Eunoia Junior College
8873 H1 Chemistry
2022 Paper 1 Suggested Solution

1 Only **A** and **B** with 2 protons has a charge of +2 on the nucleus.

The mass of an atom or ions is due primarily to protons and neutrons in the nucleus as an electron is ~ $\frac{1}{1836}$ the mass of a proton or neutron.

B with 4 nucleons (neutrons and protons) will have a greater mass than **A** with 3 nucleons.

⇒ **B**

2
- **A** ✗: $_{22}Ti$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2 \rightarrow$ $_{22}Ti^{2+}$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$
- **B** ✗: $_{24}Cr$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
- **C** ✓: $_{26}Fe$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$
- **D** ✗: $_{29}Cu$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1 \rightarrow$ $_{29}Cu^+$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

⇒ **C**

3 Atomic radius decreases across the period due to increasing effective nuclear charge. Excluding Group 18, the element with the smallest atomic radius in its period must be a **Group 17** element.

For an element to have only 2 electrons in its p sub-shell, the element must have a valence electronic configuration of $ns^2\ np^2$, *i.e.* in **Group 14**.

⇒ **A**

4 As is [Ar] $3d^{10}\ 4s^2\ 4p^3$ (Period 4, Group 15)
Sb is [Kr] $4d^{10}\ 5s^2\ 5p^3$ (Period 5, Group 15)
Se is [Ar] $3d^{10}\ 4s^2\ 4p^4$ (Period 4, Group 16)
Te is [Kr] $4d^{10}\ 5s^2\ 5p^4$ (Period 5, Group 16)

There will be a significant jump between the 3rd and 4th IE for a Group 15 element (**A** and **C**) since the 4th electron is removed from a lower energy *n*s subshell, while the first 4 electrons are removed from the *n*p subshell for a Group 16 element, showing a more gradual increase (**B** or **D**).

A period 5 element in the **same group** will have lower *x*th IE compared to a period 4 element as the electrons removed are further away from the nucleus.

⇒ **B**

5
- 1 ✓: Ice adopts an open hexagonal lattice structure due to hydrogen bonding, resulting in ice having a lower density than water.
- 2 ✓: The high surface tension of water is due to the strong intermolecular hydrogen bonds between water molecules on the surface.
- 3 ✗: Water can act as an acid since it can donate a H^+, and as a base since it can accept a H^+, exemplified by its auto-ionisation:
  $H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$
- 4 ✗: The pH of pure water at 25 ºC is 7.00 due to the auto-ionisation of water:
  $H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$
  resulting in equal concentration of H^+ and OH^- of 10^{-7} mol dm^{-3} each.

⇒ **B**

6 The Arrhenius definition of a base is a substance that dissociates to produce hydroxide ions in aqueous solution.

⇒ **C**

7 pH = –lg [H^+]
[H^+] at pH 4 = 10^{-4} mol dm^{-3}
[H^+] at pH 6 = 10^{-6} mol dm^{-3}

change in [H^+] = $\frac{10^{-6}}{10^{-4}} = \frac{1}{100}$

⇒ **B**

8
$$n_{Ba(OH)_2} = \frac{1.00}{137.3 + (16.0 + 1.0) \times 2}$$
$$= 5.838 \times 10^{-3}\ \text{mol}$$
$$\left[Ba(OH)_2\right] = \frac{5.838 \times 10^{-3}}{\frac{500}{1000}} = 0.01168\ \text{mol dm}^{-3}$$

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

$$\left[OH^-\right] = 2\left[Ba(OH)_2\right] = 0.02335\ \text{mol dm}^{-3}$$
$$pOH = -lg\left[OH^-\right] = 1.63$$
$$pH = 14 - pOH = 12.37$$

