<table>
<tr><th>Q</th><th></th><th></th><th>Mark(s)</th></tr>
<tr><td>1 (a)</td><td></td><td>21 protons</td><td>1</td></tr>
<tr><td>(b)</td><td>(i)</td><td>
<table>
<tr><th>Element</th><th>C</th><th>H</th><th>O</th></tr>
<tr><td>Mass (g)</td><td>$\frac{12}{44}$ x 1.76
= 0.48</td><td>$\frac{2}{18}$ x 0.54
= 0.06</td><td>1.18 - 0.48 – 0.06 = 0.64</td></tr>
<tr><td>number of mole (mol)</td><td>$\frac{0.48}{12}$
= 0.04</td><td>$\frac{0.06}{1}$
=0.06</td><td>$\frac{0.64}{16}$
=0.04</td></tr>
<tr><td>mole ratio</td><td>1</td><td>1.5</td><td>1</td></tr>
<tr><td>simplest whole number ratio</td><td>2</td><td>3</td><td>2</td></tr>
<tr><td>Empirical formula</td><td colspan="3">$C_2H_3O_2$</td></tr>
</table>
</td><td>1
1
1
1</td></tr>
<tr><td></td><td>(ii)</td><td>$(C_2H_3O_2)_n$ =118
59n =118
n =2
molecular formula of compound Y is $C_4H_6O_4$</td><td>1
1</td></tr>
<tr><td>(c)</td><td></td><td>Number of mole of thiophene
$= \frac{9.660}{(4x12)+(4x1)+32} = \frac{9.660}{84.1}$ = 0.115 mol

Mass of toluene = density x volume
= 0.867 g/mL x 260 mL
= 225.42 g

Molality of the thiophene solution
$= \frac{\textbf{mole of solute (mol)}}{\textbf{mass of solvent (kg)}}$
$= \frac{0.115\ mol}{0.22542\ kg}$
= 0.51 mol kg^{-1} @ m</td><td>1
1
1
1</td></tr>
<tr><td>(d)</td><td>(i)</td><td>$2H_2S$ (g) + $3O_2$ (g) → $2SO_2$ (g) +$2H_2O$ (l)</td><td>1</td></tr>
<tr><td></td><td>(ii)</td><td>Number of mole of H_2S = $\frac{6}{24.0}$ = 0.25 mol (given)

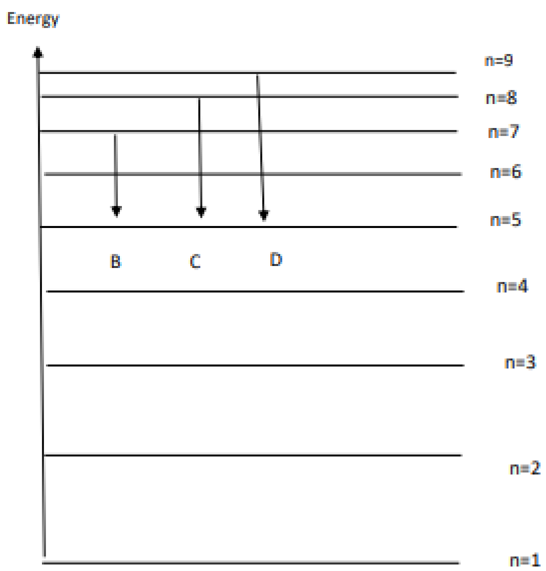
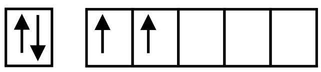
Number of mole of O_2 = $\frac{12}{24.0}$ = 0.5 mol (given)

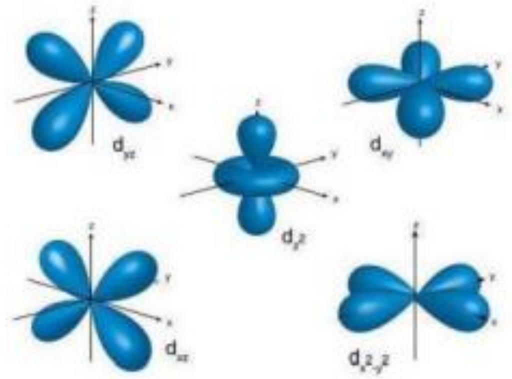
From chemical equation, 2 mol of H_2S ≡ 3 mol of O_2
In this reaction, 0.25 mol of H_2S ≡ x mol of O_2

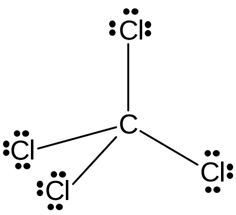
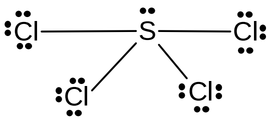
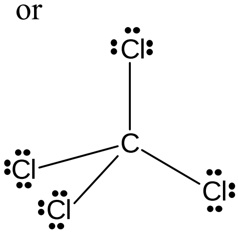
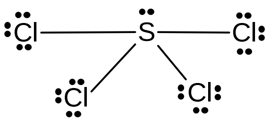
x = $\frac{0.25x3}{2}$ = 0.375 mol of O_2 (required)

number of mole of O_2 needed (0.375 mol) < number of mol of O_2 provided,
therefore O_2 is excess reactant and H_2S is limiting reactant.</td><td>1
1
1
1
1</td></tr>
<tr><td></td><td>(iii)</td><td>At the end of the reaction, all the H_2S are used up. There are remaining O_2 and also SO_2 that produced.

