Chemistry

2024 Insight Publications Trial Examination

Worked solutions

This book contains:

- worked solutions
- explanatory notes
- mark allocations
- tips.

Section A – Multiple choice

Question	Answer
1	*D*
2	*C*
3	*B*
4	*C*
5	*D*
6	*C*
7	*A*
8	*A*
9	*D*
10	*C*
11	*D*
12	*B*
13	*B*
14	*C*
15	*D*

Question	Answer
16	*D*
17	*A*
18	*C*
19	*B*
20	*B*
21	*C*
22	*C*
23	*C*
24	*A*
25	*D*
26	*B*
27	*A*
28	*B*
29	*A*
30	*C*

Question 1

Answer: D

Explanatory notes

Option D is correct. Cellular respiration is the reaction of glucose in body cells to produce CO_2 and water, releasing energy. The equation is

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Option A is incorrect. It refers to photosynthesis.

Option B is incorrect. Respiration does not occur in the lungs.

Option C is incorrect. The ratios are wrong and energy is released rather than absorbed.

Question 2

Answer: C

Explanatory notes

Option C is correct. The energy profile diagram shows

- a ΔH value of –3120 kJ
- $2C_2H_6$ as the starting point.

The question also states that the graph is for the production of $H_2O(l)$.

Option A is incorrect. It shows $H_2O(g)$.

Option B is incorrect. The value of ΔH needs to be doubled.

Option D is incorrect. The ΔH value is wrong.

Question 3

Answer: B

Explanatory notes

Option B is correct. The combustion of bioethanol releases less energy than an equivalent mass of a hydrocarbon fuel, as it is already partially oxidised.

Option A is incorrect. Bioethanol has the same structure as synthetic ethanol.

Option C is incorrect. It is important to remove the water from ethanol for it to be an effective fuel.

Option D is incorrect. The combustion of bioethanol releases CO_2.

Question 4

Answer: C

Explanatory notes

Option C is correct. C_4H_{10} is the limiting reagent

$$n(C_4H_{10}) = \frac{V}{V_m} = \frac{0.0248}{24.8} = 0.001 \text{ mol}$$

$$n(CO_2) = 4n(C_4H_{10}) = 0.004 \text{ mol}$$

$$\text{mass}(CO_2) = 0.004 \times 44 = 0.176 \text{ g}$$

Option A is incorrect. The mole ratio in the balanced equation has not been applied.

Option B is incorrect. The mole ratio in the balanced equation has been applied incorrectly.

Option D is incorrect. The units of volume in the question are mL, not L.

Tip

- *In Unit 2, you learnt about gases and used the ideal gas equation. In Unit 3, the SLC gas equation is the only gas equation you are expected to use.*

Question 5

Answer: D

Explanatory notes

Option D is correct. From the Data Book, the heat of combustion of oil is 37 kJ g^{-1}.

Energy released = 2 × 37 = 74 kJ = 74 000 J

Theoretical temperature change will be found from $q = 4.18 \times 1600 \times \Delta T = 74\,000$ J.

$\Delta T = 74\,000/(4.18 \times 1600) = 11.1$ °C

$$\% \text{ Efficiency} = \frac{8 \times 100}{11.1} = 72.3\%$$

Note: the correct answer can be arrived at in more than one way.

Option B is incorrect. It uses a 1.0 g sample instead of a 2.0 g sample.

Options A and C are incorrect. The answer is 72%.

Tip

- *There will be several instances on the Chemistry exam where the question does not seem to provide enough data. Often the answer will lie in the Data Book provided to you. For this question, for example, the energy content of fats and oils is provided as 37 kJ g^{-1}. Once you know this value, the question is relatively straightforward.*

Question 6

Answer: C

Explanatory notes

Option C is correct. The half-equations occurring during discharge are

$I_3^- + 2e^- \rightarrow 3I^-$

$Na \rightarrow Na^+ + e^-$ oxidation at the anode, which is negative

Overall eqn: $2Na + I_3^- \rightarrow 2Na^+ + 3I^-$

Voltage = 0.53 – (–2.71) = 3.24 V

The half-equations show that sodium releases electrons at the negative anode.

Option A is incorrect. The voltage and anode reactant are both wrong.

Option B is incorrect. Sodium metal reacts at the anode.

Option D is incorrect. Sodium metal reacts rather than sodium ions, and the voltage is incorrect.

Tip

- *Most Chemistry exams include at least one question on a new, innovative battery system. You will not be familiar with the workings of this cell, but you should be confident that you have the skills to break it down into the half-equations occurring and to determine the polarity of the electrodes.*

Question 7

Answer: A

Explanatory notes

Option A is correct. From the solution to **Question 6**, the discharge reaction is

$2Na + I_3^- \rightarrow 2Na^+ + 3I^-$

Therefore, the recharge reaction is the reverse of this.

$2Na^+ + 3I^- \rightarrow 2Na + I_3^-$

Option B is incorrect. The equation is not balanced correctly.

Options C and D are incorrect. They are showing Na metal and I_3^- as the reactants, whereas they are the products.

Question 8

Answer: A

Explanatory notes

Option A is correct. The electrolysis of $Pb(NO_3)_2$ will lead to a reaction of water at the anode, producing oxygen gas, and lead ions at the cathode, producing lead metal.

Option B is incorrect. Electrolysis of $Al(NO_3)_3$ will produce a gas at both electrodes.

Option C is incorrect. Copper is brown or orange in colour rather than grey.

Option D is incorrect. The iodine produced at the anode will not be a colourless gas.

Tip

- *Answering this question requires a thorough understanding of how to use the electrochemical series for both galvanic and electrolytic cells, given in the Data Book.*

Question 9

Answer: D

Explanatory notes

Option D is correct. When batteries are recharged, the polarity of each terminal does not change. The direction of electron flow does change but not the polarity.

Options A and B are incorrect. The polarity does not change.

Option C is incorrect. The voltage required for recharge needs to be slightly greater than the voltage produced during discharge.

