"Any alternative method of solution to any question that is scientifically and mathematically correct, and leads to the same answer will be accepted with full credit. Partially correct answers will gain partial credit."

For questions requiring calculations, full credit is given only if necessary steps of the calculations are written.

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

$$E = E^\circ - \frac{RT}{2F}\ln\frac{a_{H_2O}{}^2}{\left(a_{SO_4^{2-}}\right)^2\left(a_{H^+}\right)^2} = E^\circ - \frac{RT}{F}\ln\frac{a_{H_2O}}{\left(a_{SO_4^{2-}}\right)^2\left(a_{H^+}\right)^2}$$

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

$Pb\ SO_4 + 2\ CH_3SO_3H_{\ (aq)} \rightarrow Pb(CH_3SO_3)_{2\ \ (aq)} + H_2SO_{4\ (l)}$ (considered for partial credit)

(2 marks)

1.11

A: $(NH_4)_2CO_3$ or $(NH_4)HCO_3$ **B**: $PbCO_3$

or

A: $(NH_4)_2C_2O_4$ **B:** PbC_2O_4

(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

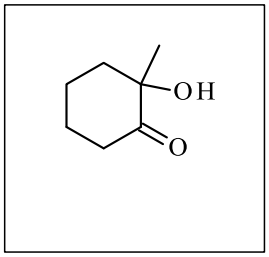
Percentage of C = 79%

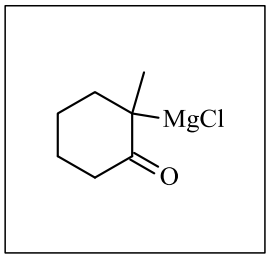
(1 mark)

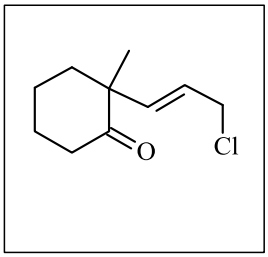
2.2 Empirical formula: $C_{12}H_{22}O$

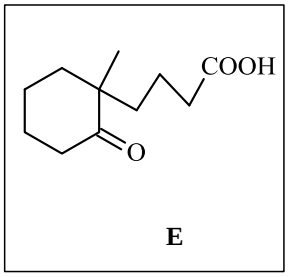
(3 marks)

2.3





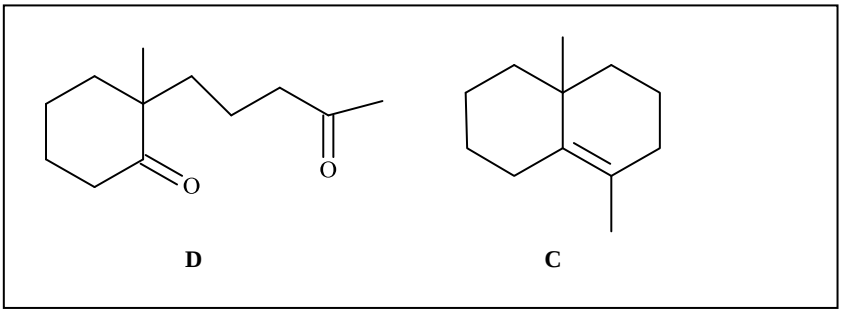




E

(3 marks)

