"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.
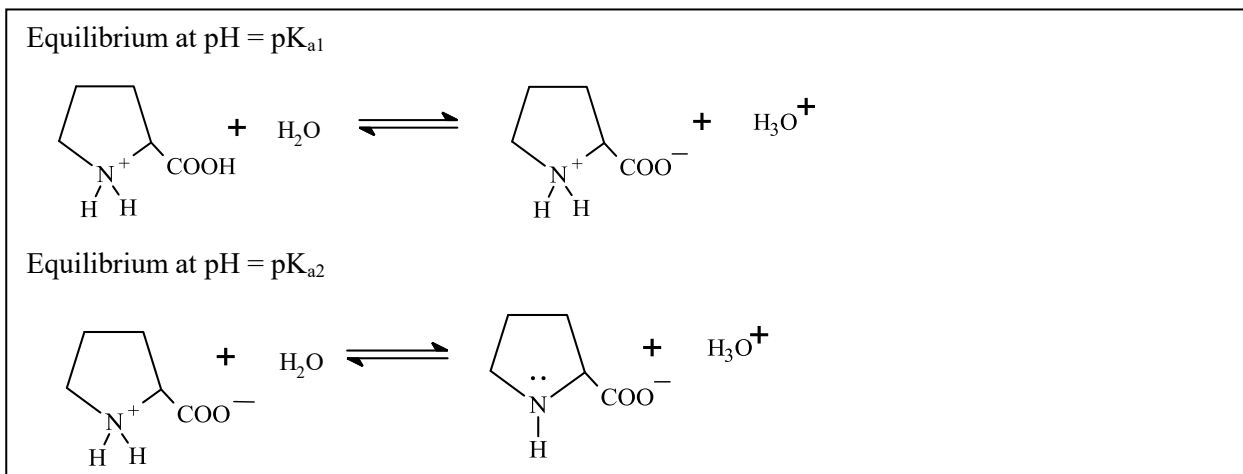
Frozen Solutions

Problem 1   **23 marks**

Common and Uncommon Amino Acids

1.1

Equilibrium at pH = pK$_{a1}$

Equilibrium at pH = pK$_{a2}$

(1 mark)

1.2 $$pI = \frac{pK_{a1} + pK_{a2}}{2}$$ **(2.5 marks)**

1.3.   **a.**   **True**   [X]
         b.   **True**   [X]   **(1 mark)**

1.4.   **a.**   iv. 2.2, 9.0, 12.5   [X]   **(1 mark)**

b.

(1 mark)

c.

Zwitter ion

Zwitter ion + H$^+$

(1.5 marks)

d. | pI = 10.75   **(1 mark)**

1.5. ii) **C, A, B** | X | **(1.5 marks)**

1.6. a.

(0.5 mark)

b.   **(3 marks)**

| $Q = CuC_5H_{10}NO_2S.H_2O$

c.

or   **(1 mark)**

d.

or

(2 marks)

1.7.i)

D

F   ($C_{22}H_{18}N_2I_2O_4$)

