Problem 1 — 20 Marks

Lead Acid Batteries

Part A: Electrochemical processes in a lead acid cell

1.1

Reaction at Cathode: $PbO_{2(s)} + SO_4^{2-}{}_{(aq)} + 4\ H^+_{(aq)} + 2e^- \rightarrow PbSO_{4(s)} + 2\ H_2O_{(l)}$

Reaction at Anode: $Pb_{(s)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4(s)} + 2e^-$

Overall discharge reaction: $Pb_{(s)} + PbO_{2(s)} + 2\ SO_4^{2-}{}_{(aq)} + 4\ H^+_{(aq)} \rightarrow 2\ PbSO_{4(s)} + 2H_2O_{(l)}$

E^0_{cell} = 2.05 V

(1.5 marks)

1.2

$\Delta H°_{rxn} = -315.7$ kJ mol^{-1}

$\Delta G°_{rxn} = -395.6$ kJ mol^{-1}

(2.5 marks)

1.3

a) 79.9 KJ mol^{-1} **(1 mark)**

b) Fraction obtained from the surrounding = 0.2 (or 1/5 or 20%) **(1 mark)**

1.4

$$E = E^0 - \frac{RT}{2F} ln \frac{[a_{H_2O}]^2}{[a_{SO_4^{2-}}]^2 [a_{H^-}]^4} = E^0 - \frac{RT}{F} ln \frac{[a_{H_2O}]}{[a_{SO_4^{2-}}][a_{H^-}]^2}$$

(0.5 mark)

1.5

Drop in EMF: 0.16 V

(1.5 marks)

1.6

i, ii

(2 marks)

1.7

	Correct	Incorrect
a)		X
b)		X
c)	X	
d)		X
e)	X	

(2.5 marks)

1.8

Cathodic: $PbO_{2(s)} + 4\ H^+_{(aq)} + 2e^- \rightarrow Pb^{2+}_{(aq)} + 2\ H_2O_{(l)}$

Anodic: $Pb_{(s)} \rightarrow Pb^{2+}_{(aq)} + 2e^-$

Overall Discharge reaction: $Pb_{(s)} + PbO_{2(s)} + 4\ H^+_{(aq)} \rightarrow 2\ Pb^{2+}_{(aq)} + 2\ H_2O_{(l)}$

Potential difference (open circuit voltage or EMF) = E^0_{cell} = 1.59 V

(1.5 marks)

1.9

	True	**False**
a.		X
b		X
c.	X	

(1.5 marks)

1.10

PbO_2 plate: $2\ PbO_{2\ (s)} + 4\ CH_3SO_3H_{\ (aq)} \rightarrow 2\ Pb(CH_3SO_3)_{2\ \ (aq)} + O_{2(g)} + 2H_2O_{(l)}$

(and/or: $Pb_{(S)} + PbO_{2\ (s)} + 4\ CH_3SO_3H_{\ (aq)} \rightarrow 2\ Pb(CH_3SO_3)_{2\ \ (aq)} + 2H_2O_{(l)}$)

Pb plate: $Pb + 2\ CH_3SO_3H_{\ (aq)} \rightarrow Pb(CH_3SO_3)_{2\ \ (aq)} + H_{2(g)}$

(2 marks)

1.11 **A**: $(NH_4)_2CO_3$ **B**: $PbCO_3$ **(1 mark)**

1.12

MW of **C** = 60 $g.mol^{-1}$

C: CH_3COOH

(1 mark)

1.13 **X**: PbI_2 **(0.5 mark)**

Problem 2 25 marks

When Rain meets the Soil

Part I: The fragrance of soil

2.1 Amount of C = 0.359 g

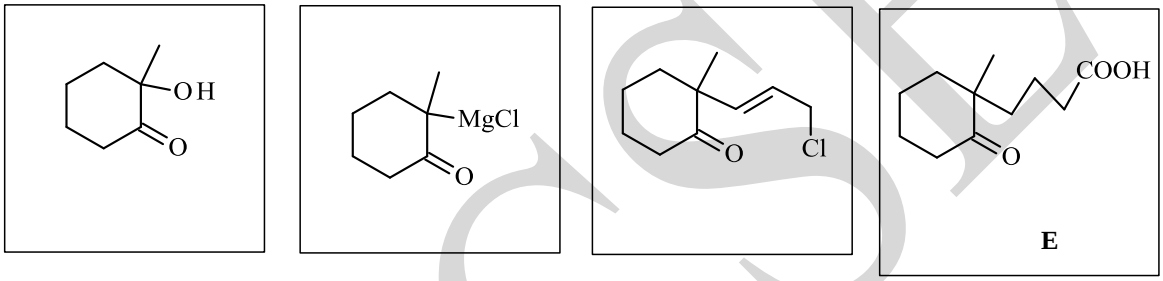
Percentage of C = 79%

(1 mark)