2.4

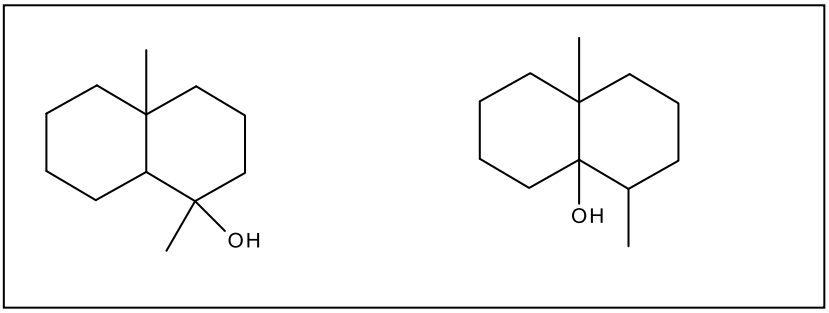


D

C

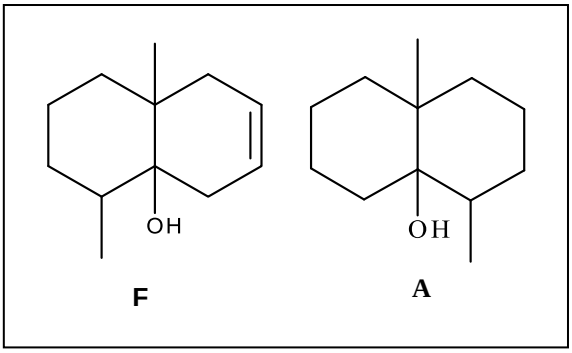
(2 marks)

2.5



(1 mark)

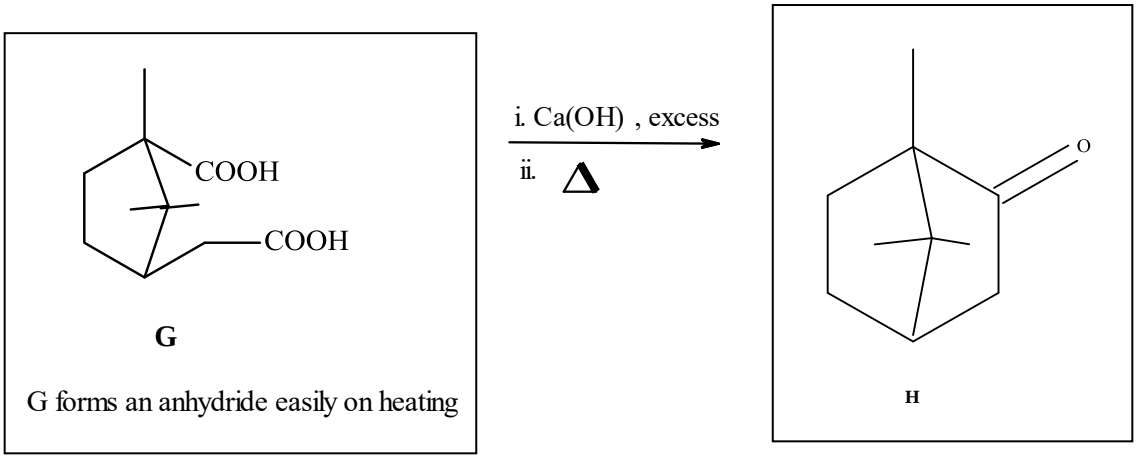
2.6



F **A**

(2 marks)

2.7



G

G forms an anhydride easily on heating

H

(1.5 marks)

2.8 a) pH = 9.5-6.5 ; 5.6-2.8 **(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

