2022 VCE Chemistry (NHT) external assessment report

Specific information

This report provides sample answers, or an indication of what answers may have included. Unless otherwise stated, these are not intended to be exemplary or complete responses. Asterisks (*) are used for some questions to indicate where marks were awarded.

Section A – Multiple-choice questions

Question	Correct answer	Comments
1	B	Carbohydrates are converted to glucose, which is converted to CO_2 while excess glucose is converted to glycogen by condensation polymerisation.
2	D	Unpolished surface reduces chance of contact between H^+(aq) and Mg(s), so fewer successful collisions.
3	C	As a result of acidification, NH_2 protonated to $^+NH_3$; COOH is not affected.
4	A	The most selected alternative was D, which is incorrect because CH_4, the major component of coal seam gas, has a higher energy density than coal.
5	B	Rancidity is associated with oxidation of unsaturated components of the oil. Lower temperature and the presence of a reducing agent – antioxidant – will reduce the amount of rancidity.
6	B	The induced fit model refers to the process where the shape of the active site is modified to enable the substrate to fit. Hence, it is associated with specific chemical reactions.
7	C	Reaction requires that reacting molecules collide in the right orientation and with energy greater than the activation energy.
8	B	Primary structure – peptide links only. Secondary structure – hydrogen bonds, polar interactions. Tertiary structure – multiple interactions, including polar. Quaternary structure – multiple peptide chains, hydrophilic and hydro interactions.
9	B	$3.85 \times 1.70 \times 10.0 \times 60$ J / $(20.8 – 19.5) = 3.02 \times 10^3$ J °C^{-1}
10	C	Most of the chemical energy is converted to electrical energy in a bioethanol fuel cell, therefore there will be less thermal energy in its products.

Question	Correct answer	Comments
11	C	Random errors impact precision. Systematic errors impact accuracy. While option A seems to be a good answer, if these variables are not controlled, random errors are introduced. Option C is the best response.
12	A	Based on the electrochemical series, $H^+(aq)$ is a stronger oxidising agent than $Fe^{2+}(aq)$ and Fe(s) is a stronger reducing agent than $H_2(g)$.
13	A	Peaks at 3200–3500 cm^{-1} [O-H(alcohol) or N-H] and at 1700 cm^{-1} [C = O].
14	D	All concentrations have increased at t_2, hence the volume was decreased.
15	A	The temperature decrease causes the rate of both the forward and reverse reactions to decrease. To return to equilibrium, the forward reaction is favoured and the $[SO_2Cl_2]$ increases. The rate of the forward reaction will decrease and the rate of the reverse reaction will increase as the system returns to equilibrium. Since the system returns to equilibrium after partially opposing the change, the rates of the forward and reverse reactions will both be lower at t_4 than at t_3.
16	D	Electrolytic cells will operate with separated half-cells if there is electrolytic conduction between the half-cells. Oxidation occurs at the anode in all electrochemical cells. Under standard conditions the strongest oxidant is reduced. A temperature rise indicates electrical energy is being converted to thermal energy rather than chemical energy.
17	A	Vitamin D most attracted and fructose least attracted to non-polar stationary phase. Vitamin D has highest retention time.
18	D	Options A and B are acid–base titrations. $(CH_3)_3COH$ is a tertiary alcohol and cannot be oxidised. $CH_3CHOHCH_3$ will be oxidised to butanone and the reaction is self-indicating since the $Cr_2O_7^{2-}(aq)$ changes colour when the oxidation number of Cr decreases.
19	B	Q $(CH_3)_3CHCl$ R $CH_3CH_2CH_2CH_2CH_2Cl$ S $CH_3CH_2CH_2CH_2Cl$, Q has the lowest boiling point, since it is branched, and packs less effectively than its linear structural isomer S. S has a lower boiling point than R because it is a smaller molecule.
20	D	Coenzymes are organic molecules, which are required by some enzymes to enable them to catalyse (speed up) reactions. Coenzymes can act as electron and atom/molecule carriers in a catalysed reaction.
21	C	Reducing the operating temperature of the fuel cell will cause an increase in the proportion of the chemical energy that is converted to thermal energy rather than usable electrical energy, hence lower cell efficiency.