2.2 Empirical formula: $C_{12}H_{22}O$

(3 marks)

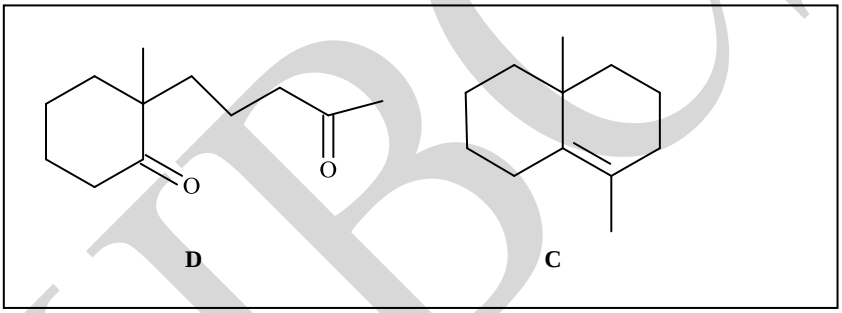
2.3



E

(3 marks)

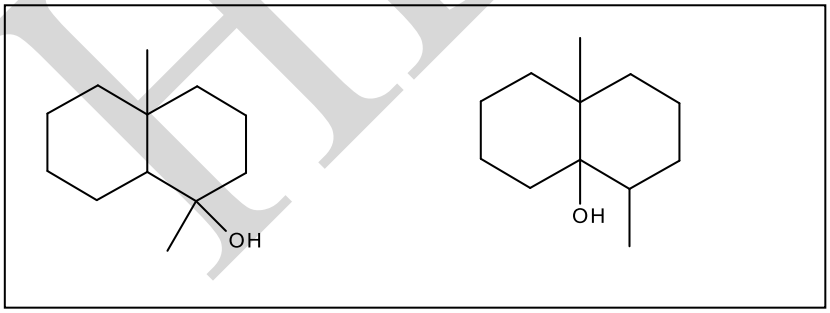
2.4



D **C**

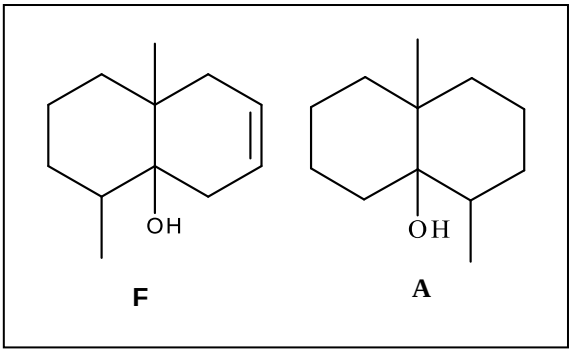
(2 marks)

2.5



(1 mark)

