Neap

Trial Examination 2022

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 D

The first change is a temperature increase. The reaction is exothermic. An increase in temperature causes all the molecules to move faster and favours the reverse endothermic reaction. Therefore, this results in more reactants being produced; this is observed in the increase in nitrogen monoxide (NO) and oxygen (O_2). Equilibrium is re-established, then the second change is a decrease in the partial pressure of NO. This results from an increase in volume of NO. The effect is a shift in the direction where a greater number of particles are produced (to the left/the reverse reaction). Therefore, more NO and O_2 is produced, and less NO_2 is produced as it is reacted.

QUESTION 2 C

$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$ for the reaction aA + bB $\rightleftharpoons$ cD + dD. Therefore, $K_c = \frac{[CO_2(g)][H_2(g)]}{[CO(g)][H_2O(g)]}$.

QUESTION 3 C

C is correct. Using the table, it can be determined that the indicator colours match the hydrogen ion concentration of 10^{-10}; this corresponds to a pH of 10, which is weakly basic.

A and **B** are incorrect. A solution with a pH of 6 would be weakly acidic, and the indicator colours would be colourless (phenolphthalein), yellow (methyl red) and red (phenol red).

D is incorrect. A solution with a pH of 10 is weakly basic.

QUESTION 4 A

A is correct. The equivalence point is midway in the steepest section of the curve. The curve is steep from pH 7 to 2.5, so midway is 5.2.

B is incorrect. This pH value is at the start of the steepest section of the curve.

C and **D** are incorrect. These pH values are at the first flat section of the curve.

QUESTION 5 A

A is correct. The R group determines the nature of an amino acid. Polar neutral amino acids contain an –OH, S or amide in the R group. Acidic amino acids contain an acid group in the R group. Basic amino acids contain an amide in the R group. Only polar neutral amino acids will form hydrogen bonds.

B is incorrect. Non-polar amino acids interact through hydrophobic interactions.

C is incorrect. Polar acidic and basic amino acids interact through ionic bonds, called a salt bridge.

D is incorrect. A disulfide bridge is formed through the bonding of sulfur atoms in the amino acid cysteine.

QUESTION 6 C

In a neutral compound, the oxidation numbers add up to zero. Oxygen has an oxidation number of –2, and hydrogen has an oxidation number of +1. Therefore, $(2 \times +1) + S + (4 \times -2) = 0$, meaning that the oxidation number of sulfur in H_2SO_4 is +6.

QUESTION 7 B

B is correct. As an acid, the $H_2PO_4^-$ ion donates a proton (hydrogen ion) to form HPO_4^{2-} (the conjugate base).

A, **C** and **D** are incorrect. These options do not show the correct donation of one proton.

QUESTION 8 B

The boiling point of octan-1-ol is 195°C and the boiling point of propanol is 97°C; octan-1-ol has the higher boiling point. The presence of the –OH functional groups causes hydrogen bonding to occur between adjacent molecules. Both molecules have an –OH group. Octan-1-ol has eight carbons and propanol has three carbons, so octanol is the longer molecule. The contact surface between adjacent molecules is greater in octan-1-ol compared to propanol, meaning that the dispersion forces increase and, therefore, the boiling point increases.

QUESTION 9 B

B is correct. Glucose exists as three isomers: α, β and a straight chain form.

A is incorrect. Glucose is a monosaccharide.

C is incorrect. Glucose has the empirical formula CH_2O.

D is incorrect. Glucose is soluble in water as it is a polar molecule (and water is also polar).

QUESTION 10 D

D is correct. The reaction with the highest K_c value will have more products than reactants. Therefore, [LHS] < [RHS].

A is incorrect. The K_c value of this reaction is very low, meaning the reaction may shift to the left instead of the right.

B and **C** are incorrect. The K_c values of these reactions are high but not as high as option **D**, so their equilibriums will not lie furthest to the right.

