INSIGHT

Year 12 ***Trial Exam Paper***

2013

CHEMISTRY

Written examination

Solutions book

This book presents:

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

CONTINUES OVER PAGE

Section A: Multiple-choice questions

Question 1

Answer is D

Worked solution

- D is correct. $n(\text{ZnO}) = \dfrac{1.62}{81.4} = 0.020 \text{ mol}$

  $$n(\text{Zn}) = n(\text{ZnO}) = 0.020 \text{ mol}$$
  $$\text{mass} = 0.02 \times 65.4 = 1.30 \text{ g}$$
  $$\% \text{ Zn} = \frac{1.30 \times 100}{1.46} = 89.1\%$$
- A is incorrect because it is half of the correct answer.
- B and C are incorrect because the correct answer is 89%.

Question 2

Answer is A

Worked solution

- A is correct. $n(\text{Cl}^-) = \dfrac{0.024}{35.5} = 6.8 \times 10^{-4} \text{ mol}$

  $$n(\text{MgCl}_2) = \frac{1}{2} n(\text{Cl}^-) = 3.4 \times 10^{-4}$$
  $$c(\text{MgCl}_2) = 3.4 \times 10^{-4} \text{ M because the volume is 1 litre.}$$
- B is incorrect because $n(\text{Cl}^-)$ has not been halved.
- C is incorrect because milligrams has not been used.
- D is incorrect because the mass needs to be converted to a number of mole.

Question 3

Answer is B

Worked solution

- B is correct. The absorbance is decreasing as the titration proceeds. One of the reactants might be coloured and the intensity of the colour drops as the titration proceeds. Titrating $KMnO_4$, a purple solution, will produce a graph such as this.
- A is incorrect. When the graph reaches the *x*-axis is a likely endpoint.
- C is incorrect because if the product was coloured, the absorbance would be increasing.
- D is incorrect because this technique is applicable to titrations.

Question 4

Answer is D

Worked solution

- D is the correct answer. Atomic absorption is a standard technique for determining the concentration of ionic solutions.
- A is incorrect because the solution has no protons.
- B is incorrect because the solution is not acidic and nickel does not have many oxidation states.
- C is incorrect because infrared spectroscopy is not used to determine concentrations.

Question 5

Answer is D

Worked solution

- D is correct. Sulfur has an oxidation number of 6 in all three compounds.
- A is incorrect because the oxidation number of chlorine is its usual –1 in $FeCl_2$ and $FeCl_3$, but is +1 in OCl_2.
- B is incorrect because the oxidation number of oxygen is –2 in MgO and H_2O, but is –1 in H_2O_2.
- C is incorrect because the oxidation number of nitrogen is +5 in KNO_3, +4 in N_2O_4 and –3 in NH_3.

Tip

- *The following rules help when determining oxidation numbers.*
  - *Hydrogen is usually +1.*
  - *Oxygen is usually –2.*
  - *Elements have an oxidation number of 0.*
  - *Many oxidation numbers can be determined from the element position on the periodic table.*

Question 6

Answer is A

Worked solution

- A is correct. This is an acid–base reaction because the NH_4^+ ions are donating a proton to the hydroxide ions.
- B is incorrect because the balanced equation shows no precipitate.
- C is incorrect because no electrons are transferred and so no redox reaction occurs.
- D is incorrect because no electrons are transferred.

Question 7

Answer is B

Worked solution

- B is correct. $n(\text{HCl}) = c \times V = 0.06 \times 1 = 0.06 \text{ mol}$

$$n(\text{NaOH}) = c \times V = 0.04 \times 0.25 = 0.01 \text{ mol}$$

$$n(\text{HCl}) \text{ after reaction} = 0.06 - 0.01 = 0.05$$

$$c(\text{HCl}) = \frac{n}{V} = \frac{0.05}{0.1} = 0.5 \text{ M}$$

$$\text{pH} = -\log(0.5) = 0.3$$

- A is incorrect because some of the acid has been neutralised.
- C is incorrect because 0.3 is the correct answer.
- D is incorrect because there was excess acid, so the pH could not be 7.

Question 8

Answer is A

Worked solution

- A is correct. $n(\text{Li}) = \frac{128}{6.9} = 18.6 \text{ mol}$

$$n(\text{O}_2) = \frac{128}{32} = 4 \text{ mol}$$

Oxygen is the scarce reagent.

$$n(\text{Li}_2\text{O}) = 8 \text{ mol}$$

$$\text{mass} = 8 \times (6.9 \times 2 + 16) = 238.4 \text{ g}$$

- B is incorrect because not all the reactant is consumed.
- C is incorrect because lithium is not the limiting reagent.
- D is incorrect because the correct answer is 238 g.

Question 9

Answer is B

Worked solution

- B is correct. The '2' is necessary in 2-propanol to describe the position of the hydroxyl group. Butanoic acid does not have the prefix 1- because the position of the carboxyl group is fixed.
- A is incorrect because it should be 2-propanol and just butanoic acid.
- C is incorrect because butanoic acid does not have the prefix of 1-.
- D is incorrect because the first molecule is 2-propanol.

Tip

- *Note the difference in naming between butanol and butanoic acid. In butanol, the position of the hydroxyl group must be stated, i.e. 2-propanol, yet in butanoic acid the position should not be stated. This is because the position of the hydroxyl group in butanol can vary but the carboxyl group in butanoic acid can only be on the end carbon atom.*

Question 10

Answer is C

Worked solution

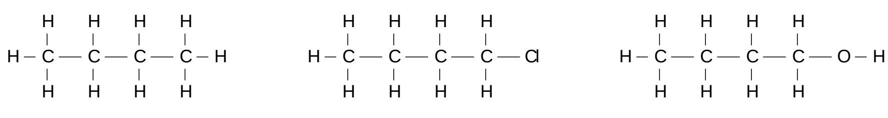
- C is correct. The 3 hydrogen atoms on each end are all equivalent. There are two neighbouring hydrogen atoms so the peak is split into $n + 1 = 3$, a triplet. The two middle hydrogen atoms are equivalent. They have 6 neighbouring hydrogen atoms, so the peak is split into a septet.
- A is incorrect because the hydrogen atoms are not all equivalent.
- B is incorrect because propane will not have a quartet.
- D is incorrect because propane has two different hydrogen environments.

