Government of **Western Australia**
School Curriculum and Standards Authority

ATAR course examination, 2017

Question/Answer booklet

CHEMISTRY

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of this box.

Student number: In figures | | | | | | | | | |

In words _____

_____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Number of additional answer booklets used (if applicable):

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet
Chemistry Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in this examination

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Multiple-choice	25	25	50	25	25
Section Two Short answer	10	10	60	85	35
Section Three Extended answer	5	5	70	100	40
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2017*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

4. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

5. 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.

6. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

See next page

Section One: Multiple-choice **25% (25 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which one of the following pairs contains a strong acid and a weak acid?

   (a) HCℓ and NaOH
   (b) $MgCO_3$ and CH_3COOH
   (c) NH_3 and KOH
   (d) HNO_3 and H_2CO_3

2. Copper reacts with nitric acid as shown in the redox equation below.

   $$Cu(s) + 4\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2\ NO_2(g) + 2\ H_2O(\ell)$$

   Which one of the following states the change in the oxidation number of nitrogen?

   (a) 3+ to 0
   (b) 5+ to 4+
   (c) 3+ to 2+
   (d) 5+ to 0

3. In the electrolysis of molten calcium bromide, one mole of bromine molecules is formed for every one mole of calcium. This is because

   (a) the formula of calcium bromide is Ca_2Br.
   (b) the valency on a calcium ion is twice that on a bromide ion.
   (c) bromine is more reactive than calcium.
   (d) the atomic mass of bromine is twice that of calcium.

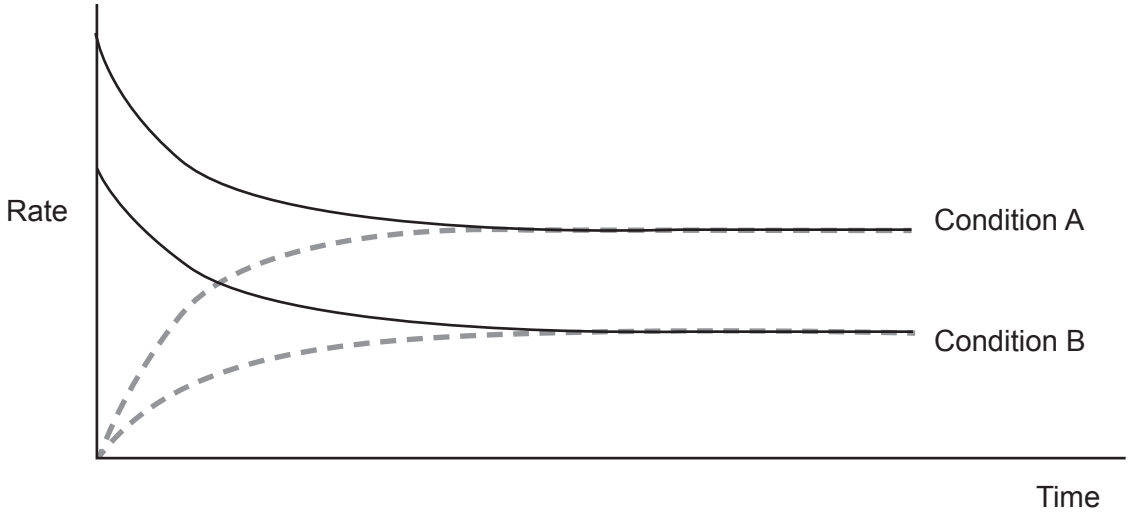
4. Which of the following are common to both galvanic and electrolytic cells?

   (i) a salt bridge
   (ii) an external circuit
   (iii) the transfer of electrons and movement of ions
   (iv) at least two different reactions with distinct reduction potentials

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

See next page

5. The following graph shows both the forward (——) and reverse (- - - -) reaction rates for a reaction under two different sets of conditions (Condition A and Condition B).



What is different about these conditions that would account for the graphs as shown?

(a) Condition A is at a higher temperature.
(b) Condition B is at a higher temperature.
(c) Condition B had a catalyst added to it.
(d) Condition B was conducted at a higher temperature and pressure.

6. The reaction of acetic (ethanoic) acid with propanol is slow at room temperature. If it is assumed that the reaction proceeds by a process involving the acid accepting a proton in the first step, then the rate at which equilibrium is reached could be increased by

(a) adding a strong acid to increase the proton concentration of the reactants.
(b) lowering the temperature to reduce the collision frequency of reactants.
(c) adding a base to lower the number of protons present in the reaction vessel.
(d) adding water to the system to alter the proton concentration.

7. Consider the following statements about the effect of a catalyst being added to a reaction mixture.

(i) The formation of intermediate species not found in the uncatalysed reaction.
(ii) The availability of a new reaction path having a lower activation energy.
(iii) An increase in the percentage of collisions resulting in a reaction.
(iv) The equal increase of both forward and reverse reaction rates.

Which of these statements describe what will occur when a catalyst is added to a reaction mixture?