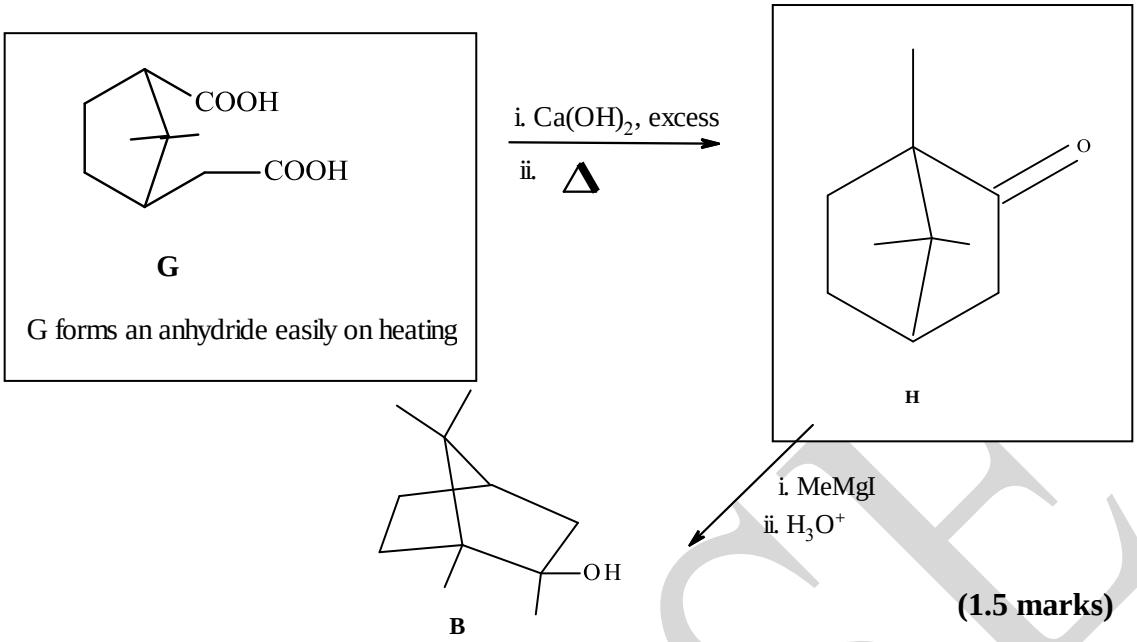
2.6



F **A**

(2 marks)

2.7



(1.5 marks)

2.8 a) pH = 9-7 ; 5-3 **(1 mark)**

b) 63.3 mL of 0.03 M H_2SO_4 **(1mark)**

c) i) X **(0.5 mark)**

2.9 pH = 9.86 **(3 marks)**

2.10 Vol of 0.03 M H_2SO_4 = 0.45 mL **(3.5 marks)**

2.11 b. X **(0.5 mark)**

2.12 b X **(0.5 mark)**

2.13 i) Na_2CO_3

ii) Na_2CO_3

iii) $CaCO_3$ **(1.5 marks)**

Problem 3 — 21 Marks

Hydrogen Bonding and Water of Crystallization

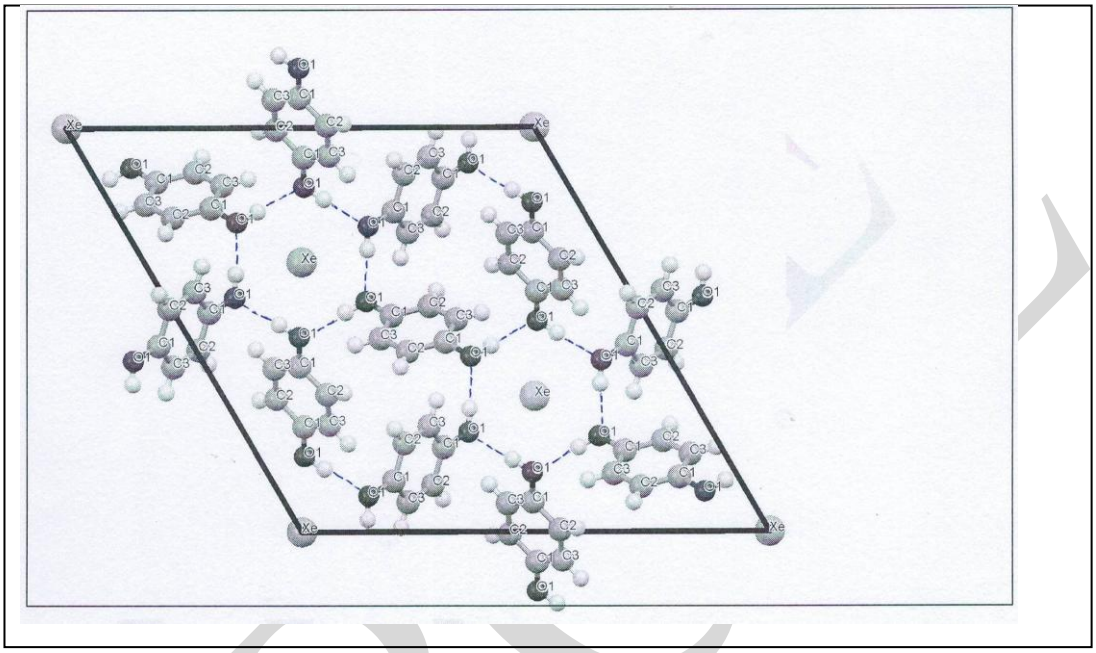
Part 1

3.1 (a) 2, 3

(c) 1, 4

(1.5 marks)

3.2



(1 mark)

3.3 In unit cell
p - quinol molecules = 9
Xe atoms = 3 atoms

(3 marks)

3.4 Density = 1,778 kg m^{-3}

(3 marks)