Tip

- *One of the questions on the 2023 VCAA Chemistry exam referred to recharging and many students wrote that the polarity of the electrodes switches during recharge. This is not correct. The positive terminal during discharge will remain the positive terminal during recharge, and vice versa for the negative electrode.*

Question 10

Answer: C

Explanatory notes

Option C is correct. If the flask is placed on a balance, its mass will decrease with time as oxygen gas is evolved from the flask. The reaction rate is high at the start, then slows down as the reactant concentration drops.

Options A and B are incorrect. The volume and mass of gas evolved will increase and not decrease.

Option D is incorrect. The acidity level does not change significantly during this experiment.

Question 11

Answer: D

Explanatory notes

Option D is correct. If Run 2 is conducted at a higher temperature, the reaction rate will be faster due to the increase in the number of collisions between particles. The curve will drop more quickly but plateau at the same value.

Option A is incorrect. A greater volume of H_2O_2 will lead to a greater mass change.

Option B is incorrect. A higher concentration of H_2O_2 will lead to a greater mass change.

Option C is incorrect. The absence of a catalyst would lead to a slower reaction and a curve that decreases at a slower rate than Run 1.

Question 12

Answer: B

Explanatory notes

Option B is correct because the reaction is endothermic. If the temperature is increased, K will increase. Therefore, the forward reaction needs to be favoured for Q to move to K_2.

Option A is incorrect. It should refer to K_2.

Option C is incorrect. The value of Q needs to increase.

Option D is incorrect. The forward reaction is favoured.

Question 13

Answer: B

Explanatory notes

Option B is correct because 0.4 mol of NO_2 has formed, hence 0.2 mol of N_2O_4 reacted.
(Mole ratio N_2O_4 : NO_2 is 1 : 2)

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.4)^2}{0.8} = 0.2 \text{ M}$$

Options A and C are incorrect. The answer is 0.2 M.

Option D is the reciprocal of the correct answer.

Question 14

Answer: C

Explanatory notes

Option C is correct. The reaction is exothermic, therefore lowering the temperature will increase the yield. Similarly, increasing the pressure will increase the yield because the ratio of reactant : product particles is 3 : 2.

Option A is incorrect. It does not include statement III.

Option B is incorrect. Statement II is not correct.

Option D is incorrect. Statement IV is not correct.

Question 15

Answer: D

Explanatory notes

Option D is correct. To prepare a standard solution, the required mass needs to be dissolved in deionised water. The volume of deionised water used to dissolve the solid needs to be less than the volume of the flask. Once the solid has been dissolved, the flask can then be made up with deionised water. In this way, the exact solution volume is obtained.

Option A is incorrect. The flask should be rinsed with deionised water.

Option B is incorrect. The solid needs to be dissolved before the volume is made up.

Option C is incorrect. The solid should have been heated before weighing, if it needs to be heated at all.

Tip

- *The revised Study Design has a greater emphasis on sustainability and key chemical skills. You will need to ensure that you find several examples of suitable questions to include in your exam preparation.*

Question 16

Answer: D

Explanatory notes

Option D is correct. Aldehyde functional groups have a higher priority than a halo group. Numbering therefore starts on the right-hand side of the molecule. The chlorine atom is on the 4th carbon.

Option A is incorrect. The molecule is an aldehyde and not a carboxylic acid.

Option B is incorrect. Numbering has started from the wrong end of the molecule.

Option C is incorrect. The aldehyde functional group can be assumed to be on the first carbon, therefore the number 1 is not used.

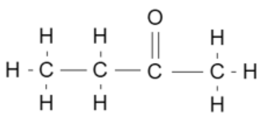
Tip

- *This is the first year that the naming of aldehydes and ketones has been part of the course. Be aware of which content is new to ensure that you cover it in your exam preparation.*

Question 17

Answer: A

Explanatory notes



Option A is correct. The presence of oxygen atoms adds significant dipoles to the structure of butanone, but a carbonyl bond cannot form hydrogen bonds with other carbonyl bonds.

Option B is incorrect. The C=O bonds do not contain a H atom to lead to hydrogen bonding.

Option C is incorrect. Dispersion forces are relatively weak.

Option D is incorrect. The covalent bonding is intramolecular.

Question 18

Answer C

Explanatory notes

Option C is correct. Linolenic acid is $C_{18}H_{30}O_2$ (from the Data Book). To make the ester, methanol is added and water is released. Molecular formula: $C_{18}H_{30}O_2 + CH_3OH – H_2O$, making the molecular formula $C_{19}H_{32}O_2$.

Options A and B are incorrect. They have not added the atoms from methanol to the linolenic acid molecule.

Option D is incorrect. Water is released when biodiesel forms.

Question 19

Answer: B

Explanatory notes

Option B is correct. The infrared spectrum includes a broad absorption around 3000 cm^{-1} and a sharp peak around 1700 cm^{-1}. These absorptions likely match –OH(acid) and C=O. Propanoic acid could produce these absorptions.

Option A is incorrect. The wave number of the broad absorption is too low.

Option C is incorrect. There is no broad absorption around 3300 cm^{-1} for the –OH bond.

Option D is incorrect. Ethyl propanoate would have no broad absorption.

Question 20

Answer: B

Explanatory notes

Option B is correct. The half-equations are both found in the Data Book:

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

When these two half-equations are combined and balanced, the overall equation is found to be

$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$

Options A, C and D are incorrect. They are not balanced equations.

Question 21

Answer: C

Explanatory notes

Option C is correct.

$n(MnO_4^-) = 0.2 \times 0.015 = 0.003$ mol

$n(Fe) = 5n(MnO_4^-) = 5 \times 0.003 = 0.015$ mol

mass(Fe) = $0.015 \times 55.8 = 0.837$ g

The other options have all used an incorrect ratio of Fe^{2+} to MnO_4^-, leading to incorrect answers.

Question 22

Answer: C

Explanatory notes

Option C is correct. The breakdown of the protein casein will be a hydrolysis reaction. Reforming the amino acids into a new protein will be a condensation reaction.

