2016

5. Which one of the following substances completes the equation illustrating the process of transesterification to produce biodiesel?

Triglyceride + [ ] → ester (biodiesel) + glycerol

(a) sodium hydroxide
(b) methanol
(c) sodium methoxide
(d) lipase

2016

22. A soap solution can be used to measure the hardness of a water sample. Four 100.0 mL water samples were tested. The table below shows the results of the tests on the four samples.

| Sample | Boiling point (°C) at atmospheric pressure | Volume (mL) of soap solution required to form a permanent lather | Mass (g) of precipitate formed when excess silver nitrate solution is added |
|---|---|---|---|
| A | 101.7 | 17.2 | 1.2 |
| B | 100.3 | 2.1 | 0.9 |
| C | 100.6 | 4.2 | 0.6 |
| D | 102.4 | 9.3 | 1.4 |

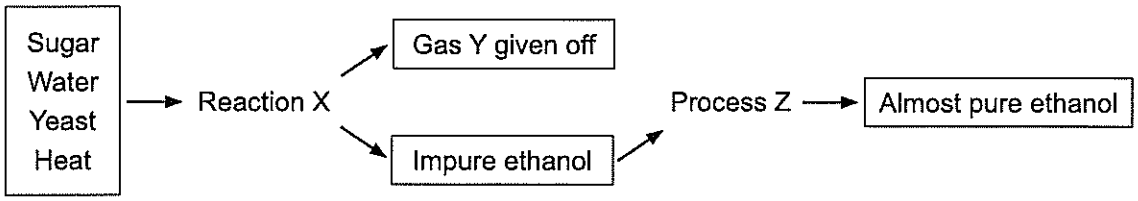
Which of the four samples contained water with the greatest hardness?

(a) Sample A
(b) Sample B
(c) Sample C
(d) Sample D

**See next page**

2016

Questions 23, 24 and 25 relate to the flow diagram below showing a process for making ethanol.




23. Reaction X is called

(a) neutralisation.
(b) fermentation.
(c) condensation.
(d) esterification.

24. Gas Y is

(a) oxygen.
(b) hydrogen.
(c) carbon dioxide.
(d) carbon monoxide.

25. Process Z is

(a) fractional distillation.
(b) condensation.
(c) filtration.
(d) precipitation.

**End of Section One**

**See next page**

2016

**Question 28** **(6 marks)**

While petroleum diesel and biodiesel are produced differently, they have similar structures to each other.

(a) The condensed structure of a petroleum diesel is given here.

$$CH_3 - CH_2 - (CH_2)_{12} - CH_2 - CH_3$$

Draw the condensed structure of a biodiesel containing the same number of carbon atoms in the chain. (3 marks)

(b) Biodiesel can be synthesised using a base-catalysed method or a lipase-catalysed method. Outline briefly an argument to justify the use of a lipase-catalysed method rather than a base-catalysed method to produce biodiesel. (3 marks)



See next page

**Question 30** **(5 marks)**

The process of chemical synthesis may involve a sequence of reactions.

(a) Use equations to show how ethyl ethanoate can be produced from ethene through the successive processes of hydrolysis and esterification. (4 marks)

(b) Write the overall equation for the process of synthesising ethyl ethanoate from ethene. (1 mark)

**Section Three: Extended answer** **40% (85 Marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the **appropriate number** of significant figures.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page

Suggested working time: 70 minutes.



2016

**Question 38** **(14 marks)**

A hydrolysis reaction is one that involves water being consumed as a reactant. Hydrolysis reactions can be represented by the following general equation.

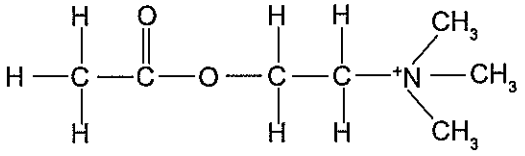
$$A—B + H_2O \rightarrow A—OH + H—B$$

Many processes within the human body involve hydrolysis reactions. These hydrolysis reactions usually require a catalyst; in living organisms that catalyst is an enzyme.

(a) What type of organic compound is an enzyme? (1 mark)

Acetylcholinesterase is an enzyme that is used in the hydrolysis of acetylcholine, a neurotransmitter in the brain.

The structure of acetylcholine is drawn below.



**Question 38** (continued)

(b) Two products are formed when acetylcholine undergoes hydrolysis in the presence of the enzyme acetylcholinesterase; one of these is a charged molecule called choline and the other is a carboxylic acid. Draw structures of these **two** products. (2 marks)

A catalyst is said to be **active** if it is working to form the desired products. To ensure the acetylcholinesterase is **active** and so catalysing the hydrolysis of acetylcholine, the charged compound found in the reacting vessel is separated and analysed using a combustion reaction to determine its empirical formula.

A 4.270 g sample was combusted in the presence of pure oxygen until no solid remained. 9.020 g of carbon dioxide, 5.169 g of water and 1.886 g of nitrogen dioxide were produced.

(c) Calculate the empirical formula of the combusted sample. (9 marks)

**See next page**

(d) Use your calculated empirical formula to demonstrate that the enzyme is **active**.

(2 marks)

**See next page**

**Question 39** **(16 marks)**

Pentlandite, $Fe_9Ni_9S_8$, is a common nickel sulfide ore that can be used to obtain the materials required to produce sulfuric acid. This metal sulfide ore is combusted in air to form sulfur dioxide according to the following equation.

$$Fe_9Ni_9S_8 + 17\ O_2 \rightarrow 9\ NiO + 9\ FeO + 8\ SO_2$$

(a) What is the volume of sulfur dioxide produced if 2.2 tonne of pentlandite is combusted in air? The process has a yield of 72.0%, and takes place at 300.0 °C and 165.0 kPa. Express your answer to the appropriate number of significant figures.

