Neap

Trial Examination 2020

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

An amphiprotic species must be able to donate a proton and accept a proton. Only HSO_4^- satisfies this criterion; it forms SO_4^{2-} when donating a proton or H_2SO_4 when accepting a proton. **B** is correct. H_2SO_4 cannot accept a proton, SO_4^{2-} cannot donate a proton and H_3O^+ cannot accept a proton; **A**, **C** and **D** are incorrect.

QUESTION 2 D

sum of oxidation states = 0 = (2 × +1) + (2 × oxidation state of S) + (7 × –2)

$\therefore$ oxidation state of sulfur in $H_2S_2O_7$ = +6

QUESTION 3 B

In open chemical systems, matter and energy can be exchanged with the surroundings; but in closed chemical systems, matter is trapped and only energy can be exchanged with the surroundings. For example, an open flask containing magnesium and hydrochloric acid will lose both hydrogen gas and heat to the surroundings. If the flask were stoppered, only heat would be lost, and the gas would remain in the closed system.

QUESTION 4 D

The reactants are butanoic acid ($CH_3CH_2CH_2COOH$) and pentan-1-ol ($CH_3CH_2CH_2CH_2CH_2OH$).
The ester formed is pentyl butanoate ($CH_3CH_2CH_2COOCH_2CH_2CH_2CH_2CH_3$).

QUESTION 5 C

This is an exothermic (heat-producing) reaction. According to Le Châtelier's principle, if the temperature of a system at equilibrium is decreased, the system will respond to partially oppose the change by favouring the forward reaction. As a result, some of the heat removed from the system will be restored. As the concentration of products will increase, the value of the equilibrium constant (K_c) will increase. This can be shown in the equilibrium expression – the products are in the numerator and the reactants (which will be the smaller number) are in the denominator.

QUESTION 6 D

$$\%\text{ atom economy} = \frac{(\text{molar mass of desired product} \times 100)}{(\text{sum of molar masses of reactants})} = \frac{(46.08 \times 100)}{64.10} = 71.88\%$$

QUESTION 7 C

In a redox reaction, the oxidation state of a reducing agent will increase as it undergoes oxidation, and the oxidation state of an oxidising agent will decrease as it undergoes reduction. In this example, the oxidation state of chlorine changes from +1 in OCl^- to –1 in Cl^-, so it is the oxidising agent and is reduced in the reaction. The oxidation state of iodine changes from –1 to 0, so I^- is the reducing agent and is oxidised.

QUESTION 8 B

This is an esterification (condensation) reaction in which ester bonds are formed. The carboxyl group in a fatty acid will react with a hydroxyl group in glycerol, producing water as a by-product. So **B** is correct; **A** and **D** are incorrect. Glycosidic bonds are formed when two hydroxyl functional groups react in a condensation reaction. **C** is incorrect.

QUESTION 9 A

All the methyl groups in atactic polypropene are spread non-uniformly around the carbon chain; in isotactic polypropene, the methyl groups are on one side of the molecule. **A** is correct. As a result, the polymer chains of isotactic polypropene can pack together closer, leading to stronger dispersion forces than in atactic polypropene. **B** is incorrect. As its intermolecular forces are stronger, isotactic polypropene melts at a higher temperature than atactic polypropene and is more dense and more rigid. **C** and **D** are incorrect.

QUESTION 10 C

The pairs of chemical species in **A** and **B** do not differ by a H^+, which is the criterion for a conjugate acid–base pair. **C** is correct; **A** and **B** are incorrect. This reaction is both an acid–base reaction and a redox reaction. The oxidation state of H changes from –1 (in H^-) to +1 (in OH^-) and from +1 (in H_2O) to 0 (in H_2). **D** is incorrect.

QUESTION 11 A

Atom economy refers to the number of atoms in reactants that appear in the desired product. When the atom economy is low, many of the reactant atoms are present in products other than the desired product. **A** is correct. The states of the reaction components or the presence of water has no bearing on atom economy. **B**, **C** and **D** are incorrect.