Question 11

Answer is D

Worked solution

- D is correct. Butane and the intermediate molecules are drawn below.



- A is incorrect because two substitution reactions would be required, not one.
- B is incorrect because 1-butanol needs to be formed before oxidation occurs.
- C is incorrect because butane is unlikely to undergo addition reactions.

Question 12

Answer is C

Worked solution

- C is correct. The polymer drawn is polypropene and the monomer needs to be propene. Be aware that each monomer can be flipped over to ensure that the structure shown is formed.
- A is incorrect because it would lead to ethyl branches on the polymer.
- B is incorrect because it would lead to a methyl group on every carbon.
- D is incorrect because it does not have a double bond and so will not undergo addition polymerisation.

Question 13

Answer is B

Worked solution

- B is correct. When a dipeptide forms, water is also produced. The mass of the two amino acids must be 192 + 18 = 210 g mol^{-1}. The only combination listed that adds to 210 is serine + serine because serine has a molar mass of 105 g mol^{-1}.
- A is incorrect because alanine is lighter than serine.
- C is incorrect because serine and alanine are lighter than 210 g mol^{-1}.
- D is incorrect because serine and cysteine would be too heavy.

Question 14

Answer is C

Worked solution

- C is correct. The bromine to fatty acid ratio for acid A is 2:1, so the fatty acid has two double bonds. This could be linoleic acid. The ratio for acid B is 3:1, so fatty acid B has three double bonds. This could be linolenic acid
- A is incorrect because myristic acid is saturated.
- B is incorrect because neither acid has two double bonds.
- D is incorrect because stearic acid is saturated.

Tip

- *You are expected to understand the bromine test. This is an addition reaction in which bromine or iodine adds across carbon-to-carbon double bonds. This is a standard test for whether a hydrocarbon is saturated or unsaturated.*

Question 15

Answer is D

Worked solution

- D is correct. Since bromine is reacting, the absorbance of UV light should be decreasing. One of the products is hydrogen ions, so the acidity is increasing and a gas is evolved so the mass of the container is decreasing.
- A is incorrect because there are two additional measurements that could be used.
- B is incorrect because option III (pH) is also possible.
- C is incorrect because NMR is not applicable for determining concentration.

Question 16

Answer is B

Worked solution

- B is correct. The number of H_3O^+ ions in the solution in beaker A is greater than in beaker B because the concentration of H_3O^+ ions is 10 times greater.
- A is incorrect because it is the wrong way around.
- C is incorrect. The solution in beaker B would require a smaller volume of NaOH to neutralise because it contains fewer H_3O^+ ions.
- D is incorrect because both beakers contain hydroxide ions.

Question 17

Answer is C

Worked solution

- C is correct. Since $K_{\text{reverse reaction}} = \dfrac{1}{K_{\text{forward reaction}}}$, the only possible solution is that $K = 1$.
- A is incorrect because equilibrium constants cannot be determined if equilibrium is not reached.
- B is incorrect. Depending upon the stoichiometry of the equation, it might be correct sometimes but not in all circumstances.
- D is incorrect. It might be correct sometimes but not always.

Question 18

Answer is A

Worked solution

- A is correct. The amount of NOCl left is 0.40 – 0.14 = 0.26 mole. If 0.14 mole of NOCl reacted, the 0.14 mole of NO and 0.07 mole of Cl_2 are formed.
- B is incorrect because the concentrations of NO and Cl_2 are incorrect.
- C is incorrect because the final concentration of NOCl is not correct.
- D is incorrect because none of the final concentrations is correct.

Question 19

Answer is D

Worked solution

- D is correct. Thymol blue is a stronger acid, so it will have the lowest pH. K_a values are given in your Data Book.
- A is incorrect because the pH of test tube A will be higher than that of test tube B.
- B is incorrect because both substances have different K_a values.
- C is incorrect because both substances are weak acids.

Question 20

Answer is C

Worked solution

- C is correct. In pure water, $[H_3O^+]$ must be equal to $[OH^-]$.
- A is incorrect because K_w is only 10^{-14} at 25°C.
- B is incorrect because K_w changes with temperature.
- D is incorrect because the $[H_3O^+]$ must be equal to $[OH^-]$.

Question 21

Answer is A

Worked solution

- A is correct. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$
  When water is added, the acid is diluted so the pH rises. However, the addition of water also pushes the reaction in the forward direction. This means the percentage ionisation increases.
- B is incorrect because the pH increases.
- C is incorrect because the percentage ionisation increases.
- D is incorrect because the pH changes.

Tip

- *Be alert to questions involving dilution and pH. When an acid is diluted, its acidity* ***decreases*** *but its pH* ***increases****.*

Question 22

Answer is A

Worked solution

- A is correct. Galvanic cells are the most efficient way of producing electrical energy from the options listed.
- B is incorrect because the process of turning a turbine to produce electrical energy is not as efficient as a galvanic cell.
- C is incorrect because photovoltaic cells are relatively inefficient.
- D is incorrect because black coal undergoes several energy transformations to produce electrical energy.

Question 23

Answer is B

Worked solution

- B is correct. The reaction is endothermic, so an increase in temperature will improve the yield and a decrease in pressure will also improve the yield because there are more product molecules than reactant molecules.
- A is incorrect because the catalyst is irrelevant and an increase in pressure lowers the yield.
- C is incorrect because although an increase in temperature might help, an increase in pressure will not.
- D is incorrect because temperature needs to increase to improve yield.