QUESTION 11 D

Propan-1-ol is the only molecule that can form hydrogen bonds (the strongest intermolecular bonds), so it has the highest boiling point. Propanone can form dipole–dipole interactions between molecules. Dipole–dipole interactions are not as strong as hydrogen bonds but are stronger than dispersion forces, so propanone has the second highest boiling point. Propane and ethane are both non-polar, so they only have dispersion forces between their molecules. As ethane is a smaller molecule than propane, it will have fewer dispersion forces and a lower boiling point than propane and so have the lowest boiling point overall.

QUESTION 12 D

D is correct. The permanganate ion (MnO_4^-) is the oxidising agent. The oxidation number of manganese has changed from +7 to +2, indicating that MnO_4^- is acting as an oxidising agent.

A is incorrect. As manganese has been reduced, it is an oxidising agent and cannot be a reducing agent.

B is incorrect. Arsenic has been oxidised as the oxidation number changes from –3 to +5. Therefore, it is a reducing agent and cannot be an oxidising agent.

C is incorrect. Oxygen has not undergone oxidation or reduction; its oxidation number is –2 on both sides of the equation.

QUESTION 13 C

C is correct. The molecule has four carbon atoms and the functional group is the carboxyl group COOH, so the molecule is butanoic acid.

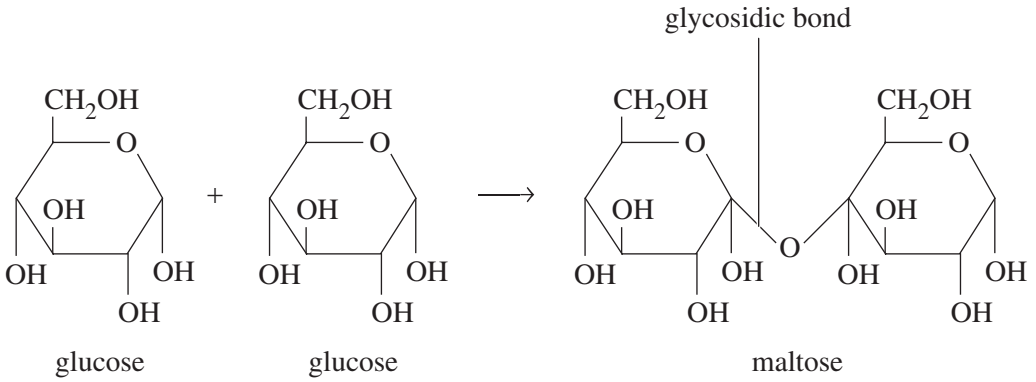
A is incorrect. For the molecule to be an alcohol, the functional group would need to be the hydroxyl group OH.

B is incorrect. Propanol has three carbon atoms and an OH group.

D is incorrect. Ethanoic acid has two carbons.

QUESTION 14 C

C is correct. The following diagram shows the glycosidic bond formed between glucose units. Water is a product of the reaction.



glucose glucose maltose

A is incorrect. Addition polymers can only be formed if the monomers contain a double bond (that is, they are unsaturated).

B is incorrect. Condensation monomers can contain more than one functional group. They join by functional groups in the monomers each losing a molecule to form a smaller molecule, usually water.

D is incorrect. Amino acids undergo condensation polymerisation to form polymers.

QUESTION 15 C

C is correct. Cl_2 is more readily reduced than Zn^{2+}, thus zinc is oxidised and electrons flow from the zinc electrode to the platinum electrode.

A is incorrect. Reduction occurs at the platinum electrode.

B is incorrect. The platinum electrode will not become thinner.

D is incorrect. The sodium ions migrate to the half-cell on the left and the nitrate ions migrate to the half-cell on the right.

QUESTION 16 D

D is correct. Ethanol is a primary alcohol. It can undergo an oxidation reaction to become ethanoic acid using acidified dichromate ($Cr_2O_7^{2-}$) as a catalyst and heat.

A and **C** are incorrect. The required reaction is oxidation not reduction.

