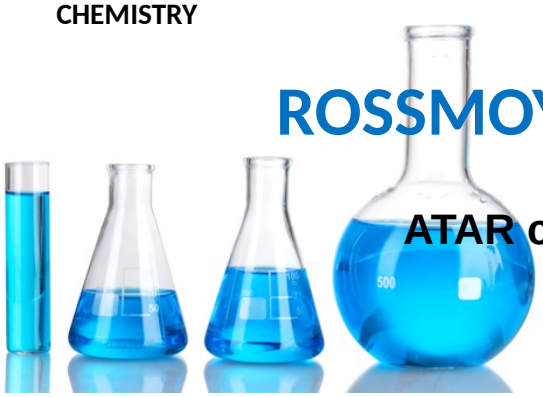


ROSSMOYNE SENIOR HIGH SCHOOL

ATAR course examination, Semester 2, 2018

SOLUTIONS booklet

CHEMISTRY
ATAR Year 12

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

1.	**a**	6	**d**	11.	**b**	16.	**b**	21.	**b**
2.	**c**	7	**a**	12.	**c**	17.	**d**	22.	**b**
3.	**d**	8	**c**	13.	**b**	18.	**c**	23.	**b**
4.	**a**	9	**c**	14.	**c**	19.	**a**	24.	**d**
5.	**c**	10	**c**	15.	**d**	20	**c**	25.	**a**

1. Water can act as either an acid or a base. Which equation shows water acting as an acid?

   (a) **$H_2O(\ell) + NH_3(g) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$**

   (b) $2\ H_2O(\ell) \rightleftharpoons 2H_2(g) + O_2(g)$

   (c) $H_2O(\ell) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$

   (d) $2\ Na(s) + 2\ H_2O(\ell) \rightarrow 2\ Na^+(aq) + 2\ OH^-(aq) + H_2(g)$

2. Which one of the following changes to pH and degree of ionisation take place when 50 mL of water is added to 50 mL of 0.1 mol L^{-1} ethanoic acid?

	pH	**Degree of ionisation**
(a)	increase	decrease
(b)	decrease	increase
(c)	**increase**	**increase**
(d)	decrease	decrease

3. In terms of acid/base theory a neutral solution requires

   (a) $[H_3O^+] = [OH^-] = 0.00$ mol L^{-1}

   (b) pH = 7 at STP

   (c) $[H_3O^+] = 1.0 \times 10^{-7}$

   (d) **$[H_3O^+] = [OH^-]$**

4. Which of the following indicators should be used in the titration of 0.1 mol/L potassium hydroxide solution with 0.1 mol/L propanoic acid solution?

   (a) **phenolphthalein, endpoint pH range 8.0 – 10.0**

   (b) bromothymol blue, endpoint pH range 6.0 – 7.6

   (c) methyl red, endpoint pH range 4.2 – 6.2

   (d) methyl orange, endpoint pH range 3.1 – 4.4

See next page

5. Consider a solution which is equimolar for ethanoic acid and sodium ethanoate. Which one of the following statements is correct?

(a) If a small amount of strong base is added, the pH remains constant.

(b) If a small amount of strong acid is added, the pH increases

(c) If more sodium ethanoate is dissolved, the pH increases

(d) If the volume is doubled by adding water, the pH decreases

6. Consider the following information for the reaction A + B → C

heat of reaction	-120 kJ mol^{-1}
activation energy	+200 kJ mol^{-1}

The activation energy, in kJ mol^{-1}, for the reaction C → A + B, is

(a) -320

(b) -80

(c) +80

(d) +320

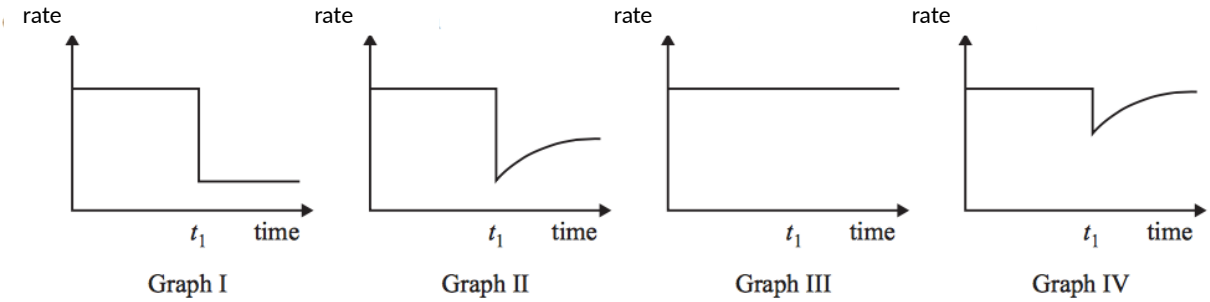
*Questions **7** and **8** refer to the following information*

Reactants A and B are placed in a sealed container with a suitable catalyst where they react according to the equation

$$A(g) + B(g) \rightleftharpoons C(g)$$

After the reaction reaches equilibrium, a small amount of a compound is added to the container at time t_1. The compound 'poisons' the catalyst and stops it working.

7. Which one of the graphs represents the **rate** of the forward reaction versus time?



(a) Graph I

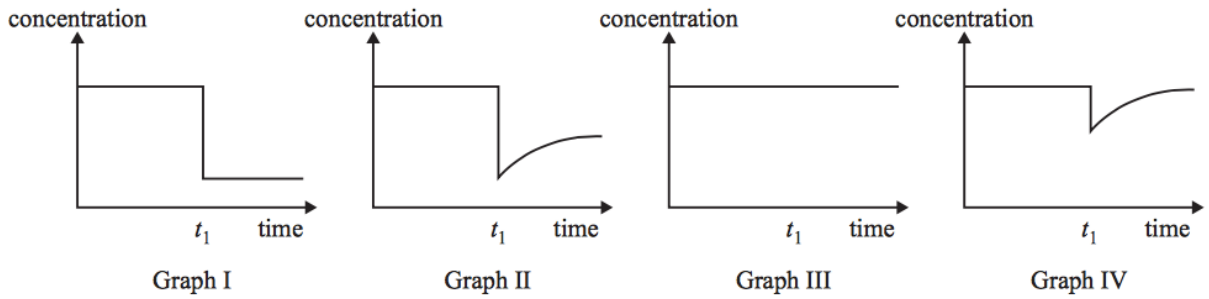
(b) Graph II

(c) Graph III

(d) Graph IV

See next page

8. Which one of the graphs represents the **concentration** of product C versus time?



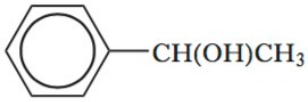
(a) Graph I

(b) Graph II

(c) Graph III

(d) Graph IV

9. Which one of the following statements about the compound below is correct?



(a) It reacts readily with bromine solution

(b) It can be oxidised to an aldehyde

(c) It can be oxidised to a ketone

(d) It is a primary alcohol

10. Which one of the following is an isomer of ethyl propanoate ($CH_3CH_2COOCH_2CH_3$)?

(a) methyl pentanoate

(b) pentan-2-one

(c) pentanoic acid

(d) pentane-1,2-diol

11. How many isomers with molecular formula $C_4H_8O_2$ are esters?

(a) 3

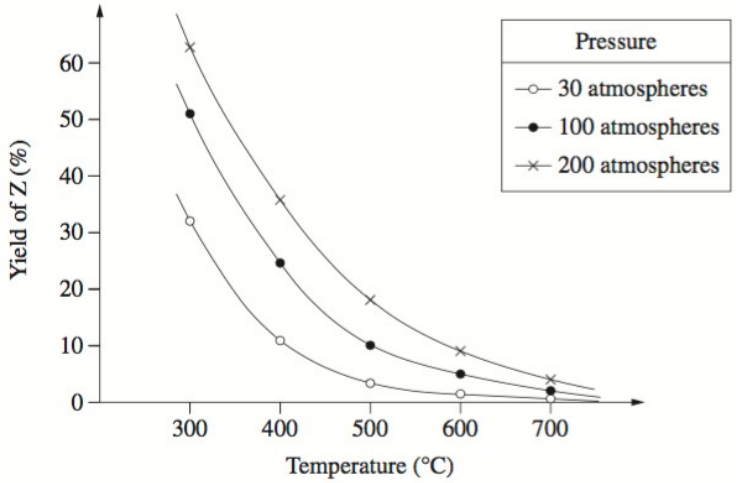
(b) 4

(c) 5

(d) 6

See next page

This graph represents the yield of an equilibrium reaction at different conditions of temperature and pressure inside a reaction vessel.