E
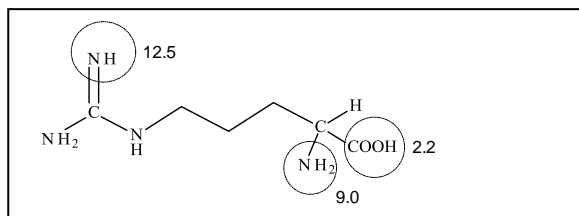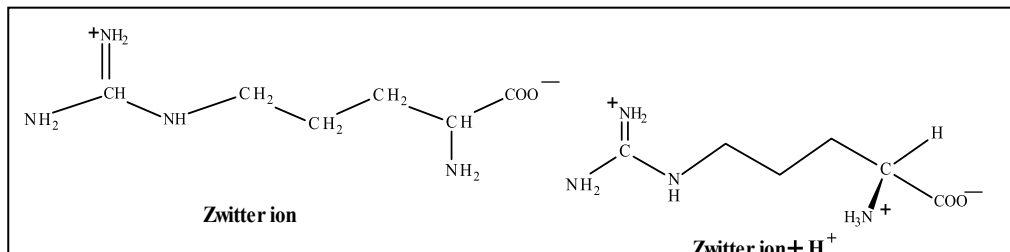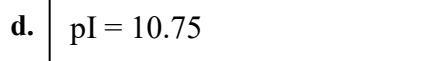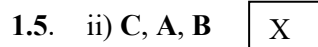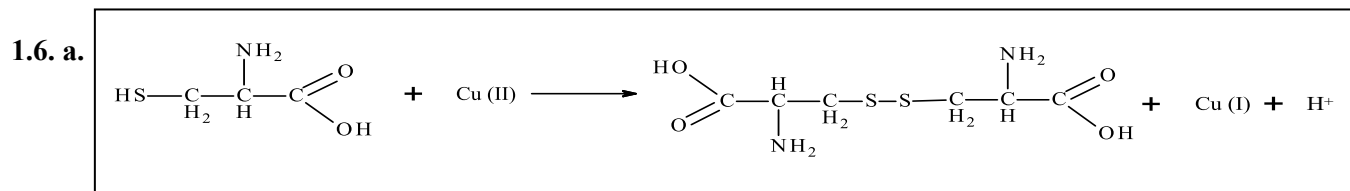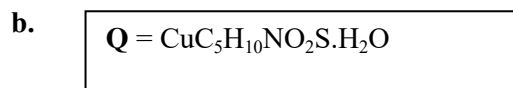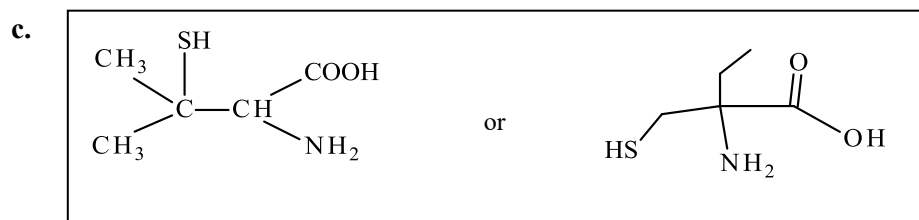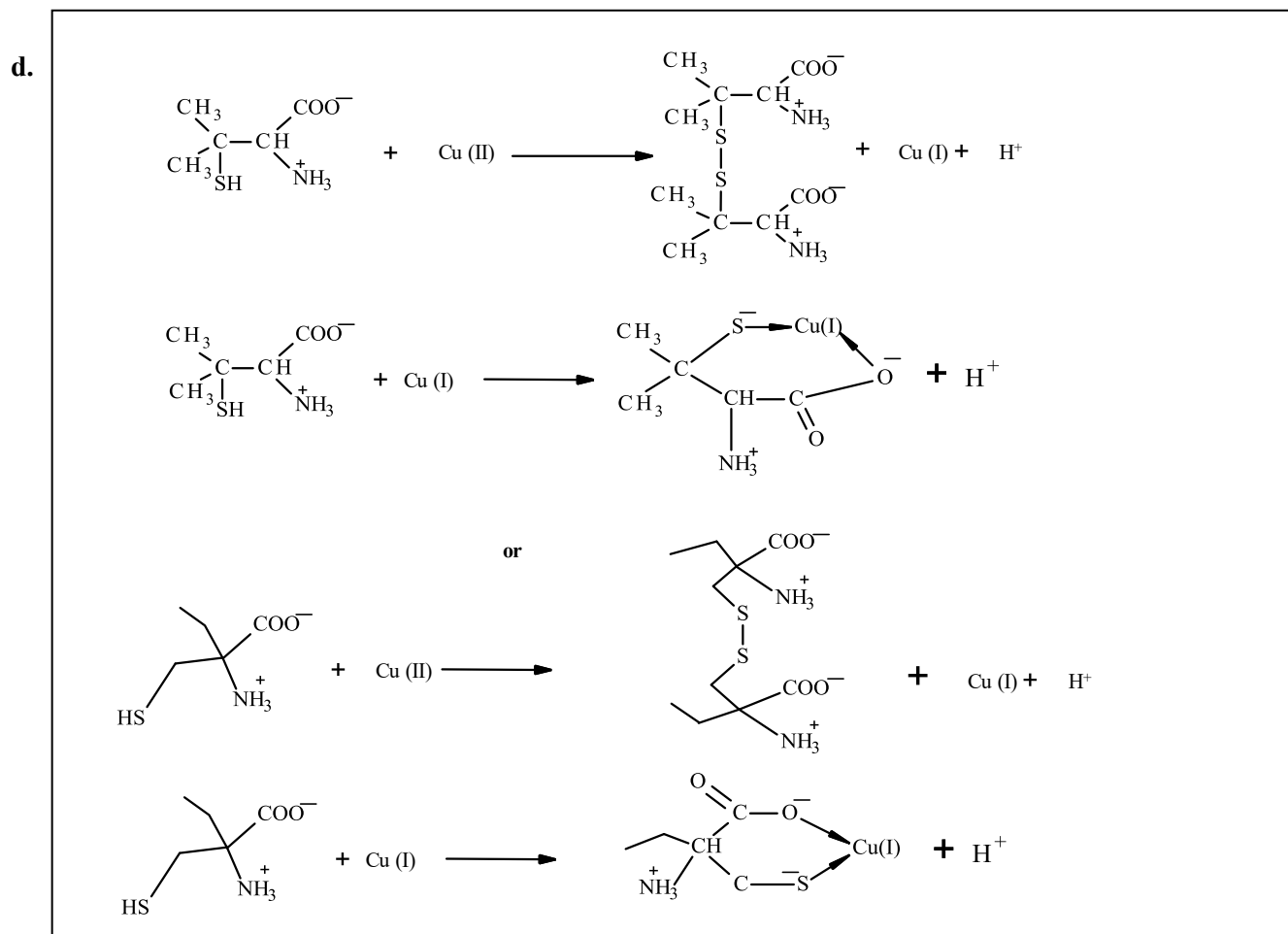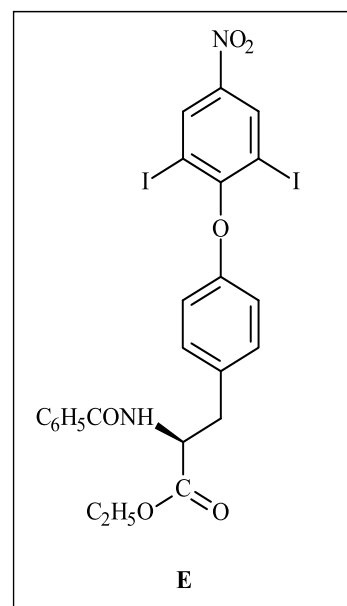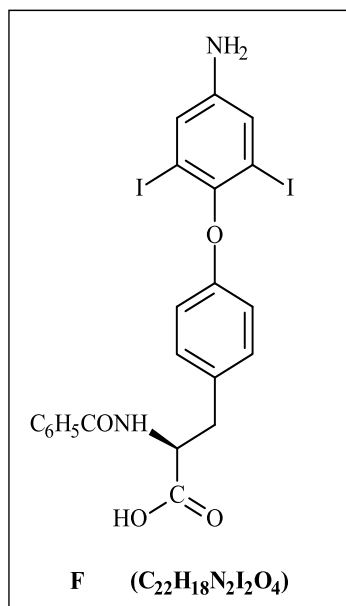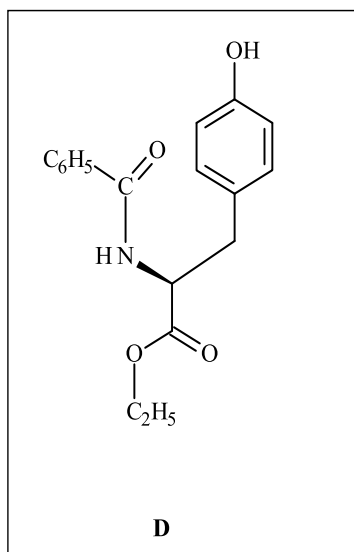
(3 marks)

