YEAR 12 *Trial Exam Paper*

2015

CHEMISTRY

Written examination

Solutions book

This book presents:

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

SECTION A – Multiple-choice questions

Question 1

Answer is C

Worked solution

C is correct. The empirical formula calculation will show that SO_3 is the correct answer.

If S = 40%, then O = 60%.

$$\frac{40}{32} : \frac{60}{16} = 1.25 : 3.75 = 1 : 3$$

So the empirical formula is SO_3.

Question 2

Answer is A

Worked solution

A is correct. The first step is to find the limiting reagent. The limiting reagent is then used to determine the amount of NO formed.
The number of mole of HNO_3 required to react with 0.66 mole of copper is

$$0.66 \times \frac{8}{3} = 1.76 \text{ mol}$$

This makes HNO_3 the limiting reagent.

$$n(\text{NO}) = 1.6 \times \frac{2}{8}$$
$$= 0.4 \text{ mol}$$

B is incorrect as 0.4 mol is the correct answer. B is obtained if you incorrectly work from the number of mole of copper instead of nitric acid.
C is incorrect as 0.4 mol is the correct answer.
D is incorrect as 0.4 mol is the correct answer.

Question 3

Answer is C

Worked solution

C is correct. The oxidation state of nitrogen can be determined by assuming the oxidation state of oxygen will be –2 and that of hydrogen will be +1.

HNO_3

$+1 + N + 3 \times -2 = 0$

$+1 + N - 6 = 0$, therefore nitrogen is +5.

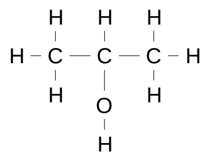
Tip

- *Note the assumptions used here:*
  - *H atoms will be +1.*
  - *atoms will be –2.*
  - *The position on the Periodic Table can tell you other values as needed.*

Question 4

Answer is B

Worked solution



B is correct. An inspection of 2-propanol shows it has three different hydrogen environments. The septet is the middle hydrogen atom that has six neighbouring hydrogen atoms; hence, it is split into a septet.
The singlet is the O–H, as oxygen atoms prevent splitting.
The two methyl groups on the molecule have equivalent environments and this environment has one neighbouring hydrogen atom so it forms the doublet shown.

A is incorrect as 1-propanol would have four different hydrogen environments.
C is incorrect as it will have only two different hydrogen environments.
D is incorrect as it has only two different hydrogen environments.

Question 5

Answer is A

Worked solution

A is correct. TLC has often been used to analyse food dyes. With an appropriate choice of solvent, the yellow dyes should have different R_f values.

B is incorrect. Atomic absorption is used for ionic solutions.
C is incorrect. Ultraviolet spectroscopy is mainly used to determine the concentration of ionic solutions. It is not used to separate substances.
D is incorrect. Most food dyes are neither acids nor bases.

Question 6

Answer is D

Worked solution

D is correct. The oxidation state of sulfur in $S_2O_3^{2-}$ is +2 and in SO_4^{2-} is +6. Chlorine atoms are reduced to Cl^- ions.

A is incorrect as sodium ions are spectator ions.
B is incorrect as chloride ions are formed in the reaction.
C is incorrect as sulfur has an oxidation state of +2 in $S_2O_3^{2-}$.

Question 7

Answer is B

Worked solution

B is correct. The titration is between a weak acid and a strong base so the indicator chosen should be one that has a transition at a high pH, such as phenolphthalein. If the student's result is poor, then they must have used an indicator that changes at the opposite end of the pH spectrum and that is likely to be methyl orange.

A is incorrect as phenolphthalein would be a good choice of indicator for this experiment.
C is incorrect as phenol red would be an acceptable choice for this titration.
D is incorrect as bromothymol blue would be an acceptable choice for this titration.

Tips

- *Choice of indicator might seem complex but, in reality, there are only two relevant scenarios:*
  - *Strong acid/weak base will be best with an indicator changing in the acid region.*
  - *Weak acid/strong base will be best with an indicator changing in the alkaline region.*

Question 8

Answer is C

Worked solution

C is correct. The number of mole of carbon is

$$\frac{0.36}{12} = 0.03 \text{ mol}$$

As the molecular formula of glucose is $C_6H_{12}O_6$, the number of mole of oxygen will also be 0.03.
The mass of 0.03 mole of oxygen is 0.03 × 16 = 0.48 g.

A is too low as the mass of oxygen has to be higher than that of carbon.
B is also too low.
D is too high.

Question 9

Answer is A

Worked solution

A is correct. Tylenol has an amide linkage between the phenylamine and the rest of the molecule. The amide linkage will form when phenylamine reacts with ethanoic acid. Water will be the other product.

B is incorrect as a reaction with ethanol would not produce an amide linkage.
C is incorrect as this is not an esterification reaction.
D is incorrect as this is not an esterification reaction.

Tip

- *In Unit 3, you study 'Chemical pathways'. Expect that you will be asked questions on unfamiliar molecules. This is not unfair because the pathways you have to apply to these molecules are the ones you have studied. In the question above, Tylenol is not in your course but amide linkages are.*

Question 10

Answer is B

Worked solution

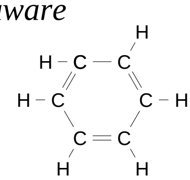
B is correct. The molecular formula of Tylenol is $C_8H_9NO_2$.
This gives a molar mass of 96 + 9 + 14 + 32 = 151 g.

A is incorrect as it is too low.
C is incorrect as it is too high.
D is incorrect as it is too high.