Question	Correct answer	Comments
		The rate of movement of oxide ions through the electrolyte would be slowed if the rate/pressure of reacting fuel was slower, but this is unlikely to reduce efficiency.
22	A	The products of the hydrolysis of aspartame are two amino acids, phenylalanine and aspartic acid, both of which have chiral centres, and methanol, which does not have a chiral centre. Aspartic acid and methanol are very soluble in water. The -COOH group on amino acids and the -OH group allow for the formation of esters.
23	A	The extent of hydrolysis of aspirin increases with increasing time. This means that the concentration of aspirin decreases with time. The results show that the concentation of the rate of reaction decreases as the concentration of aspirin decreases, so the rate of reaction decreased as time increased.
24	B	Peak area 6.9 mm^2 $\rightarrow$ c(diluted solution) = 25.5 mg mL^{-1} c(undiluted solution) = 5 × 27.5 = 127.5 mg mL^{-1} = 137.5 g L^{-1} = (127.5 / 342) mol L^{-1} = 0.402 M
25	A	Only 2-butanol, $CH_3CH_2CHOHCH_3$, has a C bonded to four different atoms / groups of atoms.
26	C	The Maxwell–Boltzmann distribution suggests that Temperature M is higher than Temperature L. The distribution is broader for Temperature L, indicating a wider range of particle energies and so a greater range of speeds at the higher temperature.
27	D	The alternatives are that the three half-cells are X^{4+}(aq)/X^{2+}(aq), X^{2+}(aq)/X(s) and H^+(aq)/H_2(g). X^{4+}(aq) is the strongest oxidising agent since it reacts with the reducing agents of both the other half-cells. H^+(aq) is a stronger oxidising agent than X^{2+}(aq) since it reacts with X(s). So X^{2+}(aq) is the weakest oxdising agent. Order of increasing half-cell potentials is: X^{2+}(aq)/X_s(aq) < H^+(aq)/H_2(g) < X^{4+}(aq)/X^{2+}(aq)
28	C	The NMR spectrum shows three different hydrogen environments as quartet, singlet and triplet. Quartet and triplet indicate the presence of CH_3CH_2–
29	A	HF is a molecular compound and does not produce ions when heated. HF(aq) contains H^+(aq) and F^-(aq) as well as H_2O. In electrolysis of HF(aq) the stronger reducing agent, H_2O(l), will be oxidised producing O_2(g) at the anode.
30	A	The voltages of the two cells when operating as standalone cells are:

Question	Correct answer	Comments
		Cell 1: E = $E°(Cu^{2+}/Cu) − E°(Ni^{2+}/Ni)$ = 0.34 V − (−0.25) V = 0.59 V Cell 2: E = $E°(Cu^{2+}/Cu) − E − E°(Mn^{2+}/Mn)$ = 0.34 V − (−1.18) V = 1.52 V Cell 2 will cause electrolysis in Cell 1. The (−) electrode in Cell 1 is connected to the (−) electrode in Cell 2. The (+) electrode in Cell 1 is connected to the (+) electrode in Cell 2. Half-equations: Cell 2: (−) $Mn(s) \rightarrow Mn^{2+}(aq) + 2e^-$; (+) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ Cell 1: (−) $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$; (+) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ Therefore, the production of $Cu^{2+}(aq)$ at the anode of Cell 1 deepens the blue colour of this solution.

Section B

Question 1ai.

Cellulose

Question 1aii.

Glycosidic link or ether link

Question 1b.

E = (37 × 14.7) + (17 × 2.0) + (16 × 1.8) *

= 607 kJ

= 6.1 × 102 kJ * / 610 kJ

Question 1c.

Vitamin C is water soluble. *

The hydroxyl (−OH) groups on the vitamin C molecules form hydrogen bonds with water molecules. *

Question 1di.

The glycaemic index (GI) of a food is a measure of how quickly blood glucose (blood sugar) levels increase after the food is consumed.

Question 1dii.