12. Which one of the following reactions would produce the trends shown in the graph?

(a) $X(g) + Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = +100$ kJ

(b) $X(g) + Y(g) \rightleftharpoons 2Z(g)$ $\Delta H = -100$ kJ

(c) $4X(g) + 2Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = -100$ kJ

(d) $2X(g) + Y(g) \rightleftharpoons Z(g)$ $\Delta H = +100$ kJ

13. In an electrolytic cell, the electrons flow

(a) from the cathode to the anode through the molten salt.

(b) from the anode to the cathode via the external circuit.

(c) directly from the reductant to the oxidant.

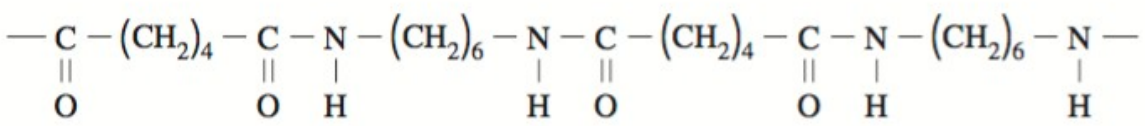
(d) from the negative electrode to the positive electrode via the external circuit.

14. Which one of the following shows the correct 'final' rinsing technique for the glassware used in the titration of potassium hydroxide with methanoic acid solution?

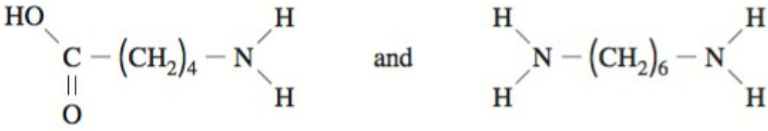
	Conical Flask	**Burette**	**Pipette**
(a)	potassium hydroxide	methanoic acid	distilled water
(b)	distilled water	distilled water	potassium hydroxide
(c)	**distilled water**	**methanoic acid**	**potassium hydroxide**
(d)	potassium hydroxide	distilled water	distilled water

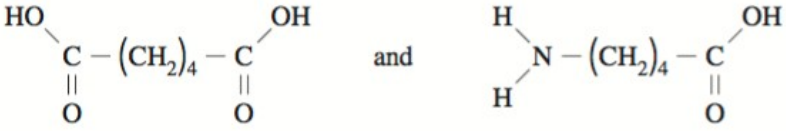
See next page

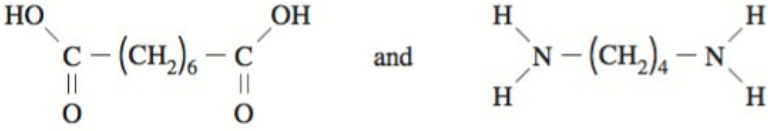
15. The diagram below represents a segment of the polymer nylon 6,6.

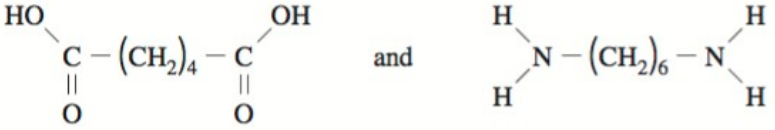


Which one of the following shows the two monomers that are used to produce nylon 6,6?

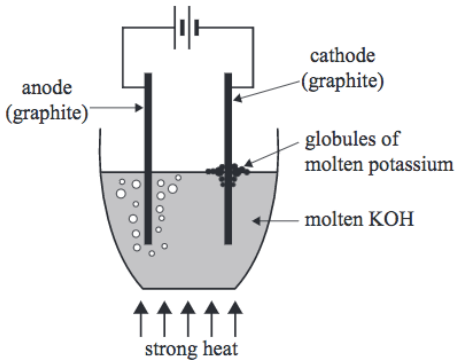
(a) 

(b) 

(c) 

(d) 

16. Potassium metal was discovered in 1807 by Sir Humphry Davy. Small, shiny beads of molten potassium were produced when an electric current from an early battery was passed through molten potassium hydroxide.



If instead Davy had electrolysed a 1.0 mol L^{-1} potassium hydroxide solution with graphite electrodes, what main products would have been observed at the anode and cathode, respectively?

(a) hydrogen gas, potassium metal

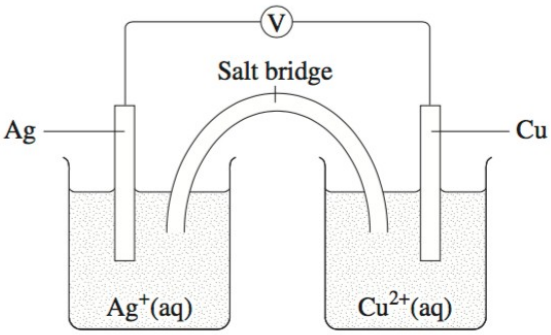
(b) oxygen gas, hydrogen gas

(c) hydrogen gas, oxygen gas

(d) no reaction would be observed as potassium ions are very poor oxidants

See next page

17. A diagram of a simple cell is shown.



Which one of the following occurs when the cell is in operation?

(a) silver ions are formed in solution

(b) the copper electrode increases in mass

(c) cations move towards the copper half cell

(d) electrons travel from the copper electrode toward the silver electrode

18. Which of the following are possible oxidation products of ethanol?

I. C_2H_5OH II. CH_3CHO III. CH_3COOH IV. CO_2 and H_2O

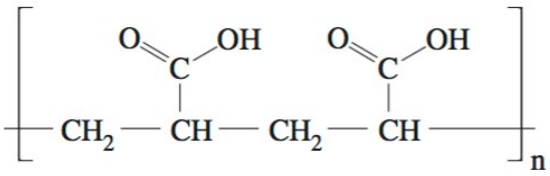
(a) I and II

(b) II and III

(c) II, III and IV

(d) I, II and III

19. A portion of resin made from acrylic acid (CH_2=CHCOOH) is shown.



Which type of reaction results in the formation of this polymer?

(a) addition

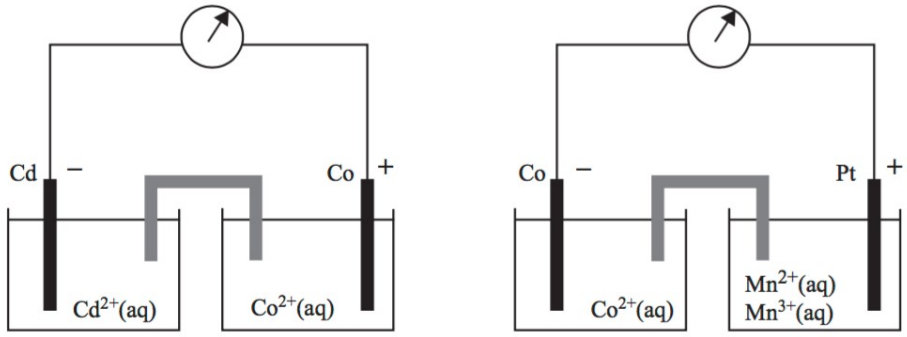
(b) condensation

(c) dehydration

(d) esterification

20. Two standard galvanic cells are shown below.

See next page



On the basis of the polarity of the electrodes in these cells, which one of the following reactions would **not** be expected to occur spontaneously?

