Suggested Answer for SH2 H2 Chemistry 2019 Prelim Paper 3

Section A
Answer **all** the questions from this section.

1 Potassium is an element found in Period 4 of the Periodic Table.

(a) **(i)** Write an equation for the second ionisation energy of potassium. [1]

$K^+(g) \rightarrow K^{2+}(g) + e^-$
Must show state symbol

(ii) Fig 1.1 shows the second ionisation energy for the consecutive elements from Period 3 and Period 4.

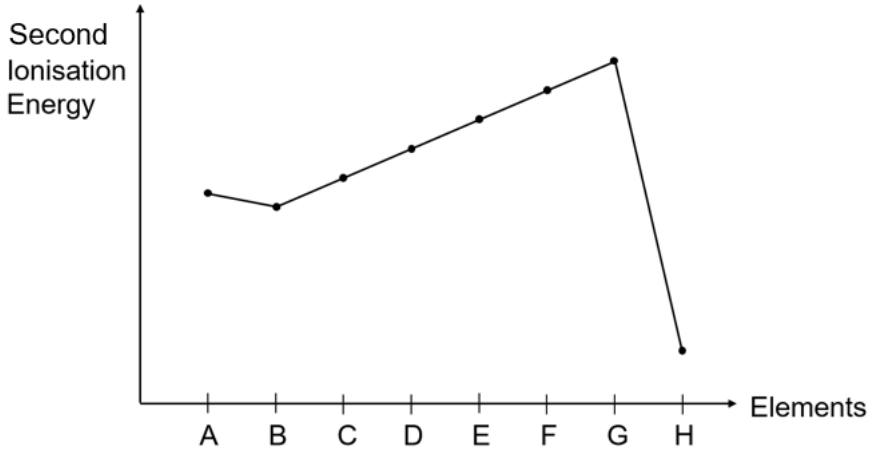


Fig 1.1

Suggest which of the above elements, **A** to **H**, is potassium. [2]
The second electron of potassium is removed from the **3p subshell (inner quantum shell)** as compared to the second electron of calcium which is removed from the **4s subshell (outer quantum shell)**. **Much more energy is required** to remove the second electron from K as compared to Ca. Hence **element G is potassium**.

Note: It is insufficient to mention that 2nd I.E. of K is much higher than 1st I.E. as the comparison with 1st I.E. is not reflected in Fig 1.1

(b) When 0.400 g of potassium dichromate(VI), $K_2Cr_2O_7$, was heated using a strong flame, a yellowish green solid mixture was obtained and a gas was evolved. The gas collected ignited a glowing splint. Upon adding water to the yellowish green solid, part of the solid dissolved to give a yellow solution of K_2CrO_4, leaving a green solid.

(i) State the identity of the gas. [1]
Oxygen gas.

(ii) The green solid that remained was collected and dried. It weighed 0.052 g and was found to be 68.4% chromium by mass and contains only chromium and oxygen.

Determine the chemical formula of the green solid. [2]

	Cr	O
Mass	$\frac{68.4}{100} \times 0.052 =$ 0.03557	$\frac{31.6}{100} \times 0.052 =$ 0.01643
A_r	52.0	16.0
Moles	0.000684	0.001027
÷ by smallest no.	1	1.5
Mol ratio	2	3

Hence chemical formula is Cr_2O_3

(iii) Using your answers to **b(i)** and **b(ii)**, write the equation for the decomposition of potassium dichromate(VI). [1]

$4K_2Cr_2O_7 \rightarrow 4K_2CrO_4 + 2Cr_2O_3 + 3O_2$

(c) State **two** physical properties of chromium that differs from calcium.
Explain the reasons for those differences. [2]

TM has **higher density** due to **larger atomic mass and smaller radius giving rise to dense close-packed structure** (allowing more small size but heavy atoms to be packed within a specific volume.)

TM has **higher melting point** due to **more delocalised electrons contributed from 3d and 4s subshells**, resulting in **stronger metallic bonding**.

TM has **higher electrical/heat conductivities** due to **more delocalised electrons contributed from 3d and 4s subshells**.

Note: Variable oxidation states and reactions to give coloured complexes are **chemical** properties.

(d) Vanadate(V) ion, VO_3^-, changes into pale yellow oxovanadium(V) ions, VO_2^+, when acid is added. Upon addition of excess zinc, the pale yellow solution changes to blue, to green and finally to violet.

(i) With the aid of an equation, explain the type of reaction that occurs when vanadate(V) ion changes into oxovanadium(V) ions. [2]

$VO_3^- + 2H^+ \rightarrow VO_2^+ + H_2O$
Acid-base reaction

(ii) Explain why vanadium is able to exhibit variable oxidation states. [1]

Because of the **close proximity** in energy of the 4s and 3d electron in V, it is able to **lose electrons from both the 3d and 4s subshells**, hence it can exhibit variable oxidation states.

(iii) With the aid of the *Data Booklet*, deduce the final oxidation state of vanadium in the violet solution. [3]

$Zn^{2+} + 2e^- \rightleftharpoons Zn \quad E^\ominus = -0.76\ V$

$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O \quad E^\ominus = +1.00\ V$

Reaction between VO_2^+ and Zn,

$E^\ominus = +1.00 - (-0.76)$

$= +1.76\ V > 0$ (reaction is feasible)

$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O \quad E^\ominus = +0.34\ V$

Reaction between VO^{2+} and Zn,

$E^\ominus = +0.34 - (-0.76)$

$= +1.10\ V > 0$ (reaction is feasible)

$V^{3+} + e^- \rightleftharpoons V^{2+} \quad E^\ominus = -0.26\ V$

Reaction between V^{3+} and Zn,

$E^\ominus = -0.26 - (-0.76)$

$= +0.50\ V > 0$ (reaction is feasible)

$V^{2+} + 2e \rightleftharpoons V \quad E^\ominus = -1.20\ V$

Reaction between V^{2+} and Zn,

$E^\ominus = -1.20 - (-0.76)$

$= -0.44\ V < 0$ (reaction is NOT feasible)

Hence final oxidation state of V is +2

Note: It is important to show that V^{2+} do not undergo further reduction when excess Zn is present.

