2023 Y6 H2 Chemistry Preliminary Examinations Paper 2 Suggested Solutions

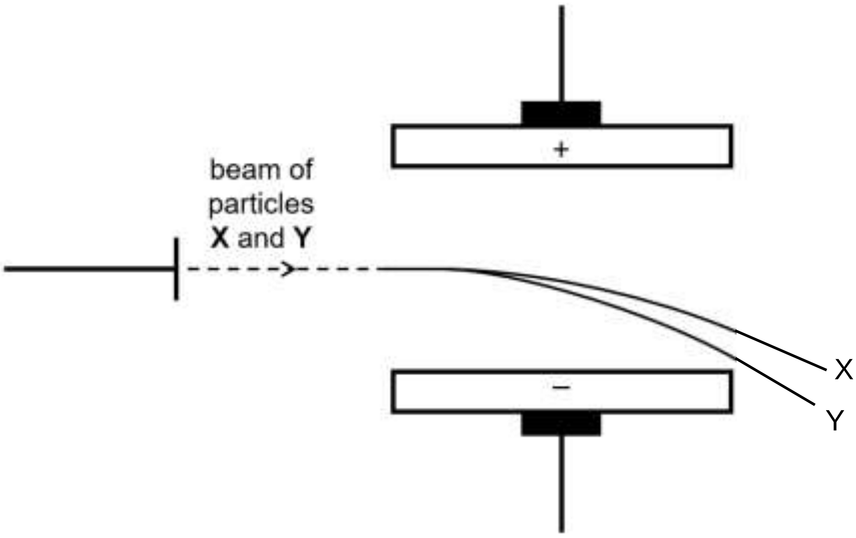
1 **(a)** The volatilities of the halogens decrease from chlorine to iodine.

From Cl_2 to I_2, the electron clouds of the halogens become larger and more polarisable. Hence, more energy is required to overcome the increasing strength of the instantaneous dipole–induced dipole interactions between the halogen molecules down the group, leading to decreasing volatility.

(b) **(i)**

	X	**Y**	**Z**
nucleon number	140	103	37
charge	+1	+1	0

(ii)

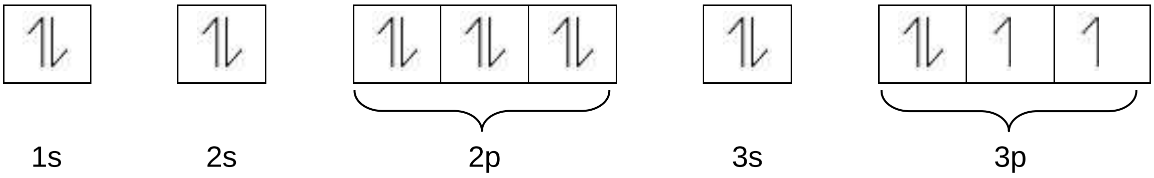


(iii) nucleon number = 103 = 31 + 35 + 37 + 37
There is 1 ^{35}Cl atom in Y.

Y is PCl_2^+.
Its shape is bent.

(c) **(i)** $P(g) + e^- \longrightarrow P^-(g)$

(ii)



(iii) ① Nuclear charge increases from A*l* to C*l* but shielding effect remains effectively constant. Effective nuclear charge increases. Electrostatic attraction between the nucleus and the incoming electron increases, resulting in an increase in the energy released.

② The attraction between the nucleus and incoming electron is weakened due to inter-electronic repulsion between this electron and the one already present in the 3p orbital. Hence, less energy is released as the first electron affinity.

2 **(a)** Au has a smaller atomic size and thus have more atoms per unit volume. It also has a larger atomic mass than Ba. Hence it has a greater mass per unit volume (i.e. higher density) as compared to Ba.