Students needed to indicate use of the nutritional information provided in the table * and refer to the digestion (metabolism) of avocados *. Possible points included:

- Avocados have a low concentration of digestible carbohydrate/sugars.
- Most of the nutrients in avocados are large macromolecules.
- The low GI of avocados means it takes a long time for avocados to increase blood sugar levels after being consumed.
- The relatively small quantity of digestible carbohydrates (1.8%) does not provide enough carbohydrates to cause a high level of glucose to be released into the blood as a result of its metabolism.
- When glucose is consumed it can enter the blood very quickly, but the large macromolecules need to undergo metabolising reactions to form glucose, which takes time.

Question 2ai.

Electrode X

Question 2aii.

Sodium ion / Na^+

Question 2bi.

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Question 2bii.

The electrochemical series predicts that (under standard conditions / 1 M NaCl) H_2O should be preferentially oxidised to produce O_2 and H+(aq).

High concentration of NaCl means that the Cl^- will be oxidised to Cl_2 instead of the H_2O being oxidised.

Question 2biii.

$n(e^-)$ = $1.80 \times 10^6 / 96500$ *

= 18.7 (mol)

$n(Cl_2)$ = $n(e^-) / 2$ *

= 18.7 / 2

= **9.32** (mol)

$m(Cl_2)$ = n × M

= 9.32 × 71.0

= **662 g** *

Question 3ai.

Since the $[O_3]$ (product) increases with temperature, the forward reaction is endothermic.

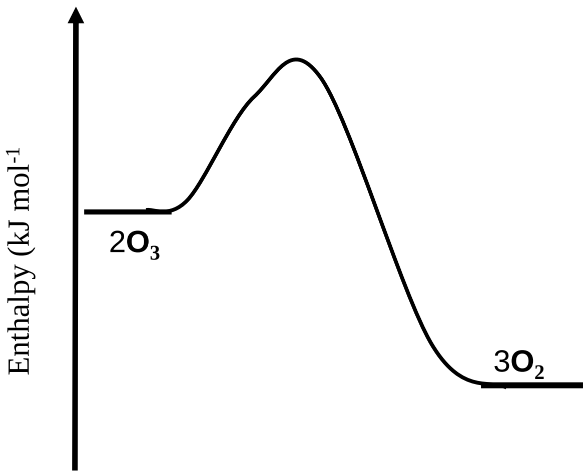
Question 3aii.

Students need to incorporate Le Chatelier's principle in their explanation.

As the temperature increases, there is a net shift to the right to produce more O_3 / forward reaction is favoured. *

System moves to partially oppose the increase in temperature by favouring the energy-absorbing (endothermic) reaction. *

Question 3aiii.



Question 3b.

	$3O_2$	**⇋**	**$2O_3$**
	***n*(O_2) mol**		***n*(O_3) mol**
Initially	**7.50×10^{-2}**		**0**
Change	**$-x$**		**$+ \frac{2x}{3}$**
	-2.34×10^{-7}		**$+ 1.56 \times 10^{-7}$ ***
Equilibrium	**0.0750**		**1.56×10^{-7}**

$[O_2]_{eqm} = {}^{0.0750}/_{3.00} = 0.0250$ M,

$[O_3]_{eqm} = 1.56 \times 10^{-3} / 3.00 = 5.20 \times 10^{-8}$ M *

$K = [O_3]^2 / [O_2]^3$ * $\quad = (5.20 \times 10^{-8})^2 / 0.0250^3$

$= 2.70 \times 10^{-15} / 1.56 \times 10^{-5}$

$= 1.73 \times 10^{-10}$ M^{-1} *

To gain full marks, students were required to submit the final calculated value with the correct units:

- 1 mark for change in moles of O_2
- 1 mark for equilibrium concentrations of O_2 and O_3
- 1 mark for equilibrium expression
- 1 mark for substitution of concentrations into equilibrium expression and final answer.

Question 4a.

$C_2H_2(g) + 5/2\ O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ * $\Delta H = -1300$ kJ mol^{-1} * / $\Delta H = -1300$ kJ

or

$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$ $\Delta H = -2600$ kJ mol^{-1} / $\Delta H = -2600$ kJ

Question 4b.

Using molar volume at SLC

n(C_2H_2) = 200 / 24.8 = 8.06 mol *

n(CO_2) = 2 × *n*(C_2H_2) = 2 × 8.06

=**16.1 *** (mol)

Using PV = nRT

n(C_2H_2) = 100 × 200 / (8.31 × 298)

= 8.08 mol *

n(CO_2) = 2 × *n*(C_2H_2) = 2 × 8.08

= **16.2*** (mol)

Question 4c.

