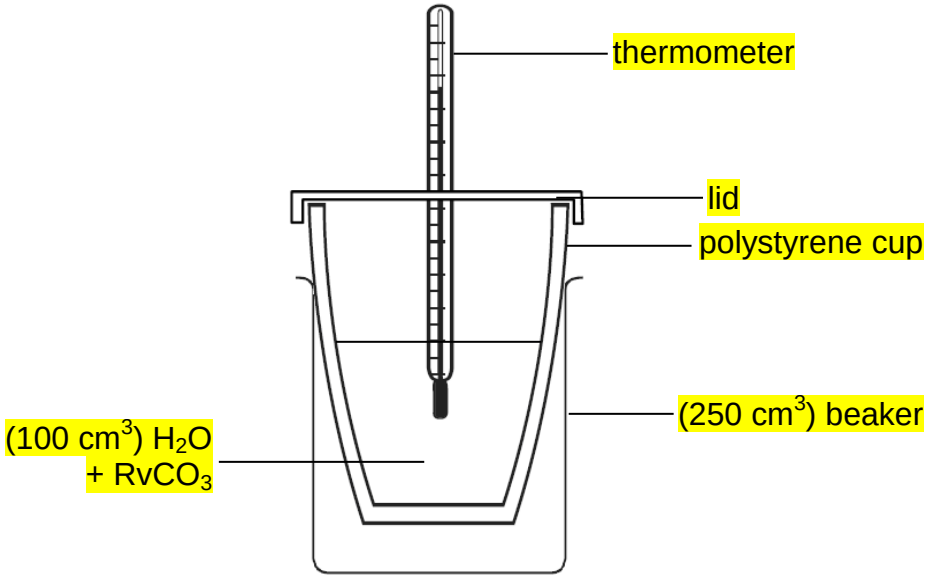
Answer key to Paper 2

1 (a) $RvCO_3 + 2HCl \rightarrow RvCl_2 + CO_2 + H_2O$ **[1]**

(b)



[2]

(c) Preparation of saturated $RvCO_3$ solution

1. Using a 100 cm^3 measuring cylinder, place about 100 cm^3 of deionised water (accept any volume between 80 – 250 cm^3) into a polystyrene cup.
2. Measure and record the initial temperature of the water using a thermometer.
3. Using a spatula, add solid $RvCO_3$ into the polystyrene cup and stir/swirl gently with the thermometer / stirrer. Continue to add more solid and stir, until some solid $RvCO_3$ remains undissolved to ensure a saturated solution is obtained.
4. Record the lowest temperature reached on the thermometer.
5. Filter the saturated solution using a dry filter funnel and dry filter paper into a dry 250 cm^3 conical flask / beaker to ensure the saturated solution is not diluted.

Justification of concentration of standard HC*l* solution

For a 25.0 cm^3 aliquot of saturated $RvCO_3(aq)$, a reasonable HC*l* titre value should be 25.00cm^3 (accept any value between 20−30 cm^3).

$RvCO_3 + 2HCl \rightarrow RvCl_2 + CO_2 + H_2O$

$RvCO_3 \equiv 2HCl$

Given that solubility of $RvCO_3$ is approximately 0.25 mol dm^{-3},

[HC*l*] required = $0.25 \times 2 \times \frac{25.0}{25.00}$

= 0.500 mol dm^{-3}

Titration of saturated $RvCO_3$ solution against HC*l*

1. Pipette 25.0 cm^3 of saturated $RvCO_3$ solution into a 250 cm^3 conical flask.
2. Add 2-3 drops of methyl orange indicator.
3. Titrate with the standard 0.500 mol dm^{-3} HC*l* from the burette until the colour of the solution changes from yellow to orange.
4. Repeat the titration to obtain two consistent results within 0.10 cm^3 in difference. **[6]**

(d) (i) n_{HCl} used = $\frac{W}{1000} \times C$ = 1.00 x 10^{-3} **WC** mol

$RvCO_3 \equiv 2HCl$

n_{RvCO3} in 25.0 cm^3 of saturated solution = 1.00 x 10^{-3} **WC** ÷ 2

= 5.00 x 10^{-4} **WC** mol

solubility of $RvCO_3$ = 5.00 x 10^{-4} **WC** ÷ $\frac{25}{1000}$

= 0.0200 **WC** mol dm^{-3}

(ii) Heat taken in by **V** cm^3 solution = **VCΔT**

= 4.18 **V ΔT** J

n_{RvCO3} dissolved in **V** cm^3 solution = 0.0200 **WC** × $\frac{V}{1000}$

= 2.00 x 10^{-5} **WCV** mol

$\Delta H_{soln} = \frac{4.18\ \mathbf{V\Delta T}}{2.00 \times 10^{-5}\ \mathbf{WCV}} = +2.09 \times 10^5 \frac{\mathbf{\Delta T}}{\mathbf{WC}}$ J mol^{-1} **[3]**