Option A is incorrect. The breaking of covalent bonds between the amino acids is hydrolysis, not denaturation.

Options B and D are incorrect. Oxidation is not occurring.

Question 23

Answer: C

Explanatory notes

Option C is correct. The formula to determine the degrees of unsaturation applied to benzene is

$$\text{maximum number of H atoms per C} - \text{actual number of H atoms per C} = \frac{14 - 6}{2} = 4$$

Options A, B and D are incorrect as the correct answer is 4.

Tip

- *The answer can be worked out without a formula but the formula above can be used, if needed.*

Question 24

Answer: A

Explanatory notes

Option A is correct. Hydrogen bonds can form between the hydroxyl group on serine and the carboxyl group on aspartic acid. Aspartic acid could also form ionic bonds with other amino acids but this does not mean it cannot form hydrogen bonds.

Option B is incorrect. Aspartic acid and lysine can form ionic bonds.

Option C is incorrect. Cysteine will not form hydrogen bonds.

Option D is incorrect. Leucine is non-polar.

Question 25

Answer: D

Explanatory notes

Option D is correct. Running standard ethanol solutions will identify which peak on the chromatogram is that of ethanol. The retention time of ethanol is likely to match one of the three peaks. The different concentrations of ethanol in the standard solutions can then be used to plot a calibration curve for the response of the HPLC to ethanol concentration. The area under the peak of the sample mixture can then be plotted on the calibration curve.

Option A is incorrect. It is not necessary to purify the sample and you would still need to run standard solutions to obtain a calibration curve.

Option B is incorrect. Converting all alcohols to carboxylic acids serves no useful purpose.

Option C is incorrect. The column is already separating the components of the mixture successfully.

Question 26

Answer: B

Explanatory notes

Option B is correct. Cyanide ions are acting as competitive enzyme inhibitors. They block the enzyme site, preventing it catalysing the reaction of cellular respiration.

Option A is incorrect. The enzyme shape is not changed.

Option C is incorrect. Denaturing is not occurring in this example.

Option D is incorrect. The problem is a limit on a desirable reaction occurring rather than an undesirable reaction happening.

Question 27

Answer: A

Explanatory notes

Option A is correct. After solvent extraction, the ethanol might contain over 30 potential active ingredients. Various forms of chromatography are used to separate these components to obtain pure samples of each that can be analysed.

Option B is incorrect. HPLC does not record boiling points.

Option C is incorrect. The identity of the ingredients is probably not known at this point.

Option D is incorrect. Identification of the active ingredients will require the use of several different instruments.

Question 28

Answer: B

Explanatory notes

Option B is correct. Part of a scientific poster is to reference note issues or hazards associated with the research covered.

Option A is incorrect. The author’s hypothesis might not be validated by the data, and this has to be acknowledged.

Option C is incorrect. The reader needs a sense of how confident the author is on the findings they are presenting.

Option D is incorrect. It is often useful to graph or tabulate the data in a way that the findings of the research are apparent to the reader.

Tip

- *This question refers to the Key Skills section of the study design. Be aware that the exam will test your understanding of this section.*

Question 29

Answer: A

Explanatory notes

Option A is correct. The three titres obtained are vastly different and the experimenter is not able to repeat the previous titre. It might be that it is too difficult to colour match the appearance of blue over the orange juice colour, or it might be that the reaction rate is very slow.

Option B is incorrect. There is no reason for the vitamin C levels in different parts of a solution to differ significantly.

Option C is incorrect. Reproducibility has not been tested.

Option D is incorrect. It is unlikely that the titres are accurate when they vary so much.

Question 30

Answer: C

Explanatory notes

Option C is correct. The scale readings provide the resolution of the burette which is 0.1 mL. The value should then be converted to decimal places, with any value between 44.5 and 44.6 being listed as 44.55.

Option A is incorrect. The scale has intervals of 0.1.

Options B and D are incorrect. The burette reading is between 44.5 and 44.6.

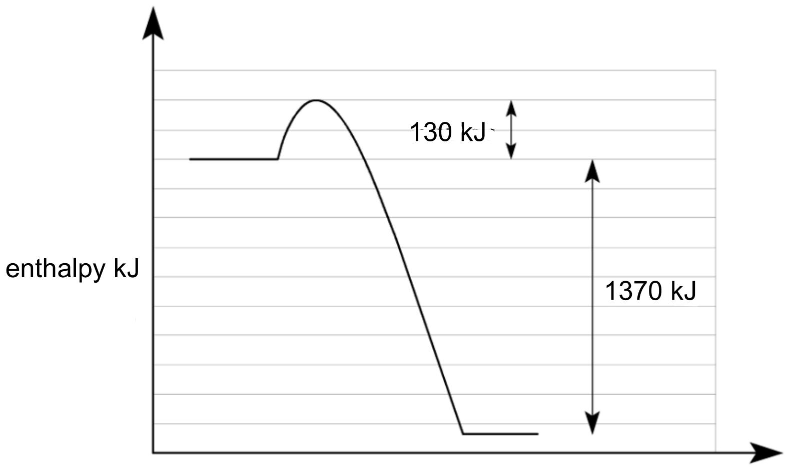
Tip

- *Different science references give different definitions of resolution. This question is based on the VCAA explanation found in the Study Design.*

Section B

Question 1a.

Worked solution



Explanatory notes

The activation energy is 130 kJ and the ∆*H* value, as given in the Data Book, is –1370 kJ.

Mark allocation: 2 marks

- 1 mark for the correct activation energy magnitude and labelling
- 1 mark for the correct ∆*H* and labelling

Question 1b.i.

Worked solution

Energy released = *m* × 29.7 = 113 kJ

Explanatory notes

The Data Book provides a heat of combustion figure of 29.7 kJ g^{-1} for bioethanol. This value is found on page 11 of the Data Book.

The energy released is then calculated from the mass × the energy from 1 g.

Mark allocation: 1 mark

- 1 mark for the correct answer and units

Question 1b.ii.