B is incorrect. The catalyst is acidified dichromate ($Cr_2O_7^{2-}$).

QUESTION 17 B

B is correct. The oxidation numbers of magnesium (Mg) and hydrogen (H) change from 0 to +2 and from +1 to 0, respectively.

A and **D** are incorrect. These options are precipitation reactions with no change in oxidation numbers.

C is incorrect. This option is an acid–base reaction with no change in oxidation numbers.

QUESTION 18 B

B is correct. To change an alkene into an alkane, hydrogen atoms need to be added to remove the double bond between the carbon atoms in the alkene, thus producing an alkane with single bonds only. This is reduction.

A is incorrect. A substitution reaction with HCl would remove a hydrogen atom from the alkene and replace it with a chlorine atom. This would not remove the double bond in the alkene.

C is incorrect. An oxidation reaction would not remove the double bond in the alkene. The addition of hydrogen atoms is required, which is reduction.

D is incorrect. Condensation refers to a reaction where water is a product. A condensation reaction would not affect the double bond in the alkene.

QUESTION 19 A

The zinc electrode is the negative electrode (anode) and the copper electrode is the positive electrode (cathode). The positive potassium ions (K^+) flow to the copper electrode where the electrons are flowing into.

QUESTION 20 C

C is correct. From the diagram, it can be seen that the chains in high-density polyethene (HDPE) are not highly branched, meaning that the chains can pack closely together.

A is incorrect. In low-density polyethene (LDPE), the chains are highly branched; this prevents the chains from packing closely together.

B is incorrect. LDPE is softer and more flexible than HDPE.

D is incorrect. In HDPE (not LDPE), the chains can pack closely together to form a rigid, highly crystalline material.

QUESTION 21 B

The products of the electrolysis of molten sodium chloride are sodium at the cathode and chlorine gas at the anode. The products of the electrolysis of a dilute aqueous solution of sodium chloride are oxygen gas at the anode and hydrogen gas at the cathode. Water is a better oxidant than sodium ions (Na^+) and a better reductant than chloride ions (Cl^-), so will undergo electrolysis at both electrodes. Chlorine gas can only be produced when the aqueous sodium chloride is very concentrated.

QUESTION 22 B

B is correct. Carbonic acid is diprotic, so it can donate two protons (hydrogen ions). This means that 2 mol of hydroxide ions would be required to reach the neutralisation point.

A, **C** and **D** are incorrect. These acids are monoprotic, meaning they can donate one proton only and 1 mol of hydroxide ions would be required to reach the neutralisation points.

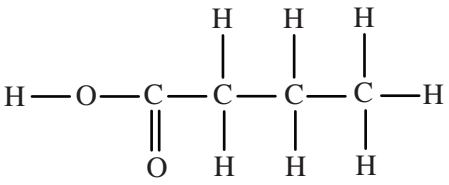
QUESTION 23 B

Zn, Mg and Mn will all react as these metals appear above Cu in the electrochemical series. Mg^{2+} is the strongest reducing agent, so the reaction in beaker Y will be the fastest. This will be followed by beaker Z (Mn^{2+}) and beaker W (Zn^{2+}). Beaker X will show no reaction as it contains Cu^{2+} and Cu; no visible interchange of electrons will be observed.

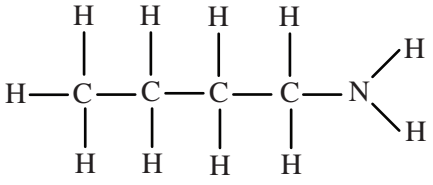
QUESTION 24 A

A is correct. Butanamide has the chemical formula C_4H_9NO.

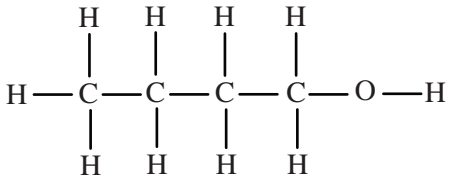
B, **C** and **D** are incorrect. The structural formulas of these molecules are shown.



butanoic acid



butylamine



butanol

QUESTION 25 C

C is correct. Biodiesel has a higher viscosity than petrodiesel and so does not flow as easily.

