Neap

Trial Examination 2023

Suggested Solutions

QCE Chemistry Units 3&4

Paper 1

SECTION 1 – MULTIPLE CHOICE QUESTIONS

	A	B	C	D
1.	○	●	○	○
2.	○	○	●	○
3.	○	○	○	●
4.	●	○	○	○
5.	●	○	○	○
6.	○	○	○	●
7.	○	○	●	○
8.	○	●	○	○
9.	○	●	○	○
10.	●	○	○	○
11.	○	○	○	●
12.	●	○	○	○
13.	○	○	●	○
14.	●	○	○	○
15.	●	○	○	○
16.	○	○	○	●
17.	○	○	○	●
18.	○	○	●	○
19.	○	○	●	○
20.	○	○	○	●

QUESTION 1 B

B is correct, and **A** and **C** are incorrect. According to Le Châtelier's principle, the system will adjust itself to partially oppose the effect of the change. If the CH_4 is removed, the system will move in the forward direction to replace it. This means that the H_2 concentration will decrease because the gas will be used up to produce more CH_4.

D is incorrect. The CO_2 would react with the H_2 to produce more CH_4; therefore, the concentration of CO_2 will decrease.

QUESTION 2 C

C is correct. For the reaction $aA + bB \rightleftharpoons cC + dD$, the formula for the equilibrium constant (K_c) is as follows.

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

The reaction that would produce the greatest amount of products relative to the amount of reactants is the reaction with the highest K_c value because the products are the numerator of the fraction. Reaction Y has the highest K_c value.

A, **B** and **D** are incorrect. These reactions have lower K_c values than reaction Y.

QUESTION 3 D

D is correct. Tartaric acid ($C_4H_6O_6$) loses one hydrogen to become $C_4H_5O_6^-$ in the first ionisation reaction. $C_4H_5O_6^-$ then loses another hydrogen to become $C_4H_5O_6^{2-}$ in the second ionisation reaction.

A is incorrect. This equation is the first ionisation reaction.

B is incorrect. This equation uses an incorrect formula for tartaric acid.

C is incorrect. This equation does not show $C_4H_6O_6$ losing a hydrogen.

QUESTION 4 A

A is correct. Aluminium (Al) loses electrons more easily than tin (Sn). Therefore, in the galvanic cell, the electrons flow from the aluminium electrode to the tin electrode via the external circuit. The aluminium half-cell reaction is represented by the equation $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$. The electrons move down the tin electrode and the tin ions take up the electrons. The tin half-cell reaction is represented by the equation $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$. Therefore, the overall reaction is represented by $2Al(s) + 3Sn^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Sn(s)$.

B is incorrect. The electrons have not been balanced.

C is incorrect. The states are incorrect.

D is incorrect. The tin and aluminum ions do not have the correct charges.

QUESTION 5 A

A is correct. Both amino acids have two NH_2 side groups. At a pH of 2, both NH_2 side groups will accept a hydrogen ion (H^+), resulting in an ion with a 2+ charge. The H on the OH end will only be lost at high pH levels.

B is incorrect. The NH_2 side groups in the amino acids accept hydrogen ions. Lysine will still be a 2+ ion at a pH of 7, but glutamine will be a 2– ion as its isoelectric point is 5.7.

C is incorrect. At a pH of 10, both amino acids will be 2– ions as their isoelectric points are both less than 10.

D is incorrect. Both amino acids have the two NH_2 side groups.

QUESTION 6 D

D is correct. Carboxylic acids, such as propanoic acid, can form dimers. A dimer occurs when two hydrogen bonds form between two molecules, and so the two molecules present as one. The resulting molecule is larger, which increases the dispersion forces. This, combined with the hydrogen bonding, means that carboxylic acids have a higher boiling point.

A is incorrect. This option does not refer to hydrogen bonding.

B is incorrect. All molecules have dispersion forces, and dispersion forces do not account for the difference between the functional groups in carboxylic acids and alcohols.

C is incorrect. The molecular masses of the three molecules are similar, and so the molecules have similar chain lengths and dispersion forces.

QUESTION 7 C

C is correct and **A** is incorrect. In the reaction, the oxidation number of the solid lead increases from 0 to +2. The increase indicates that the lead has undergone oxidation and so is the reducing agent.

