2019 VCE Chemistry (NHT) examination report

Specific information

Section A – Multiple-choice questions

Question	Answer	Comments
1	B	The molecule contains a carbon that is attached to four different groups
2	D	There is not enough information to identify the gas produced or whether the electrodes are the same or different. Electrons flow through the external circuit.
3	A	Amine group has a higher priority than chloro group and therefore has the lower number. Hence, 3-chloro-pentan-2-amine.
4	B	Because a catalyst lowers the activation energy (via an alternative reaction pathway) it increases the proportion of (total) collisions that are successful at a given temperature.
5	C	
6	A	$12 \times 16 + 7 \times 17 + 5 \times 37 = 496$ kJ The energy content of food groups is given in table 13 of the Data Book.
7	C	Biofuel is from renewable sources, e.g plants; coal is a fossil fuel.
8	A	The largest difference in retention times will produce the largest separation.
9	C	Repetition of the exercise should reduce the impact of errors and the uncertainty, thus making results more reliable.
10	B	
11	D	44.0 g $C_2H_4O_2 \rightarrow$ 62.0 g $C_2H_6O_2$ 86.0 g $C_2H_4O_2 \rightarrow$ x g $C_2H_6O_2$ x g $C_2H_4O_2 \rightarrow (62/44) \times 86.0 = 121.2$ g $C_2H_6O_2$ in theory % yield = $(86.0/121.2) \times 100 = 71.0$ %
12	D	The word ‘alkaline’ implies the presence of OH^-. Oxidation, which involves the loss of electrons, occurs at the anode.

Question	Answer	Comments
13	B	All 4 fatty acids have equal chain length. Saturated fatty acids have stronger intermolecular attraction than unsaturated fatty acids with the same number of C atoms. The saturated hydrocarbon chains lack the kinks associated with C=C bonds in unsaturated hydrocarbons.
14	D	
15	C	1-bromo-1-chloropropane, 1-bromo-2-chloropropane 1-bromo-3-chloropropane, 2-bromo-2-chloropropane 1-chloro-2-bromopropane
16	B	$n(CO_2) = 200 \times 0.750 / (8.31 \times 301)$ $= 0.0600$ mol $m(CO_2) = 0.0600 \times 44.0$ $= 2.64$ g
17	C	Option A was incorrect as it is a redox titration Option B was incorrect as pH at endpoint > 7 Option D was incorrect as burettes/pipettes rinsed with transfer solutions
18	A	Of the options given, only an ester fits the features listed and has the general formula $C_nH_{2n}O_2$, i.e has 2 O atoms.
19	A	Reaction 2 reaches equilibrium earlier/has a steeper gradient.
20	D	The student's diagram is consistent with options A, B and D. Of these only D is incorrect. While option C is a chemically incorrect statement, is it not shown on the student's diagram.
21	D	Added $OH^-(aq)$ reacts with $H^+(aq)$ causing the position of equilibrium to shift to the left. Note: Adding H_2O decreases all concentrations and will also cause the position of this equilibrium to shift to the left. However, at equilibrium, the concentrations of all the mixture components will be lower than their original concentrations.
22	C	Reaction of the alkene with HCl produces chloroalkanes. While there are two possible products, compound K must be 1-chloroalkane since the final product is butan-1-ol. The chloroalkane is normally converted to the alcohol by reaction with $OH^-(aq)$. However, the same outcome can be achieved, albeit slowly, by reaction with H_2O. $CH_3CH_2CHCH_2 + HCl \rightarrow CH_3CH_2CHClCH_2$ / $CH_3CH_2CH_2CH_2Cl$ $CH_3CH_2CH_2CH_2Cl + H_2O \rightarrow CH_3CH_2CH_2CH_2OH$ (+ HCl)
23	D	$n(C_2H_6) = 0.50 / 30.0 = 0.0167$ mol Energy released = $4.18 \times 200 \times 26.5 = 2.22 \times 10^4$ J = 22.2 kJ Energy per mol = 22.2 / 0.167 = 1330 kJ mol^{-1} $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$; $\Delta H = -2660$ kJ mol^{-1}
24	A	Butane (non-polar) molecules will be more strongly attracted to the non-polar mobile phase (hexane) than butanoic acid (polar) molecules.