Molar mass of $Fe_9Ni_9S_8$ = 1287.42 g $mol^{-1}$. (7 marks)



See next page

This sulfur dioxide is then passed over four beds of a vanadium pentoxide or platinum catalyst at 450 °C to produce sulfur trioxide.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -197.78\ kJ$$

(b) State **two** justifications for the use of catalysts in this process. (2 marks)

One: _____

_____

Two: _____

_____

(c) State the effect of raising the pressure of the system on both the rate and yield. (2 marks)

Effect on rate: _____

_____

Effect on yield: _____

_____

(d) Use the Collision Theory to explain the effect of raising the total pressure on the yield. (5 marks)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____



See next page

2017

11. The purpose of 'green chemistry' is to

(a) utilise renewable energy sources (such as wind, solar or wave) at all times, even if they are more costly.
(b) design chemical products and processes that maximise profits and, if economical to do so, reduce harm to the environment.
(c) design chemical products and processes that work most efficiently.
(d) design safer chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

2017

21. The structure of detergent could be represented as R-X where R is dodecylbenzene and X is a sulfonate. X is represented by which one of the following?

(a) $SO_4^{2-}$
(b) $SO_3^{2-}$
(c) $SO_3^-$
(d) $SO_2^-$

**See next page**

2017

**Question 30** **(8 marks)**

Carbonyl chloride, $COC\ell_2$, is a colourless, poisonous gas that is used in the production of insecticides and a variety of plastics. It is produced through the exothermic reaction between carbon monoxide and chlorine gases. Carbonyl chloride is a liquid below 8 °C at 100.0 kPa.

The following equation is used to represent the reaction.

$$CO(g) + C\ell_2(g) \leftrightharpoons COC\ell_2(g) \qquad \Delta H < 0$$

(a) For this industrial process state the conditions that would optimise the: (2 marks)

rate of reaction _____

_____

yield _____

_____

(b) State **one** compromise in conditions that might be required to produce carbonyl chloride, $COC\ell_2$, in an industrial process. Explain the effect of this condition on the rate and yield and justify why this compromise is required. (6 marks)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

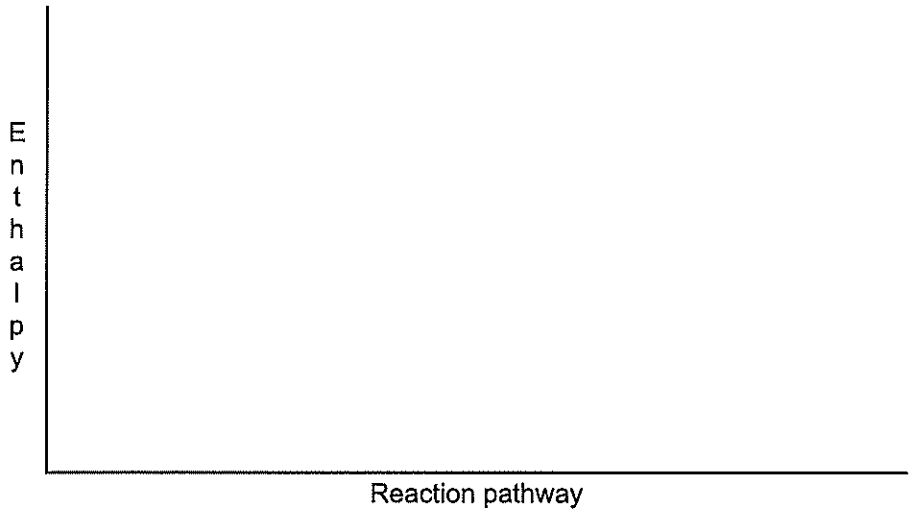


See next page

**Question 33** **(9 marks)**

Both dynamite and TNT are explosive substances that are sometimes confused with each other. The active ingredient in dynamite is a stabilised form of nitroglycerine, $C_3H_5N_3O_9$, while TNT is the common name for the explosive compound 2,4,6-trinitrotoluene, $C_6H_2(NO_2)_3CH_3$.

(a) An explosion is a 'very fast and very exothermic reaction'. Use a solid line (——) to draw, and then label, an energy profile diagram reflecting an explosive reaction. (3 marks)




Nitroglycerin is extremely shock-sensitive and readily becomes unstable. In dynamite the nitroglycerin is combined with inhibitors and stabilisers, making it safer to use. Typically, dynamite is between 25% to 50% nitroglycerine.

(b) An inhibitor is a substance that decreases the rate of, or prevents, a chemical reaction. On the diagram in part (a) above, indicate by way of a dashed line ( - - - ) any change/s that would be evident if an inhibitor were to be introduced. (2 marks)

(c) The energy density of dynamite is 5.0 MJ $kg^{-1}$ and the energy density of TNT is 4.0 MJ $kg^{-1}$. Show by calculation and by reasoning which of these two explosives produces more energy per mole of the **active** ingredient. (4 marks)

$M(C_3H_5N_3O_9) = 227.10$ g $mol^{-1}$ $M(C_6H_2(NO_2)_3CH_3) = 227.14$ g $mol^{-1}$

See next page

**Section Three: Extended answer** **40% (100 Marks)**

This section contains five **(5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

2017

**Question 36** **(19 marks)**

Australia is a significant producer of antimony. Antimony, Sb, and its compounds have a wide range of uses. The metal is used to form alloys with other metals, such as lead, to increase their hardness, while compounds of antimony can be used in the manufacture of many substances such as plastics, pigments and match heads.

High-grade antimony ores are converted to the metal through the use of a blast furnace.
- Antimony sulfide ore is first heated to convert it to an oxide.
- Antimony oxide is then heated with carbon to convert it to a metal.

The following equations represent these two reactions.

