2014 HCI C2 Chemistry Prelim Paper 2 – Answers

1 (a) Cathode: $2H^+(aq) + 2e^- \rightarrow H_2(g)$ **[1]**

(b) Q = It = (0.50)(10)(60) = 300 C
No. of moles of electrons = 300 / 96500 = 0.003109
No. of moles of hydrogen gas = 1.554×10^{-3}
Volume of hydrogen gas = $1.554 \times 10^{-3} \times 24000 = 37.3\ cm^3$ **[1]**

(c) Diagram – **3** marks:

- Battery (correct polarity)
- complete circuit with ammeter
- appropriate choice of electrodes – Pt or graphite
- appropriate choice of apparatus for collecting H_2 and holding electrolyte – E.g. inverted measuring cylinder/burette, beaker/ water trough

Electrolysis – **2** marks:

- Record initial and final current to find average current
- Stop experiment after 10 min
- Record initial and final burette / measuring cylinder

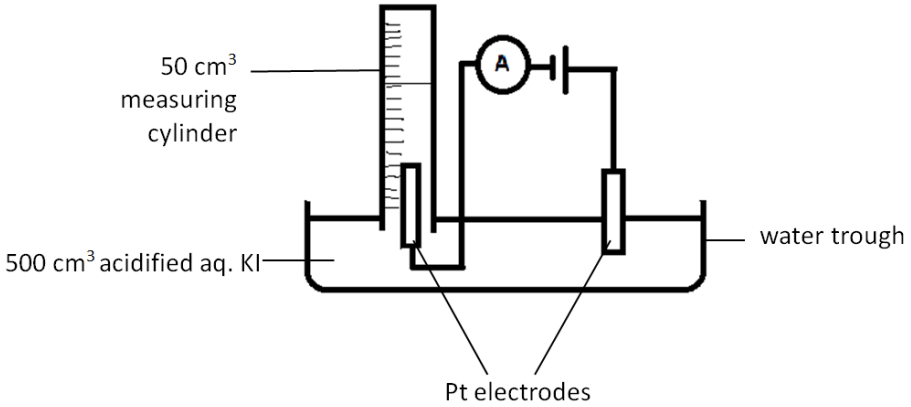
Titration – **3** marks:

- Stir/swirl the electrolyte after disconnecting the set-up
- Pipette out 25.0 cm^3 of electrolyte into a conical flask, fill up burette
- Record initial and final burette readings
- Add starch indicator at correct juncture
- State colour change – blue-black to colourless

Calculations – **2** marks:

- Determine number of moles of electrons at anode
- Determine L using the equation L = (average current x time) / (number of moles of electrons x charge of an electron)

Sample answer:



1) Using the given 500 cm^3 of acidified KI, fill a 50 cm^3 measuring cylinder with some acidified KI and transfer the remaining solution into the water trough. Invert the measuring cylinder over the Pt electrode and set up the apparatus as shown above. Do not connect the battery yet.
2) Record the initial reading on the measuring cylinder.

3) Connect the battery and immediately record the initial current shown on the ammeter. Start the stopwatch at the same time.
4) At 10 minutes, record the final current and final reading on the measuring cylinder. Disconnect the battery. Dismantle the setup and empty the solution in the measuring cylinder into the water trough.
5) Stir the electrolyte using a glass rod.
6) Pipette 25.0 cm^3 of the electrolyte into a 250 cm^3 conical flask.
7) Fill up a burette with aqueous $Na_2S_2O_3$. Record initial burette reading.
8) Titrate the solution in the conical flask with aqueous $Na_2S_2O_3$ until the solution turns pale yellow. Add about 1 cm^3 of starch.
9) Continue titration until the solution turns from blue-black to colourless. Record final burette reading.

<u>Processing of Data</u>

Let the titre value be V cm^3.