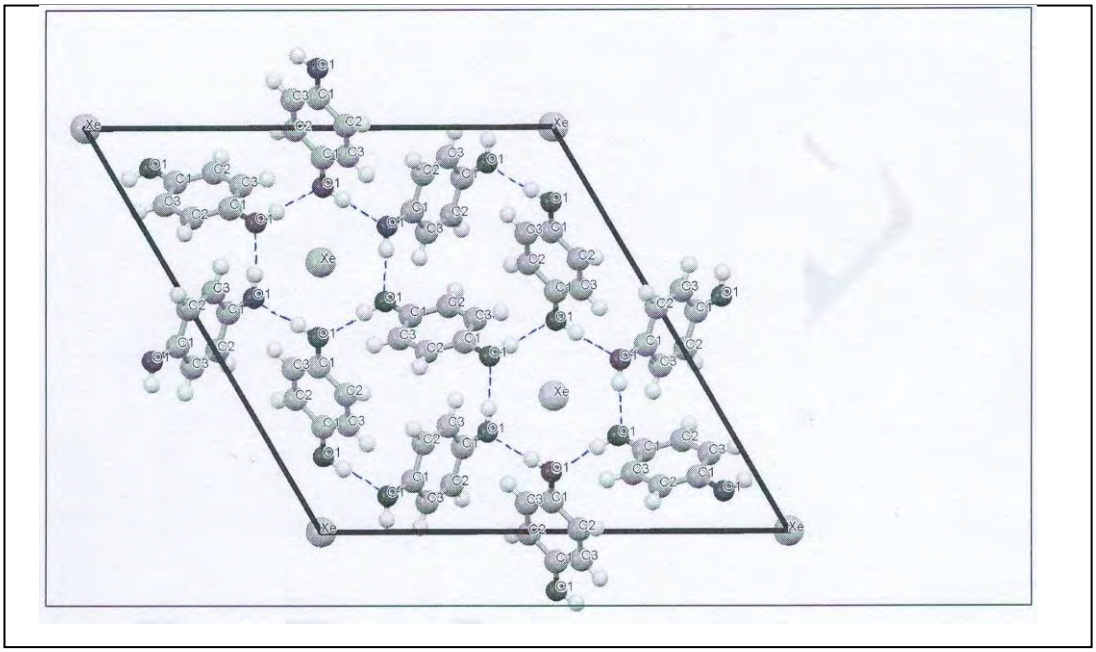
Part 1

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)

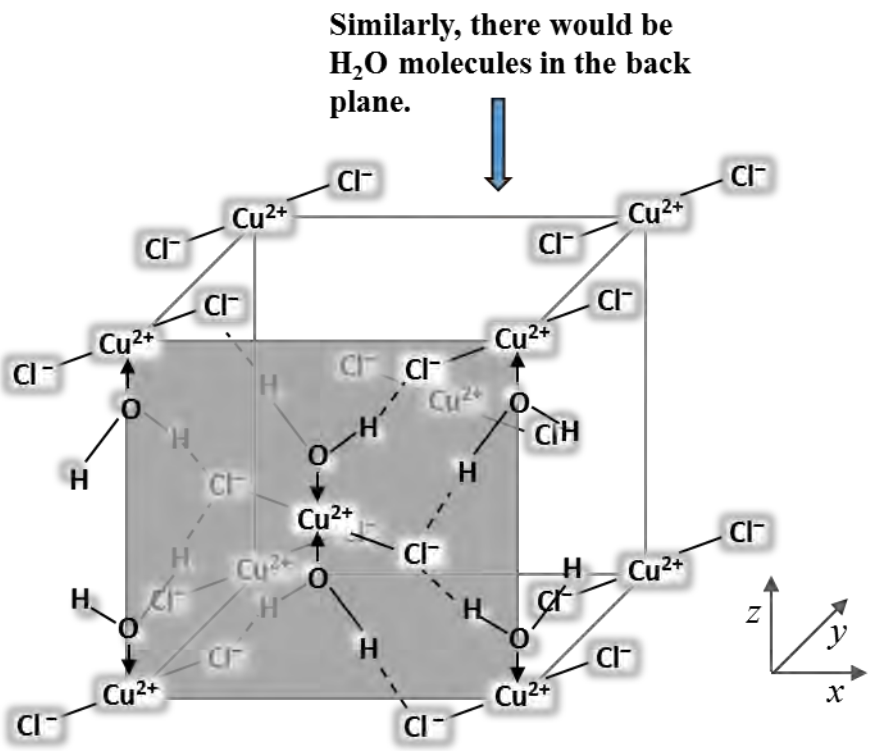
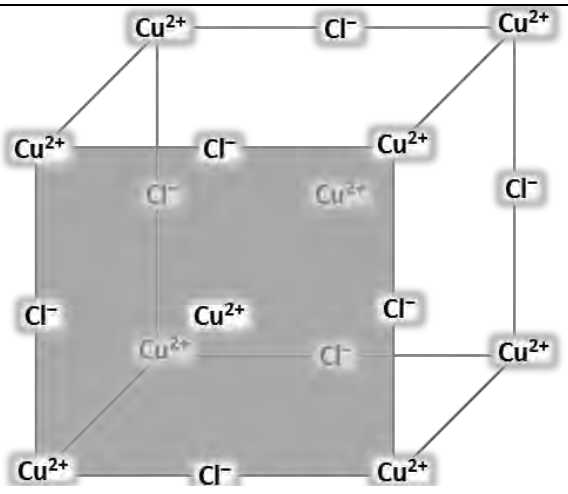
3.5 Volume = 93.1 cm^3