Reaction one: $2\ Sb_2S_3(s) + 9\ O_2(g) \leftrightharpoons 2\ Sb_2O_3(s) + 6\ SO_2(g)$

Reaction two: $2\ Sb_2O_3(s) + 3\ C(s) \leftrightharpoons 4\ Sb(s) + 3\ CO_2(g)$

(a) What mass of ore would be required to produce 6.00 tonnes of antimony, assuming the ore contains 25.6% by mass of antimony(III) sulfide and the reactions go to completion? (6 marks)

See next page

(b) Calculate the maximum volume of sulfur dioxide that could be produced in Reaction one at 525.0 °C and 105 kPa. Give the answer to the correct number of significant figures.
(4 marks)

**Question 39** **(25 marks)**

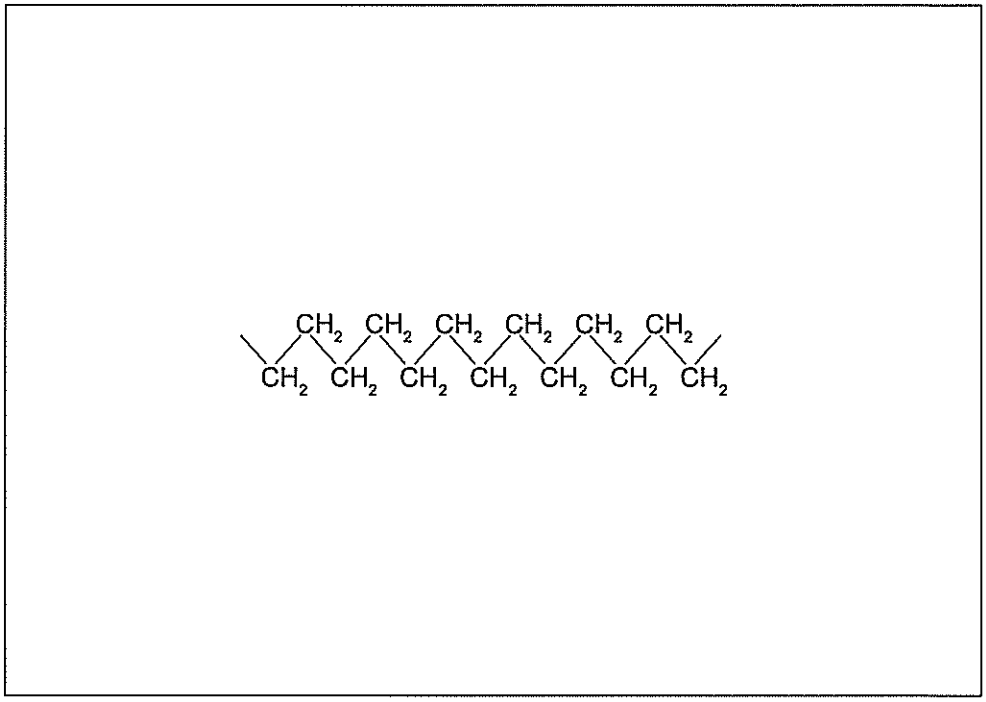
A cosmetic company advertises a range of 'inspiring quality organic, natural and essential personal care ingredients' in its skin care, hair care, aromatherapy and soaps products. It claims that the soaps it sells are made from different ingredients boasting 'an array of perfumes and cosmetic benefits'.

Soaps are a class of substances used to clean grease, dirt or oils from a surface such as skin. They do this because they are capable of dissolving in both aqueous and oily systems at the same time.

(a) (i) On the diagram below:

- complete the structure of a soap
- identify and label the key structural features of soap
- draw **two** molecules of water showing how they are orientated about soap.

(5 marks)






See next page

The process of dissolving is a consequence of attractive forces between solvent and solute. The different parts of soap are capable of producing different types of attractive forces.

(ii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and water. (3 marks)

(iii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and oil. (3 marks)

(b) Explain why soaps do **not** function very effectively in hard water. (2 marks)

**Question 39** (continued)

Fats and oils are essentially esters of fatty acids. These esters are called 'triglycerides' and are derived from glycerol and three fatty acids.

(c) (i) Name the functional group in glycerol. (1 mark)

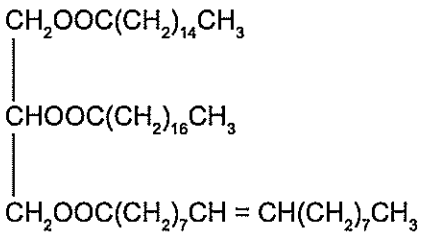
_____

(ii) State the **two** distinctive parts of a fatty acid used to make soap. (2 marks)

One: _____

Two: _____

Below is a typical animal fat (triglyceride).



To produce soap, the above fat can be hydrolysed with concentrated sodium hydroxide solution.

(d) Draw structural formulae of the **four** products from this saponification process. Names are **not** required. (4 marks)

| | |
|---|---|
| | |
| | |

(e) Why are soap solutions basic? (2 marks)

Under Australian law, any company wishing to make soap commercially using a saponification process must register with the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) administered by the Department of Health.

(f) State **one** health risk caused by chemicals used in the saponification process that would require careful monitoring by NICNAS. (1 mark)

The following table claims to list soaps in increasing order of cleaning effectiveness.

**Soaps and their chemical structure**

| Common name | Chemical structure |
|---|---|
| Sodium caprylate | $CH_3(CH_2)_6COONa$ |
| Sodium caprate | $CH_3(CH_2)_8COONa$ |
| Sodium laurate | $CH_3(CH_2)_{10}COONa$ |
| Sodium myristate | $CH_3(CH_2)_{12}COONa$ |
| Sodium palmitate | $CH_3(CH_2)_{14}COONa$ |
| Sodium stearate | $CH_3(CH_2)_{16}COONa$ |
| Sodium arachidate | $CH_3(CH_2)_{18}COONa$ |
| Sodium behenate | $CH_3(CH_2)_{20}COONa$ |
| Sodium lignocerate | $CH_3(CH_2)_{22}COONa$ |
| Sodium cerotic | $CH_3(CH_2)_{24}COONa$ |

least effective ↓ most effective

(g) Use the information in the table to write an **hypothesis** that could be used to investigate cleaning effectiveness. (2 marks)

See next page

JEF

2018

16. Chemists must act ethically when conducting research. Which of the following statements relate to **ethical** behaviour?

(i) Chemists calibrate all of their instruments with primary standards.
(ii) Chemists give due credit to all contributors to an investigation in their written reports.
(iii) Chemists record their experimental results accurately and without alteration to fit their prediction.
(iv) Chemists dispose of their waste materials carefully, especially those containing heavy metals.
(v) Chemists ensure that there is only one independent variable in every experiment they perform.
(vi) Chemists declare any conflict of interest relevant to their investigation.