ii) a) Reducing agent | X | **(0.5 mark)**

iii) **

G

Z   ($C_{15}H_{15}O_4N$)

(1.5 marks)

iv)

(I atoms attached to any other aromatic C atom will also be accepted)
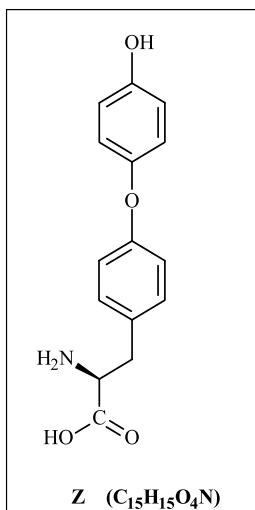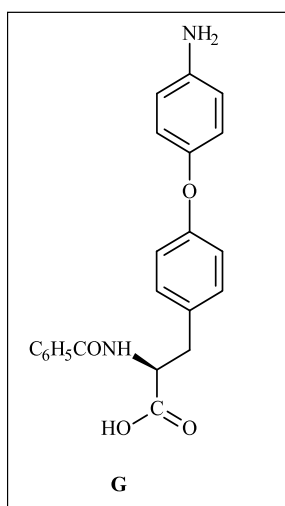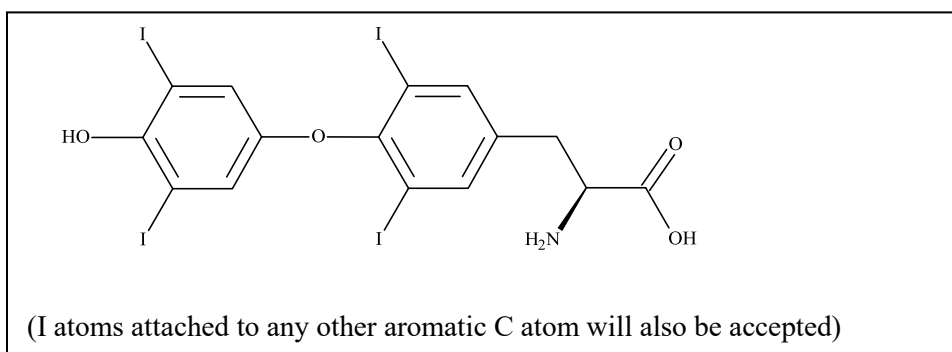
(1 mark)