Worked solution

n(ethanol) = $\frac{3.8}{46}$ = 0.0826 mol

$n(CO_2)$ = 2n(ethanol) = 2 × 00826 = 0.165 mol

$V(CO_2)$ = n × 24.8 = 0.165 × 24.8 = 4.10 L

Explanatory notes

The number of mole of CO_2 needs to be calculated before the volume is calculated. From the balanced equation, the number of mole will be twice the number of mole of ethanol. The volume is then calculated using the formula $V = n \times V_m$.

Mark allocation: 2 marks

- 1 mark for the correct number of mole of ethanol
- 1 mark for the correct volume of CO_2 and units

Tip

- *This year the ideal gas equation (PV = nRT) is no longer in the Study Design. Expect that questions relating to gas volumes will use the equation $V = n \times V_m$.*

Question 1c.

Worked solution

The sugar cane waste is used rather than the sugar cane juice. The juice can be used for table sugar.

The CO_2 evolved is captured and so does not add to greenhouse emissions. It is used to make a useful product in methanol.

The remaining biomass is converted to fertiliser rather than becoming landfill.

Explanatory notes

Manufacturers seek to maximise the amount of useful product that can be gained from the one resource. They make table sugar, bioethanol and fertiliser, thus using all parts of the plant. The capture of CO_2 helps minimise the impact of the process on the environment.

Mark allocation: 3 marks

- 1 mark for each valid reason provided, with a maximum of 3 marks

Tip

- *Questions relating to sustainability are more explicit on the VCAA sample exam than in the past. These questions will refer to green chemistry principles and sustainability goals.*

Question 1d.i.

Worked solution

glycosidic link or ether bond

Explanatory notes

The –O– bond joining two monosaccharides is referred to as an ether bond or a glycosidic linkage.

Mark allocation: 1 mark

- 1 mark for either ether or glycosidic

Question 1d.ii.

Worked solution

CO_2 is produced during the fermentation reaction, where glucose is converted to ethanol. CO_2 is the other product of this reaction. The equation for this reaction is

$$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$$

Explanatory notes

The action of yeast on glucose produces ethanol and CO_2. The CO_2 bubbles continuously from the surface of the liquid during fermentation.

Mark allocation: 2 marks

- 1 mark for explaining where the CO_2 is produced
- 1 mark for the fermentation equation

Question 2a.i.

Worked solution

The student could use distillation to separate the alcohols. The alcohol with the lowest boiling point will boil first and can be collected from the top of the flask when it is condensed.

Explanatory notes

The mixture of ethanol and propan-2-ol can be heated in a distillation flask. The liquid with the lower boiling point (ethanol) will turn to a gas and be evolved from the top of the flask. If this gas is then cooled, a liquid sample of the ethanol is obtained. (Technically, fractional distillation would be a better option than simple distillation because the boiling point of propan-2-ol is only a few degrees higher than that of ethanol, but it is not an expectation that students know this.)

Mark allocation: 2 marks

- 1 mark for choosing distillation
- 1 mark for explaining how separation occurs

Question 2a.ii.

Worked solution

Alcohol compounds should form an ester when reacted with a carboxylic acid, using concentrated sulfuric acid as a catalyst. The presence of an ester can be detected from its odour.

Explanatory notes

The student could react each alcohol with a carboxylic acid such as ethanoic acid, using sulfuric acid as a catalyst. If the compound is an alcohol, a sweet-smelling ester will form. The presence of this odour confirms that an alcohol molecule was part of the reaction.

Mark allocation: 2 marks

- 1 mark for identifying esterification as a likely method to use
- 1 mark for referring to the fruity odour of most esters

Tip

- *This question is an example of how the phrasing of a question is intentionally used to provide clues to the approach expected. There are several ways of trying to test whether molecules are alcohols, but the question suggests using ethanoic acid. This is a pointer to the expected approach of forming esters from the molecules.*

Question 2a.iii.

Worked solution

Both liquids can be reacted with acidified dichromate ions, $Cr_2O_7^{2-}$. Ethanol will be oxidised to ethanoic acid, whereas propan-2-ol will be oxidised to propanone. Ethanoic acid is a weak acid whereas propanone is neutral. pH paper could be used to distinguish between the two products.

Explanatory notes

Dichromate ions will oxidise both alcohols but ethanol forms ethanoic acid whereas propan-2-ol forms a ketone (propanone).

Ethanol + $Cr_2O_7^{2-}/H^+ \rightarrow$ ethanoic acid

propan-2-ol + $Cr_2O_7^{2-}/H^+ \rightarrow$ propanone

Any test for acidity could be used to distinguish ethanoic acid from propanone. Ethanoic acid, for example, will react with magnesium to evolve hydrogen gas, but propanone will not.

Mark allocation: 3 marks

- 1 mark for suggesting oxidation with acidified $Cr_2O_7^{2-}$
- 1 mark for the reaction of ethanol to ethanoic acid and propan-2-ol to propanone
- 1 mark for a method of testing whether a liquid is acidic

Question 2b.

Worked solution

n(linolenic acid) = $\frac{1}{278}$ = 0.00360

n(iodine) = 3n(linolenic acid) = 0.0108 mol

$V = \frac{n}{c} = \frac{0.0108}{0.2}$ = 0.0540 L

Explanatory notes

Each molecule of linolenic acid contains 3 C=C double bonds. Therefore, the mole ratio of linolenic acid : iodine will be 1 : 3.

Mark allocation: 3 marks

- 1 mark for n(linolenic acid)
- 1 mark for n(iodine)
- 1 mark for the correct volume

Question 3a.i.

Worked solution

Number of carbon atoms	**Possible molecular formula**
4	$C_4H_6O_2$
5	$C_5H_{10}O$

Explanatory notes

The question states that the compound contains carbon, hydrogen and oxygen. The mass spectrum shows the parent molecular ion with an m/z ratio of 86. The most likely formulas are C_4 with 2 O atoms or C_5 with 1 O atom. The number of H atoms in the molecular formula is arranged for the relative molecular mass to arrive at 86.

Mark allocation: 2 marks

- 1 mark for each molecular formula

Question 3a.ii.

