

## 2024 JC2 H2 Chemistry 9729 Prelim Exam Paper 2

## Suggested Solutions

1 (a) (i) Proton and deuterons are <u>deflected to the negative plate</u>, but hydrogen atoms is <u>not deflected</u>. This is because protons and deuterons are <u>positively charged</u>, whereas hydrogen atoms are <u>electrically neutral</u>.

The mass of a proton is <u>half of</u> the mass of a deuteron (1 neutron and 1 proton), thus <u>angle of deflection for proton doubled</u> to that of deuterons.

(ii) +1310 kJ mol<sup>-1</sup> (Same value as first IE for hydrogen.)

The electron to be removed from deuterium atom and hydrogen atom experience the <u>same nuclear charge</u> and <u>no shielding effect</u>. They are of <u>similar/same distance from the nucleus</u>. Thus, the <u>attraction of positive nucleus for the (1s) electrons to be removed is the same</u>.

Or

Hydrogen and deuterium have the <u>same electronic configuration</u>. Although deuterium has an <u>additional neutron</u>, it has <u>no charge</u>, therefore <u>does not affect the attraction of nucleus for the electrons to</u> <u>be removed</u>.

[2]

[2]

**(b)** (i)  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ 

(ii) For all atoms, there is an <u>increase in successive ionisation energies</u> as the <u>electron is removed from an ion of increasing positive charge</u>.

The significant jump from 2<sup>nd</sup> to the 3<sup>rd</sup> ionisation energy for element A is due the <u>removal of the 3<sup>rd</sup>/3p electron from an inner principal quantum shell</u> which is more strongly attracted to the positive nucleus compared to a 3s electron.

3d and 4s electrons are very close in energy. Similar amount of energy is required to remove the 4s/2<sup>nd</sup> and 3d/3<sup>rd</sup> electron from Ni.

- (iii) Element **B** is Mg.
- (c) (i)  $2NO + 2CO \rightarrow N_2 + 2CO_2$ Or  $NO_2 + 2CO \rightarrow \frac{1}{2}N_2 + 2CO_2$ 
  - (ii) During <u>adsorption</u>, the formation of <u>weak bonds between the NO<sub>x</sub></u> <u>molecules and the active sites on rhodium</u> surface <u>weakens/breaks</u> <u>the bonds within the NO<sub>x</sub> molecules</u>.

<u>Reaction</u> occurs more readily as the  $NO_x$  particles are held on rhodium surface in <u>close proximity</u> and in the <u>correct orientation</u>.

During <u>desorption</u>, the <u>weak bonds between the product particles</u> and the rhodium surface are broken. The products formed <u>diffuse</u> <u>away</u> from the surface of the catalyst and the <u>active sites become</u> <u>available</u> again.

[3]

[2]

[1]

[1]

(d) (i) First order with respect to  $C_xH_y$  at low concentration, but zeroth order at high concentration.

At high  $[C_xH_y]$ , adding more substrates cannot accelerate the reaction as all the active sites on the catalyst surface are saturated/ occupied.



[2]

A catalyst provides an <u>alternative reaction pathway with a lower</u> <u>activation energy</u>. As a result, <u>more reactant particles possess</u> <u>energy  $\geq$  activation energy required for an effective collision</u> and the <u>frequency of effective collisions increases</u>. Thus, <u>rate constant is</u> <u>increased</u>.



(e) NO<sub>2</sub> forms <u>photochemical smog</u> which causes respiratory problems. [1]







(d) The tertiary <u>carbocation</u> intermediate in the formation of **G** is <u>more stable</u> as there are <u>3 electron-donating alkyl groups</u> to spread out the positive charge.

[1]

[2]

(e) Test: add acidified KMnO<sub>4</sub> (or K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>), heat.

Observations:  $KMnO_4$  remains purple (or  $K_2Cr_2O_7$  remains orange) for **C**, while purple  $KMnO_4$  decolourises (or orange  $K_2Cr_2O_7$  turns green) for **J**.

or

Test: add NaOH, heat; followed by add I<sub>2</sub>(aq), warm.

Observations: no pale yellow ppt formed for **C**, while pale yellow ppt formed for **J**.

3 (a) An Arrhenius acid is a compound that dissolves in water to yield hydrogen ions.



(ii) When 30.0 cm<sup>3</sup> of NaOH has been added, the solution contains excess NaOH and conjugate base of the amino acid.

Amount of excess NaOH =  $\frac{10.0}{1000} \times 0.100 = 1.000 \times 10^{#3}$  mol Concentration of OH<sup>#</sup> =  $1.000 \times 10^{#3} \div \frac{40.0}{1000} = 2.500 \times 10^{#2}$  mol dm<sup>#3</sup> pOH = 1.602



(iv)  $CH_3$  $+H_3N - C - CO_2^-$ 

-CO<sub>2</sub>H is a stronger acid than  $H_2CO_3$  so  $-CO_2^{\#}$  will not be protonated by  $H_2CO_3$ .

 $-NH_3^+$  is <u>weaker acid</u> than  $H_2CO_3$  so  $-NH_2$  will be protonated by  $H_2CO_3$ . [2]

-  $NH_2$  is a stronger base than  $CO_2^{\#}$ , so - $NH_2$  is protonated.