Solid vanadium(V) oxide, V_2O_5, is used as a catalyst for reaction 1.

reaction 1: $SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3(g)$

(iv) State the type of catalysis and outline the mode of action when V_2O_5 is used for reaction 1. [3]

Heterogeneous catalysis is involved in the reaction:

Reactants are **adsorbed** on the surface of the catalyst; the reactant molecules are **brought closer together with correct orientation** and the **bonds to be broken are weakened, thus E_a for the reaction is lowered**.

The products formed **desorb** and leave the surface of the catalyst.

(v) NO_2 can also act as a catalyst for reaction 1.

Write two equations to show how NO_2 acts as a catalyst in reaction 1. [2]

$NO_2 + SO_2 \rightarrow SO_3 + NO$

$NO + ½\ O_2 \rightarrow NO_2$

Note: Eqns can be found under Org Book 1 > Alkane > Environmental pollutants.
NO_2 is acting as a homogeneous catalyst and it should produce a gaseous intermediate during catalysis.

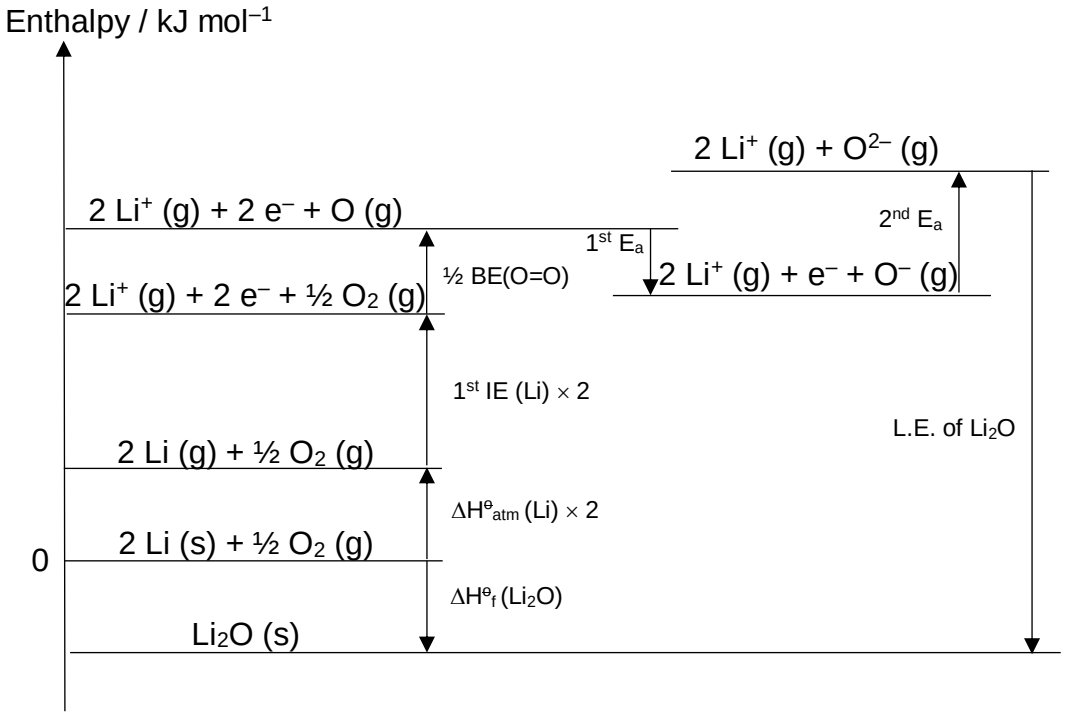
[Total : 20]

2 Lithium oxide, Li_2O, is used in traditional ceramic glazing to create a blue hue with copper on ceramics.

(a) Using the data below and any appropriate data from the *Data Booklet*, construct a labelled energy level diagram to calculate the standard enthalpy change of formation of $Li_2O(s)$.

	/ kJ mol^{-1}
first electron affinity of oxygen	–141
second electron affinity of oxygen	+798
lattice energy of lithium oxide	–2863
standard enthalpy change of atomisation of lithium	+159

[5]



- **State symbol**
- **Balanced equation**
- **Correct enthalpy change**

By Hess' Law,

$\Delta H^{\ominus}_f (Li_2O) = 2[\Delta H^{\ominus}_{atm} (Li)] + 2[1^{st} IE (Li)] + \Delta H_{atm} (O_2) + 1^{st} E_a (O) + 2^{nd} Ea (O) + L.E.$

$= 2(+159) + 2(+519) + ½ (+496) + (–141) + (+798) + (–2863)$

$= –602 \text{ kJ mol}^{-1}$

(b) Lithium oxide is produced during the thermal decomposition of lithium peroxide, Li_2O_2, at 450 °C.

$$Li_2O_2(l) \longrightarrow Li_2O(s) + \frac{1}{2}O_2(g)$$

(i) Given that the standard enthalpy change of formation of $Li_2O_2(l)$ is –606 kJ mol^{-1} and using your answer in **(a)**, calculate the enthalpy change for the thermal decomposition of Li_2O_2. [1]

enthalpy change for the thermal decomposition of Li_2O_2
$= \sum\Delta H^{\ominus}_f$ (products) – $\sum\Delta H^{\ominus}_f$ (reactants)
$= \Delta H^{\ominus}_f (Li_2O) + \Delta H_f (O_2) - \Delta H^{\ominus}_f (Li_2O)$
$= (-602) + 0 - (-606)$
$= +4$ kJ mol^{-1}

(ii) Explain why the thermal decomposition of Li_2O_2 is feasible. [2]

$\Delta G = \Delta H - T\Delta S$
The increase in the entropy ($\Delta S > 0$) from the production of O_2 gas and the elevated temperature readily offset the slightly endothermic enthalpy change causing ΔG to be negative, hence the reaction is feasible.