No. of moles of $Na_2S_2O_3$ used = $\frac{V}{1000} \times 0.0100$ = 1 x 10^{-5} V

No. of moles of iodine used for titration = ½ x 1 x 10^{-5} V

No. of moles of iodine produced in electrolysis = $\frac{500}{25}$ x ½ x 1 x 10^{-5} V

No. of moles of electrons = 2 x $\frac{500}{25}$ x ½ x 1 x 10^{-5} V = 2 x 10^{-4} V

Let average current be I

Total charge passed through = It = I x (10 x 60) = 600I

L = $\frac{Q}{ne} = \frac{600I}{2 \times 10^{-4}V \times 1.6 \times 10^{-19}}$

Total: [12]

2 (a) (i) $Mg^{2+}(aq) + 2F^{-}(aq) = MgF_2(s)$

$K_{sp} = [Mg^{2+}][F^-]^2$ $mol^3\ dm^{-9}$ **[1]**

(ii) $[F^-] = (\frac{1 \times 10^{-3}}{19.0})$ = 5.26 x 10^{-5} mol dm^{-3}

IP of $MgF_2 = [Mg^{2+}][F^-]^2 = [Mg^{2+}](5.26 \times 10^{-5})^2$

Precipitation first occurs when $[Mg^{2+}][F^-]^2 = K_{sp}$

$\therefore \quad [Mg^{2+}](5.26 \times 10^{-5})^2 = 5.16 \times 10^{-11}$

$[Mg^{2+}] = 0.0186$ mol dm^{-3}

The minimum concentration of Mg^{2+} is 0.0186 mol dm^{-3}. **[2]**

(b) (i) Hydrogen gas (H_2), chlorine gas (Cl_2) and sodium hydroxide **[1]**

(ii) $3Cl_2(g)/(aq) + 6NaOH(aq) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$ OR

$3Cl_2(g)/(aq) + 6OH^-(aq) \rightarrow 5Cl^-(aq) + ClO_3^-(aq) + 3H_2O(l)$ **[1]**

(c) Hydrogen iodide formed is **<u>oxidised</u>** by conc, H_2SO_4 **to <u>iodine</u>** since HI is easily oxidised

any of these equations (state symbols not required)

$2HI(g) + H_2SO_4(l) \rightarrow I_2(g) + SO_2(g) + 2H_2O(l)$
$6HI(g) + H_2SO_4(l) \rightarrow 3I_2(g) + S(s) + 4H_2O(l)$
$8HI(g) + H_2SO_4(l) \rightarrow 4I_2(g) + H_2S(g) + 4H_2O(l)$

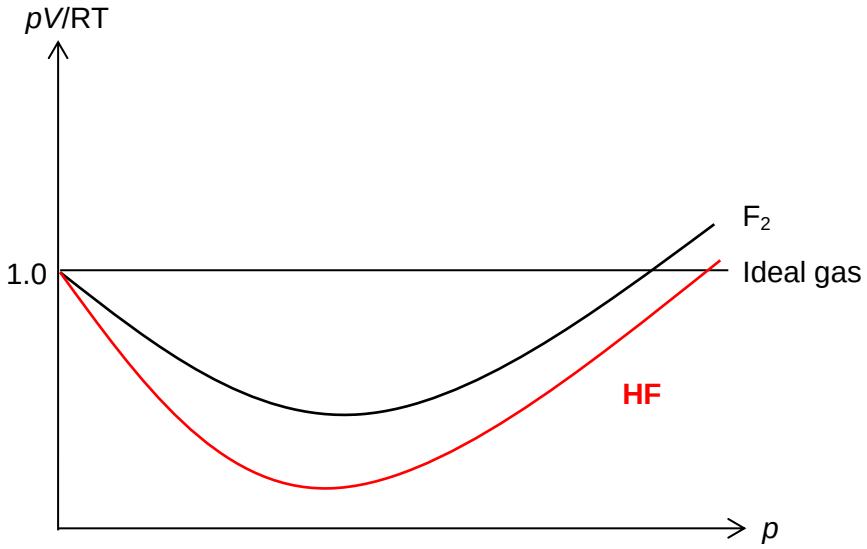
[2]

(d) **(i)**

- molecules/particles of an ideal gas have zero/negligible volume.
  (reject: Ideal gases have zero volume)
- there are negligible (or NO) intermolecular forces of attraction between ideal gas molecules/particles
- collisions between ideal gas molecules are perfectly elastic (i.e. no loss of energy during collision)

[3]

(ii)



HF deviates more from ideal behaviour because it experiences <u>stronger Intermolecular hydrogen bonding</u> between the molecules compared to F_2 which has only (instantaneous dipole–induced dipole interaction or dispersion forces) between its molecules.