Tip

- *The hexagon in the structure of Tylenol represents benzene. Benzene is in your course and it is expected that you will be aware of its exact structure.*

benzene

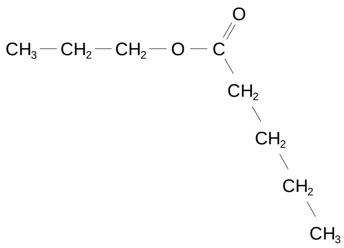


Question 11

Answer is B

Worked solution

B is correct and is determined by drawing the structure of the molecule.



Propyl pentanoate has a molecular formula of $C_8H_{16}O_2$, therefore the empirical formula is C_4H_8O.

A is incorrect as the empirical formula is not as simple as this.
C is incorrect as the number of oxygen atoms has not been halved.
D is incorrect as it is the molecular formula and not the empirical formula.

Question 12

Answer is A

Worked solution

A is correct. The longest carbon chain is six carbon atoms long, so the base of this molecule is hexane.
Numbering must start from the right-hand end of the molecule as this leads to lower numbers than starting from the left end.
Second carbon has 2 chlorine atoms, therefore 2,2-dichloro.
Third carbon has a methyl group, therefore 3-methyl.
Putting all this together, the answer is 2,2-dichloro-3-methylhexane.

B is incorrect as this is not an example of a heptane molecule.
C is incorrect as numbering has started from the left-hand end.
D is incorrect as the numbers for chlorine and the methyl group are around the wrong way.

Tip

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

Question 13

Answer is B

Worked solution

B is correct. Alkanes are relatively unreactive. The usual pathway to make them react is to first substitute a chlorine onto the molecule. This has not happened here. All other options are acceptable ways of making ethanol.

A is incorrect. Fermentation does produce ethanol.
C is incorrect. The reaction of chloroethane in potassium hydroxide is a standard pathway.
D is incorrect. The formation of ethanol from ethene in an addition reaction is a common pathway.

Question 14

Answer is D

Worked solution

D is correct. Glycerol bonds to fatty acids in lipids with an ester linkage. Amino acids form amide linkages when they combine with each other in proteins. Glucose and fructose form an ether linkage when they react to form sucrose. The reaction between stearic acid and ethanol forms a biodiesel molecule and this is an ester.

A is incorrect as glycerol to a fatty acid is not an ether linkage.
B is incorrect as glycerol to a fatty acid is not an ether linkage.
C is incorrect as the amine linkage should be an amide linkage.

Question 15

Answer is B

Worked solution

C is correct. Cytosine and guanine form three hydrogen bonds, whereas adenine and thymine form two. Adding up option C gives 2 + 2 + 3 + 2 + 3 = 12 bonds.

A is incorrect as it adds to 13 bonds.
B is incorrect as it adds to 11 bonds.
D is incorrect as it adds to 13 bonds.

Question 16

Answer is D

Worked solution

D is correct. The question is referring to the **percentage** of successful collisions, not the **number** of collisions. This is an important distinction. Options A, C and D will all lead to more collisions but not necessarily to a higher percentage of successful collisions. Option D, in fact, is the only alternative that will to a higher percentage of successful collisions because the temperature is higher. At a higher temperature, the average kinetic energy of the particles will be higher and the percentage of collisions that have sufficient energy to react will be higher.

A is incorrect. It will have more collisions but not a higher percentage of successful ones. An increase in concentration will not change the average kinetic energy of the particles.
B is incorrect. The change in surface area should not affect the percentage of successful collisions.
C is incorrect. The change in surface area will not change the average kinetic energy so the percentage of successful collisions will be unchanged.

Question 17

Answer is C

Worked solution

C is correct. Once an enzyme has catalysed a reaction, the product can move away from the enzyme allowing it to perform the same function on another substrate.

A is incorrect as the enzyme should be unchanged by a reaction.
B is incorrect as the rate of reaction varies significantly with temperature.
D is incorrect as an enzyme’s shape usually works on only one specific biochemical reaction.

Question 18

Answer is A

Worked solution

A is correct. Sulfuric acid is the strongest acid as it is a diprotic strong acid. Hydrochloric acid is a monoprotic strong acid and so comes next. Benzoic acid has a higher K_a than ethanoic, acid so it ranks before ethanoic acid.

B is incorrect as ethanoic acid is weaker than benzoic acid.
C is incorrect as the list goes from highest pH to lowest.
D is incorrect as the list is almost highest pH to lowest.

Tip

- *This question highlights a common trap – that pH and acid concentration are inversely proportional. If the concentration of an acid drops, then the pH rises and vice versa.*

Question 19

Answer is D

Worked solution

D is correct. The pH of ethanoic acid is higher as it is a weak acid but it will still neutralise the same volume of NaOH.

A is incorrect as it neutralises the same volume.
B is incorrect as the pH of ethanoic acid is higher and the volume neutralised is the same.
C is incorrect as the pH of ethanoic acid is higher.

Question 20

Answer is B

Worked solution

B is correct. The production of electricity from uranium harnesses the significant release of energy that occurs when uranium atoms undergo nuclear fission. The thermal energy released is used to produce steam. The steam then turns a turbine to produce electrical energy.

A is incorrect as nuclear fission does not release large quantities of electrons.
C is incorrect as it is not nuclear fusion that occurs.
D is incorrect as oxygen is not relevant to the process.

Question 21

Answer is A

Worked solution

A is correct. Bioethanol is produced from plant material that can be replenished. Sugar cane and corn are typical commercial sources.

B is incorrect as the answer is irrelevant to whether a fuel is a biofuel or not.
C is incorrect as the material in coal was once living but it is not renewable.
D is incorrect as bioethanol will usually produce carbon dioxide when burnt.

