

2017 NJC H1 Chemistry Prelim Paper 2 Suggested Answers

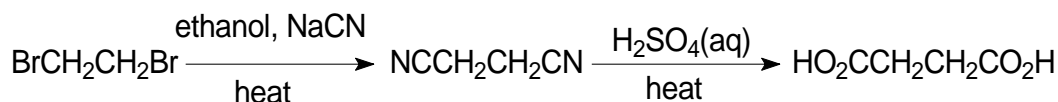
- 1 (a) (i) The mass of an isotope of an element relative to $1/12$ the mass of one atom of ^{12}C .

(ii) relative atomic mass of chlorine
 $= (75.76/100) \times 35 + (24.24/100) \times 37$
 $= 35.48$ (4s.f.)

- (b) (i) The boiling point **increases** from as 1-fluorobutane to 1-iodobutane. The halogenoalkanes are made up of **simple covalent molecules** held by **temporary dipole-induced dipole interactions**. There is an increase in M_r from 1-fluorobutane to 1-iodobutane and hence the **electron cloud size increases**, making it **more easily polarised** and leading to **increasingly stronger** temporary dipole induced dipole interactions. Hence, **more energy** is needed to overcome the increasingly stronger temporary dipole induced dipole interactions between the halogenoalkanes, leading to the increase in boiling point from 1-fluorobutane to 1-iodobutane.

- (ii) Both are **simple covalent compounds** with **temporary dipole – induced dipole interactions**. 1-chloro-2-methylpropane is **branched while 1-bromobutane is a straight chain**. Thus, there is **greater surface of contact** between the 1-bromobutane molecules than 1-chloro-2-methylpropane, leading to **greater temporary dipole - induced dipole** interactions between 1-bromobutane that requires **more energy** to overcome.

(c)



- 2 (a) (i) Amount of hydromagnesite = $1/466 = 2.146 \times 10^{-3}$ mol

$$\text{Amount of CO}_2 \text{ given off} = 0.378/44.0 = 8.591 \times 10^{-3} \text{ mol}$$

$$\text{Mole ratio of hydromagnesite: CO}_2 = 2.146 \times 10^{-3} : 8.591 \times 10^{-3} \\ = 1 : 4$$

$$x = 4$$

- (ii) I
 $\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$

$$\text{Amount of NaOH used to neutralise remaining HCl in } 25 \text{ cm}^3 \\ = (28.50/1000) \times 0.10 \\ = 2.85 \times 10^{-3} \text{ mol}$$

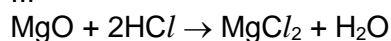
$$\text{Amt of remaining HCl in } 250 \text{ cm}^3 = (2.85 \times 10^{-3}) \times (250/25.0) \\ = 0.02850 \text{ mol}$$

II

Amount of HCl used in 50 cm^3 of HCl solution
 $= (50/1000) \times 1.0$
 $= 0.05000 \text{ mol}$

Amt of HCl reacted with MgO
 $= 0.05000 - 0.02850$
 $= 0.02150 \text{ mol}$

III

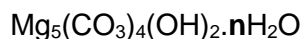


Amt of MgO formed $= 0.02150/2 = 0.0107 \text{ mol}$

Mole ratio of hydromagnesite: $\text{MgO} = 2.146 \times 10^{-3} : 0.0107$
 $= 1 : 5$

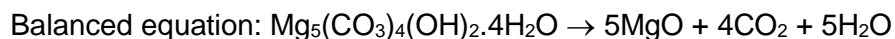
$$y = 5$$

(iii) Molar mass of hydromagnesite $= 466 \text{ g mol}^{-1}$



Mass of water per mole of hydromagnesite
 $= 466 - [(5 \times 24.3) + (4 \times 12.0) + (14 \times 16.0) + 2(1.0)]$
 $= 70.5 \text{ g}$

$$n = 70.5/18.0 = 3.917 \approx 4$$



3 (a) (i) Standard enthalpy change of combustion of hydrazine is the heat liberated when 1 mole of hydrazine is completely burnt in excess oxygen at 298 K and 1 atm.