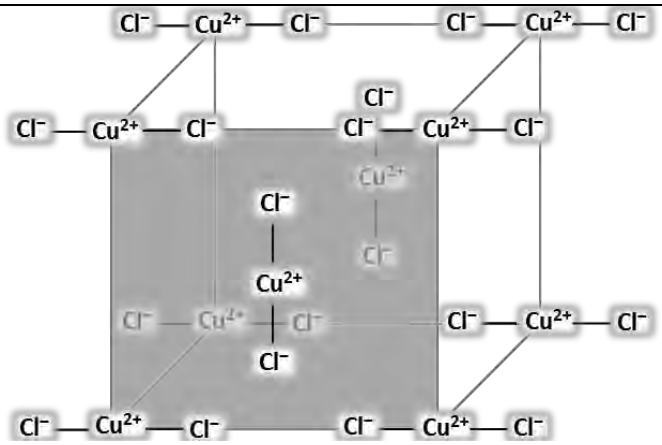
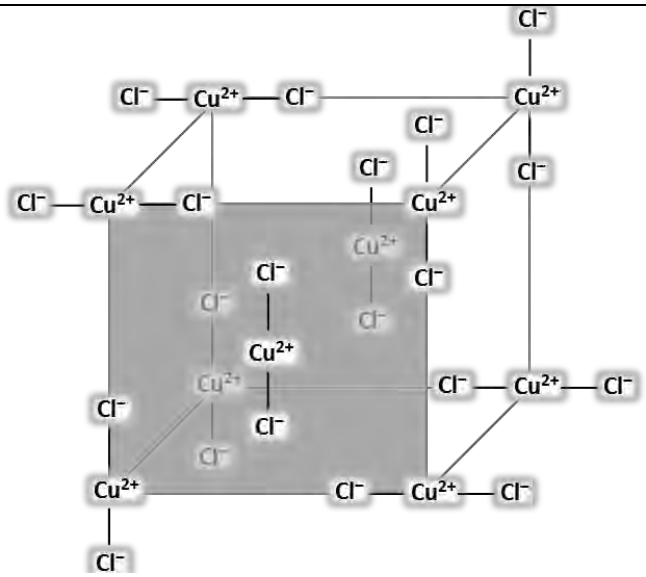
(2.5 marks)

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} = 37.75 kJ/mol **(2 marks)**

3.9 21.37 kg anhydrous $CuCl_2$ **(1 mark)**

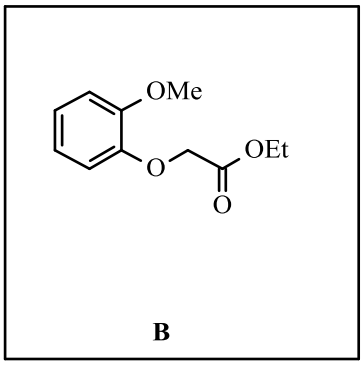
Problem 4 — 19 Marks

Lignin

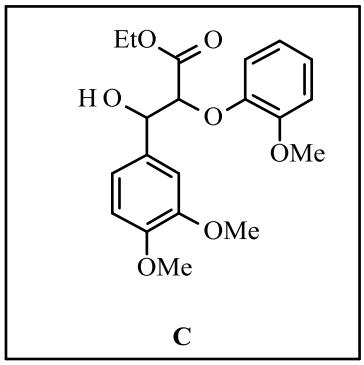
4.1 In the above structure of lignin, identify the functional groups present. (Mark **X** against the correct option/s)