Energy = 25 MJ = 25000 kJ

Mass = Energy / Heat of combustion *

= 25000 kJ / 49.9 kJ g^{-1}

= 501.0 g

= 0.50 *(kg)

Alternatively:

n(C_2H_2) = 25000 kJ / 1300 kJ mol^{-1} = 19.23 mol

mass(C_2H_2) = 19.23 × 26.0 = 500 g = 0.50 (kg)

Question 4c.

Mass of water = 500.0 mL × 0.997 g mL^{-1}

= 498.5 g *

E (joules) = mcΔT

112500 = 4.18 × 498.5 × ΔT

ΔT = 112500 / (498.5 × 4.18)

= 54.0 °C *

Final temperature 54.0 + 25.0 = **79.0 °C ***

Question 5ai.

Bromoethane

Question 5aii.

$C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$

Atom economy = (mass of bromoethane / mass of products) × 100%

= $m(C_2H_5Br)$ / [$m(C_2H_5Br)$ + m(HBr)]} × 100 *

= [108.9 / (108.9 + 80.9)] × 100 *

= 57.4% *

Alternatively:

m(bromoethane) / m(reactants) = $m(C_2H_5Br)$ / [$m(C_2H_6)$ + $m(Br_2)$] = 108.9 / (30.0 + 159.8) = 57.4%

Question 5aiii.

Substitution reaction

Question 5aiv.

$CH_3CH_2NH_2$

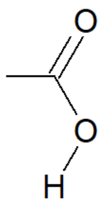
Question 5bi.

H_2SO_4 acts as a reactant / source of $H^+(aq)$ ions.

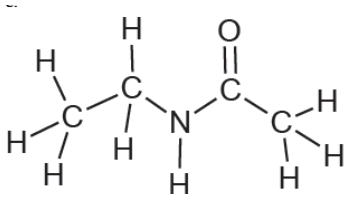
Question 5bii.

Ethanoic acid

Question 5biii.



Question 5c.



One mark for structure. One mark for accurate amide group.

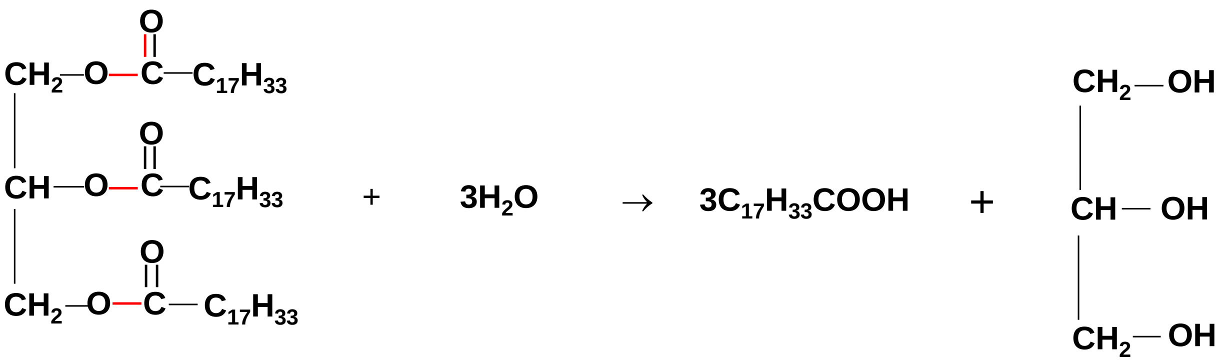
Question 6a.

linoleic acid / arachidonic acid

Question 6b.

One mark for correct reactants. One mark for correct products.

Semi-structural or molecular formulae were acceptable.



or

$C_{57}H_{104}O_6 + 3H_2O \rightarrow C_3H_8O_3 + 3C_{18}H_{34}O_2$

Question 6c.

An essential amino acid is an amino acid that the body uses/needs, but cannot make for itself / needs to be part of the diet.

Students were required to refer to both the need for the amino acid and why it must be in the diet.

Question 6d.