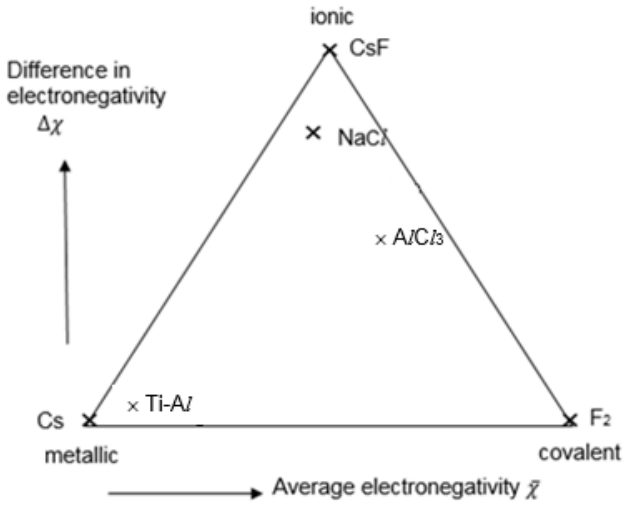
[2]

Total: [12]

3 **(a)** **(i)**

	Type of bonding	Position in the triangle
NaC*l*	ionic	any point below CsF
A*l*C*l*$_3$	covalent	any point below and to the right of NaC*l*
Ti-A*l* alloy	metallic	any point close to Cs

(ii)



[3]

(b) **(i)** The discrepancies in lattice energy values are due to the presence of <u>covalent character in the silver halides</u>. A greater difference between lattice energy values is observed for AgI due to a <u>more polarisable electron cloud of the anion / smaller difference in electronegativity between Ag and I</u>.

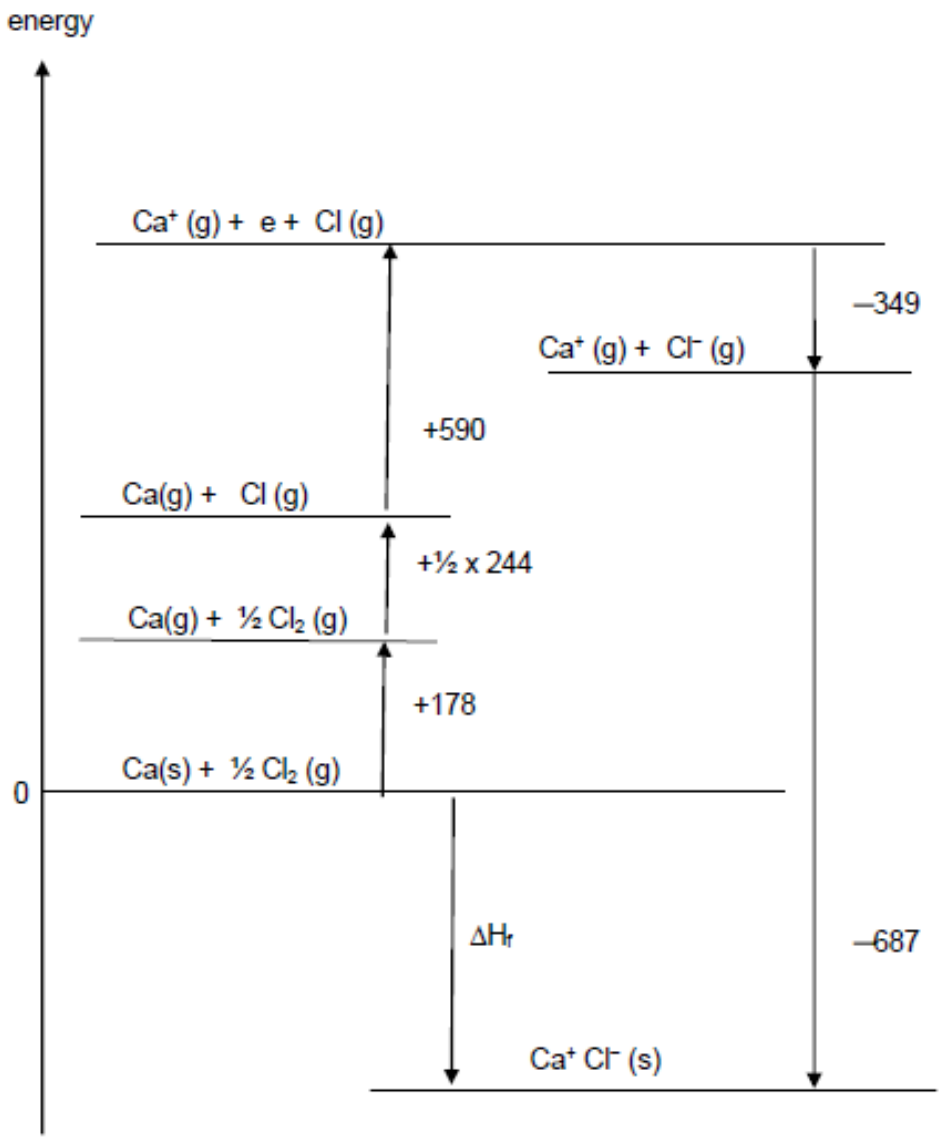
[1]

