insight™

YEAR 12 *Trial Exam Paper*

2014
CHEMISTRY
Written examination

Solutions book

This book presents:

- correct solutions with full working
- explanatory notes
- tips mark allocations
- tips and guidelines

SECTION A – Multiple-choice questions

Question 1

Answer is D

Worked solution

- D is correct. The number of moles of each alternative has to be calculated and then compared.

  $$n(\text{CaCO}_3) = \frac{m}{M} = \frac{300}{100} = 3 \text{ mol}$$

  $$n(\text{O}) = 3n(\text{CaCO}_3) = 9 \text{ mol}$$

- A is a lower value than 9. $n(\text{O}_2) = \frac{67.2}{22.4} = 3$ mol. $n(\text{O}) = 2 \times 3 = 6$ mol
- B is a lower value than 9. $n(\text{SO}_2) = \frac{128}{64} = 2$ mol. $n(\text{O}) = 2 \times 2 = 4$ mol
- C is a lower value than 9.

Tip

- *In questions of this nature, make sure you focus on the quantity asked for, in this case 'number of oxygen atoms'. If the question was 'mass of oxygen' or 'mole of compound', then the answer might be quite different.*

Question 2

Answer is C

Worked solution

- C is correct. A balanced equation for the reaction is needed:

  $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$

  $n(CH_3OH) = \frac{m}{M} = \frac{64}{32} = 2 \text{ mol}$

  2 mol of methanol reacts with 3 mol of oxygen gas.
- A is incorrect as the answer is 3.
- B is incorrect as the answer is 3.
- D is incorrect as the answer is 3.

Question 3

Answer is B

Worked solution

- B is correct. A balanced equation is required:

  $4Na + O_2 \rightarrow 2Na_2O$

  $n(Na) = \frac{m}{M} = \frac{92}{23} = 4 \text{ mol}$ $n(O_2) = \frac{m}{M} = \frac{34}{32} = 1.06 \text{ mol}$

  From the balanced equation, 4 mol of Na will react with 1 mol of O_2.
  1 mol of O_2 is 32 g. This leaves 2 g of oxygen gas unreacted.
- A is incorrect as the answer is 2 g of oxygen.
- C is incorrect as the answer is 2 g of oxygen.
- D is incorrect as the answer is 2 g of oxygen.

Question 4

Answer is A

Worked solution

- A is correct. Reading from the graph an absorbance of 3 corresponds to a concentration of 25 mg L^{-1} of Na^+ ions. The concentration needs to be changed to M.

  $$n\left(\text{in 1 litre}\right) = \frac{m}{M} = \frac{0.025}{23} = 1.1 \times 10^{-3}$$

  As the volume is 1 litre, concentration is also 1.1×10^{-3} M.
- B is incorrect as the answer is 1.1×10^{-3}.
- C is incorrect as the answer is 1.1×10^{-3}. Incorrect unit conversion used.
- D is incorrect as the answer is 1.1×10^{-3}.

Tip

- *You may find the unit 'mg L^{-1}', difficult to handle. It is a measure of concentration but it is a 'mass per volume', not a 'mole per volume'. mg L^{-1}, mass per volume; M, mole per volume.*

Question 5

Answer is C

Worked solution

- C is correct. If sodium is present in town water supply, an absorbance will be recorded so option I is feasible.
  Option II is not feasible as a sodium lamp cannot be used for potassium solutions.
  Option III is feasible as sausage meat contains sodium ions. The negative ion present is irrelevant.
- A is incorrect as option I is also possible.
- B is incorrect as option III is also possible.
- D is incorrect as option II is not possible.

Question 6

Answer is D

Worked solution

- D is correct. n(citric acid) $= c \times V = 0.02 \times 0.25 = 0.005$ mol
  n(NaOH) $= c \times V = 0.4 \times 0.0375 = 0.015$ mol
  Ratio between the citric acid and the sodium hydroxide is 1:3 $\Rightarrow$ citric acid is triprotic.
- A is incorrect as citric acid is triprotic.
- B is incorrect as citric acid is triprotic.
- C is incorrect as citric acid is triprotic.

Question 7

Answer is B

Worked solution

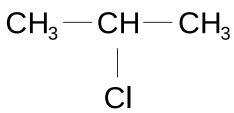
- B is correct. In IO_4^- the oxidation number of iodine is +7. This can be determined by assuming oxygen has a charge of –2. In IO_3^- the iodine is +5, determined in the same way by assuming oxygen has an oxidation number of –2.
- A is incorrect as the oxidation number goes from +7 to +5.
- C is incorrect as the oxidation number goes from +7 to +5.
- D is incorrect as the oxidation number goes from +7 to +5.

Question 8

Answer is A

Worked solution

- A is correct. 2-Chloropropane (shown here) has two different hydrogen environments.

  One hydrogen has six neighbours, so its signal will be a septet.
  The two methyl groups have one neighbour so their signal will be a doublet.
- B is incorrect as the spectrum for 1-chloropropane would have three sets of peaks.
- C is incorrect as there is no peak with a shift around 11 that matches a carboxylic acid.
- D is incorrect as all shifts in propane would be lower than 2.

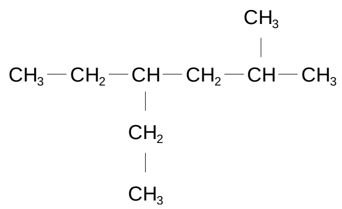
Question 9

Answer is A

Worked solution

- A is correct. The molecule should be numbered from the right-hand end to give the side chains the lowest possible numbers.