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

See next page

8. The indicator HIn is used in a titration between hydrochloric acid and magnesium hydroxide solutions. The following equation represents how the indicator works.

$$\underset{\text{green}}{HIn(aq)} \rightleftharpoons H^+(aq) + \underset{\text{purple}}{In^-(aq)}$$

The indicator is added to 20.0 mL of magnesium hydroxide solution in a conical flask and the hydrochloric acid is added via a burette until the end point is observed. The acidic and basic solutions are of similar concentrations and the flask is swirled continuously as the acid is added.

Which one of the following statements describes the expected observations for the colour of the solution in the conical flask?

(a) The solution starts green and turns purple after the addition of approximately 10 mL.
(b) The solution starts green and turns purple after the addition of approximately 40 mL.
(c) The solution starts purple and turns green after the addition of approximately 10 mL.
(d) The solution starts purple and turns green after the addition of approximately 40 mL.

9. An example of an undesirable electrochemical process is the corrosion of metals. Which one of the following equations does **not** represent what might occur during corrosion?

(a) $4\ Fe(OH)_2(s) + 2\ H_2O(aq) + O_2(g) \rightarrow 4\ Fe(OH)_3(s)$
(b) $O_2(g) + 2\ H_2O(\ell) + 4\ e^- \rightarrow 4\ OH^-(aq)$
(c) $FeC\ell_3(s) \rightarrow Fe^{3+}(aq) + 3\ C\ell^-(aq)$
(d) $Pb^{2+}(aq) \rightarrow Pb^{4+}(aq) + 2\ e^-$

10. Which one of the following reactions will be spontaneous under standard conditions?

(a) $Cr_2O_7^{2-}(aq) + 3\ H_2O_2(aq) + 8\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(\ell) + 3\ O_2(g)$
(b) $3\ O_2(g) + 4\ Au(s) + 12\ H^+(aq) \rightarrow 4\ Au^{3+}(aq) + 6\ H_2O(\ell)$
(c) $2\ Ag^+(aq) + 2\ Br^-(aq) \rightarrow 2\ Ag(s) + Br_2(\ell)$
(d) $2\ C\ell^-(aq) + I_2(s) \rightarrow C\ell_2(g) + 2\ I^-(aq)$

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.

See next page

12. A sealed glass tube at room temperature contains nitrogen dioxide (a brown gas) and dinitrogen tetroxide (a colourless gas) in equilibrium, as represented by the following equation.

$$2\,NO_2(g) \leftrightharpoons N_2O_4(g) \qquad \Delta H < 0$$

If the appearance of the gas mixture at room temperature is pale brown, which one of the following is **true** if the glass tube is placed in hot water?

(a) The gas mixture will not undergo any noticeable change in appearance.
(b) The gas mixture will become darker brown.
(c) The gas mixture will become even paler at first, but would then return to its original appearance of pale brown.
(d) The gas mixture will become colourless.

13. Consider the following reaction sequence.

Step 1 $H_2O_2(aq) + I^-(aq) \rightarrow H_2O(\ell) + IO^-(aq)$
Step 2 $H_2O_2(aq) + IO^-(aq) \rightarrow H_2O(\ell) + O_2(g) + I^-(aq)$

At the same temperature, Step 1 consumes $H_2O_2(aq)$ at a rate of 4.55×10^{22} molecules per second and Step 2 consumes $H_2O_2(aq)$ at a rate of 3.67×10^{24} molecules per second.

The only source of $IO^-(aq)$ for Step 2 comes from the reaction in Step 1.

Which one of the following statements identifies, with justification, the rate-determining step?

(a) Step 1, because it is the first step in the sequence.
(b) Step 2, because it is the last step in the sequence.
(c) Step 1, because it is the slower step in the sequence.
(d) Step 2, because it is the faster step in the sequence.

14. Which of the following are isomers of $C_5H_8O_2$?

i $CH_3CH_2COCH_2CHO$
ii $CH_3CH_2CH_2CH_2COOH$
iii $CH_3COCH(CH_3)CHO$
iv $CH_2CHCH_2CH_2COOH$

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

See next page

15. Which one of the following is the dominant form of glycine in basic solution?

(a) $NH_2 – CH_2 – COOH$
(b) $NH_2 – CH_2 – COO^-$
(c) $NH_3^+ – CH_2 – COO^-$
(d) $NH_3^+ – CH_2 – COOH$

16. A chemist attempts to identify a pungent, colourless liquid by conducting several experiments. The results are shown in the table below:

Experiment	Observations
add acidified potassium dichromate solution	orange solution turns green
a lighted taper held above the liquid	flame and heat produced
add sodium metal	metal reacts and colourless, odourless gas evolved
add acidified, concentrated acetic (ethanoic) acid	fruity odour produced

Using this information, identify the functional group present in the liquid.

(a) ketone
(b) alcohol
(c) amine
(d) carboxylic acid

17. The amino acid sequence of a protein is referred to as its

(a) primary structure.
(b) secondary structure.
(c) tertiary structure.
(d) parent chain.

18. The acidification of oceans due to their increased concentrations of carbon dioxide decreases the rate and amount of calcification in some marine organisms, e.g. shellfish and coral reefs.

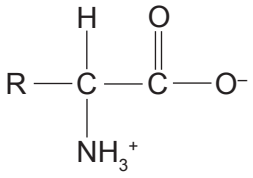
Which one of the following equations **best** represents the chemistry involved in decreasing the rate and amount of calcification?