(b) max % of Au in amalgam = 100% − 40% = 60%
max mass of Au in 250 g of amalgam = 0.6×250
= 150 g

(c) conc of Hg vapour
= 1 g of Hg / 1 m^3 of air
= 1 g of Hg / 1.19 kg of air
= 1 g of Hg / 1190 g of air
= $(\frac{1}{1190})$ g of Hg / 1 g of air
= $(\frac{1}{1190} \times 10^6)$ g of Hg / 10^6 g of air
= 840.3 g of Hg / 10^6 g of air
≈ 840 ppm

(d) **(i)** Water prevents / reduces the vaporisation / evaporation of the collected mercury.

(ii) When heated, the mercury in the amalgam vaporises and then condenses on the cooler inner surface of the glass bowl. Then it slides back down to accumulate on the sand to be collected and recovered.

(iii) advantage

- low cost/convenient to set up because of the use of simple household items or no need special equipment (e.g. metal apparatus)
- no mercury-contaminated wastewater produced

disadvantage

- the mercury collected will mix with the sand and hence be harder to recover
- the setup is not as airtight as Method I, i.e. mercury vapour has higher chance to escape back into the atmosphere
- when the bowl is removed, mercury can vaporise again whilst collecting the mercury from the sand
- mercury poisoning from re-use of cooking pot used in the extraction

for cooking purposes

(e) **(i)** $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

(ii) mol ratio 4Au : $1O_2$: $4e^-$
Each Au atom loses 1 e^- to form Au^+.

The oxidation state of Au is <u>+1</u>.

(iii) CN^- is the ligand in D.
The complex anion which is linear would be formed as such: $^-NC\rightarrow Au^+ \leftarrow CN^-$.

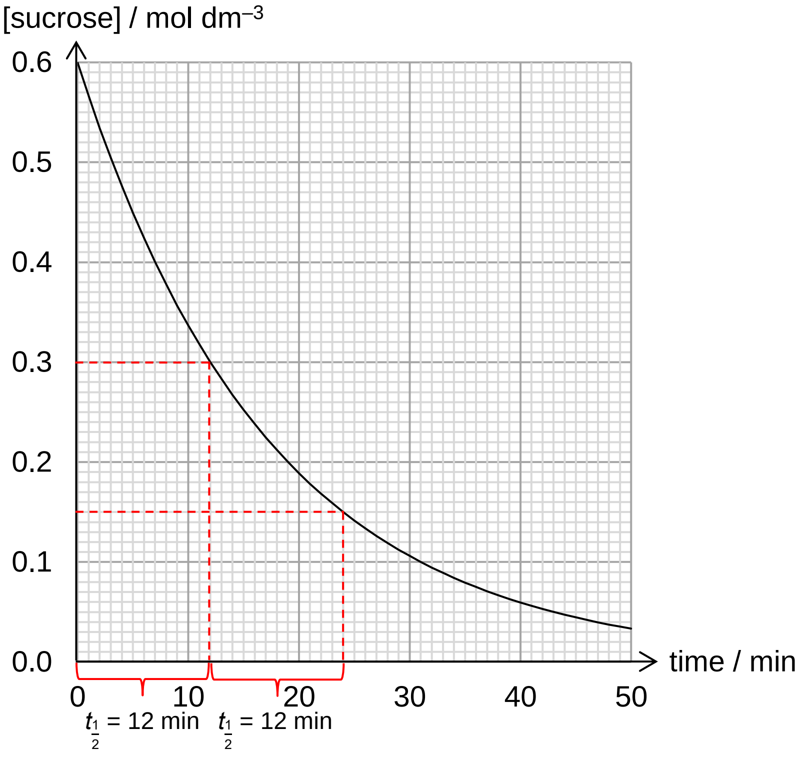
D is $[Au(CN)_2]^-$.

(f) **(i)** Metallic bond is the <u>electrostatic attraction</u> between a lattice of <u>positive ions</u> and <u>delocalised electrons</u>.