(a) i, ii and iii only
(b) ii, iv and v only
(c) ii, iii, iv and vi only
(d) i, iii, iv, v and vi only

**See next page**



2018

20. Ethanol can also be produced by reacting ethene with steam. The equation for this reaction, which is known as hydration, is shown below.

$$CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

Which statement about this reaction is **incorrect**?

(a) The hydration reaction requires higher pressures than fermentation to achieve an economically-viable rate.
(b) The hydration of ethene is an addition reaction.
(c) Enzymes decrease the activation energies of both the hydration and fermentation reactions.
(d) The hydration reaction requires higher temperatures than fermentation to achieve an economically-viable rate.

Questions 19 and 20 refer to two different methods of synthesising ethanol.

2018

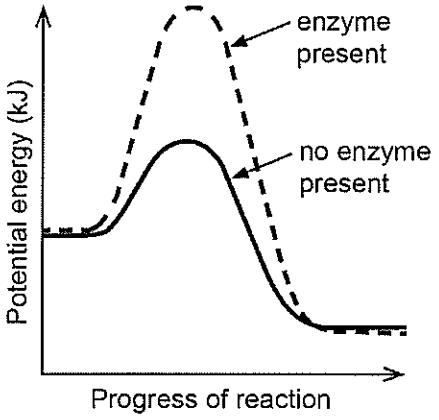
19. Ethanol can be synthesised by combining sugar, a suitable enzyme and water. The equation for this is shown below.

$$C_6H_{12}O_6(aq) \rightleftharpoons 2\,CH_3CH_2OH(aq) + 2\,CO_2(g) + \text{energy}$$

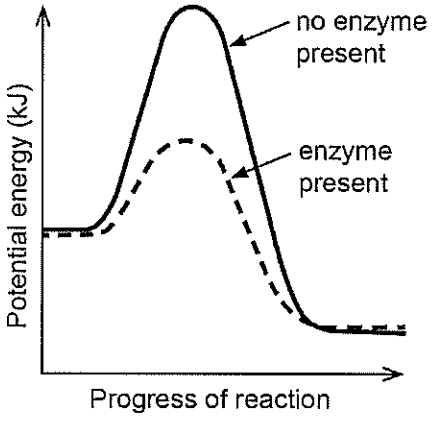
This process is known as 'fermentation'.

Which of these energy profile diagrams shows the effect of an enzyme on this reaction? All other conditions are constant.

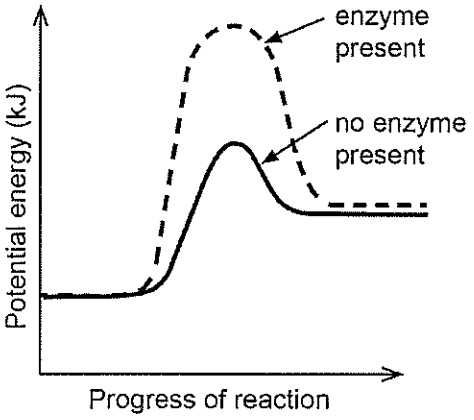
(a)



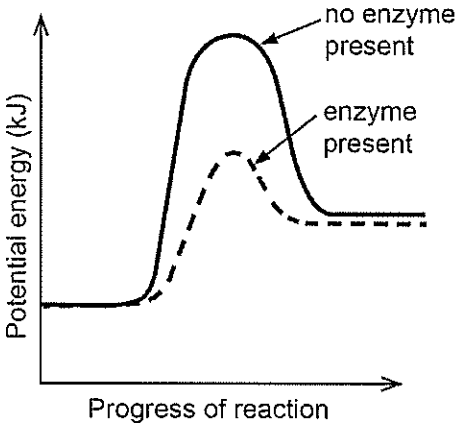

(b)




(c)

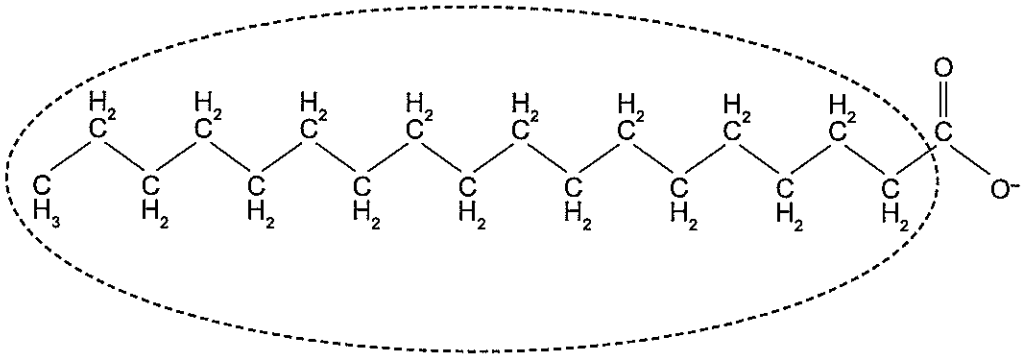



(d)



2018

24. Soap and water can be used to remove oil and grease from human skin. The following diagram represents an anion of soap.



Which of the following correctly describes the orientation of the circled section and the attractive force it forms?

| | Orientation | Attractive force |
|---|---|---|
| (a) | toward oil and grease | dispersion forces |
| (b) | toward oil and grease | dipole-dipole forces |
| (c) | toward water | hydrogen bonds |
| (d) | toward water | ion-dipole forces |

**See next page**

**Question 36** **(17 marks)**

A scientist was given the task of investigating the concentration of dissolved heavy metals in abandoned open-cut mines that had filled with water to create small freshwater dams.

Using a map, the scientist identified 180 locations containing abandoned open-cut mines that had become freshwater dams. The scientist decided to randomly select locations to take water samples. The procedure for water sampling at each location was as follows:

1. Take two samples using separate 100.0 mL bottles at a water depth of 0.50 m.
2. Acidify each sample with a few drops of nitric acid solution to minimise heavy metal precipitation.
3. Wait eight hours before measuring heavy metal concentration.
4. Calculate the average concentration of a range of heavy metals, using two samples per location.

(a) Outline the difference between random and systematic errors. Give an example of each that might be encountered in this investigation. (4 marks)



See next page

Water samples were collected from 59 of the 180 possible locations.