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

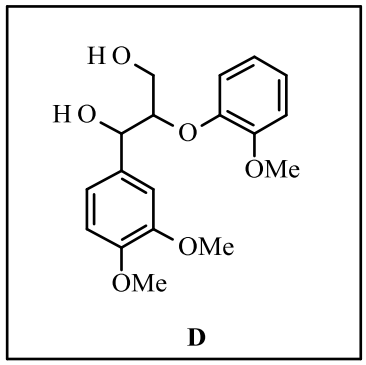
4.2



B



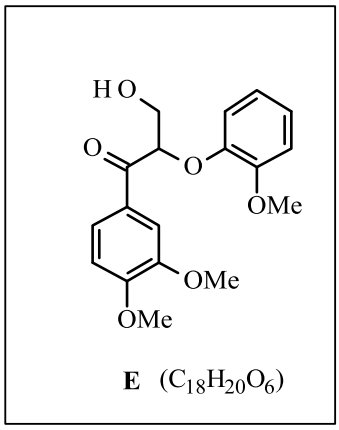
C



D

(2.5 marks)

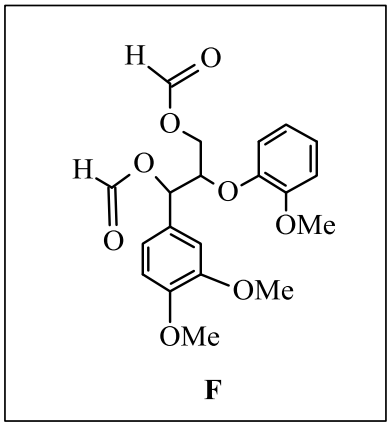
4.3



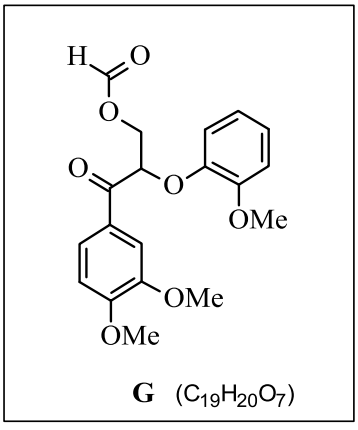
E ($C_{18}H_{20}O_6$)

(1 mark)

4.4



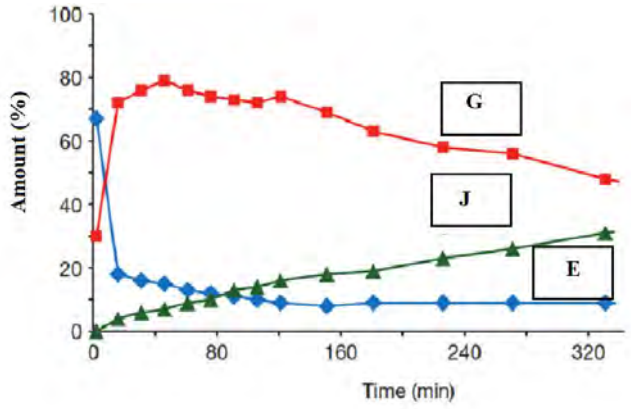
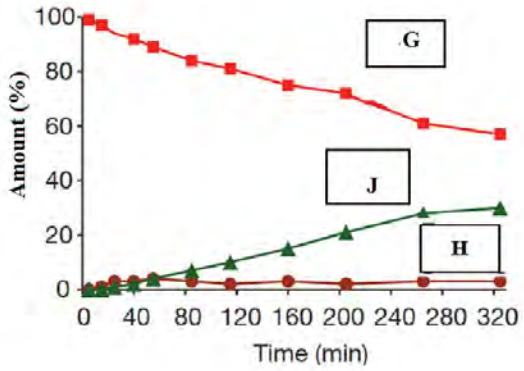
F