		In all other options the mixture contains chemicals that are both polar or both non-polar, so the differences in attraction to the mobile phase and retention times will be less significant.
25	B	$n(O_2) = 19.6 \times 10^{-3} / 24.8 = 7.90 \times 10^{-4}$ mol Energy released per mol O_2 reacting = 2816 / 6 kJ Energy released = $7.90 \times 10^{-4} \times (2816/6)$ = 0.37 kJ
26	D	$n(e^-) = 3.0 \times 60 \times 60 / 96500 = 0.112$ mol If Cu, n(Cu) = 0.056 mol, m(Cu) = 0.056 × 63.5 = 3.56 g If Ag, n(Ag) = 0.112 mol, m(Ag) = 0.112 × 107.9 = 12.1 g If Cr, n(Cr) = 0.112 / 3 = 0.0373 mol m(Cr) = 0.0373 × 52.0 = 1.9
27	C	The proportion of collisions that are successful is indicated by the area under the curves for kinetic energy ≥ 7 arbitrary units.
28	B	Consider the fat (37 kJ g^{-1}) and relative carbohydrate (16 kJ g^{-1})/protein (17 kJ g^{-1}) content. Avocado and egg have similar amounts of fat and significantly more fat than the other two components. Egg has, in total, more protein and carbohydrate content than avocado and so can provide the largest amount of energy per serve.
29	A	Current depends on the amount of electrons flowing. Ca atoms release 2 electrons, whereas K atoms release 1 electron, i.e. Ca produces more electrons per mol than K.
30	B	Forward reaction is exothermic, so reverse reaction is endothermic with $\Delta H = +50$ kJ mol^{-1}. Only option B reflects the profiles for both forward and reverse reactions accurately.

Section B

Question 1a.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\Delta H = -2220$ kJ mol^{-1}

One mark each was awarded for correct:

- formulas and stoichiometry
- states
- enthalpy (ΔH).

Question 1b.

Energy = 50.5 kJ g^{-1} × 290g

= 14 645 kJ

= 1.46×10^4 kJ (14 600 kJ)

An answer correct to three significant figures was required.

Question 1c.

$n(C_3H_8) = 68.5/44.0$

$= 1.56$ mol

$n(O_2) = 5 \times 1.56$ mol $= 7.78$ mol

$V(O_2)$ at SLC $= n(O_2) \times V_m = 7.78 \times 24.8$

$= 193$ L

193 L = 21% of V(air) = 0.21 × V(air)

V(air) = 193/0.21

= 919 L

One mark each was awarded for:

- correct $n(O_2)$
- correct $V(O_2)$
- accurately taking into account the percentage of oxygen in the air to obtain the answer in litres.

Question 1d.

Butanol / butan-1-ol / butan-2-ol

The isomer, 1-butanol or 2-butanol, was not specified in the data. However, students should be aware that if they are asked to name or identify the structure of an alcohol with four carbon atoms, the isomer must be indicated.

Question 1e.

Feature:

- There are more carbon to carbon (C=C) double bonds in linoleic acid molecules (2 C=C) than in oleic acid molecules(1 C=C).
- Linoleic acid molecules are polyunsaturated, but oleic acid molecules are monounsaturated.
- Linoleic acid molecules have more kinks in their hydrocarbon chains.

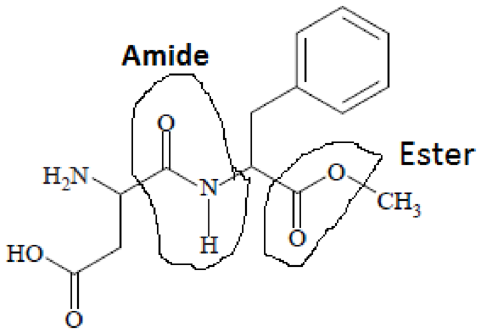
Justification:

- Alkyl esters with fatty acids with the same number of carbon atoms (similar hydrogen chain length) differ in viscosity based on how many C=C double bonds are present in the fatty acid. The larger the number of carbon–carbon double bonds, the lower the viscosity.
- Kinks in the fatty acid chains due to the C=C double bonds lower the strength of intermolecular forces and decrease the viscosity of the fuel. Hence, the greater the number of C=C doubles the weaker the intermolecular attraction and the lower the viscosity.