(b) (i) Calculate the sample size as a percentage of the testable locations. (1 mark)

_____

(ii) Propose **two** reasons why samples were not collected from all locations. (2 marks)

One: _____

_____

Two: _____

_____

(iii) Predict the effect of using a smaller sample size on the reliability of the overall results. Justify your answer. (2 marks)

_____

_____

_____

_____

**Question 36** (continued)

Once the samples had been analysed, the scientist found that a particular sampling location had a high concentration of cadmium(II) ions. The dam from which the sample came is now used as a water source for leisure activities and irrigation of surrounding food crops.

Cadmium is known to be harmful to human health. Authorities are concerned that the cadmium could be consumed accidentally by humans at that water source or they could be exposed to cadmium from crops irrigated by the dam.

After further investigation, the scientist determined that the freshwater dam had:

- a volume of $1.123 \times 10^9$ L
- an average cadmium(II) ion concentration of 0.5310 mg $L^{-1}$ with an error margin of $\pm 0.09100$ mg $L^{-1}$.

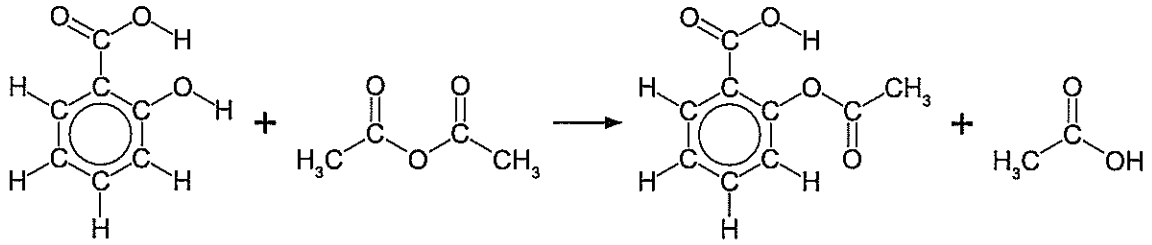
To remove the cadmium(II) ions, phosphate ions can be added to immobilise the cadmium as an insoluble precipitate. The scientist proposes that sodium phosphate, $Na_3PO_4(s)$, be used to remove the cadmium(II) ions.

(c) Calculate the minimum mass of sodium phosphate needed to remove all the cadmium(II) ions from the water. Give your final answer to the appropriate number of significant figures. Assume that there are no species other than cadmium(II) ions present in the dam that will react with the phosphate ions. (8 marks)

See next page

**Question 40** **(17 marks)**

Acetylsalicylic acid is better known as aspirin. It is used to treat pain and inflammation. Aspirin can be synthesised from salicylic acid and acetic anhydride ($C_4H_6O_3$). This process can be represented by the equation below.



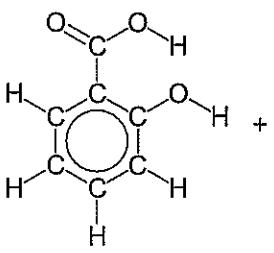
salicylic acid acetic anhydride aspirin acetic acid

The molar mass of salicylic acid is 138.121 g $mol^{-1}$.
The molar mass of aspirin is 180.158 g $mol^{-1}$.
This reaction is an equilibrium reaction with a K value of approximately 5.

(a) In the synthesis of aspirin, 45.0 g of salicylic acid was reacted with excess acetic anhydride. This produced 50.2 g of aspirin. What was the percentage yield of this reaction? (4 marks)

A student conducts a titration to determine the percentage purity of a sample of salicylic acid that was to be used in the synthesis of aspirin.

(b) Complete the equation for the reaction between salicylic acid and sodium hydroxide solution. (2 marks)



See next page

**Question 40** (continued)

An amount of 3.55 g of salicylic acid was dissolved in distilled water and added to a 250.0 mL volumetric flask, which was filled to the calibration line with additional distilled water. 20.00 mL aliquots of the acid solution were titrated against 0.0966 mol $L^{-1}$ sodium hydroxide solution. The average titre obtained was 18.45 mL.

(c) Calculate the mass of salicylic acid in the sample and therefore the percentage purity of the sample. (5 marks)

During the titration, the student used the following procedure.

| Number | Procedure |
|---|---|
| 1 | Swirl the conical flasks while adding sodium hydroxide solution from the burette. |
| 2 | Use the same number of drops of indicator for each titration. |
| 3 | Stop the titration at the first sign of the indicator showing a colour change. |
| 4 | Wash the pipette with distilled water before filling with salicylic acid solution. |
| 5 | Slow down the addition of sodium hydroxide solution as the end point is approached. |
| 6 | Rinse down the sides of the conical flask during the titration. |

(d) Identify **two** incorrect procedures from the list above, select the effect on the calculated concentration of salicylic acid and give the reason for the effect. (6 marks)

| Number | Effect on calculated concentration (circle your answer) | Reason |
|---|---|---|
| | increase<br>decrease<br>no change | |
| | increase<br>decrease<br>no change | |

**End of questions**

2019

11. Which one of the following statements about catalysis in the production of biodiesel is correct?

(a) Base catalysis generally has a higher reaction rate but, unlike lipase catalysis, can cause saponification, which decreases the biodiesel yield.

(b) The sodium hydroxide and potassium hydroxide used in base catalysis are readily available and relatively cheap, but lipase catalysis produces more toxic waste water.

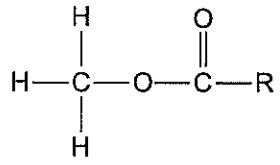
(c) Base catalysis involves only one step, while lipase catalysis involves many steps in its synthesis sequence, which in turn adds to the cost of the process.

(d) Base catalysis typically has a lower rate and yield of biodiesel but lipase catalysis is sensitive to alcohols, such as methanol, and has higher energy costs.

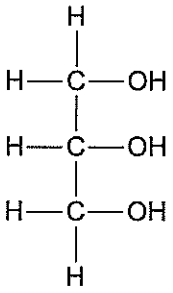
2019

13. One method of producing biodiesel is by a transesterification reaction where triglycerides are converted into simpler methyl esters (the biodiesel) of the fatty acids. Which one of the following is a reactant of this transesterification reaction?