(ii) Amount of heat gained by water, $q = mc\Delta T$
 $q = 200 \times 4.18 \times 8$
 $= 6688 \text{ J}$

Amount of heat evolved, $q = 6688 \times (100/80)$
 $= 8360 \text{ J}$

Amount of hydrazine $= 0.42/32 = 0.01313 \text{ mol}$

$$\begin{aligned} \Delta H_c^\ominus(\text{hydrazine}) &= -q/n_{\text{hydrazine}} \\ &= -8360/0.01313 \\ &= -637000 \\ &= -637 \text{ kJ mol}^{-1} \end{aligned}$$

(iii)	bonds broken	bond energy/ kJ mol ⁻¹	bonds formed	bond energy/ kJ mol ⁻¹
	1 N–N	+160	1 N≡N	–945
	4 N–H	4(+390)	4 O–H	4(–460)
	1 O=O	+496		

$$\begin{aligned}
 \Delta H^{\ominus}_c(\text{hydrazine}) &= \text{BE}(\text{Bonds broken}) + \text{BE}(\text{Bonds formed}) \\
 &= [160 + 4(390) + 496] + [(-945) + 4(-460)] \\
 &= -569 \text{ kJ mol}^{-1}
 \end{aligned}$$

- (iv) The bond energy values obtained from the Data booklet are average values which would differ from the actual bond energy in the molecule due to the different chemical environment. Therefore, there would be discrepancy in the calculated value.

Or

The bond energy values obtained from the Data booklet are used on gaseous molecules. However, in the balanced equation of combustion of hydrazine, both hydrazine and water are in liquid state and not in gaseous state. Therefore, there would be discrepancy in the calculated value.

- (b) (i) The production of NH₃ is an exothermic reaction since at lower temperature, there is a higher percentage of NH₃ at equilibrium, implying that the forward exothermic reaction is favoured to counteract the decrease in temperature.
- (ii) When more H₂ is added to the reaction vessel, by **Le Chatelier's principle**, position of **equilibrium shifts right** to **partially remove the increased concentration of H₂**, resulting in a **greater yield of NH₃**.

(iii)

	N ₂	+	3H ₂	⇌	2NH ₃
Initial amount / mol	2		7		0
Change / mol	–x		–3x		+2x
Equilibrium amount / mol	2–(1.6) =0.4		7–3(1.6) =2.2		3.2
Equilibrium concentration / mol dm ⁻³	0.4/2 =0.2		2.2/2 = 1.1		3.2/2 = 1.6

$$2x = 3.2$$

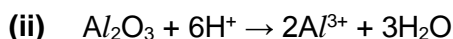
$$x = 1.6$$

$$\begin{aligned}
 K_c &= \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} \\
 &= \frac{[1.6]^2}{[0.2][1.1]^3}
 \end{aligned}$$

$$\begin{aligned}
 K_c &= 9.617 \\
 &= 9.62 \text{ mol}^{-2} \text{ dm}^6
 \end{aligned}$$

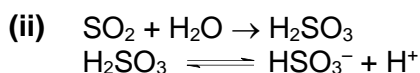
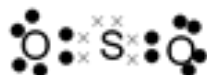
- 4 (a) Both MgO and Na₂O have giant ionic lattice structure with strong ionic bonds between the oppositely charged ions. Both compounds contain the same O²⁻ ion, but Mg²⁺ ion has a higher charge and smaller ionic radius than Na⁺ ion. Since $|L.E.| \propto \frac{q^+q^-}{r^+ + r^-}$, MgO, therefore, has a higher magnitude of lattice energy than that of Na₂O and hence more energy is needed to overcome the stronger ionic bond in MgO than in Na₂O. Thus, MgO has higher melting point than Na₂O.

- (b) (i) SiO₂ has a giant covalent lattice structure with covalent bonding between Si and O atoms. The covalent bond in SiO₂ are too strong to overcome. Hence, SiO₂ are insoluble in water.



Add hot HCl(aq) to the contaminated mixture to remove the Al₂O₃. Filter the mixture and keep the residue which contains the SiO₂.