(ii) In mercury, poor shielding results in the outermost electrons being held so tightly by the nucleus that it is very <u>difficult</u> (or requires a lot of energy) for the <u>outermost electrons to be delocalised</u>.

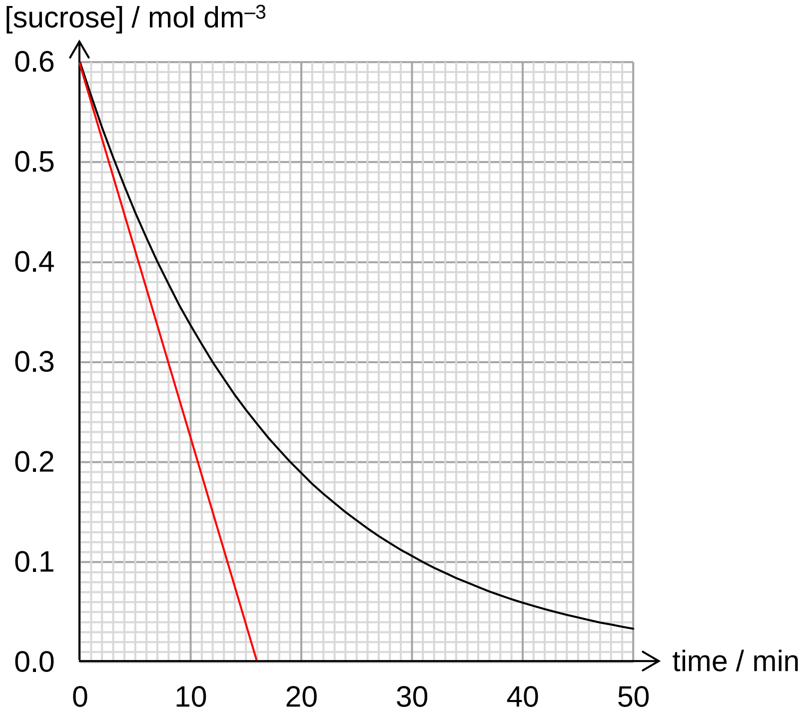
Hence, only <u>weak metallic bonds are formed</u>, resulting in mercury being a liquid and not a solid at room temperature.

3 **(a)** **(i)**



Since half-life is <u>constant</u> at 12 min, order of reaction with respect to sucrose = 1, hence *x* = 1.

(ii)



initial rate of reaction

$= \left|\frac{0.60 - 0.00}{16 - 0}\right| = 0.0375 \text{ mol dm}^{-3} \text{ min}^{-1}$

(iii) Ratio of the rate of reaction of experiment **1** and **2**
= (0.0375 / 0.0125)
= 3

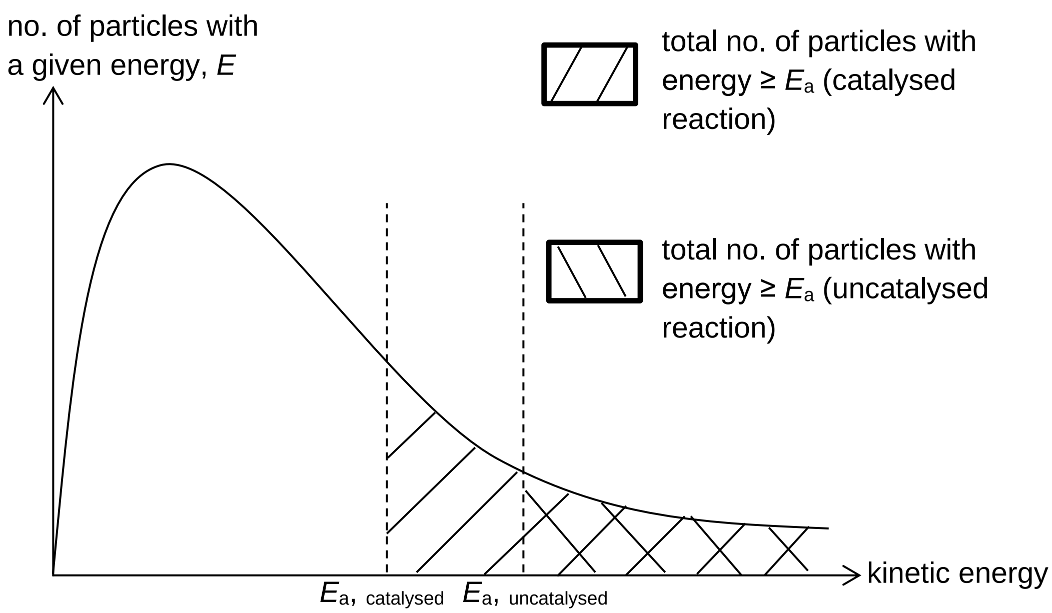
Comparing expt **2** to **1**, when <u>$[H^+]$ x 3, initial rate x 3</u> ⇒ rate ∝ $[H^+]$, hence <u>order of reaction with respect to H^+ = 1</u>, *y* = 1.