**During the exam, the following additional instruction was communicated to the students.

Q. 1.7(iii) Draw the structures of compounds **G** and **Z** with stereochemistry.

Problem 2   **17 marks**

Boron Compounds through the Ages

2.1

$NaBH_4 + 4H_2O \rightarrow 4H_2 + NaB(OH)_4$

Volume V= 257.6 L

(2.5 marks)

2.2

Gas phase   Solid phase
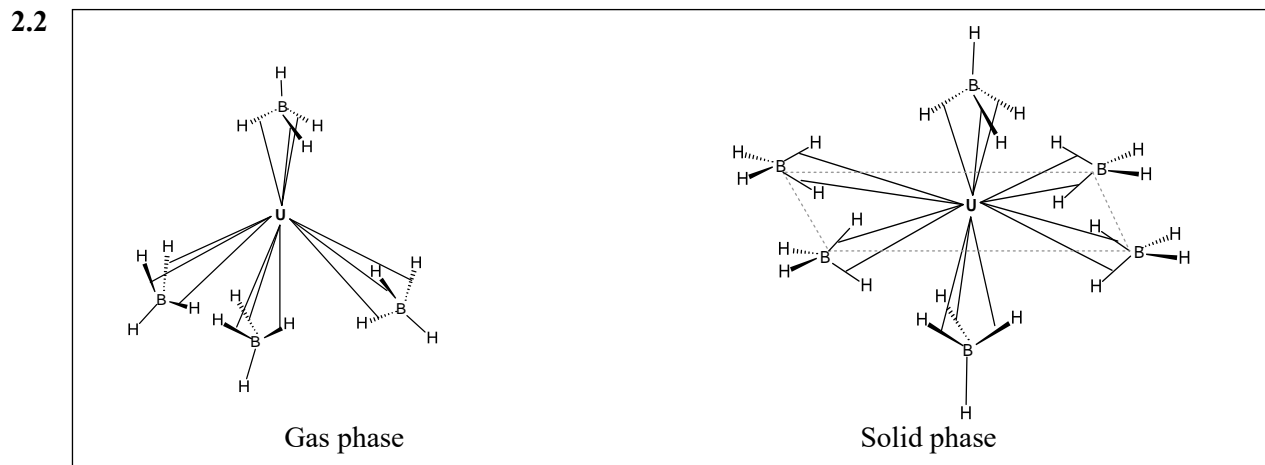
(3.5 marks)

2.3 $^{10}B = 20\%$ **(1.5 marks)**

2.4   Saturated solution of H_3BO_3 **(2.5 marks)**

2.5   Mg/Dry ether

P   **Q**   **R**

(2 marks)

2.6   6   **(1 mark)**

2.7

CH

BH
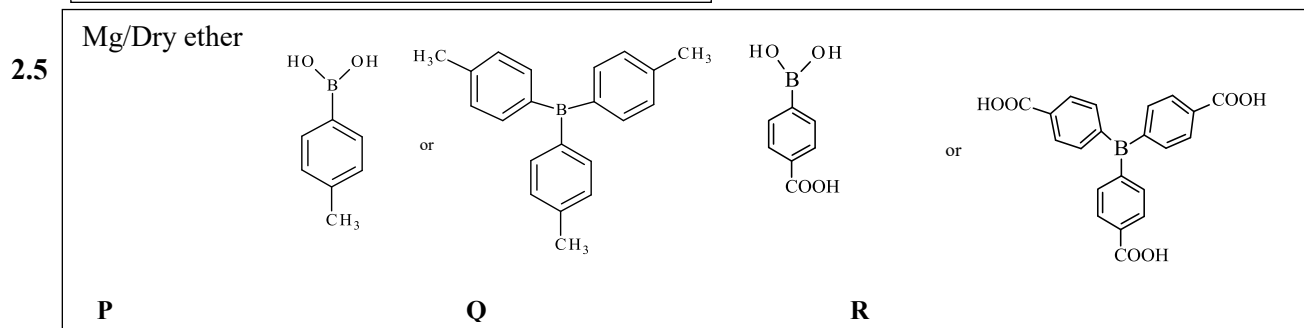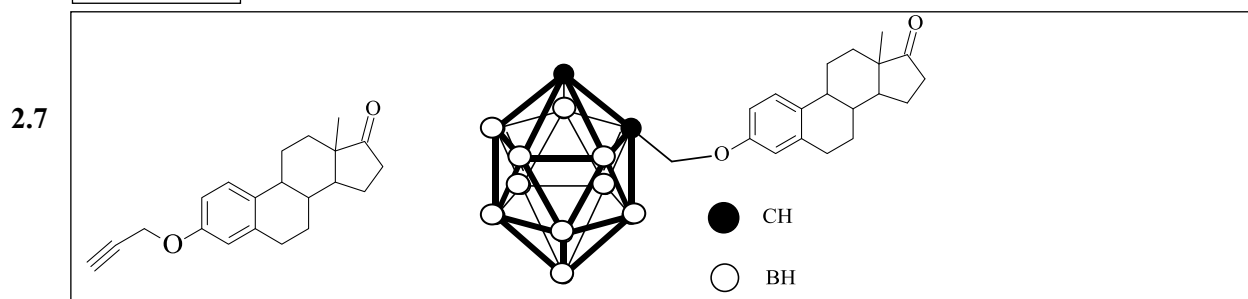
(2 marks)