- (c) (i)

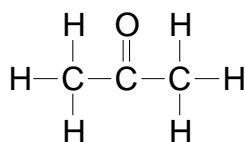


- 5 (a) (i)

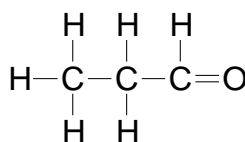
	C	H	O
Composition by mass	62.1	10.3	27.6
Divide by A _r	62.1/12 = 5.175	10.3/1 = 10.3	27.6/16 = 1.725
Divide by smallest number	5.175/1.725 = 3	10.3/1.725 = 6	1.725/1.725 = 1
Simplest mole ratio	3	6	1

Molecular formula of **H** = Empirical formula of **H** = C₃H₆O (M_r = 58)

- (ii)

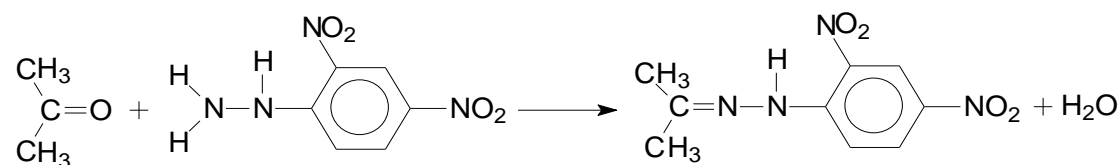


propanone



propanal

- (iii)



Condensation

(b) (i) I: $\text{CH}_2(\text{OH})\text{CH}(\text{OH})\text{CH}_2(\text{OH})$

II: $\text{CH}_2=\text{CHCH}_2\text{Cl}$

III: $\text{CH}_2(\text{I})\text{CH}(\text{Cl})\text{CH}_2(\text{OH})$

(ii) Test: Add $\text{Br}_2(\text{aq})$ or Br_2 in CCl_4

Observation:

M: Decolourisation of orange $\text{Br}_2(\text{aq})$ / reddish-brown Br_2 in CCl_4

propan-2-ol: orange $\text{Br}_2(\text{aq})$ / reddish-brown Br_2 in CCl_4 remains.

OR

Test: KMnO_4 , dilute H_2SO_4 , heat

Observation:

M: Decolourisation of purple KMnO_4 and effervescence.

propan-2-ol: Decolourisation of purple KMnO_4 .

OR

Test: cold, $\text{NaOH}(\text{aq})$, KMnO_4

Observation:

M: Decolourisation of purple KMnO_4 , brown ppt of MnO_2 formed.

propan-2-ol: No decolourisation of purple KMnO_4 / Purple solution remains.

OR

Test: $\text{I}_2(\text{aq})$, $\text{NaOH}(\text{aq})$, warm

Observation:

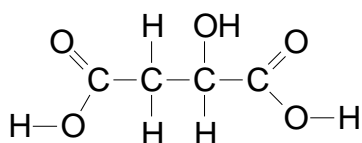
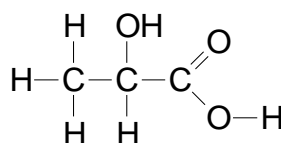
M: No yellow ppt of CHI_3

propan-2-ol: Yellow ppt of CHI_3 is formed.

(c)

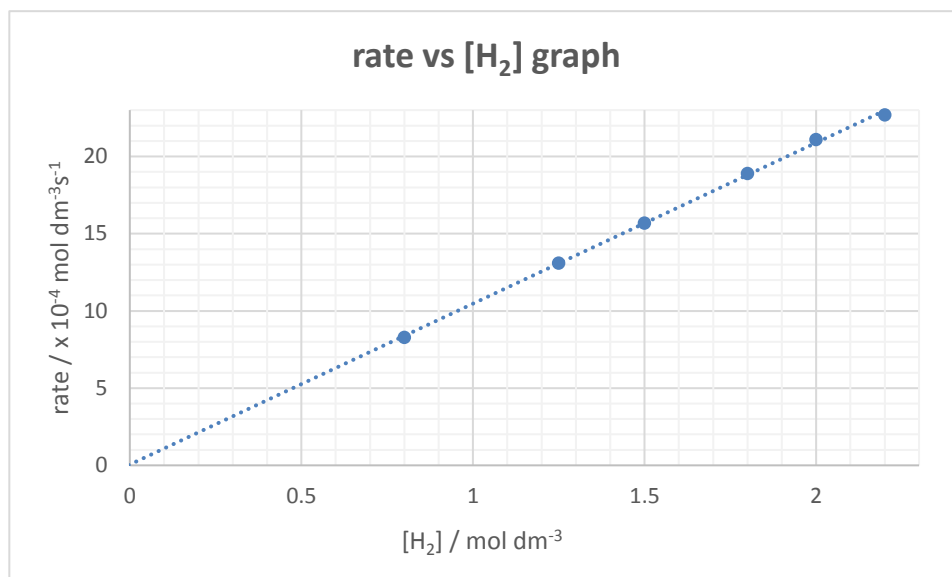
Information	Deduction
Both J and K react with sodium hydroxide	J and K undergoes acid base reaction with sodium hydroxide. → Both compounds contain COOH group.
Both J and K react with acidified $\text{K}_2\text{Cr}_2\text{O}_7$, but not with 2,4-dinitrophenylhydrazine reagent.	J and K undergoes oxidation reaction with $\text{K}_2\text{Cr}_2\text{O}_7$. → Both compounds are not carbonyl compound and contain OH group.