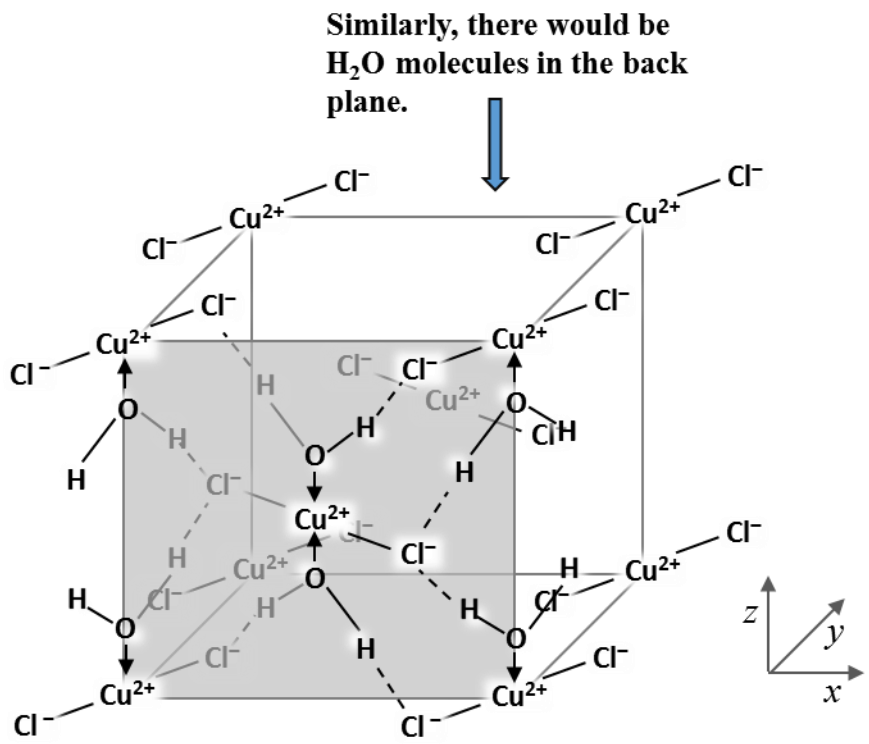
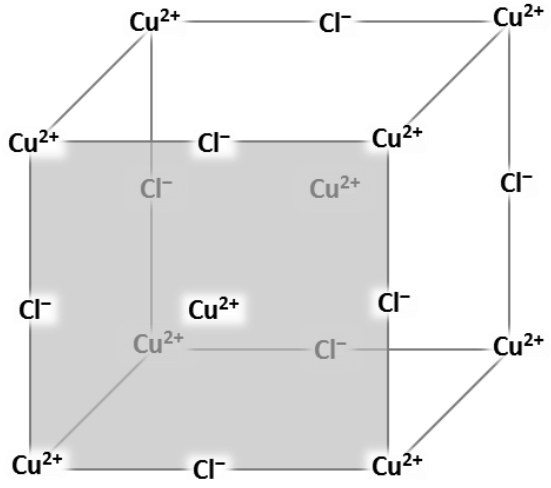
3.5 Volume = 93.1 cm^3

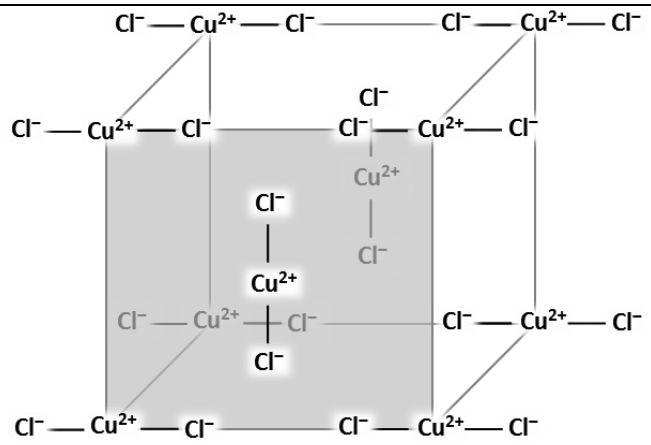
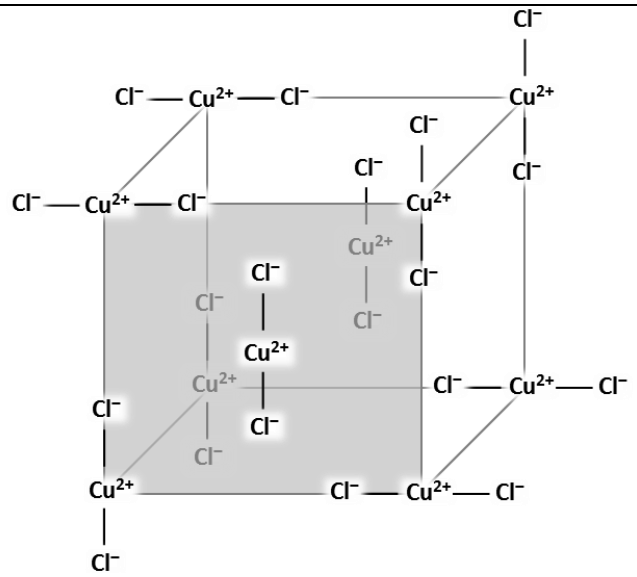
(2.5 marks)