  6 5 4 3 2 1

  The methyl group is attached to carbon no. 2.
  The ethyl group is attached to carbon no. 4.
  The side chains should be in alphabetical order, so ethyl comes before methyl.
- B is incorrect as the numbering starts from the wrong end.
- C is incorrect as butane is not the longest chain.
- D is incorrect as this is not a linear alkane.

Tip

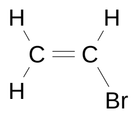
- *It is useful to bring a highlighter into the exam and trace out the longest possible carbon chain. In this case, the chain will be six carbon atoms long, making this a hexane.*

Question 10

Answer is B

Worked solution

- B is correct (shown here). The polymer is formed from an addition reaction of bromoethene.



- A is incorrect as the monomer must have a double bond.
- C is incorrect as the IUPAC name for the monomer should not include a 1.
- D is incorrect as it does not contain a carbon double bond.

Tip

- *Most addition monomers are derivatives of ethene. Try drawing ethene and adapting it to get the polymer desired.*

Question 11

Answer is C

Worked solution

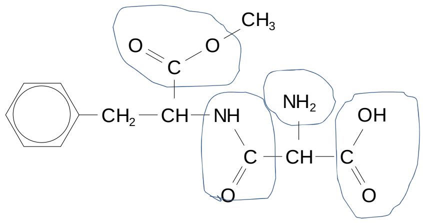
- C is correct. Locate lysine in the Data Book and count the atoms. The molecular formula is $C_6H_{14}O_2N_2$. This formula can be divided by 2 to give the empirical formula.
- A is incorrect as the atom ratio is wrong.
- B is incorrect as the number of nitrogen and oxygen atoms have not been divided by 2.
- D is incorrect as it is a molecular formula.

Tip

- *This is the first of several questions on the exam for which the Data Book must be used. When you think that a question has not supplied enough information, ask yourself whether the Data Book could help.*

Question 12

Answer is A



Worked solution

- A is correct. The four functional groups are circled and can be read from left to right.
- B is incorrect as there is no –OH group present and the amine group has been missed.
- C is incorrect as there is no –OH group present and the carboxyl group has been missed.
- D is incorrect as there is no –OH group present and the ester group has been missed.

Question 13

Answer is B

Worked solution

- B is correct. All reactions that form larger carbohydrate molecules are endothermic. This is a reaction between two monosaccharides to form a disaccharide. It will be endothermic.
- A is incorrect as fermentation is exothermic.
- C is incorrect as respiration is exothermic.
- D is incorrect as this is a very vigorous dehydration reaction.

Question 14

Answer is D

Worked solution

- D is correct. Milk contains proteins. Acid conditions denatures proteins. The protein is still a protein but its tertiary structure is disrupted.
- A is incorrect as the carbohydrates should not be affected by a weak acid.
- B is incorrect as the solubility of fatty acids is not affected.
- C is incorrect as the proteins are not broken down to amino acids.

Question 15

Answer is C

Worked solution

- C is correct. Between each G and C base there will be three hydrogen bonds, and between each A and T base there will be two hydrogen bonds. This makes a total of: 3 + 3 + 3 + 2 + 2 + 3 = 16
- A is incorrect as the total is 16.
- B is incorrect as the total is 16.
- D is incorrect as the total is 16.

Question 16

Answer is B

Worked solution

- B is correct. Enzymes have a unique 3D shape that is specific for one particular substrate. The molecule attaches to the enzyme where its bonds are weakened and a reaction can occur. After the molecule reacts, the products detach from the enzyme.
- A is incorrect as enzymes work for one specific reaction only.
- C is incorrect as enzymes work for one specific reaction only.
- D is incorrect as enzymes themselves do not react.

Question 17

Answer is D

Worked solution

- D is correct. The Data Book shows sucrose as a disaccharide formed from glucose and fructose. This is a hydrolysis reaction and it requires water.
- A is incorrect as sucrose is formed from glucose and fructose.
- B is incorrect as sucrose breaks down rather than polymerises.
- C is incorrect as enzymes denature at high temperatures.

Question 18

Answer is D

Worked solution

- D is correct. The equation asked for is the reverse of the one on the graph, making it an exothermic reaction, meaning ΔH is negative.
- A is incorrect as ΔH is negative.
- B is incorrect as ΔH is negative.
- C is incorrect as the activation energy is always positive.

Tip

- *Be alert to questions that provide information on a reaction and then ask about the reverse reaction.*

Question 19

Answer is C

Worked solution

- C is correct. All of the alternatives listed are acids. The solution with the highest OH^- concentration will be the weakest acid solution. From the Data Book, boric acid is the weakest acid. The concentration of 0.001 M HCl is lower than that of the boric acid but the very low K_a value for boric acid will lead to the boric acid solution having a higher pH.
- A is incorrect as HCl is a strong acid and will lead to a more acidic solution than C.
- B is incorrect as the concentration is higher than that of C.
- D is incorrect as methanoic acid is a stronger acid than boric acid.

Question 20

Answer is D

Worked solution

- D is correct. The correct answer needs to be an option that favours the forward reaction as there are more product molecules than reactant molecules. An increase in volume will decrease the pressure. The system will move forward to oppose this because the number of particles on the product side is greater than on the reactant side.
- A is incorrect as a decrease in temperature will favour the back reaction.
- B is incorrect as a catalyst will have no impact on the number of particles of an equilibrium mixture.
- C is incorrect as an increase in pressure will favour the back reaction.

Question 21

Answer is A

Worked solution

- A is correct. If the volume of the container is doubled, then each concentration will be immediately halved. The system will move to oppose this change but the immediate impact is still a halving of the concentration.
- B is incorrect. Each concentration is halved but this does not mean the concentrations are dropping by the 'same' amount.
- C is incorrect as the concentrations halve not double.
- D is incorrect. At the start the concentrations will be half the initial values but after the system responds, they will no longer be in that proportion.