(a) $2\,H^+ + CaCO_3 \rightarrow Ca^{2+} + H_2O + CO_2$
(b) $CO_2 + H_2O + CO_3^{2-} \rightarrow 2\,HCO_3^-$
(c) $4\,H^+ + 2\,CO_3^{2-} \rightarrow H_2CO_3 + H_2O + CO_2$
(d) $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

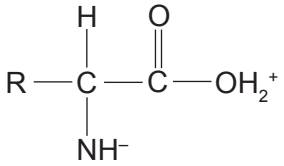
See next page

19. Which one of the following structures represents a zwitterion?

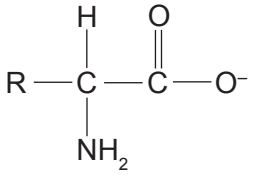
(a)



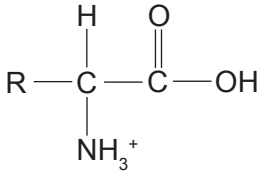
(b)



(c)



(d)



20. The function of a protein is linked closely to

(a) its method of production.
(b) the nature of its intermolecular forces.
(c) the number of atoms bonded to it.
(d) its structure.

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

Questions 22 to 25 refer to the following information.

Some chemistry students were investigating the relationship between concentration and rate of reaction. In the investigation, different concentrations of hydrochloric acid were added to a sodium thiosulfate solution to produce solid sulfur. This reaction was represented by the following equation.

$$2\ H^+(aq) + S_2O_3^{2-}(aq) \rightarrow SO_2(g) + S(s) + H_2O(\ell)$$

A piece of paper with a cross drawn on it was placed under the reaction vessel. The time taken for the cross to disappear due to the formation of the precipitate was measured.

22. The independent variable was the

(a) time taken for the cross to disappear.
(b) total volume of the mixture.
(c) rate of reaction.
(d) concentration of hydrochloric acid.

23. The type of data collected and the source of data are best characterised as

(a) qualitative and primary.
(b) qualitative and secondary.
(c) quantitative and primary.
(d) quantitative and secondary.

24. When a number of laboratory groups pooled their data, one group's results were consistently higher than those of the others. This is an example of

(a) a systematic error.
(b) not enough trials.
(c) a random error.
(d) uncertainty.

25. One group chose to have its members take turns observing and timing the cross disappearing. This was poor methodology because

(a) it could make the data invalid.
(b) it introduced a possible systematic error.
(c) more trials would be needed to produce better results.
(d) the data would be less reliable.

End of Section One

See next page

Section Two: Short answer **35% (85 Marks)**

This section has **10** questions. Answer **all** questions. Write your answers in the spaces provided.

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: 60 minutes.

Question 26 **(13 marks)**

A limited amount of sodium metal was added to a beaker of distilled water containing a few drops of phenolphthalein.

(a) (i) List **three** changes that would be observed. (3 marks)

One: _____

Two: _____

Three: _____

(ii) Write the ionic equation for any reaction involving both sodium and water. Include **all** state symbols. (3 marks)

Excess propene gas was bubbled through an aqueous bromine solution.

(b) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

(ii) Write descriptions of the substances **before** and **after** mixing. (2 marks)

Before _____

After _____

A thick strip of lead metal was immersed into a small beaker containing a solution of 1.00 mol L^{-1} iron(III) nitrate.

(c) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

(ii) List **all** observations that would be made for any reaction, describing clearly the substances before and on completion of any reaction. (3 marks)

See next page

Question 27 **(6 marks)**

Balance the following redox equation by determining and then combining the oxidation and reduction half-equations. State symbols are **not** required.

$$SCN^- + IO_3^- + C\ell^- \rightarrow SO_4^{2-} + HCN + IC\ell$$

Oxidation half-equation
Reduction half-equation
Overall equation

See next page

Question 28 **(10 marks)**

A hydrogen sulfate/sulfate system is represented by the following equation.

$$HSO_4^-(aq) + H_2O(\ell) \leftrightharpoons SO_4^{2-}(aq) + H_3O^+(aq)$$

(a) Predict how
- the forward reaction rate and
- the pH

will differ from their original values after the following changes are imposed on the system and equilibrium has been re-established. Use the terms **increase**, **decrease**, **no change**. (6 marks)

Change imposed by the addition of	**Effect on forward reaction rate when equilibrium is re-established**	**Effect on pH when equilibrium is re-established**
a few drops of concentrated hydrochloric acid		
a few drops of concentrated lead(II) nitrate solution		
distilled water		

(b) The reaction in part (a) is endothermic in the forward direction as written. Predict what will happen to the pH when the temperature is increased. Justify this prediction. (4 marks)

See next page

Question 29 **(10 marks)**

In a beaker 12.00 mL of 0.0334 mol L^{-1} sulfuric acid solution, $H_2SO_4(aq)$, is added to 32.50 mL of 0.0288 mol L^{-1} potassium hydroxide solution, KOH(aq).