[2]

[3]

4 (a) Lactide has <u>more electrons</u> than lactic acid. <u>More energy is needed to overcome the stronger instantaneous dipole-induced dipole interactions between lactide molecules</u> than the <u>hydrogen bonds between lactic acid molecules</u>.

Since O is more electronegative than N, <u>O–H bond is more polar than N–H</u> bond. More energy is needed to overcome the <u>stronger</u> <u>hydrogen bonds</u> between lactic acid molecules than that between 1,4-butanediamine molecules.

(b) (i)  $\pi$  bond: overlap between p orbitals of C and O



 $\sigma$  bond: overlap between  $sp^2$  orbitals of C and O

[1]

р

(ii)  $\Delta G = \Delta H - T \Delta S$ 

Since  $\Delta H < 0$ ,  $\Delta S < 0$ ,  $-T\Delta S > 0$ , so as temperature increases,  $|-T\Delta S| > |\Delta H|$ ,  $\Delta G$  becomes positive.

Therefore, the polymerisation becomes less spontaneous.

- [2]
- (c) (i) Increasingly positive/ decreasingly negative due to the increase in disorder in the system as the number of ways to arrange the polymer [1]

chain/ greater flexibility in the rotation of bonds in the open chain increases.

(ii) 
$$\Delta H = 2(360) + 2(390) - 2(305) - 2(460)$$
  
= -30.0 kJ mol<sup>-1</sup> [2]

(d) The <u>sp<sup>2</sup> C<sub>1</sub> in norbornene becomes sp<sup>3</sup> hybridised</u> in **B**. The sp<sup>2</sup> orbital is <u>closer to the nucleus/ smaller in size</u>, so C<sub>1</sub> – H bond is <u>shorter</u> in norbornene.



- (ii) The sp<sup>2</sup> <u>carbocation is trigonal planar</u>. The <u>bromide ion/ nucleophile</u> <u>attack from both sides</u> of the plane, which give rise to a pair of stereoisomers.
- (iii) Br

There is an <u>internal plane of symmetry</u> the <u>mirror images of</u> <u>stereoisomer are superimposable</u>, thus this structure is optically inactive. [2]

- 5 (a) (i) A transition element is a d-block element which forms at least one stable ion with a partially filled d subshell. [1]
  - (ii) In the presence of (H<sub>2</sub>O) ligands, the degenerate partially filled 3d orbitals are split into 2 sets of orbitals with a (small) energy difference  $(\Delta E)$ .

This  $\Delta E$  is different for V<sup>2+</sup> and V<sup>3+</sup> because these ions have different oxidation states/ charges on ions/ number of electron/ electronic configuration.

Radiation from visible light spectrum is absorbed to promote an electron from a lower energy d-orbital to another d-orbital of higher energy.

The green colour observed for  $V^{3+}$  corresponds to the complement of the red colours absorbed.

The violet colour observed for  $\mathsf{V}^{2+}$  corresponds to the complement of the yellow colours absorbed.



## (b) (i) Electrode A (through external circuit) to electrode B. [1]

(ii) 
$$E_{\text{cell}}^{\ominus} = E^{\ominus}(VO_2^+ | VO^{2+}) - E^{\ominus}(V^{3+} | V^{2+})$$
  
= (+1.00) - (-0.26) = +1.26V [1]

(iii) As the pH increased, [H<sup>+</sup>] decreased.

$$VO_2^+(aq) + 2H^+ + e = VO^{2+}(aq) + H_2O(I) ----- (1)$$

The <u>position of equilibrium of (1) shifts to the left</u> and  $E(VO_2^+(aq)/VO^{2+}(aq))$  becomes <u>less positive</u>. Thus, *E*<sub>cell</sub> becomes <u>less positive</u>. [2]

When the cell becomes flat, 76.9% of yellow  $VO_2^+$  is converted to blue  $VO^{2+}$ . The colour is green as the solution contains a mixture of yellow  $VO_2^+$  and blue  $VO^{2+}$ .

(ii) 
$$VO_{2^{+}} \equiv V^{2_{+}} \equiv e^{-}$$
  
Amount of electrons, n =  $5.00 \times 2.00 \times \frac{76.9}{100}$  = 7.69 mol  
Capacity = Q = nF = 7.69 × 96500 = 7.421 × 10<sup>5</sup> C [2]

(iii) Capacity = Q =  $7.42 \times 10^5$  C = current × time taken Current =  $600 \times 10^{-3} \times 50 = 30$  A Time taken =  $\frac{7.42 \times 10^5}{30} = 24737$ s = 6.87 h [2]

- (d) (i) Electrode in Tank **A**:  $VO^{2+}(aq) + 2H^{+}(aq) + 2e \rightarrow V^{2+}(aq) + H_2O(I)$ Electrode in Tank **B**:  $VO^{2+}(aq) + H_2O(I) \rightarrow VO_2^{+}(aq) + 2H^{+}(aq) + e$ Ratio of charge required for tank **A** to tank **B**: 2:1 [3]
  - (ii) <u>Electrode in Tank B</u>.

When  $VO^{2+}$  is depleted tank **B**, water is oxidised to oxygen gas at electrode in Tank **B**. [2]