Possible responses included:

- Milk contains lactose and some people do not produce enough of the enzyme (lactase) needed to catalyse the hydrolysis of lactose. *
- Lactose molecules are polar and remain in the liquid and separated from the curd after the addition of acid. / It is easier to metabolise curd because they do have the enzymes necessary for digestion of curd (proteins). *

Students were required to relate the difficulty in hydrolysing carbohydrates in milk to the lack of the lactase and explain why the lactose and curd separate or why the protein in curd can be metabolised.

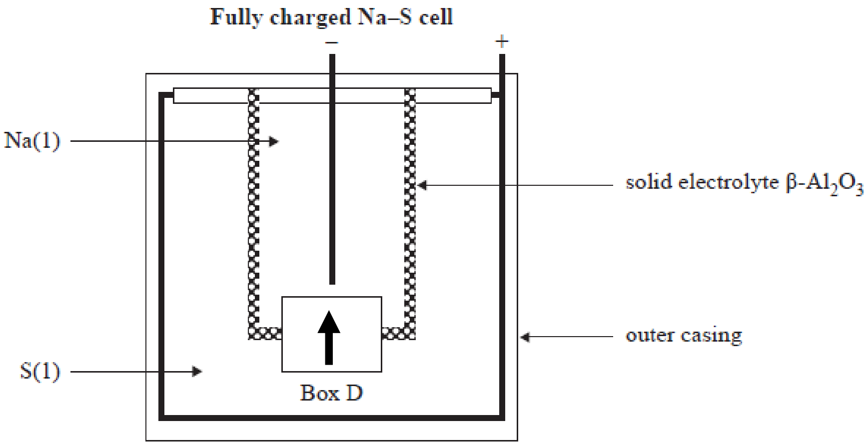
Question 6e.

Possible responses included:

- The addition of acid protonated the surface amino acids / denatured the protein by breaking bonds in the secondary and tertiary structure. *
- The changes in the (surface) structure of the proteins decreases the attraction to water and they drop out of solution. *

Students were required to describe the impact of acid on the protein surface or structure by the addition of acid and why this caused the protein to separate from the solution.

Question 7ai.



Question 7aii.

Possible responses included that the cell is:

- reversible * – allows the cell to be recharged *
- portable – enables it to be used in a vehicle that is moving
- two separated half cells – avoids a spontaneous reaction
- anode/cathode – enables an external circuit to be connected
- contains an electrolyte that conducts ions – completes the circuit.

Question 7bi.

$Na(l) \rightarrow Na^{+}(l) + e^{-}$

Question 7bii.

$Na_2S_3(s) \rightarrow 2Na(l) + 3S(l)$

Question 7biii.

Possible features (one mark) and explanations (one mark) included:

- If discharge product is not in contact with the electrode battery life/efficiency is reduced because the battery cannot be recharged, and reactions cannot be reversed.
- Side reactions reduce the efficiency of the cell by reducing the amount of useful product that can be recharged.
- High temperatures increase the possibility of increasing side reactions.
- Low temperatures increase the possibility of crystallisation.

Question 7c.

According to the electrochemical series, Na is a strong reductant and reacts violently with water. *

Equation: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ * *or* $2H_2O(l) + 2e^{-} \rightarrow H_2(g) + 2OH^{-}(aq)$

Safety issues: $H_2(g)$ is explosive * / $H_2(g)$ is stored under pressure / the reaction generates a lot of heat.

Question 8a.

One of:

- O–H or O–H(acids)
- C=O or C=O(acids)
- C–H

Appropriately circled within the quotes wave number range for the bond.

Question 8bi.

$C_5H_{10}O_2$

Question 8bii.

m/z = **57** *

$[C_4H_9]^+$ or $[C_3H_5O]^+$ *

Question 8c.

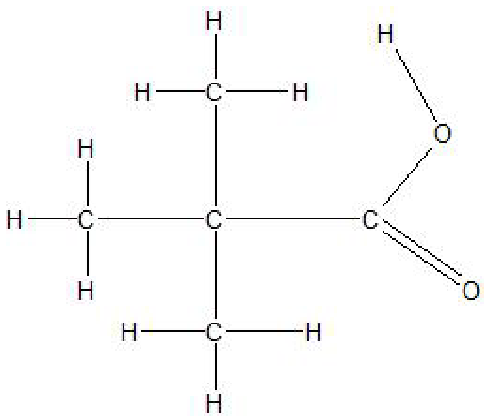
The molecule has three different carbon environments. *

Question 8d.