(a) $Cd^{2+}(aq) + Co(s) \rightarrow Cd(s) + Co^{2+}(aq)$

(b) $2\ Mn^{3+}(aq) + Co^{2+}(aq) \rightarrow 2\ Mn^{2+}(aq) + Co(s)$

(c) $\mathbf{2\ Mn^{3+}(aq) + Cd(s) \rightarrow 2\ Mn^{2+}(aq) + Cd^{2+}(aq)}$

(d) $2\ Mn^{2+}(aq) + Cd^{2+}(aq) \rightarrow 2\ Mn^{3+}(aq) + Cd(s)$

21. Which of the following procedures would enable you to distinguish between 1-butanol and 2-methyl-2-butanol?

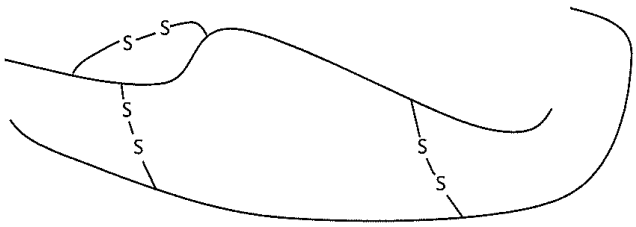
(a) Shaking each compound with bromine water and observing a colour change.

(b) Warming each compound with an acidified solution of sodium dichromate and observing a colour change.

(c) Shaking each compound with ethanol and observing whether the two liquids mix.

(d) Mixing each compound with iodine water in bright light, and observing a colour change.

22. The following diagram is a simplified illustration of the protein, insulin. Insulin consists of 51 amino acids arranged in two individual chains linked by disulfide bridges.



How many peptide links are present in one molecule of insulin?

(a) 48

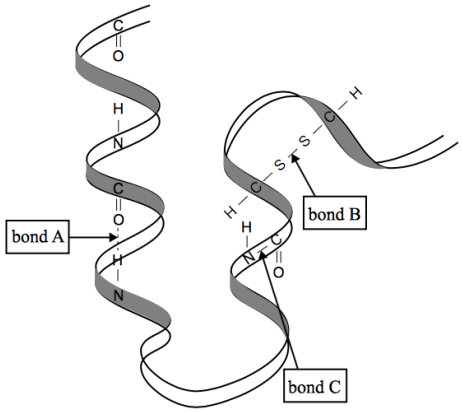
(b) 49

(c) 50

(d) 51

See next page

23. Enzymes, which are composed mostly of protein, catalyse many chemical reactions. The structure of a portion of an enzyme, with some of its constituent atoms shown, is represented at right.



Which level of protein structure is each of the chemical bonds involved in?

	Bond A	Bond B	Bond C
(a)	primary	tertiary	secondary
(b)	**secondary**	**tertiary**	**primary**
(c)	tertiary	primary	secondary
(d)	primary	secondary	tertiary

24. Which one of the following lists only shows substances that dissolve in water to form a basic solution?

(a) CH_3OH, KCH_3COO, NH_3, $MgHCO_3$

(b) $Mg(HSO_4)_2$, CH_3NH_2, KOH, Na_2S

(c) K_2CO_3, NH_3, SO_2, NH_4Cl

(d) $Ba(OH)_2$, Na_3PO_4, $Mg(CH_3COO)_2$, NH_3

25. Three of the following statements concerning the use of enzymes in industrial processes are true. Identify the false statement.

(a) They allow the reaction to proceed at a good rate at ambient temperatures by lowering both the activation energy and enthalpy change.

(b) Enzymes are specific and therefore improve the quality of the product by limiting side reactions.

(c) Enzymes make the process more economical by reducing the energy requirements for high temperature, high pressure reactions.

(d) Enzymes provide an alternative pathway for industrial reactions with a lower activation energy.

END OF SECTION 1

See next page

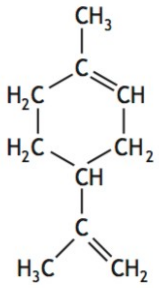
Question 26 **(1 mark for each correct answer Total = 6 marks)**

Complete the table by writing the name or formula for a substance that fits the description.

Description	Name or Formula
a primary standard substance that can be used to standardise a hydrochloric acid solution	**Anhydrous sodium carbonate Na_2CO_3** ***With or without anhydrous is correct***
a weak diprotic acid	**H_2CO_3, or H_2SO_3**
an acid base indicator which is colourless in 0.1 mol L^{-1} HCl(aq)	**Phenolphthalein**
a species that will oxidise aqueous iron(II) ions	**<u>Acidified</u> MnO_4^- (aq), acidified $Cr_2O_7^{2-}$ (aq)** ***Must have acidified*** ***Also accept other correct oxidisers***
the alcohol formed when fats and oils are hydrolysed	**Glycerol or propan1,2,3-triol**
the conjugate base of the HPO_4^{2-} ion	**PO_4^{3-}**

Question 27 **(6 marks)**

Limolene is an essential oil which is added to some cleaning products to give them a lemon scent.



(a) Determine the empirical and molecular formula of limolene.

Empirical formula **C_5H_8** **(1 mark)**

Molecular formula **$C_{10}H_{16}$** **(1 mark)**

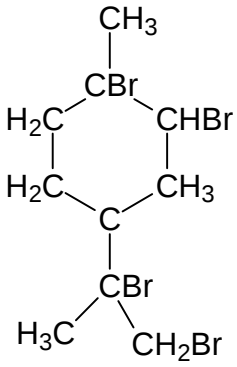
(b) The concentration of limolene present in a cleaning product can be foundd by titrating a solution of limolene dissolved in ethanol with bromine solution in the absence of UV light.

(i) Name the type of organic chemical reaction taking place when limolene reacts with bromine solution.

Addition **(1 mark)**

(ii) Draw the structure of the organic product of this reaction.

See next page



(1 mark)

(iii) Explain why was the experiment carried out in the absence of UV light?

To prevent substitution from taking place **(1 mark)**

(iv) A 20.0 mL sample of limolene solution (colourless) was pipetted into a conical flask and titrated with bromine solution until equivalence. No indicator was used. How would the experimenter know when the equivalence point was reached?

(First permanent) change to orange colour (in conical flask) **(1 mark)**

Question 28 **(6 marks)**

(a) What type of polymer is this? (1 mark)

condensation **(if stated polyester and didn't say ester in (b) allocate 1 mark)**

(b) What type of functional group provides the link between monomers in this polymer?

ester **(1 mark)**

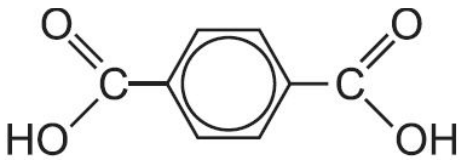
(c) What types of intermolecular forces will act between adjacent chains of this polymer?

dispersion **(1 mark)**

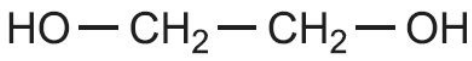
dipole-dipole forces **(1 mark)**

(subtract a mark for H bonding or other error)

(d) Draw the structure(s) of the monomer(s) that reacted together to form this polymer. (2 marks)



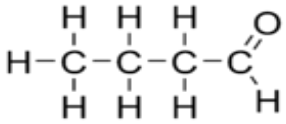
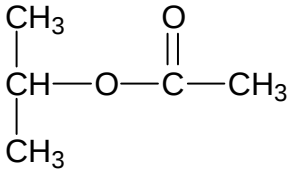
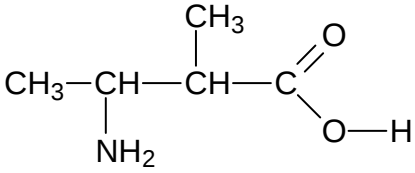
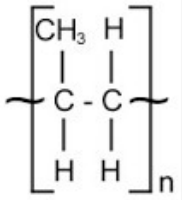
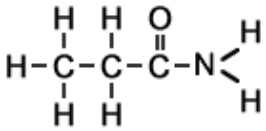
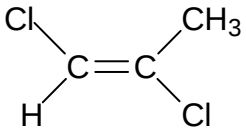
(1 mark)