Worked solution

The presence of a heavier isotope of C, H or O, such as ^{13}C

Explanatory notes

The m/z peak of 87 is one above the molecular formula value of 86. It is a small peak and will be due to the presence of a heavier isotope of one of the atoms present.

Mark allocation: 1 mark

- 1 mark for any valid isotope, such as ^{2}H, ^{13}C or ^{17}O.

Question 3b.

Worked solution

Conclusion 1: The compound contains a C=O (carbonyl) bond, indicated by the absorption around 1720 cm^{-1}.

Conclusion 2: The absence of a broad absorption between 2500 and 3600 cm^{-1} rules out the presence of any form of –OH functional group.

Explanatory notes

As the molecule contains oxygen, the infrared spectrum should be checked for the presence of hydroxyl or carbonyl bonds. The absorption around 1720 cm^{-1} confirms a carbonyl bond, but the lack of a broad peak above 2600 cm^{-1} rules out an –OH group.

Mark allocation: 2 marks

- 1 mark for each valid peak reference

Question 3c.i.

Worked solution

Two hydrogen environments.

Explanatory notes

The ^{1}H NMR shows two sets of peaks, indicating two different hydrogen environments.

Mark allocation: 1 mark

- 1 mark for a correct answer of 2

Question 3c.ii.

Worked solution

The area ratio is 2 : 3.

Explanatory notes

The heights of the peaks are in the ratio of 2 : 3, therefore the ratio between the hydrogen atoms is 2 : 3.

Mark allocation: 1 mark

- 1 mark for the ratio 2 : 3

Tip

- *Make sure you take a ruler into the Chemistry exam. It would be difficult to determine the exact ratio of 2 : 3 without a ruler to measure the length of the integration peaks. A ruler is also helpful for reading the axes values in graphical questions.*

Question 3c.iii.

Worked solution

The molecular formula must be $C_5H_{10}O$.

Explanatory notes.

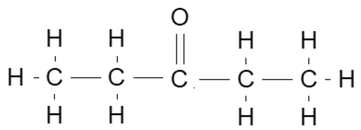
The ratio of hydrogen atoms in the two peaks has been found to be 2 : 3. If the actual number is double that (i.e. 4 and 6), then the total number of hydrogen atoms is 10, giving a formula that matches $C_5H_{10}O$.

Mark allocation: 1 mark

- 1 mark for the correct molecular formula

Question 3d.i.

Worked solution



Explanatory notes

The structure shown fits all of the evidence provided,

- relative molecular mass of 86
- molecular formula of $C_5H_{10}O$
- two hydrogen environments
- hydrogen ratio of 2 : 3.

Mark allocation: 2 marks

- 1 mark for a structure with the correct molecular formula
- 1 mark for the correct structure

Question 3d.ii.

Worked solution

pentan-3-one

Explanatory notes

The molecule has 5 carbon atoms, hence ‘pent-’. It is a ketone with the ketone group on the third carbon atom, hence pentan-3-one.

Mark allocation: 1 mark

- 1 mark for the correct answer of pentan-3-one

Question 4a.i.

Worked solution

$Ca^{2+}(l) + 2Cl^{-}(l) \rightarrow Ca(l) + Cl_2(g)$

Explanatory notes

Calcium ions are reduced at the negative electrode and chloride ions are oxidised at the positive electrode.

Mark allocation: 1 mark

- 1 mark for the correct reactants and products

Question 4a.ii.

Worked solution

The calcium electrode is the negative electrode. (The circle on the diagram needs to show a negative sign.)

Explanatory notes

Calcium ions are reduced. Reduction occurs at the cathode and the cathode is negative in an electrolytic cell.

Mark allocation: 1 mark

- 1 mark for a negative sign written in the circle

Question 4a.iii.

Worked solution

Minimum voltage needs to be greater than 1.36 – (–2.87); that is, 4.23 V.

Explanatory notes

The Data Book provides a half-equation potential of 1.36 V for chloride ions and –2.87 V for calcium ions. A voltage slightly over the voltage difference must be used to drive the electrolytic cell. (The exact half-cell potentials will be slightly different from the values above, as non-standard conditions are used.)

Mark allocation: 1 mark

- 1 mark for a voltage over 4.23 V. (**Note:** simply writing 4.23 V is not an acceptable answer.).

Question 4a.iv.

Worked solution

A small addition of $BaCl_2$ causes a large drop in the melting point of the electrolyte. This significantly lowers the amount of energy required to drive this reaction. Sustainability is improved when the energy demand is less.

Explanatory notes

The energy required to melt large masses of calcium chloride is very high. If the temperature required can be lowered by about 100 °C, considerable energy savings can be made. Given the cost of energy, this improves the sustainability of the process.

Mark allocation: 1 mark

- 1 mark for stating that a decrease in energy consumption is possible

Question 4b.i.

Worked solution

anode: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

cathode: $2H^+ + 2e^- \rightarrow H_2$

Explanatory notes

Water reacts at the anode to produce oxygen gas and hydrogen ions. The hydrogen ions migrate to the negative electrode, where hydrogen gas is formed. A PEM cell does not use an aqueous electrolyte.

Mark allocation: 2 marks

- 1 mark for each correct half-equation. (States are not required as it is non-aqueous.)

Tip

- *Both of the half-equations required in this question can be found in the electrochemical series in the Data Book. You do not have to write them from first principles.*

Question 4b.ii.

Worked solution

Hydrogen gas is highly flammable, therefore fire safety precautions need to be in place for its transport. The density of hydrogen gas is low, so it is often liquified to increase its density.

Explanatory notes

Transport of hydrogen gas is challenging due to the flammability of hydrogen and its low density as a gas. It is costly to convert the gas to a liquid.

Mark allocation: 2 marks

- 1 mark for noting the flammability of hydrogen
- 1 mark for noting the low density of hydrogen

Question 5a.

