2017 H1 Chemistry Preliminary Examination Paper 2 Answers

Section A

1 **(a)** **(i)** Since the forward reaction is exothermic, a low temperature will cause the position of equilibrium to shift to the right to produce more heat and thus producing more NH_3. However, the rate of reaction will be slow at low temperature, therefore, to increase the rate of reaction, a moderate temperature of 450^{o}C is used.

(ii) Iron catalyst provides an alternative reaction pathway with a lower activation energy.

(iii) At a higher pressure, position of equilibrium shifts to the right so as to decrease the pressure by favouring the production of fewer number of moles of gases. The equilibrium is not affected as it is only affected by temperature.

(iv)

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

(v) $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$

Let the number of moles of N_2 reacted be x

	N_2	$3H_2$	$2NH_3$
Initial no. of moles / mol	4	8	0
Change in no. of moles / mol	- x	- 3x	+ 2x
Equilibrium no. of moles / mol	4 - x	8 - 3x	2x

Given that the total number of moles of gases at equilibrium is 8,
4 - x + 8 – 3x + 2x = 8
Solving for x, x = 2
At equilibrium, there is 2 mol of N_2, 2 mol of H_2 and 4 mol of NH_3.

(vi)

$$K_c = \frac{\left(\frac{4}{2}\right)^2}{\left(\frac{2}{2}\right)\left(\frac{2}{2}\right)^3} = 1.00\ \text{mol}^{-2}\,\text{dm}^{6}$$

(b) **(i)** $NH_3(g) + \frac{7}{4}O_2(g) \rightarrow NO_2(g) + \frac{3}{2}H_2O(g)$

(ii) $\Delta H = \Delta H_f(NO_2) + \frac{3}{2}\Delta H_f(H_2O) - \Delta H_f(NH_3) - \frac{7}{4}\Delta H_f(O_2)$

$\Delta H = (-34) + (\frac{3}{2} \times -242) - (-46) - 0 = -351 \text{ kJ mol}^{-1}$

(iii) $\Delta H = \Sigma BE(\text{bonds broken}) - \Sigma BE(\text{bonds formed})$

Bonds broken = $3BE(N\text{-}H) + \frac{7}{4}BE(O{=}O)$

$= 3 \times 390 + \frac{7}{4} \times 496 = 2038 \text{ kJ mol}^{-1}$

Bonds formed = $3BE(O\text{-}H) + 2BE(N\text{-}O) = 3 \times 460 + 2BE(N\text{-}O)$

$= 1380 + 2BE(N\text{-}O)$

$-351 = 2038 - 1380 - 2BE(N\text{-}O)$

$BE(N\text{-}O) = +504 \text{ kJ mol}^{-1}$

(iv) n(ammonia) = $\frac{44}{17} = 2.59$ mol = $n(NO_2)$

Theoretical mass of $NO_2 = 2.59 \times 46 = 119.14$ g

Percentage efficiency = $\frac{89}{119.14} \times 100 = 74.7\%$

(c) $NH_3 + CH_3CH_2Br \rightarrow CH_3CH_2NH_2 + HBr$

Ethanolic concentrated NH_3, heat in a sealed tube

The organic products belongs to the primary amine functional group.

[Total: 20]

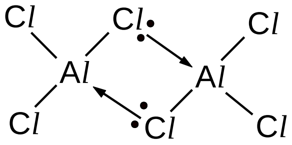
2 **(a)** **(i)** Al_2O_3 dissolves in both HCl and excess NaOH. P_4O_{10} dissolves in NaOH.

(ii) $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq)$

$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$

(b) **(i)**



The aluminium atom in $AlCl_3$ has only 6 electrons surrounding it hence it is electron-deficient. The lone pair of electrons from a chlorine atom in a neighbouring molecule would be donated via a dative bond, resulting in a dimer.

(ii) Al_2Cl_6 has simple molecular structure. The dispersion forces between the Al_2Cl_6 molecules are weak and hence, only a small amount of energy is needed to overcome the weak interactions.

[Total: 10]

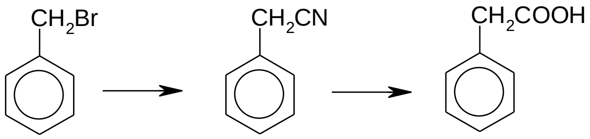
3 **(a)** Cl_2(g), $AlCl_3$, (rt)

(b) Step 2: oxidation
Step 3: reduction

(c) **B** dissociates to give H^+ and the conjugate base, $C_6H_5CO_2^-$ (benzoate). The negative charge on the benzoate ion is delocalised equally over two highly electronegative oxygen atoms. The negative charge is dispersed and the carboxylate anion is greatly stabilised.