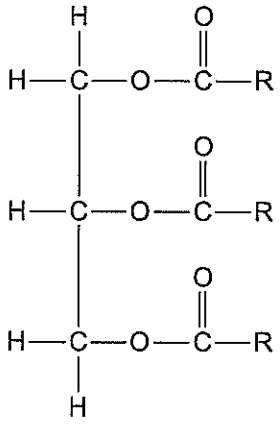
(a)



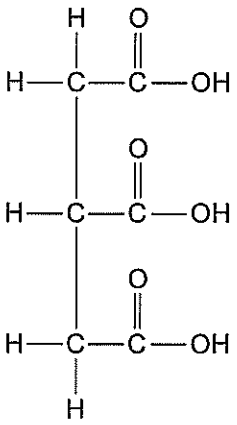
(b)



(c)



(d)



**See next page**

**Question 29** **(8 marks)**

Sulfuric acid is a very useful chemical that is produced industrially by a multi-stepped process. These steps are summarised by the following equations.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Equation 1 | $S(\ell)$ | + | $O_2(g)$ | $\rightarrow$ | $SO_2(g)$ | | |
| Equation 2 | $2\ SO_2(g)$ | + | $O_2(g)$ | $\rightleftharpoons$ | $2\ SO_3(g)$ | + | 198 kJ |
| Equation 3 | $H_2SO_4(\ell)$ | + | $SO_3(g)$ | $\rightarrow$ | $H_2S_2O_7(\ell)$ | | |
| Equation 4 | $H_2O(\ell)$ | + | $H_2S_2O_7(\ell)$ | $\rightarrow$ | $2\ H_2SO_4(\ell)$ | | |

When dihydrogen sulfate, $H_2SO_4(\ell)$, is mixed with water, it produces sulfuric acid, $H_2SO_4(aq)$.

(a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $H_2SO_4(\ell)$, from sulfur dioxide, $SO_2(g)$. (2 marks)

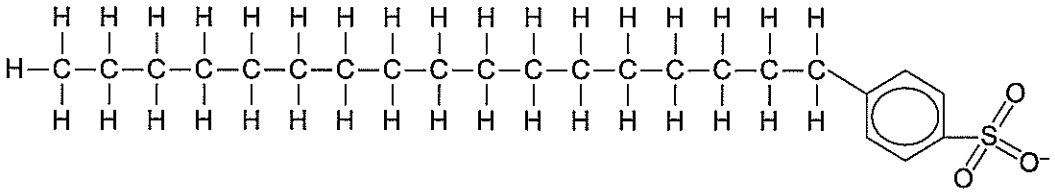
(b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

| | **Advantage/s** | **Disadvantage/s** |
|---|---|---|
| High temperature | | |
| High pressure | | |

**See next page**

**Question 37** **(24 marks)**

Detergents and soaps are both used as cleaning agents. The general structure of a detergent is given below.



(a) Explain how detergents are able to remove grease from a surface by referring to the intermolecular forces present. Include a labelled diagram to illustrate your answer.

(7 marks)



See next page

Detergents are considered to be more versatile cleaners than soap.

(b) Explain why soaps are generally less effective than detergents as cleaning agents in hard water. Include a relevant equation in your answer. (4 marks)

**Question 37** (continued)

Alkenes can also form soaps.

(c) Draw a structural diagram for the soap ion, $C_{17}H_{31}CO_2^-$ using the incomplete structure below. Show **all** atoms and bonds. (2 marks)

C—C—C—C—C—C—C—C—C—C—C—C—C—C—C—C—C

(d) Write an equation showing the formation of this soap from the fat (triglyceride) shown below. (3 marks)

$C_{17}H_{31}COOCH_2$
|
$C_{17}H_{31}COOCH$ +
|
$C_{17}H_{31}COOCH_2$

The formation of soap is both an endothermic and equilibrium reaction.

(e) Predict and explain the conditions that would result in the highest yield of soap in the shortest amount of time. (8 marks)



See next page

**Question 40** **(22 marks)**

A chemist was developing a new method for extracting lithium metal from ores rich in the mineral lepidolite. The procedure being proposed by the chemist is as follows:

| | |
|---|---|
| Step 1 | crush and grind the ore |
| Step 2 (Leach) | add sulfuric acid to the crushed ore to dissolve lepidolite (and other soluble ore constituents) |
| Step 3 | add reagents to the leach solution that will precipitate unwanted soluble species |
| Step 4 | recover lithium as lithium carbonate. |

In a test of Step 2, performed by the chemist, 5.0 L of sulfuric acid, which was in excess, was added to a crushed and ground sample of a lepidolite-containing ore.

The leach solution was analysed and found to contain sulfate ions and hydrogen ions from the sulfuric acid and the ions stated in the table below.

| Ions present | Concentration |
|---|---|
| $Li^+$ | 2.13 g $L^{-1}$ |
| $Rb^+$ | 1.30 g $L^{-1}$ |
| $A\ell^{3+}$ | 1.86 g $L^{-1}$ |
| Fe (as $Fe^{2+}$ and $Fe^{3+}$) | 1.27 g $L^{-1}$ |

The chemist tried to remove the rubidium and aluminium ions from the leach solution by cooling the solution to 5.00 °C so as to precipitate them as rubidium alum, $RbA\ell(SO_4)_2$. The equation is shown below.

$$Rb^+(aq) + A\ell^{3+}(aq) + 2\,SO_4^{2-}(aq) \rightarrow RbA\ell(SO_4)_2(s)$$

The chemist found that, while all of the $Rb^+$ precipitated, there was a considerable quantity of $A\ell^{3+}$ ions still dissolved in the leach solution.

(a) Calculate the concentration of $A\ell^{3+}$ ions remaining in the 5.0 L of leach solution. Give your answer in grams per litre (g $L^{-1}$) to the appropriate number of significant figures. (9 marks)

See next page

To remove the remaining $A\ell^{3+}$ ions from the leach solution, the chemist added 2.63 L of a 0.0550 mol $L^{-1}$ $K_2SO_4$ solution, with the result being the precipitation of potassium alum as shown in the equation below.

$$K^+(aq) + A\ell^{3+}(aq) + 2\,SO_4^{2-}(aq) \rightarrow KA\ell(SO_4)_2(s)$$

The sulfate ions remained in excess due to the initial addition of sulfuric acid.