3.6 (i) X

(1 mark)

3.7

Framework	**Reason/s for impossible framework wherever applicable**
	
	III

	I
	II

(6 marks)

3.8 ΔH_{sol} = 37.55 kJ/mol **(2 marks)**

3.9 21.36 kg anhydrous $CuCl_2$ **(1 mark)**

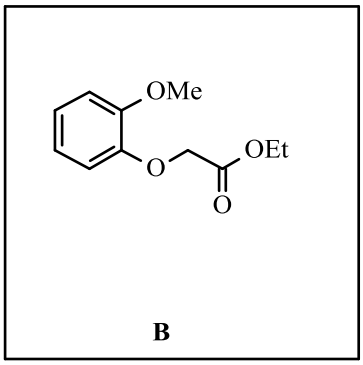
Problem 4 — 19 Marks

Lignin

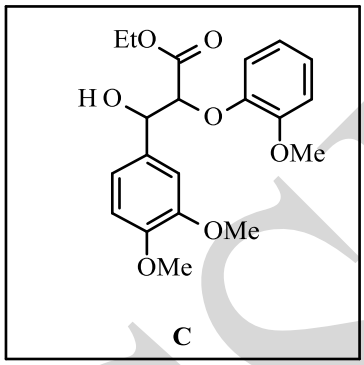
4.1 In the above structure of lignin, identify the functional groups present. (Mark **X** against the correct option/s)

a) [X] b) [X] c) [X] f) [X] **(1 mark)**

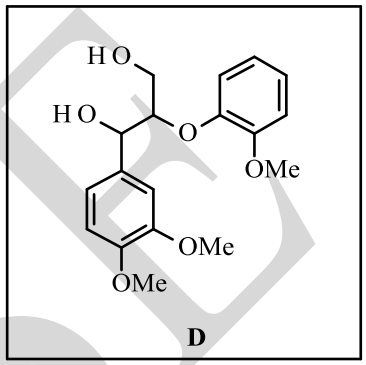
4.2



B



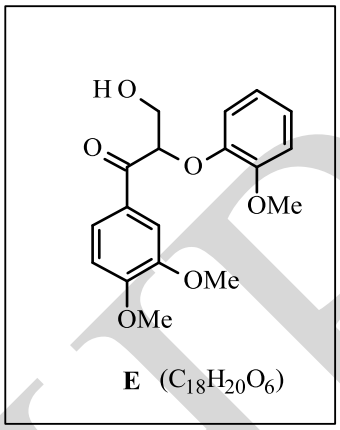
C



D

(2.5 marks)

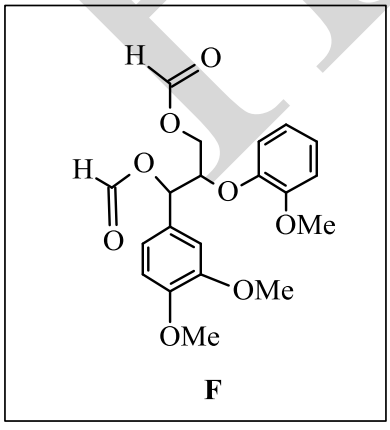
4.3



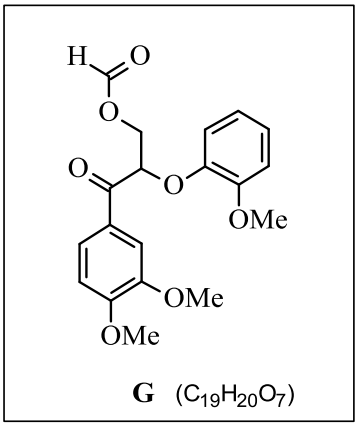
E ($C_{18}H_{20}O_6$)

(1 mark)