Question 22

Answer is B

Worked solution

- B is correct. In pure water, $[H_3O^+]$ will be equal to $[OH^-]$. If the pH is 6.6, then $[OH^-]$ will be $10^{-6.6}$. For this to occur, the temperature is obviously not 25°C.
- A is not correct as the pH of water is only 7 at 25°C.
- C is incorrect as $[H_3O^+]$ will be equal to $[OH^-]$.
- D is incorrect as $[H_3O^+]$ and $[OH^-]$ must be equal in pure water.

Tip

- *You may find it hard to accept that the pH of water might not be 7. It is only 7 when the temperature is 25°C. What is always true is that $[H_3O^+]$ will be equal to $[OH^-]$ in pure water.*

Question 23

Answer is D

Worked solution

- D is correct. The values in the table are per mole and they clearly show pentane with a higher value than butane.
- A is incorrect. Per gram, rather than per mole, hydrogen releases more energy.
- B is incorrect. The values for the two isomers of propanol show this.
- C is incorrect. Ethanol releases less energy per mole or per gram than ethane.

Question 24

Answer is A

Worked solution

- A is correct.

  $n(\text{ethanol}) = \frac{0.5}{46} = 0.0109 \text{ mol}$

  $E = 0.0109 \times 1364$ (Data Book) = 14.8 kJ

  $\text{CF} = \frac{\text{energy}}{\Delta T} = \frac{14.8}{14.8} = 1$
- B is incorrect as the answer is 1.0.
- C is incorrect as the answer is 1.0.
- D is incorrect as the answer is 1.0.

Question 25

Answer is C

Worked solution

- C is correct. Sunlight is abundant and this compensates for the relative inefficiency of photovoltaic panels.
- A is incorrect as uranium undergoes fission in a reactor.
- B is incorrect as coal is not considered energy dense.
- D is incorrect as natural gas is a fossil fuel that is not renewable.

Question 26

Answer is C

Worked solution

- C is correct. To derive the equation requested, the second equation provided needs to be reversed and added to the first equation:

  $2CO_2(g) \rightarrow 2CO(g) + O_2(g)$
  $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

  This gives the desired equation but it also needs to be halved.
  This means Δ*H* will be:
  $\frac{(+566-484)}{2} = +41 \text{ kJ mol}^{-1}$
- A is incorrect as the Δ*H* of the second equation is positive when it is reversed.
- B is incorrect as the answer is +41.
- D is incorrect as only one of the two equations was reversed so both Δ*H* values were not positive.

Question 27

Answer is A

Worked solution

- A is correct. If the half equations are arranged in order of voltage, then the barium half equation will be the lowest one. In the barium half equation it is the Ba(s) that is the reductant.
- B is incorrect. $Ba^{2+}(aq)$ is a very different answer from Ba(s).
- C is incorrect as nickel is not the strongest reductant.
- D is incorrect as $Cd^{2+}(aq)$ is an oxidant.

Tips

- *The electrochemical series in your Data Book is in order of voltage. However, many references provide half equations in alphabetical order. Be sure to rearrange the half equations into order of voltage before applying your usual rules to them.*
- *When nominating a reductant or oxidant, be specific. In this question, Ba(s) is a correct answer but $Ba^{2+}(aq)$ is not.*

Question 28

Answer is B

Worked solution

- B is correct. Cadmium metal is more reactive than manganese and can replace it in solution.
- A is incorrect as it is the converse of option A so cannot work.
- C is incorrect as nickel is less reactive than barium.
- D is incorrect as nickel is less reactive than manganese.

Question 29

Answer is C

Worked solution

- C is correct. A definition of reduction is that it is the reaction that occurs at the cathode.
- A is incorrect as the anode is negative in a galvanic cell.
- B is incorrect as the electrons flow from the negative to the positive terminal in a galvanic cell.
- D is incorrect as electrolytic cells do not need a salt bridge.

Question 30

Answer is D

Worked solution

- D is correct. $Q = It = 2.5 \times 35 \times 60 = 5250$ C

  $n(\text{e}) = \dfrac{5250}{96500} = 0.0544 \text{ mol}$

  $n(\text{Sn}) = \dfrac{1.62}{118.7} = 0.01365 \text{ mol}$

  Ratio between 0.01366 and 0.0544 is 1:4 $\Rightarrow$ half equation is $Sn^{4+} + 4e^{-} \rightarrow Sn$
- A is incorrect as charge on tin was Sn^{4+}.
- B is incorrect as charge on tin was Sn^{4+}.
- C is incorrect as charge on tin was Sn^{4+}.

END OF SECTION A

SECTION B – Short-answer questions

Question 1a.i.

Worked solution

Fatty acids

Mark allocation: 1 mark

- 1 mark for fatty acid (Lipid or oil will not be accepted)

Question 1a.ii.

Worked solution

Linolenic acid

Mark allocation: 1 mark

- 1 mark for linolenic acid

Question 1a.iii.

Worked solution

Liquid. Linolenic acid is polyunsaturated. The presence of double bonds leads to weaker dispersion forces between the molecules and therefore a lower melting point.

Mark allocation: 1 mark

- 1 mark for answer of 'liquid' with an explanation that relates weak intermolecular bonds with a low melting point or states that plant oils are usually liquids at room temperature

Explanatory notes

The long non-polar chain followed by a carboxyl group is characteristic of a fatty acid. To identify the molecule, you have little choice other than to count the number of carbon and hydrogen atoms and to compare your total with the fatty acids listed in the Data Book. Linolenic acid is $C_{17}H_{29}COOH$. Unsaturated fatty acids are usually liquids at room temperature because the molecules do not pack together as well as those of saturated fatty acids.