(1 mark)

See next page

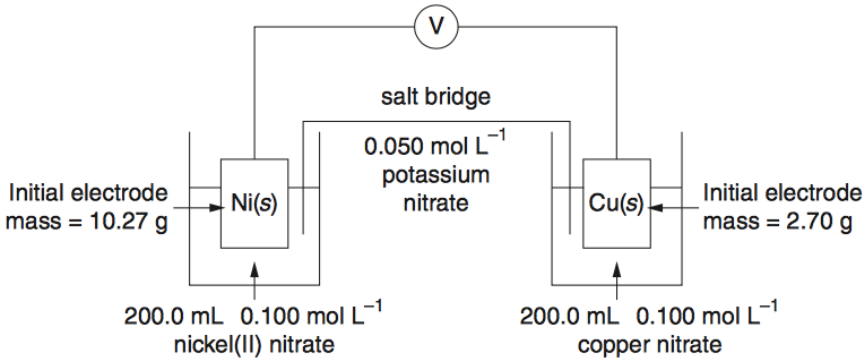
Question 29 **(6 marks)**

IUPAC Name	Structural formula
Butanal	
2-propyl ethananoate	
3-amino butanoic acid	
polypropene or polypropelene	
propanamide	
trans-1,2-dichloropropene	

See next page

Question 30 **(5 marks)**

A galvanic cell was constructed as shown in the diagram below.



(a) Explain, in terms of energy transformation, how a galvanic cell differs from an electrolytic cell. (2 marks)

galvanic cell: chemical (potential) energy is converted to electrical energy (1 mark)

electrolytic cell: electrical energy is converted to chemical (potential) energy (1 mark)

(b) Give the oxidation and reduction half-equations and the overall reaction for the above cell. (3 marks)

(Ni is best reductant thus oxidised at anode)

oxidation **$Ni \rightarrow Ni^{2+} + 2e^-$** **(1 mark)**

reduction **$Cu^{2+} + 2e- \rightarrow Cu$** **(1 mark)**

cell reaction **$Ni + Cu^{2+} \rightarrow Ni^{2+} + Cu$** **(1 mark)**

No marks if use double arrows!

Question 31 **(12 marks)**

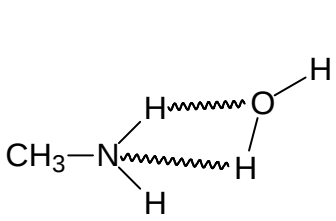
Methanamine, CH_3NH_2, is a weak base.

(a) Explain, including structural diagrams, why methanamine is soluble in water. (3 marks)

Both methanamine and water have hydrogen bonding as most significant inter molecular force. (1 mark)

Strong hydrogen bonds (solute-solvent) can be established between methanamine and water allowing good solubility (energetically favourable) (1 mark)

(1 mark) for clearly labelled structural diagram



See next page

(b) Explain the difference in boiling point between methanamine and methanol. (4 marks)

substance	boiling point ^oC	molar mass $gmol^{-1}$
methanamine	6	31
methanol	65	32

Similar molar mass therefore similar strength dispersion forces, difference in boiling point due to other intermolecular forces. (1 mark)

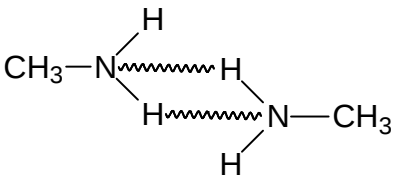
In both molecules hydrogen bonds are most significant intermolecular force but they differ in strength. (1 mark)

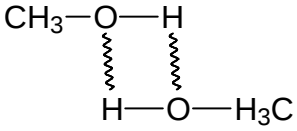
O is more electronegative than N and so the O-H bond is more polar (larger dipole) than the N-H bond (1 mark)

The strength of the hydrogen bonds between methanol molecules is greater than those between methanamine molecules and so the energy required to overcome the cumulative IMFs is greater for methanol accounting for the higher boiling point (1 mark)

(nothing to do with number of H bonds, methanol can receive 2 & form 1, methanamine can receive 1 & form 2 – on average same number of intermolecular H-bonds)

"H bond"





(c) Methanamine reacts with hydrochloric acid to form the salt methanammonium chloride, CH_3NH_3Cl. A solution of this salt is slightly acidic.

List all the species present in a solution of methanammonium chloride in order of decreasing concentration (do not include water) and **justify the order given**, including dissociation and hydrolysis equations, where necessary. (5 marks)

Cl^- $CH_3NH_3^+$ H_3O^+ CH_3NH_2 OH^-

highest concentration **no mistakes (2 marks) 1 mistake (1 mark)** lowest concentration

Dissociation $CH_3NH_3Cl(s) \rightarrow CH_3NH_3^+(aq) + Cl^-(aq)$ (1 mark)

acidic neutral

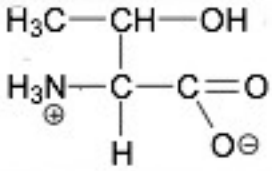
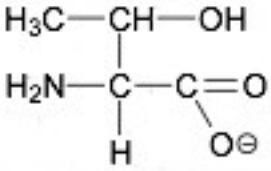
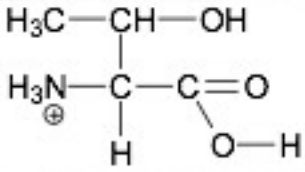
Hydrolysis $CH_3NH_3^+(aq) + H_2O(aq) \rightleftharpoons CH_3NH_2(aq) + H_3O^+(aq)$ (1 mark)

$H_3O^+(aq)$ more abundant than $CH_3NH_2(aq)$ since some $H_3O^+(aq)$ ions occur from the ionisation of water $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ (1 mark)

See next page

Question 32 **(5 marks)**

(a) The amino acid threonine is listed in the Data booklet. It exists as a zwitterion in aqueous solution at pH = 7. Complete the table below showing the structure of threonine at each of the indicated pH values.
(3 marks)

pH of solution	Structure
7	
9	
5	

(3 marks)

(b) Ionic interactions help to maintain the three dimensional shape of proteins. Explain why a pH change can denature a protein.

(c)

$-NH_2 + H^+ \rightleftharpoons -NH_3^+$ $\quad$ $-COO^- + H^+ \rightleftharpoons -COOH$

Increasing the pH (adding OH^-) decreases $[H^+]$, resulting in more NH_2 and COO^- groups, while decreasing the pH (adding H^+) results in more NH_3^+ and COOH groups forming. (1 mark)

Some ionic interactions will be disrupted and others may be established resulting in changes to the 3D shape (tertiary structure) of the protein and so the protein is denatured. (1 mark)

See next page

Question 33 **(6 marks)**

Predict whether the following reactions are likely to occur spontaneously by determining the E^o value of the reaction. Give observations where a reaction is predicted..

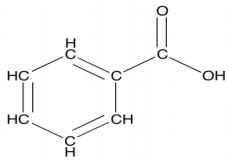
Reactants	E^o value of the reaction	Observations if reaction is predicted to occur
a piece of cadmium metal is placed into a solution of silver nitrate	**+1.20V (1 mark)**	**A silvery solid dissolves in a colouress solution and a grey solid appears (1 mark)**
Hydrogen sulfide gas is bubbled into bromine solution	**+0.91 V (1 mark)**	**A (colourless, foul/pungent) gas dissolves in an orange solution. A yellow precipitate forms and the solution turns colourless Accept solution turns opaque (1 mark)**
acidified hydrogen peroxide solution is mixed with cobalt nitrate solution	**-0.98V (1 mark)**	**No reaction (1 mark)**

Question 34 **(9 marks)**

See next page

Benzoic acid, $H_6C_7O_2$, also known as E330 in the food industry, is a weak acid that acts as a buffer and helps to preserve food. The benzoic acid molecule contains a benzene ring.

