

HWA CHONG INSTITUTION 2024 C2 H2 CHEMISTRY PRELIMINARY EXAMINATION SUGGESTED SOLUTIONS



- (b) (i) First ionisation energy is the energy required to remove one mole of electrons from one mole of free gaseous atoms to form 1 mole of unipositively charged gaseous ions.
- (b) (ii) 1st IE of Se is lower than As [1/2] Selenium has a lower 1st IE than arsenic because selenium contains a paired electron in one of its p orbitals, thus it experiences inter-electron repulsion. So, less energy is required to remove the outermost electron in selenium compared to arsenic.

[1] Explains that inter-electron repulsion in p-orbital leads to lower 1st IE in Se compared to As.

1st IE of Kr is higher than Br [1/2]

Krypton has a higher 1st IE than bromine because krypton has a greater effective nuclear charge than bromine. This is inferred from the fact the krypton has a larger proton number / greater nuclear charge, and electrons are added to the same quantum shell / leading to a relatively constant shielding effect. Therefore, the attraction between the nucleus and the outermost electron is stronger, and more energy is required to remove the outermost electron in krypton than bromine.

[1] Uses effective nuclear charge to explain the stronger attraction between the outermost electron in Kr and the nucleus compared to that in Br, leading to higher 1st IE.

2 (a) (i) Trigonal planar **[1]**, 120° **[1]**

2 (a) (ii) One 2s orbital is mixed with two 2p orbitals to give 3 hybridised sp² orbitals.

[1/2] correct type of atomic orbitals (2s and 2p)[1/2] correct number of atomic orbitals (1 and 2 respectively)

(a) (iii) The three sp² hybridised orbitals are degenerate and will be equally spaced apart in a trigonal planar arrangement to minimise repulsion.

[1/2] Indication of number of hybrid orbitals (state 'three' or 'trigonal planar') **[1/2]** Applying VSEPR Theory in the context of hybrid orbitals (i.e. hybrid orbitals will be equally spaced apart / minimise repulsion).

- (b) PTFE has a greater number of electrons / larger electron cloud than $F_2C=CF_2$ [1], thus it is more polarisable and has stronger dispersion forces than $F_2C=CF_2$. More energy is required to overcome the stronger dispersion forces in PTFE [1], and so it has a higher boiling point, and is a solid at room temperature while $F_2C=CF_2$ is a gas.
- (c) The C–C and C–F bonds in PFAS are very strong [1] and do not break/hydrolyse in typical environmental conditions.
- (d) (i) $RO \bullet + CHC_l = CH_2 \rightarrow RO CHC_l CH_2 \bullet [1]$ $RO - CHC_l - CH_2 \bullet + CHC_l = CH_2 \rightarrow RO - CHC_l - CH_2 - CHC_l - CH_2 \bullet [1]$
- (d) (ii) The carbon atom is chiral because it has a **tetrahedral geometry [1/2] and** is bonded to four different groups [1/2].



Туре 3

[1] Type 1 ; [1] Type 2

[1] Type 3 (any variation showing more random arrangement in the stereochemical arrangements)



[1] diagram, taking note of:

- axes
- labels
- shape of graph (starts from intersection of axes),
- shaded areas (legend can be embedded in response)

[-0.5] for each error

At higher temperatures, there is a <u>higher proportion of molecules that have</u> kinetic energies greater than or equal to E_a [1] Hence, frequency of effective collisions is higher [0.5], increasing rate of reaction [0.5].





[2] Drawing of mechanism, inclusive of the following:

- Partial charges on C-Br atoms
- <u>NO</u> indication of slow or fast steps
- Balanced equations for the step of the mechanism (including balance of charge)
- Correct structure of transition state
- Lone pair on O atom of OH⁻
- Correct drawing and placement of curly arrows
- (b) (ii) When the concentration of 2-bromopropane increases, the number of 2-bromopropane molecules per unit volume increases / the 2-bromopropane molecules are closer [1]. This increases the frequency of effective collisions which in turn increases the rate of reaction [1]. [-0.5 for not mentioning effective collisions]

- 3 (b) (iii) Circle z [2-bromopropane][OH⁻]. [1] In the mechanism, <u>both</u> reagents / the 2-bromopropane and OH⁻ are involved in the <u>rate-determining/only/slow step</u>.[1]
 - (b) (iv) rate = y [2-bromopropane] + z [2-bromopropane][OH⁻] From experiment 1, $7.1 \times 10^{-7} = y(0.1) + z(0.1)(0.1)$ From experiment 2, $1.2 \times 10^{-6} = y(0.1) + z(0.2)(0.1)$ Both equations – [1]

y = 2.20×10^{-6} units of y = s⁻¹ z = 4.90×10^{-5} units of z = mol⁻¹ dm³ s⁻¹

Each unit – [1] Each value – [0.5]