(c) Table 2.1 gives the melting points of two lithium ionic compounds.

compound	melting point / °C
Li_2O	1400
Li_2O_2	195

Table 2.1

Explain the difference in the melting points. [2]

$|L.E| \propto \frac{q_+ \times q_-}{r_+ + r_-}$

Both Li_2O and Li_2O_2 have the **same Li^+ cation**, but different anion. Since **O_2^{2-}** in Li_2O_2 has a **larger ionic radius** as compared to the **O^{2-}** in Li_2O with a **smaller ionic radius**, the **magnitude of the lattice energy of Li_2O_2** is **smaller** **(or lattice energy of Li_2O_2 is less exothermic)** than that of Li_2O. Hence, **less energy is need to overcome the weaker ionic bond** in Li_2O_2 resulting in lower melting point.

(d) Similar to lithium peroxide, Li_2O_2, lithium nitrate, $LiNO_3(s)$, undergoes thermal decomposition to produce oxygen and a brown gas.

(i) Write a balance equation, with state symbols, for the thermal decomposition of lithium nitrate. [2]

$2LiNO_3(s) \rightarrow Li_2O(s) + 2NO_2(g) + \frac{1}{2}O_2(g)$

(ii) Among the Group 1 metal nitrates, only lithium nitrate undergoes thermal decomposition.

Explain why lithium nitrate can undergo thermal decomposition. [2]

Although Li^+ ion has a singly positively charge, but it has the **smallest ionic radius** among the Group 1 metal ions. Therefore, Li^+ ion, with a **high** $\frac{\text{charge}}{\text{size}}$ **ratio, polarises/distorts the electron cloud of NO_3^- anion** and **weakens the N–O bond** in NO_3^-. Hence, $LiNO_3$ undergoes thermal decomposition, but not other Group 1 metal nitrate.

(e) Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a chelating agent that is widely used to remove transition metal ions such as copper(II) ions from aqueous solutions.

(i) Suggest a synthesis of ethylenediamine tetraacetate, $[EDTA]^{4-}$, starting from methanal and 1,2−diaminoethane ($NH_2CH_2CH_2NH_2$), according to the scheme in Fig. 2.1. Deduce the structure of compound **A**. Include reagents and conditions for all reactions, and the structures of all other intermediate compounds, in your answer.

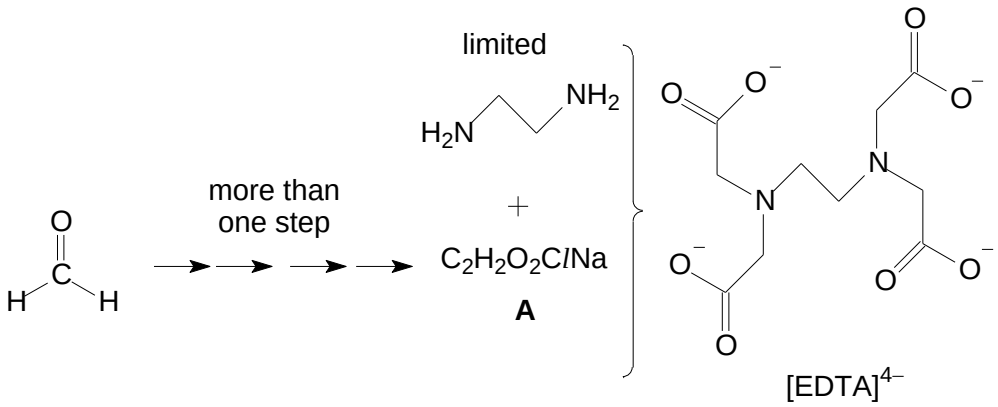
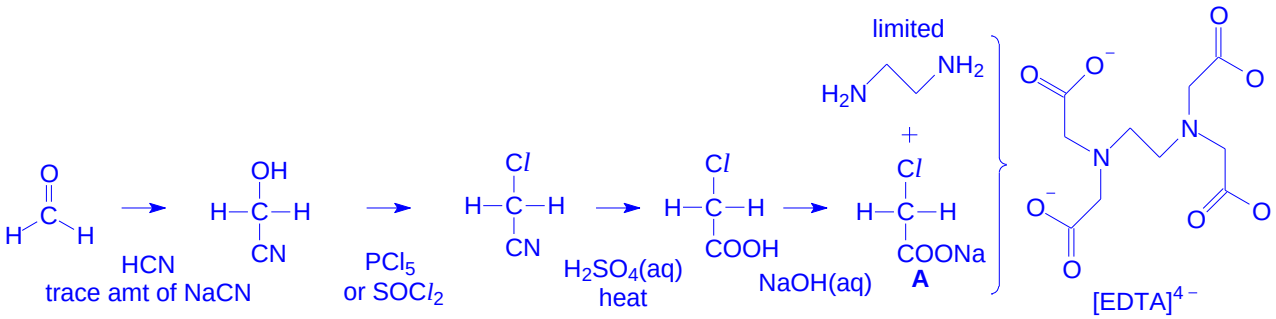


Fig 2.1

[5]



(ii) When aqueous ammonia is added to a solution of $CuSO_4$, a blue precipitate is formed which dissolves in excess aqueous ammonia to give a deep blue solution. On addition of Na_4(EDTA) solid to the mixture, the colour of the solution turns light blue.