Question 24

Answer is D

Worked solution

- D is correct. The half reactions are:

  anode: $2H_2O(1) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ H^+ increasing the acidity

  cathode: $2H_2O(1) \rightarrow H_2(g) + 2OH^-(aq) + 2e^-$ OH^- increasing the alkalinity
- A is incorrect because electrons travel in the opposite direction.
- B is incorrect because water will react before chloride ions when the solution is dilute.
- C is incorrect because electrolysis does not produce electricity.

Question 25

Answer is C

Worked solution

- C is correct. ΔH for the exothermic reaction will have the opposite sign to the endothermic reaction. The activation energy for the exothermic reaction is the activation energy of the endothermic reaction minus the ΔH value = 31.6 – 26.2 = 5.4 kJ mol^{-1}
- A is incorrect because the activation energy of the reverse reaction should not be the same magnitude as for the forward reaction.
- B is incorrect because the activation energy for the reverse reaction should not be the same as for the forward reaction.
- D is incorrect because activation energy is always positive.

Question 26

Answer is A

Worked solution

- A is correct. To derive the desired equation, the first equation must be doubled and the second must be reversed and doubled:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(1) \quad 2 \times -287 = -574$$

$$2H_2O(1) \rightarrow 2H_2O(g) \quad 2 \times 44 = 88$$

$$\Delta H = -574 + 88 = -486$$

- B is incorrect because the values of ΔH given for both equations need to be doubled.
- C is incorrect because the value of ΔH for the first equation is negative.
- D is incorrect because the two values of ΔH have not been doubled.

Tip

- *Don't forget to apply your general science knowledge to questions where possible. You should know that the reaction of hydrogen and oxygen is an explosive one. Therefore, the enthalpy change must be exothermic and the value negative.*

Question 27

Answer is A

Worked solution

- A is correct. The value of ΔT will be low due to the extra water. The value of ΔH will therefore also be low.
- B is incorrect because the value of ΔH will be low.
- C is incorrect because the value of ΔT will be low.
- D is incorrect because the value of ΔT will be low.

Question 28

Answer is C

Worked solution

- C is correct. From the electrochemical series, it can be predicted that Cl_2 will react with Al metal.
  $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ reduction: cathode: Cl_2 oxidant
  $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$ oxidation: anode: Al reductant
- A is incorrect because all options are wrong.
- B is incorrect because the oxidant and reductant are the wrong way around, as is the anode and cathode.
- D is incorrect because the anode and the cathode are the wrong way around.

Question 29

Answer is B

Worked solution

- B is correct. The equation is obtained by balancing the electrons in the half equations:
  $3 \times (O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq))$
  $4 \times (Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(aq) + 3e^-)$
  When combined, and the OH^- ions are cancelled, the equation in B is reached.
- A is incorrect because the $Al(OH)_3$ half equation was not reversed.
- C is incorrect because the electrons have not been balanced.
- D is incorrect because the water has been omitted.

Question 30

Answer is B

Worked solution

- B is correct. Each solution has to be tested to see if the amount of products is consistent with the charge passed through the cell. B is the only solution that matches.

  $Q = It = 8 \times 24000 = 192000$ C

  $$n(\text{e}) = \frac{Q}{96500} = \frac{192000}{96500} = \text{approx. 2 mol}$$

  If 1 mole of metal is obtained, the metal must have a charge of +2. It must also be able to be extracted from an aqueous solution.

  $$\text{For the gas, } n = \frac{V}{22.4} = \frac{11.2}{22.4} = 0.5 \text{ mole}$$

  Therefore, the gas half equation must have 4 electrons in it. The formation of oxygen at 1.23 V is a likely example. Alternative B is the only one that matches the above constraints.
- A is incorrect because an aqueous solution of $MgCl_2$ will not produce any metal.
- C is incorrect because it will not produce any gas at the cathode.
- D is incorrect because silver ions do not have a +2 charge.

Section B – Short answer questions

Question 1a.

Worked solution

i. $MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(1)$

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

iii. $MnO_4^{-}(aq) + 5Fe^{2+}(aq) + 8H^{+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(1)$

Mark allocation: 3 marks

- 1 mark for each correct equation.

Explanatory notes

The half equation for the reaction of Fe^{2+} can be found in the Data Book. The Fe^{2+} is oxidised and the MnO_4^{-} is reduced. The oxidation state of manganese changes from +7 to +2 because it is reduced. This is caused by the gain of 5 electrons. To form the overall equation, the half equation for Fe^{2+} has to be multiplied by 5 to balance the electrons.

Tip

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

Question 1b.

$$n(\text{MnO}_4^-) = c \times V = 0.132 \times 0.01456 = 0.00192 \text{ mol}$$

$$n(\text{Fe}^{2+}) = 5n(\text{MnO}_4^-) = 5 \times 0.00193 = 0.00961 \text{ mol}$$

$$c = \frac{n}{V} = \frac{0.00961}{0.02} = 0.480 \text{ M}$$

Mark allocation: 3 marks

- 1 mark for $n(\text{MnO}_4^-)$.
- 1 mark for $n(\text{Fe}^{2+})$.
- 1 mark for the correct answer.

Explanatory notes

This is a standard titration procedure. The first step is the number of mole of the standard used. The second step uses the stoichiometry from the balanced equation, in this case a mole ratio of 5:1. The final step calculates the concentration.

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Question 2a.

Worked solution

The identity of each peak could be established by running a sample of each alkanol through the column and noting the retention time.

Mark allocation

- 1 mark for suggesting the running of pure samples through the gas chromatograph.

Explanatory notes

There are five different liquids in this mixture and they are not all from the same homologous series. The safest way to identify each substance would be to run it as an individual sample and to note the retention time obtained.

Question 2b.