A is incorrect. As biodiesel has polar bonds, it has a greater tendency than petrodiesel to absorb water.

B is incorrect. Petrodiesel contains smaller, non-polar molecules than biodiesel, resulting in a lower viscosity than that of biodiesel.

D is incorrect. Biodiesel produces slightly less energy per litre of fuel than petrodiesel.

SECTION 2

QUESTION 26 (2 marks)

a) The catalyst will have no effect on the equilibrium yield.

[1 mark]
1 mark for predicting no effect.

b) The catalyst will increase the rate of reaction.

[1 mark]
1 mark for predicting an increase in rate of reaction.

QUESTION 27 (3 marks)

a) When the solution containing Fe^{3+} ions is added, the equilibrium shifts to the right to use up the Fe^{3+} ions, producing more $FeSCN^{2+}$ ions; this makes the colour of the resulting solution darker.

[1 mark]
1 mark for explaining the colour change.

b) According to Le Châtelier's principle, when there is an increase in temperature, a system will shift to remove that heat. In this reaction, when the temperature is increased, there is a shift to the left towards the reactants, indicated by the change in colour to yellow. This means that the reaction releases heat; therefore, it is exothermic.

[2 marks]
1 mark for explaining the colour change.
1 mark for deducing that the reaction is exothermic.

QUESTION 28 (5 marks)

Reaction 1:

$$2NH_3(g) + NaOCl(g) \rightarrow N_2H_4(g) + NaCl(aq) + H_2O(l)$$

molar masses: 34.08 + 74.44 $\rightarrow$ 32.06 + 58.44 + 18.02

$$\text{atom economy} = \frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times 100$$

$$= \frac{32.06}{34.08 + 74.44} \times 100$$

$$= \frac{32.06}{108.52} \times 100$$

$$= 29.54\%$$

Reaction 2:

$$ClNH_2(g) + \text{excess } 2NH_3(g) \rightarrow N_2H_4(g) + NH_4Cl(aq)$$

molar masses: 51.48 + 34.08 $\rightarrow$ 32.06 + 53.5

$$\text{atom economy} = \frac{32.06}{51.48 \times 34.08} \times 100$$

$$= \frac{32.08}{85.56} \times 100$$

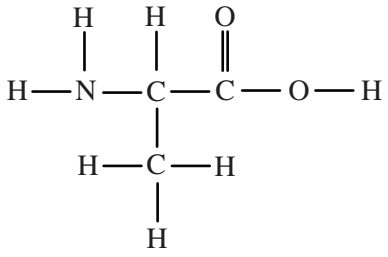
$$= 37.49\%$$

Therefore, reaction 2 has better atom economy and is more efficient.

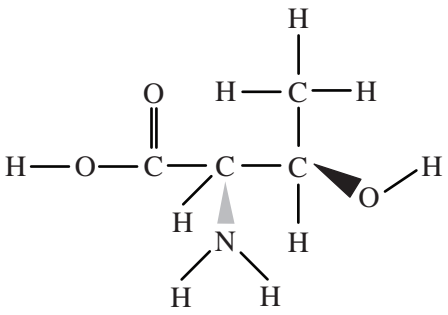
[5 marks]
1 mark for showing working to determine the atom economy of reaction 1.
1 mark for determining the atom economy of reaction 1.
1 mark for showing working to determine the atom economy of reaction 2.
1 mark for determining the atom economy of reaction 2.
1 mark for stating that reaction 2 is more efficient.

