2018 PRELIMINARY EXAMINATION
International Baccalaureate 2

Chemistry
Higher level
Paper 2

1. (a) (i) Weighted **average mass** of its isotopes when compared to $\frac{1}{12}$ the mass of a ^{12}C atom. [1]

(ii) $A_r = \frac{69(65)+71(35)}{100} = 69.7$ [1]

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ [1]

(ii) Negative [1]
Decrease in number of gaseous particles, less disordered [1]

(iii) $\Delta G = \Delta H - T\Delta S$
Since $\Delta H < 0$ and $\Delta S < 0$,
For a reaction to be spontaneous, $\Delta G < 0$.
Hence, $|\Delta H| > |T\Delta S|$ [1]
Reaction is only spontaneous at low temperatures. [1]

(iv) $nGa = \frac{10.0}{69.72} = 0.1434$ mol [1]
$nN_2 = \frac{1}{2}(0.1434) = 0.07172$ mol
vol $N_2 = 0.07172(22.7) = 1.63\ dm^3$ [1]
Absolute uncertainty $= \frac{0.2}{69.72}(\frac{1}{2})(22.7) = 0.04\ dm^3$ (1sf) [1]

(c) (i) $nNaOH = \frac{14.00}{1000}(0.100) = 0.0014$ mol [1]

(ii) nHCl reacted with NaOH = 0.0014 mol
total $nHCl = \frac{200}{1000}(0.300) = 0.06$ mol [1]
nHCl in excess = 0.06 – 0.0014 = 0.0586 mol [1]

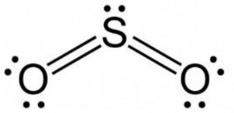
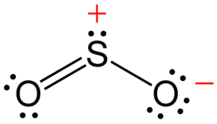
(iii) $nGa_2O_3 = 0.0586\ (\frac{1}{6}) = 0.009767$ mol [1]
$mGa_2O_3 = 0.009767\ (69.72 \times 2 + 16.00 \times 3) = 1.83$ g [1]

2. (a) **Na_2O + H_2O → 2NaOH** [1]
NaOH releases OH^- ions. **pH = 13**
P_4O_6 + $6H_2O$ → $4H_3PO_3$ [1]
H_3PO_3 releases H^+ ions. **pH ≈ 2 / 3 / 4**
[Award 1 mark only if both pH are stated correctly.] [1]

(b) (i) Both have **giant ionic structure** / ionic lattice structure, with strong **ionic bonds**. [1]
Charge of Mg^{2+} > Na^+ and **radius of Mg^{2+} < Na^+** [1]
MgO has stronger ionic bonds, more energy needed to overcome. [1]

(ii) SiO_2 has **giant covalent structure**, and strong Si−O **covalent bonds**. [1]
P_4O_6 has **simple covalent/molecular structure**, and weak **van der Waals' forces / intermolecular forces**. [1]
Covalent bonds are **stronger** than van der Waals' forces, more energy required to overcome. [1]
[Award full 3 marks only if comparison of the strength of the bonds to be overcome is stated.]

(c) (i) [4]

Lewis structure I	Lewis structure II
	

[Award 1 mark each for each correct Lewis structure.]
[Award 1 mark each for correct formal charges indicated on both S AND O atoms on each structure.]

(ii) Lewis structure I. All atoms have a formal charge of 0. [1]
Recap: More stable:
(i) structure with greater no. of 0 FC;
(ii) negative FC on electronegative atom e.g. F, O, N

(iii) sp^3 (SiO_2 is like diamond) [1]

(d) (i) Energy change when 1 mol of MgO (s) is formed from its elements Mg (s) and O_2 (g) under standard conditions. [1]
[Accept general definition.]

(ii) A : enthalpy change of atomization of Mg [1]
D : Sum of 1st and 2nd electron affinity of O (g) [1]

(iii) $\Delta H = -(-602) + (702) + (2186) + (248) + (150)$ [1]
$= +3888 \text{ kJ mol}^{-1}$ [1]
[Award 1 mark for final answer only if sign is shown.]

(iv) 2nd IE = 2186 – 738 = +1448 kJ mol^{-1} [1]
After an electron is removed, the **remaining electrons experience greater** [1]

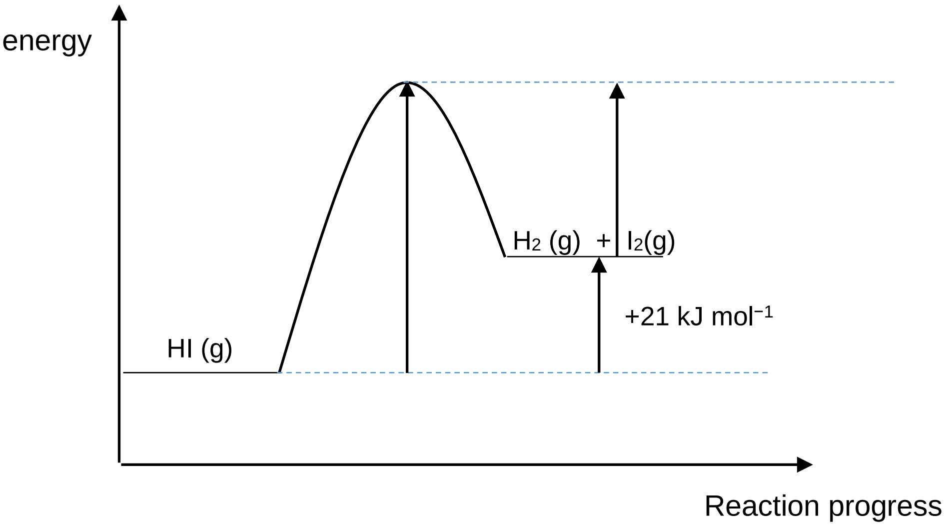
nuclear attraction / more strongly attracted,
More energy required to remove the 2nd electron.