Question 22

Answer is C

Worked solution

C is correct. From the graph ΔH is 30 kJ mol^{-1}. The energy required to react 0.05 mole of A will be $30 \times 0.05 = 1.5$ kJ or 1500 J.
If the calibration factor is 750 kJ °C^{-1}, then the temperature change will be 2°C. As the reaction is endothermic, the temperature change is negative.

A is incorrect as the reaction is endothermic.
B is incorrect as the reaction is endothermic.
D is incorrect as the temperature change is too great.

Question 23

Answer is B

Worked solution

B is correct. Mass change = 10.0 – 8.22 = 1.78 g

$$n(\text{Cu}) = \frac{1.78}{63.6} = 0.0280\,\text{mol}$$

$$n_e = 2n(\text{Cu}) = 2 \times 0.028 = 0.056\,\text{mol}$$

$$Q = n_e \times 96\,500 = 0.056 \times 96\,500 = 5400\text{ C}$$

The current and time that gives this same value of 5400 is 6 amps for 15 minutes:

$Q = 6 \times 15 \times 60 = 5400$ C

A is incorrect as the current is one-tenth of the current required.
C is incorrect as it leads to a charge that is double the correct value.
D is incorrect as it leads to a charge that is too high.

Question 24

Answer is D

Worked solution

D is correct. If copper is to react and form copper ions, then the half-equation must be

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

This is an oxidation reaction that will occur at the anode and the anode is positive in an electrolytic cell.

A is incorrect as the copper has to be the anode.
B is incorrect as copper has to be the anode.
C is incorrect as copper has to be the positive electrode.

Question 25

Answer is C

Worked solution

C is correct. The graph shows three species present. The concentrations of two of the species are decreasing so there are two reactants and one product. The ratio between the amounts the reactants drop is 1 : 3; C must be the correct answer. The rate at which the product forms is also consistent with C.

A is incorrect as it does not have the correct ratio between the rate the two reactants are dropping.
B is incorrect as it would require both reactant concentrations to drop at the same rate.
D is incorrect as it involves only two species, not three.

Question 26

Answer is D

Worked solution

D is correct. If the volume decreases, the concentration will rise instantly. The system will move to oppose the increase in pressure by favouring the reverse reaction as there is only one reactant molecule compared with two product molecules. The concentration of phosgene should continue to increase until a new equilibrium is reached.

A is incorrect as the amount of phosgene would drop if phosgene was added.
B is incorrect as the addition of a catalyst would have no impact upon a system at equilibrium.
C is incorrect as a decrease in pressure would mean an initial drop in phosgene concentration and this is not what happened.

Question 27

Answer is B

Worked solution

B is correct. The value 0.074 is the square root of the original value of 0.0055. The original equation must have been halved and this is what option B shows.

A is incorrect as it would lead to the value of 0.0055 being squared.
C is incorrect as it would produce a value of K that is the reciprocal of 0.0055.
D is incorrect as the value of K is not correct.

Question 28

Answer is D

Worked solution

D is correct. In this cell, the half-reactions occurring will be

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ reduction; cathode; oxidant

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ oxidation; anode; reductant

A is incorrect as the oxidant and reductant are not correct.
B is incorrect. All responses are incorrect.
C is incorrect as the oxidant and reductant are the wrong way around.

Question 29

Answer is A

Worked solution

A is correct. The electrons are released when copper atoms form copper ions. The copper electrode is gradually consumed in this process.

B is incorrect as copper is not deposited at this electrode.
C is incorrect as the direction of electron flow is wrong.
D is incorrect as electrons do not flow through the salt bridge.

Question 30

Answer is C

Worked solution

C is correct. A reduction reaction occurs at the cathode. It is oxygen gas that is reduced in a fuel cell. The conditions in this cell are alkaline, so the oxygen half-equation producing OH^- ions will be the correct answer.

A is incorrect as it is an oxidation reaction.
B is incorrect as it would occur only in acid conditions.
D is the overall equation, not the half-equation.

SECTION B – Short-answer questions

Question 1a.

Worked solution

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

Mark allocation: 1 mark

- 1 mark for balanced equation, including states

Explanatory notes

A metal and an acid will form a salt and hydrogen gas.

Tip

- *You are expected to know standard equations such as*
  - *acid and metal*
  - *acid and base*
  - *acid and carbonate*

Question 1b.

Worked solution

$$\text{mass } Mg = 82.4\% \times 1.04 = 0.857 \text{ g}$$

Mark allocation: 1 mark

- 1 mark for correct mass

Explanatory notes

This is a straightforward percentage calculation.

Question 1c.

Worked solution

$$n(\mathrm{Mg}) = \frac{m}{M} = \frac{0.857}{24.3} = 0.0353\,\mathrm{mol}$$

$$n(\mathrm{H_2}) = n(\mathrm{Mg}) = 0.0353\ \mathrm{mol}$$

$$V = \frac{nRT}{P} = \frac{0.0353 \times 8.31 \times 293}{101.3} = 0.848\,\mathrm{L}$$

Mark allocation: 3 marks

- 1 mark for number of mole of magnesium
- 1 mark for correct substitution into gas equation
- 1 mark for correct answer and units

Explanatory notes

From the mass of magnesium, the number of mole can be calculated. This equals the number of mole of hydrogen gas. The volume of this hydrogen is calculated from the ideal gas equation. The pressure and temperature need to be converted to kPa and K respectively.

Question 1d.i.

Worked solution

$$n(\mathrm{NaOH}) = c \times V = 0.5 \times 0.072 = 0.036\ \mathrm{mol}$$

Mark allocation: 1 mark

- 1 mark for correct number of mole

Question 1d.ii.

Worked solution

$$n(\mathrm{HCl\ in\ excess}) = n(\mathrm{NaOH}) = 0.036$$

Mark allocation: 1 mark

- 1 mark for recognising that the number of mole is the same

Question 1d.iii.