One mark each was awarded for:

- a correct feature
- a valid justification of how the feature contributes to weaker intermolecular forces (hence, lower viscosity).

Question 2a.



One mark each was awarded for the correct circling and naming of each of the two functional groups.

Question 2b.

Aspartic acid and phenylalanine

Question 2c.

While they all have the same energy content (kJ per gram), aspartame is 180 times sweeter than the others. Less aspartame is added in the soft drink, therefore less energy is consumed (the drink has a lower energy content).

Question 2d.

$n(C_6H_{12}O_6) = 1.00/180$

$= 5.56 \times 10^{-3}$

Energy released $= 5.56 \times 10^{-3}$ mol $\times$ 2810 kJ mol^{-1}

$= 15.6$ kJ

CF $= 15.6$ kJ/1.60 °C^{-1}

$= 9.75$ kJ °C^{-1} or 9.75×10^3 (9750) J °C^{-1}

or

$(1.00/180) \times 2810 / 1.60 = 9.76 \times 10^3$ kJ °C^{-1}

One mark each was awarded for accurately calculating:

- moles of fructose that reacted
- energy released
- calibration factor and including units.

Question 3a.

red

Question 3b.

- At the anode: oxygen/O_2
- At the cathode: hydrogen/H_2

Appropriate half-equations were also acceptable.

Question 3ci.

$2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

Question 3cii.

Any two of:

- difficulty maintaining the required temperature or difficulty/danger in keeping temperature at or above 801 °C
- lack of correct equipment to safely collect toxic Cl_2 or difficulty in safely removing Cl_2
- difficulty keeping Na produced away from air
- difficulty of keeping Na and Cl_2 from coming into contact (violent spontaneous reaction)
- issues in sourcing suitable electrodes
- issues with maintaining electric circuit at the high temperature.

Other reasonable responses were accepted.

Students needed to give two specific responses that indicated a clear understanding of the practical issues.

Question 3d.

Process	Galvanic cells	Electrolytic cells
Oxidation occurs at the cathode.	false	false
Chemical energy is converted to electrical energy.	true	false
Spontaneous reactions take place.	true	false

Question 4a.

$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$

Question 4bi.

glycerol or fatty acid

Question 4bii.

ester

Question 4c.

Acceptable enzyme properties included:

- enzyme allows access to active site for protein via lock and key and/or induced fit mechanisms
- enzyme binds the protein (substrate) to the active site so the peptide links react with water (hydrolyses)
- enzyme lowers E_a for hydrolysis of peptide links or acts as a catalyst for hydrolysis of peptide links
- enzyme retains shape after reaction.

One mark each was awarded for:

- indication that the active site has a specific shape
- recognition that the enzyme lowers activation energy (E_a)/acts as a catalyst for hydrolysis
- recognition the peptide bonds are hydrolysed (react with water).