(d) Reagents and conditions: $Br_2(l)$, UV light
The substitution is uncontrollable and multi-substituted products may be obtained.

(e)



Step 1: Ethanolic KCN, heat
Step 2: Dilute H_2SO_4, heat

[Total: 10]

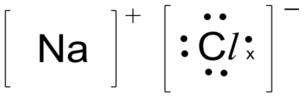
Section B

4 **(a)** **(i)** Cooking oil is primarily made up of long hydrocarbon chains, and experiences dispersion forces between molecules, whereas water experiences hydrogen bonding between water molecules. Because of the long hydrocarbon chains, the dispersion forces experienced by these molecules is extensive and stronger than the hydrogen bonding experienced by water molecules. Thus, more energy is required to overcome the dispersion forces in cooking oil compared to water, and the boiling point of cooking oil is thus higher.

(ii) The cooking oil and water is immiscible (no need to comment on relative density). This is because the molecules in cooking oil are largely non-polar, and do not form favourable interactions with the polar water molecules.

(iii) When the noodles undergoes deep frying, the high temperature of the heated oil causes the water in the noodles to vaporize. As water molecules do not form favourable interactions with the cooking oil, the water molecules escape as steam, thus drying out the noodles.

(b) **(i)**



(ii) Sodium chloride has a giant ionic lattice structure, and experiences strong electrostatic forces of attraction between oppositely charged cations and anions.

The attraction between oppositely charged ions is very strong and requires a lot of energy to overcome. Thus, a high temperature must be achieved to provide enough energy for melting to occur.

In the giant ionic lattice, the cations and anions are arranged in an alternating fashion. When a force is applied, the lattice structure is disrupted, causing similarly charged ions to be aligned with one another. The resulting repulsion between like charges causes the lattice to shatter, thus accounting for sodium chloride's brittle nature.

(iii) Lattice energy is the heat evolved when one mole of pure ionic solid is formed from its constituent gaseous ions.

$$LE \propto \frac{q^+q^-}{r^++r^-}$$

The chloride anion has a smaller charge (–1) compared to the oxide anion (–2). The chloride anion has a larger ionic radii compared to the oxide anion (period 3 vs period 2). Since lattice energy is directly proportional to charge and inversely proportional to ionic radii, the magnitude of the lattice energy of sodium chloride is smaller than that of sodium oxide.

(iv) Sodium chloride dissolves in water to form a colourless solution of neutral pH.

$NaCl_{(s)} + aq \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

In an excess of water, $AlCl_3$ dissolves to form a colourless solution of acidic pH. Al^{3+} forms a complex ion with 6 water molecules, as shown below.

$AlCl_{3(s)} + 6\,H_2O_{(l)} \rightarrow [Al(H_2O)_6]^{3+}_{(aq)} + 3\,Cl^-_{(aq)}$

$[Al(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [Al(H_2O)_5OH]^{2+}_{(aq)} + H_3O^+_{(aq)}$

A violent reaction with water producing fumes of HC*l* gas. Complete hydrolysis occurs in this case.

$SiCl_{4(l)} + 4\,H_2O_{(l)} \rightarrow SiO_2.2H_2O_{(s)} + 4\,HCl_{(aq)}$

(v) Sodium chloride is an ionic compound while silicon chloride is a covalent compound. Therefore, as the degree of covalency increases across the period, so does the extent of hydrolysis with water.

5 **(a)** **(i)** First ionisation energy is the energy required to form 1 mol of unipositively charged cations from 1 mol of gaseous atoms.

(ii) Potassium has one more quantum shell than sodium, thus the outermost electron is further away from the nucleus in potassium compared to sodium. Therefore, the attraction between the outermost electron and the nucleus of potassium is weaker, and requires less energy to remove compared to that of sodium.

The 3*p* subshell of aluminium is further away from the nucleus than the 3*s* subshell. There is weaker attraction between the nucleus and the outermost electron. Hence less energy is required to remove the 3*p* electron from aluminium, resulting in a lower ionisation energy for aluminium.

Sulfur has a set of paired electrons in the p subshell, whereas the p orbitals in phosphorus are singly filled. The inter-electronic repulsion between the paired electrons causes the outermost electron of sulfur to be easier to remove, thus less energy is required to ionise sulfur.