⇒ **D**

9 A buffer contains a large reservoir of a weak acid, HA, and its conjugate base, A^-.

The conjugate base A^- is able to remove small amount of H^+ added in:

$$A^- + H^+ \rightarrow HA$$

The weak acid HA is able to remove small amount of OH^- added in:

$$HA + OH^- \rightarrow A^- + H_2O$$

⇒ **B**

10
- **A** ✗: P_4O_{10} dissolves in water to give an acidic solution (H_3PO_4; pH < 7)
- **B** ✗: Al_2O_3 is a solid with strong ionic bonds between Al^{3+} and O^{2-}, hence very high melting point, while P_4O_{10} has a simple covalent structure and does not conduct electricity at r.t.
- **C** ✗: Both $AlCl_3$ and PCl_5 reacts rapidly with water, producing acidic fumes.
- **D** ✓: Both $AlCl_3$ and PCl_5 reacts rapidly with water, producing acidic fumes. In both cases, an acidic solution results, which turns blue litmus red.
  $2AlCl_3 + 3H_2O \rightarrow Al_2O_3 + 6HCl$
  $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

⇒ **D**

11 When an atom loses electron(s) to form a cation, there is a decrease in shielding, while nuclear charge remains the same. Hence effective nuclear charge increases, resulting in a decrease in radius.

When an atom gains electron(s) to form an anion, there is an increase in shielding, while nuclear charge remains the same. Hence effective nuclear charge decreases, resulting in an increase in radius.

⇒ **A**

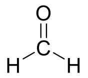
12 n_{Ag} deposited $= \frac{0.216}{107.9} = 2.002 \times 10^{-3}$ mol

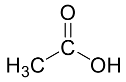
total no. of Ag atoms deposited
$= 2.002 \times 10^{-3} \times 6.02 \times 10^{23}$
$= 1.205 \times 10^{21}$

no. of Ag deposited per cm^3
$= \frac{1.205 \times 10^{21}}{150}$
$= 8.03 \times 10^{18}$

⇒ **A**

13
- 1 ✗: They can have different functional groups, undergoing different chemical reactions. *E.g.*


CH_2O
aldehyde


$C_2H_4O_2 \equiv (CH_2O)_2$
carboxylic acid

- 2 ✗: The compounds can be made up of different multiples of CH_2O, hence different M_r.
- 3 ✗: Compounds made up of different multiples of CH_2O are not isomers as they have different numbers of atoms, *i.e.* different molecular formula
- 4 ✓: Consider $(CH_2O)_n$.
  percentage by mass of C
  $$= \frac{n \times 12.0}{n(12.0 + 1.0 \times 2 + 16.0)} \times 100\%$$
  $$= \frac{12n}{30n} \times 100\% = 40\%$$

⇒ **D**

14
$$n_{CH_4} = \frac{6.4 \times 10^3}{12.0 + 1.0 \times 4} = 400\ \text{mol}$$
$$n_{H_2} = 3n_{CH_4} = 1200\ \text{mol}$$
$$V_{H_2} = n_{H_2} \times V_m = 1200 \times 24\ \text{dm}^3$$
$$= 28\ 800\ \text{dm}^3$$

⇒ **D**

15 $2HI \rightarrow I_2 + 2H^+ + 2e^-$

Since HI reacts with HNO_3 in a 2 : 1 ratio, the nitrogen in the +5 oxidation state in each molecule of HNO_3 accepts two electrons, becoming +3 in the oxide.

⇒ **C**

16
- 1 ✗: The activation energy for reaction X is the same as the activation energy for the slowest stage, *i.e.* stage Y. So the magnitude should be ΔE_1.
- 2 ✓: The magnitude of activation energy of stage Y is the difference between the energy of P and the transition state, ΔE_1. The magnitude of the enthalpy change for stage Y is the difference between the energy of P and intermediate Q, ΔE_3.
- 3 ✓: The magnitude of activation energy of stage Z is the difference between the energy of intermediate Q and the transition state, ΔE_6. The magnitude of the enthalpy change for stage Z is the difference between the energy of intermediate Q and R, ΔE_7.

⇒ **C**

17 Lattice energy is the energy released when one mole of a solid ionic lattice is formed from its *constituent gaseous ions*, all under standard states.

$$Ca^{2+}(g) + O^{2-}(g) \rightarrow CaO(s)$$

⇒ **D**

18 $\text{L.E.} \propto \left|\frac{q_+ q_-}{r_+ + r_-}\right|$ is always exothermic.

