Neap

Trial Examination 2021

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.	○	○	○	●

	A	B	C	D
16.	○	○	●	○
17.	○	●	○	○
18.	○	●	○	○
19.	●	○	○	○
20.	○	●	○	○
21.	○	○	●	○
22.	○	○	○	●
23.	○	●	○	○
24.	●	○	○	○
25.	○	○	●	○

QUESTION 1 B

B is correct. The amide functional group is $CONH_2$. **A** is incorrect. This option shows an amine. **C** is incorrect. The molecule has ether and amine functional groups. **D** is incorrect. This option shows a nitrile.

QUESTION 2 D

D is correct. A solution of pH 2 is highly acidic and has a high concentration of H^+ ions. Adding H^+ ions to the indicator equilibrium reaction shown will shift the equilibrium position to the left as the system moves to restore equilibrium. The acid form of the indicator, HG, is yellow, so the solution will turn yellow.

QUESTION 3 D

D is correct. $K_w = [H_3O^+] \times [OH^-] = (1.71 \times 10^{-7})^2 = 2.92 \times 10^{-14}$ M^2. **A** and **B** are incorrect. Pure water is neutral, and $[H_3O^+] = [OH^-]$ at all temperatures. **C** is incorrect. The concentration of ions at 40°C is $2 \times 1.71 \times 10^{-7}$ M. This is greater than the value at 25°C, $2 \times 1.00 \times 10^{-7}$ M.

QUESTION 4 A

A is correct. The oxidation number for sulfur is –2. **B** is incorrect. The oxidation number for sulfur is +4. **C** is incorrect. The oxidation number for sulfur is +6. **D** is incorrect. The oxidation number for sulfur is +4.

QUESTION 5 B

B is correct. Reduction is the gain of electrons and oxidation is the loss of electrons. The relevant half-equation is $S(s) + 2e^- \rightarrow S^{2-}(s)$. There is a gain of electrons, so sulfur is reduced.

QUESTION 6 A

A is an incorrect statement about the section of the protein and so is the required response. The peptide link is CONH. The circled link does not contain a nitrogen atom. **B** is a correct statement. The serine side group is CH_2OH. **C** is a correct statement. The cysteine side group CH_2SH is present and could form disulfide links. **D** is a correct statement. The H* in a peptide link could form hydrogen bonds with an oxygen atom in another peptide link along the chain as part of the secondary structure.

QUESTION 7 D

D is an incorrect statement and so is the required response. In a fuel cell, as in a galvanic cell, reduction occurs at the positively charged cathode. **A**, **B** and **C** are all features of fuel cells.

QUESTION 8 A

A is correct, and **C** and **D** are incorrect. The final pH value is 12, suggesting a strong base. The initial pH is 5, suggesting a weak acid. The pH at equivalence is greater than 7, due to the presence of a weak base (the conjugate of the weak acid used in the titration). This is a weak acid with strong base titration. **B** is incorrect. The graph does not show the form of a weak acid with weak base titration as it has a clear equivalence point.

QUESTION 9 C

C is correct. Homologous series show increasing boiling points with increasing molecular size due to increasing strength of intermolecular dispersion forces. **A** is incorrect. The aldehyde functional group is CHO. **B** is incorrect. Homologous series members differ by a $-CH_2$ group. **D** is incorrect. Primary, secondary and tertiary isomers apply to alcohols and amines, not aldehydes. In the aldehyde there can only be one carbon atom bonded to the carbon atom of the CHO group.

QUESTION 10 C

C is correct, and **B** and **D** are incorrect. At 25°C the solution is neutral when $[H_3O^+] = [OH^-] = 1.00 \times 10^{-7}$ M. For an acidic solution, $[H_3O^+] > 1.00 \times 10^{-7}$ M and $[OH^-] < 1.00 \times 10^{-7}$ M. **A** is incorrect. In an aqueous solution, $[H_2O]$ is approximately 56 M, so $[H_2O] > [H_3O^+]$.