Both J and K react with excess hot concentrated H_2SO_4 , but only J gives a mixture with a pair of cis-trans isomers.	J and K undergoes elimination of H_2O to form alkene. Alkenes obtained from J exhibited cis-trans isomerism, but not that of K (terminal alkene).
A 0.234 g sample of J reacts completely with 35 cm^3 of 0.10 mol dm^{-3} NaOH .	J undergoes neutralisation/acid base reaction with NaOH . $\text{Amt of J} = \frac{0.234}{134} = 1.746 \times 10^{-3} \text{ mol}$ $\text{Amt of NaOH} = 3.5 \times 10^{-3} \text{ mol}$ Mole ratio of J : NaOH is 1:2 J is dibasic acid which contains two COOH groups.
K give a yellow precipitate with alkaline aqueous iodine.	K undergoes mild oxidation with alkaline aqueous iodine. K contains the following structure <div style="text-align: center;"> $\begin{array}{c} \text{OH} \\ \\ \text{CH}_3 - \text{C} - \\ \\ \text{H} \end{array}$ </div>
A $7.5 \times 10^{-4} \text{ mol}$ of K produces 18 cm^3 H_2 gas when excess Na is added.	K undergoes redox/ acid metal reaction with Na . $\text{Amt of H}_2 \text{ liberated} = \frac{18}{24000} = 7.5 \times 10^{-4} \text{ mol}$ Mole ratio of K : H_2 is 1:1 K contains two OH groups (make up of 1 COOH and 1 OH group).

J:**K:**

- 6 (a) NO is one of the pollutants which causes photochemical smog. Such smog causes respiratory problems.

(b) (i)



Correct axes label with appropriate units and appropriate scale
Correct plotting of points and the graph must occupy at least half of the grid paper.

- (ii) Since the graph is a straight line graph with constant gradient, this implies that the rate is directly proportional to [H₂], therefore it is 1st order reaction w.r.t H₂.

$$(iii) \frac{\text{rate}_{\text{expt1}}}{\text{rate}_{\text{expt2}}} = \frac{[\text{H}_2]_{\text{expt1}}[\text{NO}]_{\text{expt1}}^n}{[\text{H}_2]_{\text{expt2}}[\text{NO}]_{\text{expt2}}^n}$$

$$\frac{3.0 \times 10^{-7}}{2.4 \times 10^{-6}} = \frac{(2.0 \times 10^{-3})(2.0 \times 10^{-3})^n}{(4.0 \times 10^{-3})(4.0 \times 10^{-3})^n}$$

$$\frac{3.0 \times 10^{-7}}{2.4 \times 10^{-6}} = \frac{(2.0 \times 10^{-3}) \left(\frac{2.0 \times 10^{-3}}{4.0 \times 10^{-3}} \right)^n}{(4.0 \times 10^{-3})}$$