(_)	/i\
(6)	(1)

			solubility of residue (if any)	
	compound	observations	in dilute	in concentrated
			aqueous ammonia	aqueous ammonia
	2-bromopropane	cream ppt	insoluble	soluble/partially soluble [0.5]
	2-chloropropane	white ppt [0.5]	soluble	soluble [0.5]
	iodobenzene	no ppt [0.5]	-	-

(c) (ii) When NH₃ is added, the Ag⁺ forms the [Ag(NH₃)₂]⁺ complex. [1]

 $Ag^{+}(aq) + 2NH_{3}(aq) \rightleftharpoons [Ag(NH_{3})_{2}]^{+}(aq)$

The formation of the [Ag(NH₃)₂]⁺ complex decreases [Ag⁺] [1],

The ionic product of $[Ag^+][Cl^-]$ decreases to below K_{sp} . Hence, AgCl dissolves. **[0.5]**

OR Hence position of equilibrium of $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ shifts rightwards to increase [Ag⁺], allowing AgCl(s) to dissolve.

However, as K_{sp} of AgBr is relatively lower, the addition of dilute NH₃(aq) is insufficient to lower [Ag⁺] till the [Ag⁺][Br⁻] decreases to below that of the K_{sp} of AgBr. Hence, AgBr does not dissolve. **[0.5]**

4 (a) Cis-trans isomerism [1]

It occurs due to restricted bond rotation caused by the presence of the C=C bond [0.5] and different groups present on <u>each</u> carbon of the C=C. [0.5]

4 (b) (i) The pH of the buffer is at 6.5 which is higher than $pK_{a,1}$. Hence the first proton would have <u>completely</u> dissociated at this point. [1]

(b) (ii)
$$\mathcal{K}_{a,2} = \frac{[-O_2CCHCHCO_2^-][H^+]}{[HO_2CCHCHCO_2^-]}$$

 $10^{-6.22} = (10^{-6.5}) \frac{[-O_2CCHCHCO_2^-]}{[HO_2CCHCHCO_2^-]}$
 $\frac{[-O_2CCHCHCO_2^-]}{[HO_2CCHCHCO_2^-]} = 1.90546 \approx 1.91 (3 \text{ s.f.})$

(b) (iii) $^{-}O_2CCHCHCO_2^{-} + H^+ \rightarrow HO_2CCHCHCO_2^{-}$ [1]

 $HO_2CCHCHCO_2^- + OH^- \rightarrow -O_2CCHCHCO_2^-$ [1]

- (b) (iv) The ratio calculated in (b)(iii) suggests higher concentration of the conjugate base (-O₂CCHCHCO₂-), hence the buffer removes acids more effectively. [1]
- (c) (i) $s = \frac{6.70 \times 10^{-3}}{128.1} = 5.230 \times 10^{-5}$ [1]

 $K_{sp} = [Ca^{2+}][C_2O_4^{2-}] = s^2 = 2.735 \times 10^{-9} \approx 2.74 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$ [1]

(c) (ii)
$$K_{sp} = [Ca^{2+}][C_2O_4^{2-}] = [C_2O_4^{2-}](2.20 \times 10^{-3}) = 2.735 \times 10^{-9}$$

 $[C_2O_4^{2-}] = 2.735 \times 10^{-9} \div (2.20 \times 10^{-3}) = 1.24 \times 10^{-6} \text{ mol dm}^{-3}$ [1]

- (c) (iii) Drink more water to reduce the concentration of Ca²⁺ and ethanedioate ions in your body. Position of equilibrium 1 will shift to the left and less solid is formed.
 - Reduce intake of foods high in ethanedioate ions (chocolate, spinach etc.) or Ca²⁺ions (e.g. milk, dairy product). Position of equilibrium 1 will shift to the left and less solid is formed.
 - Increase the intake of acidic foods will lower the concentration of ethanedioate ions due to the formation of H₂C₂O₄. Position of equilibrium 1 will shift left and less solid is formed.
- (d) (i) step 1: one mole equivalent or limited LiA/H₄ (in dry ether) [1] step 2: excess concentrated H₂SO₄, heat [1] step 3: CH₃OH, (a few drops of) conc H₂SO₄, heat [1]