2.8   i.   +3   ii.   Tetrahedral

iii.   X= F   iv.   **b**   **(2 marks)**

Problem 3	**19 Marks**

Chemistry behind Henna – Lawsone

Part I: Properties of Lawsone
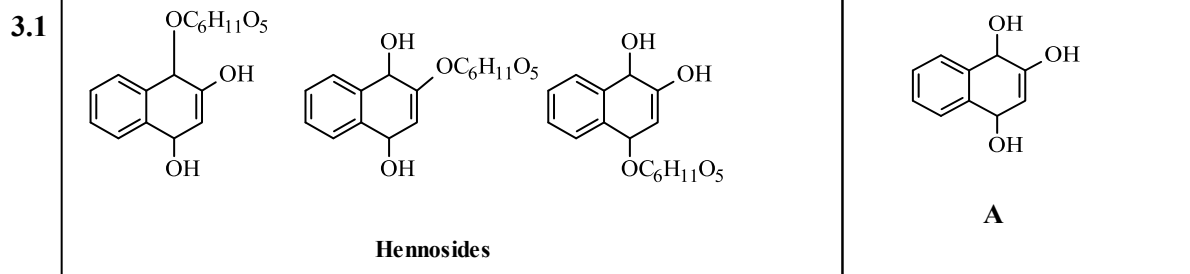
3.1

Hennosides

A

(2.5 marks)

3.2   a) Lemon juice | X | **(1 mark)**

3.3

B

(0.5 mark)

3.4

Reduced Species   **Resonance Structures**

(2 marks)

3.5
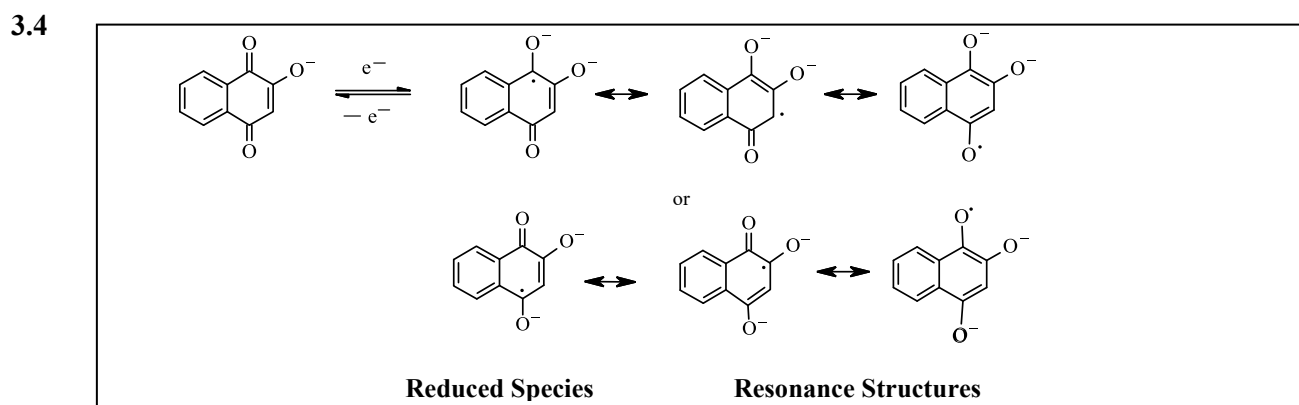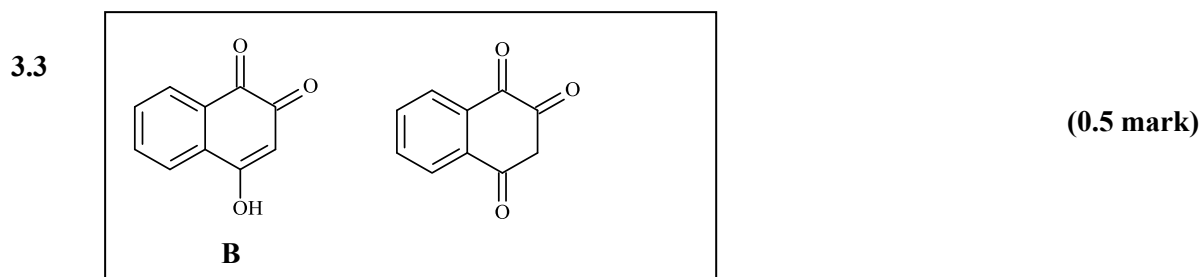
Lawsone   Juglone
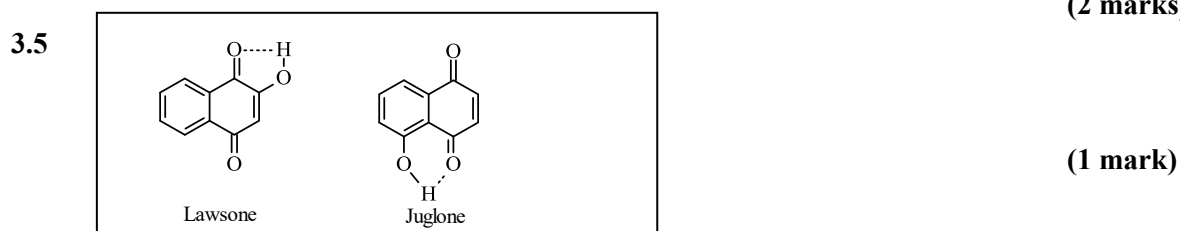
(1 mark)