3. (a) (i) When [HI] doubles, rate quadruples. Order of reaction w.r.t. HI = 2 [1]

(ii) Rate = $k[HI]^2$ [1]

(iii) $0.41 = k\,(1.67)^2$
$k = 0.147$ [1]
Units of k = $mol^{-1}\,dm^3\,s^{-1}$ [1]

(iv) [3]



[Axis must be clearly and correctly labelled. Energy of reactants lower than products. E_a of forward reaction labelled.]
[Award 1 mark for correct value and sign of ΔH.]

(v) Catalyst provides an alternative pathway of **lower activation energy**. [1]
More particles have energy ≥ activation energy [1]
Frequency of effective collisions increases [1]
[Do not accept frequency of collisions. Accept number of effective collisions per unit time.]

(b) (i) $K_c = \frac{[H_2][I_2]}{[HI]^2}$ [1]

(ii) $[HI]\text{ initial} = \frac{0.10}{2} = 0.05\text{ mol dm}^{-3}$

$[HI]\text{ equilibrium} = \frac{0.564}{2} = 0.0282\text{ mol dm}^{-3}$

	HI	H_2	I_2	
Initial	0.05	0	0	
Change	−0.0218	+0.0109	+0.0109	
Eqm	0.0282	0.0109	0.0109	[1]

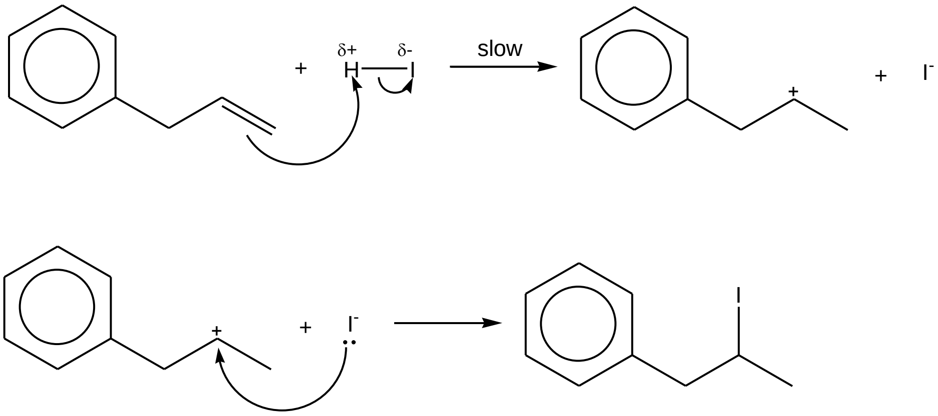
$K_c = \frac{(0.0109)(0.0109)}{(0.0282)^2} = 0.149$ No units [1]

[1]

(iii) **No effect** on / **No shifting** of position of equilibrium [1]
Equal number of gaseous particles on both sides of the equation. [1]

4. (a) (i) Electrophilic addition [1]

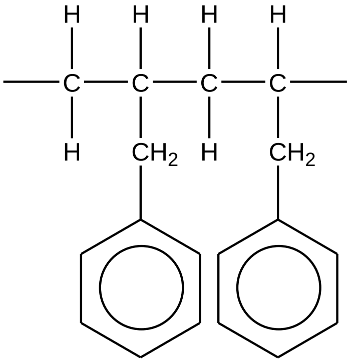
(ii) [3]



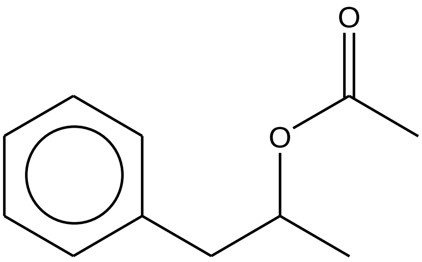
[Two step mechanism. Step 1 is the slow step. Equation must be balanced. Correct direction of arrows to indicate movement of electrons (double headed arrow)
Lone pair of electrons on I^- must be shown.]