QUESTION 29 (4 marks)

a) alanine and threonine



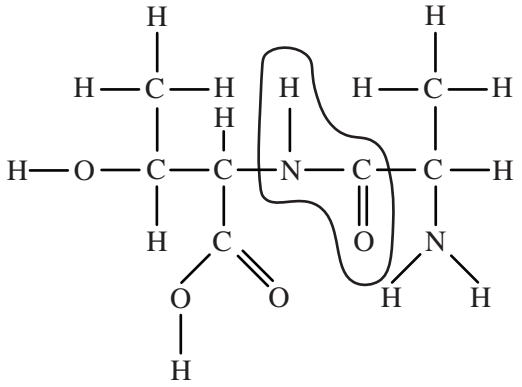
alanine



threonine

[2 marks]
1 mark for identifying alanine.
1 mark for identifying threonine.
Note: Diagrams are not required to obtain full marks.

b)



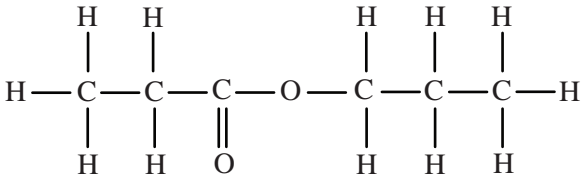
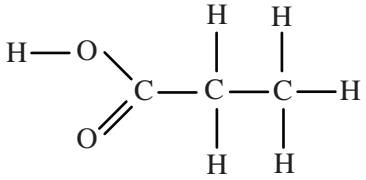
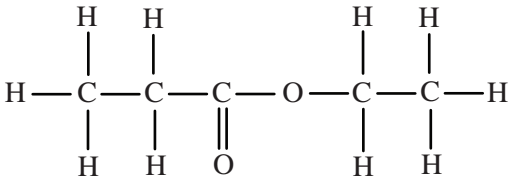
[1 mark]
1 mark for circling the peptide bond.

c) As this amino acid molecule has two acid functional groups, it can donate two protons (hydrogen ions) and form a 2– anion.

[1 mark]
1 mark for determining that the molecule has two functional groups that donate hydrogen atoms.

QUESTION 30 (7 marks)

a)

Compound	Structural formula
A	
C	
D	

[3 marks]
1 mark for each correct structural formula.

b) **Reaction that produces compound B:** Reverse of esterification **OR** hydrolysis – this reaction type involves the addition of water to an ester to form an acid and an alcohol

Reaction that produces compound D: Esterification – this reaction type involves the combining of an acid and an alcohol to form an ester.

[2 marks]
1 mark for identifying both types of reaction
1 mark for describing each type of reaction.

c) Compound B is propanol and compound C is propanoic acid. Both alcohols and carboxylic acids have hydrogen bonds. However, propanoic acid molecules can form dimers, which have double the mass of the single acid molecules. This results in stronger dispersion forces between the dimers and their neighbours. The combination of stronger dispersion forces and hydrogen bonds requires more energy to break the bonds, resulting in propanoic acid having a higher boiling point.

[2 marks]
1 mark for identifying both compounds and that they have hydrogen bonds.
1 mark for explaining why compound C has the higher boiling point.

QUESTION 31 (4 marks)

a) The yield will be higher, and the value of the equilibrium constant (K_c) will increase. The reaction is exothermic, so lowering the temperature will cause the reaction to shift to the right to replace the heat lost, producing more D(g). The value of K_c depends on the amount of reactants and products, so the value will increase as a result of the amount of product increasing.

[2 marks]
1 mark for predicting a higher yield and increased K_c.
1 mark for explaining why the yield will be higher and why K_c will increase.

b) The yield will be higher, and the value of K_c will remain changed. Increasing the pressure will cause the reaction to shift to the right (the direction where there are fewer particles) to reduce the pressure, producing more D(g). The value of K_c will remain unchanged as it is temperature specific; only a change in temperature will cause it to change.

[2 marks]
1 mark for predicting a higher yield and no change in K_c.
1 mark for explaining why the yield will be higher and why K_c will remain unchanged.

