and bonding.

Aspartame exists as zwitterions with opposite charged ions $-CO_2^-$ and $-NH_3^+$ held together by strong ionic bonds in the giant lattice.
It can form strong ion-dipole interactions with water, which liberates sufficient energy to overcome the hydrogen bonds in water as well as ionic bonds in aspartame and is thus soluble in water.

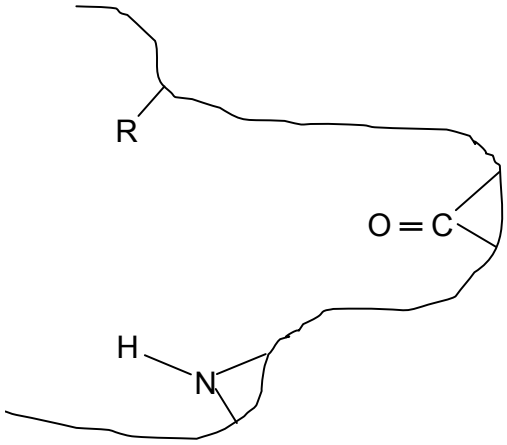
(ii) Draw the structural formulae of all the organic products formed when aspartame is boiled with aqueous KOH, labelling with an asterisk any chiral carbon atom in each product.





CH_3OH

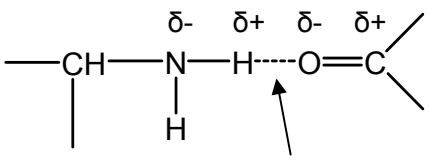
(iii) Scientists believe that molecules which promote the sensation of sweetness fit into a receptor site in the taste buds on the tongue, which is essentially a protein molecule. A simplified diagram of the receptor site is shown below.

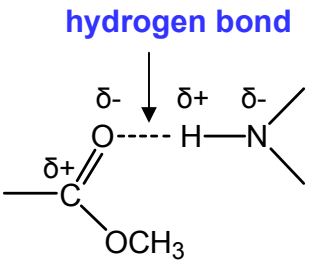


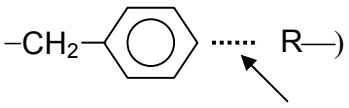
R = non-polar group

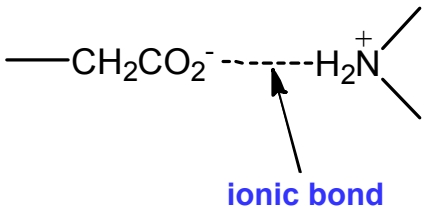
State **two** different types of interactions that can be formed between an aspartame molecule and the receptor protein. Illustrate your answer with labelled diagrams.

2 diagrams to illustrate 2 different interaction types:









[7]

[Total: 20]