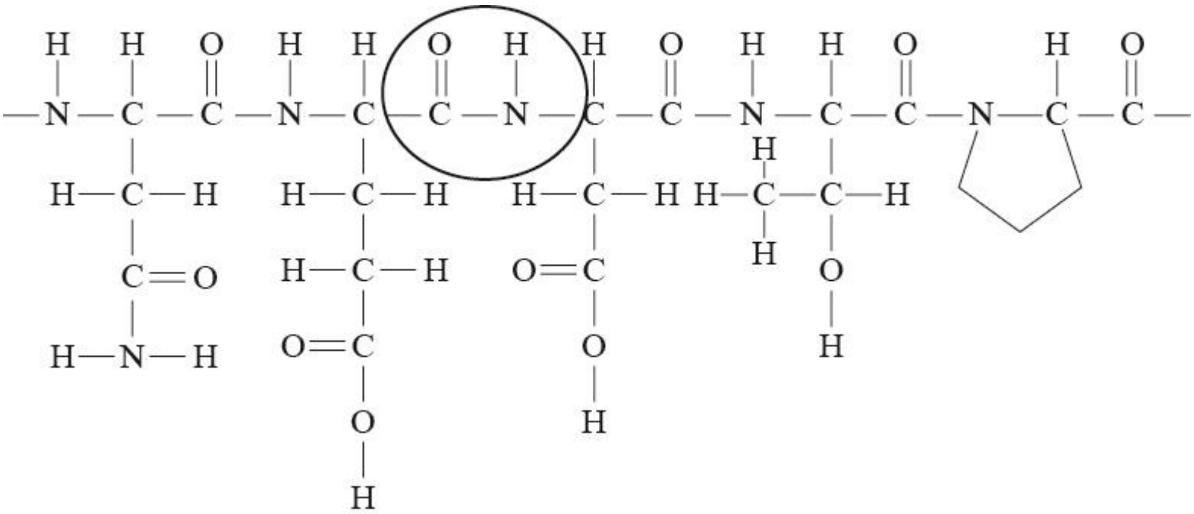
Question 4d.

- hydrolysis: breakdown of primary structure (covalent bonds)
- denaturation: breakdown of tertiary structure (multiple bond types) and secondary structure (hydrogen bonds)

One mark each was awarded for:

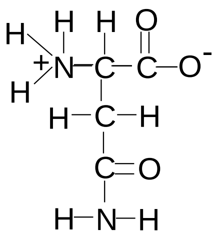
- primary/covalent bonds broken in hydrolysis
- secondary (hydrogen bonds) and tertiary (multiple bond types) structures disrupted in denaturation.

Question 4e.

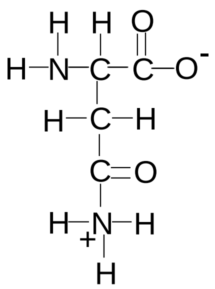


Students were required to circle any one of the four peptide linkages present.

Question 4f.



or



One mark each was awarded for:

- structure derived from correct amino acid (asparagine)
- an accurate zwitterion diagram with one positive on the N of either $–NH_3$ and one negative on the $COO^–$ group.

Question 5a.

Fe(s)/Fe/iron

Question 5bi.

R = Fe(s)/Fe/iron

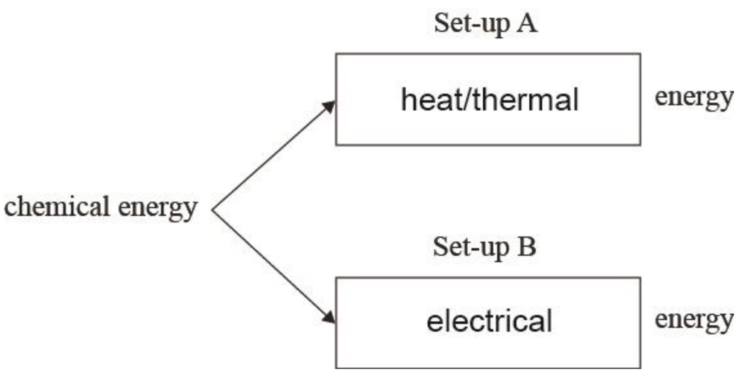
S = Ni(s)/Ni/nickel/Pt/C or any other inert electrode, e.g. Sn, Pb, Cu, Ag, Au (any metal higher than Ni on the electrochemical series)

Question 5bii.

T = $Ni(NO_3)_2$/ $NiSO_4$/$NiCl_2$ or other Ni^{2+} solution

$Ni(NO_3)_2$ not Ni^{2+} alone or Ni^{2+} (aq)

Question 5c.



Question 5d.

anode

Question 5e.

$O_2 + 4e^- \rightarrow 2O^{2-}$

One mark was awarded for a correct balanced half-equation.