Worked solution

$n(\text{HCl that reacted with Mg}) = 0.100 - 0.036 = 0.064 \text{ mol}$

$n(\text{Mg}) = \frac{1}{2}n(\text{HCl}) = 0.032 \text{ mol}$

This is lower than the value of 0.0353 obtained earlier, so the value of 82.4% by mass is too high.

Mark allocation: 2 marks

- 1 mark for calculating number of mole of magnesium
- 1 mark for conclusion that the real percentage of magnesium is lower than 82.4% by mass

Explanatory notes

The amount of NaOH reveals how much of the original HCl did *not* react with magnesium. Subtract this figure from the original amount of HCl to find the real number of mole of magnesium present. Compare this to the quoted value of 82.4%.

Question 2a.

Worked solution

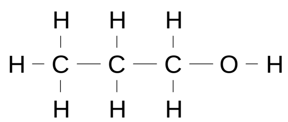
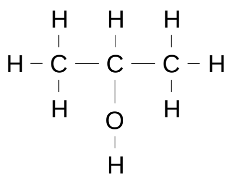
The alkanol is likely to be 2-propanol. 2-Propanol cannot be oxidised to a carboxylic acid as it is not a primary alkanol; that is, the hydroxyl group is not on the end of the molecule.

Mark allocation: 2 marks

- 1 mark for stating that the propanol is likely to be 2-propanol
- 1 mark for stating that only primary alkanols can be oxidised

Explanatory notes

There are two isomers of propanol, as shown below. 1-Propanol, the first molecule, can undergo oxidation but 2-propanol cannot. The sample in this question must be 2-propanol.

Question 2b.

Worked solution

Biodiesel is carbon neutral because carbon dioxide is absorbed by the canola crop as it grows. Canola can also be replenished at a sustainable rate. Diesel from petroleum is not renewable; it was formed millions of years ago.

Mark allocation: 2 marks

- 1 mark for reference to being carbon neutral
- 1 mark for explanation that canola can be replenished at a sustainable rate

Explanatory notes

Plants take in carbon dioxide and water as they grow. This compensates for the carbon dioxide produced when the fuel is used. Canola crops can be grown each year so they are considered to be a renewable fuel source.

Tip

- *When comparing two items, ensure that your response mentions both items. It is not enough to explain the advantages of biodiesel without reference to the limitations of traditional diesel.*

Question 2c.

Worked solution

The reaction must be one that has the same number of reactant molecules as there are product molecules.

Mark allocation: 1 mark

- 1 mark for explaining that this reaction must have equal numbers of reactants and product molecules

Explanatory notes

Le Chatelier's Principle states that a system at equilibrium will oppose change. If there are equal numbers of reactant molecules as there are product molecules, then the reaction will not shift forwards or backwards because neither change alters the pressure in the system.

Question 2d.

Worked solution

The temperature of the water is not 25°C. The pH of pure water is 7 only when at 25°C.

Mark allocation: 2 marks

- 1 mark for acknowledging the water is pure but not at 25°C
- 1 mark for explaining the pH of water is 7 when at 25°C

Explanatory notes

The self-ionisation of water is a reversible reaction, so the value of K_w is temperature dependent. At 25°C, K_w is 1×10^{-14} so the pH will be 7. At any other temperature, K_w will not be 1×10^{-14} so the pH will be different.

Question 2e.

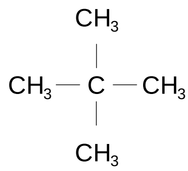
Worked solution

The alkane will not be normal pentane but the isomer 2,2-dimethylpropane. All hydrogen atoms have the same environment in this molecule so the NMR spectrum will have one peak only.

Mark allocation: 2 marks

- 1 mark for identifying that the alkane is an isomer of pentane
- 1 mark for stating that the isomer has only one hydrogen environment

Explanatory notes



The likely structure of the alkane is drawn here.
The name of this molecule is 2,2-dimethylpropane.
All hydrogen atoms in this molecule have the same environment so the NMR spectrum has one peak only.

Question 3a.

Worked solution

The mass spectrum is for 1-propanol. The parent molecular ion has a mass of 60, matching that of 1-propanol and the peak at 31 is consistent with the $–CH_2OH^+$ fragment found in alkanols.

Mark allocation: 2 marks

- 1 mark for identifying 1-propanol
- 1 mark for two valid reasons for this selection. Several possible fragments could be used as an answer but they would need to be fragments that are not present in propanoic acid.

Explanatory notes

The relative molecular mass of 1-propanol is 60. This matches the parent molecular ion on the spectrum. The obvious peak that confirms this is the base peak at *m*/*z* ratio of 31. Primary alkanols have a peak at 31 matching the fragmentation of $–CH_2OH^+$ from the molecule.

Question 3b.

Worked solution

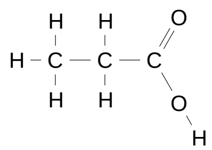
The spectrum is that of 1-propanol. There is no peak at 1750 cm^{-1} so there is no C=O present. The propanoic acid spectrum would have this peak.

Mark allocation: 2 marks

- 1 mark for identifying 1-propanol
- 1 mark for stating the absence of a peak at 1750 cm^{-1} as evidence that there is no C=O bond in the molecule

Explanatory notes

Propanoic acid has a C=O bond, as shown. This will show on an infrared spectrum as a peak at 1750 cm^{-1}. 1-Propanol will not have this peak. The absence of the peak on the spectrum provided confirms that it is 1-propanol.