$$n = 2$$

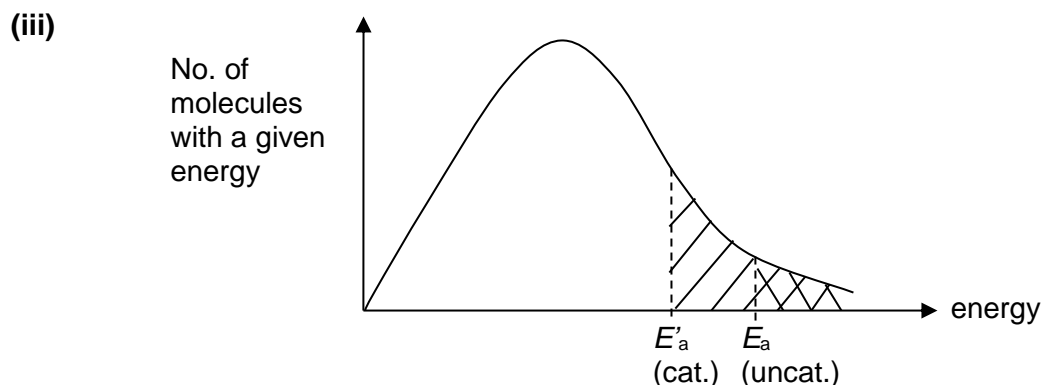
Order of reaction w.r.t NO is 2.

(iv) $\text{rate} = k[\text{NO}]^2[\text{H}_2]$

(v) $k = \text{rate}/[\text{NO}]^2[\text{H}_2]$
 $= (3.0 \times 10^{-7}) / (2.0 \times 10^{-3})^3$
 $= 37.5 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$



(ii) The fine mesh is used so as to maximise the surface area on which the catalytic reaction takes place.



Correct axes label, graph start from origin, labels and shading for E_a for each catalysed and un catalysed reaction.

In the presence of a catalyst, the reaction proceeds via an alternative reaction pathway with a lower activation energy.

Hence, frequency of effective collisions increases as more reactant molecules possess sufficient energy to overcome the lowered activation energy, E_a' (shown by the greater shaded area under the curve) and rate of reaction increases.

(d) (i) Compound **S**: Cl_2 and anhydrous AlCl_3

Compound **T**: excess $\text{Cl}_2(\text{g})$ and UV light or high temperature

(ii) Reactivity: **I** < **II** < **III**

(iii) During hydrolysis, the C–X (where X = Cl, Br & I) bond needs to be broken. Down the group, the atomic radius of the halogens increases from Cl to I and hence the C–X bond length increases from C–Cl to C–I. Thus, the C–X bond strength decreases down the group resulting in increasing ease of hydrolysis from C–Cl to C–I.

Or

Quote the bond energy for C–X from Data booklet

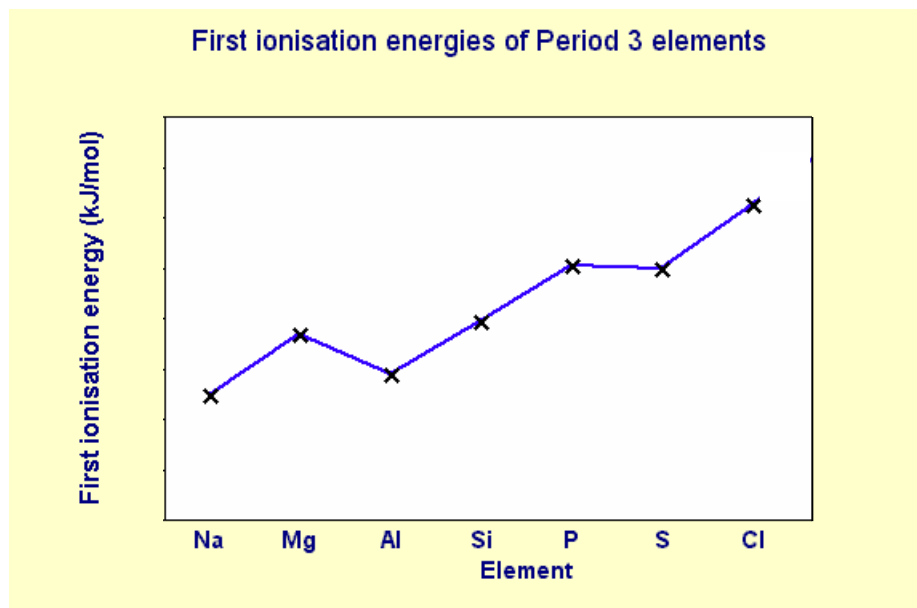
$$\text{BE}(\text{C–Cl}) = 340 \text{ kJ mol}^{-1}$$