Worked solution

This procedure could have problems if there is any possibility of 2-methylpropanol being present in the sample. It would be easy to confuse the ethanol and 2-methylpropanol peaks.

Mark allocation

- 1 mark for recognising the overlap of ethanol and 2-methylpropanol peaks.

Explanatory notes

Gas chromatography relies upon a substance having a peak that is separate from other components that are likely to be present in a mixture. Hence, the presence of 2-methylpropanol is an issue. If it is not likely to be present, then the other alkanols separate quite well. If it is likely to be present, the process is compromised.

Question 2c.

Worked solution

Perhaps a retention time around 7.2. 1-pentanol is the next alkanol in the homologous series and the retention time seems to be increasing by a little over 1 with each member of the series.

Mark allocation: 2 marks

- 1 mark for nominating a retention time between 7 and 7.5.
- 1 mark for linking the retention time to the position of the alkanol in the homologous series.

Explanatory notes

1-pentanol has one more $–CH_2–$ group than 1-butanol. Therefore, it will probably have a longer retention time. The difference between the retention times of 1-propanol and 1-butanol suggests a difference in retention time of just over 1 minute.

Question 2d.

Worked solution

1-butanol and 2-methylpropanol are structural isomers but their retention times are quite different. This suggests that this technique might have the potential to separate structural isomers.

Mark allocation: 2 marks

- 1 mark for stating the two structural isomers.
- 1 mark for recognising their different retention times.

Explanatory notes

Structural isomers can have very similar properties. Therefore it is not easy to distinguish one from another. The difference in retention times between 1-butanol and 2-methylpropanol is significant. It implies that it should be easy to analyse for them if they are the only two components in a sample.

Question 2e.

Worked solution

If the concentration is doubled, the area under the peak should be doubled.

Mark allocation: 1 mark

- 1 mark for stating that the area under the peak should double.

Explanatory notes

As the concentration increases, the peak on the gas chromatogram gets larger. The peak is integrated to estimate the area under the peak and it is this area that is recorded.

Question 2f.

Worked solution

At a higher temperature, the retention times of each alkanol should be shorter. The order of peaks will be the same.

Mark allocation

- 1 mark for mentioning the shorter retention times of each molecule.

Explanatory notes

At a higher temperature, the components vaporise earlier and will generally move through the column faster. They elute in the same order but the peaks are closer together as the retention times are shorter.

Tip

- *Recent exams have highlighted the need for precise language. Many students lose marks on the descriptive responses because their answer is not quite accurate. For example, if you said 'The peak will be double the size when the concentration is doubled', you might not be marked correct. It is the area under the peak that doubles, not the height of the peak.*

Question 3a.

Worked solution

i. Mass of hydrogen = 2.800 – 1.710 – 0.664 = 0.426 g

ii. Empirical formula $= \frac{1.71}{12} : \frac{0.664}{14} : \frac{0.426}{1} = 0.142 : 0.0474 : 0.426 = 3 : 1 : 9$

Empirical formula = C_3H_9N

Mark allocation: 3 marks

- 1 mark for subtraction to get the mass of hydrogen.
- 1 mark for empirical formula numbers entered correctly.
- 1 mark for the correct empirical formula.

Explanation

This is a standard process for calculating an empirical formula.

Tip

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

Question 3b.

Worked solution

i. The base peak has a value of 29.

ii. The parent molecular ion has a mass of 59. This matches the empirical formula of C_3H_9N. Therefore, the empirical formula and the molecular formula are both C_3H_9N.

Mark allocation: 2 marks

- 1 mark for the value of 29.
- 1 mark for recognising that the parent ion has a mass of 59; therefore, the empirical formula and the molecular formula are the same.

Explanatory notes

The base peak is the most abundant species and shows up as the highest peak on the spectrum. The heaviest peak will usually be the parent molecular ion. This will tell you the molecular mass of the molecule.

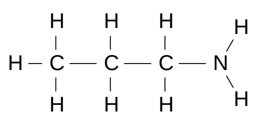
Tip

- *It is worth checking that the molecular formula you obtain is feasible. In this case, C_3H_9N would match a typical alkane with an amine group. You can approach the remainder of the question confidently.*

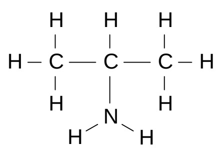
Question 3c.

Worked solution

Isomer 1



Isomer 2



Name: 1-aminopropane (or propan-1-amine)   Name: 2-aminopropane (or propan-2-amine)

Mark allocation: 2 marks

- 1 mark for each structure with its correct name.

Explanatory notes

The amine group has two possible positions and this leads to the two possible isomers of this molecule.

Question 3d.

Worked solution

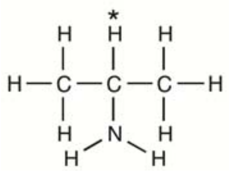
The molecule is 2-aminopropane. It has three different hydrogen environments in its structure and this matches the NMR shown. 1-aminopropane would have four different hydrogen environments.

Mark allocation: 2 marks

- 1 mark for picking 2-aminopropane.
- 1 mark for a valid reason for your selection. The peak splitting could also be used to reach this conclusion.

Explanatory notes

Examination of this molecule shows that this molecule has three different hydrogen environments. The hydrogen atom marked with an asterisk (*) will have 6 neighbouring hydrogen atoms. Hence the peak will split into seven. This matches the septet on the spectrum.



Question 4a.

Worked solution

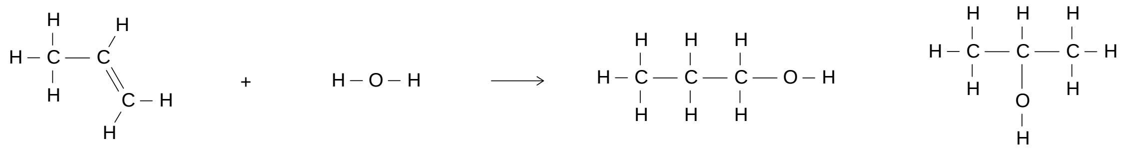
i. $C_3H_6(g) + H_2O(g) \rightarrow C_3H_7OH(g)$
ii. No. 2-propanol might also be formed.