[Total: 12]

2 **(a)** **(i)** initial $n_{Br2} = \frac{0.107}{2 \times 79.9} = 6.70 \times 10^{-4}$ mol

At 900 K,

$Br_2(g) \rightarrow 2Br(g)$

initial $n_{Br} = 2 \times 6.70 \times 10^{-4} = 1.34 \times 10^{-3}$ mol

(ii)

	$W(s)$	+	$4Br(g)$	⇌	$WBr_4(g)$
initial amount / mol	–		1.34×10^{-3}		0
change in amount / mol	–		$-4y$		$+y$
equilibrium amount / mol	–		$1.34 \times 10^{-3} - 4y$		y

mass of gas at equilibrium

$= (1.34 \times 10^{-3} - 4y)(79.9) + (y)(184 + 4(79.9))$

$= 0.107 + 184y$

$0.107 + 184y = 0.003 \times 50$ g

$y = 2.34 \times 10^{-4}$ mol

equilibrium $n_{WBr4} = 2.34 \times 10^{-4}$ mol

equilibrium $n_{Br} = 1.34 \times 10^{-3} - 4(2.34 \times 10^{-4}) = 4.04 \times 10^{-4}$ mol

(iii) equilibrium $p_{WBr4} = \frac{2.34 \times 10^{-4} \times 8.31 \times 900}{50 \times 10^{-6}} = 3.50 \times 10^4$ Pa

equilibrium $p_{Br} = \frac{4.04 \times 10^{-4} \times 8.31 \times 900}{50 \times 10^{-6}} = 6.04 \times 10^4$ Pa

K_p at 900 K $= \frac{P_{WBr4}}{(P_{Br})^4} = \frac{3.50 \times 10^4}{(6.04 \times 10^4)^4} = 2.63 \times 10^{-15}$ Pa^{-3}

(iv) When the temperature increases from 900 K to 2800 K, the K_p decreases. This implies that the equilibrium position shifts to the left to favour the backward reaction near the tungsten filament.

(v) The addition of bromine gas allows the formation of $WBr_4(g)$, which is converted back to tungsten at the filament, slowing down the thinning of the tungsten filament. **[9]**

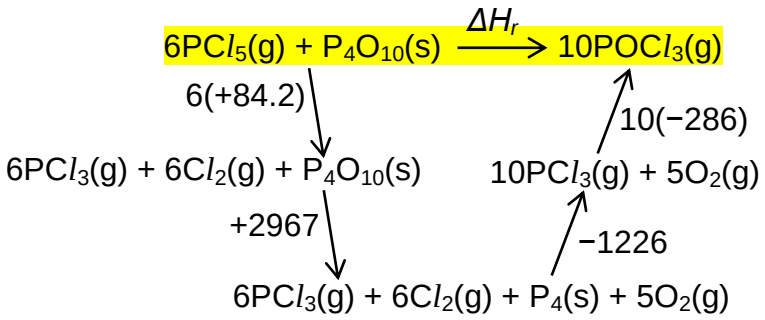
(b) **(i)** $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

pH of resultant solution = 2

(ii) PCl_5 is able to undergo hydrolysis in water because P atom is able to use its energetically accessible vacant 3d orbitals for dative bonding with water molecules.

NCl_3 does not undergo hydrolysis because N atom does not have energetically accessible vacant orbitals/ N atom is in Period 2 and not Period 3.

(iii)



Using Hess's law,

ΔH_r = 6(+84.2) +2967 + (−1226) + 10(−286)

= −614 kJ mol^{-1} (3sf) **[7]**

[Total: 16]

3 (a) (i) Both copper and calcium have giant metallic structure. In Cu, both the 4s and 3d electrons can be contributed to the sea of delocalised valence electrons as they are very close in energy. The resulting copper ions have a smaller ionic radius than Ca^{2+}. A larger amount of energy is required to overcome the stronger electrostatic attraction between the copper ions and the delocalised/mobile valence electrons compared to that between Ca^{2+} and delocalised/mobile valence.

(ii) Cu conducts electricity in the solid state due to the presence of mobile (delocalised) valence electrons that can migrate freely through the giant metallic structure when a potential difference is applied.