(a) Identify the limiting reagent in this reaction. Show **all** workings. (5 marks)

(b) Calculate the final concentration of the excess reagent. Show **all** workings. (3 marks)

(c) Calculate the pH of the final solution. Show **all** workings. (2 marks)

See next page

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)

_____

_____

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See next page

Question 31 **(8 marks)**

Water is capable of self-ionisation.

(a) Write an equation for the self-ionisation of water. (2 marks)

(b) Write the equilibrium constant expression for the self-ionisation of water. (1 mark)

(c) The equilibrium constant for the self-ionisation of water K_w is 1.00×10^{-14} at 25 °C. What does this value indicate about this reaction? (1 mark)

The K values for the self-ionisation of water at 100.0 kPa are given here for a number of different temperatures.

Temperature (°C)	K value
0	0.114×10^{-14}
25	1.00×10^{-14}
50	5.48×10^{-14}
75	19.9×10^{-14}
100	51.3×10^{-14}

(d) Calculate the pH of water at 50 °C. (2 marks)

See next page

(e) Is water acidic, basic or neutral at 50 °C? State a reason for your answer. (2 marks)

See next page

Question 32 **(9 marks)**

Ethanol and methanol are completely miscible (soluble) in water.

(a) By referring to any intermolecular forces present, describe the dissolving process as ethanol is added to water. (3 marks)

(b) Explain what happens to the solubility of alcohols in water as the hydrocarbon chain length increases. (3 marks)

(c) For each of the following substances, list **all** force/s of attraction formed between the solute and solvent when each substance dissolves in water. (3 marks)

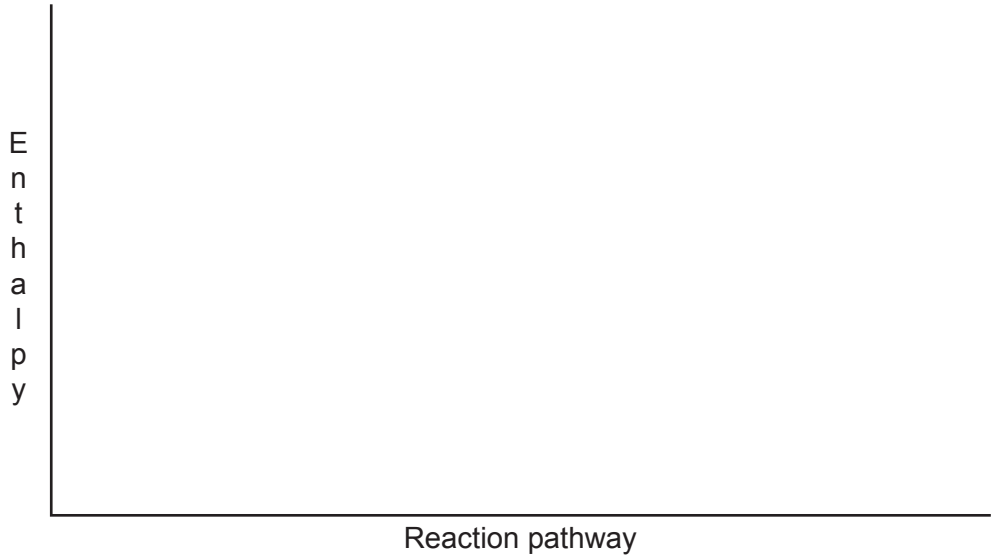
Substance	Force/s of attraction with water
Propanal	
Methanoic acid	
Sodium chloride	

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)

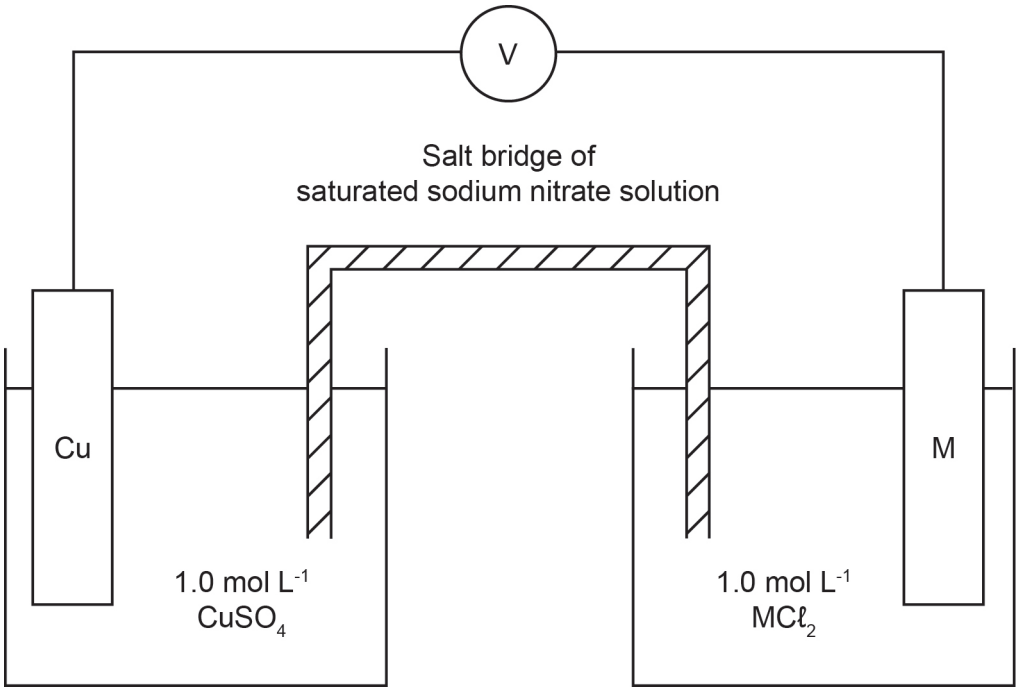
(c) The energy density of dynamite is 5.0 MJ kg^{-1} and the energy density of TNT is 4.0 MJ kg^{-1}. Show by calculation and by reasoning which of these two explosives produces more energy per mole of the **active** ingredient. (4 marks)