(iv) from **(a)(i)** and **(a)(iii)**; rate = k[sucrose]$[H^+]$
from **(a)(iii)**; initial rate = 0.0125 mol dm^{-3} min^{-1}

(0.0125) = k(0.6)(2.0)

$k = \underline{1.04 \times 10^{-2}}$ mol^{-1} dm^{3} min^{-1}

(b)

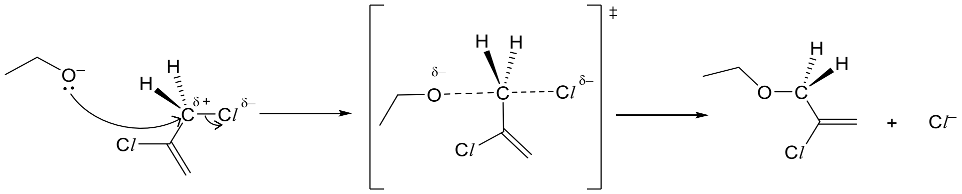


A catalyst provides an alternative pathway of lower activation energy ($E_{a,\ catalysed}$) than the uncatalysed reaction. More molecules possess energy greater than or equal to $E_{a,\ catalysed}$, hence the frequency of effective collision increases, and the rate of reaction increases.

A lower $E_{a,\ catalysed}$ also results in a larger rate constant.

(c) **(i)** *a*: –1, *b*: 3

(ii)

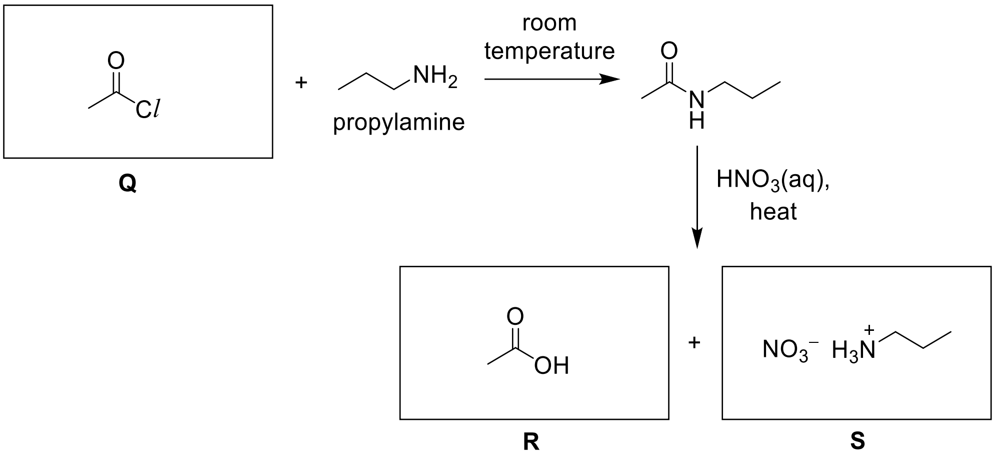


(iii) The p-orbital of C*l* in **C** overlaps with the π-electron cloud of the C=C bond, causing the lone pair of electrons on C*l* atom to delocalise into the C=C bond. This causes the C–C*l* bond in C to have a partial double bond character and is strengthened. Hence, more energy is required to break this bond. This results in a higher activation energy for the reaction and therefore a smaller value of the rate constant, *k*.