B and **D** are incorrect. The oxidation number of the solid lead oxide decreases from +4 to +2. The decrease indicates that the lead oxide has undergone reduction and so is the oxidising agent.

QUESTION 8 B

B is correct. A primary alcohol can undergo oxidation to become an aldehyde. An example of this is the oxidation of propan-1-ol to become propanal.

A is incorrect. A nitrile undergoes reduction to become an amine; this requires the addition of hydrogen across the triple bond between the carbon and nitrogen in a nitrile molecule.

C is incorrect. The reaction between a carboxylic acid and an amine is a condensation reaction.

D is incorrect. The addition of hydrogen gas indicates reduction.

QUESTION 9 B

In a neutral compound, the oxidation numbers of the compound's components total zero. The oxidation number of chlorine in each of the compounds shown is calculated as follows.

$KClO_4(aq)$:

$$+1 + (\text{oxidation number of Cl}) + (-8) = 0$$

$$\text{oxidation number of Cl} = +7$$

$Cl_2(g)$: oxidation number of $Cl = 0$

$HCl(g)$:

$$+1 + (\text{oxidation number of Cl}) = 0$$

$$\text{oxidation number of Cl} = -1$$

$Cl_2O(g)$:

$$(\text{oxidation number of Cl}) + (-2) = 0$$

$ClF_3(g)$: oxidation number of $Cl = +1$ (as there are two Cl atoms)

$$(\text{oxidation number of Cl}) + (-5) = 0$$

$$\text{oxidation number of Cl} = +5$$

QUESTION 10 A

A is correct. Cellulose is formed from β-glucose monomers and has large, straight chains. This results in strong hydrogen bonding between the chains.

B is incorrect. Glycogen is formed from α-glucose monomers and is highly branched.

C is incorrect. Starch is formed from α-glucose monomers only.

D is incorrect. Amylose and amylopectin are the two starch polymers. Amylose is a straight-chain polymer; however, amylopectin is occasionally branched due to the orientation of the glucose monomers.

QUESTION 11 D

Molecule W is propanol (an alcohol). Molecule X is propanoic acid (a carboxylic acid). Molecule Y is 1-bromopropane (a bromoalkene, which is a haloalkane). Molecule Z is propanal (an aldehyde).

A haloalkane (molecule Y) can be converted to an alcohol (molecule W) through a substitution reaction. Since molecule Y is 1-bromopropane, the alcohol produced is a primary alcohol; this can be oxidised using acidified potassium dichromate ($H^+/Cr_2O_7^{2-}$) to produce an aldehyde (molecule Z), and then can be further oxidised to produce a carboxylic acid (molecule X). So, the order in which the molecules are produced is $Y \rightarrow W \rightarrow Z \rightarrow X$.

QUESTION 12 A

A is correct. This equation shows a base reacting with an acid to produce a salt and water; which is a neutralisation reaction.

$$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$$

base + acid → salt + water

B is incorrect. This equation shows a dilute acid reacting with a metal to produce hydrogen (H_2) gas, not a neutral solution.

C is incorrect. The equation shows a precipitation reaction with silver chloride (AgCl) as the precipitate.

D is incorrect. The equation shows an acid and a carbonate reacting to produce a salt, carbon dioxide (CO_2) gas and water. Calcium carbonate ($CaCO_3$) is insoluble and so would not be considered basic.

QUESTION 13 C

C is correct and **D** is incorrect. Chloroethene molecules are polar. The strength of the dipole–dipole attractions, not hydrogen bonding, between the molecules makes PVC very rigid. Its rigidity does not make it suitable as a coating for frying pans because it would not adhere to the shape of a frying pan.

A and **B** are incorrect. Tetrafluoroethylene molecules are non-polar. The intermolecular forces between these molecules are weak dispersion forces.

QUESTION 14 A

A is correct. In atactic polypropene, the CH_3 side groups are randomly distributed. This prevents the chains stacking closely together, making the polymer very soft and limiting its usefulness.

B, **C** and **D** are incorrect. In isotactic polypropene, the CH_3 side groups are all on one side of the polymer chain.