Mark allocation: 2 marks

- 1 mark for a balanced equation. Phases are not essential because you would not be expected to know that this reaction requires very high temperatures. Note: semi-structural formulas are asked for.
- 1 mark for stating that 2-propanol might also form.

Explanatory notes

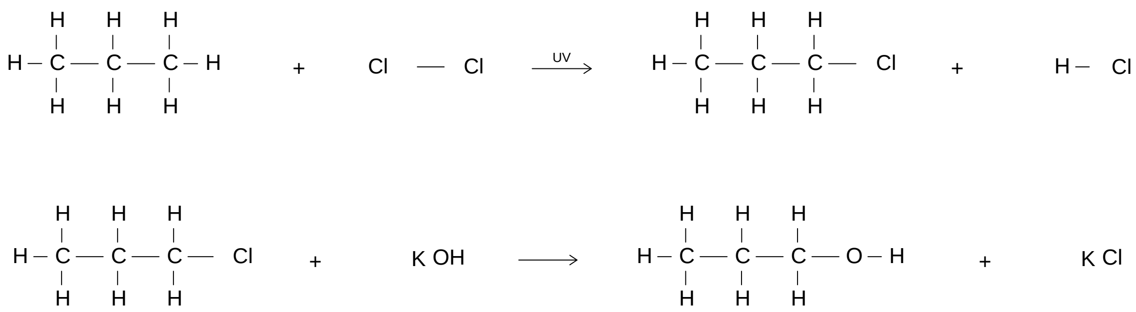
The reaction, showing the two possible isomers, is



Question 4b.

Worked solution

i. 1-propanol can be synthesised in two steps from propane. The first step is to react propane with Cl_2 to form 1-chloropropane, using UV light. The second step is to react the 1-chloropropane with KOH to form 1-propanol and KCl. The steps are shown below.



ii. No. HCl could be formed in the first step and NaCl or KCl in the second. Other isomers of chloropropane could also have formed or multiple substitutions of chlorine on propane could have occurred.

Mark allocation: 4 marks

- **i**. There are several ways this question could be answered. Showing both reactions above is acceptable. Drawing an annotated flowchart could be acceptable and a written description could also be. Essentially you are looking for 1 mark for a description of the first reaction, 1 mark for a description of the second, and 1 mark for noting all other products and reagents, such as KOH.
- **ii**. 1 mark for any of the alternative products listed in the explanatory notes.

Explanatory notes

The formation of an alkanol from an alkane is a standard process involving two substitution reactions. The first substitutes a chlorine atom onto the relatively unreactive alkane. The chlorine atom is then replaced by the hydroxyl group.
There are many other products possible in this process. Other isomers of 1-chloropropane could form or multiple substitutions of chlorine could occur.

Question 4c.

Worked solution

Yes. 1-propanol has relatively high solubility. This is due to the hydrogen bonding between the hydroxyl groups and water.

Mark allocation

- 1 mark for answering yes and an explanation that mentions the interaction between the hydroxyl group and water.

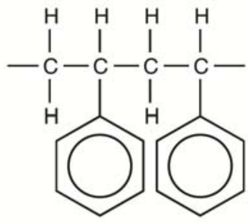
Explanatory notes

Water is a polar solvent. 1-propanol, with a hydroxyl group, will have a significant dipole. The hydroxyl group will form hydrogen bonds with water.

Question 5a.

Worked solution

Polystyrene



Mark allocation

- 1 mark for a segment showing a benzene ring on every second carbon.

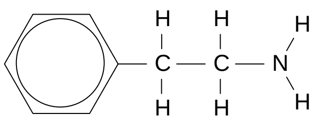
Explanatory notes

This is an addition polymerisation. The double bond in the monomer is not present in the polymer because the electrons are needed to form covalent bonds between the monomers.

Question 5b.

Worked solution

Phenylethylamine



Mark allocation

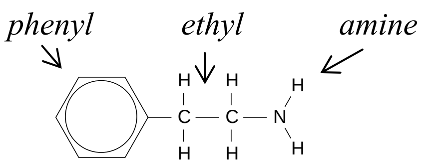
- 1 mark for the correct structure.

Explanatory notes

Although you may not have studied the formation of amines by addition reactions, the name of the molecule and the fact that it is an addition reaction should give you enough of a clue to answer this question.

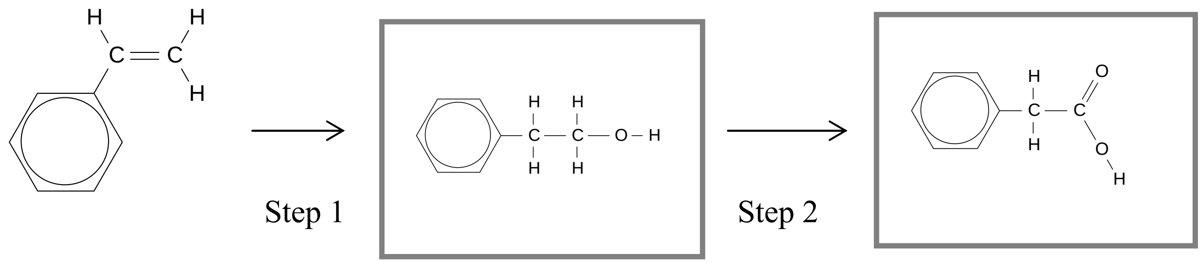
Tip

- *Systematic naming of organic molecules is meant to be helpful and in this case it should be*



Question 5c.

Worked solution



Mark allocation: 2 marks

- 1 mark for each of the two structures drawn correctly.