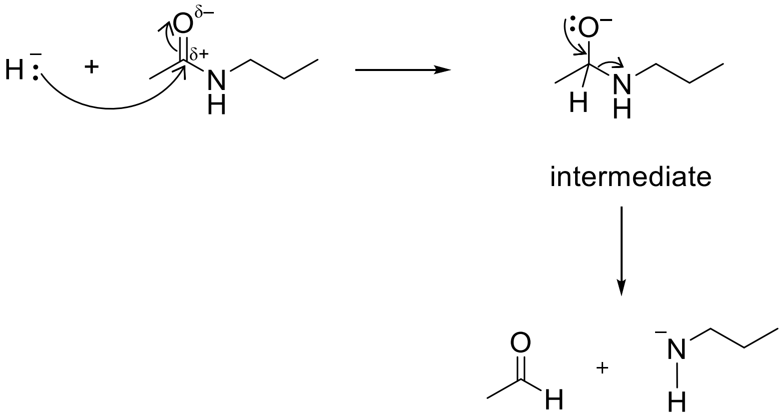
(iv) The carbocation from the S_N1 reaction of compound **B** is stabilised as the empty p-orbital of the positively charged carbon overlaps with the π-electron cloud of the C=C bond. The π electrons delocalises into the empty p-orbital dispersing the positive charge on the carbocation, hence stabilising it.

For S_N2, the presence of bulky C*l* atoms bonded to the electron deficient carbon causes the approach of the nucleophile to be sterically hindered.

4 **(a)**



(b)



(c) **(i)** $CH_3CH_2CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2CH_2NH_3^+ + OH^-$

(ii)

$$\begin{aligned} pOH &= -\lg\sqrt{4.7\times10^{-4}\times1.3} \\ &= 1.606 \\ pH &= 14 - 1.606 \\ &= 12.4 \end{aligned}$$

(iii) $n_{\text{HC}l} = 0.025 \text{ x } 1.3 \text{ x } \frac{1}{2} = 0.01625 \text{ mol}$

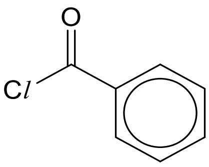
$V_{\text{HC}l} = 0.01625 / 0.80 = 0.02031 \text{ dm}^3 = 20.3 \text{ cm}^3$

$pH = -\lg\frac{10^{-14}}{4.7\times10^{-4}} = 10.67 = 10.7$

(iv) When H^+ is gradually added to the buffer solution, it reacts with $CH_3CH_2CH_2NH_2$. Therefore, $[CH_3CH_2CH_2NH_2]$ decreases, concentration of $CH_3CH_2CH_2NH_3^+$, increases and the position of equilibrium shifts slightly towards the left. Since the ratio of the amine to its conjugate acid remains relatively constant, pH remains unchanged.

5 **(a)** Oxybenzone absorbs radiation over a larger range of wavelengths because the π electrons in oxybenzone are delocalised over a larger number of atoms resulting in greater extent of delocalisation. Hence oxybenzone is a better choice for sunscreen because it absorbs both UVA and UVB radiation whereas compound **U** absorbs only UVB radiation.

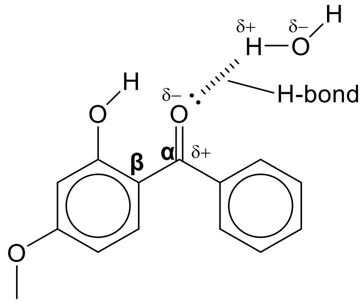
(b) **(i)**



(ii) Test: Add 2,4-DNPH to each sample placed in separate test tubes.