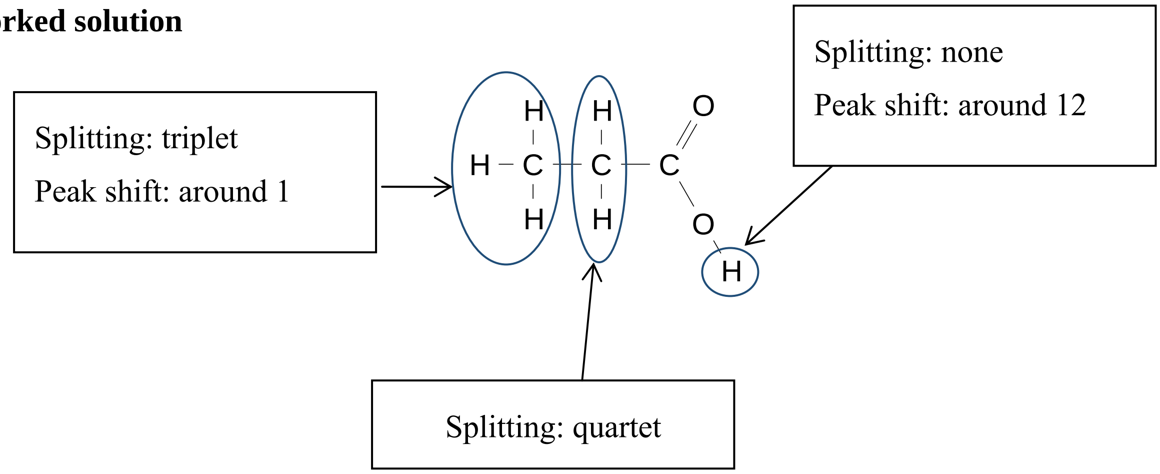


Tip

- *There are limitations to how to incorporate infrared spectra into exam questions. Therefore, differentiating between alkanols and carboxylic acids is a very common question to prepare for.*

Question 3c.

Worked solution



Mark allocation: 5 marks

- 1 mark for each correct response

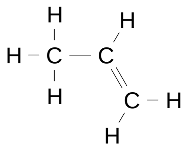
Explanatory notes

The methyl group on the left end of the molecule has two neighbouring hydrogen atoms, so under the *n* + 1 rule it will be a triplet. The shift will be minimal, around 1 as the methyl group is not adjacent to any functional groups.
The middle $–CH_2–$ has three neighbouring hydrogen atoms, so it will be a quartet.
The hydrogen atom on the –O–H bond will have no splitting as it has no direct neighbouring hydrogen atoms. The Data Book shows this as a shift of 11.5.

Question 4a.i.

Worked solution

A is propene.



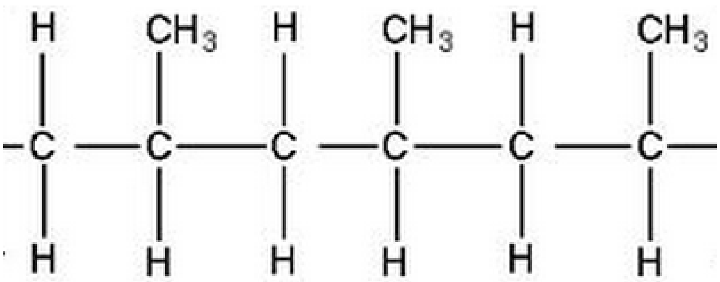
Mark allocation: 2 marks

- 1 mark for the name propene
- 1 mark for drawing propene correctly

Question 4a.ii.

Worked solution

The polymer is polypropene.



Mark allocation: 1 mark

- 1 mark for showing a segment of polypropene. It must show at least three repeating units and open ends to show the structure continues.

Explanatory notes

The reaction shown has only one product, suggesting that it is an addition reaction. Molecule A must be propene. When it reacts with chlorine, the double bond breaks and two chlorine atoms bond in its place.
Propene can polymerise with itself to form the polymer polypropene.

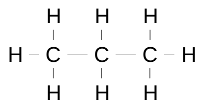
Tip

- *When asked to draw a polymer segment, ensure that you show open bonds at each end of the segment to signify that it is a polymer and also show whole repeating units.*

Question 4b.

Worked solution

Molecule B will be propane.



Mark allocation: 2 marks

- 1 mark for identifying molecule B as propane
- 1 mark for drawing it correctly

Explanatory notes

As there are two products, this reaction is a substitution reaction. The presence of ultraviolet light as a catalyst confirms this. Propane reacts with chlorine to form chloropropane and HCl.

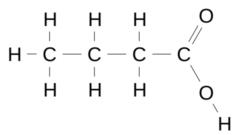
Tip

- *Chemistry has certain 'cues', the mention of UV light being one of them. Ultraviolet light almost always signifies substitution on an alkane, just as $Cr_2O_7^{2-}$ signifies conversion of an alkanol to a carboxylic acid.*

Question 4c.i.

Worked solution

C will be butanoic acid.



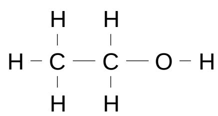
Mark allocation: 2 marks

- 1 mark for butanoic acid
- 1 mark for drawing the molecule correctly

Question 4c.ii.

Worked solution

D will be ethanol.



Mark allocation: 2 marks

- 1 mark for ethanol
- 1 mark for drawing the molecule correctly
- Note: It is acceptable if the answers to parts **i.** and **ii.** are reversed.

Question 4c.iii.

Worked solution

H_2SO_4

Mark allocation: 1 mark

- 1 mark for H_2SO_4. The formula must be given, not the name.

Explanatory notes

The reactant is an ester. Esters are made from a carboxylic acid and an alkanol. The first part of the molecule is the carboxylic acid – it has four carbon atoms so it is butanoic acid. The second part of the molecule is ethanol as it has two carbon atoms.