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

See next page

Question 34 **(7 marks)**

The diagram below represents a simple galvanic cell set up at 25.0 °C.



One electrode/electrolyte pair is Cu/Cu^{2+}. The other electrode is of an unknown metal, represented as M/M^{2+}. It was observed, that over time, the unknown metal electrode reduced in size and the solution remained colourless.

(a) Write a chemical equation to show the reaction at the anode of the cell. (1 mark)

(b) List **two** observations that would be expected in the Cu/Cu^{2+} cell. (2 marks)

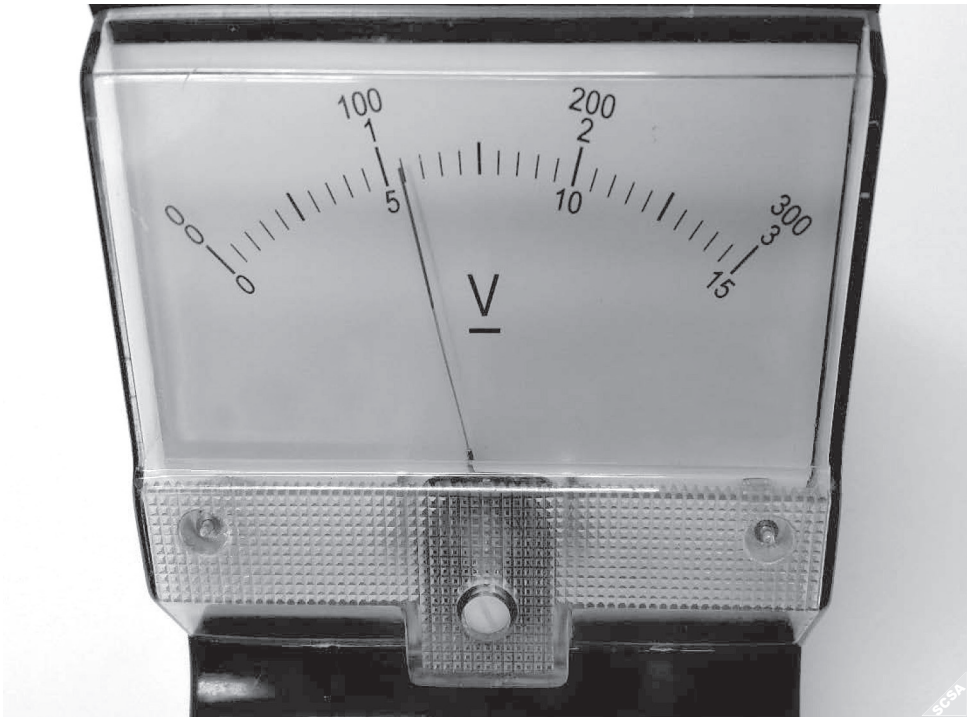
One: _____

_____

Two: _____

_____

Below is a photograph of the voltmeter attached to the diagram of the cell on page 20. There are three scales on the voltmeter. The scale being used is the one with the range from 0 to 3 volts.



(c) (i) To the appropriate degree of accuracy, what is the reading on the voltmeter?

(1 mark)

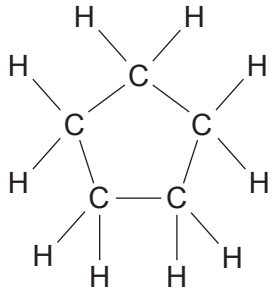
(ii) Using the voltmeter reading and other relevant information, predict the identity of the unknown metal. Clear reasoning, including a calculation, **must** be provided.

(3 marks)

See next page

Question 35 **(5 marks)**

There are a number of different isomers with the molecular formula of C_5H_{10}. These include chain isomers and cyclic isomers such as cyclopentane, which is shown here.



(a) Draw **one** chain isomer for C_5H_{10} that satisfies each of the following types. For each isomer, show **all** atoms and **all** bonds. (2 marks)

Type	Diagram
Trans isomer	
Cis isomer	

See next page

Chemical tests (adding reagent/s) can be used to distinguish between **chain** and **cyclic** isomers in this question.

(b) In the table below suggest a distinguishing test by stating the reagent/s used and the observations expected for any reaction with each isomer. (3 marks)

Reagent/s		
	Cis/trans chain isomer	**Cyclic isomer**
Observations		

End of Section Two

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.