(ii) $\Delta H_{latt}(\text{CaCl}) = \dfrac{107.9 \times 2 \times (+1) \times (-1)}{(0.133 + 0.181)} = -687 \text{ kJ mol}^{-1}$

$\Delta H_{latt}(\text{CaCl}_2) = \dfrac{107.9 \times 3 \times (+2) \times (-1)}{(0.099 + 0.181)} = -2312 \text{ kJ mol}^{-1}$

[2]

(iii)



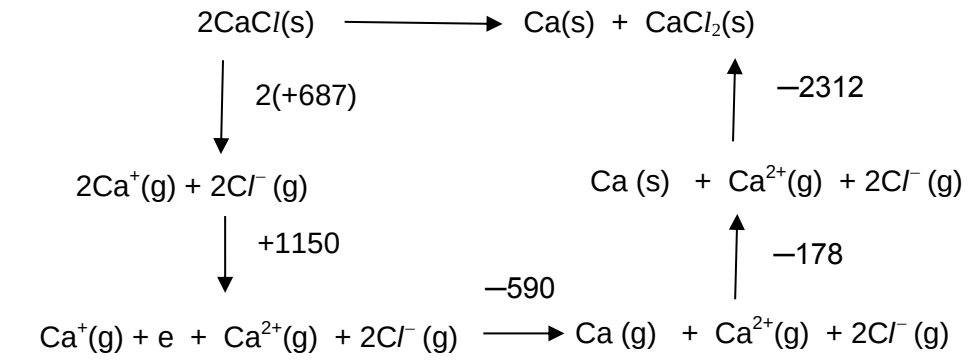
By Hess's Law,

ΔH_f = (+178) + (+½ x 244) + (+590) + (–349) + (–687)

= –146 kJ mol^{-1}

[4]

(iv)



ΔH_r = 2(+687) + (+1150) + (–590) + (–178) + (–2312)

= –556 kJ mol^{-1}

[3]

(v) *Provides support :* **(b)(iv)**

Explanation :

Although a negative ΔH_f (= −146 kJ mol^{-1}) means that CaC*l* is stable with respect to its elements, CaC*l* is unstable with respect to its disproportionation products. So the reason for the non-existence of CaC*l* is because the ΔH_r of the disproportionation reaction is strongly exothermic (= −556 kJ mol^{-1}). **[1]**

(c) (i) $2Ba(NO_3)_2(s) \rightarrow 2BaO(s) + 4NO_2(g) + O_2(g)$ **[1]**

(ii) Cs^+ has a lower positive charge and larger ionic radius, hence a lower charge density.
It is unable to polarize the electron cloud of the nitrate ion sufficiently / completely to cause it to break up into O^{2-}.