(iii) Addition polymerization [1]

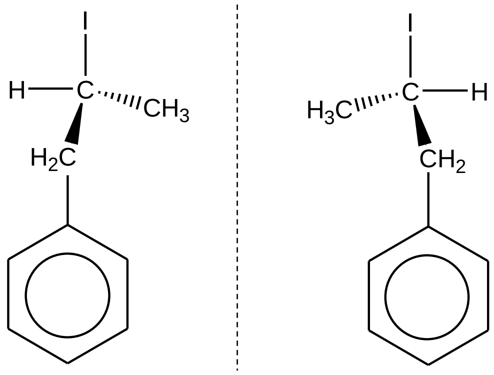
(iv) [1]



(b) (i) [1]



(ii)



[1]
[1]

*[Correct chiral carbon and 3D diagram.
Correctly drawn mirror images.]*

(iii) Both S_N1 and S_N2 occurs. [1]

S_N2 gives ≈ 100% of inversion of configuration, while S_N1 gives ≈ 50% of each configuration. [1]

(iv) C−I bond is weaker than C−Br bond. [1]

[Students can quote bond length or bond energy to explain.]

(v) Concentrated HNO_3, concentrated H_2SO_4, 30 °C ES [1]

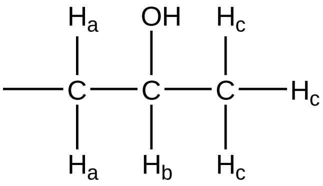
$K_2Cr_2O_7$, H_2SO_4 (aq), heat / acidified $K_2Cr_2O_7$ (aq), heat oxidation [1]

(c) (i) [2]

Chemical shift / ppm	**Splitting**	**Integration factor**
1.2	Doublet	3
2.0	Singlet	1
2.7	Doublet	2
3.8	Multiplet	1
7.2	Singlet	5

[Award full marks for all correct answers. Award 1 mark for at least 2 correct answers.]

(ii)



H_b has <u>two different neighbouring</u> environment. [1]

H_a splits the signal of H_b into a <u>triplet</u> [1]

H_c splits the signal of H_b into a <u>quartet</u>. They overlap into multiplet.

[OWTTE]

(d) One similarity :

Strong peaks at 2850 – 3090 cm^{-1} (C–H bond) [1]

One difference :

(2−iodopropyl)benzene shows a peak at 490 – 620 cm^{-1} (C–I) absent in 1−phenylpropan−2−ol / [1]

1−phenylpropan−2−ol shows a peak at 3200 – 3600 cm^{-1} (O–H), absent in (2−iodopropyl)benzene

5. (a) (i) $K_a = \frac{[C_5H_7CO_2^-][H^+]}{[C_5H_7CO_2H]}$ [1]

(ii) $\frac{x^2}{0.22} = 7.4 \times 10^{-4}$
$x = 0.0128$ mol dm^{-3}
pH = 1.89 [1]

(iii) A solution that resists changes in pH when **small amounts** of acid or base is added. [1]
[Accept H^+ or OH^- is added.]

(iv) When H^+ is added,
$C_5H_7O_4CO_2^- + H^+ \rightarrow C_5H_7O_4CO_2H$ [1]
When OH^- is added,
$C_5H_7O_4CO_2H + OH^- \rightarrow C_5H_7O_4CO_2^- + H_2O$ [1]

(v) pH = pK_a for a solution at maximum buffer capacity
pH = $-\log_{10}(7.4 \times 10^{-4}) = 3.13$ [1]

(b) $H_2O \rightleftharpoons H^+ + OH^-$ $\Delta H > 0$ / **endothermic** [1]
Increasing temperature **shifts position of equilibrium to the right** to favour the forward endothermic reaction, [1]
$[H^+]$ <u>increases</u>, pH decreases

6. (a) (i) Anode : $H_2O\ (l) \rightarrow \frac{1}{2} O_2\ (g) + 2OH^-\ (aq) + 2e^-$ [1]
Cathode : $Cu^{2+}\ (aq) + 2e^- \rightarrow Cu\ (s)$ [1]

(ii) Effervescence occurs at the anode / [2]
Pink copper deposited at the cathode /
Solution becomes paler blue.
[Accept any two observations]

(iii) Current / Time [1]

(iv) Cl_2 (g) [1]
$\frac{1}{2} Cl_2\ (g) + e^- \rightleftharpoons Cl^-\ (aq)$ +1.36 V
$\frac{1}{2} O_2\ (g) + 2H^+\ (aq) + 2e^- \rightleftharpoons H_2O\ (l)$ +1.23 V
Increasing $[Cl^-]$, (eqm shift left to decrease $[Cl^-]$) E < 1.36 V, falls below 1.23 V [1]
Cl^- is more likely to be oxidized [1]

(v) Cu^{2+} has **partially filled 3d orbitals** [3]
5 degenerate 3d orbitals **split** into **two** sets of orbitals with **different energy**
An **electron is excited from lower energy d orbital to higher energy d**

orbital,
Absorbing energy / light from the visible light spectrum.
Colour observed is complementary to the colour absorbed.
[4 required points. Deduct 1 mark for each missing point.]

(b) (i) Maintain charge neutrality / Allows movement of ions between half−cells to complete the circuit [1]

(ii) E = (+0.34) – (−0.45) = +0.79 V [1]

(iii) From Fe electrode to Cu electrode [1]