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

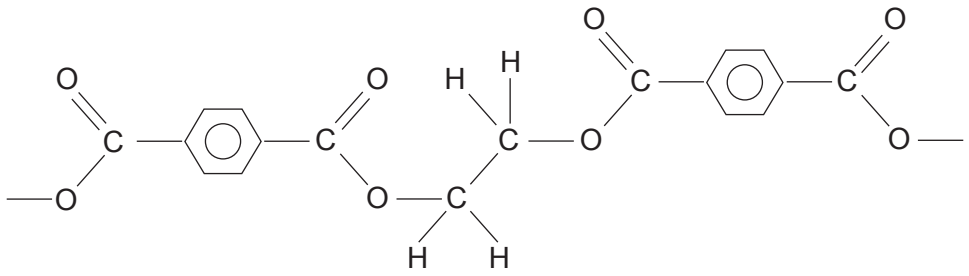
(a) What mass of ore would be required to produce 6.00 tonnes of antimony, assuming the ore contains 25.6% by mass of antimony(III) sulfide and the reactions go to completion? (6 marks)

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 36 (continued)

Pure antimony(III) oxide is used as a catalyst in the production of polyethylene terephthalate (PET).



A section of a PET polymer

(c) Draw the monomers required to produce this polymer. (4 marks)

(d) State **one** common use for PET and state **two** properties that enable it to be used for this purpose. (3 marks)

Use: _____

Properties:

One: _____

Two: _____

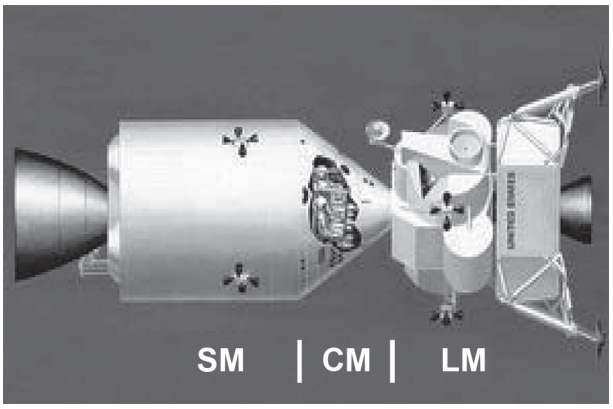
PET is produced through condensation polymerisation; another type of polymer is produced through addition polymerisation. Each of these types of polymerisation uses different types of monomers.

(e) Distinguish between the types of monomers used for each type of polymerisation.
(2 marks)

See next page

Question 37 **(24 marks)**

In 1971, the seventh manned Apollo mission, Apollo 13, was launched and expected to land on the moon. Two days into the mission, one of the oxygen tanks exploded. The mission was aborted, but in order for the spacecraft to return to Earth safely, many problems needed to be solved. A number of them involved chemistry.



The spacecraft consisted of three sections:
- the Service Module (SM)
- the Command Module (CM)
- the Lunar Module (LM).

The Lunar Module was designed to hold two astronauts for the short trip between lunar orbit and the moon's surface. On the trip back to Earth, the astronauts were required to spend more time than expected in the lunar module.

One of the problems encountered was how to remove the carbon dioxide breathed out by the astronauts from the atmosphere in the spacecraft. This was done by reacting it with lithium hydroxide, which was housed in canisters.

(a) Write an equation for the reaction between carbon dioxide gas and lithium hydroxide to form lithium carbonate and water. (2 marks)

(b) A typical lithium hydroxide canister contains 750.0 g of lithium hydroxide. What mass of carbon dioxide would be required to react completely with the lithium hydroxide in each canister? (3 marks)

See next page

On returning to Earth, a partially-used canister was analysed to determine the percentage of lithium hydroxide remaining.

A 12.33 g sample of the canister contents was dissolved in distilled water and sufficient barium nitrate solution was added to precipitate the carbonate ions. The solution was filtered and transferred to a 500.00 mL volumetric flask, which was then filled to the mark. 20.00 mL aliquots of the solution were transferred to conical flasks and titrated against a standardised 0.116 mol L^{-1} solution of hydrochloric acid.

The following results were obtained from the titrations.

Volume (mL)	**1**	**2**	**3**	**4**
Final Volume	18.55	34.90	18.50	34.85
Initial Volume	1.50	18.55	2.20	18.50
Titre				

(c) Complete the results table above and calculate the percentage of lithium hydroxide remaining in the canister. (6 marks)

See next page

Question 37 (continued)

(d) From the list of indicators given below, identify **two** that could be used in the titration between lithium hydroxide and hydrochloric acid. Explain why both indicators are appropriate choices for this titration. (4 marks)

Indicator	Low pH colour	Transition pH range	High pH colour
Methyl violet	yellow	0.0 – 1.6	blue
Bromothymol blue	yellow	6.0 – 7.6	blue
Phenolphthalein	colourless	8.3 – 10.0	pink
Thymolphthalein	colourless	9.4 – 10.6	blue

Indicator one: _____

Indicator two: _____

Explanation: _____

_____

_____

_____

_____

The tank that exploded during the mission provided oxygen for the fuel cells that powered the spacecraft.