Tip

- *Questions like these, showing whole fatty acids or triglycerides, have become more frequent; be prepared for them. You need to be able to look at the formula of each fatty acid in the Data Book and quickly tell whether it is unsaturated or not. Similarly, you need to expect that you might be asked for the combustion reaction of these molecules, even though the coefficients in the equations are very large.*

Question 1b.i.

Worked solution

Polyunsaturated means that the molecule contains more than one double or triple carbon-to-carbon bond. Linolenic acid has three.

Mark allocation: 1 mark

- 1 mark for stating that linolenic acid has more than one carbon-to-carbon double bond

Question 1b.ii.

Worked solution

Solubility in polar solvents such as water will be low because the fatty acid has a long hydrocarbon section that will be non-polar.

Mark allocation: 1 mark

- 1 mark for stating that linolenic acid has a long hydrocarbon section. This section will not dissolve in water

Explanatory notes

In a saturated molecule, the carbon-to-carbon bonds are all single bonds. In an unsaturated molecule, there is one or more double or triple carbon-to-carbon bonds. Polyunsaturated implies there is more than one carbon-to-carbon bond that is a double or triple bond. Linolenic acid has three carbon-to-carbon double bonds.
Fatty acids are all insoluble in water. The long hydrocarbon section is non-polar and will not dissolve in polar solvents such as water.

Tip

- *On the 2013 exam, it was not considered sufficient to say ‘the molecule has double bonds’. You need to be explicit that the double bonds are ‘carbon-to-carbon double bonds’.*

Question 1c.

Worked solution

$2C_{18}H_{30}O_2(l) + 49O_2(g) \rightarrow 36CO_2(g) + 30H_2O(g)$

Mark allocation: 2 marks

- 1 mark for correct products and phases
- 1 mark for correct coefficients

Explanatory notes

The products of any combustion reaction should be carbon dioxide and water. Careful balancing leads to the coefficients shown.

Tip

- *To balance these equations, use the following process:*
  - *Balance the carbon atoms.*
    $C_{18}H_{30}O_2(l) + O_2(g) \rightarrow 18CO_2(g) + H_2O(g)$
  - *Balance the hydrogen atoms.*
    $C_{18}H_{30}O_2(l) + O_2(g) \rightarrow 18CO_2(g) + 15H_2O(g)$
  - *Balance the oxygen atoms last.*
    $2C_{18}H_{30}O_2(l) + 49O_2(g) \rightarrow 36CO_2(g) + 30H_2O(g)$

Question 1d.

Worked solution

$$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH_2CH_2CH_2CH_2CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}OCH_3$$

Mark allocation: 1 mark

- 1 mark for correct structure

Explanatory notes

Biodiesel is formed when a fatty acid forms an ester with a small alkanol molecule. This produces the ester molecule given above and water.

Question 2a.

Worked solution

Change	**Effect of the change on the value of *K***	**Effect of the change on the colour intensity of the equilibrium mixture**
Addition of oxygen gas	no change	increase
Increase in the volume of the reactor	no change	decrease
Increase in temperature of the reactor	decrease	decrease

Mark allocation: 1 + 1 + 1 = 3 marks

- 1 mark for both answers in each row being correct

Explanatory notes

Addition of oxygen: Temperature is not changed so *K* does not change. The forward reaction is favoured by the oxygen addition, leading to the production of more brown particles.
Volume increase: Temperature is not changed so *K* does not change. Increase in volume causes the brown intensity to decrease. The system moves in the forward direction but only partially opposes this change.
Temperature increase: This is an exothermic reaction so the value of *K* decreases and the amount of NO_2 must also decrease, lowering the intensity of brown colour.

Question 2b.

Worked solution

The role of the catalyst is to increase the rate of the reaction, converting NO to NO_2 faster.

Mark allocation: 1 mark

- 1 mark for stating that the catalyst increases the rate of the reaction that forms NO_2

Explanatory notes

The role of a catalyst is to increase the rate of the reaction. It is important to do this while the gas is still in the exhaust system. The concentration of toxic NO in the air is reduced in this way.

Question 2c.

Worked solution

$2NO(g)$	+	$O_2(g)$	$\rightleftharpoons$	$2NO_2(g)$	
0		0		0.80	start
				0.64	equilibrium
0.16		0.08		0.16	change

$$K = \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{(0.64)^2}{(0.16)^2(0.08)} = 200\ M^{-1}$$

Mark allocation: 4 marks

- 1 mark for calculating the number of moles of NO at equilibrium
- 1 mark for calculating the number of moles of oxygen
- 1 mark for correct substitution into expression for *K*
- 1 mark for correct answer (units not required)

Explanatory notes

The equilibrium amounts of both reactants need to be calculated first. This is done by determining the amount of NO_2 that has reacted (0.16 mol).

$n(\text{NO formed}) = n(NO_2 \text{ reacting})$ as shown in balanced equation $= 0.16$

$n(O_2) = \frac{1}{2} n(NO_2) = 0.08$

These values are then substituted into the expression for *K*. The container is a 1 L container so the concentrations of each reactant are equal to the amounts.

Tip

- *Notice that the original amount of 0.80 mol quoted in the question is not used in the expression for* K. *This is because it is not an equilibrium amount. Be careful to recognise situations like this.*

Question 3a.i.

Worked solution

An α-amino acid has an amine group and a carboxyl group attached to the same carbon atom.

Mark allocation: 1 mark

- 1 mark for mentioning the amine group and carboxyl group and that they are attached to the same carbon

Question 3a.ii.

Worked solution

Amino acid B will be the least soluble because it has a non-polar side chain.

Mark allocation: 1 mark

- 1 mark for selecting amino acid B with a comment on the lack of dipoles on the side chain

Question 3a.iii.