For CuO in solid state, the Cu^{2+} and O^{2-} ions are held in fixed positions in a giant ionic lattice structure and are not mobile. **[4]**

(b) (i) $K_{sp} = [Cu^{2+}][OH^-]^2$

$= (1.77 \times 10^{-7})(2 \times 1.77 \times 10^{-7})^2$

$= 2.22 \times 10^{-20}$ mol^3 dm^{-9}

(ii) Common ion effect refers to the reduced solubility of a sparingly soluble salt (when compared to its solubility in water) in an aqueous solution containing an ion common to that salt.

Let x be the solubility of $Cu(OH)_2$ in 0.050 mol dm^{-3} of NaOH

	$Cu(OH)_2(s)$	$\rightleftharpoons$	$Cu^{2+}(aq)$	+	$2OH^-(aq)$
Initial [ ] / mol dm^{-3}			0		0.050
Change in [ ] / mol dm^{-3}			+ x		+2x
Eqm [ ] / mol dm^{-3}			x		2x + 0.050

$x (2x + 0.050)^2 = 2.22 \times 10^{-20}$

Assume x is small such that $2x + 0.050 \approx 0.05$

$x = 8.88 \times 10^{-18}$ mol dm^{-3} << 1.77×10^{-7}

(iii) (Pale) Blue precipitate dissolves to give a dark blue solution.

$Cu(OH)_2 + 4NH_3 + 2H_2O \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^-$ **[6]**

(c) **(i)** Ppt **X**

Identity : CuI

Colour : off-white/cream

Solution **Y**

Identity : I_2

Colour : (reddish) brown

Solid **Z**

Identity : Cu

(ii) Reducing agent **[4]**

(d) $2Cu(s) + CO_2(g) + H_2O(g) + O_2(g) \rightarrow Cu(OH)_2(s) + CuCO_3(s)$ **[1]**

[Total: 15]

4 **(a)** **(i)** Anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

Cathode: $Mg^{2+}(l) + 2e^- \rightarrow Mg(l)$

(ii) Amount of Mg per day = $(20 \times 1000 \times 1000) \div 24.3$

$= 8.23 \times 10^5$ mol

$Mg \equiv 2e^-$

Amount of electrons per day $= 1.65 \times 10^6$ mol

$I = nF/t$

$= (1.65 \times 10^6 \times 96500) \div (24 \times 60 \times 60)$

$= 1.84 \times 10^6$ A **[4]**

(b) **(i)** $E^{\ominus}(H_2O/H_2) = -0.83$ V

$E^{\ominus}(Mg^{2+}/Mg) = -2.38$ V

Electrolyis of seawater would produce hydrogen gas as water is preferentially reduced since the $E^{\ominus}(H_2O/H_2)$ is more positive than $E^{\ominus}(Mg^{2+}/Mg)$.

(ii) The melting point of magnesium oxide is much higher than magnesium chloride. Melting magnesium oxide would require significantly more energy and thus incur higher cost.

(iii) Magnesium – White

Strontium/calcium – crimson/(brick) red **[6]**

(c) (i) Experiment 1: Oxygen

Experiment 2: Chlorine

$E^{\ominus}(O_2/H_2O) = +1.23$ V

$E^{\ominus}(Cl_2/Cl^-) = +1.36$ V

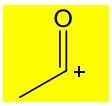
In experiment **1** water is preferentially oxidised to oxygen gas as $E^{\ominus}(O_2/H_2O)$ is more negative than $E^{\ominus}(Cl_2/Cl^-)$.

In experiment **2** chloride anion is preferentially oxidised to chlorine gas as the increased concentration of choride ions shifts the position of equilibrium $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ to the left, making $E(Cl_2/Cl^-)$ more negative than $E(O_2/H_2O)$.

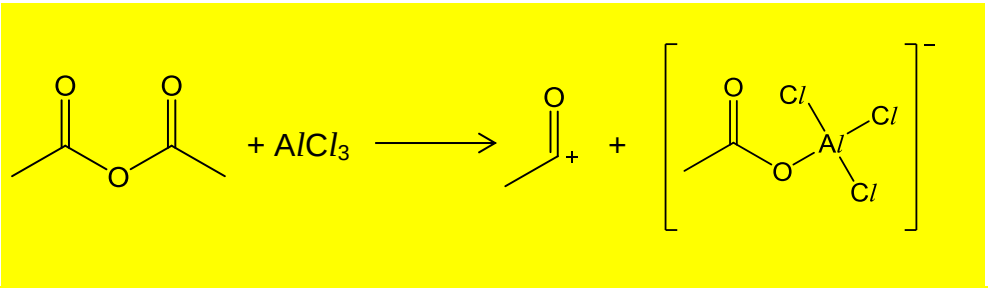
(ii) $3Cl_2(g) + 6OH^-(aq) \rightarrow 5Cl^-(aq) + ClO_3^-(aq) + 3H_2O(l)$ **[5]**