Suggest explanations for the above observations, writing equations as appropriate. [3]

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

Precipitation of $Cu(OH)_2(s)$ occurs.
$[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s) + 6H_2O(l)$ ---- Eqm (1)
blue soln blue ppt

Blue ppt dissolves due to formation of tetraamine copper(II) complex
$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$
blue ppt deep blue

or
$[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 6H_2O(l)$
deep blue
$[Cu(H_2O)_6]^{2+}$decreases causing the eqm (1) to shift left and $Cu(OH)_2$ (s) dissolves.

Ligand exchange results in the deep blue solution turning to light blue
$[Cu(NH_3)_4]^{2+}(aq) + [EDTA]^{4-}(aq) \rightleftharpoons [Cu(EDTA)]^{2-}(aq) + 4NH_3(aq)$
deep blue soln light blue soln

[Total : 22]

3 (a) Phenol is a white crystalline solid that is volatile. It is mildly acidic and requires careful handling as it can cause chemical burns.

Table 3.1 shows the physical properties for phenol and its derivatives.

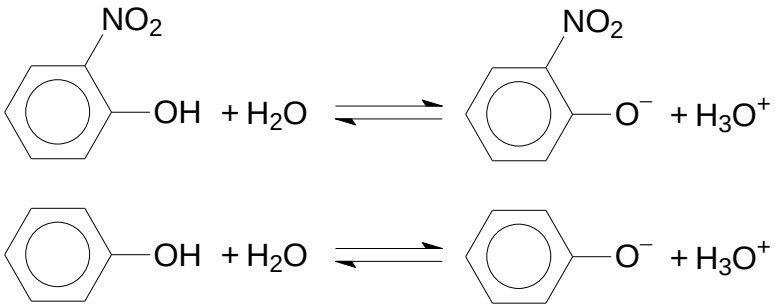
compound	melting point / °C	K_a / mol dm^{-3}
phenol	41	1.12×10^{-10}
2−nitrophenol	46	5.89×10^{-8}
4−nitrophenol	114	7.08×10^{-8}

Table 3.1

(i) Explain the difference in melting points between 2−nitrophenol and 4−nitrophenol. [2]

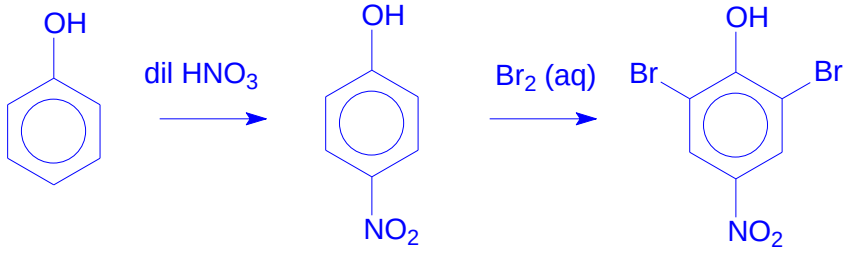
2−nitrophenol can exhibit **intramolecular H-bonding** and hence there are **less extensive intermolecular H-bonding** as compared to 4−nitrophenol.
Less energy is needed to overcome the weaker intermolecular forces of attractions between molecules of 2−nitrophenol, hence its melting point is lower than 4−nitrophenol.

(ii) Explain the difference in the acidities of phenol and 2−nitrophenol. [2]



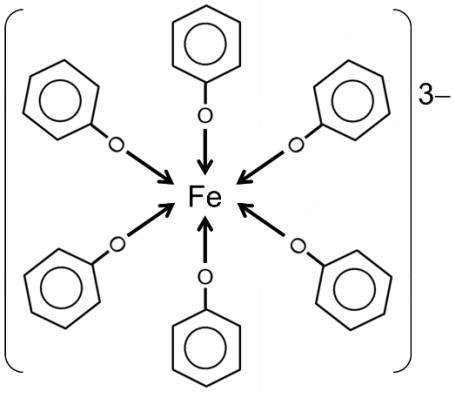
Electron-withdrawing $-NO_2$ groups decrease the intensity of the negative charge/disperse negative charge on the conjugate base and **stabilises it**, thus the **dissociation** of 2−nitrophenol into H^+ and conjugate base is **more favourable (or position of equilibrium shifts to the right)**. Hence 2−nitrophenol is more acidic than phenol.

(iii) Suggest how 2,6−dibromo−4−nitrophenol can be synthesised from phenol in a 2−step synthesis. In your synthesis, you should state the reagents and conditions needed for each step, and show clearly the structure of any intermediate compounds. [3]



(b) When aqueous neutral $FeCl_3$ is added to a solution containing phenol, a violet solution containing the complex ion $[Fe(C_6H_5O)_6]^{3-}$ is formed.

(i) Draw the structure of the complex ion. [1]

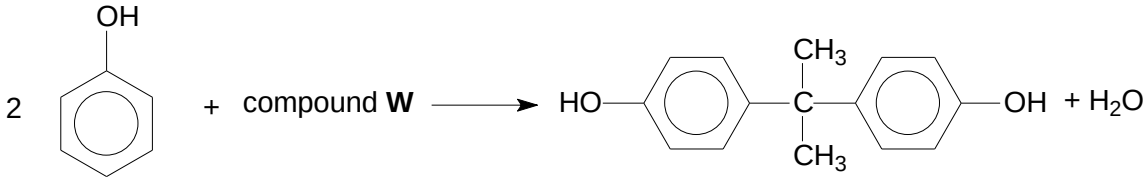


(ii) The violet complex ion $[Fe(C_6H_5O)_6]^{3-}$ is not observed in **both** acidic and alkaline solutions. Suggest explanations for the above observation. [2]

In acidic solution, the **phenoxide ligands gain H^+** to become phenol, there are no phenoxide ligands.