QUESTION 12 D

The product of both reactions is butan-2-ol (using Markovnikov's rule in the case of 1-butene), so **D** is correct. The reaction of an alkene with water is an addition reaction. **A** is incorrect. **B** and **C** are incorrect because the reactions produce the same single product butan-2-ol. This means the reactions' products have the same molecular formula and structure, and belong to the alcohols homologous series.

QUESTION 13 A

The infrared spectrum has a strong signal at 1750 cm^{-1}, which is indicative of the C=O group in ketones. The compound is most likely propanone, so **A** is correct. There are no strong signals that would indicate an alcohol (3200 to 3600 cm^{-1}), carboxylic acid (2500 to 3000 cm^{-1}) or amine (3300 to 3500 cm^{-1}). **B**, **C** and **D** are incorrect.

QUESTION 14 B

Inspection of the polymer structure reveals that the monomer is $H_2C{=}CHCl$. The molar mass of this compound is $(2 \times 1) + (2 \times 12) + 1 + 35.5 = 62.5$ g mol^{-1}.

QUESTION 15 C

The other possible structures are $CH_3CHClCH_2Cl$, $CH_3CCl_2CH_3$ and $ClCH_2CH_2CH_2Cl$.

QUESTION 16 C

After ionisation of the weak acid, $[HNO_2] = 0.10$ M approximately and $[H_3O^+] = [NO_2^-]$.

$K_a \times [HNO_2] = [H_3O^+][NO_2^-] = [H_3O^+]^2$

$[H_3O^+]^2 = 4.0 \times 10^{-4} \times 0.10 = 4.0 \times 10^{-5}$

$[H_3O^+] = 6.3 \times 10^{-3}$ M

$pH = -\log_{10}[H_3O^+] = -\log_{10}10^{-2.19} = 2.2$

QUESTION 17 A

$[NaOH] = [OH^-] = 0.0351 \text{ M} = 10^{-1.45}$ M

$pOH = -\log_{10}[OH^-] = -\log_{10}10^{-1.45} = 1.45$

QUESTION 18 D

The equilibrium law expression is the concentration of the reaction's products raised to their coefficients and multiplied together, divided by the concentration of the reactants raised to their coefficients and multiplied together. Only **D** satisfies this criterion, and so is correct.

QUESTION 19 B

From the graph, $[HCl] = 10^{-1} \text{ M} = 0.10$ M and 40.0 mL of NaOH was needed for neutralisation.

At the equivalence point, $n(HCl) = n(NaOH)$.

$0.10 \times 0.0200 = c(NaOH) \times 0.0400$

$c(NaOH) = 0.050$ M

QUESTION 20 D

Ethanol is a small molecule that forms hydrogen bonds with water. **D** is correct. Solubility is determined not only by the functional groups in a compound but also by the size of the compound molecule and its polarity. **A** is incorrect. Water molecules will form hydrogen bonds with the hydroxyl group in the hexanol molecule but not with the non-polar carbon chain, which is a large part of the hexanol molecule. **B** is incorrect. Like ethanol, methanol is fully soluble in water because it is a small molecule that forms hydrogen bonds with water. **C** is incorrect.

QUESTION 21 C

Even though ethanoic acid has four hydrogen atoms in each molecule, only the hydrogen atom in the carboxyl functional group can be removed as a hydrogen ion. Thus, the acid is classed as monoprotic because it can only donate this hydrogen ion to a base, so **C** is correct. Acids donate one or more protons, not hydrogen atoms, to bases. **A** and **B** are incorrect. **D** is incorrect because it is a factual statement (that ethanoic acid is a weak acid) but does not explain why ethanoic acid is a monoprotic acid.

QUESTION 22 B

Green chemistry principles aim to maximise atom economy by reducing unwanted products in a reaction, so **B** is correct. These principles aim to maximise, not limit, the practices outlined in **A**, **C** and **D**. So **A**, **C** and **D** are incorrect.

QUESTION 23 A

A is correct:

- Ni^{2+} ions are stronger oxidants than the conjugate of Zn – a reaction will occur.
- Ni^{2+} ions are weaker oxidants than the conjugate of Pb – a reaction will not occur.