Worked solution

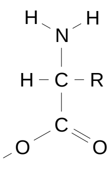
Amino acid A as it has a second amine group. Amine groups can act as bases.

Mark allocation: 1 mark

- 1 mark for selecting amino acid A and giving the second $–NH_2$ as the reason

Explanatory notes

α-Amino acids have an amine group and a carboxyl group attached to the same carbon atom. There are around 20 different possibilities for the R group on the molecule.



The nature of the R group will determine the solubility and acidity of the molecule. Atoms such as oxygen and nitrogen in the R group will increase polarity and solubility.

Tip

- *Recent exams have highlighted the need for precise language. Many students lose marks on the descriptive responses because their answers are not quite accurate. For example, if you said for part* **i.** *that an amino acid has a carboxyl group and an amine group, you would not receive a mark even though what you have said is true. An answer needs to be complete and specific.*

Question 3b.i.

Worked solution

6

Mark allocation: 1 mark

- 1 mark for the correct answer

Question 3b.ii.

Worked solution

2

Mark allocation: 1 mark

- 1 mark for the correct answer

Explanatory notes

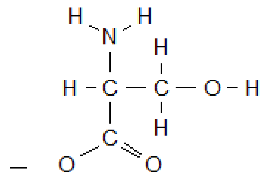
For three amino acids there will be six possible tripeptides:
ABC ACB BCA BAC CBA CAB
A peptide link forms between each two amino acids so a tripeptide will have two peptide bonds.

Tip

- *Keep in mind that the order in a dipeptide is important. AB (e.g. gly–ala) is a different molecule from BA (ala–gly) – they are structural isomers.*

Question 3c.

Worked solution



Mark allocation: 1 mark

- 1 mark for the structure shown. The negative sign must be included.

Explanatory notes

In an alkaline solution, OH^- is abundant. This will react with hydrogen ions, the hydrogen atom on the carboxyl group being the obvious choice.

Question 3d.

Worked solution

Enzymes work because of their specific shape. Only one substrate is likely to match the specific shape of the enzyme.

Mark allocation: 1 mark

- 1 mark for a response that highlights the specific shape of the enzyme

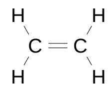
Explanatory notes

Enzymes have a tertiary structure, a very specific shape. It is this shape that makes the enzyme effective. A substrate will fit neatly into the active site of the enzyme.

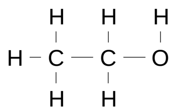
Question 4a.

Worked solution

Compound A:



Compound B:



Mark allocation: 2 marks

- 1 mark for correct structure A
- 1 mark for correct structure B

Explanatory notes

This is a standard reaction pathway – an addition reaction on ethene will give ethanol. Ethanol can be oxidised to ethanoic acid in the presence of a strong oxidant such as MnO_4^-.

Question 4b.

Worked solution

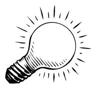
Compound A: ethene
Compound B: ethanol

Mark allocation: 2 marks

- 1 mark for each correct name

Explanatory notes

Ethene is the first member of the alkene series.
The –OH functional group implies an alkanol, making compound B ethanol.



Tip

- *The pathway from an alkene to a carboxylic acid to an ester is very standard and should be learnt by rote. The usual reagent for the oxidation step is $Cr_2O_7^{2-}$. In this case, although MnO_4^- has been used, you need to recognise that it is still the process you have learnt.*

Question 4c.

Worked solution

Anode reaction:

$CH_3CH_2OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$

Cathode reaction:

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

Overall reaction:

$5CH_3CH_2OH(aq) + 4MnO_4^-(aq) + 12H^+ (aq) \rightarrow 5CH_3COOH(aq) + 4Mn^{2+}(aq) + 11H_2O(l)$

Mark allocation: 1 + 1 + 1 = 3 marks

- 1 mark for each correct equation

Explanatory notes

Ethanol is being oxidised to ethanoic acid. This reaction requires acid conditions.

$CH_3CH_2OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$

This is an oxidation reaction so it occurs at the anode.

MnO_4^- is the oxidant. In the process it is reduced to Mn^{2+}.

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

The overall equation is obtained by adding the two half equations together after the number of electrons are balanced.

Tip

- *Writing balanced equations for polyatomic ions usually follows three steps:*
  - *Balance the O atoms, using water.*
    $MnO_4^- \rightarrow Mn^{2+} + 4H_2O$
  - *Balance the H atoms, using H^+.*
    $MnO_4^- + 8H^+(aq) \rightarrow Mn^{2+} + 4H_2O$
  - *Balance charges.*
    $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

Question 4d.

Worked solution

$C_6H_{12}O(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Mark allocation: 1 mark

- 1 mark for providing fermentation reaction

Explanatory notes

The formation of ethanol from plant material is called fermentation. This reaction occurs in the absence of air. It is the glucose in the plant material that reacts.

Tip

- *Rote learn this equation – it has appeared frequently on recent papers.*

Question 4e.i.

Worked solution

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

Mark allocation: 1 mark

- 1 mark for balanced equation and for states. $NaCH_3COO$ also accepted

Question 4e.ii.

Worked solution

$n(\text{NaOH}) = c \times V = 0.204 \times 0.0326 = 0.00665$ mol
$n(\text{CH}_3\text{COOH}) = n(\text{NaOH}) = 0.00665$ mol

$$c(\text{dilute ethanoic}) = \frac{n}{V} = \frac{0.00665}{0.02} = 0.333 \text{ M}$$
$$c(\text{original ethanoic acid}) = 0.333 \times \frac{100}{10} = 3.33 \text{ M}$$

Mark allocation: 3 marks

- 1 mark for correct number of moles of ethanoic acid
- 1 mark for correct concentration of diluted ethanoic acid
- 1 mark for correct final concentration of ethanoic acid

Explanatory notes

Ethanoic acid donates a hydrogen ion like any other acid. The hydrogen ion donated is the lone one on the end of the molecule.