4.4



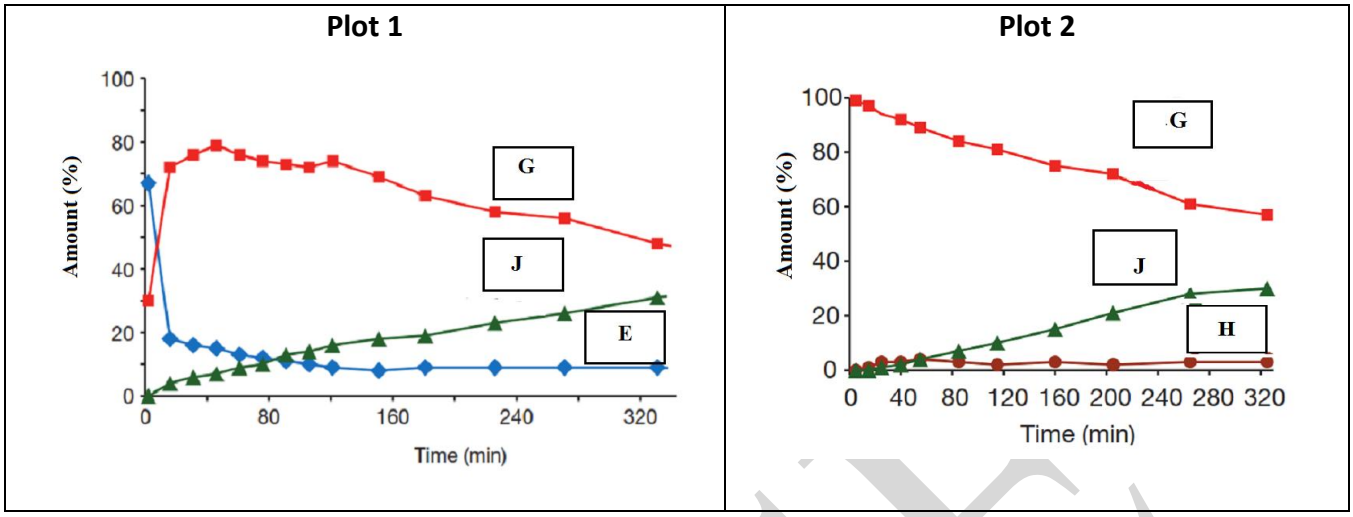
F



G ($C_{19}H_{20}O_7$)

(1 mark)

4.5

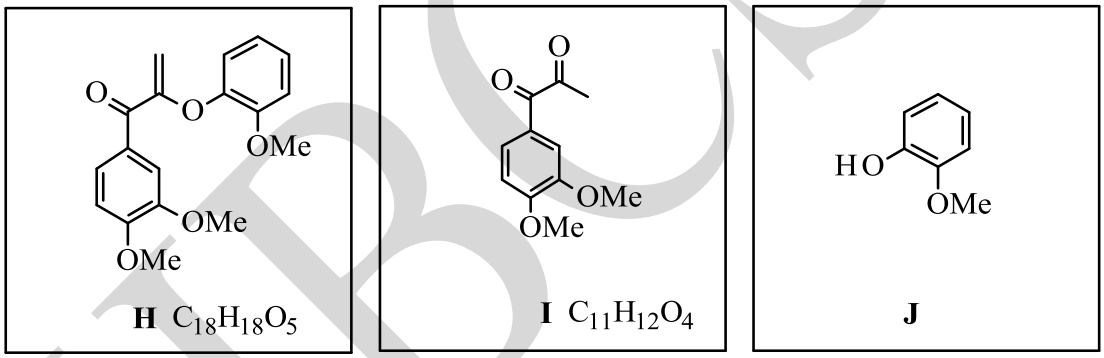


(2 marks)

4.6 iv) X **(1 mark)**

4.7 b) X c) X **(1.5 marks)**

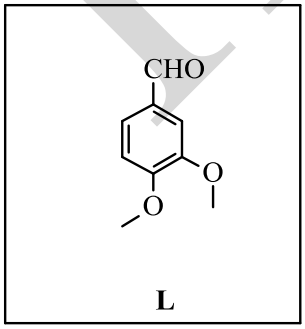
4.8



(3 marks)

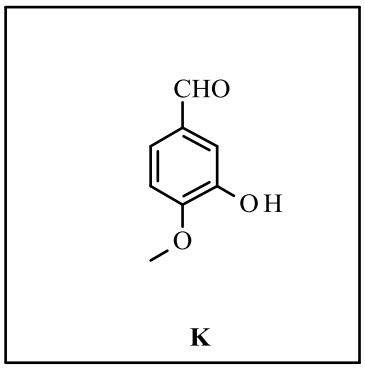
4.9 b) X c) X **(2 marks)**

4.10

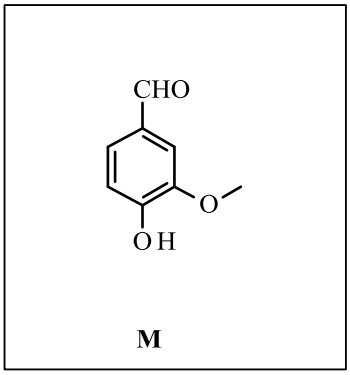


(0.5 mark)