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

(1 mark)

4.5

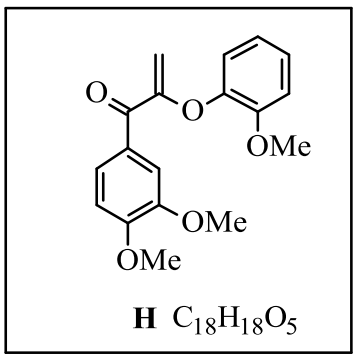
Plot 1	Plot 2
	

(2 marks)

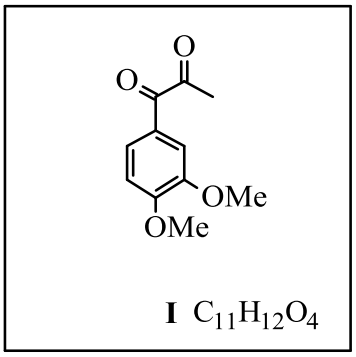
4.6 iv) [X] (if (i) is marked along with (iv) then given full credit) **(1 mark)**

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

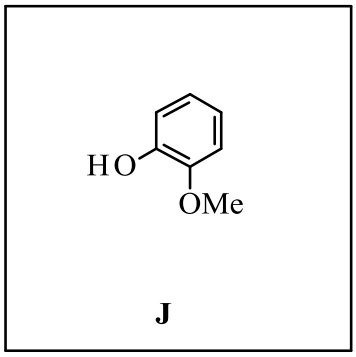
4.8



H $C_{18}H_{18}O_5$



I $C_{11}H_{12}O_4$

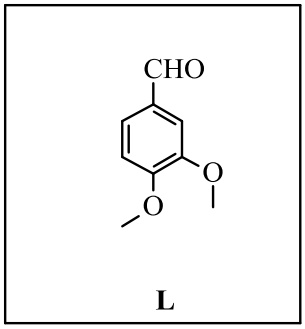


J

(3 marks)

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

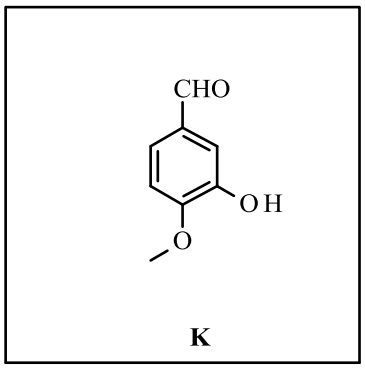
4.10



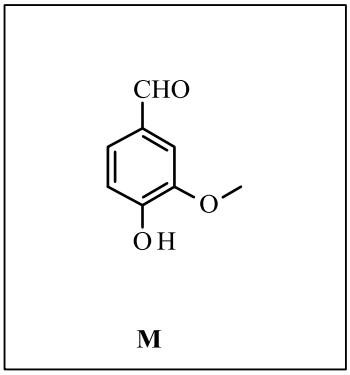
L

(0.5 mark)

4.11



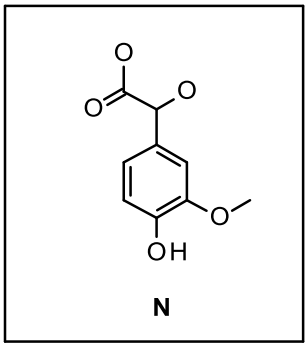
K



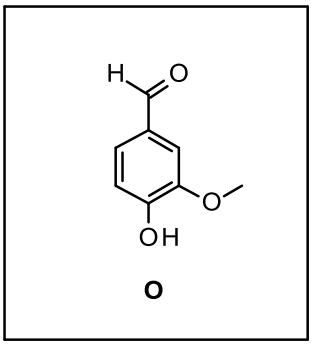
M

(1 mark)