In alkaline solution, Fe^{3+} would react with OH^- to **give $Fe(OH)_3$ red brown ppt instead.**

(c) Phenol can react with compound **W** under suitable conditions to give bisphenol-A (BPA).



BPA

The use of the table of characteristic infra-red absorption frequencies for some selected bonds in the *Data Booklet* is relevant to this question.

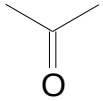
Infra-red absorptions can be used to identity functional groups in organic compounds. For example, phenol shows absorption at 3200−3600 cm^{-1} due to the O−H bond.

The analysis of compound **W** shows absorptions at 1670−1740 cm^{-1}.

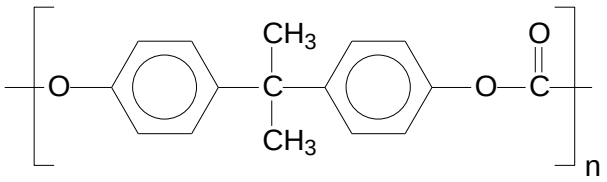
Identify the bond present in compound **W** and suggest its structure. [2]

Bond present is C=O

Based on the balanced equation, we can conclude that compound **W** has molecular formula of C_3H_6O. Compound **W** is propanone.



(d) BPA can react with another monomer **X** to produce polycarbonates. Polycarbonates are commonly used in the manufacturing of water bottles.

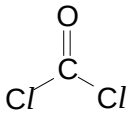


polycarbonates

(i) Identify the new functional group formed in the polycarbonates. [1]

Ester

(ii) Suggest the structure of monomer **X**. [1]



Note: Phenol reacts with acyl chloride to form ester

(iii) Research has shown that BPA can leach into beverages from the polycarbonate water bottles under certain conditions. Exposure to BPA is a concern because of possible health effects of BPA on the brain.

Discuss whether it is safe to consume cold lemon juice stored in a polycarbonate water bottle. [1]

Yes it is likely to be safe. **Complete hydrolysis of polymer into monomer BPA did not occur** and it would require **presence of concentrated acid and heating at high temperature.**

OR

No it is unsafe, eventhough rate of hydrolysis is slow, **some hydrolysis might occur and small amount of BPA** could be released into the lemon juice.

(e) BPA can react with epoxides to form epoxy resins. Fig 3.1 shows the simplified equations for the reaction.

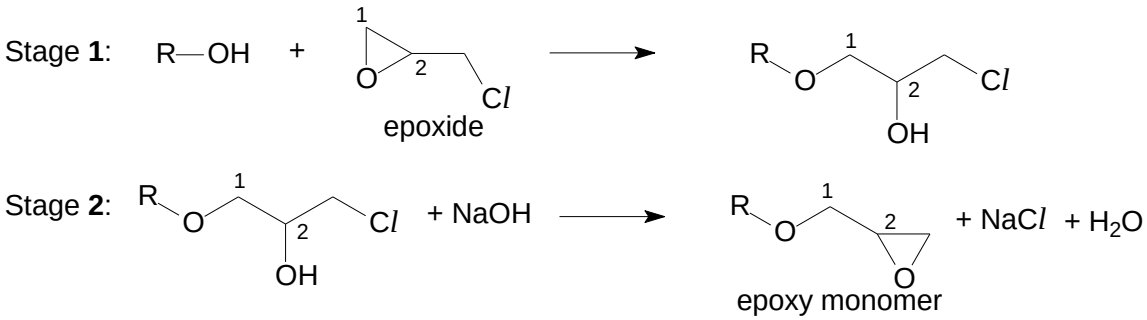


Fig 3.1

(i) For stage **1**, the phenol group of BPA acts as the nucleophile. Suggest why the nucleophile attacks C^1 instead of C^2. [1]

C^1 is less steric hindered than C^2.

(ii) For stage **2**, state the type of reaction and the role of NaOH in the reaction. [2]

Nucleophilic substitution

NaOH acts as a base.

[Total : 18]

Section B

Answer **one** question from this section.

4 (a) Diphenylmethanone can be synthesized from methylbenzene in three steps as shown in Fig 4.1.

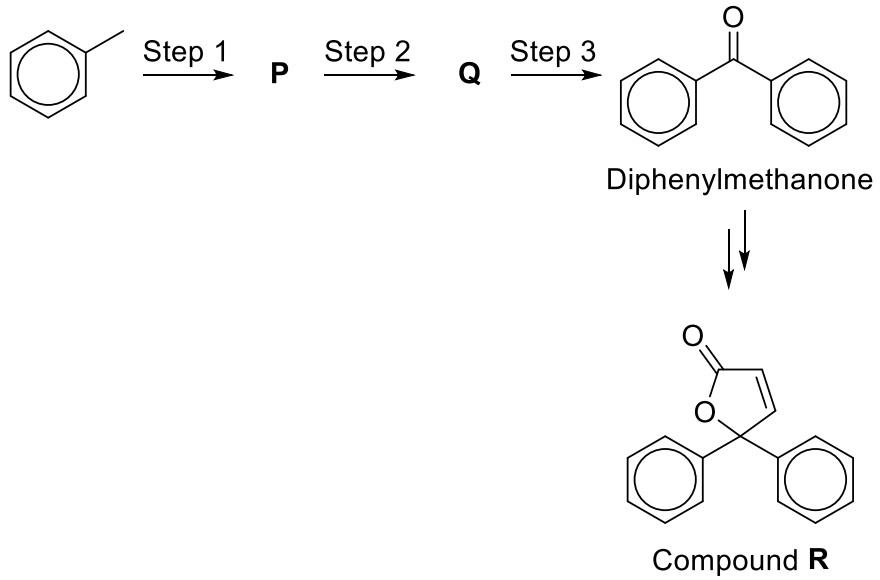
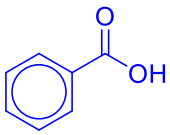