 5 (a) (i) HCI does not decompose even on strong heating. [0.5] Strong heating of HBr yields brown fumes of Br₂. [0.5] <u>Violet fumes</u> of I₂ are obtained when a red-hot rod is plunged into a jar of HI. [0.5]

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The <u>thermal stability decreases</u> from HCI to HBr to HI. **[0.5]** As down Group 17, the H–X bond length increases and <u>bond strength</u> <u>decreases</u> **[0.5]** so less <u>energy</u> is needed to break the H–X bond. **[0.5]**

 5 (a) (ii) Bond broken: 1 × H–Cl: 431 kJ mol⁻¹ Bond formed: ½ × H–H: ½ × 436 = 218 kJ mol⁻¹ Bond formed: ½ × Cl–Cl: ½ × 244 = 122 kJ mol⁻¹

> Standard enthalpy change of decomposition of HCI = 431-218-122 = +91.0 kJ mol⁻¹

[1] for correct bond energy values[1] for correct coefficients and application of bond breaking/forming and final answer

(b) (i) Volume of 100 g of conc HCl = $100 \div 1.2 \div 1000 = 0.0833$ dm³ [1]

Concentration of conc HCl = $(37 \div 36.5) \div 0.0833 = 12.2 \text{ mol dm}^{-3}$ [1]

(b) (ii) Number of moles of HCl required = $250 \div 1000 \times 0.1 = 0.025$ mol

Volume v = $0.025 \div 12.2 = 0.00205 \text{ dm}^3 = 2.05 \text{ cm}^3$ [1]

(b) (iii) It is the enthalpy change when 1 mole of a substance is formed from its constituent elements in their standard states at 298K and 1 bar. [1]

(iv)
$$HCl(g) \xrightarrow{+91 \ kJmol^{-1}}_{(from \ aii)}$$
 $\frac{1}{2} H_2(g) + \frac{1}{2} Cl_2(g)$
 $\downarrow -62.6 \ kJmol^{-1}$ $\frac{1}{2} H$
 $HCl(conc, 37\% \ w/w) \xrightarrow{\Delta H} HCl(aq, 0.1 \ mol \ dm^{-3})$
 $\Delta H = -(-62.2) + 91 - 167.2 = -13.6 \ kJ \ mol^{-1}$
[2] for energy cycle
[1] for correct application of Hess Law and final answer

- (b) (v) As the dilution in (b)(iv) is exothermic, outline B is preferred as the heat liberated while diluting the concentrated acid is transferred to / absorbed by a larger volume of water/solution already in the flask, to avoid the temperature from rising too high. [1]
- (c) (i) $t_{eq} = 100 \text{ s}$ [1]
- (c) (ii) $Q = It = 0.24 \times 100 = 24.0 C$ [1]
- 5 (c) (iii) Number of moles of HCl = $2.50 \div 1000 \times 0.100 = 0.000250 \text{ mol}$ [1]

Number of moles of electrons passed = number of moles of $H^+ = 0.000250$ mol

 $F = Q / n_e = 24.0 \div 0.00025 = 96\ 000\ C\ mol^{-1}$ [1]

(iv) $L = F / e = 96000 \div (1.60 \times 10^{-19}) = 6.00 \times 10^{23} \text{ mol}^{-1}$ [1]

(c) (v) $Ag^+ + e^- \rightleftharpoons Ag$ $2H^+ + 2e^- \rightleftharpoons H_2$ $2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^ E^{\circ} = +0.80 \lor --(1)$ $E^{\circ} = 0.00 \lor --(2)$ $E^{\circ} = -0.83 \lor --(3)$

[0.5] for quoting the reduction potential for (1) and at least one of (2) and (3)

The reduction potential for Ag^+/Ag is <u>more positive</u> than for H^+/H_2 and H_2O/H_2 , **[0.5]** so silver ions will be <u>preferentially reduced</u> at the cathode **[0.5]**

so (1) will occur in addition to/instead of (2) and (3), so t_{eq} obtained may be too large/ t_{eq} may not be obtainable/pH may not change.

[0.5] correct argument about the effect on the experiment

- (c) (vi) t_{eq} obtained by student Y will be larger than expected because the <u>working</u> <u>pH range</u> of the given indicator (10.2 to 12.0) is <u>higher than</u> the <u>equivalence</u> <u>point pH of 7</u> (and also higher than the range of pH at the rapid change at the equivalence point). [1]
- (c) (vii) ratio = 0.500 or 1:2 or $\frac{1}{2}$ [1]

Final pH = 10.7 [1] (accept 10.6 to 10.8)