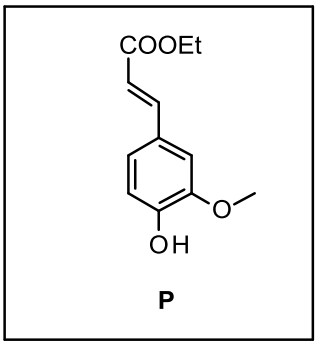
4.12



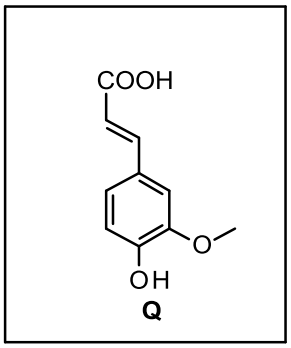
N



O



P



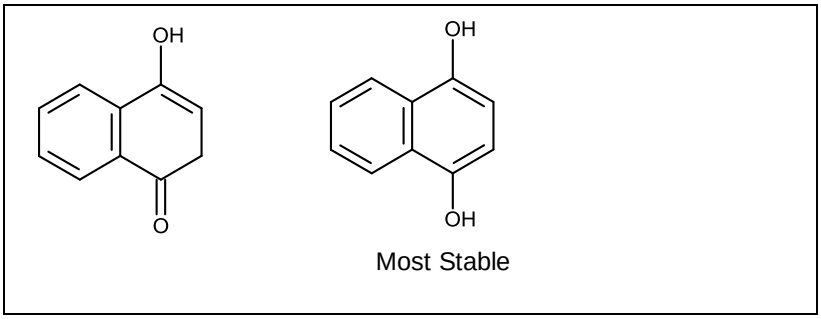
Q

(2.5 marks)

Problem 5 — 22 marks

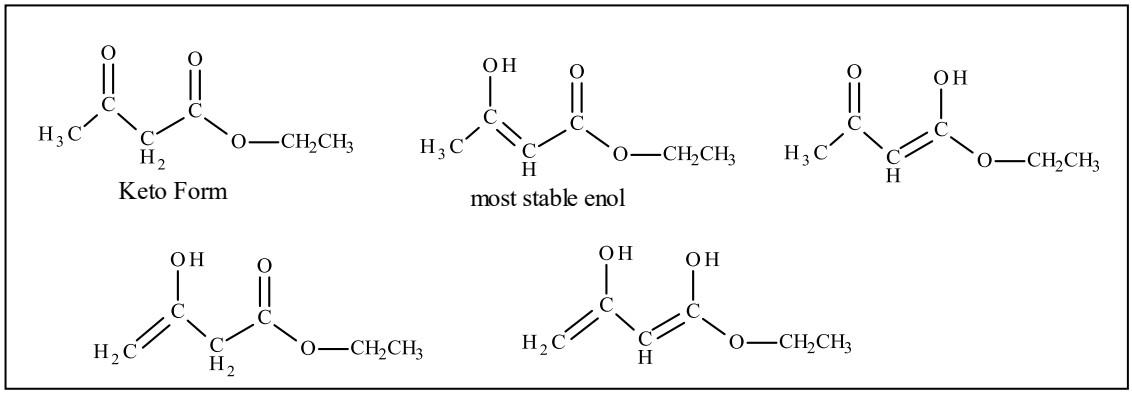
Keto-Enol Tautomerism: Kinetics and Thermodynamics

5.1



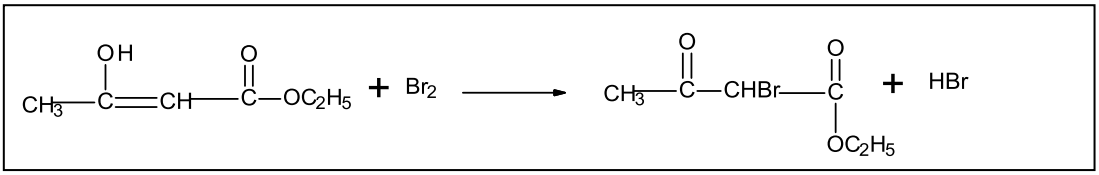
(1mark)