The anode half-equation for this cell is: $CH_4 + 4O^{2-} \rightarrow CO_2 + 2H_2O + 4e^-$

Question 5f.

SOFCs involve direct conversion of chemical to electrical energy so are more efficient than a conventional power station.

Both reactions will produce the greenhouse gases carbon dioxide and water vapour.

An SOFC is more efficient and will hence produce less CO_2/greenhouse gas(es) for a given amount of energy produced.

One mark each was awarded for three separate statements.

Examples of appropriate responses included:

- that an SOFC is more efficient
- both produce CO_2/greenhouse gases
- an SOFC produces less CO_2 (greenhouse gases) for a given amount of energy produced
- an explanation of relative efficiencies using energy transformations.

Question 6a.

Random error

Examples of how random error may occur include:

- gradations (on measuring cylinder) make it difficult to see meniscus
- vibrations causing balance reading to fluctuate
- temperature variations/fluctuations

One mark each was awarded for:

- type of error
- example consistent with Step 5.

Question 6b.

Data is within a narrow range of 0.03 g from highest to lowest./Data values are close together.

Data is close together with no outliers.

Question 6ci.

0.99766 (0.99764 – 0.99768)

Question 6cii.

Equipment	Average volume delivered (mL)	Range (mL)
25 mL pipette	*mass*/*density* 24.96/0.99766 = 25.02 mL (25.00 – 25.03)	0.03
25 mL measuring cylinder	*mass*/*density* 24.73 / 0.99766 = 24.79 mL (24.78 – 24.80)	0.12

Question 6d.

The calculation of the average volume delivered will not be affected as it has been adjusted for temperature when converting between mass and volume by using the density at 22.5 °.

Question 6e.

- The wider range of volumes for the measuring cylinder suggests that the results and are less reliable and less accurate than for the pipette.
- Pipette data is more precise – results are more accurate (closer to true value) and are more reliable due to the narrower range of results.

Students needed to give a reasonable comparison of relative accuracy and a reasonable comparison of relative reliability.

Question 6f.

The pipette

Reason:

- greater accuracy of pipette due to narrower meniscus/more accurate volume/more accurate *n*(NaOH)/higher precision
- valid conclusion that an exact number of moles is needed

- narrower tube in pipette means variation in student method has less impact.

Question 7a.

K_c = [$CoCl_4^{2-}$] / [[$Co(H_2O)_6$]$^{2+}$][Cl^-]^4

One mark each was awarded for correct:

- species and numerator/denominator
- indices.

Students seemed unaware that water is not included in the equilibrium law for reactions occurring in aqueous solutions.

Question 7bi.

The dilution decreases the concentration of all ions. To compensate for this change, this reaction will shift to the left, since there are more ions on this side of the equation.

Consequently, after the initial change to a lighter blue (due to a decrease in [$CoCl_4^{2-}$]), the colour will become a deeper pink (more pink) as the [$Co(H_2O)_6^{2+}$] increases.

One mark each was awarded for:

- colour changing towards pink/mauve/light purple
- a valid explanation of why the equilibrium shifts to the left.

Question 7bii.

When Cl^- ions are precipitated, [Cl^-(aq)] decreases. This means there are fewer Cl^- ions to collide with [$Co(H_2O)_6$]$^{2+}$ ions, so successful collisions between these two species are less frequent and the rate of the forward reaction will decrease.

The rate of the back reaction has remained unchanged since there is no initial change in [species] on the right-hand side of the equation. The rate of the forward reaction is now less that the rate of the backward reaction, so there will be a net shift to the left.

One mark each was awarded for:

- decrease in [Cl^-] ions and effect on successful collisions
- change in relative rates of reverse and forward reactions
- net shift to the left since forward reaction is slower than reverse reaction.

Question 7c.

Endothermic

The solution is pink at 4 °C and is blue at 25 °C. This means that the reaction shifts to the right when the temperature increases, indicating that the forward reaction is endothermic.

Question 8ai.

- methanol
- propanoic acid

Question 8aii.