(e) List **two** advantages that fuel cells have over primary and secondary cells. (2 marks)

One: _____

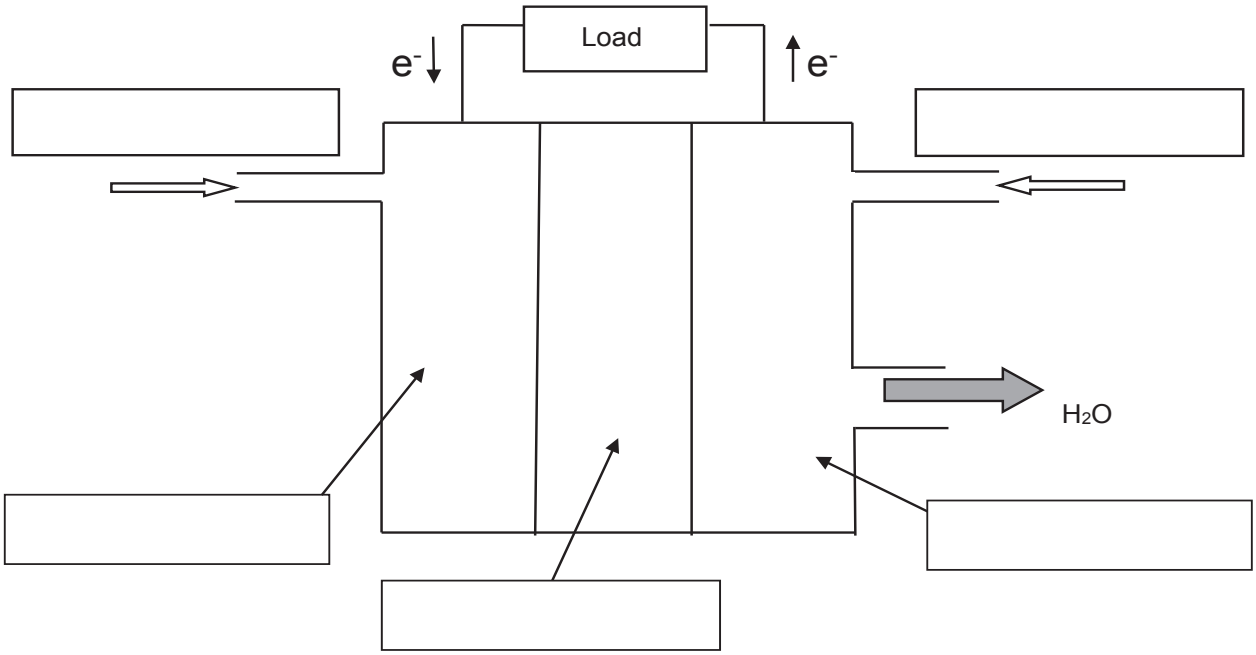
_____

Two: _____

_____

See next page

(f) In the boxes provided, label the following diagram of a typical hydrogen-oxygen fuel cell. Include anode, cathode, electrolyte, hydrogen gas and oxygen gas. (3 marks)



(g) Explain the function of the electrolyte. (2 marks)

(h) From the table provided in the Chemistry Data booklet, calculate the EMF for the reaction between hydrogen gas and oxygen gas. (1 mark)

(i) A hydrogen-oxygen fuel cell on the Apollo spacecraft generally produced an EMF of 1.21 V per cell. State **one** reason why the theoretical (calculated) value was not the same as the actual EMF generated by the fuel cells on the spacecraft. (1 mark)

See next page

Question 38 **(17 marks)**

Caffeine is an organic molecule found in tea, coffee and energy drinks. It is a stimulant that also can be taken in tablet form. Pure caffeine is a white odourless powder that tastes bitter and contains carbon, hydrogen, nitrogen and oxygen.

A 2.55 g sample of caffeine was combusted to produce 4.623 g of carbon dioxide and 1.18 g of water. A second, 3.33 g sample of caffeine was treated to convert all of the nitrogen to 1.17 g of ammonia.

(a) Determine the empirical formula of caffeine. (13 marks)

See next page

Empirical formula

A third, 1.05 g sample of caffeine was converted to the gaseous phase. Measurement showed that 100.0 mL of the gas exerted 370 kPa pressure at a temperature of 550 °C.

(b) Calculate the molar mass of caffeine. (2 marks)

(c) From your answers to part (a) and part (b), determine the molecular formula of caffeine, showing clearly how this was determined. (2 marks)