- **A** ✗: $q_{Mg^{2+}} = 2 \times q_{Na^+}$
  $\Rightarrow \left|\text{L.E.}(MgCl_2)\right| > \left|\text{L.E.}(NaCl)\right|$
- **B** ✗: $r_{Mg^{2+}} < r_{Ca^{2+}}$
  $\Rightarrow \left|\text{L.E.}(MgO)\right| > \left|\text{L.E.}(CaO)\right|$

C ✓: $r_{\text{C}l^-} > r_{\text{F}-}$

$\Rightarrow |\text{L.E.}(\text{KC}l)| < |\text{L.E.}(\text{KF})|$

D ✘: $r_{\text{Na}^+} < r_{\text{K}^+}$

$\Rightarrow |\text{L.E.}(\text{NaBr})| > |\text{L.E.}(\text{KBr})|$

⇒ **C**

19 $2Br(g) + 6F(g) \rightarrow 2BrF_3(g)$ involves forming 6 Br–F bonds.

Using the cycle and the information that

$\frac{1}{2}Br_2(l) + \frac{3}{2}F_2(g) \rightarrow BrF_3(l)$ $\Delta H_f^\ominus = -300$ kJ mol^{-1}

$$-6\text{B.E.}(\text{Br–F}) = -(+700) + 2\times(-300) + 90$$

$$\text{B.E.}(\text{Br–F}) = \frac{-1210}{-6} = +202 \text{ kJ mol}^{-1}$$

⇒ **B**

20 Let rate = $k[CNO^-]^n[NH_4^+]^m$.

Using expt 1 and 2,

$$\frac{5.80}{1.16} = \frac{k(0.5)^n(2.5)^m}{k(0.5)^n(0.5)^m}$$

$$5 = 5^m \Rightarrow m = 1$$

Using expt 2 and 3,

$$\frac{1.16}{23.20} = \frac{k(0.5)^n(0.5)^1}{k(2.0)^n(2.5)^1}$$

$$\frac{1}{20} = \frac{1}{5(4^n)} \Rightarrow n = 1$$

Using expt 2 and 4,

$$\frac{1.16}{X} = \frac{k(0.5)^1(0.5)^1}{k(1.0)^1(2.0)^1}$$

$$\frac{1.16}{X} = \frac{1}{8} \Rightarrow X = 9.28$$

⇒ **C**

21 **A ✓**: Adsorption of reactants on the heterogeneous catalyst leads to formation of bonds with the catalyst and weakening of bonds within the reactants, hence lowering E_a.

B ✘: A catalyst speeds up a reaction by providing an alternative pathway with lower E_a.

C ✘: Reactants (alkene and hydrogen) are *adsorbed* on the nickel. After reaction, the products (hydrogenated alkene) must be *desorbed* to release active sites for other reactants to bind.

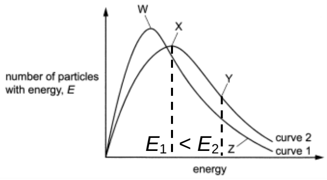
D ✘: There is no change to the enthalpy change for the overall reaction as the reactants and products are the same. The catalyst only provides an alternative pathway with lower E_a.

⇒ **A**

22 The spread of energy among the particles increases with temperature. Hence curve 2 corresponds to a higher temperature than curve 1.

Rate constant, *k*, increases with temperature. Hence curve 2 applies to the reaction occurring with the higher rate constant.

Point X indicates particles with energy E_1, which is lower than E_2 at point Y.



⇒ **D**

23 At the start, *t* = 0, there are no $PCl_3(l)$ and $Cl_2(g)$. Hence rate of reverse reaction is 0. As the $PCl_5(s)$ is warmed, it starts to dissociates to form more PCl_3 and Cl_2. As the concentration of $Cl_2(g)$ increases, the rate of the reverse reaction starts to *increase*, until it *remains constant* when equilibrium is reached, where the rate of forward reaction equals rate of the reverse reaction.

⇒ **D**

24 **A ✘**: Catalyst does not affect the position of equilibrium. It simply increases the rate of both forward and backward reaction so that equilibrium is reached faster.