QUESTION 32 (6 marks)

a) tartaric acid

[1 mark]
1 mark for determining that tartaric acid is the strongest acid.
Note: Tartaric acid has the lowest pK_a value of 2.95.
The lower the pK_a value, the stronger the acid.

b) Malic acid is a diprotic acid, meaning it can donate two protons (hydrogen ions). Therefore, it has a pK_a value that corresponds to each proton donated.

[1 mark]
1 mark for stating that malic acid is diprotic and that the pK_a values relate to the protons that can be donated.

c) Ethanoic acid ionises according to the following equation.

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

At equilibrium, $\left[CH_3COO^-\right] = \left[H_3O^+\right]$.

Ethanoic acid is a weak acid; its pK_a value is much higher than that of the other acids, which are also weak acids. $\left[CH_3COOH\right]$ is assumed to be approximately equal to 0.50 M because the degree of ionisation is very low for a weak acid.

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3COO^-\right]}{\left[CH_3COOH\right]}$$

$$1.75 \times 10^{-5} = \frac{\left[H_3O^+\right]^2}{0.50}$$

$$\left[H_3O^+\right]^2 = 1.75 \times 10^{-5} \times 0.50$$

$$\left[H_3O^+\right] = \sqrt{1.75 \times 10^{-5} \times 0.50}$$

$$= 2.9580 \times 10^{-3}$$

$$pH = -\log\left[H_3O^+\right]$$

$$= -\log 2.9580 \times 10^{-3}$$

$$= 2.5290$$

$$\approx 2.53$$

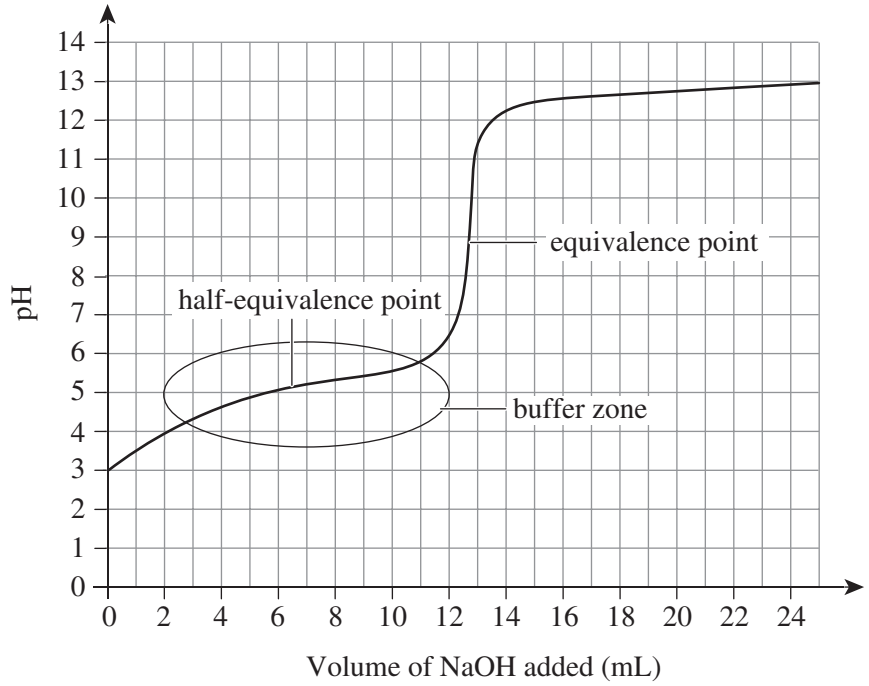
[4 marks]
1 mark for including a balanced equation for the ionisation of ethanoic acid.
1 mark for stating the assumption that the concentration of ethanoic acid is 0.50 M.
1 mark for calculating the concentration of H_3O^+.
1 mark for calculating the pH.

QUESTION 33 (4 marks)

a) pH = 3.0

[1 mark]
1 mark for stating the initial pH as read from the graph.

b)



[3 marks]
1 mark for each correct label.