(b) Was sufficient $K_2SO_4$ solution added to precipitate all of the $A\ell^{3+}$ ions remaining in the leach solution? Justify your answer with relevant calculations. (4 marks)

See next page

**Question 40** (continued)

The final purification step was the removal of iron from the leach solution. To do this the chemist added a suitable oxidant (1.00 mol $L^{-1}$ hydrogen peroxide) to convert all of the $Fe^{2+}$ ions to $Fe^{3+}$ ions. The chemist then added excess sodium hydroxide solution to precipitate all of the iron (now present as $Fe^{3+}$ ions) as $Fe(OH)_3$. This precipitate, and the alum precipitates formed earlier, were removed by filtration.

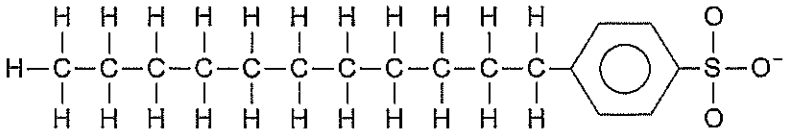
(c) Write a balanced overall equation to show the conversion of $Fe^{2+}$ to $Fe^{3+}$ by hydrogen peroxide. (3 marks)

The leach solution, now free from rubidium, aluminium and iron, was heated and evaporated to dryness, yielding a lithium-rich residue. The residue was further treated to produce lithium carbonate suitable for use in lithium-ion battery manufacture, with the mass of lithium carbonate recovered being equal to 46.7 g.

(d) Calculate the percentage yield of lithium carbonate, $Li_2CO_3$, based on the theoretical amount that should have been recovered. Use the concentration of $Li^+(aq)$ in the table on page 42. (6 marks)

See next page

2020
9. Consider the molecule shown below.



This molecule shows

(a) an anionic detergent which contains a sulfonate group.
(b) a monomer that can be used to synthesise a condensation polymer.
(c) a carboxylic acid which can be used to synthesise a soap.
(d) an aromatic hydrocarbon which has donated an electron.

2020
22. When cleaning greasy/dirty objects in hard water, it is **best** to use

(a) a soap, because it forms a precipitate with the ions causing water hardness, thereby removing these ions from solution.
(b) a detergent, because it does not react with the ions causing water hardness.
(c) a detergent, because it forms a precipitate with the ions causing water hardness, thereby removing these ions from solution.
(d) a soap, because it does not react with the ions causing water hardness.

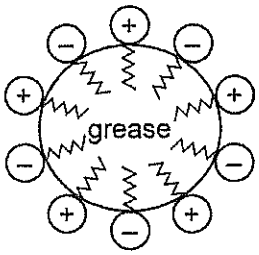


**See next page**

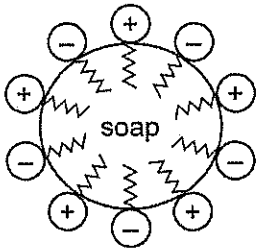
2020

23. Which of the following diagrams represents the micelle that forms in water when soap is used to remove grease from dirty dishes?

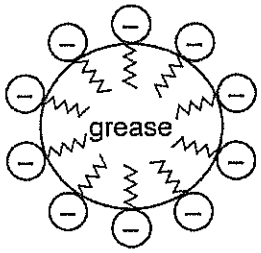
(a)



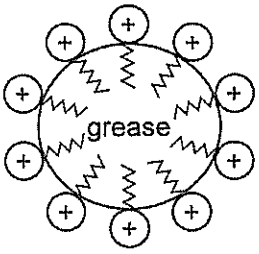

(b)




(c)




(d)



**Question 32** **(13 marks)**

Some students were asked to identify the 'best' cleaning solvent for the removal of graffiti from concrete. They were given black spray paint and five different cleaning solvents.

The students sprayed five different 10 cm by 10 cm areas of a concrete wall with the black paint and allowed the paint to dry for 24 hours. They then used 100 mL of cleaning solvent to try to remove the black paint, with a different cleaning solvent being used for each square. The students subsequently ranked the cleaning solvents from 1 to 5 based on their ability to dissolve the black paint with 1 being the best and 5 being the worst.

The results of the students' investigation, plus some information about the composition of each cleaning solvent, are shown in the table below.

| Solvent | Investigation ranking | Composition of cleaning solvent |
|---|---|---|
| distilled water | 5 | water |
| turpentine | 2 | straight-chain hydrocarbons containing ten carbon atoms and one double bond |
| acetone | 3 | propanone |
| white spirit | 1 | straight-chain hydrocarbons C7 to C12 |
| methylated spirits | 4 | 5% methanol, 95% ethanol |

(a) Identify the independent and dependent variables in the students' investigation. (2 marks)

| | |
|---|---|
| Independent variable | |
| Dependent variable | |

(b) State **two** variables that the students needed to control in their investigation. (2 marks)

One: _____

_____

Two: _____

_____

See next page

(c) What could the students do to ensure that their investigation was:

(i) valid? (1 mark)

(ii) reliable? (1 mark)

(d) Identify **two** safety risks associated with the students' investigation and state how each risk could be minimised. (4 marks)

| Safety risk | How to minimise the risk |
|---|---|
| | |
| | |

(e) Paints contain, among other things, a pigment (which is the paint colour) and a solvent (which dissolves the pigment). When paint dries, the solvent evaporates, leaving the pigment behind.

Use this information, the students' results and your knowledge of chemistry to identify the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

**Question 39** **(12 marks)**

Fluorescent lights are glass tubes which are coated on the inside with rare earth metal phosphates (such as cerium, lanthanum and terbium phosphates) that provide light. Cerium, lanthanum and terbium are expensive, so are recovered once the fluorescent light is no longer functional.