The titration calculation is a standard one, whereby the acid and the base react in a 1:1 ratio. The ethanoic acid was diluted by a factor of 10 so the final step must compensate for this.

Question 5a.

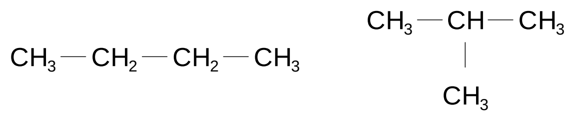
Worked solution

The splitting pattern on the spectra will differ. Butane will show a triplet and a quartet. Methyl propane will show a doublet, then a peak split into 10.

Mark allocation: 1 mark

- 1 mark for reference to different splitting patterns (both spectra will have two sets of peaks, so simply stating the number of sets of peaks is not an acceptable answer)

Explanatory notes



There are two hydrogen environments in each molecule but in butane the splitting will be a quartet and a triplet. In methylpropane, the splitting will be a doublet and then splitting into 10.

Question 5b.

Worked solution

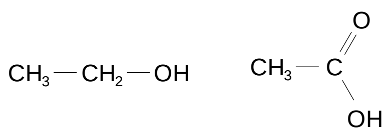
Ethanoic acid has a carbonyl group (C=O). This absorbs strongly about 1750 cm^{-1}. Ethanol will not have this peak.

Mark allocation: 1 mark

- 1 mark for reference to peak around 1750 cm^{-1} (reference to the –OH absorbance could be a correct answer but take care with this – both molecules have this absorbance but the frequency of the absorbance will be slightly different for each)

Explanatory notes

The obvious absorption to focus on is the C=O bond in ethanoic acid. This absorbs around 1750 cm^{-1}. Ethanol will not have this peak.



Question 5c.

Worked solution

Same retention time for the ethanol peak in both samples. The area under the peak for the 0.08 M solution will be four times greater than that of the 0.02 M solution.

Mark allocation: 2 marks

- 1 mark for stating that the retention times will be the same for both solutions
- 1 mark for identifying the 1:4 ratio in the peak areas

Explanatory notes

Any ethanol solution passed through this column should produce a peak after the same amount of time. The retention time in a GC is considered to be qualitative. The difference is that the area under the peak can be studied to determine the concentration of a solution. The higher the concentration, the greater the area under the peak.

Question 5d.

Worked solution

The colours of the solutions are different. One solution will absorb at 480 nm but the other does not.

Mark allocation: 1 mark

- 1 mark for suggesting the solutions have a different colour

Explanatory notes

Iron thiocyanate has a bright red colour. It absorbs strongly at 480 nm. Iron nitrate is relatively colourless. It does not absorb at 480 nm. (You do not need to state the colour of the solutions but you should suggest that the colour of each is different.)

Question 5e.

Worked solution

Butanoic acid molecules fragment readily. Most molecules break down to fragments under electron bombardment, so the parent ion has a low intensity.

Mark allocation: 1 mark

- 1 mark for stating that the abundance of the complete molecule must be low

Explanatory notes

The height of the peak reflects the abundance of the ion causing that peak. A low peak height informs us that a high percentage of the butanoic acid molecules must fragment in some way.

Question 6a.

Worked solution

$C_7H_6O_2(s) + H_2O(l) \leftrightarrow H_3O^+(aq) + C_7H_5O_2^-(aq)$
or
$C_6H_5COOH(s) + H_2O(l) \leftrightarrow H_3O^+(aq) + C_6H_5COO^-(aq)$

Mark allocation: 1 mark

- 1 mark for either form of the equation above – it must be shown as a reversible reaction

Explanatory notes

The formula of benzoic acid can be obtained from the Data Book. The reaction with water is a typical weak acid reaction during which the carboxyl hydrogen atom is donated to water.

Tip

- *The question states 'Write a balanced equation'. It is not acceptable to draw the products using structures like the benzoic acid structure given in the question. It is useful to remember that benzene itself has a molecular formula of* C_6H_6.

Question 6b.

Worked solution

$C_6H_5COOH(s) + H_2O(l) \leftrightarrow H_3O^+(aq) + C_6H_5COO^-(aq)$

The addition of base lowers the H_3O^+ concentration, pushing the reaction forwards, and thereby increasing the benzoic acid solubility.

Mark allocation: 1 mark

- 1 mark for explaining the impact of the hydroxide ion reacting with the hydronium ion to favour the forward reaction

Explanatory notes

The hydroxide ions added react with the hydronium ions.
$H_3O^+ + OH^- \rightarrow H_2O$
This lowers the H_3O^+ concentration and the reaction moves forward to replace this. The forward reaction occurring means more of the C_6H_5COOH ionises to soluble $C_6H_5COO^-$.

Question 6c.i.

Worked solution

$$K_a = \frac{\left[H_3O^+\right]\left[C_6H_5COO^-\right]}{\left[C_6H_5COOH\right]} = 6.4 \times 10^{-5}$$

$$\therefore \quad \frac{\left[H_3O^+\right]\left[C_6H_5COO^-\right]}{0.1} = 6.4 \times 10^{-5}$$

Let $x = \left[H_3O^+\right]$ then $x^2 = 6.4 \times 10^{-5} \times 0.1 = 6.4 \times 10^{-6}$

$$x = 0.00253$$

$$\text{pH} = -\log\left(0.00253\right) = 2.6$$

Mark allocation: 3 marks

- 1 mark for substituting correctly into expression for K_a
- 1 mark for correct $[H_3O^+]$
- 1 mark for correct pH value

Question 6c.ii.