QUESTION 11 B

B is correct. All amino acids are amphiprotic due to their acidic COOH and basic NH_2 groups. The diprotic amino acids are those with an acidic side group, such as aspartic acid. **A**, **C** and **D** are incorrect. Alanine, arginine and asparagine do not have acidic side groups.

QUESTION 12 A

A is correct. Metal X reacts with Q^{2+}, hence metal X is a stronger reducing agent than metal Q. Metal P reacts with X^{2+}, hence metal P is a stronger reducing agent than X. Reducing agent strength is therefore P > X > Q.

QUESTION 13 C

C is correct. Having the same molecular formula requires the same number of carbon atoms per molecule, and both molecules have the molecular formula, C_4H_9Cl, with their atoms arranged differently. **A** is incorrect. The compounds differ in their molecular formulas, $C_4H_{11}N$ and C_4H_7N. **B** is incorrect. The compounds differ in their molecular formulas, $C_6H_{14}O$ and $C_5H_{10}O$. **D** is incorrect. The compounds differ in their number of hydrogen atoms.

QUESTION 14 D

D is correct. The negatively charged sulfate ion will be attracted to the positively charged electrode – the anode in an electrolytic cell. The strongest reducing agent present will be oxidised. In this cell, water is the strongest reducing agent and so it will react. The sulfate ion will not be oxidised. Reduction occurs at the negatively charged cathode.

QUESTION 15 D

D is correct. This option gives the definition of a secondary alcohol. **A** and **B** are incorrect. The three alcohols are isomers and so have the same empirical and molecular formulas. **C** is incorrect. Secondary alcohols are oxidised to ketones, not aldehydes.

QUESTION 16 C

C is correct. Cations in a galvanic cell salt bridge move towards the cathode half-cell to restore the charge balance. In the electrolytic cell, cations are attracted to the negatively charged cathode. **A** is incorrect. The cathode is negatively charged in an electrolytic cell, and positively charged in a galvanic cell. **B** is incorrect. Oxidation occurs at the anode in both cells. **D** is incorrect. Conversion of electrical to chemical energy occurs in electrolytic cells, not galvanic cells.

QUESTION 17 B

B is correct. Potassium will be produced by the reduction of the potassium ion at the negatively charged cathode in an electrolytic cell, provided that the potassium ion is the strongest oxidising agent present. This will be the case when using a molten potassium salt. When an aqueous potassium salt is used, water is the strongest oxidising agent present and so is preferentially discharged at the cathode. Potassium will not be produced in this cell.

QUESTION 18 B

$[A^-] = [H_3O^+] = 10^{-pH} = 10^{-2.92}$

[HA] at equilibrium is close to [HA] initially for a weak acid.

$$K_a = \frac{[H_3O^+] \times [A^-]}{[HA]} = \frac{(10^{-2.92})^2}{0.200} = 7.23 \times 10^{-6}$$

QUESTION 19 A

A is correct. Hydrocarbons are non-polar with dispersion forces only between the molecules. These weak forces lead to relatively low melting points. Non-polar substances are generally soluble in non-polar solvents.

QUESTION 20 B

B is correct. This oxidation reaction requires an oxidising agent like acidified dichromate solution. **A** is incorrect. This option shows the reagent for a substitution reaction. **C** is incorrect. This option shows the reagents for an esterification reaction. **D** is incorrect. This option shows the reagent for an addition reaction.

QUESTION 21 C

C is correct. The extensive hydrogen bonding between molecules forms a strong, brick wall-like structure. **A** is incorrect. Cellulose polymer molecules are linear, not branched. **B** is incorrect. Links between cellulose polymers are by hydrogen bonds between OH groups, not covalent cross-links. **D** is incorrect. The covalent glycosidic links between glucose units are the same strength for different polysaccharide molecules.

QUESTION 22 D

D is correct, and **A** and **C** are incorrect. The glutamine $CH_2CH_2CONH_2$ and serine CH_2OH side groups can have hydrogen bonds between them. Dispersion forces will also be present between these side groups. **B** is incorrect. Dipole–dipole forces between NH_2 and OH groups are called hydrogen bonding. In addition, dispersion forces must also be present.