(a) Draw the structural formula of benzoic acid. (1 mark)



benzoic acid

(b) Given 0.100 mol L^{-1} solutions of benzoic acid and potassium hydroxide only, briefly describe how you could prepare a buffer solution. (2 marks)

50% neutralize the benzoic acid solution (1 mark)

e.g. add 50 mL of the KOH solution to 100 mL benzoic acid solution (1 mark)

(c) Write an equation for this buffer system and explain how it behaves to stabilise pH when a strong acid is added. (3 marks)

$H_6C_7O_2$ + H_2O ⇌ $H_5C_7O_2^-$ + H_3O^+ (no mark if single arrow) (1 mark)

addition of a strong acid increases [H_3O^+], the reverse reaction is now faster relative to the forward reaction (1 mark)

So H_3O^+ ions are consumed as equilibrium is reestablished, resisting pH change (1 mark)

(d) Could a similar buffer system be prepared using nitric acid and sodium hydroxide solutions? Explain. (3 marks)

No (1 mark)

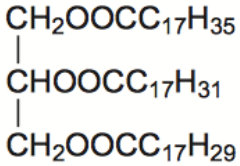
Nitric acid is strong and 100% ionises leaving no species in the system with protons that can be released if required (no weak acid species) (1 mark)

The nitrate ion, being the conjugate base of a strong acid can't accept protons (no basic species) (1 mark)

DO NOT WRITE IN THIS AREA

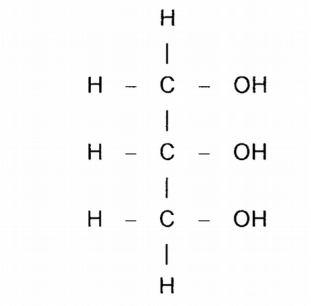
Question 35 **(9 marks)**

One industrial use of methanol, CH_3OH, is in the production of biodiesel from vegetable oils, such as the vegetable oil shown below.



(a) One mole of vegetable oil will produce three moles of biodiesel. Give the structural formula of the other organic product in the box below. (1 mark)

See next page

vegetable oil + methanol ⟶  biodiesel +

(b) Give the formula of one of the compounds found in the biodiesel formed by the reaction of methanol with the vegetable oil above. (2 marks)

e.g. $C_{17}H_{35}COOCH_3$ or $C_{17}H_{31}COOCH_3$ or $C_{17}H_{29}COOCH_3$
(1 mark) ester link, (1 mark) rest of molecule if minor error

(c) The presence of double bonds in the carbon chains of vegetable oils can be determined by reacting iodine with a given mass of the vegetable oil.

(i) Name the type of reaction that would occur when iodine is reacted with the vegetable oil.

Addition **(1 mark)**

(ii) How many moles of iodine would react with one mole of the vegetable oil shown above? Show your working. (3 marks)

$C_{17}H_{35}$- group has only single C-C bonds (saturated) **(1 mark)**

$C_{17}H_{31}$- group has 4 less H atoms so 2 double bonds
$C_{17}H_{29}$- group has 6 less H atoms so 3 double bonds **(1 mark)**

5 double bonds in total requires <u>5 moles of iodine</u> **(1 mark)**

(d) Give two reasons why the replacement of petroleum fuels with biofuels is consistent with the principles of green chemistry.
(2 marks)

biofuels are renewable, fossil fuels are not, therefore more sustainable

biofuels are 'close' to carbon neutral as CO_2 released on combustion is cancelled by CO_2 used for photosynthesis (less impact on global warming)

less environmental impact, e.g. acid rain, as biofuels don't produce SO_2 on combustion but fossil fuels do.

(1 mark) for each of 2 valid reasons, no marks for vague statements

Question 36 **(9 marks)**

See next page

Molybdenum chloride ($MoCl_2$) is a yellow solid. When it dissolves in water, the molybdenum ions react with the chloride ions to form hexachloromolybdenum(III) ions which are blue in colour. The equilibrium mixture appears green in colour.

$$\underset{\text{yellow}}{Mo^{2+}(aq)} + 6\,Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{MoCl_6^{3-}(aq)} + 33kJ$$

Complete the table below indicating, how the forward rate of reaction, concentration of $MoCl_6^{3-}$ (aq) and moles of Cl^-(aq) are affected once equilibrium has been re-established when the system is subjected to the following changes.

Answer: increase decrease, or no change.

Change made to system	forward rate	concentration of $MoCl_6^{3-}$ (aq)	moles of Cl^-(aq)
temperature is increased	**Increase**	**decrease**	**Increase**
volume is doubled by the addition of water	**decrease**	**decrease**	**increase**
a few drops of concentrated silver nitrate solution is added	**decrease**	**decrease**	**decrease**

Do not accept arrows

End of Section Two

Section Three: Extended answer **40% (91 Marks)**

Question 37 **(10 marks)**

A student was given the job of determining the sulfuric acid content in car battery acid. This was done by titrating a diluted solution of the car battery acid with a standardised sodium hydroxide solution (NaOH) of **pH 13.3**. The following procedure was followed:

Step 1: 10.0 mL of car battery acid was dissolved in water and made up to 500.0 mL of solution in a volumetric flask.

Step 2: A burette was filled with this solution and used to titrate 20.00 mL samples of the NaOH solution, using a suitable indicator.

The student's results from repeated titrations were as follows:

Final reading (mL)	20.60	19.55	20.75	20.80	19.05
Initial reading (mL)	4.90	3.80	5.25	5.00	3.20
Titration volume (mL)	**16.10**	**15.75**	**15.50**	**15.80**	**15.85**

(1 mark) (2 dp)

(a) Complete the table and determine the average titre volume. (2 marks)

Average Titre: **15.80 ml** **(1 mark) average of 3 concordant values**

(b) Write a molecular equation for the reaction occurring during the titration. (2 mark)

$H_2SO_4(aq)$ + 2 NaOH(aq) → $Na_2SO_4(aq)$ + 2 $H_2O(l)$ **(1 mark) molecular**

(1 mark) balanced

(c) Calculate the concentration (in mol L^{-1}) of the sodium hydroxide solution. (2 marks)

pH = 13.3 → pOH = 0.7 → $[OH^-]$ = $10^{-0.7}$ = 0.1996 = 0.200 mol L^{-1}

(1 mark) (1 mark)

OR

$[H+] = 10^{-13.3} = 5.012 \times 10^{-14}$ → $[OH^-] = \frac{Kw}{[H+]}$ = 0.200 mol L^{-1}

(1 mark) (1 mark)

(d) Calculate the concentration of the sulfuric acid in the original car battery acid in moles per litre. (4 marks)

$n(OH^-)$ = cV = 0.1996 x 0.0200 = 0.003992 **(1 mark)**

$n(H_2SO_4)$ in av titre = ½ $n(OH^-)$ = 0.001996 **(1 mark)**

$n(H_2SO_4)$ in total = $\frac{500}{15.80}$ x 0.001996 = 0.06316 **(1 mark)**

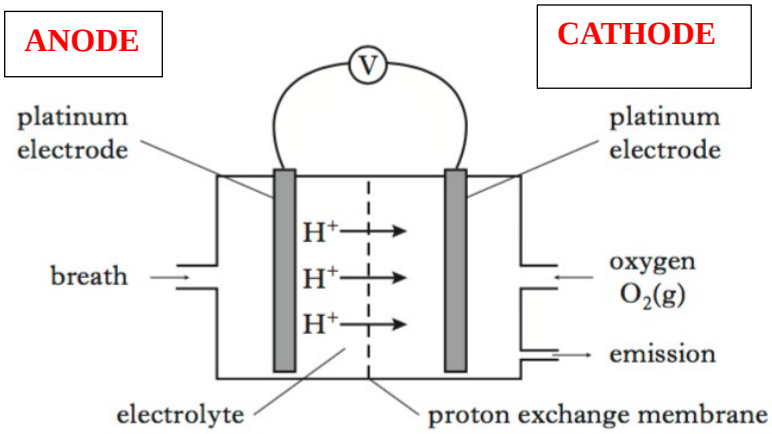
$c(H_2SO_4) = \frac{n}{v} = \frac{0.06316}{0.0100}$ = 6.32 mol L^{-1} **(1 mark)**