Tip

- *If asked for the 'formula' of a catalyst, a formula must be given. The name of the chemical is not acceptable and the formula must be completely correct.*

Question 5a.

Worked solution

glycine, serine, alanine

Mark allocation: 3 marks

- 1 mark for each correct response

Explanatory notes

Each amide linkage (–CONH–) signifies the next amino acid. From the Data Book, the amino acids are (from the left) glycine, glycine, serine and alanine.

Question 5b.i.

Worked solution

The ‘primary structure’ of a protein is the sequence of amino acids in the protein.

Mark allocation: 1 mark

- 1 mark for mentioning the sequence of amino acids

Question 5b.ii.

Worked solution

The secondary structure results from parts of the protein molecule attracting other parts. In particular, hydrogen bonding occurs with the oxygen atoms on one part of the peptide and with hydrogen atoms on another part of the same peptide.

Mark allocation: 2 marks

- 1 mark for mentioning hydrogen bonding
- 1 mark for identifying that bonding occurs between hydrogen and oxygen

Explanatory notes

Proteins are polymers formed from amino acids. The sequence of amino acids joining together is referred to as the primary structure of the protein.
The secondary structure is the result of attractions between different parts of the protein chain. The presence of nitrogen and oxygen atoms leads to significant dipoles and these allow hydrogen bonds to form between different parts of the chain. Amino acids with a sulfur atom can also form covalent disulfide linkages between different parts of the chain.

Question 5c.i.

Worked solution

Enzymes are heat sensitive. They denature at high temperatures and lose their effectiveness.

Mark allocation: 1 mark

- 1 mark for mentioning denaturing or loss of molecule shape

Question 5c.ii.

Worked solution

glucose and fructose

Mark allocation: 1 mark

- 1 mark for stating both glucose and fructose

Explanatory notes

Enzymes work because they have a specific shape that catalyses a reaction. The action of heat or acid will disrupt this shape. This is denaturing.
From the Data Book, sucrose is a disaccharide formed from glucose and fructose.

Question 6a.i.

Worked solution

F

Mark allocation: 1 mark

- 1 mark for F

Question 6a.ii.

Worked solution

$$C_{18}H_{36}O_2(l) \quad + \quad 26O_2(g) \rightarrow 18CO_2(g) \ + 18H_2O(g)$$

Mark allocation: 2 marks

- 1 mark for correct formulas of each species and for correct states
- 1 mark for balancing equation

Explanatory notes

A saturated fatty acid has twice as many hydrogen atoms as carbon atoms. It will also have two oxygen atoms. Molecule F is the only correct solution.
Combustion usually forms carbon dioxide and water. Balance the carbon atoms first, then hydrogen, then oxygen.

Tip

- *Do not show the state of fuels as (aq) in equations. They are usually liquids (l).*

Question 6b.i.

Worked solution

C

Mark allocation: 1 mark

- 1 mark for C

Question 6b.ii.

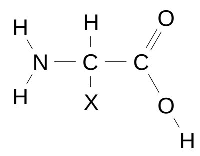
Worked solution

alanine

Mark allocation: 1 mark

- 1 mark for identifying alanine

Explanatory notes



Amino acids contain at least one nitrogen atom and at least one oxygen atom. This makes C the only possible answer.
Once the amine and carboxyl groups are accounted for, the atoms left are CH_3. This makes the amino acid alanine.

Question 6c.

Worked solution

D

Mark allocation: 1 mark

- 1 mark for D

Explanatory notes

A disaccharide is formed from the reaction of two molecules like glucose, $C_6H_{12}O_6$. When this happens, water is also produced so the molecular formula will be $C_{12}H_{22}O_{11}$.

Question 6d.i.

Worked solution

A

Mark allocation: 1 mark

- 1 mark for A

Question 6d.ii.

Worked solution

4 carbon-to-carbon double bonds

Mark allocation: 1 mark

- 1 mark for 4

Explanatory notes

A saturated fatty acid has twice as many hydrogen atoms as carbon atoms. It will also have two oxygen atoms. A saturated fatty acid with 20 carbon atoms will have 40 hydrogen atoms. As this fatty acid has 8 less hydrogen atoms, it must have 4 double carbon-to-carbon bonds.

Tip

- *Be careful when discussing unsaturated molecules to refer to 'carbon-to-carbon double bonds'; do not just use the term 'double bond'.*

Question 6e.

Worked solution

H

Mark allocation: 1 mark

- 1 mark for molecule H

Explanatory notes

Benzene itself has a molecular formula of C_6H_6. Benzoic acid is listed in the Data Book amongst the weak acids. Molecule H is benzoic acid, the name and similar molecular formula to benzene being clues.

Tip

- *This question is another example of how many times the Data Book can be used to answer a question. Be very familiar with its contents.*

Question 6f.i.

Worked solution

B

Mark allocation: 1 mark

- 1 mark for B

Question 6f.ii.

Worked solution

G

Mark allocation: 1 mark

- 1 mark for G

Explanatory notes

Fermentation is the action of yeast on glucose to form ethanol and carbon dioxide. The formula of glucose is $C_6H_{12}O_6$, matching the structure of molecule B. The molecular formula of ethanol is C_2H_6O, matching the structure of molecule G.

Tip

- *It is expected that you have rote-learnt the equation for fermentation, as the question occurs frequently.*

Question 7a.

Worked solution

A weak acid is an acid that does not ionise completely in water.

Mark allocation: 1 mark

- 1 mark for an explanation that the acid does not ionise completely in water

Explanatory notes

An acid such as HI is a weak acid if every molecule does not donate its proton when the acid is added to water. A weak acid does not fully ionise in water.

Question 7b.i.