3.6   Lawsone | X | Juglone | X | **(1 mark)**

3.7   Lawsone | X | **(1 mark)**

3.8

(2.5 marks)

3.9   a) Base | X | **(0.5 mark)**

3.10 | 2-propenoyl chloride | **(2 marks)**

3.11

$H_2SO_4 \text{ (aq)} + Et_3N \text{ (aq)} \longrightarrow$

 $(HSO_4)^-_{\text{(aq)}}$

Aqueous phase (organic/aqueous interface also accepted)
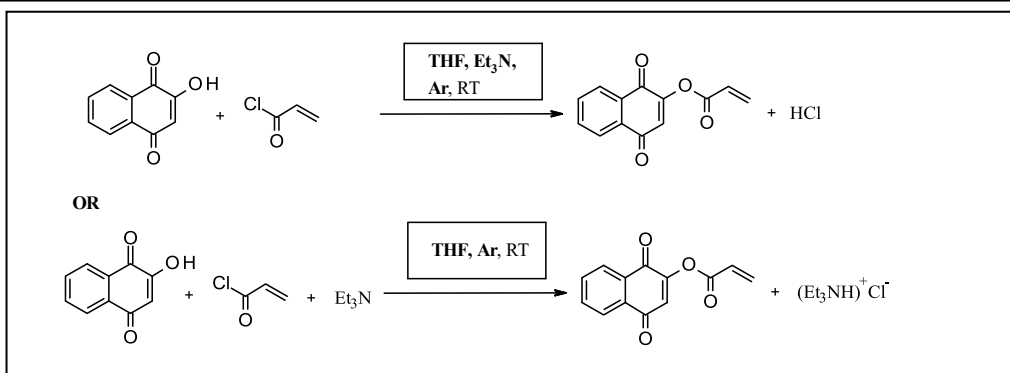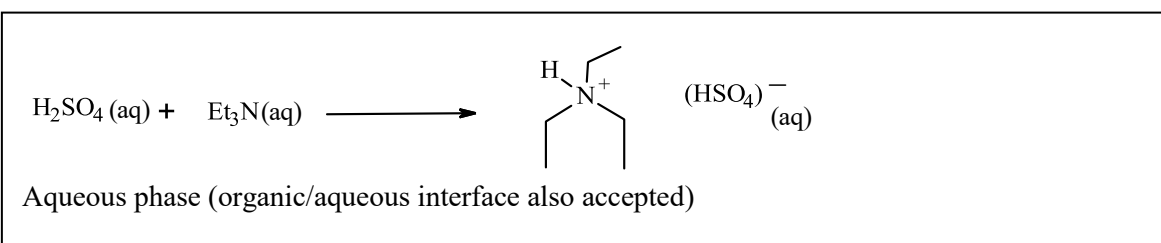
(1.5 marks)

3.12
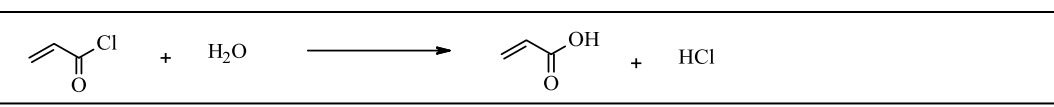
(1 mark)

3.13
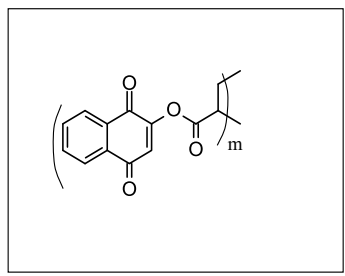
(1 mark)

3.14   **True**   **False**

(i) | | | X |

(ii) | X | | | **(1.5 marks)**

(iii) | X | | |

Problem 4   **23.5 Marks**

Gold Refining

Part I: Cyanidation Method

4.1

$2Au$ (s) $+ 4NaCN$ (aq) $+ O_2$ (aq) $+2H_2O \rightarrow 2Na[Au(CN)_2]$ (aq) $+ 2NaOH$ (aq) $+ H_2O_2$(aq)

$2Au$ (s)$+ 4NaCN$ (aq) $+ H_2O_2$ (aq) $\rightarrow 2Na[Au(CN)_2]$ (aq) $+ 2NaOH$ (aq)