Question 39 **(25 marks)**

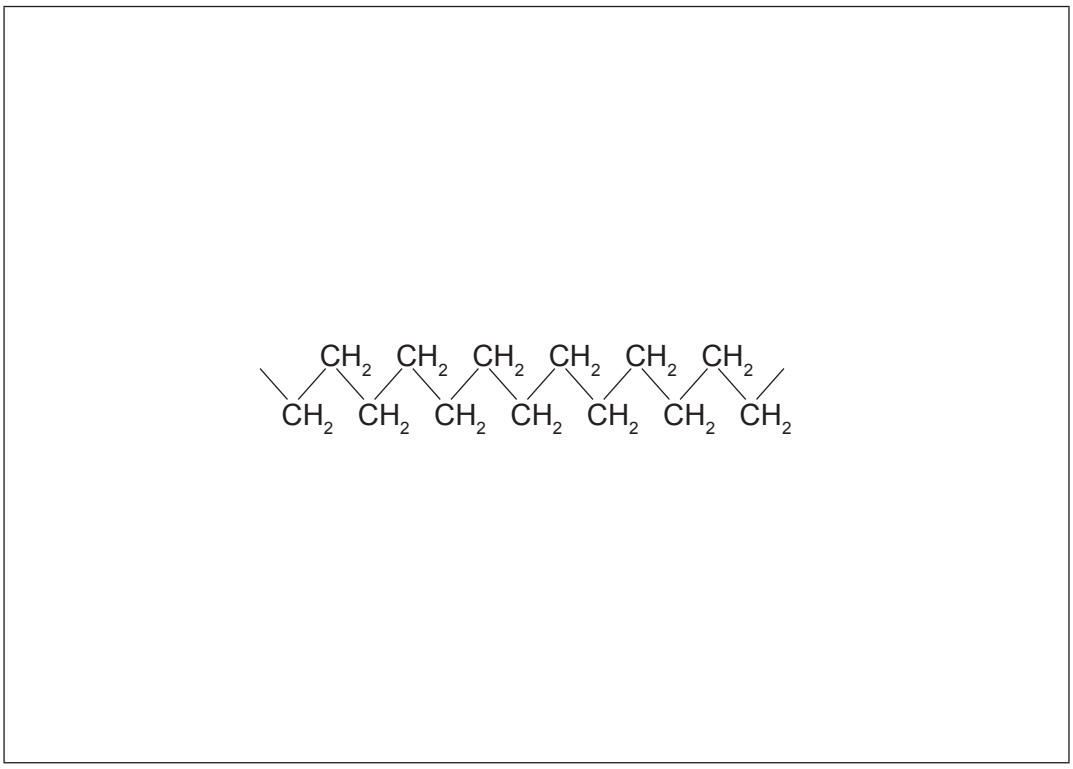
A cosmetic company advertises a range of 'inspiring quality organic, natural and essential personal care ingredients' in its skin care, hair care, aromatherapy and soaps products. It claims that the soaps it sells are made from different ingredients boasting 'an array of perfumes and cosmetic benefits'.

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)



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)

See next page

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)

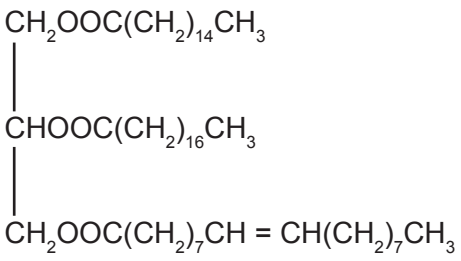
_____

(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)

See next page

(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

Question 40 **(15 marks)**

The properties of human hair can be attributed to it being composed almost entirely of the strong fibrous protein, keratin.

Structure of keratin:

- Keratin is a polypeptide and consists of a repeating pattern of amino acids.
- Common amino acids in keratin, in order from most to least abundant, are: cysteine (17.5%), serine, glutamic acid, threonine, glycine, leucine, valine, arginine, aspartic acid and alanine (4.8%).

(a) Draw a section of the polypeptide that is composed of the **three** most abundant amino acids found in keratin. (4 marks)

See next page

(b) With reference to the structure drawn in part (a), state **three** types of attractive forces/bonding other than dispersion forces, that can occur **between** neighbouring keratin polypeptide chains. (3 marks)

One: _____

Two: _____

Three: _____

(c) Describe the α-helix structure of keratin. (2 marks)

_____

_____

_____

_____

One of the physical properties of hair is its capacity to absorb water, increasing a strand's diameter by roughly 20%.

(d) State why hair can absorb water. (1 mark)

_____

_____

See next page

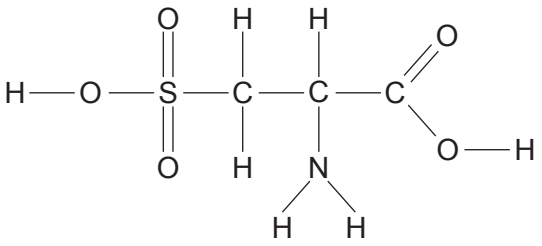
Question 40 (continued)

Keratin is often chemically analysed for cysteine, due to its effect on the strength of hair. One method of determining the proportion of cysteine is titration with bromide in an acidic solution. Under these conditions, the cysteine is oxidised to cystine and then to cysteic acid.

Two cysteine molecules joined together by a disulfide bond is called cystine.

(e) Draw the structure of cystine. (2 marks)

(f) On the structural formula of cysteic acid drawn below, circle and label any functional groups as acidic or basic. (3 marks)



End of questions

Supplementary page

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ACKNOWLEDGEMENTS

Question 37 Meltzer, D. (2012). *Apollo CMS_LM spacecraft* [Image]. Retrieved March 4, 2017, from https://en.wikipedia.org/wiki/File:Apollo-CSM-LM.png

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