B is incorrect:

- Ag^{+} ions are weaker oxidants than the conjugate of Cl^{-} ions – a reaction will not occur.
- Ag^{+} ions are stronger oxidants than the conjugate of Cu – a reaction will occur.

C is incorrect:

- Sn^{2+} ions are weaker oxidants than the conjugate of OH^{-} ions – a reaction will not occur.
- Sn^{2+} ions are stronger oxidants than the conjugate of Ca – a reaction will occur.

D is incorrect:

- Mg^{2+} ions are weaker oxidants than the conjugate of Al – a reaction will not occur.
- Mg^{2+} ions are weaker oxidants than the conjugate of Fe – a reaction will not occur.

QUESTION 24 A

Galvanic cells generate electricity by using a spontaneous redox reaction, whereas electricity is used to produce a non-spontaneous redox reaction in an electrolytic cell. **A** is correct. Reduction occurs at the positive cathode in a galvanic cell, so **B** is incorrect. Both electrolytic and galvanic cells allow movement of ions within the electrolyte. **C** is incorrect. The half-cell reactions in a galvanic cell must be separated, but they can also be separated in an electrolytic cell and the cell will still function. **D** is incorrect.

QUESTION 25 D

Predictions of cell voltage in non-standard conditions would not be reliable as the table of standard reduction potentials was formulated under standard conditions. **D** is correct. An oxidising agent is likely to react with a reducing agent if the conjugate of the reducing agent is a weaker oxidising agent. **A** is incorrect. The greater the potential difference of a cell, the more likely the redox reaction will go to completion as the value of the equilibrium constant is also greater. **B** is incorrect. By comparing the $E°$ values of two oxidising agents in reduction half-reactions, the comparative strength of the two species can be accurately determined. **C** is incorrect.

Section 2

QUESTION 26 (3 marks)

As the members of each homologous series increase in relative molecular mass, the amount of intermolecular forces (dispersion forces) increases. *[1 mark]*

More energy is needed to disrupt the greater amount of intermolecular forces, so the boiling points increase with increasing relative molecular mass. *[1 mark]*

Carboxylic acid molecules have a polar carboxyl functional group, which results in stronger intermolecular forces (hydrogen bonds) than those found in alkanes (which do not have a polar functional group). More energy is needed to disrupt attraction between carboxylic acid molecules than alkane molecules, therefore, carboxylic acids have higher boiling points than alkanes. *[1 mark]*

QUESTION 27 (5 marks)

a) At 25ºC, $[H_3O^+][OH^-] = 10^{-14}\ M^2$

$[H_3O^+] \times (6.25 \times 10^{-4}) = 10^{-14}$, so $[H_3O^+] = 1.60 \times 10^{-11} = 10^{-10.8}$ M *[1 mark]*

$pH = -\log_{10}[H_3O^+] = -\log_{10}10^{-10.8} = -(-10.8) = 10.8$ *[1 mark]*

b) $n(OH^-) = cV = 0.1135 \times 0.02000 = 2.270 \times 10^{-3}$ mol *[1 mark]*

To reach the equivalence point, $n(OH^-) = n(H^+)$.

$n(H^+) = 2.270 \times 10^{-3}$ mol *[1 mark]*

$c(H_2SO_4) = \frac{1}{2} \times c(H^+) = \frac{1}{2} \times \frac{(2.270 \times 10^{-3})}{0.01935} = 0.05866$ M *[1 mark]*

QUESTION 28 (6 marks)

a) The percentage of ionisation measures the extent to which an acid forms ions in solution – so the higher the percentage, the more ions present. *[1 mark]*

The electrical conductivity of a solution depends on the solution's concentration of ions, so measuring the conductivity of each liquid would be a successful method for distinguishing between the acids. *[1 mark]*

Even though the percentage of ionisation is different for each acid, the total number of hydrogen ions that each acid can donate depends only on the concentration of the acid. *[1 mark]*