Or [ionic equation]

$2Au$ (s)$+ 4CN^-$(aq) $+ O_2$ (aq) $+2H_2O \rightarrow 2[Au(CN)_2]^-$(aq) $+ 2OH^-$ (aq) $+ H_2O_2$(aq)

$2Au$ (s)$+ 4CN^-$ (aq) $+ H_2O_2$ (aq) $\rightarrow 2[Au(CN)_2]^-$(aq) $+ 2OH^-$(aq)

Or

$2Au$ (s)$+ 4CN^-$(aq) $+ O_2$ (aq) $+2H^+ \rightarrow 2[Au(CN)_2]^-$(aq) $+ H_2O_2$(aq)

$2Au$ (s)$+ 4CN^-$ (aq) $+ H_2O_2$ (aq) $+2H^+ \rightarrow 2[Au(CN)_2]^-$(aq) $+ 2 H_2O$(aq)

(1.5 marks)

4.2

Net reaction: $4Au$ (s) $+ 8CN^-$(aq) $+O_2$ (aq) $+ 2H_2O \rightarrow 4[Au(CN)_2]^-$ (aq) $+ 4OH^-$(aq)
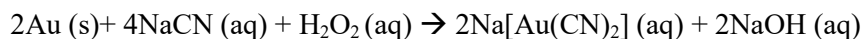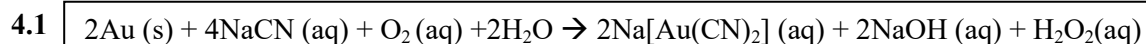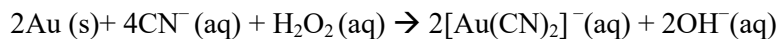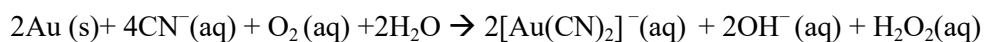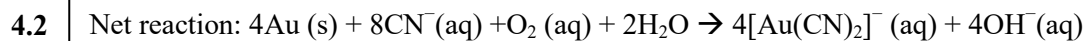
NaCN concentration $= 0.105$ g L^{-1}.

(2 marks)

4.3   Linear , $\mu_{spin} = 0$ **(1mark)**

4.4   **(2.5 marks)**

$$E_{(Au(CN)_2)^-/Au} = -0.57 - 0.059 \, log \frac{[CN^-]^2}{[Au(CN)_2]^-}$$

4.5   **(i)**   Au, Ag, Pd, Pt

(ii)   Au > Ag > Pd > Pt   **(3 marks)**

4.6   pH ≈ 9.1 **(1 mark)**

4.7 $[Cu(CN)_4]^{3-}$, $[Cu(CN)_3]^{2-}$ **(1 mark)**

4.8   a)   X   d)   X   **(2 marks)**

Part II: Thiourea Method

4.9 $Au + 2CS(NH_2)_2 + Fe^{3+} \longrightarrow [Au(CS(NH_2)_2)_2]^+ + Fe^{2+}$
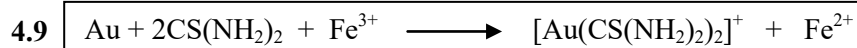
(1 mark)

4.10
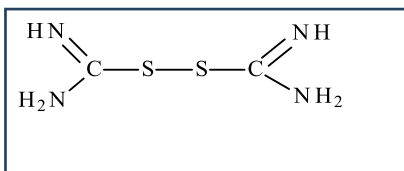
(1 mark)

4.11 $295\ K$

(2.5 marks)

4.12 (A) $\boxed{X}$ (C) $\boxed{X}$

(1 mark)

4.13 $6CS(NH_2)_2 + KIO_3 + 6H^+ \rightleftharpoons 3[CS(NH_2)_2]_2^{2+} + 3H_2O + KI$

(1 mark)

4.14 Mass of gold recovered $= 5.91\ g\ L^{-1}$

(3 marks)

Problem 5   **24 marks**

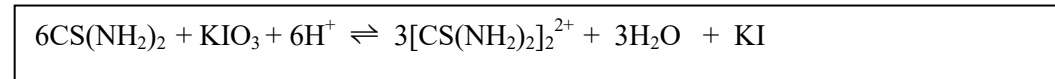**Phosphate and Struvite**

Part I: Struvite from Phosphate

5.1

> 13.26 mg L^{-1}

(**1.5 marks**)

5.2

> Molar ratio MAP: MKP = 3.3: 1

(**2 marks**)

5.3

> A = MgHPO$_4$, Molar mass = 120.4 g mol^{-1}
> B = Mg$_2$P$_2$O$_7$, Molar mass = 222.6 g mol^{-1}

(**3 marks**)