$$\text{BE}(\text{C–Br}) = 280 \text{ kJ mol}^{-1}$$

$$\text{BE}(\text{C–I}) = 240 \text{ kJ mol}^{-1}$$

Thus, the C–X bond strength decreases down the group resulting in increasing ease of hydrolysis from C–Cl to C–I.

7 (a) (i)



- (ii) There is a general increase in 1st ionization energy from Na to Cl. Across the period, as the number of proton increases, **nuclear charge increases**. However, the number of inner core electrons remain the same, thus **shielding effect remains relatively constant**. Therefore, increasing ionisation energy is needed to remove the most loosely held electron from the increasing nuclear attraction.

There are two anomalies in 1st ionisation energy between.

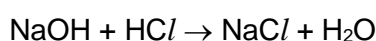
(i) Mg vs Al

The most loosely held electron in Al is in the 3p orbital while the most loosely held electron in Mg is in the 3s orbital. **The 3p orbital is further away (at a higher energy level) from the nucleus than the 3s orbital. This outweighs the increase in nuclear charge**, resulting in a **weaker nuclear attraction for the most loosely held electron** and thus requires less energy to remove it, giving Al a lower first ionisation energy

(ii) P vs S

The most loosely held electron from S is from the paired electrons in 3p orbital whereas that of P comes from the singly filled 3p orbital. The **inter-electronic repulsion between the paired electrons in the same orbital outweighs the effect of increasing nuclear charge**, resulting in **weaker nuclear attraction for the most loosely held electron**. Less energy is thus needed to remove it, giving S a lower first ionisation energy

- (iii) Acid-base reaction/ Neutralisation



- (iv) $\Delta H^\circ_{\text{rxn}} = [\Delta H^\circ_f(\text{NaCl}) + \Delta H^\circ_f(\text{H}_2\text{O})] - [\Delta H^\circ_f(\text{HCl}) + \Delta H^\circ_f(\text{NaOH})]$
 $= [(-407.27) + (-285.83)] - [(-167.20) + (-469.15)]$
 $= -56.75$
 $= -56.8 \text{ kJ mol}^{-1}$

- (v) $\Delta H^\circ_{\text{neu}} = -56.8 \text{ kJ mol}^{-1}$ as $\text{Ba}(\text{OH})_2$ is a strong base.
 $\Delta H^\circ_{\text{neu}}$ for strong acids + strong base reactions are the same.

(b) (i) -2

(ii) step 1: $\text{K}_2\text{Cr}_2\text{O}_7$, $\text{H}_2\text{SO}_4(\text{aq})$, heat with immediate distillation

step 2: HCN , trace amount of NaCN or NaOH , cold

step 3: $\text{K}_2\text{Cr}_2\text{O}_7$, $\text{H}_2\text{SO}_4(\text{aq})$, heat

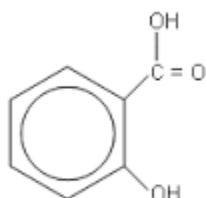
step 4: LiAlH_4 in dry ether/ H_2 , Pt / H_2 , Ni , heat

(c) (i) Addition of H^+ : $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$
 Addition of OH^- : $\text{H}_2\text{CO}_3 + \text{OH}^- \rightarrow \text{HCO}_3^- + \text{H}_2\text{O}$
 When small amount of H^+ or OH^- is added, the large reservoir of HCO_3^- and H_2CO_3 will neutralise H^+ and OH^- respectively. Hence pH is maintained.

(ii) $\text{pH} = -\log [\text{H}^+]$

$$\begin{aligned} [\text{H}^+] &= 10^{-2.5} \\ &= 3.162 \times 10^{-3} \\ &= 3.16 \times 10^{-3} \text{ mol dm}^{-3} \text{ (3 s.f.)} \end{aligned}$$

(d)



CH_3COOH