See next page

Question 38 **(14 marks)**

The concentration of ethanol in a person's breath can be determined by measuring the voltage produced in a fuel cell. The overall reaction for the fuel cell is given below.

$$CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$$



(a) in the boxes on the diagram above, indicate which electrode is the anode and which is the cathode. **If not in boxes no marks**

(1 mark)

(b) Why is it important that the membrane is chosen so that protons can pass through but oxygen and ethanol are too large to pass through? (2 marks)

Movement of protons is required to complete the internal circuit (cations to cathode) (1 mark)

O_2 and CH_3CH_2OH must be kept separate to prevent direct reaction. (1 mark)

(c) Calculate the mass of ethanol in 1.00 L of a drink-driving suspect's breath if a voltage of 20.0 mV was recorded at 27°C and 102 kPa. (4 marks)

From graph, V(ethanol) = 0.110L (1 mark)

$$n = \frac{PV}{RT} = \frac{102 \times 0.110}{8.314 \times 300.15} = 0.004496$$ **(2 marks)**

m(ethanol) = nM = 0.04496 x 46.068 = 0.207g (1 mark)

(d) In earlier forms of the breathylyser, police asked the person suspected of drink driving to blow through a glass tube containing acidified sodium dichromate crystals until the plastic bag fully inflated.

See next page

(i) Write a balanced redox equation for the oxidation of ethanol with acidified dichromate solution. (3 marks)

[$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4\,H^+ + 4\,e^-$] x 3 **(1 mark)**

[$Cr_2O_7^{2-} + 14\,H^+ + 6e^- \rightarrow 2Cr^{3+} + 7\,H_2O$] x 2 **1 mark)**

$3\,CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11\,H_2O$ **(1 mark)**

(ii) What colour change would be observed in the glass tube if the person had ethanol vapour in their breath? (1 mark)

Orange to deep green **(1 mark)**

(iii) Why is sulfuric acid also present in the glass tubing? (1 mark)

To produce the hydrogen ions for acidifying the dichromate solution or acidifying the dichromate solution **(1 mark)**

(iv) Could the sulfuric acid be replaced with hydrochloric acid in this breathylyser without affecting its reliability? Explain (2 marks)

No, the chloride ions in HCl(aq) may be oxidized by the acidified dichromate solution **(1 mark)**

The acidified dichromate solution would change colour without the presence of ethanol, hence a false positive result will occur **(1 mark)**

See next page

Question 39 **(18 marks)**

An amino acid extracted from animal protein was subjected to several types of analysis to determine its structure. Spectroscopic analysis of a vapourised sample of the amino acid showed that it was composed of the elements carbon, hydrogen, nitrogen and oxygen.

A sample of the amino acid of mass 2.175 g underwent combustion, producing 3.930 g of carbon dioxide and 1.871 g of water vapour.

In a further experiment, 0.286 g of the amino acid was treated with concentrated nitric acid to convert all the nitrogen present into ammonia. The ammonia produced was then dissolved in 50.0 mL of water. This solution was titrated against 0.126 $molL^{-1}$ hydrochloric acid and required 31.0 mL to reach the end point.

(a) Determine the empirical formula of the amino acid. (12 marks)

2.175 g

$n(C) = n(CO_2) = \frac{m}{M} = \frac{3.930}{44.01} = 0.08930$

$m(c) = nM = 0.08930 \times 12.01 = 1.0725$ g **(%C = $\frac{1.0725}{2.175} \times 100 = 49.31\%$)** **(2 marks)**

$n(H) = 2n(H_2O) = 2 \times \frac{1.871}{18.016} = 0.2077$

$m(H) = nM = 0.2077 \times 1.008) = 0.2094$ g **(%H = $\frac{0.2094}{2.175} \times 100 = 9.628\%$)** **(2 marks)**

0.286g

$n(N) = n(NH_3) = n(HCl) = cv = 0.126 \times 0.0310 = 0.003906$

n(N) in 2.175 g = $\frac{2.175}{0.286} \times 0.003906 = 0.0297$ **(3 marks)**

$m(N) = nM = 0.0297 \times 14.01 = 0.4162$ g **(%N = $\frac{0.4162}{2.175} \times 100 = 19.14\%$)**

m(O) = 2.175 – (m(C+H+N)) = 0.4769 g

$n(O) = \frac{m}{M} = \frac{0.4769}{16.00} = 0.0298$ **(%O = $\frac{0.4769}{2.175} \times 100 = 21.93\%$)**

(2 marks)

	C	H	N	O		C	H	N	O
m	1.0725	0.2094	0.4162	0.4769	%/m	49.31	9.628	19.14	21.93
n	0.0893	0.2077	0.0297	0.0298	n	4.106	9.552	1.367	1.371
SR	3	7	1	1	SR	3	7	1	1

(2 marks)

empirical formula = $C_3H_7N_1O_1$ **(1 mark)**

See next page

(b) Another sample of the amino acid, weighing 2.579 g, was heated in the absence of air. It was found that the vapour occupied a volume of 519 mL at 100°C and 105.6 kPa. Find the molecular formula of the amino acid. (5 marks)

n = $\frac{PV}{RT}$ **=** $\frac{105.6\,x\,0.519}{8.314\,x\,373.15}$ **= 0.01767** **(2 marks)**

M = $\frac{m}{n}$ **=** $\frac{2.579}{0.01767}$ **= 146** **(1 mark)**

emp M = 73.1 → 146/73.1 = 2 hence molecular formula = 2 x emp formula **(1 mark)**

molecular formula = $C_6H_{14}N_2O_2$ **(1 mark)**

(c) Identify the amino acid, using the list of α-amino acids in the Chemistry Data Book.

Lysine **(1 mark)**

Question 40 **(17 marks)**

Stearic acid, $C_{17}H_{35}COOH$, is a weak acid and is often used to make soaps which contain sodium stearate.

(a) (i) Write an equation showing stearic acid acting as a Bronsted-Lowry weak acid. **(2 marks)**

$C_{17}H_{35}COOH + H_2O \rightleftharpoons C_{17}H_{35}COO^-(aq) + H_3O^+$

(i) Identify the conjugate acid-base pairs in the equation above. (2 marks)

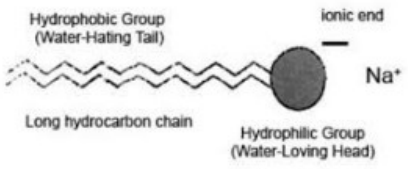
acid **$C_{17}H_{35}COOH$** conjugate base **$C_{17}H_{35}COO^-$** **(1 mark)**

base **H_2O** conjugate acid **H_3O^+** **(1 mark)**

(b) Explain fully how soap acts as a cleaning agent. Diagrams will assist your answer. (8 marks)

See next page

The long non-polar hydrophobic hydrocarbon tail dissolves in the dirt/ grease by forming dispersion forces with the generally non-polar dirt/ grease. **(1 mark)**



Strong ion-dipole forces form between the anionic hydrophilic head and polar water molecules. **(1 mark)**