Fig 4.1

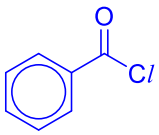
(i) Suggest the reagents and conditions for steps **1**, **2** and **3**, and draw the structures for compounds **P** and **Q**. [5]

Step 1: $KMnO_4$, H_2SO_4(aq), heat
Step 2: anhydrous $SOCl_2$ or anhydrous PCl_3 or anhydrous PCl_5
Step 3: anhydrous $FeCl_3$, benzene

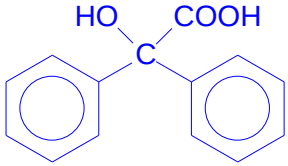
P:



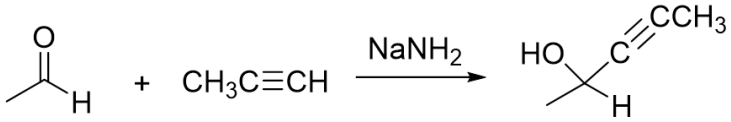
Q:



(ii) When compound **R** is heated with acidified $KMnO_4$, compound **S** is formed as the only organic product. Suggest the structure of compound **S**. [1]



(b) Propyne, $CH_3C{\equiv}CH$, is a weak acid. It can react with an aldehyde in the presence of trace amount of strong base such as $NaNH_2$.



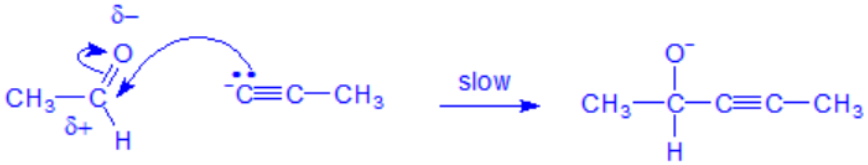
When propyne reacts with NH_2^-, propynyl ion, $CH_3C{\equiv}C^-$ is formed.

(i) State the type of reaction that occurred between propyne and ethanal. [1]

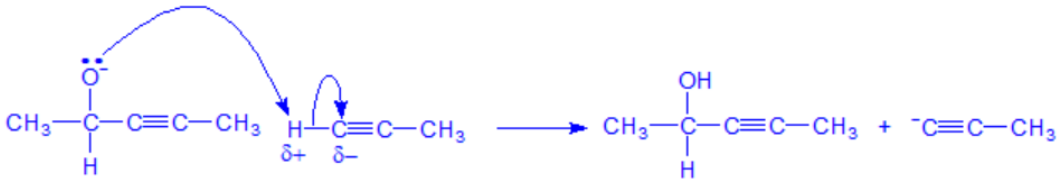
Nucleophilic addition

(ii) Describe the mechanism for this reaction. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. [2]

Step 1:



Step 2:



(iii) Suggest if the organic product formed from this reaction would rotate plane−polarised light. [2]

Trigonal planar carbonyl C is **attacked by the nucleophile from either side of the plane with equal probability**. The **two enantiomers are formed in equal amount**. The product is a racemic mixture where the **rotation of plane−polarised light by one enantiomer is completely cancelled out by the other enantiomer**. Hence the organic product formed **would not rotate plane−polarised light.**

(c) The mechanism for the reaction between compounds **T** and **U** is as shown.

Step 1: **T** + **U** $\rightleftharpoons$ **V**

Step 2: **T** + **V** → **W** (slow)

(i) Write a balanced overall equation for the reaction between compounds **T** and **U**. [1]

2**T** + **U** ⟶ **W**

(ii) Write an expression for K_c for step 1, stating its units. [2]

$K_c = \frac{[V]}{[T][U]}$ units = $mol^{-1}dm^3$

(iii) Using the information given in the question and your answer to **c(ii)**, derive the rate equation for the reaction between compounds **T** and **U**. [2]

$[V] = K_c[T][U]$

Rate = $k[T][V]$

$= k[T](K_c[T][U]) = kK_c[T]^2[U]$ or $k'[T]^2[U]$

(iv) A concentration−time graph was plotted for step 1 as shown in Fig 4.2. Equilibrium was established at t_0. At t_1, a change was introduced.

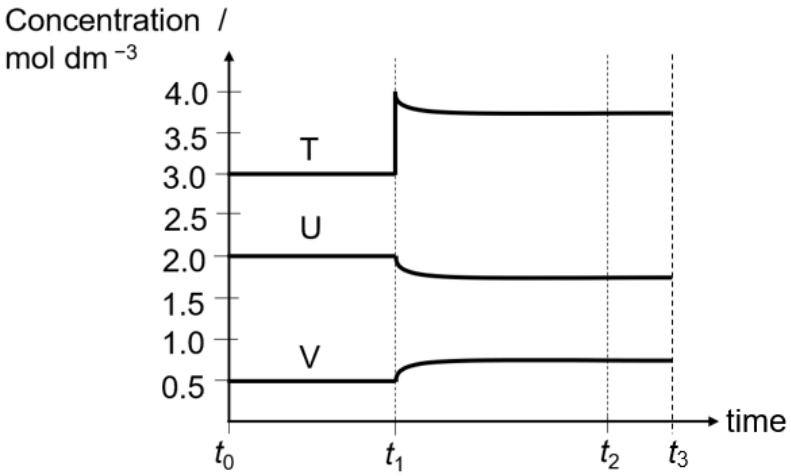


Fig 4.2

State the change that occurred at t_1. Explain the trend observed in the graph from t_1 to t_2. [2]

Concentration of **T** was increased at t_1.