QUESTION 15 A

Molecule P is benzyl heptane (an alkane). Molecules Q, R and S are alcohols; Q is 8-benzyl 1-octanol, R is 7-benzyl 1-heptanol, and S is 7-benzyl 4-amino 1-heptanol. The silica stationary phase has been modified by the addition of long hydrocarbon chains, which make it non-polar. The mobile phase is a polar mixture of methanol and water. Molecule P is non-polar, while molecules Q, R and S are polar. Since molecule P is non-polar, it will stay attached to the silica for the longest time. The polar molecules will move in the mobile phase. Hence, molecule P will have the longest retention time.

QUESTION 16 D

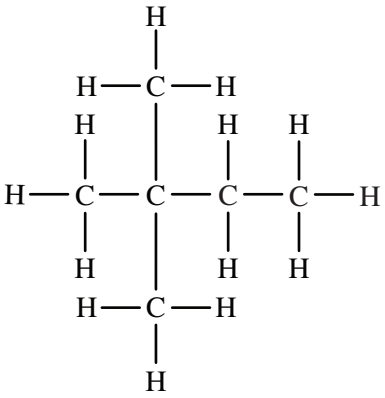
D is correct. The three-dimensional shapes of large proteins are tertiary structures. They involve hydrogen bonding between polar functional groups on side chains, disulfide bonds between cysteine R groups; dispersion forces between non-polar R groups and ionic attractions between charged R groups. Of these four types of bonds, hydrogen bonding and disulfide bonds are the strongest.

A, **B** and **C** are incorrect. These options do not identify the two strongest bonds.

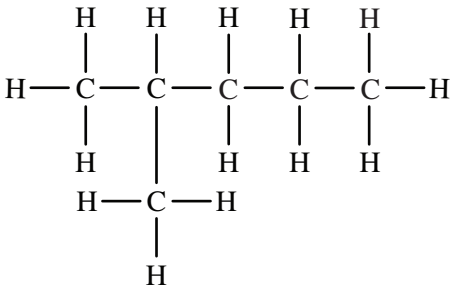
QUESTION 17 D

D is correct. 2,2-dimethylbutane and 2-methylpentane both have the formula C_6H_{14}. Their structural formulas are shown.

2,2-dimethylbutane



2-methylpentane



A is incorrect. Butane and 2-methylpropane both have the formula C_4H_{10}.

B is incorrect. 2-pentene has the formula C_5H_{10}.

C is incorrect. 2,2-dimethylbutene is not a possible molecule.

QUESTION 18 C

C is correct.

$$\begin{aligned}\text{atom economy} &= \frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times 100 \\ &= \frac{2\times\big((2\times 12.01)+(6\times 1.01)+16.00\big)}{(6\times 12.01)+(12\times 1.01)+(6\times 16.00)} \times 100 \\ &= \frac{2\times(24.02+6.06+16.00)}{72.06+12.12+96.00} \times 100 \\ &= \frac{92.16}{180.18} \times 100 \\ &= 51.1\%\end{aligned}$$

A is incorrect. This option is one quarter of the correct percentage.

B is incorrect. This option is half the correct percentage.

D is incorrect. Carbon dioxide gas is a byproduct of the reaction, so not all the glucose is converted to ethanol.

QUESTION 19 C

C is correct. Unsaturated fatty acids have at least one C=C bond in their chain. Monounsaturated fatty acids have only one C=C bond and the general formula $C_nH_{2n-2}O_2$. Oleic acid follows this formula ($CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ or $C_{18}H_{34}O_2$) and has one C=C bond.

A is incorrect. Linoleic acid has two C=C bonds and so is polyunsaturated.

B and **D** are incorrect. Stearic acid and lauric acid have only single bonds between their carbon atoms and so are saturated.

QUESTION 20 D

D is correct. In an electrolytic cell, oxidation occurs at the anode and reduction occurs at the cathode. In this cell, bromine ions are the stronger reductant than water and so oxidise to form bromine gas (Br_2) at the anode. Water is a stronger oxidant than sodium ions and so reduces to form hydrogen gas (H_2) at the cathode.

A is incorrect. Sodium ions are not preferentially reduced.

B is incorrect. Water is not oxidised to form oxygen gas (O_2).

C is incorrect. This option incorrectly has oxidation occurring at the cathode and reduction at the anode.