QUESTION 23 B

B is correct and **A** and **D** are incorrect. Reduction of Br_2 requires a reducing agent that has a lower E° value than the Br^- ion (that is, a stronger reducing agent than the Br^- ion). Cu and Fe^{2+} are possible reducing agents here, while Cl^- is not. Cu is a stronger reducing agent than I^-, and so will reduce I_2. Fe^{2+} sits between Br^- and I^- in reducing agent strength on the electrochemical series and so is the required response. **C** is incorrect. Ag^+ is an oxidising agent and so will not reduce Br_2 nor I_2.

QUESTION 24 A

A is correct and **B** is incorrect. The reaction occurring is $2Ag^+(aq) + Zn(s) \rightarrow 2Ag(s) + Zn^{2+}(aq)$ as Ag^+ is the stronger oxidising agent present. Electrons move from the reducing agent, Zn, to the oxidising agent, Ag^+. Reduction of the Ag^+ ion occurs at the positively charged Ag cathode. **C** and **D** are incorrect. No power supply is present to force a non-spontaneous reaction to occur.

QUESTION 25 C

C is correct and **A** is incorrect. CH_2CH_2 contains a C=C and so will undergo addition reactions, not substitution. **B** is incorrect. The carbon atom oxidation numbers are –2 in CH_2CH_2 and –2 in CH_3CH_2OH. This is not a redox reaction as there is no change in oxidation numbers. **D** is incorrect. Condensation results in the removal of H_2O, not the addition of H_2O.

SECTION 2

QUESTION 26 (4 marks)

a) Copper is deposited by reduction at the cathode. At the other electrode, the strongest reducing agent(water) will be oxidised.

$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ *[1 mark]*

Production of the H^+ ion at the electrode lowers the pH as the solution near the electrode becomes acidic. *[1 mark]*

b) The strongest oxidising agent will be reduced at the cathode. In an aqueous solution containing Mg^{2+} this will be water, not the Mg^{2+} ion, as water has the higher reduction potential/E° value. *[1 mark]*

Water will be preferentially reduced to form H_2 and OH^- ions. No magnesium will be deposited. *[1 mark]*

QUESTION 27 (4 marks)

a) negative (*electrons are generated here by the oxidation of the Al*) *[1 mark]*

b) $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ *[1 mark]*

c) i) *For example, one of:*

- It has a continuous supply of a gaseous oxidising agent, O_2.
- It has a porous electrode.

[1 mark]

ii) *For example, one of:*

- The 'fuel' is not continuously supplied but is a metal electrode.
- The electrodes do not have a catalytic function.

[1 mark]

QUESTION 28 (6 marks)

a)

	$4NH_3$	+	**$5O_2$**	$\rightleftharpoons$	**$4NO$**	+	**$6H_2O$**
***n* initially**	0.300 mol		0.400 mol		0 mol		0 mol
Change	$\frac{-4}{4} \times 0.200$		$\frac{-5}{4} \times 0.200$		+0.200		$\frac{+6}{4} \times 0.200$
***n* equilibrium**	**0.100 mol**		**0.150 mol**		0.200 mol		**0.300 mol**

[3 marks]

1 mark for each of the bolded amounts in the fourth row of the table.

b) By Le Châtelier's principle, when an increase in pressure occurs the system will shift to reduce the pressure. *[1 mark]*

This will be a shift to the side of the reaction with the lower number of moles of gas, and so the lower pressure. *[1 mark]*

For this reaction, 9 moles of reactant gases produce 10 moles of product gases, so equilibrium will shift to the reactant side/to the left of the balanced equation shown in the question. *[1 mark]*

QUESTION 29 (4 marks)

a) i) plant material *[1 mark]*

ii) hydrolysis *[1 mark]*

b) *For example, any two of:*

- Enzymes are biological catalysts, increasing reaction rates without themselves being consumed.
- Enzymes are highly specific, with each type only catalysing one type of reaction.
- Enzymes only function in narrow ranges of temperature and pH.
- Enzyme activity depends on the tertiary structure of the protein comprising the enzyme.