5.2



(2.5 marks)

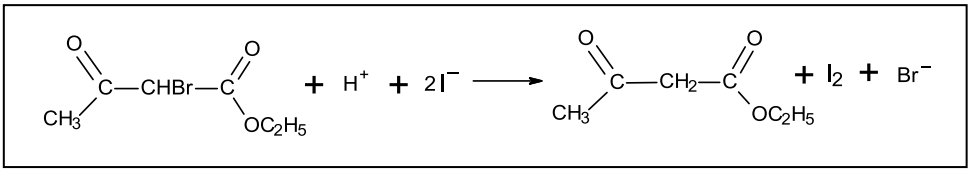
5.3



(1 mark)

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

5.5



(1 mark)

5.6

$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$

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

(0.5 mark)

5.7

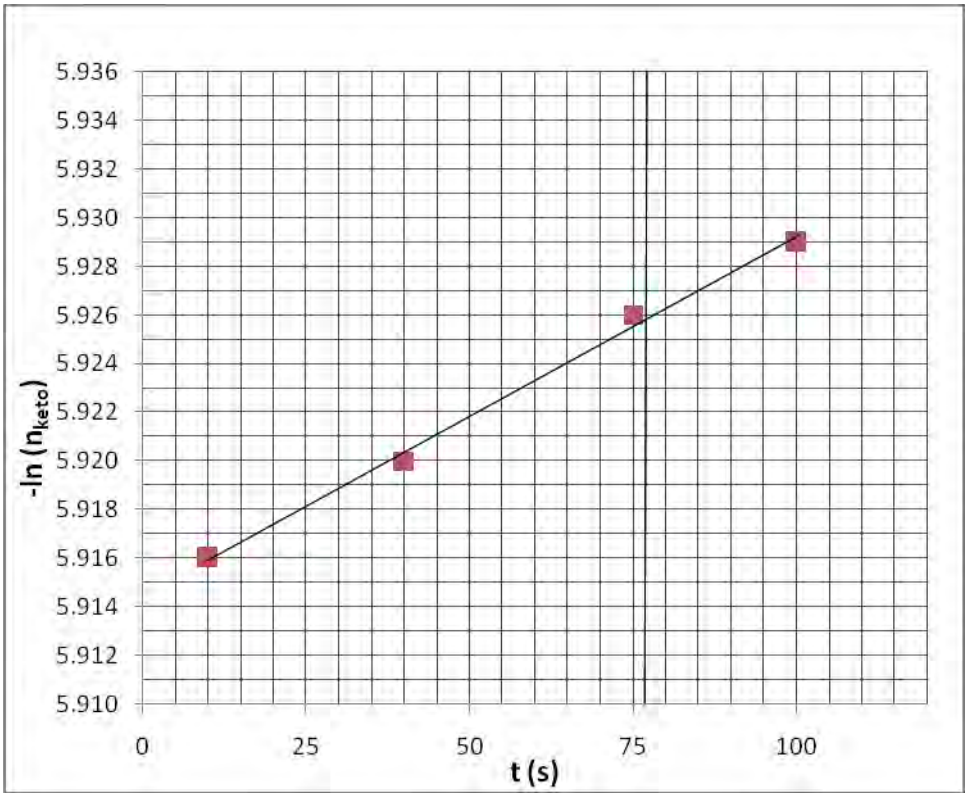
Flask A: Moles of ketone = 2.695×10^{-3} mol

Flasks B: Moles of ketone = 2.683×10^{-3} mol

Flasks C: Moles of ketone =2.669×10^{-3} mol

(3 marks)

5.8



a. Order = 1

b. Rate Constant = 1.480×10^{-4} s^{-1}

c. K_{eq} = 0.068093

(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 or 3907 s

(4.5 marks)