SECTION 2

QUESTION 21 (3 marks)

a) The change in colour indicates that more permanganate ion (MnO_4^-) is being reacted as more hydrogen peroxide (H_2O_2) is added. According to Le Châtelier's principle, the system changes direction to counteract the addition; that is, it favours the forward reaction to use up the additional H_2O_2.

[1 mark]
1 mark for explaining the change in colour using Le Châtelier's principle.

b) The darker colour indicates that more MnO_4^- is being produced; therefore, the system is favouring the reverse reaction.

The temperature has been increased and so the system has moved in the direction that will absorb the heat. Therefore, the reaction is exothermic.

[2 marks]
1 mark for stating that the reverse reaction is favoured.
1 mark for deducing that the reaction is exothermic.

QUESTION 22 (6 marks)

Methods 1 and 2 produce CO_2 gas, which is a greenhouse gas and harmful to the environment. Method 1 uses hydrocarbons, which are derived from fossil fuels and so are non-renewable. Method 3 does not produce any greenhouse gases, only H_2 gas and O_2 gas, and is not derived from fossil fuels.

The atom economies of each method are as shown.

Method 1:

$$\begin{aligned}\text{atom economy} &= \frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times 100 \\ &= \frac{12 \times (2 \times 1.01)}{\big((6 \times 12.01) + (10 \times 1.01) + (5 \times 16.00)\big) + \big(7(2 \times 1.01) + (7 \times 16.00)\big)} \times 100 \\ &= \frac{24.24}{288.3} \times 100 \\ &= 8.4\%\end{aligned}$$

Method 2:

$$\begin{aligned}\text{atom economy} &= \frac{2 \times 1.01}{(12.01 + 16.00) + \big((2 \times 1.01) + 16.00\big)} \times 100 \\ &= \frac{2.02}{46.03} \times 100 \\ &= 4.4\%\end{aligned}$$

Method 3:

$$\begin{aligned}\text{atom economy} &= \frac{2 \times 1.01}{(4 \times 1.01) + (2 \times 16.00)} \times 100 \\ &= \frac{2.02}{36.04} \times 100 \\ &= 5.6\%\end{aligned}$$

The three methods are similar in terms of atom economy, 8.4%, 4.4% and 5.6%.

Therefore, method 3 is the greenest in terms of both green principles (it does not produce greenhouse gases and is not derived from fossil fuels) and atom economy (it has the second highest atom economy out of the three methods).

[6 marks]

1 mark for identifying whether each method does or does not produce greenhouse gases.
1 mark for identifying that method 1 uses a non-renewable reactant.
1 mark for calculating the atom economy of method 1.
1 mark for calculating the atom economy of method 2.
1 mark for calculating the atom economy of method 3.
1 mark for determining that method 3 is the greenest.

QUESTION 23 (4 marks)

a) 4-methylpentanamide

[1 mark]
1 mark for deducing the IUPAC name.

b)

Molecule A	Molecule B	Molecule C
amide	amine	nitrile

[1 mark]
1 mark for stating all three classes.

c) Molecules A and B would form hydrogen bonds. This is because they contain a nitrogen atom bonded to a hydrogen atom; the hydrogen atoms can form bonds with nitrogen, oxygen or fluorine atoms in other molecules.

[2 marks]
1 mark for identifying molecules A and B.
1 mark for explaining reasoning.

QUESTION 24 (5 marks)

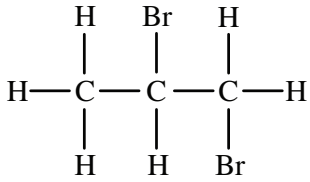
a) **The production of dibromopropane from 1-bromopropane:** substitution

The production of 1-propene from dibromopropane: elimination

The production of dibromopropane from 1-propene: addition

[3 marks]
1 mark for identifying each reaction type.

b)



IUPAC name: 1,2-dibromopropane

[2 marks]
1 mark for drawing the structural formula.
1 mark for deducing the IUPAC name.

QUESTION 25 (4 marks)

The equation shows a 1 : 1 : 1 ratio of 1-pentanol to ethanoic acid to pentyl ethanoate.