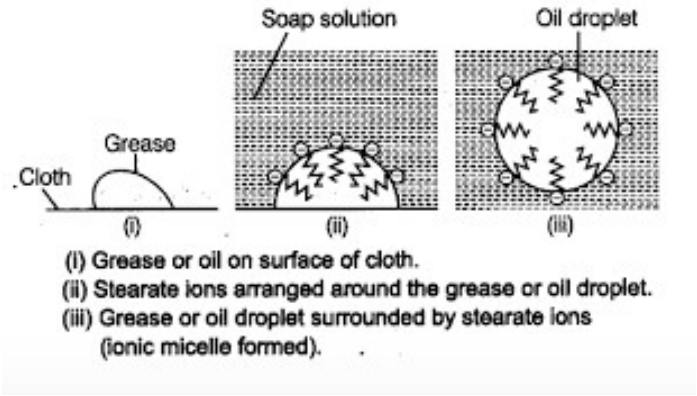
(1 mark)

The soap molecules arrange themselves with their non-polar tails immersed in grease and their polar heads dissolved in water. **(1 mark)**

The ion-dipole forces are stronger than the hydrogen bonds that need to be broken between the water molecules and so the dissolving process is energetically favourable. **(1 mark)**

Agitation breaks up the grease into small globules (micelles). **(1 mark)**

These remain suspended in the water due to the ion-dipole forces and eventually the grease is rinsed away with the water. **(1 mark)**



(1 mark)

(c) Soaps like sodium stearate do not function well in hard water (water containing Ca^{2+} ions). Explain with the aid of an equation. (2 marks)

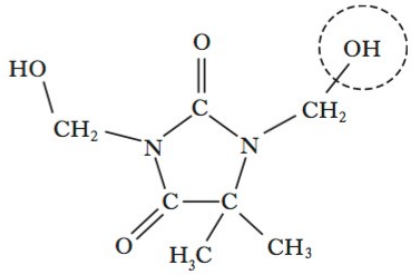
Soaps form an insoluble scum (precipitate) in hard water which prevents them functioning properly as ion-dipole bonds cannot be established. **(1 mark)**

$2\ C_{17}H_{35}COO^-(aq) + Ca^{2+}(aq) \rightarrow Ca(C_{17}H_{35}COO)_2(s)$ **(1 mark)**

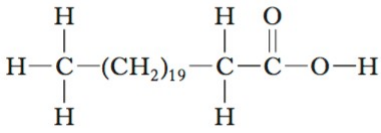
(d) Hair products contain a large variety of different chemicals. Hydantoins are used as preservatives in shampoos to kill any bacteria. A typical hydantoin is shown below. Name the functional group circled.

hydroxy or alcohol **(1 mark)**

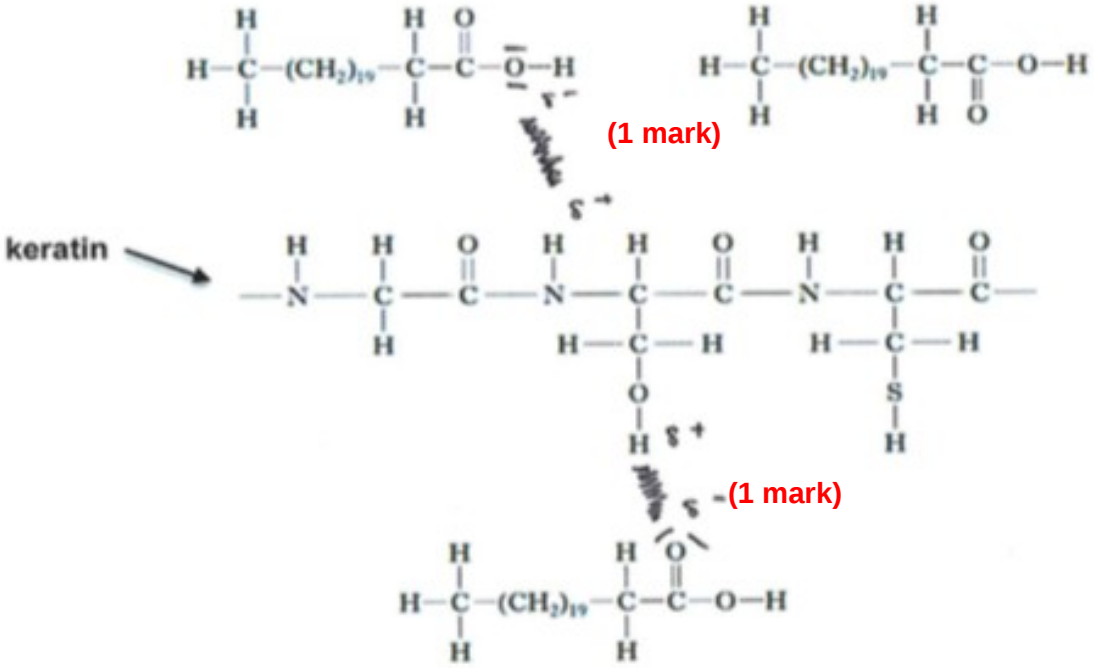
See next page



(e) When conditioner containing behenic acid is applied to hair, the behenic acid molecules make intermolecular hydrogen bonds to the keratin protein molecules in hair.
The structure of behenic acid is:



On the diagram below show **two** hydrogen bonds that could be made between a behenic acid molecule and the keratin(polypeptide). Include non-bonding pairs and partial charges on the atoms involved in the hydrogen bond. (2 marks)



Question 41 **(18 marks)**

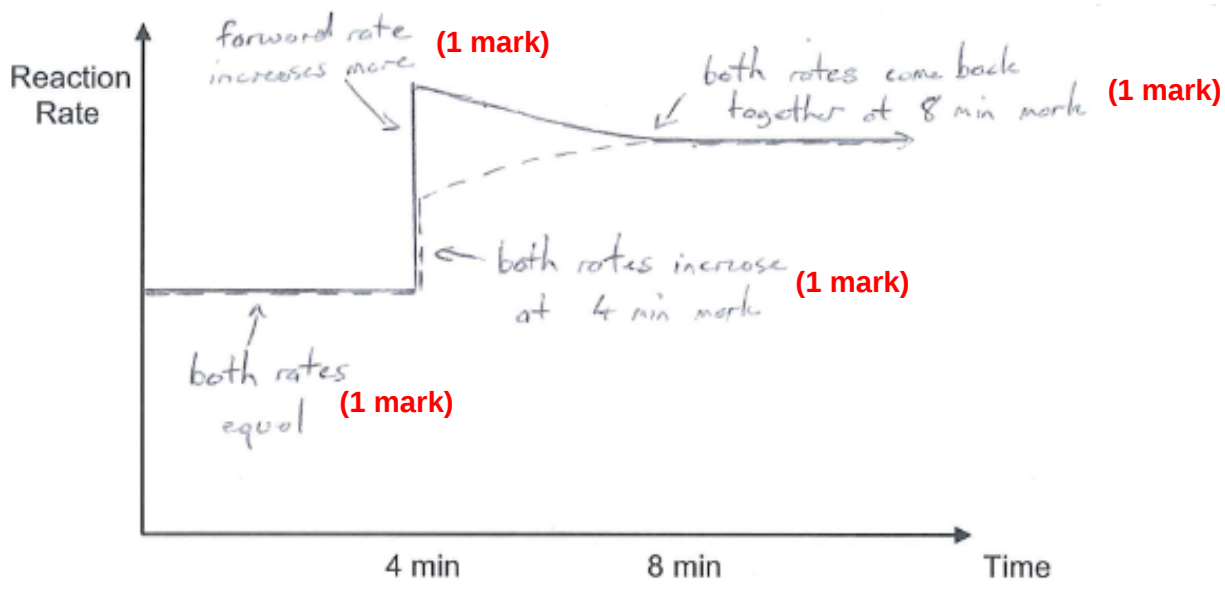
The graph drawn below shows the concentrations of the three substances in the reacting system given by the following equation, plotted against time.