[Total: 15]

5 **(a)** **(i)**



(ii)



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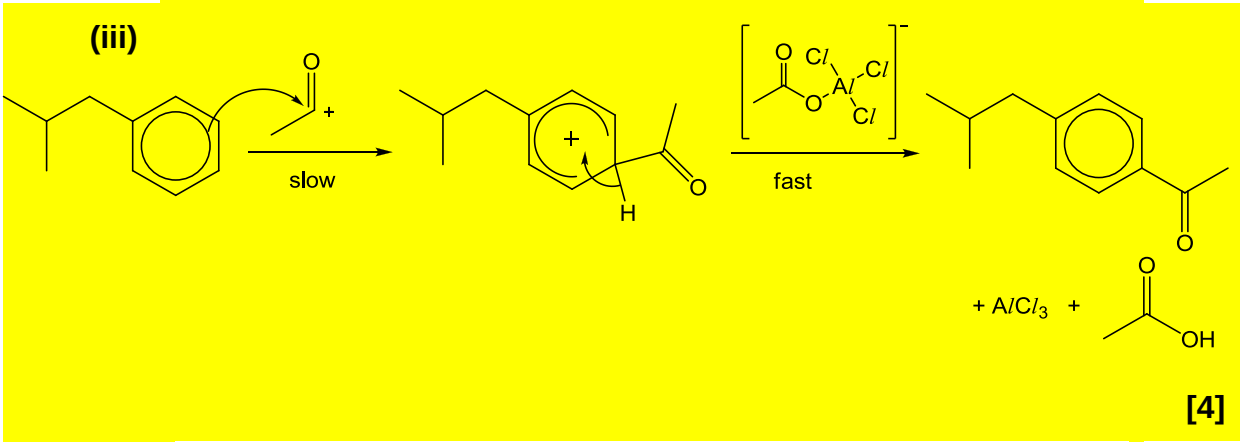
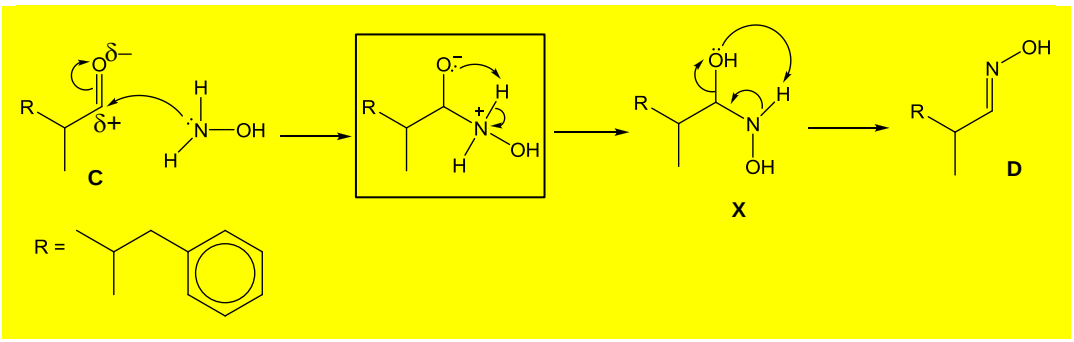


[4]

(b) The carbon is sp^3 hybridised. The 60° bond angle makes the three-membered ring highly strained hence epoxides react in ring-opening reactions to relief the ring strain/to attain the (preferred) 109.5°. **[2]**

(c)



[3]

(d) **(i)** The solubility of ibuprofen lysine salt is higher so it is more easily absorbed by the body.

(ii) The non-polar part of ibuprofen makes it difficult to penetrate the polar inner layer of the skin. When mixed with the more polar propan-2-ol, the mixture becomes sufficiently polar to penetrate the inner layer of the skin. **[3]**

(e) Any one of the following tests and observations:

1) Add Na_2CO_3

Observation: Effervescence of carbon dioxide gas that formed white precipitate with limewater observed for ibuprofen but no gas evolved for 2-methylpropylbenzene.

2) Add PCl_5 or $SOCl_2$

Observation: White fumes of HCl observed for ibuprofen but no fumes evolved for 2-methylpropylbenzene. **[2]**

[Total: 14]