Calculating the amount of 1-pentanol reacted gives:

$$\begin{aligned} n(\text{1-pentanol}) &= \frac{m}{M} \\ &= \frac{4.89}{(5\times 12.01)+(12\times 1.01)+16.00} \\ &= \frac{4.89}{88.17} \\ &= 0.0555 \text{ mol} \end{aligned}$$

Calculating the amount of ethanoic acid reacted gives:

$$\begin{aligned} n(\text{ethanoic acid}) &= \frac{2.57}{(2\times 12.01)+(4\times 1.01)+(2\times 16.00)} \\ &= \frac{2.57}{60.06} \\ &= 0.0428 \text{ mol} \end{aligned}$$

Therefore, 0.0428 mol of pentyl ethanoate would be produced.

Calculating the molar mass of pentyl ethanoate gives:

$$\begin{aligned} M(\text{pentyl ethanoate}) &= (7\times 12.01)+(14\times 1.01)+(2\times 16.00) \\ &= 84.07+14.14+32.00 \\ &= 130.21 \text{ g mol}^{-1} \end{aligned}$$

Calculating the mass of pentyl ethanoate gives:

$$\begin{aligned} m(\text{pentyl ethanoate}) &= M\times n \\ &= 130.21\times 0.0428 \\ &= 5.57 \text{ g} \end{aligned}$$

[4 marks]

1 mark for identifying the 1:1:1 ratio. Note: This may be implied by subsequent working.

1 mark for calculating the amount of 1- pentanol reacted.

1 mark for calculating the amount of ethanoic acid reacted and determining that this is the amount of pentyl ethanoate produced. Note: This may be implied by subsequent working.

1 mark for calculating the mass of pentyl ethanoate produced.

QUESTION 26 (4 marks)

Calculating the amount of sodium hydroxide (NaOH) gives:

$$n(\text{NaOH}) = \frac{m}{M} = \frac{2.00}{40.00} = 0.0500 \text{ mol}$$

$\text{NaOH(aq)} \rightarrow \text{Na}^+\text{(aq)} + \text{OH}^-\text{(aq)}$

NaOH will dissociate completely; therefore, $n(\text{NaOH}) = n(\text{OH}^-) = 0.0500$ mol.

Calculating the concentration of the solution gives:

$$c(\text{NaOH}) = \frac{n}{V} = \frac{0.0500}{0.500} = 0.100 \text{ mol L}^{-1}$$

Determining $\left[\text{H}_3\text{O}^+\right]$ to calculate the pH gives:

$$K_\text{w} = \left[\text{H}_3\text{O}^+\right]\left[\text{OH}^-\right] = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$$

$$\left[\text{H}_3\text{O}^+\right] = \frac{K_w}{\left[\text{OH}^-\right]}$$

$$= \frac{1.00 \times 10^{-14}}{0.100}$$

$$= 1.00 \times 10^{-13}$$

$$\text{pH} = -\log_{10}\left[\text{H}_3\text{O}^+\right]$$

$$= -\log_{10} 1.00 \times 10^{-13}$$

$$= 13.00$$

[4 marks]

1 mark for calculating the amount of NaOH in the solution and determining that the amount of NaOH is equal to the amount of OH^-.

1 mark for calculating the concentration of the solution.

1 mark for calculating $\left[H_3O^+\right]$.

1 mark for calculating the pH of the solution.

QUESTION 27 (4 marks)

a) An amphiprotic species can donate or accept protons depending on what it is reacting with; it can behave as an acid or a base.

[1 mark]

1 mark for defining the term.

b) When the phosphate ion (PO_4^{3-}) acts as a base, it accepts a proton that is donated from a water molecule. Therefore, the water molecule acts as an acid. The half-equations are as follows.

$PO_4^{3-}(aq) + H^+(aq) \rightarrow HPO_4^{2-}(aq)$

$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$

Therefore, the reaction occurs according to the equation shown.

$PO_4^{3-}(aq) + H_2O(l) \rightarrow HPO_4^{2-}(aq) + OH^-(aq)$

[3 marks]

1 mark for explaining how PO_4^{3-} acts as a base and providing the balanced half-equation.

1 mark for explaining how water acts as an acid and providing the balanced half-equation.

1 mark for providing the balanced equation.