Part II: Precipitation Conditions for Struvite

5.4

> At pH 7,
> $([PO_4^{3-}]/[H_2PO_4^-])$ = 3.02 ×10^{-6}:1
> At pH 11,
> $[PO_4^{3-}]/[HPO_4^{2-}]$ = 0.048:1

(**2 marks**)

5.5

> a) % NH$_4^+$ = 50%
>
> b) % NH$_4^+$ = 1.67%
>
> c) pH ≈ 7.24

(**2.5 marks**)
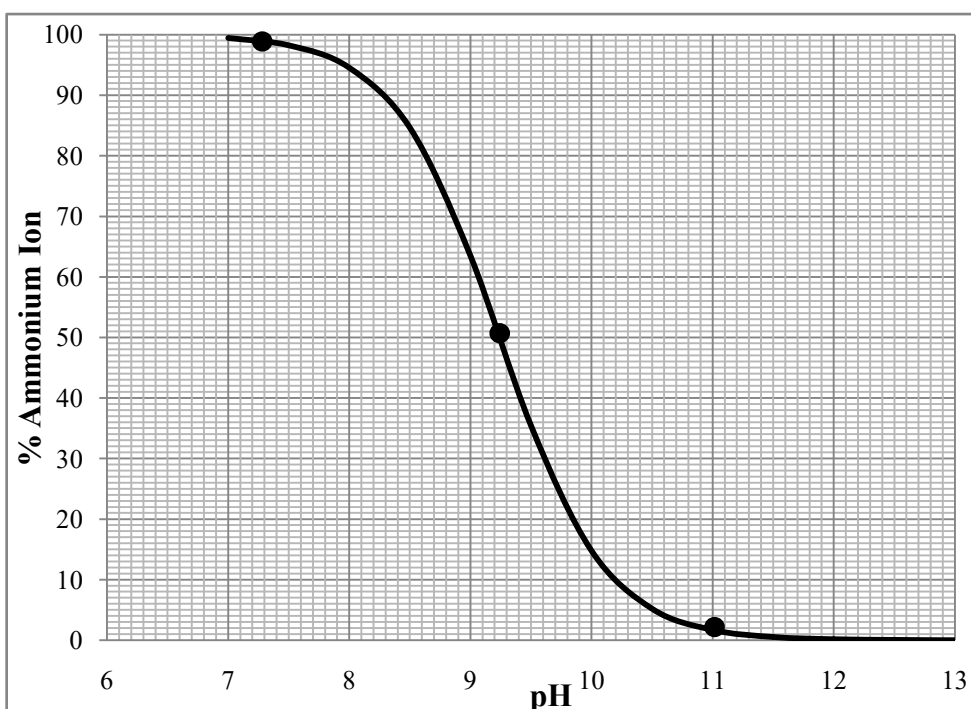
(**1.5 marks**)

5.6 | % Mg^{2+} = 71.56% | **(2 marks)**

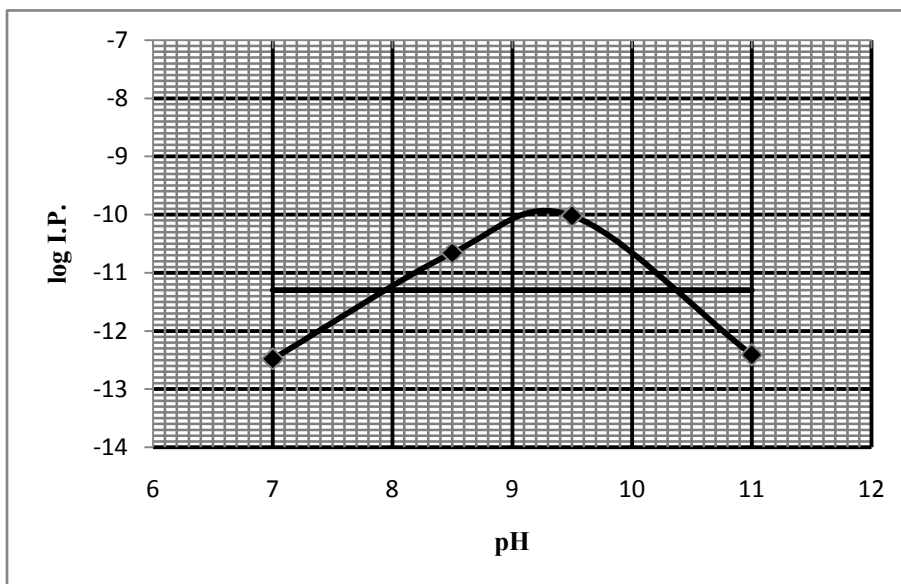**5.7**   **(i)** | At pH 7, I.P. = 3.24 × 10^{-13}

At pH 11, I.P. = 3.85 × 10^{-13} | **(4 marks)**

(ii)

| **pH Range:** 7.9- 10.4 |

                                                                    (2.5 marks)

5.9   **c)** | X | **(1 mark)**

5.10   **Effect**

a) | iii |

b) | iii |

c) | iii |

d) | i | **(2 marks)**