Worked solution

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3CH_2COO^-(aq)$$

Mark allocation: 1 mark

- 1 mark for correct equation and states and double arrow

Question 7b.ii.

Worked solution

$$CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow H_2O(l) + CH_3CH_2COONa(aq)$$

Mark allocation: 1 mark

- 1 mark for correct equation and states

Explanatory notes

Propanoic acid's reaction with water is the same as any weak acid.
The reaction between propanoic acid and sodium hydroxide is an acid–base reaction, which forms a salt and water, the salt being sodium propanoate in this example.

Question 7c.i.

Worked solution

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$$

Mark allocation: 1 mark

- 1 mark for correct expression for K_a

Question 7c.ii.

Worked solution

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$$

$$1.3 \times 10^{-5} = \frac{X \times X}{0.2}$$

$$X = \left[H_3O^+\right] = \sqrt{2.6 \times 10^{-6}} = 1.61 \times 10^{-3}$$

$$\text{pH} = -\log_{10} 1.61 \times 10^{-3} = 2.79$$

Mark allocation: 3 marks

- 1 mark for correct substitution
- 1 mark for $[H_3O^+]$
- 1 mark for pH

Question 7c.iii.

Worked solution

$$\%\ \text{Ionisation} = \frac{\left[H_3O^+\right]}{[\text{acid}]} \times \frac{100}{1}$$

$$= \frac{1.61 \times 10^{-3}}{0.200} \times \frac{100}{1}$$

$$= 0.805\%$$

Mark allocation: 1 mark

- 1 mark for the correct answer

Explanatory notes

The expression for K_a is standard. The value of K_a comes from the Data Book. The pH is found by substitution into the expression for K_a.
Similarly, the percentage ionisation is a standard calculation that compares the concentration of hydronium ions formed, $[H_3O^+]$, with the original concentration of acid.

Question 7d.i.

Worked solution

The extra water makes the acid more dilute, so the pH increases.

Mark allocation: 1 mark

- 1 mark for 'increase'

Question 7d.ii.

Worked solution

The addition of water pushes the reaction in the forward direction. This increases the percentage ionisation.

Mark allocation: 1 mark

- 1 mark for 'increase'

Explanatory notes

Consider the reaction in question.

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3CH_2COO^-(aq)$$

An increase in the volume of water will push the reaction in the forward direction to try and make more particles in the solution. This shift increases the amount of H_3O^+ but not its concentration, given the initial addition of water. If the concentration of H_3O^+ drops, the pH rises. If the amount of H_3O^+ increases, then the percentage ionisation increases.

Question 8a.

Worked solution

No, it is a reversible reaction so not all reactant is consumed.

Mark allocation: 1 mark

- 1 mark for 'no' with a valid explanation that some reactant always remains for an equilibrium system

Explanatory notes

If this was an irreversible reaction, the statement would be correct. In a reversible reaction, not all reactant is consumed, so 0.80 mole of product will not form.

Question 8b.i.

Worked solution

$2NOCl(g)$	$\leftrightharpoons$	$2NO(g)$	$+$	$Cl_2(g)$	
0.76		0		0	start
0.60		$0+0.16$		$0+0.08$	equilibrium

$$K = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$$

$$= \frac{(0.16)^2(0.08)}{(0.60)^2}$$

$$= 5.69 \times 10^{-3}\ \text{M}$$

Mark allocation: 3 marks

- 1 mark for determining equilibrium amounts
- 1 mark for correct substitution into expression for *K*
- 1 mark for correct answer

Question 8b.ii.

Worked solution

K for reverse reaction = reciprocal of $5.7 \times 10^{-3} = 176$

Mark allocation: 1 mark

- 1 mark for calculating the reciprocal of answer to part **i.** even if its value was incorrect

Explanatory notes

0.76 mol is an initial amount of chemical, not an equilibrium amount. At equilibrium, the amount of NOCl has dropped to 0.60 – a change of 0.16 mol. This figure is used to calculate the amounts of products formed. Since it is a 1.0 L reactor, the amounts can be substituted into the expression for *K*.
When a reaction is reversed, the new *K* value is the reciprocal of the original value.

Tip

- *Part **ii.** is an example in which consequential marking is applied. If your answer to part **i.** is wrong but you apply the correct process to that answer for part **ii.**, then you will be awarded the mark for part **ii**.*

Question 8c.i.

Worked solution

The rate of the forward reaction will be increased.

Mark allocation: 1 mark

- 1 mark for ‘increase’

Question 8c.ii.

Worked solution

The rate of the back reaction will be increased.

Mark allocation: 1 mark

- 1 mark for ‘increase’

Question 8c.iii.

Worked solution

The position of equilibrium will be unchanged.

Mark allocation: 1 mark

- 1 mark for 'unchanged'

Explanatory notes

A catalyst increases the rate of a reaction but it does not affect the value of *K*. It also increases the rate of the back reaction.

Question 8d.i.

Worked solution

The second addition pushes the reaction in the forward direction, increasing the amounts of both products.

Mark allocation: 1 mark

- 1 mark for 'forward reaction favoured'

Question 8d.ii.

Worked solution

The amount of NOCl at the second point of equilibrium will be greater than at the first point of equilibrium.

Mark allocation: 1 mark

- 1 mark for 'greater'

Explanatory notes

$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$

The system will partially oppose the addition of extra NOCl and move in the forward direction. This will remove some of the extra NOCl added but there is still more present at the second point of equilibrium than was there at the start.

Question 9a.i.

Worked solution

$$n(\text{HCl}) = c \times V = 0.05 \times 1 = 0.0500 \text{ mol}$$

Mark allocation: 1 mark

- 1 mark for correct number of mole

Question 9a.ii.