The key steps in one method proposed for recovery of these rare earth metals are summarised below:

- **Step 1:** Physical separation of the rare earth metal phosphates from the glass and any metallic components. This gives an impure powder consisting of cerium, lanthanum and terbium phosphates.
- **Step 2:** Add excess solid sodium carbonate to the powder and heat, completely converting each rare earth metal phosphate to its corresponding oxide, as shown by the following balanced equations:

  $2\ LaPO_4(s) + 3\ Na_2CO_3(s) \rightarrow La_2O_3(s) + 2\ Na_3PO_4(s) + 3\ CO_2(g)$

  $4\ CePO_4(s) + 6\ Na_2CO_3(s) + O_2(g) \rightarrow 4\ CeO_2(s) + 4\ Na_3PO_4(s) + 6\ CO_2(g)$

  $2\ TbPO_4(s) + 3\ Na_2CO_3(s) \rightarrow Tb_2O_3(s) + 2\ Na_3PO_4(s) + 3\ CO_2(g)$
- **Step 3:** Wash the product from Step 2 with water.
- **Step 4:** Add hydrochloric acid to the washed product from Step 3 to leach (dissolve) only the rare earth metal oxides.
- **Step 5:** Use solvent extraction to separate the different rare earth metals from each other and create separate solutions of each of them.
- **Step 6:** Add oxalic acid to the separated solutions to precipitate the rare earth metal ions as oxalate salts.
- **Step 7:** Heat the oxalate salts to recover the rare earth metals as pure oxides, namely $La_2O_3$, $Tb_4O_7$ and $CeO_2$.

A chemist used the above procedure to determine the percentage by mass of lanthanum, terbium and cerium in some fluorescent lights and, after completing Step 1, had recovered 1.20 kg of the coating chemicals.

(a) At the completion of Step 2, the mass of the mixture had decreased by 11.3 g. Calculate the mass of sodium carbonate that reacted with the rare earth metal phosphates.

(3 marks)



See next page

**Question 39** (continued)

The mass of the solid sent from Step 3 to Step 4 was 1.16 kg. This solid was leached with 6.00 mol $L^{-1}$ HCℓ at a solid to liquid ratio of 150 g per litre. Analysis of the solution at the end of leaching showed that it contained lanthanum, terbium and cerium, with its lanthanum concentration being $8.65 \times 10^{-3}$ mol $L^{-1}$.

(b) Calculate the percentage, by mass, of lanthanum in the fluorescent light coating chemical, given that the leaching efficiency for lanthanum was 86%.

Note that the balanced equation for the leaching of lanthanum with hydrochloric acid is:

$$La_2O_3(s) + 6\ HC\ell(aq) \rightarrow 2\ LaC\ell_3(aq) + 3\ H_2O(\ell)$$

(5 marks)

Analysis of the cerium-containing solution produced in Step 5 showed that its cerium concentration was 0.146 mol $L^{-1}$. This solution, which had a volume of 424 mL, was added to 110 mL of aqueous 1.15 mol $L^{-1}$ oxalic acid during Step 6, resulting in the precipitation of cerium oxalate, $Ce(C_2O_4)_2$. The balanced equation for this reaction is:

$$CeC\ell_4(aq) + 2\ H_2C_2O_4(aq) \rightarrow Ce(C_2O_4)_2(s) + 4\ HC\ell(aq)$$

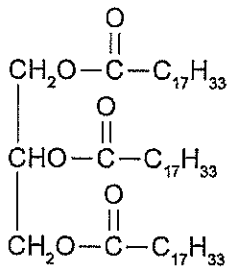
(c) Did the chemist add enough oxalic acid solution to precipitate all of the cerium? Use calculations to support your answer. (4 marks)

**Question 40**

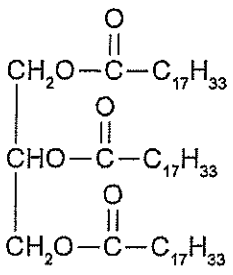
**(16 marks)**

Thousands of fast-food outlets across Australia use vegetable oil in cooking. Large volumes of vegetable oil waste are thus produced and need to be disposed of. A disposal option is turning the vegetable oil waste into biodiesel.

Vegetable oil waste is a mixture of free fatty acids and triglycerides. Triolein, the triglyceride of the free fatty acid oleic acid, is typically present in large amounts. The condensed structural formulae of oleic acid and triolein are shown below.

| | |
|---|---|
| $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ |  |
| oleic acid (a free fatty acid) | triolein (the triglyceride of oleic acid) |

(a) Write a balanced equation, using condensed structural formulae, to show the formation of biodiesel from triolein and ethanol. Assume that a suitable catalyst is present. (3 marks)



(b) Lipase is a protein that can be used to catalyse the reaction between triolein and ethanol. To which class of biological chemicals (other than proteins) does lipase belong? (1 mark)

---

**Question 40** (continued)

The free fatty acids found in vegetable oil waste will react with the ethanol that was intended for biodiesel synthesis, establishing an equilibrium.

(c) Complete the following equation to show the equilibrium that is established between oleic acid and ethanol. Represent all organic substances as condensed structural formulae and assume acidic conditions. (2 marks)

$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH + CH_3CH_2OH$

$\rightleftharpoons$ [ ]

In an industrial setting, reaction conditions are adjusted to favour the forward direction of the oleic acid/ethanol equilibrium.

(d) Identify **two** different actions that can be carried out to favour the forward direction of this equilibrium. (2 marks)

One: _____

_____

Two: _____

_____

The base sodium hydroxide can also catalyse the reaction between triolein and ethanol. The free fatty acids in the vegetable oil waste also react with the base.

(e) (i) Write a balanced equation showing the reaction of oleic acid with sodium hydroxide. Represent all organic substances as condensed structural formulae. (2 marks)

$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$

(ii) To which class of compounds does the organic product of this reaction belong? (1 mark)

_____

(f) Which of the catalysts, lipase or sodium hydroxide, is more likely to be the industrially preferred catalyst when using vegetable oil waste to make biodiesel? Justify your answer. (3 marks)

(g) Other than the recycling of vegetable oil waste, give **two** different reasons why the production of biodiesel from vegetable oil waste is an example of green chemistry but the production of diesel from fossil fuels is not. Each of your reasons needs to contrast biodiesel and fossil fuel diesel. (2 marks)

One:

Two:

**End of questions**