As each acid has the same concentration (0.10 M), the same amount of base is needed for neutralisation, so determining the volume of NaOH solution needed for neutralisation would not be a successful method for distinguishing between the acids. *[1 mark]*

b) The acid dissociation constant (K_a) measures the extent of ionisation of an acid, so weaker acids will have a lower K_a value. *[1 mark]*

As the $pK_a = -\log_{10}K_a$, weaker acids have a higher pK_a value, so ethanoic acid (the weakest of the three acids) would have the highest pK_a. *[1 mark]*

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QUESTION 29 (5 marks)

a) Conclusion 1: The two bases have different concentrations. *[1 mark]*

The volume of HCl needed to neutralise base P is approximately 23 mL, whereas approximately 30 mL is needed to neutralise base Q. Given that identical volumes of the bases were used in the titrations, but more HCl was needed to neutralise base Q, the concentrations of the bases must be different. *[1 mark]*

Conclusion 2: Base P is a stronger base than base Q. *[1 mark]*

The equivalence point for base P is at pH 7, whereas for base Q it is at pH 5. This indicates that base Q is the weaker base. *[1 mark]*

b) *either* methyl red *or* bromothymol blue *[1 mark]*

QUESTION 30 (4 marks)

a) $n(H_2) = 3 \times n(CH_4) = 3 \times \frac{12.4}{16.05} = 2.317 \text{ mol}$ *[1 mark]*

$$\text{percentage yield of } H_2 = \frac{\text{actual mass}}{\text{theoretical mass}} \times 100$$

$$= \frac{3.71 \times 100}{2.317 \times 2.02} = 79.3\%$$ *[1 mark]*

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

Anode: $H_2(g) \rightarrow 2H^+(aq) + 2e^-$ *[1 mark]*

Award 1 mark if the half-equations are correct but matched to the incorrect electrodes.

QUESTION 31 (5 marks)

a) $K_a = \frac{[In^-] \times [H_3O^+]}{[HIn]}$ *[1 mark]*

b) At a low pH, there is a high concentration of hydrogen ions, so the equilibrium position is well to the left with the reactants – that is, HIn is in high concentration and its colour is evident. *[1 mark]*

As a base is added, the hydrogen ion concentration decreases and the position of equilibrium moves to the right; an intermediate colour may be evident when $[HIn] = [In^-]$. *[1 mark]*

As more base is added and the hydrogen ions are used up, the position of equilibrium is well to the right, and the colour of In^- is clearly observable. *[1 mark]*

c) The region of the titration curve known as the buffer zone is relatively flat. This is because when a base is added to an acid, the concentration of the acid and its pH do not change significantly at the beginning of a titration. *[1 mark]*

QUESTION 32 (5 marks)

a) At constant pressure, increasing the temperature causes a decrease in the yield of ammonia. *[1 mark]*

According to Le Châtelier's principle, increasing the temperature of an exothermic reaction at equilibrium will move the position of equilibrium toward the reactants, reducing the yield of product. *[1 mark]*

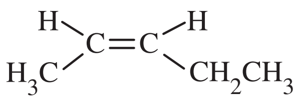
b) The best yield is produced using high pressures and low temperature. *[1 mark]*

The best rate of reaction is produced using high pressures and high temperature. *[1 mark]*

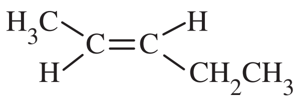
In the industrial production of ammonia, an economically good yield at a reasonable rate is achieved by using moderate pressure because it is very costly to build and maintain high pressure equipment, and moderate temperatures, which is a compromise to address the low temperature/high temperature conflict indicated above. *[1 mark]*

QUESTION 33 (2 marks)

In the *cis* isomer of pent-2-ene, the hydrogen atoms on C2 and C3 are on the same side of the double bond (as shown in the structural formula below). *[1 mark]*



In the *trans* isomer, the hydrogen atoms on C2 and C3 are on diagonally opposite sides of the double bond (as shown in the structural formula below). *[1 mark]*



Note: Structural formulas are not required for full marks.

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