Worked solution

$$n(\text{NaOH}) = c \times V = 0.05 \times 1.2 = 0.0600 \text{ mol}$$

Mark allocation: 1 mark

- 1 mark for correct number of mole

Explanatory notes

This question requires the straightforward use of $n = c \times V$.

Question 9b.

Worked solution

$$E = 4.18 \times 100 \times 6.6 = 2760 \text{ J}$$

$$\Delta H = \frac{E}{n} = \frac{2760}{0.0500}$$

$$= -55.2 \text{ kJ mol}^{-1}$$

Mark allocation: 3 marks

- 1 mark for energy value
- 1 mark for calculating ΔH
- 1 mark for negative sign and correct units

Explanatory notes

The total volume in the cup will be 100 mL. It can be assumed 100 mL of water has a mass of 100 g. The energy released is calculated from 100 g of water gaining 6.6˚C. To calculate ΔH, use the number of mole of the scarce reagent, which is HCl.
The reaction is exothermic.

Question 9c.

Worked solution

The answer obtained should be the same value because all neutralisation reactions are the same:

$H^+ + OH^- \rightarrow H_2O$

Mark allocation: 1 mark

- 1 mark for stating the value should be the same with a valid explanation that the reaction is the same for either acid

Explanatory notes

The reaction occurring with HCl is:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

As a partial ionic equation, this is:

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

The reaction between nitric acid and sodium hydroxide has the same partial ionic equation, and, hence, the same answer.

Question 10a.

Worked solution

Anode half-equation: $Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(aq) + 3e^-$

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

Mark allocation: 2 marks

- 1 mark for the correct anode half-equation
- 1 mark for the correct cathode half-equation

Explanatory notes

The reaction of Al is shown on the electrochemical series. The spectator ions, OH^-, have been included. The oxygen half-equation is also given at 0.40 V. This oxygen half-equation is chosen as it contains alkali ions.

Tip

- *The question tells you 'Refer to your Data Book'. This is there for a reason. This would be a difficult question without a Data Book but both half-equations are there.*

Question 10b.

Worked solution

$$n(\mathrm{Al}) = \frac{20}{27} = 0.741\,\mathrm{mol}$$

$$\mathrm{Al} \rightarrow \mathrm{Al}^{3+} + 3e^-$$

$$n_e = 3 \times 0.741 = 2.22 \text{ mol}$$

$$Q = 2.22 \times 96\,500 = 214\,000 \text{ C}$$

Mark allocation: 2 marks

- 1 mark for the number of mole of aluminium
- 1 mark for the final value of charge

Explanatory notes

Aluminium forms Al^{3+} ions. If 20 g of aluminium is consumed, then the number of mole of electrons produced will be three times the number of mole of aluminium. The charge on 1 mole is 96 500, so this figure is used to obtain the answer.

Question 10c.

Worked solution

$E = VQ$

$= 2.74 \times 214\,000 = 586\,000$ J

or 586 kJ (accept 586 000–588 000 range)

Mark allocation: 1 mark

- 1 mark for the correct answer

Explanatory notes

Energy = *VIT* or, in this case, *VQ*.

Question 11a.i.

Worked solution

$$2Na^+(l) + 2Cl^-(l) \rightarrow 2Na(l) + Cl_2(g)$$

Mark allocation: 1 mark

- 1 mark for balanced equation including states

Question 11a.ii.

Worked solution

The two products would need to be kept apart as they react vigorously and the materials are all at very high temperatures.

Mark allocation: 2 marks

- 1 mark for each valid reason given

Question 11a.iii.

Worked solution

The number of mole of sodium at the cathode will be twice the number of mole of chlorine at the anode.

Mark allocation: 1 mark

- 1 mark for recognising the factor of two

Explanatory notes

In molten solution, the Na^+ ions react to form Na and the Cl^- ions react to form Cl_2 gas.
Molten solutions require high temperatures so precautions would include safe handling of hot materials, keeping the two products apart and not ingesting pungent chlorine gas.
The balanced equation shows the ratio of sodium to chlorine gas as 2:1.

Question 11b.i.

Worked solution

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

Mark allocation: 1 mark

- 1 mark for correct equation with states

Question 11b.ii.

Worked solution

Anode: it would be red because acidic.
Cathode: it would be yellow because alkaline.

Mark allocation: 2 marks

- 1 mark for anode = red/acidic
- 1 mark for cathode = yellow/alkaline

Explanatory notes

In aqueous conditions, water is the strongest oxidant and water is the strongest reductant. The two half-equations occurring are:

$$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$$
$$(2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)) \quad \times 2$$

When the second half-equation is doubled and added to the first, the overall equation simplifies to $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$.

Question 11c.i.

Worked solution

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

Mark allocation: 1 mark

- 1 mark for correct half-equation

Question 11c.ii.

Worked solution

The electrochemical series is based on 1 M solutions. At higher concentrations, the Cl^- ions will surround the positive electrode and react in preference to water.

Mark allocation: 1 mark

- 1 mark for valid explanation that Cl^- ions will react at high concentrations

Question 11c.iii.

Worked solution

$Q = It$

$= 4 \times 2 \times 60 \times 60 = 28\,800 \text{ C}$

$$n_e = \frac{28\,800}{96\,500} = 0.30 \text{ mol}$$

$$n(H_2) = \frac{1}{2} n_e = 0.15 \text{ mol}$$

Mark allocation: 3 marks

- 1 mark for calculation of Q
- 1 mark for n_e
- 1 mark for correct final answer

Explanatory notes

The values for current and time are used to calculate the charge. The value for charge is converted to number of mole.
The gas produced at the cathode is hydrogen and the half-equation is:

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

The number of mole of hydrogen is half the number of mole of electrons.

END OF SOLUTIONS BOOKLET