4.11



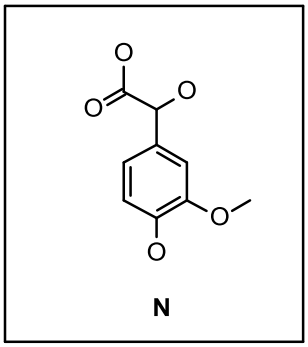
K



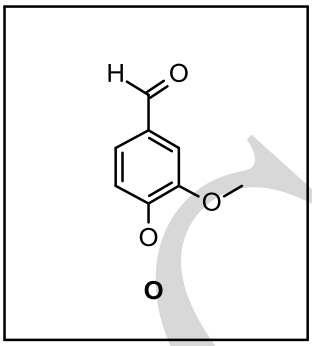
M

(1 mark)

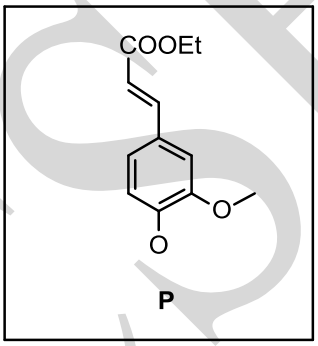
4.12



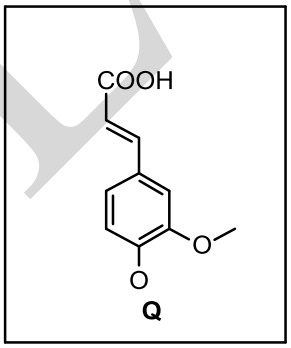
N



O



P



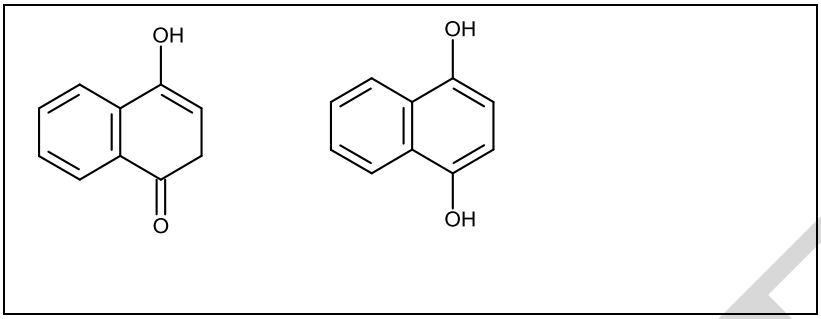
Q

(2.5 marks)

Problem 5 — 22 marks

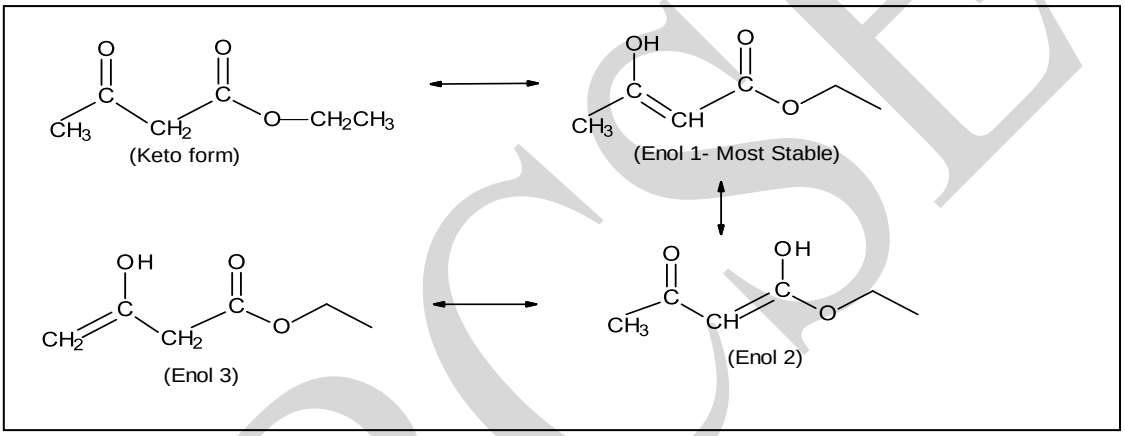
Keto-Enol Tautomerism: Kinetics and Thermodynamics