Worked solution

$2NO(g) \rightleftharpoons N_2(g) + O_2(g)$ N: reduced

$CO(g) + O_2(g) \rightleftharpoons CO_2(g)$ C: oxidised

Explanatory notes

The oxidation state of nitrogen changes from +2 to 0 in the first equation, hence reduction.

The oxidation state of carbon changes from +2 to +4 in the second equation, hence oxidation.

Mark allocation: 2 marks

- 1 mark for each correct change

Question 5b.

Worked solution

The use of long thin tubes maximises the surface area of the catalyst, helping to ensure that the reactant gases contact the catalyst.

Explanatory notes

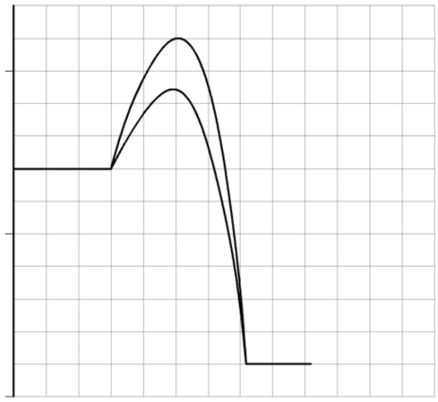
In the exhaust of a car, a high volume of hot gas needs to pass quickly over a catalyst. The higher the surface area, the more likely the gases will react.

Mark allocation: 1 mark

- 1 mark for an answer that emphasises the importance of maximising the surface area

Question 5c.

Worked solution



Explanatory notes

A catalyst lowers the activation energy but does not change the ΔH value.

Mark allocation: 1 mark

- 1 mark for a correct diagram

Question 5d.

Worked solution

Reason 1: When the car first starts, the temperature is lower, so the rate of reaction will be lower, with fewer particles having sufficient energy to react.

Reason 2: Both reactions are reversible. The value of the equilibrium constant will differ between the two temperatures, affecting the yield.

Explanatory notes

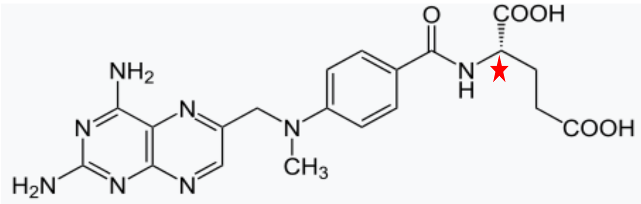
The temperature difference will impact both the yield and the rate of both reactions. The rate will be lower, decreasing the effectiveness of the catalyst. The impact on yield will depend upon whether the reactions are exothermic or endothermic. (The reaction of CO is exothermic, whereas the reaction of NO is endothermic.)

Mark allocation: 2 marks

- 1 mark for each valid difference

Question 6a.

Worked solution



The carbon atom in D-methotrexate marked on the diagram with a red asterisk is a chiral carbon. It has 4 different atoms or groups attached to it. This means there will be 2 different spatial arrangements of the molecule possible that cannot be superimposed on each other.

Explanatory notes

Methotrexate has two enantiomers due to the presence of a chiral carbon. If a mirror image of one form of methotrexate is prepared, it cannot be superimposed on the first enantiomer due to the different spatial arrangements around the chiral carbon. The enantiomers will have similar properties but will differ in the direction in which they rotate polarised light.

Mark allocation: 2 marks

- 1 mark for identifying a chiral carbon
- 1 mark for explaining the significance of a chiral carbon

Question 6b.i.

Worked solution

D-methotrexate acts as a competitive enzyme inhibitor to the enzyme that catalyses the reaction of folic acid. This is possible due to the very similar shapes of folic acid and methotrexate. If D-methotrexate molecules occupy the enzyme's active site, the enzyme will not catalyse the harmful reaction of folic acid, limiting the spread of cancerous cells.

Explanatory notes

Competitive enzyme inhibitors act by occupying enzyme's active sites, making the usual functioning of the enzyme less likely. The relative concentrations of the inhibitor and the usual substrate will impact the extent to which the usual reaction is blocked.

Mark allocation: 3 marks

- 1 mark for mentioning the similar shapes of the two molecules
- 1 mark for explaining the competition for the enzyme site
- 1 mark for describing the consequence of methotrexate occupying this site

Question 6b.ii.

Worked solution

L-methotrexate has a different spatial arrangement around the chiral carbon. This arrangement does not complement the enzyme's active site, so it is not effective as an inhibitor.

Explanatory notes

The two enantiomers have similar structures but, to the body, they are like different molecules. The spatial arrangement around D-methotrexate matches that of the enzyme's active site but the spatial arrangement around L-methotrexate does not.

Mark allocation: 2 marks

- 1 mark for identifying the different spatial arrangement of each enantiomer
- 1 mark for explaining how this different arrangement affects the interaction with an enzyme's active site

Question 6c.

Worked solution

The higher the purity of the folic acid sample, the closer the melting point will be to 250 °C and the narrower the range of the melting point. As the methotrexate content increases, the melting point will be more difficult to discern and it will be further from 250 °C.

Explanatory notes

Small levels of impurity affect the ability of molecules of a substance to bond with each other to form a solid. The greater the level of impurity, the more significant the interference is. As a general rule, if the substance is pure the melting point will be within 2 °C of the accepted value.

Mark allocation: 2 marks

- 1 mark for explaining the melting point of a pure sample
- 1 mark for explaining the impact of increasing levels of impurity

Tip

- *This question assesses several concepts that are in the study design for the first time in 2024:*
  - *the use of melting points to test purity*
  - *the action of competitive enzyme inhibitors*
  - *the reactions of enantiomers in the human body.*

  Take steps to ensure you are familiar with this new content.

Question 7a.

Worked solution

Compounds A and E

Explanatory notes

Biodiesel can be formed from the condensation reaction between a fatty acid and an alcohol. Methanol is the more common alcohol used but ethanol will also form biodiesel.

Mark allocation: 1 mark

- 1 mark for nominating Compounds A and E

Tip

- *Scanning through the food molecules included in the Data Book will be useful for questions of this type. The similar molecules provided in the Data Book can reassure you that you are on the right path.*

Question 7b.