[2 marks]

QUESTION 30 (4 marks)

$CH_3CH_2CH_2Br \xrightarrow{KCN} CH_3CH_2CH_2CN$ *[2 marks]*

1 mark for the reagent.
1 mark for the semi-structural formula for nitrile.

$CH_3CH_2CH_2CN \xrightarrow{H_2/Ni} CH_3CH_2CH_2CH_2NH_2$ *[2 marks]*

1 mark for the reagent.
1 mark for the semi-structural formula for amine.

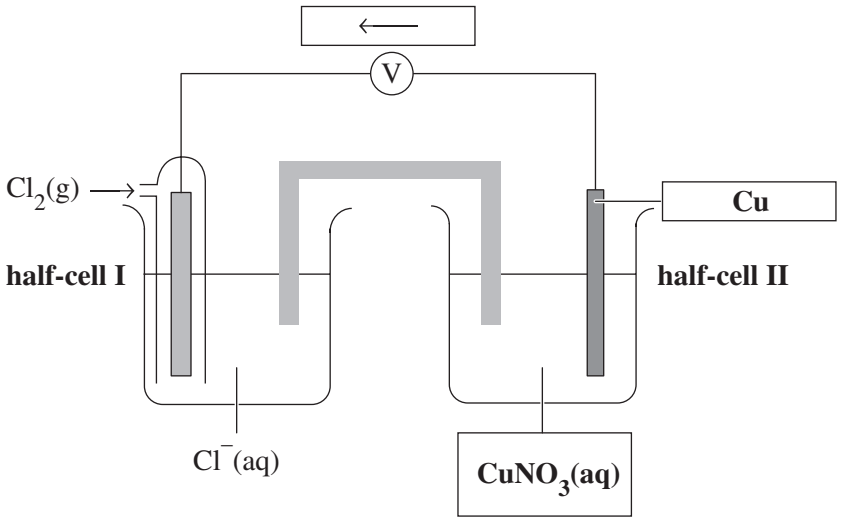
QUESTION 31 (5 marks)

a) E°(chlorine half-cell) = +1.36 V

cell voltage required = 0.84 V

E°(other half-cell) = +1.36 – 0.84 = +0.52 V *(This is the Cu^+/Cu half-cell.)* *[1 mark]*

b)



[3 marks]
1 mark for each correct label.

c) *Any one of the following:*

- It must contain ions that are free to move.
- The ions must not react with the contents of either half-cell.

[1 mark]

QUESTION 32 (4 marks)

The molar mass is 58. Hence, the molecular formula is C_4H_{10}. *[1 mark]*

Two possible structures are $CH_3CH_2CH_2CH_3$ and $(CH_3)_3CH$. *[1 mark]*

$CH_3CH_2CH_2CH_3$ would likely produce fragments of $CH_3CH_2^+$ with molar mass 29, and $CH_3CH_2CH_2^+$ with molar mass 43. $(CH_3)_3CH$ would produce likely fragments of $(CH_3)_2CH^+$ with molar mass 43, and $(CH_3)_3C^+$ with molar mass 57. It would be unlikely to produce a fragment with molar mass 29. *[1 mark]*

The spectrum shows a clear fragment at molar mass 29 and so is most likely to be the spectrum of butane, $CH_3CH_2CH_2CH_3$. *[1 mark]*

QUESTION 33 (4 marks)

The valine molecule is amphiprotic and will act as an acid or a base depending on its surroundings. Its isoelectric point is 6.0. *[1 mark]*

At a high pH, the valine molecule will act as an acid, donating a proton to form the anion with a COO^- group. *[1 mark]*

At a low pH, the valine molecule will act as a base, accepting a proton to form the cation with an NH_3^+ group. *[1 mark]*

COO^- ions will be attracted to the positively charged anode, while the NH_3^+ ions will be attracted to the negatively charged cathode. *[1 mark]*