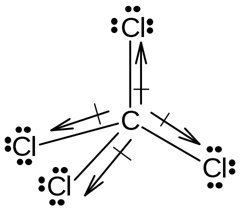
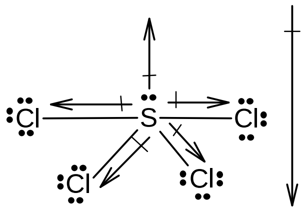
Number of mol of O_2 remaining = 0.5 - 0.375
= 0.125 mol</td><td>1</td></tr>
</table>

		From chemical equation, **1 mol of $H_2S \equiv$ 1 mol of SO_2** Therefore, number of mol of SO_2 that produced = 0.25 mol Total number of mol of gas = 0.125+0.25 **= 0.375 mol** Volume of the gaseous mixture = 0.375 mol x 24 $dm^3\ mol^{-1}$ **= 9 dm^3**	1 1 1
		TOTAL	**21 marks**
2(a)	i	Transition **B : n7-n5** **C : n8-n5** **D : n9 – n5** 	Axis 1 Arrow 1 Label 1
	ii	**Line A = n6-n5** $\Delta E = R_H\left(\frac{1}{n_i^{\ 2}} - \frac{1}{n_f^{\ 2}}\right)$ $= 2.18\times10^{-18}\ J\left(\frac{1}{6^2} - \frac{1}{5^2}\right)$ **= $-2.66\ x\ 10^{-20}$ J @** **= $-2.66\ x\ 10^{-23}$ kJ**	**1** **1**
	iii	**E< D < C < B < A**	**1**
2(b)	i	**$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$**	**1**
	ii	 4s 3d	**1**

	iii		Any 2 3D structure 2
	iv	**(4,0,0, +1/2) or any suitable answer**	1
	v	**12 electron**	1
		TOTAL	**12 marks**
		MAX	**10 marks**
3(a)	i		

compounds	CCl_4	SCl_4	
Total valens electron	C = 4 Cl = 7 x 4 = 28 = 32 -8 24 -24 0	S = 6 Cl = 7 x 4 = 28 = 34 -8 26 -24 2 -2 0	**1**
Lewis Structure			**1**
Number and arrangement of electron domain according to VSEPR	**4 (bonding pair) tetrahedral**	**5(4 bonding pair + 1 lone pair) Trigonal bipyramidal**	**1**
Molecular geometry	**Tetrahedral** or 	**See-saw** or 	**1**

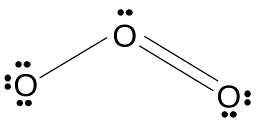
ii

compounds	CCl_4	SCl_4
Bond dipole (show @ explain)	 @ **C-Cl bond is polar because Cl is more electronegative than C**	 @ **S-Cl bond is polar because Cl is more electronegative than S**
polarity	**Bond dipole cancel each other or** **$\mu = 0$** **Non-polar molecule**	**Bond dipole do not cancel each other** **$\mu \neq 0$** **Polar molecule,**

Marks: **1**, **1**, **1**, **1**

8 marks

(b)



Number of electron domain = 3 **1**

Type of hybridisation = sp^2

O (ground state) = [↑↓] 2s [↑↓][↑][↑] 2p **1**

O^+ (ground state) = [↑↓] 2s [↑][↑][↑] 2p **1**

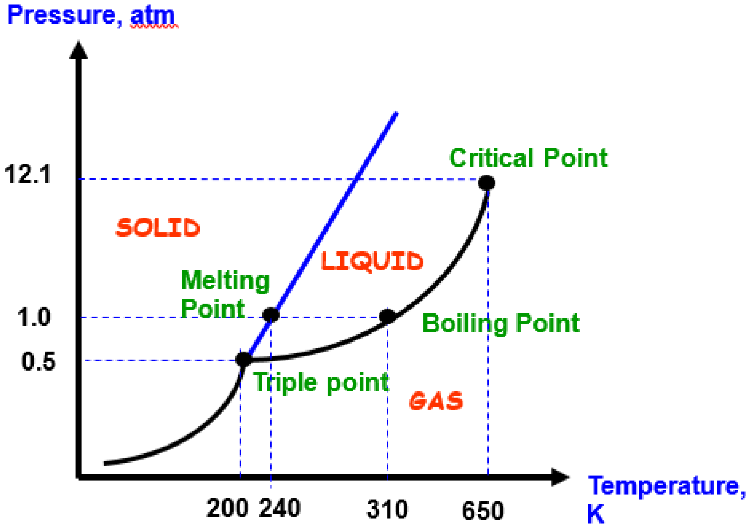
O^+ (excited state) = [↑↓] 2s [↑][↑][↑] 2p **1**

O^+ (hybrid state) = [↑↓][↑][↑] sp^2 [↑] 2p **1**

5 marks

(c) i.