Worked solution

Compounds A and C

Explanatory notes

Three molecules of fatty acid can react with glycerol to form a triglyceride.

Mark allocation: 1 mark

- 1 mark for nominating Compounds A and C

Question 7c.

Worked solution

Compound A

Explanatory notes

Compound A has the least partial oxidation. It will release the most energy when combusted. Compound A is similar to a fat or oil, which has a higher energy density than proteins or carbohydrates.

Mark allocation: 1 mark

- 1 mark for nominating Compound A

Question 7d.

Worked solution

1 only

Explanatory notes

The only peptide bond present is the join between the two amino acids in compound D.

Mark allocation: 1 mark

- 1 mark for the answer of 1

Question 7e.

Worked solution

glucose

Explanatory notes

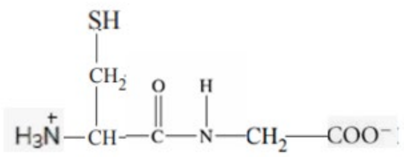
Compound B is a disaccharide because it consists of two glucose molecules. Hydrolysis will produce glucose.

Mark allocation: 1 mark

- 1 mark for stating glucose

Question 7f.

Worked solution



(**Note:** Compound F could form a similar zwitterion because it contains the same two functional groups.)

Explanatory notes

Compound D will form a zwitterion. Compound F is not an amino acid but it could also form a zwitterion.

Mark allocation: 1 mark

- 1 mark for the correct diagram

Question 7g.

Worked solution

Compound A

Explanatory notes

The fatty acid molecule has a long hydrocarbon chain, leading to a molecule that is virtually non-polar.

Mark allocation: 1 mark

- 1 mark for nominating Compound A

Question 8a.

Worked solution

Dependent variable: voltage produced by the cell.

A controlled variable: possible answers include concentration of the solutions, volume of the solutions and salt bridge solution.

Explanatory notes

The independent variable is the cell temperature. The voltage produced will depend upon the temperature.

Controlled variables include solution temperature and volume. The electrode depth and separation are also possible answers.

Mark allocation: 2 marks

- 1 mark for the voltage produced
- 1 mark for a controlled variable

Question 8b.i.

Worked solution

$Ag^+(aq) + e^- \rightarrow Ag(s)$

Explanatory notes

Ag^+ ions are the strongest oxidising agent in this cell and Ni metal is the strongest reducing agent.

The overall reaction is $2Ag^+(aq) + Ni(s) \rightarrow 2Ag(s) + Ni^{2+}(aq)$.

Reduction occurs at the positive cathode in a galvanic cell, so the half-equation is

$$Ag^+(aq) + e^- \rightarrow Ag(s)$$

Mark allocation: 1 mark

- 1 mark for the half-equation above, including the states

Question 8b.ii.

Worked solution

$n(\text{Ni}) = \dfrac{m}{M} = \dfrac{0.0587}{58.7} = 0.001 \text{ mol}$

$n(\text{Ag}^+)$ reacting = $2n(\text{Ni}) = 2 \times 0.001 = 0.002$ mol

mass(Ag) = $m \times M$ = 107.9 × 0.002 = 0.216 g = 0.22 g (to 2 significant figures)

Explanatory notes

The mass change at the nickel electrode can be used to calculate the number of mole of nickel reacting. The balanced equation shows the number of mole of silver reacting is double that of the nickel, due to the charge on silver ions being Ag^+ compared to the charge on nickel ions being Ni^{2+}. The mass change can be calculated from the number of mole. One of the electrodes is gaining mass and the other is losing mass but that does not affect the working.

Mark allocation: 3 marks

- 1 mark for calculating the number of mole of nickel
- 1 mark for showing that the number of mole of silver is double that of nickel
- 1 mark for the correct answer, in g

Question 8c.i.

Worked solution

The student's conclusion assumes that the experimental data is flawed because it does not support the student's prior knowledge. The student needs to consider the data from an impartial point of view and to think about what the data suggests. Given that there is an evident trend in the voltage change with temperature, other conclusions are possible.

Explanatory notes

The data shows a trend in the voltage dropping as the temperature increases. Given that this is a consistent trend, the student needs to consider that this is a valid result and that the data might not be flawed. (The voltage values are below the value predicted from the electrochemical series because standard conditions were not used.)

Mark allocation: 2 marks

- 1 mark for suggesting that the student's conclusion that the data is flawed is not a reasonable conclusion
- 1 mark for a valid reason why the data might in fact be valid (e.g. a consistent trend in voltage change can be seen)

Question 8c.ii.

Worked solution

The data suggests that the voltage of the cell drops as the temperature increases. This relationship would need to be tested for a wider range of solutions and solution concentrations before this conclusion is confirmed.

Explanatory notes

There is a definite decrease in voltage as the temperature increases. Whether this applies in all circumstances has not been tested.

(**Note:** It is not necessary for this question, but the effect of temperature on voltage is explained by the Nernst equation. Whether the voltage increases or decreases with temperature depends upon the relative concentrations of the two solutions. In this case, the lower concentration of the silver solution will lead to a voltage drop.)

Mark allocation: 2 marks

- 1 mark for identifying the trend evident between voltage and temperature
- 1 mark for acknowledging that one cell with different solution concentrations provides a very limited dataset

Tip

- *Students often assume that increasing the temperature must lead to an increase in reaction rate. This is not necessarily the case with galvanic cells.*

Question 8d.

Worked solution

The student's use of inconsistent temperature increments will not affect the validity of the experiment. As long as the temperature and voltage are read carefully, any trends will still be evident.

Explanatory notes

The voltage produced by this cell is dropping with each temperature rise. As long as the temperature and voltage are measured carefully, it will not matter what the temperature increments are. If the data is plotted, the line of best fit should be similar whether or not even temperature increments were used.

Mark allocation: 2 marks

- 1 mark for stating that consistent increments are not essential
- 1 mark for a valid reason why consistent increments are not essential (e.g. that the same trend will be evident)

Question 8e.