Explanatory notes

The pathway for producing a carboxylic acid is via the alkanol and oxidation of the alkanol to the carboxylic acid.

Tip

- *In chemistry, there are certain 'cues', $Cr_2O_7^{2-}$ being one of them. It most likely suggests the oxidation of a primary alkanol to a carboxylic acid. The use of UV light in the substitution of a chlorine atom onto an alkane is another cue.*

Question 6.

Worked solution

a. B
b. D
c. F
d. G
e. C
f. E

Mark allocation: 6 marks

- 1 mark for each correct response.

Explanatory notes

a. Molecule B, $C_{19}H_{38}O_2$, represents stearic acid bonded to methanol, a typical biodiesel ester.

b. Molecule D. Glucose has a formula $C_6H_{12}O_6$. When a disaccharide forms, this formula will be duplicated but water is eliminated. This leads to $C_{12}H_{22}O_{11}$.

c. A by-product of the hydrolysis of lipids is glycerol. The molecular formula of glycerol is $C_3H_8O_3$.

d. $C_{18}H_{34}O_2$ is an unsaturated fatty acid. If it was saturated, the formula would be $C_{18}H_{36}O_2$.

e. $C_5H_5N_5$ is the molecular formula of the base adenine.

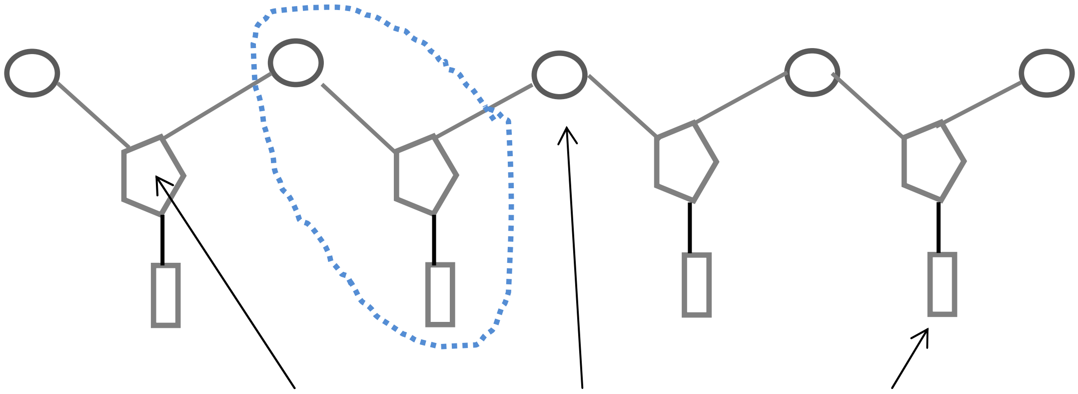
f. Proteins are formed from amino acids. The amino acid is molecule E, $C_3H_7O_2NS$. This is cysteine.

Tip

- *Many clues for questions of this nature can be found in the Data Book. The molecular formulas of the fatty acids are provided and the structures of simple sugars and bases are shown.*

Question 7

Worked solution



a. Each pentagon is a sugar, each circle is a phosphate group and each rectangle is a base.
b. A typical nucleotide is circled.
c. 4
d. One of the bases is cytosine or guanine; the other three are adenine or thymine.

Mark allocation: 4 marks

- 1 mark for each correct response.

Explanatory notes

The structure of DNA is well documented in textbooks. Each nucleotide is formed from the reaction between a phosphate group and a deoxyribose sugar. The sugar will bond with a base molecule. There are four possible base molecules, all shown in the Data Book.
There are two hydrogen bonds between each adenine and thymine pair. Cytosine and guanine have three hydrogen bonds. For the four base pairs to have a total of nine hydrogen bonds, there must be three AT pairs (six hydrogen bonds) and one CG pair (three hydrogen bonds).

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Question 8a.

Worked solution

The volume of hydrogen gas is doubled so the mass of magnesium must have been doubled.

Mark allocation

- 1 mark for stating the mass of magnesium has doubled. (An increase in acid concentration, or a temperature rise, are not correct responses.)

Explanatory note

The volume of hydrogen evolved is double that of experiment 1. Since magnesium is the limiting reagent, the mass of magnesium could be doubled. Note that doubling the concentration of acid is not a correct response as the acid is not the limiting reagent.

Question 8b.

Worked solution

Possible changes include decreasing the magnesium surface area by adding it as a ball, reducing the volume of the acid, and reducing the concentration of acid.

Mark allocation: 3 marks

- 1 mark for each valid response.

Explanatory note

The total volume of hydrogen gas evolved is the same as in experiment 1 but the gas evolves more slowly. This means that the rate of reaction is reduced. This could be caused by conducting the experiment at a lower starting temperature, decreasing the acid concentration or decreasing the surface area of the magnesium.

Question 8c.

Worked solution

The change in mass of the reactor over time or the change in pH of the solution over time.

Mark allocation: 2 marks

- 1 mark for each correct response.

Explanatory notes

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2 + H_2(g)$

The evolution of hydrogen gas means the mass of the beaker or flask used will decrease with time. The flask could be placed on a balance and the mass recorded at regular intervals.
The HCl concentration will also decrease as the reaction proceeds. The pH could be monitored with an appropriate probe.

Question 9a.

Worked solution

i. $HLt(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Lt^-(aq)$

ii. Blue

Mark allocation: 2 marks

- 1 mark for the correct equation with states.
- 1 mark for blue.

Explanatory notes

i. Acids donate a proton, so HLt will donate the proton, leaving Lt^-.

ii. Litmus is red in acid and blue in base.

Question 9b.

Worked solution

The OH^- ions will react with the hydronium ions. This will lower the hydronium concentration, favouring the reaction moving in the forward direction. This will favour a blue colour.