By Le Chatelier's Principle, the equilibrium position will shift to the right to partially decrease the concentration of **T** and **U** and cause partial increase in concentration of **V**.

(v) Suggest whether there would be any change in the individual concentrations of compounds **T**, **U** and **V** when a catalyst is added to the reaction mixture at t_3. [2]

Catalyst increases both the rate of forward and backward reaction by the same extent but not the equilibrium position. Hence, there will be no change in K_c. The proportion of compound T, U and V remains unchanged.

[Total : 20]

5 (a) Describe and explain the variation in volatility of the elements in Group 17. [2]

Down the Group, ***volatility*** of the halogens ***decreases***.

Cl_2, Br_2 and I_2 are non-polar molecules with weak **temporary dipole- induced dipole interactions (td-id)** between the molecules.

Down the Group, the total no. of electrons in the molecules or relative molecular mass increases, **size of electron cloud increases and is thus more easily distorted**.

Increasing amount of energy is required to overcome the increasingly stronger td-id intermolecular forces.

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

Explain the following observations in terms of the relative thermal stabilities of the hydrides of the Group 17 elements.

compound	HC*l*	HBr	HI
decomposition behaviour	does not decompose even on strong heating	strong heating yields reddish brown fumes of Br_2	purple fumes of I_2 obtained when red-hot rod is plunged into jar of HI

[2]

Thermal stability of the hydrogen halides **decreases down the Group.**

The thermal stability of the hydrogen halide depends on the **strength of the H-X bond**.

BE(H−C*l*) = 431 kJ mol^{-1}, BE(H−Br) = 366 kJ mol^{-1}, BE(H−I) = 298 kJ mol^{-1}.

and hence **less energy is needed to overcome the bond** and the HX decomposes more readily.

(c) State and explain the observations when separate solutions of chloride and iodide ions are mixed with aqueous silver nitrate, followed by excess aqueous ammonia. [3]

White AgC*l* ppt, soluble in excess NH_3

Yellow AgI ppt, insoluble in excess NH_3

In the presence of excess NH_3, $Ag^+(aq)$ forms complex with NH_3, thus decreasing $[Ag^+]$.

$$Ag^+ + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+ \quad \text{.....(1)}$$

When $[Ag^+]$ decreases, ionic products for silver chloride & silver iodide decrease, but since **silver chloride has a larger K_{sp}** than silver iodide, ionic product of silver chloride becomes less than its K_{sp} and it dissolves in aqueous ammonia while silver iodide does not.

(d) Carbon monoxide in a sample of polluted air can readily be determined by passing through solid iodine(V) oxide, I_2O_5, to give carbon dioxide and iodine.

(i) Write a balanced equation for the reaction between carbon monoxide and iodine(V) oxide. [1]

$I_2O_5 + 5CO \rightarrow I_2 + 5CO_2$

(ii) The iodine produced is dissolved in a suitable solvent and titrated with aqueous sodium thiosulfate, $Na_2S_2O_3$.

1 dm^3 sample of air produced iodine that required 20.0 cm^3 of 0.10 mol dm^{-3} sodium thiosulfate to discharge the iodine colour.

Calculate the mass of carbon monoxide in this sample of polluted air. [2]

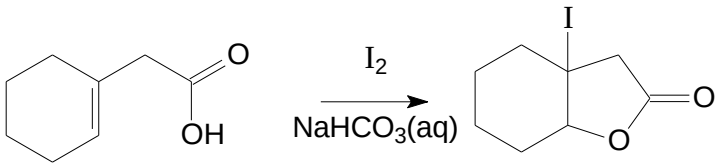
$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$

No. of moles of $S_2O_3^{2-} = 0.10 \times \frac{20}{1000}$
$= 2.00 \times 10^{-3}$

$2S_2O_3^{2-} \equiv I_2 \equiv 5CO$
No. of moles of $I_2 = 1.00 \times 10^{-3}$
No. of moles of $CO = 5.00 \times 10^{-3}$

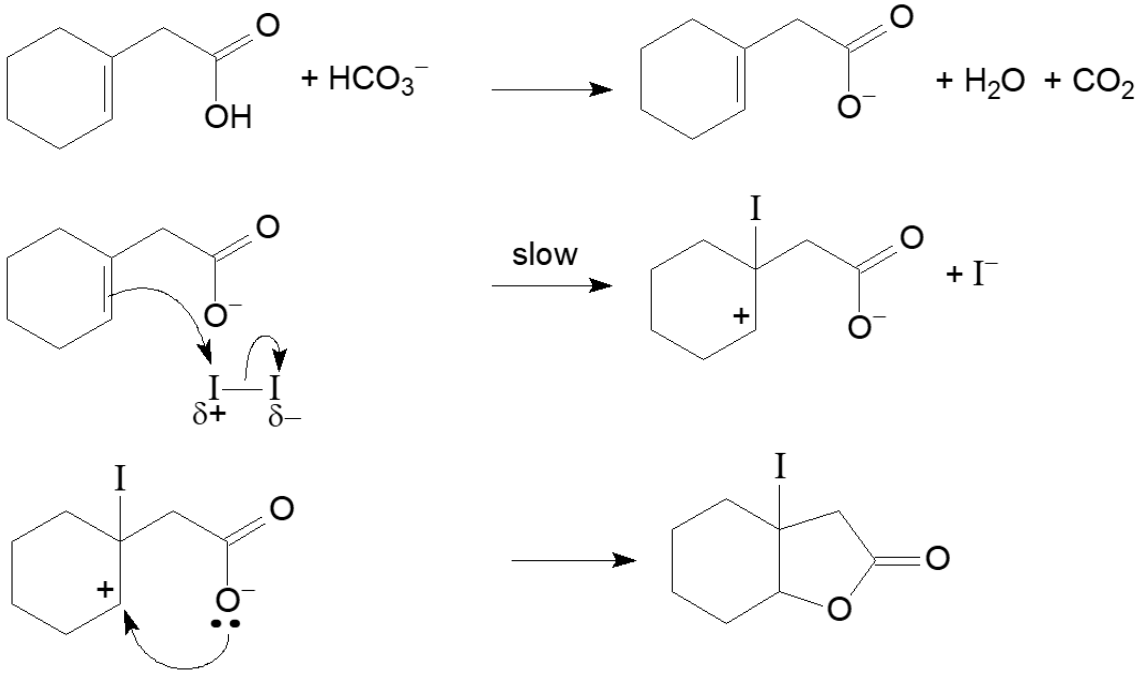
Mass of $CO = 5.00 \times 10^{-3} \times 28.0$
$= 0.140$ g