Worked solution

$$\text{\% Ionisation} = \frac{\left[H_3O^+\right] \times 100}{\left[C_6H_5COOH\right]} = \frac{0.00253 \times 100}{0.1} = 2.53\%$$

Mark allocation: 2 marks

- 1 mark for correct expression for the percentage ionisation
- 1 mark for final answer

Explanatory notes

The expression for K_a for benzoic acid is $K_a = \frac{\left[H_3O^+\right]\left[C_6H_5COO^-\right]}{\left[C_6H_5COOH\right]}$.

The concentration of benzoic acid is given in the question as 0.1 and the value of K_a is given in the Data Book as 6.4×10^{-5}.

$[H_3O^+]$ will be equal to $[C_6H_5COO^-]$, so the numerator of the expression is x^2. Completing the calculation leads to the value of pH = 2.6.

Formula for % ionisation is $\frac{\left[H_3O^+\right] \times 100}{\left[C_6H_5COOH\right]}$

$[H_3O^+]$ was determined in part **i.** as 0.00253.

Question 7a.

Worked solution

$$n(CO_2) = \frac{m}{M} = \frac{11.980}{44} = 0.272 \text{ mol} \qquad n(H_2O) = \frac{m}{M} = \frac{6.54}{18} = 0.363 \text{ mol}$$

$$n(C) = n(CO_2) = 0.272 \text{ mol}$$

$$n(H) = 2n(H_2O) = 0.363 \times 2 = 0.726 \text{ mol}$$

Empirical formula $\frac{0.272}{0.272} : \frac{0.726}{0.272} \quad = 1:2.66 \ = 3:8$

Empirical formula is C_3H_8.

Mark allocation: 3 marks

- 1 mark for *n*(C)
- 1 mark for *n*(H)
- 1 mark for empirical formula

Explanatory notes

The key here is to realise that any carbon in carbon dioxide came from the molecule in question. Therefore, the number of moles of carbon is equal to the number of moles of carbon dioxide.

Similarly for hydrogen, the number of moles of hydrogen is twice the number of moles of water.

The ratio of carbon to hydrogen is 1:2.66. This ratio needs to be multiplied by three to get 3:8 as the empirical formula.

Tip

- *Empirical formula calculations are examples of calculations where care with accuracy needs to be taken. If you round off at an early point in this type of calculation, even to two significant figures, you might not get the correct empirical formula.*

Question 7b.i.

Worked solution

The molar mass is 44 g mol^{-1}. This equals the mass of the empirical formula C_3H_8.
The molecular formula is the same as the empirical formula, C_3H_8.

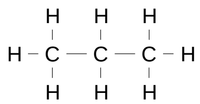
Mark allocation: 1 mark

- 1 mark for C_3H_8

Question 7b.ii.

Worked solution

The molecule is propane.



Mark allocation: 2 marks

- 1 mark for the correct name
- 1 mark for drawing the structure correctly

Explanatory notes

The molar mass needs to be compared to the empirical formula.
C_3H_8 has a mass of 44 g mol^{-1} and this matches the molar mass of 44 given. The molecular formula must also be C_3H_8.
C_3H_8 is the alkane propane.

Question 8a.i.

Worked solution

Cathode

Mark allocation: 1 mark

- 1 mark for correctly stating cathode

Question 8a.ii.

Worked solution

Element: Manganese
Oxidation number before reaction: 4+
Oxidation number after reaction: 3+

Mark allocation: 3 marks

- 1 mark for manganese
- 1 mark for Mn^{4+}
- 1 mark for Mn^{3+}

Explanatory notes

The half equation given has electrons on the left side so it is a reduction reaction.

Reduction occurs at the cathode.

The oxidation state of manganese in MnO_2 is +4, whereas in $LiMnO_2$ it is +3.

Question 8b.

Worked solution

Half equation: $Li \rightarrow Li^{+} + e^{-}$

Overall equation: $MnO_2 + Li \rightarrow LiMnO_2$

Mark allocation: 2 marks

- 1 mark for the lithium half equation
- 1 mark for the overall equation

Explanatory notes

The lithium is oxidised. This half equation can be obtained from the Data Book.
The overall equation can be obtained by adding both half equations together. The lithium ions cancel when this happens.

Question 8c.i.

Worked solution

$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$

Mark allocation: 1 mark

- 1 mark for balanced equation and states

Question 8c.ii

Worked solution

It produces gaseous hydrogen – a very flammable gas.

Mark allocation: 1 mark

- 1 mark for a valid reason; stating the production of a dangerous gas would also be acceptable

Question 8d.

Worked solution

$$Q = It = 0.48 \times 2 \times 60 \times 60 = 3456 \text{ C}$$

$$n(\text{e}) = \frac{Q}{96500} = \frac{3456}{96500} = 0.0358$$

$$n(\text{Li}) = n(\text{e}) = 0.0358 \text{ mol}$$

$$\text{Mass} = n \times M = 0.0358 \times 6.9 = 0.25\ g$$

Mark allocation: 3 marks

- 1 mark for correct calculation of charge
- 1 mark for correct number of moles of lithium
- 1 mark for correct mass of lithium

Explanatory notes

If the current and time are supplied, then the charge can be calculated, and then the number of moles of electrons. The mole ratio between lithium and the electrons is 1:1. Final calculation is the conversion of the number of moles of lithium to a mass.

Question 9a.i.

Worked solution

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

Mark allocation: 1 mark

- 1 mark for balanced equation with states

Question 9a.ii.