5.1



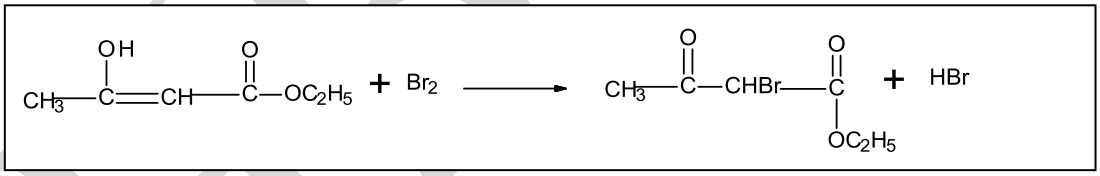
(1mark)

5.2



(2.5 marks)

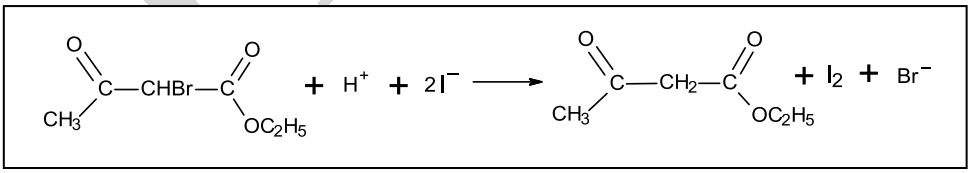
5.3



(1 mark)

5.4 ii) X **(1 mark)**

5.5



(1 mark)

5.6 $I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$ **(0.5 mark)**

5.7

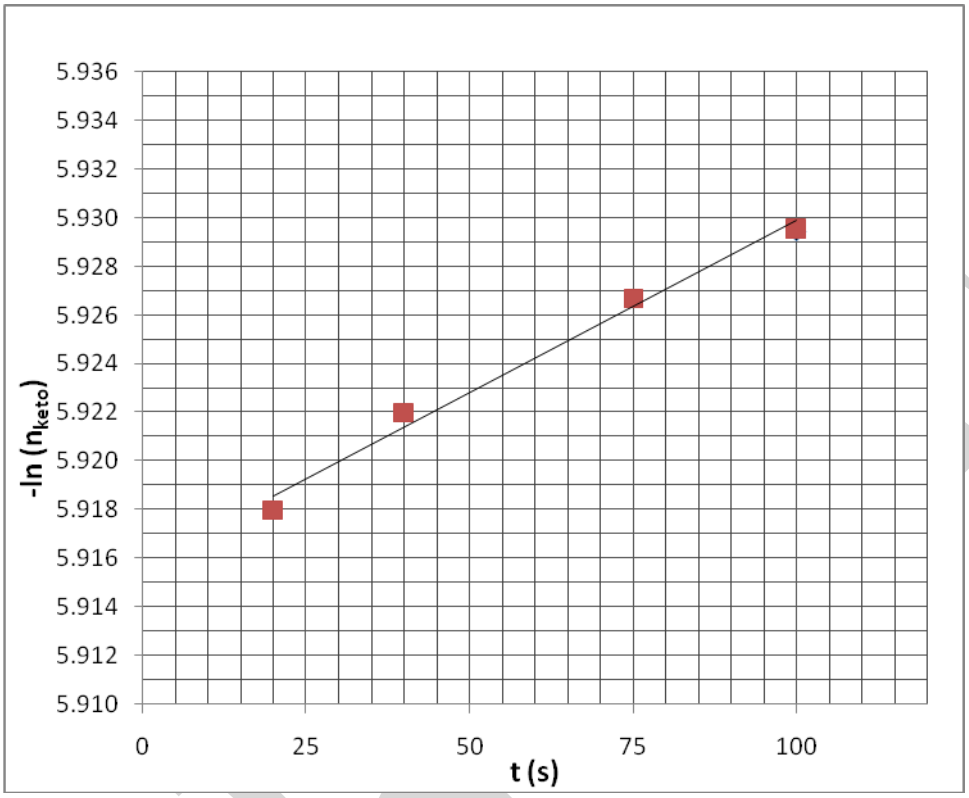
Flask A: Moles of ketone = 2.69×10^{-3} mol

Flasks B: Moles of ketone = 2.68×10^{-3} mol

Flasks C: Moles of ketone =2.66×10^{-3} mol

(3 marks)

5.8



a. Order = 1

b. K_{eq} = 0.06911

(4 marks)

5.9

$\Delta S^0 = -0.0348$ kJ mol^{-1} K^{-1}

$\Delta H^0 = -3.69$ kJ mol^{-1}

(3 marks)

5.10 (ii) **X**

(0.5 mark)

5.11

t = 1.08 hr

(4.5 marks)