Worked solution

An obvious change would be to include some gentle stirring of the solutions. Stirring will ensure that all the liquid in the beakers is at the same temperature.

Explanatory notes

The temperature of the contents of a beaker sitting on a hot plate will vary, causing the temperature readings to be dependent upon where you are holding the thermometer. Stirring the contents will eliminate this problem. Other possible answers might focus on ensuring that the electrode depth and separation is constant all the way throughout the experiment.

Mark allocation: 1 mark

- 1 mark for the necessity of stirring or for another valid suggestion

Tip

- *The VCAA Chemistry exams have featured a question on experimental procedures and design for many years now. Expect that you will have to identify the independent and dependent variables and interpret data for any trends or inconsistencies it might show. Where data is provided, examine the data carefully and don't restrict your thinking to your theoretical understanding of the concept. Be aware also that the Study Design now includes the term* resolution *this year, not just* reproducibility *and* repeatability*.*

Question 9a.i.

Worked solution

The ratio of reactant : product molecules in this reaction is 1 : 2. Therefore, the use of a low pressure will favour the forward reaction, increasing the yield of ethene.

Explanatory notes

If a low pressure is used, the system moves to favour the side with more particles, that is, the products. This improves the yield.

Mark allocation: 2 marks

- 1 mark for stating the reactant : product ratio
- 1 mark for explaining that using a low pressure leads to a higher yield

Question 9a.ii.

Worked solution

The production of ethene is an endothermic reaction. The value of *K* increases with temperature. Therefore, higher temperatures will increase the yield.

Explanatory notes

A system partially opposes change. If the temperature is increased, the forward reaction of an endothermic process is favoured to remove heat. This leads to a higher yield. Very high temperatures are not used due to the impact of side reactions.

Mark allocation: 2 marks

- 1 mark for stating that the reaction is endothermic
- 1 mark for stating that higher temperatures favour higher yields

Tip

- *This question refers to a reversible reaction that is endothermic rather than exothermic. Most questions use exothermic reactions, but this does not mean you should not watch for endothermic examples.*

Question 9b.

Worked solution

Gas is a fossil fuel, depleting reserves and adding to CO_2 emissions. The use of electrical energy obtained renewably solves both of these problems: it does not drain scarce reserves nor produce high volumes of CO_2.

Explanatory notes

The use of electrical energy from renewable sources is occurring in the green hydrogen industry. Using renewable energy means the production process is not draining the Earth's scarce resources and it leads to lower CO_2 emissions.

Mark allocation: 2 marks

- 1 mark for stating the necessity of obtaining electrical energy from renewable sources
- 1 mark for explaining the positive impact of this change

Question 9c.i.

Worked solution

$2CO_2 + 12H^+ + 12e^- \rightarrow C_2H_4 + 4H_2O$

Explanatory notes

Balance this half-equation in stages:

$2CO_2 \rightarrow C_2H_4 + 4H_2O$

$2CO_2 + 12H^+ \rightarrow C_2H_4 + 4H_2O$

$2CO_2 + 12H^+ + 12e^- \rightarrow C_2H_4 + 4H_2O$

Mark allocation: 1 mark

- 1 mark for the correct half-equation

Tip

- *Note the technique used in the explanatory notes to write this half-equation.*
  The procedure below is a useful one to adopt.
  - *Step 1: Balance the key element, carbon.*
  - *Step 2: Balance the oxygen atoms, using H_2O.*
  - *Step 3: Balance the hydrogen atoms, using H^+.*
  - *Step 4: Balance the charge, using electrons.*

Question 9c.ii.

Worked solution

CO_2 (+4) $\rightarrow$ C_2H_4 (–2)

Explanatory notes

Assuming that H is +1 and O is –2 allows the oxidation state of carbon to be determined as +4 in CO_2 and –2 in C_2H_4.

Mark allocation: 1 mark

- 1 mark for the correct oxidation state change

Question 9c.iii.

Worked solution

The use of a fuel cell supports the green chemistry principle of preferring 'less hazardous substances'. Using ethane at the lower temperatures as those used by an electrolytic cell avoids the dangers of handling ethane and ethene at temperatures over 800 °C.

Another green chemistry principle is 'design for energy efficiency'. The use of renewable energy to power the fuel cell will use far less non-renewable energy at 800 °C than a gas-fired plant.

Explanatory notes

The conversion of ethane to ethene at temperatures over 800 °C is both energy intensive and hazardous. The use of an electrolytic cell powered by renewable energy offers the potential for a safer and more efficient production method.

Mark allocation: 2 marks

- 1 mark for each relevant green chemistry principle mentioned

Question 10

Worked solution

Pathway 1: ethane + Cl_2(UV) → chloroethane + KOH → ethanol + $Cr_2O_7^{2-}/H^+$ → ethanoic acid

Pathway 2: sugar → glucose + yeast → ethanol + microorganisms → ethanoic acid

Sustainability improvements:

- Waste from the grape industry might be difficult to dispose of, so converting it to a useful product solves this problem. The use of ethane from fossil fuels is harmful to the environment because fossil fuels have to be mined and are a scarce resource.
- Fermentation can take place at temperatures around 35 °C. This is a much lower temperature than required in the production of chloroethane. Considerable energy savings are possible when high temperatures are not required.
- The use of natural microorganisms as catalysts in the fermentation process offers improved safety for workers compared to using high-temperature processes and are less draining on resources than the synthetic catalysts used in Pathway 1.

Explanatory notes

The reactions in Pathway 1 feature several toxic chemicals that need to be handled carefully. The raw materials are scarce fossil fuels that have many other important uses. The temperatures required for the reactions are very high, increasing the energy costs of manufacture. Switching to Pathway 2 addresses most of these issues. The biomass used can be handled fairly easily and high temperatures are not required. The biomass can be replenished sustainably. The use of microorganisms as catalysts also limits the deletion of resources.

Mark allocation: 5 marks

- 1 mark for each valid pathway to make ethanoic acid
- 1 mark for each valid sustainability gain (up to 3 marks)

End of Worked Solutions

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