(e) In the presence of aqueous sodium hydrogencarbonate, iodine does not add across the C=C bond of compound **D** as might be expected. Instead, the following reaction occurs.



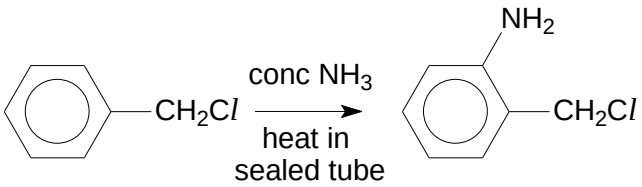
compound **D**

The first step of the mechanism involves a fast acid-carbonate reaction. Describe the mechanism for this electrophilic addition reaction. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. [2]



[Turn over

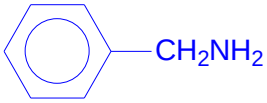
(f) A student attempted to make compound **E** from (chloromethyl)benzene as shown.



(chloromethyl)benzene compound **E**

However, a different product with molecular formula C_7H_9N was obtained.

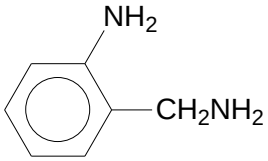
(i) Draw the displayed formula of the product obtained from the reaction. [1]



(ii) Explain why compound **E** was not obtained. [1]

NH_3 is an electron rich nucleophile. NH_3 undergoes nucleophilic substitution at C-C*l* bond instead of attacking the electron rich benzene ring for electrophilic substitution.

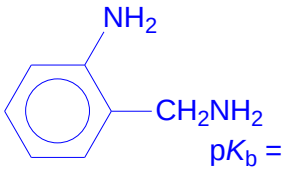
(g) The pK_b values of the two amine groups in compound **F** are 3.4 and 9.1.



compound **F**

(i) Copy the structure of compound **F** to your answer booklet and assign the pK_b values to the two amine groups. Explain your answer. [2]

pK_b = 9.1



pK_b = 3.4

Phenylamine is a weaker base with higher pK_b value. The lone pair electron on N is delocalized into the π electron cloud of the benzene ring. Hence the N atom is less likely to accept an H^+.

(ii) Calculate the initial pH of 0.100 mol dm^{-3} of compound **F**. [2]

Let compound F be **B**

$pK_b = 3.4 \Rightarrow K_b = 10^{-3.4}$

Method 1: Weak base, use ICE and K_b to calculate OH^- dissociated

	B	+ H_2O	⇌	BH^+	+ OH^-
Initial / mol dm^{-3}	0.1	-		0	0
Change / mol dm^{-3}	$-x$	-		$+x$	$+x$
Eqm / mol dm^{-3}	$0.1 - x$	-		x	x

Base dissociation constant, $K_b = \frac{[BH^+][OH^-]}{[B]} = 10^{-3.4}$

$\frac{x^2}{0.1-x} = 10^{-3.4}$

Since B is a weak base, x *<< 0.1* and we can assume that $(0.1 - x) \approx 0.1$

$\frac{x^2}{0.1} = 10^{-3.4}$

x = 0.006310 mol dm^{-3} = $[OH^-]_{eqm}$

pOH = 2.20

pH = 14 – 2.20 = **11.80 (2d.p.)**

Method 2: Weak base, use formula to calculate OH^- dissociated

Weak base,

$[OH^-] = \sqrt{K_b \times [weak\ base]} = \sqrt{10^{-3.4} \times 0.10}$

$[OH^-]$ = 0.006310 mol dm^{-3}

pOH = 2.20

pH = 14 – 2.20 = **11.80 (2d.p.)**

(h) Explain the observations when Br_2(aq) is added to the two samples.

sample	phenylamine	phenylamine dissolved in excess sulfuric acid
observations	orange Br_2 (aq) decolourises and white precipitate forms	orange Br_2 (aq) remains

[2]

Phenylamine undergoes electrophilic substitution with Br_2(aq) as N atom **donates lone pair of electrons into the ring (OR –NH_2 is a strong activating group)** which increases the electron density of the benzene ring, making it more susceptible to the electrophilic attack.

White ppt of 2,4,6-tribromophenylamine is produced.

In the presence of sulfuric acid, -NH_2 group, a base, **is protonated to form -NH_3^+** (which is a deactivating group), hence the **benzene ring is no longer activated** and cannot react with Br_2(aq).