- **Oxygen atom is more electronegative than nitrogen atom** 1
- Hydrogen bond between water molecules is stronger than hydrogen bonds between the ammonia molecules. 1

	ii	• Aluminium has **3 valence electrons** per atom while magnesium has **2 valence electrons** per atom. • Metallic bond in aluminium is stronger than in magnesium	1 1
			4 marks
		TOTAL	**17 marks**
4(a)	i	$P_{Ne} = X_{Ne} . P_T$ $1.3 = \frac{1}{4} \times P_T$ P_T = **5.2 atm**	1
	ii	$P_{He} = \frac{2}{4} \times 5.2$ = **2.6 atm** $P_1V_1 = P_2V_2$ $(2.6)(12.5) = P_2 (5.0)$ P = **6.5 atm**	1 1
(b)		Condition that gas deviates: **High pressure, low temperature** • **Volume of gas particles is significant.** • **Attractive and repulsive forces between gas particle is significant.**	1+1 1 1
(c)		 -label all points given (b.p, m.p, triple point and critical point) -sketch correct curve -label all phases	1 1 1
		TOTAL	**10 marks**
		MAX	**9 marks**
5(a)		$[COCl_2]$ = **0.8 M** $[CO]$ = **0.5 M** $[Cl_2]$ = **0.6 M**	1

		$Kc = \frac{[CO][Cl2]}{[COCl2]}$ @ $= \frac{[0.5][0.6]}{[0.8]}$ = 0.375	1 1
(b)		New Kc = 1.5 x 0.375 = **0.5625** $Kp = Kc\,(RT)^{\Delta n}$ = 0.5625 (0.08206 X 520)^1 = **24**	1 1
(c)	i	In order to reattain the equilibrium, **the equilibrium position will shift to the left** so that **the concentration of carbon monoxide will decrease.**	1 1
	ii	In order to reattain the equilibrium, **the equilibrium position will shift to the right** with a **greater number of moles of gas** so that the **pressure of the system will increase.**	1 1
		TOTAL	**9 marks**
6(a)	i	$$C_5H_5N\,(aq) + H_2O(l) \rightleftharpoons C_5H_5NH^+(aq) + OH^-(aq)$$	1

$[\ ]_i$ / M	2.5 x10^{-3}	-	0	0
$[\ ]_\Delta$ / M	-x	-	+ x	+ x
$[\ ]_{Eq}$ / M	2.5 x10^{-3} - x	-	x	x

$$\boldsymbol{\alpha\% = \frac{[\ ]\Delta}{[\ ]i} \times 100\%}$$ 1

$$0.082\% = \frac{x}{2.5 \times 10^{-3}} \times 100\%$$

x = 2.05 x10^{-6}

$[OH^-] = [C_5H_5NH^+] =$ 2.05 x10^{-6} M

$[C_5H_5N]$ = (2.5 x10^{-3}) – (2.05 x10^{-6}) = **2.50 x10^{-3} M** 1

$$K_b = \frac{[OH^-][C_5H_5NH^+]}{[C_5H_5N]}$$

$$= \frac{(2.05\times10^{-6})^2}{2.50\times10^{-3}}$$ 1

= 1.68 x10^{-9} 1

	ii	$pOH = -\log\,[OH^-]$ $= -\log(2.05 \times 10^{-6})$ $= \mathbf{5.69}$ $\therefore pH = 14 - 5.69 = \mathbf{8.31}$	 1 1

6(b)	i	$\boldsymbol{pH = pK_a + log\frac{[CH_3COO^-]}{[CH_3COOH]}}$ $pH = -\log(1.8 \times 10^{-5}) + log\left(\frac{0.4}{0.3}\right)$ $\boldsymbol{= 4.86}$	1 1
	ii	**$Mg_3(PO_4)_2$ (s) ⇌ 3Mg (aq) $^{2+}$ + $2PO_4^{3-}$ (aq)** 3y 2y **K_{sp} = $[Mg^{2+}]^3$ $[PO_4{}^{3-}]^2$** 5.2 x 10^{-24} = $(3y)^3$ $(2y)^2$ 5.2 x 10^{-24} = $108y^5$ **y = 8.64 x 10^{-6} M** Molar solubility = 8.64 x 10^{-6} M $\text{Solubility (gL}^{-1}) = \text{molar solubility} \times \text{molar mass}$ $= (8.64 \boldsymbol{\times 10^{-6}\ molL^{-1}})\ (262.9\ \boldsymbol{gmol^{-1}})$ $= 2.27 \boldsymbol{\times 10^{-3}\ gL^{-1}}$	1 1 1 1 1
		TOTAL	**14 marks**