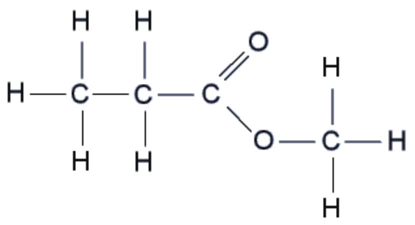
- Reactant: methanol, Spectrum: B
  O-H (alcohol) absorption band at 3450cm^{-1} (3200–3600 cm^{-1}); no C=O (acids) absorption band
- Reactant: propanoic acid, Spectrum: C

O-H (acids) absorption band at 3000 cm^{-1} (2500-3500 cm^{-1}); C=O (acids) absorption band at 1700 cm^{-1} (1680–1740 cm^{-1})

One mark each was awarded for:

- compound and spectrum
- accurate supporting absorption band evidence.

Question 8b.



One mark each was awarded for:

- correct ester linkage
- accurate overall structure, i.e. CH_3 and CH_3CH_2 correctly attached to the ester group.

Question 8c.

Spectrum Y. Parent ion m/z is at $M_r(CH_3CH_2COOCH_3) = 88.0$

Fragment peak at m/z = 57, which is 31 less than the parent ion, is consistent with loss of OCH_3 to give the fragment $CH_3CH_2CO^+$.

Fragment peak at m/z = 31 is consistent with OCH_3^+.

Fragment peak at m/z = 15 – CH_3^+, not shown on X

The base peak at m/z = 29 is consistent with $C_2H_5^+$ also consistent with methyl propanoate.

Fragment peak at m/z = 59 is consistent with $CH_3.O.CO^+$

One mark each was awarded for:

- spectrum Y
- a valid reason based on the spectra relating one m/z value to a fragment consistent with $CH_3CH_2COOCH_3$.

Question 8d.

Three peaks indicate three hydrogen environments consistent with $CH_3CH_2COOCH_3$.

Combination of a quartet at $\delta = 2.4$ ppm and a triplet at $\delta = 1.2$ ppm is consistent with the presence of CH_3CH_2– (ethyl group)

Singlet at $\delta = 3.6$ ppm is consistent with hydrogens on a C atom with no neighbouring hydrogens as in $CH_3.O.CO$

Shift	Splitting	Information
3.6 ppm	Singlet	No Hs on neighbouring C $\rightarrow$ $-CH_3$
2.4 ppm	Quartet	3 Hs on the neighbouring C
1.2 ppm	Triplet	2 Hs on the neighbouring C

Consistent with $CH_3CH_2COOCH_3$

t q s

Question 9a.

- No, NaBr(s) is not suitable as an electrolyte.
- NaBr (s) is an ionic solid in which the ions are unable to move between electrodes.
- Electrolytes must allow for the free movement of charged particles (ions) between the electrodes.

One mark each was awarded for:

- indication NaBr(s) is not suitable
- why ionic solid is unsuitable
- essential requirement of electrolyte.

Question 9b.

For a battery to be rechargeable:

- the discharge reaction must be reversible
- the products of discharge remain in the vicinity of electrodes.

Improvements could lead to a greater cell potential/better performance/enhanced safety, for example:

- Replace the Na in the electrode with another metal (Ca, K) to give a higher electrode potential (V).
- Replace the Na in the electrode with a less reactive metal (e.g. Fe) to improve the safety.
- Replace Br in the complex electrode with Cl for a higher electrode potential.
- Replace NaBr with another molten electrolyte that allows transport of ions. The replacement electrolyte must not react with Na in the electrodes so it cannot be aqueous.
- Dissolve NaBr in a non-reactive organic solvent (e.g. CCl_4) to allow transport of ions. Toxicity of organic solvent is a safety concern.

Safety implications

Any relevant safety consideration for improvement to the HBH was required. This could involve the changes being more or less safe. It might involve isolating the cell to prevent reactions with oxygen and water, or the changes may lead to a much safer alternative.

One mark each was awarded for:

- requirements of a rechargeable battery
- suggestion for improvement
- justification of the suggestion
- safety implications.