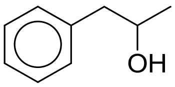
Argon has more protons than chlorine, thus the nuclear charge of argon is higher. As electrons are added to the same quantum shell, shielding effect is relatively constant for chlorine and argon. Thus the effective nuclear charge increases from chlorine to argon, implying that the attraction between the nucleus and the outermost electron has increased. Thus, more energy is required to remove the electron.

(iii) X is magnesium
After the 2nd ionisation energy, there is a large increase in the 3rd IE, which suggests that the 3rd electron is from an inner quantum shell. Thus X is a Group 2 element.

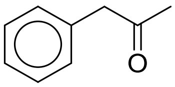
Y is chlorine
After the 7th ionisation energy, there is a large increase in the 8th IE, which suggests that the 8th electron is from an inner quantum shell. Thus X is a Group 17 element.

(b)

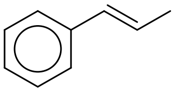
Observations	**Deductions**
Molecular formula of $C_9H_{12}O$	• High C:H ratio, benzene ring may be present. • One oxygen atom present suggests an alcohol or a ketone may be present.
exposed *uv* light in the presence of chlorine gas	• Substitution reaction
3 monosubstituted compounds	• Molecule is highly symmetrical / only 3 possible positions where substitution can occur
heated with acidified $K_2Cr_2O_7$	• Oxidation has occurred, **A** must be an alcohol
B gives an orange precipitate with 2,4-DNPH	• Carbonyl compound present
heated with excess concentrated sulfuric acid	• Dehydration
C and **D** are stereoisomers	• C=C bond present, **C** and **D** are geometic isomers.



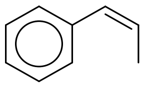
A



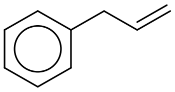
B



C

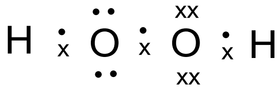


D



E

6 **(a)** **(i)**



$$\mathrm{H} \,\substack{\bullet\\ \times}\, \overset{\bullet\bullet}{\underset{\bullet\bullet}{\mathrm{O}}} \,\substack{\bullet\\ \times}\, \overset{\times\times}{\underset{\times\times}{\mathrm{O}}} \,\substack{\bullet\\ \times}\, \mathrm{H}$$

(ii) Around each oxygen atom, there are 2 bond pairs and 2 lone pairs of electrons. Thus, it is bent around each oxygen atom.

(iii) The bond angle is 104.5°. As the lone pair-lone pair repulsion is greater than the bond pair-bond pair repulsion, the bond pairs will be pushed closer together thus bond angle smaller than 109.5°.

(b) **(i)** H_2O_2 is reducing agent. The oxidation state of Mn is reduced from +7 to +2.

(ii) $n(MnO_4^-) = (21.80 \div 1000) \times 0.200 = 4.36 \times 10^{-3}$ mol
$n(H_2O_2) = 4.36 \times 10^{-3} \times 5/2 = 0.0109$ mol

(iii) $n(H_2O_2)$ in 100 cm^3 standard solution = $0.0109 \times 4 = 0.0436$ mol
$[H_2O_2]$ in stock solution = $0.0436 \div 20/1000 = 2.18$ mol dm^{-3}

(c) **(i)** correct axis, labels, units
suitable scale
shape of graph

(ii) construction lines to show at least 2 constant half-life, $t_{1/2} \approx 60$ s
conclude that reaction is 1st order with respect to I^-

(iii) When the $[H_2O_2]$ is doubled, the initial rate doubles. Thus rate is directly proportional to $[H_2O_2]$, thus the order with respect to H_2O_2 is 1.

(iv) Rate = $k\,[H_2O_2][I^-]$

(v) Determine initial rate by drawing tangent at t = 0 s
Initial rate = $-[(3.00 - 4.00 \times 10^{-4}) \div (63 - 0)] = 1.11 \times 10^{-5}$ mol dm^{-3} s^{-1}

Using the rate equation,
$1.11 \times 10^{-5} = k(0.05)(10.00 \times 10^{-4})$
$k = 0.222$ mol^{-1} dm^3 s^{-1}

OR

$t_{1/2} = \ln 2 / k[H_2O_2]$
$60 = \ln 2 / k(0.05)$
$k = 0.231$ mol^{-1} dm^3 s^{-1}