Worked solution

Anode: $CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$

Cathode: $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(g)$

Mark allocation: 1 + 1 = 2 marks

- 1 mark for each balanced half-equation

Explanatory notes

Combustion produces carbon dioxide and water. The balancing required is

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

The half reaction of oxygen is the one at 1.23 V on the electrochemical series.
The half reaction of methanol forms carbon dioxide and hydrogen ions:

$CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$

Question 9b.i.

Worked solution

$m = d \times V = 200 \times 0.792 = 158.4$ g

Mark allocation: 1 mark

- 1 mark for correct mass

Question 9b.ii.

Worked solution

$$n(\text{methanol}) = \frac{m}{M} = \frac{158.4}{32} = 4.95 \text{ mol}$$

$E = n \times \Delta H = 4.95 \times 725 = 3590$ kJ

Mark allocation: 2 marks

- 1 mark for correct number of moles of methanol
- 1 mark for calculating correctly the final energy amount

Explanatory notes

The ΔH value for methanol is listed in the Data Book as –725 kJ mol^{-1}. To calculate the number of moles, the volume of methanol needs to be converted to a mass. The formula $m = d \times V$ is used to do this.

Tips

- *Don't forget the junior science formula* $d = \frac{m}{V}$.
- *If a value of density is provided in a question, then there is a good chance that it will involve this equation.*

Question 10a.

Worked solution

$Q = It = 3 \times 35 \times 60 = 6300 \text{ C}$

$n(\text{e}) = \dfrac{Q}{96500} = \dfrac{6300}{96500} = 0.0653$

$n(\text{Ni}) = \dfrac{1}{2} n(\text{e}) = 0.0653 \times 0.5 = 0.0326 \text{ mol}$

$\text{Mass} = n \times M = 0.0326 \times 58.7 \text{ g} = 1.91 \text{ g}$

Mark allocation: 3 marks

- 1 mark for correct calculation of charge
- 1 mark for correct number of moles of nickel
- 1 mark for correct mass of nickel

Explanatory notes

This is a standard mass calculation in electrolysis. Current and time values are supplied so the charge can be calculated and then the number of mole of electrons.

The half equation for the deposit of nickel is $Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$.

From the half equation, it is evident that the number of moles of nickel is half that of the electrons.

Question 10b.

Worked solution

$$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$$

$$n(O_2) = \frac{1}{4}n(e^-) = \frac{1}{4} \times 0.0653 = 0.0163 \text{ mol}$$

$$V = n \times 22.4 = 0.0163 \times 22.4 = 0.366 \text{ L}$$

Mark allocation: 3 marks

- 1 mark for half equation or knowing that there is a factor of ¼
- 1 mark for the correct number of mole of oxygen
- 1 mark for the correct answer for volume

Explanatory notes

The reaction occurring at the anode is water reacting. It reacts in preference to chloride ions:

$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

The number of moles of oxygen gas will be a quarter of the number of moles of electrons. The number of moles of electrons has already been determined in part **a.** Since STP is given, the volume will be $n \times 22.4$.

Question 10c.

Worked solution

The supply of nickel ions will be exhausted if the cell runs too long.

Mark allocation: 1 mark

- 1 mark for recognising nickel ions as a limiting factor

Explanatory notes

The reaction at the cathode is $Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$.

As the cell operates, the concentration of nickel ions will drop. Eventually a point is reached where nickel can no longer be deposited.

Question 10d.

Worked solution

The pH of the solution will drop as the cell reaction proceeds. One of the products at the anode is hydrogen ions.

Mark allocation: 1 mark

- 1 mark for stating that the pH will drop

Explanatory notes

The reaction occurring that will influence the pH is the reaction at the anode:

$2H_2O(l) \rightarrow O_2(g) + 4H^{+}(aq) + 4e^{-}$

This produces $H^{+}(aq)$, so the solution is becoming more acidic, meaning the pH will drop.

Tip

- *Remember that if the solution is becoming more acidic, the pH is dropping. This is a consequence of the pH formula being a log function.*

Question 11a.i.

Worked solution

Electricity production from brown coal.

Mark allocation: 1 mark

- 1 mark for brown coal, natural gas or oil

Question 11a.ii.

Worked solution

Coal is abundant and relatively cheap.

Mark allocation: 1 mark

- 1 mark for a valid reason such as abundance

Question 11a.iii.

Worked solution

The combustion of carbon produces large quantities of carbon dioxide and coal is not a renewable resource.

Mark allocation: 2 marks

- 1 mark for each valid reason. Possible answers include greenhouse impact, inefficiency of process, production of a range of pollutants, non-renewable resource.

Explanatory notes

Electricity is produced from coal when it is burnt. The thermal energy released converts water to steam. The steam turns a turbine and the turbine generates electrical energy. In Victoria, we rely heavily on this process because we have abundant reserves of brown coal. However, it is a very polluting and relatively inefficient process.

Question 11b.

Worked solution

Energy is conserved as it is in all processes, but it is not all converted to mechanical energy. Some energy is lost in the process as sound or friction or thermal energy.

Mark allocation: 1 mark

- 1 mark for stating energy is conserved but not necessarily in the form you want

Explanatory notes

Energy will be conserved but it will be converted to a variety of forms. As the turbine turns, sound energy is produced and friction reduces the efficiency of the process. Waste thermal energy is always released from these processes, as well. The process, as a whole, is only around 30% efficient at converting electrical energy.

Question 11c.

Worked solution

When a turbine turns inside a magnetic field, electrical energy can be produced. The steam provides the energy to turn the turbine.

Mark allocation: 1 mark

- 1 mark for explaining that a turbine turning inside a magnetic field generates an electric current

Explanatory notes

Electrical energy can be produced in a generator. If a metal loop turns inside a magnetic field, then electrical energy is produced.

END OF SOLUTIONS BOOK