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \qquad \Delta H = +108 \text{ kJ}$$

(a) Describe the different events that disturbed the equilibrium, as shown on the graph, at each of the following points in time. (3 marks)

Time	Event that disturbed the equilibrium
4 mins	**increase in temperature (1 mark)**
10 mins	**decrease in [CO] or some CO removed (1 mark)**
14 mins	**increase in volume or decrease in pressure (1 mark)**

(b) Show, on the axes below, how both the forward reaction rate (solid line) and reverse reaction rate (dashed line) change, from before the event that occurred at the 4 minute mark until after equilibrium was re-established at the 8 minute mark. (4 marks)



(c) Give an explanation, in terms of collision theory, for how the system returns to equilibrium after the event that occurred at the 10 minute mark. (3 marks)

Decrease in [CO] reduces the frequency of successful collisions between CO and Cl_2 molecules (1 mark)

See next page

Reduces the rate of the reverse reaction which is now slower relative to the forward reaction. **(1 mark)**

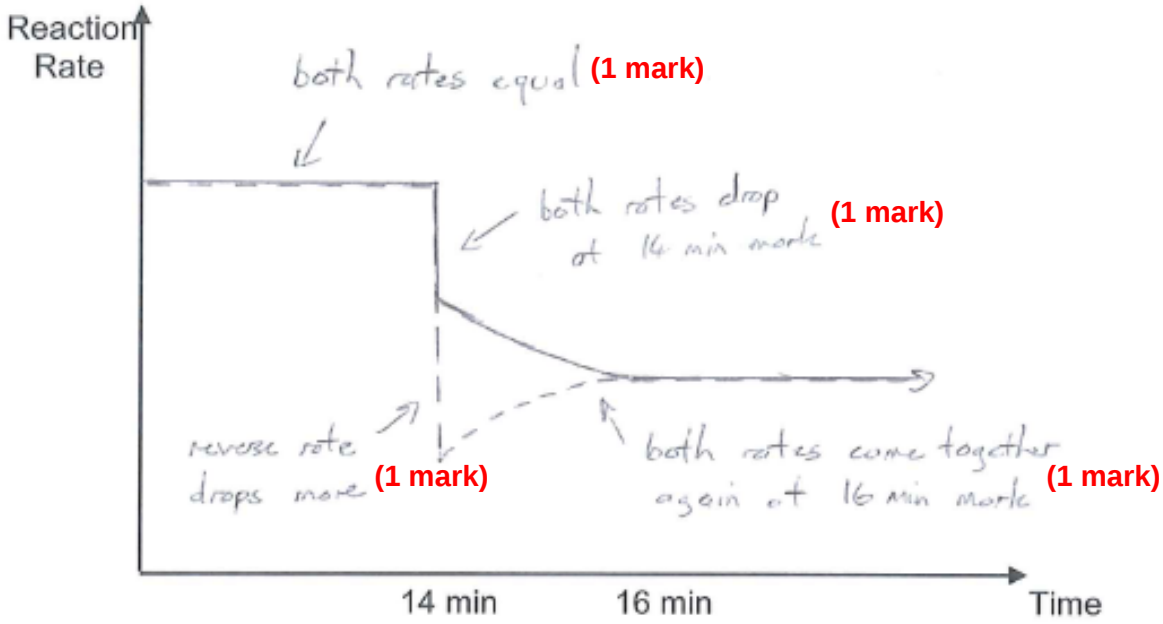
Products build up and reactants are consumed until rates become equal again and equilibrium is re-established **(1 mark)**

(d) The system has returned to equilibrium by the 12 minute mark. Write the equilibrium constant expression for this system and calculate its value at the 12 minute mark by using values from the concentration versus time graph above. (2 marks)

$$K = \frac{\{COCl2}{[Cl2][CO]} = \frac{0.12 \times 0.06}{0.03} = 0.24$$

(1 mark) **(1 mark)**

(e) Show, on the axes below, how both the forward reaction rate (solid line) and reverse reaction rate (dashed line) change, from the event that occurred at the 14 minute mark until equilibrium was re-established at the 16 minute mark. (4 marks)



(f) Circle your choice for the value of the equilibrium constant, compared to the value you calculated at the 12 minute mark, at each of the following times (2 marks)

(i) 2 minutes **lower** **same** **higher** **(1 mark)**

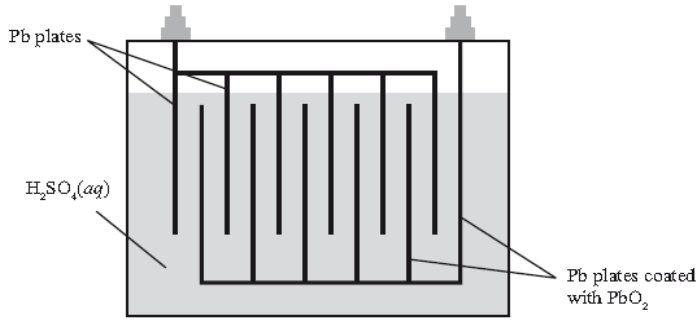
(i) 18 minutes **lower** **same** **higher** **(1 mark)**

See next page

See next page

Question 42 **(14 marks)**

The following diagram represents the lead-acid battery often used in motor cars.



The reactions occurring when the battery is operating are:

Reaction 1 $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

Reaction 2 $PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

The lead acid battery comprises 6 identical cells in series and has a total voltage of 12 V. The volume of acid is 0.700 L

In a particular fully charged cell the sulfuric acid concentration is 4.50 mol L^{-1}. One of the anodes was weighed and after some time was reweighed and found to have increased in mass by 1.35 g.

(a) Write the overall discharge equation.

$Pb(s) + PbO_2(s) + 2\ SO_4^{2-}(aq) + 4\ H^+(aq) \rightarrow 2\ PbSO_4(s)$ **(1 mark)**

(b) Why did the anode increase in mass?

Pb (s) is converted to $PbSO_4$ and so the extra mass is due to the sulfate ion in the lead (II) sulfate solid. **(1 mark)**

(c) How many moles of sulfuric acid was consumed in total in each cell? (3 marks)

1.35 g mass added due to sulfate ion

n = 1.35/ 96.07 = 0.01405 mols = n(Pb) oxidised at anode **(1 mark)**
(1 mark)

$n(H_2SO_4)$ consumed in each cell is 2 x 0.01405 = 0.0281 mols **(1 mark)**

(d) Determine the concentration of sulfuric acid after this period of discharge. (4 marks)

$n(H_2SO_4) = cV = 4.5 \times 0.7 = 3.15$ mols **(1 mark)**

$n(H_2SO_4)$ consumed = 6 x 0.0281 mols = 0.1686 mols **(1 mark)**

$n(H_2SO_4)$ remaining = 3.15 – 0.1686 = 2.981 mols **(1 mark)**

$[H_2SO_4] = n/V = 2.981/0.7 = 4.26$ mol L^{-1} **(1 mark)**

See next page

(e) Assuming that the ionisation of the second proton in sulfuric acid is only 10.0%, determine the pH of the original 4.50 mol L^{-1} acid. (3 marks)

$[H^+]$ from second proton = 4.50 x 10% = 0.45 mol L^{-1} (1 mark)

Total $[H^+]$ = 4.50 + 0.45 = 4.95 mol L^{-1} (1 mark)
pH = -log $[H^+]$ = -log 4.95 = -0.695 (1 mark)

(f) By considering the overall discharge equation in part (a) above, explain why the lead acid battery can be readily recharged. (2 marks)

The product lead sulfate at the anode and cathode is insoluble, and remains coating the electrodes at the sites of oxidation/reduction. (1 mark)

During recharge the original reactants lead and lead (II)oxide are reformed at the sites of oxidation/reduction ready for discharge again. (1 mark)

End of Section Three

END OF QUESTION

Question	Marks Available	Your Mark	Teacher
1-25	50		All
26-33	52		JV
34-38	51		BL
39	18		SH
40	17		MD
41-42	32		TF
Total	**220**		