Mark allocation: 2 marks

- 1 mark for noting that the hydronium and hydroxide ions react.
- 1 mark for stating that the forward reaction is favoured or a blue colour will be produced.

Explanatory notes

$HLt(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Lt^-(aq)$

The OH^- ions added will react with the hydronium ions to form water:

$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$

Since the H_3O^+ concentration drops, the forward reaction is favoured. The production of a blue colour is favoured.

Question 9c.

Worked solution

i. $K_a = \frac{[H_3O^+][Lt^-]}{[HLt]}$

ii. At transition, the value of [HLt] is equal to the value of $[Lt^-]$. Therefore they cancel, making $K_a = [H_3O^+] = 3 \times 10^{-7}$.

$\text{pH} = -\log[H_3O^+] = -\log(3 \times 10^{-7}) = 6.52$

Mark allocation: 4 marks

- 1 mark for a correct expression.
- 1 mark for stating that [HLt] is equal to the value of $[Lt^-]$.
- 1 mark for value of K_a.
- 1 mark for the correct answer.

Explanatory notes

i. The expression for K_a works the same for litmus as any other weak acid.

ii. An indicator is at transition when the concentrations of the acid and its conjugate base are equal or close to equal.

$K_a = \frac{[H_3O^+][Lt^-]}{[HLt]}$

This means the expression for K_a simplifies if $[HL] = [Lt^-]$. They both cancel from the expression leaving $K_a = [H_3O^+]$. Since we know the value of K_a, we also know $[H_3O^+]$.

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Question 10a.

Worked solution

$$C_2H_6(g) \rightleftharpoons C_2H_2(g) + 2H_2(g)$$

	$C_2H_6(g)$	$C_2H_2(g)$	$2H_2(g)$
No. mole at start	2	0	0
No. mole at equilibrium	1.28 therefore, 2 – 1.28 = 0.72 mole of ethane reacts		
Equilibrium amounts	1.28	0.72	1.44
Equilibrium concentrations	0.64	0.36	0.72

$$K = \frac{[C_2H_2][H_2]^2}{[C_2H_6]} = \frac{(0.36)(0.72)^2}{(0.64)} = 0.29\ \text{M}^2$$

Mark allocation: 4 marks

- 1 mark for equilibrium amounts of each chemical.
- 1 mark for equilibrium concentrations of each chemical.
- 1 mark for correct substitution into expression for *K*.
- 1 mark for the correct answer.

Explanatory notes

If 2 mole of ethane enters the reactor, you need to calculate how much ethyne and hydrogen have formed at equilibrium. The grid in the solution is used to do this. 0.72 mole of ethane reacts, so the same amount of ethyne and twice as much hydrogen formed.

Tip

- *Notice that the question states that 2.0 mole of ethane is added to a reactor. This means that it cannot be an equilibrium value to place in an equilibrium expression. The equilibrium amounts need to be determined.*

Question 10b.

Worked solution

i. The reaction is endothermic, so increasing the temperature will improve the yield.
ii. The pressure could be decreased to improve the yield.

Mark allocation: 2 marks

- 1 mark for each correct response.

Explanatory notes

i. With an endothermic reaction, the yield is increased if the temperature is increased.
ii. This reaction has more product molecules than reactant molecules. Therefore lowering the pressure increases the yield.

Question 10c.

Worked solution

i. $2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$

ii. $E = 4.18 \times 440 \times 19.1 = 35\ 100$ J

$$n = \frac{m}{M} = \frac{0.71}{26} = 0.0273 \text{ mol}$$

$$\text{Energy from 1 mole} = \frac{35100}{0.0273} = 1.29 \times 10^6 \text{ J} = 1.29 \times 10^3 \text{ kJ}$$

iii.

$$\Delta H = -2 \times 1.29 \times 10^3 = -2.57 \times 10^3 \text{ kJ mol}^{-1}$$

Mark allocation: 5 marks

- 1 mark for the correct equation.
- 1 mark for the correct answer.
- 1 mark for calculating the number of mole.
- 1 mark for energy calculation.
- 1 mark for final ΔH value and for correct units.

Explanatory notes

i. Combustion usually produces carbon dioxide and oxygen.

ii. Energy is calculated using the formula $E = 4.18 \times m_w \times \Delta T$, where m_w is the mass of water present

iii. ΔH is the energy per balanced equation. 0.0273 mole was used in this experiment so this needs to be adjusted to obtain ΔH. Since the balanced equation has $2C_2H_2$ in it, the answer actually requires the amount of energy from 2 mole of ethyne.

Tip

- *Be aware that ΔH actually refers to the amount of energy produced from a balanced equation. Since this equation contains a coefficient of 2 ($2C_2H_2$), ΔH will be the amount of energy released by 2 mole of ethyne.*

Question 11a.

Worked solution

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

ii. The glucose or other carbohydrates are usually sourced from plant materials. Large-scale production will require large amounts of land and fertiliser and water. The plant material might also be more essential to the food industry.

Mark allocation: 2 marks

- **i**. 1 mark for the correct equation.
- **ii.** 1 mark for stating that there are limits to how much land and resources we can direct to bioethanol when land can be in short supply.

Explanatory notes

Fermentation is conducted in an oxygen-free environment. The products are ethanol and carbon dioxide.

Tip

- *The equation for fermentation needs to be memorised as it appears frequently on exams. The equation for combustion of any organic chemical is also common.*

Question 11b.

Worked solution

i. Biogas

ii. Anode: $CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$

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

iii. chemical potential → thermal energy → steam thermal energy → mechanical → electrical energy

iv. Fuel cell

Mark allocation: 5 marks

- **i.** 1 mark for biogas.
- **ii**.1 mark for each equation.
- **iii.** 1 mark for the correct flowchart.
- **iv.** 1 mark for fuel cell.

Explanatory notes

The half equation for the reaction of oxygen in a fuel cell can be taken straight from the electrochemical series in the Data Book. The overall equation will be the same as for combustion of methane.