B ✓: Addition of strong alkali removes H^+, causing the $[H^+]$ to decrease. Hence position of equilibrium shifts to the right in attempt to counter this by producing more H^+.

C ✘: In strong alkali, $[H^+]$ will be very low. Hence the position of equilibrium lies to the right, resulting in a high concentration of **yellow** CrO_4^{2-}.

D ✘: Lowering pH implies $[H^+]$ increases. The position of equilibrium shifts to the left in attempt to counter this by reacting more H^+. This leads to a decrease in the $[CrO_4^{2-}(aq)]$.

⇒ **B**

25

	diol	+ 2 acid	⇌ ester	+ 2 water
initial amt/mol	1	2	–	–
change in amt/mol	**–(1–*x*)**	–2(1–*x*)	+(1–*x*)	+2(1–*x*)
eqm amt/mol	*x*	2*x*	1–*x*	2(1–*x*)

⇒ **A**

26 1 ✓: Assuming the same density,

Volume of sphere = $\frac{4}{3}\pi r^3$.

$$\frac{\text{no. of 5 nm nanoparticles}}{\text{no. of 10 nm nanoparticles}} = \left(\frac{5 \text{ nm}}{2.5 \text{ nm}}\right)^3 = 8$$

Surface area of sphere = $4\pi r^2$.

$$\frac{\text{total surface area of 5 nm nanoparticles}}{\text{total surface area of 10 nm nanoparticles}} = 8\times\left(\frac{2.5}{5}\right)^2 = 2$$

The total surface area of 1.0 g of spherical nanoparticles with a diameter of 5 nm is about twice that of spherical nanoparticles with a diameter of 10 nm. Hence there are approximately twice as many active sites available for catalysis.

2 ✘: The platinum nanoparticles helps to weaken the bonds in NO_x, lowering the activation energy for their reaction with CO and unburnt C_xH_y, to give N_2, CO_2 and H_2O.

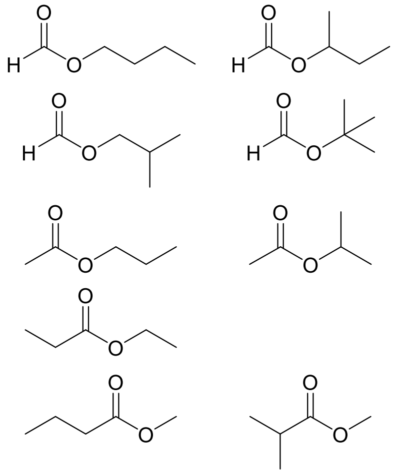
3 ✓: Nanoparticles of platinum possess a much larger total surface area compared to a single piece of platinum of the same total volume, giving a larger surface area to volume ratio. This provides more active sites on the surface for reactions to take place.

⇒ **B**

27 Graphene has good electrical conductivity as the p orbital containing the single electron remaining on each carbon atom, after accounting for the 3 σ bonds making up the hexagonal graphene plane, overlaps sideway, giving rise to π bonding where the π electrons are delocalised through the layer.

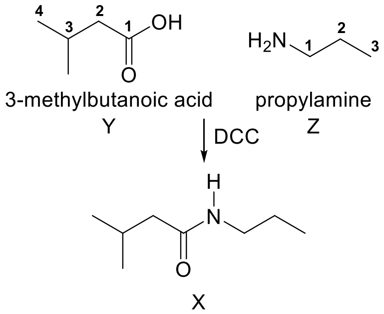
⇒ **C**

28 The constitutional isomers are



⇒ **C**

29



⇒ **D**

30 The polymer used must be water soluble, able to form favourable hydrogen bonds with water.

⇒ **A**

Answer Key

Qn	Ans	Qn	Ans	Qn	Ans
1	B	11	A	21	A
2	C	12	A	22	D
3	A	13	D	23	D
4	B	14	D	24	B
5	B	15	C	25	A
6	C	16	C	26	B
7	B	17	D	27	C
8	D	18	C	28	C
9	B	19	B	29	D
10	D	20	C	30	A