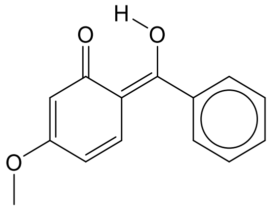
Observation:
For 3-methoxyphenol, no orange ppt formed.
For oxybenzone, orange ppt formed.

(c) **(i)**



(ii) At high temperatures, the intramolecular H-bonds in oxybenzone can be overcome. Hence oxybenzone would be able to form more extensive H-bonds with H_2O, increasing its solubility in water.

(d)



(e) **(i)** $Zn(s) + H_2O(g) \rightleftharpoons ZnO(s) + H_2(g)$

	Zn(s)	H_2O(g)	ZnO(s)	H_2 (g)
initial amount / mol	2.60	2.60	0	0
change in amount / mol	−2.58	−2.58	+2.58	+2.58
equilibrium amount / mol	0.02	0.02	2.58	2.58

partial pressure of H_2 at equilibrium = $\left(\frac{2.58}{0.02 + 2.58}\right) \times 10 = \underline{9.92 \text{ atm}}$

(e) **(ii)**

$$K_p = \frac{p_{H_2}}{p_{H_2O}}$$

$$= \frac{\left(\frac{2.58}{2.60}\right) \text{ x } 10}{\left(\frac{0.02}{2.60}\right) \text{ x } 10} = 129$$

(iii) At lower temperatures, position of equilibrium shifts right to favour the forward exothermic reaction that releases heat, increasing the yield of zinc oxide.

6 **(a)** number of π electrons in styrene: 8

number of π electrons in acrylonitrile: 6

(b) **(i)** $\Delta H = \sum$ BE of bonds broken in rxts – $\sum$ BE of bonds formed in pdts

= BE(C=C) – 2BE(C-C)

= 610 – 2(350)

= –90.0 kJ mol^{-1}

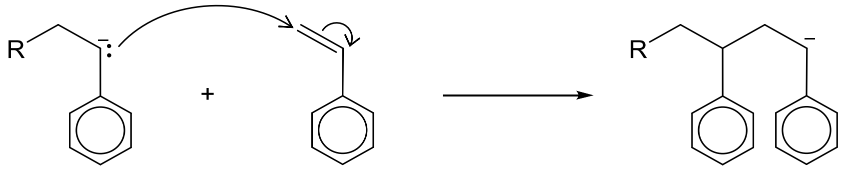
(ii) Entropy is a measure of disorderliness of the system. The more disordered the system is, the larger its entropy.

(iii) There is a decrease in entropy because there is a decrease in number of particles, and hence a decrease in number of ways to arrange the particles and their energies.

(b) **(iv)** $\Delta G = \Delta H - T\Delta S$

At high temperatures (i.e. $T > \frac{\Delta H}{\Delta S}$), $\Delta G > 0$ because the positive $-T\Delta S$ outweighs the negative ΔH.

(c) **(i)**



(c) **(ii)** The intermediate from styrene is stable, whereas the intermediate from acrylonitrile is unstable.

For the intermediate from styrene, the empty p orbital of the positively charged carbon overlaps with the π electron cloud of the benzene ring. π electrons from the benzene ring are able to delocalise into the empty p orbital, dispersing the positive charge, hence stabilising the intermediate.

For the intermediate from acrylonitrile, the −CN group is electron-withdrawing and therefore further intensifies the positive charge on the positively charged carbon, hence making the intermediate even less stable.

(d) When two radicals of short chain lengths terminate, they produce a short polymer chain. When two radicals of long chain lengths terminate, they produce a long polymer chain.

OR

The radical mechanism produces radicals of different chain lengths which randomly combine/ terminate to form polymers of different chain lengths.