[2]

(d) (i) $K_a = \frac{[H^+]^2}{0.100}$ (assume that $[H^+] << 0.100$)

$[H^+] = \sqrt{10^{-5.0} \times 0.100} = 10^{-3}$
pH = 3 **[1]**

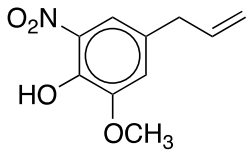
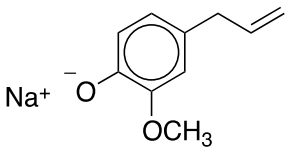
(ii) *Cation:* Al^{3+} or Fe^{3+}

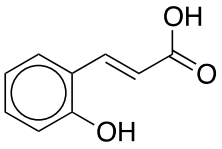
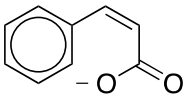
Explanation:
The aqua complex of Al^{3+} (or Fe^{3+}) has a lower pK_a value than that of H_2CO_3. Hence, it is a stronger acid than H_2CO_3 / is able to protonate HCO_3^- to form H_2CO_3, which decomposes to give CO_2 and H_2O.

Observations and products::
A*l*$^{3+}$: effervescence of CO_2 and white ppt of A*l*$(OH)_3$
Fe^{3+}: efferverscence of CO_2 and reddish brown ppt of $Fe(OH)_3$ **[3]**

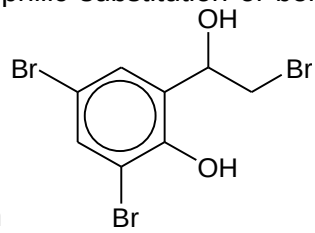
Total: [21]

4 (a)

reagent	compound **A**, **B**, **C** or **D**	structural formula of the organic product
dilute HNO_3	D	
Na	D	

dilute H_2SO_4, heat	A	
Fehling's reagent	B	

[4]

(b) Step I: Electrophilic substitution of benzene ring with Br_2(aq) will also take place to produce the  product shown OR lone pair of electrons on O in phenol group delocalises into benzene ring, hence making benzene ring more electron rich towards attack by electrophile.

Step II: Nucleophilic substitution requires nucleophile (CN^-) which is in very low concentration as HCN is a weak acid.

Alternative method: Heat with ethanolic KCN

Step V: Esterification between $–CO_2H$ and phenol group cannot take place under such conditions. The lone pair of electrons on O in phenol group is not nucleophilic enough to attack the $–CO_2H$ as it is delocalized into the benzene ring.

Alternative method: Add PCl_5 / $SOCl_2$ **[6]**

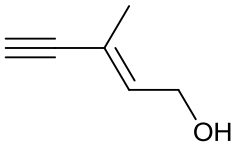
(c) No. of moles of compound A = 10/146 = 0.06849 mol

No. of moles of 2-vinylphenol needed = 0.06849 x $(100/80)^5$ = 0.2090 mol

Mass of 2-vinylphenol needed = 0.2090 x 120 = 25.1 g **[2]**

[Total = 12]

5 (a) (i) Geometric isomerism. Geometric isomerism arises when there is restricted rotation about the double bond and the two groups on each C of the restricted bond must not be identical. **[2]**

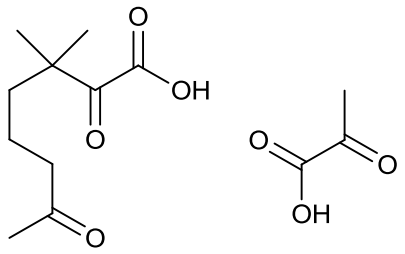
(ii)  **[1]**

(iii) Reduction/ Hydrogenation. **[1]**

(iv) Palladium is a heterogeneous catalyst in this reaction. It is able to bring the reactant molecules close due to the presence of partially filled *d* orbitals that can accept electron pairs from, or donate electron pairs to them. **[2]**

(v) H_2/Ni will cause all the double bonds (and triple bond) to be reduced. **[1]**

(b) **(i)**



[2]

(ii) BCO is an enzyme and has a very specific action, in this case, to cleave only one of the C=C bond. There are many other C=C double bonds in *β*-carotene, which will all be cleaved using acidified $KMnO_4$ in the laboratory. **[2]**

(iii) Phenylalanine. The side chain of phenylalanine is very non-polar and will be able to form favourable van der Waals' forces of attraction with the non-polar *β*-carotene. **[2]**

(iv) **I**: Tertiary structure.The sodium hydroxide will deprotonate ionic R groups and disrupt ionic bonds.

II: Primary structure. When heated under reflux with aqueous sodium hydroxide, the primary structure will be destroyed when the peptide bonds are broken/the protein is hydrolysed. **[2]**

Total: [15]