Tip

- *It is often possible to follow a process to write the equations for a fuel cell:*
  - *the overall equation will be the same as for combustion in air, then*
  - *the half equation for the oxygen gas is the one at 1.23 V on the electrochemical series (assuming acidic conditions), then*
  - *the other half equation can be derived from the above two equations.*

Question 12a.

Worked solution

Anode: $Na \rightarrow Na^{+} + e^{-}$ polarity –ve
Cathode: $Ni^{2+} + 2e^{-} \rightarrow Ni$ polarity +ve

Mark allocation: 3 marks

- 1 mark for each half equation.
- 1 mark for the correct polarity.

Explanatory notes

The half equations are easily derived from the overall equation provided. Just remember to reverse it because the recharge equation was given: $2Na + NiCl_2 \rightarrow 2NaCl + Ni$.
The half equations are both available from the Data Book.

Tip

- *Whenever a word in a question is in bold print, stop and ask why. The Chief Assessor for Chemistry often comments that students working under pressure tend to miss the significance of terms in bold print. The two most common examples of the use of bold print are* ***recharge/discharge*** *or* ***reverse*** *reaction.*

Question 12b.

Worked solution

Low density; high voltage as sodium is one of the lowest voltages on the electrochemical series; sodium is relatively abundant; rechargeable.

Mark allocation: 2 marks

- 1 mark for each valid reason.

Explanatory notes

Sodium and lithium are much lighter than other metals used, such as nickel and lead. Sodium is relatively abundant in the Earth's crust and the voltages obtained from cells with these reactive metals will be high.

Question 12c.

Worked solution

i. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

ii. The reaction of sodium with water is vigorous. It would be dangerous in a cell, especially as one of the products is the flammable hydrogen gas.

Mark allocation: 2 marks

- 1 mark for a correctly balanced equation.
- 1 mark for stating that the above reaction is a dangerous one to be occurring in a cell.

Explanatory notes

Group 1 metals all react vigorously with water. Any attempt to use an aqueous solution will be too dangerous.

Question 12d.

Worked solution

The reaction in this cell is very exothermic. It might have been a problem dissipating this heat but, instead, it can be used to maintain the high cell temperature.

Mark allocation

- 1 mark for stating that the reaction is very exothermic and the energy produced can be harnessed to keep the cell at an efficient temperature.

Explanatory note

Many cells used in home appliances operate at room temperature. A cell at 300°C might offer some challenges. However, in a car temperatures such as this are manageable. The cell quickly heats up when it is operating because the sodium reaction is very exothermic.

Question 12e.

Worked solution

$E = VIt = 2.58 \times 3.2 \times 72 \times 60 = 35\ 700\ \text{J} = 36\ \text{kJ}$

Mark allocation: 2 marks

- 1 mark for the correct substitution into energy formula.
- 1 mark for the correct answer.

Explanatory note

Energy is given by the formula $E = VIt$, where time is in seconds.

Question 13a.

Worked solution

i.

	Reaction at anode	**Reaction at cathode**
$CuBr_2(aq)$	$2Br^-(aq) \rightarrow Br_2(l) + 2e^-$	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
$KCl(aq)$	$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$	$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$

ii. Beaker A: $Cu^{2+}(aq) + 2Br^-(aq) \rightarrow Cu(s) + Br_2(l)$

Beaker B: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Mark allocation: 6 marks

- 1 mark for each equation.
- 1 mark for each equation.

Explanatory notes

For $CuBr_2$ the possible half equations are:

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
$Br_2(l) + 2e^- \rightarrow \underline{2Br^-}(aq)$
$\underline{Cu^{2+}}(aq) + 2e^- \rightarrow Cu(s)$
$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$

Therefore, $Cu^{2+}(aq)$ and $2Br^-(aq)$ react.

For KCl the possible half equations are:

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow \underline{2H_2O}(l)$
$\underline{2H_2O(l)} + 2e \rightarrow 2OH^-(aq) + H_2(g)$
$K^+(aq) + e^- \rightarrow K(s)$

Therefore, $H_2O(l)$ reacts with itself

Tip

- *For electrolysis of aqueous solutions, the same two half equations involving water are always possible reactants:*
  - $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
  - $2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$
- *These two half equations can be taken straight from the Data Book. The second equation is the dividing line between metals that can be obtained from aqueous solutions and those that can only be obtained by electrolysis of molten solutions.*

Question 13b.

Worked solution

i. $Q = It = 4.6 \times 4.5 \times 60 \times 60 = 74520 \text{ C}$

$$n(\text{e}) = \frac{\text{Q}}{96500} = \frac{74520}{96500} = 0.772 \text{ mol}$$

ii. Beaker A anode: $n(\text{Br}_2) = \frac{1}{2}n(\text{e}) = \frac{1}{2} \times 0.772 = 0.386 \text{ mol}$

Beaker A cathode: $n(\text{Cu}) = \frac{1}{2}n(\text{e}) = \frac{1}{2} \times 0.772 = 0.386 \text{ mol}$

Beaker B anode: $n(\text{O}_2) = \frac{1}{4}n(\text{e}) = \frac{1}{4} \times 0.772 = 0.193 \text{ mol}$

Beaker B cathode: $n(\text{H}_2) = \frac{1}{2}n(\text{e}) = \frac{1}{2} \times 0.772 = 0.386 \text{ mol}$

Mark allocation: 6 marks

- **i.** 1 mark for calculation of charge.
  1 mark for the number of mole of electrons.
- **ii.** 1 mark for each correct response.

Explanatory notes

i. This is a standard use of $Q = It$ to calculate the charge. 1 mole of electrons is 96 500 C, so charge is compared to this.

ii. The number of mole of electrons is the same for each electrode, so the number of mole of products is determined from the electrons in the half equation.

END OF SOLUTIONS BOOK