1.233 ppm: −CH3 *

11.49 ppm: −COOH *

Question 8e.



One mark for $C_5H_{10}O_2$ carboxylic acid.

One mark for correct structure with 3 CH_3 groups.

Question 9a.

In a suitable, labelled waste container.

Question 9b.

The time it takes for 20 mL of liquid to be delivered from the burette or viscosity.

Question 9ci.

Possible responses included:

- the extent of opening of the burette tap
- the initial level of liquid in the burette / initial flowrate from the burette
- the number of carbon atoms in soybean biodiesel and petrodiesel
- heat loss during transfer of samples from water to burette.

Question 9cii.

One mark was awarded for the impact on the dependent variable, and one mark for the associated explanation, linked to flowrate of liquid.

Differences in the extent of opening of the burette tap would affect the flowrate of liquid. If the burette tap is not fully open, the time taken to deliver 20 mL will be higher → lower viscosity.

If the liquids in each test start from different heights in the burette, there will be different initial flowrates. The higher the starting level, the lower the time taken to collect 20 mL → higher viscosity.

The flowrate of the two fuels is affected by the size of the molecules in the liquid, since larger molecular size increases viscosity and hence the time taken to deliver 20 mL, since the flowrate will be lower. Using the same number of carbon atoms in both liquids ensures that students can compare the effect of temperature on the viscosity of the liquids.

Question 9d.

The time taken for delivery of 20 mL of soybean biodiesel is greater * at all temperatures, so the viscosity of soybean biodiesel is higher * than the viscosity of petrodiesel.

Question 9ei.

As temperature increases, the viscosity decreases / time decreases.

At higher temperatures, the average kinetic energy of the molecules is higher. This increases the frequency of collisions between molecules and weakens the intermolecular forces, causing lower viscosity.

Question 9eii.

Viscosity at 30 °C for petrodiesel is higher than expected. The higher-than-expected time to deliver 20 mL could be due to one of the:

- temperature of petrodiesel being lower than 30 °C, increasing the time to deliver 20 mL
- burette tap not being opened as much as for the other temperatures
- initial level of petrodiesel being lower than for the other temperatures.

Question 10a.

One mark was awarded for a comparison of the renewability of the methane sources:

- Coal seam gas is a fossil fuel, hence is not renewable. Landfill gas and biogas are formed from the decomposition of organic material over a short timeframe, hence are renewable.

Two marks were awarded for environmental impacts, such as:

- Coal seam gas is obtained by mining that usually involves fracking, which can cause damage to the immediate environment.
- Coal seam gas can release methane into the atmosphere during the mining process.
- As coal seam gas is a fossil fuel, its use releases stored carbon into the atmosphere, increasing the chance of global warming.
- Landfill gas and biogas reuse carbon captured from the atmosphere, not increasing the amount of carbon in the atmosphere.
- Landfill gas is produced when large amounts of organic waste is sent to landfill.
- Anaerobic digesters can produce more efficient biogas and reduce the amount of waste that goes to landfill.
- Biogas, if it is to be used extensively, may require a large number of crops dedicated to producing the organic material required, potentially causing land degradation.

One mark was awarded for environmental impacts, such as:

- Landfill gas contains a large amount of carbon dioxide – if that is captured before use then the amount of carbon can be reduced.

Question 10b.

One mark was available for a statement or conclusion indicating which fuel is better for the environment.

Three marks were available for valid comparison points related to the environment. Areas of reference could include:

- Petrodiesel:
  - requires drilling/mining, which can affect the local environment
  - spills can be damaging to the environment and wildlife
  - oil refineries can be polluting.
- Biodiesel:
  - significant increase in the amount of biodiesel could use amounts of land that would otherwise be used for food production
  - food can be grown renewably
  - biodiesel is less polluting than petrodiesel
  - biodiesel is more carbon neutral.

To access full marks, one of the three comparisons should have extended detail.