Answers
and
Marking Scheme

2007

HIGHER SCHOOL CERTIFICATE

TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A Data Sheet and a Periodic Table are provided
- Write your Student Number at the top of this page

Total Marks – 100

Section I ~ Pages 2 – 15
75 marks
This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt Questions 1 – 15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt Questions 16 – 29
- Allow about 1 hour and 45 minutes for this part

Section II ~ Pages 16 – 17
25 marks
- Attempt Question 30
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1 – 15
Allow about 30 minutes for this part

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

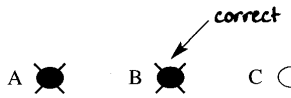
Sample: $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



Answer Box for Questions 1 – 15				
1	**A** ●	**B** ○	**C** ○	**D** ○
2	**A** ○	**B** ●	**C** ○	**D** ○
3	**A** ○	**B** ●	**C** ○	**D** ○
4	**A** ○	**B** ○	**C** ○	**D** ●
5	**A** ○	**B** ○	**C** ●	**D** ○
6	**A** ○	**B** ○	**C** ●	**D** ○
7	**A** ○	**B** ○	**C** ●	**D** ○
8	**A** ●	**B** ○	**C** ○	**D** ○
9	**A** ○	**B** ●	**C** ○	**D** ○
10	**A** ○	**B** ○	**C** ○	**D** ●
11	**A** ○	**B** ○	**C** ●	**D** ○
12	**A** ○	**B** ○	**C** ○	**D** ●
13	**A** ○	**B** ●	**C** ○	**D** ○
14	**A** ○	**B** ○	**C** ○	**D** ●
15	**A** ●	**B** ○	**C** ○	**D** ○

► ***Mark your answers for Questions 1 – 15 in the Answer Box on page 2.***

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1 What is the catalyst used in the Haber process?

(A) iron oxide
(B) vanadium oxide
(C) platinum
(D) sulfuric acid

2 How many isomers exist for $C_3H_6F_2$?

(A) 3
(B) 4
(C) 5
(D) 6

3 Which application is an industrial use of ammonia?

(A) The industrial production of sodium hydroxide.
(B) The preparation of agricultural fertiliser.
(C) The final step in the Contact process.
(D) As a flocculent in water purification.

4 Which ion can cause water hardness?

(A) Cl^-
(B) SO_4^{2-}
(C) Na^+
(D) Ca^{2+}

5 Which element is transuranic and contains only radioactive isotopes?

(A) Pm
(B) Po
(C) Pu
(D) Pa

6 Which of the following will favour the production of ammonia in the Haber process?

(A) Increasing the temperature.
(B) Decreasing the concentration of $N_2(g)$.
(C) Increasing the pressure of the system.
(D) Increasing the volume of the system.

7 Which solution has the lowest pH?

(A) 0.1 mol L^{-1} CH_3COOH
(B) 0.1 mol L^{-1} HCl
(C) 0.1 mol L^{-1} H_2SO_4
(D) 0.1 mol L^{-1} NH_3

8 What is the pH of a 5×10^{-5} mol L^{-1} solution of nitric acid?

(A) 4.3
(B) 5.0
(C) 9.7
(D) 11.5

9 Which device could be used to detect the leakage of radiation from a nuclear reactor?

(A) Atomic absorption spectrometer
(B) Scintillation counter
(C) Cyclotron
(D) Data logger

10 All of the following substances can be purchased at a supermarket.
Which substance is basic?

(A) C_2H_5OH
(B) $C_6H_{12}O_6$
(C) NaCl
(D) $NaHCO_3$

11 A student constructs a galvanic cell in order to measure the cell potential between magnesium and silver half-cells.

What is the cell potential $E^{\ominus}$ (e.m.f.) for the cell?

(A) – 1.56 V
(B) 0.76 V
(C) 3.16 V
(D) 3.96 V

12 What conditions were assumed when determining the cell potential in Question 11?

	Electrolyte	*Temperature*
(A)	1 mol L^{-1} $AgNO_3(aq)$	0°C
(B)	2 mol L^{-1} $NaNO_3(aq)$	25°C
(C)	0.1 mol L^{-1} $MgSO_4(aq)$	25°C
(D)	1 mol L^{-1} $AgNO_3(aq)$	25°C

13 One of the common plastics used for drink bottles is polyethylene terephthalate (PET).
This condensation polymer plastic is formed from two monomers, terephthalic acid and 1,2-ethanediol:

terephthalic acid: HOOC-C_6H_6-COOH 1,2-ethanediol: HO-$(CH_2)_2$-OH

Which equation shows the reaction involved?

(A) HOOC-C_6H_6-COOH + HO-$(CH_2)_2$-OH → HOOC-C_6H_6-COO-$(CH_2)_2$-OH

(B) HOOC-C_6H_6-COOH + HO-$(CH_2)_2$-OH → HOOC-C_6H_6-COO-$(CH_2)_2$-OH + H_2O

(C) HOOC-C_6H_6-COOH + HO-$(CH_2)_2$-OH → —(HOOC-C_6H_6-COOHHO-$(CH_2)_2$-OH)—

(D) HOOC-C_6H_6-COOH + HO-$(CH_2)_2$-OH → —(OC-C_6H_6-COO-$(CH_2)_2$-O)— + $2H_2O$

14 Elements D, J, Q and T are located in Groups I, II, III, and VI respectively of the Periodic Table. Which oxide is the most acidic?

(A) D_2O
(B) JO
(C) Q_2O_3
(D) TO_3

15 Which of the following changes could be caused by acid rain?

(A) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
(B) The pH of the water in a lake could change from 7.6 to 8.3.
(C) $2O_3(g) \rightarrow 3O_2(g)$
(D) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Section I (continued)

Part B – 60 marks
Attempt Questions 16 – 29
Allow about 1 hour and 45 minutes for this part

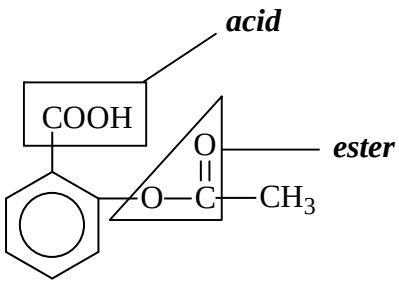
Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (5 marks)

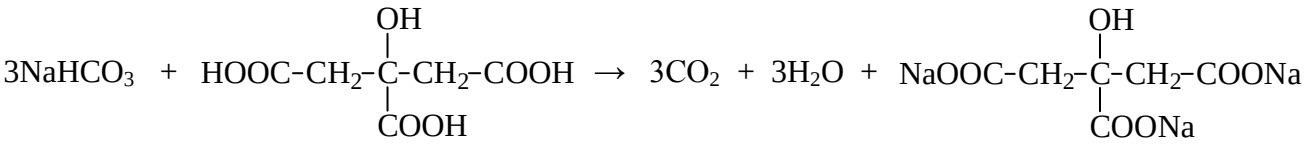
An Alka-Seltzer® effervescent headache tablet contains 0.32 g of aspirin, 1.7 g of sodium hydrogen carbonate and 1.2 g of citric acid.

(a) Aspirin has a structural formula of…



Clearly identify, by circling and labelling, the alkanoic acid and ester functional groups on the structure above. **(2 marks)**

(b) The equation below shows the reaction between sodium hydrogen carbonate and citric acid in the tablet. Calculate the volume of carbon dioxide produced at 25°C and 100 kPa. **(3 marks)**



mol $NaHCO_3$ = m ÷ M = 1.7 g ÷ 84.008 g mol^{-1} = 0.02024 mol

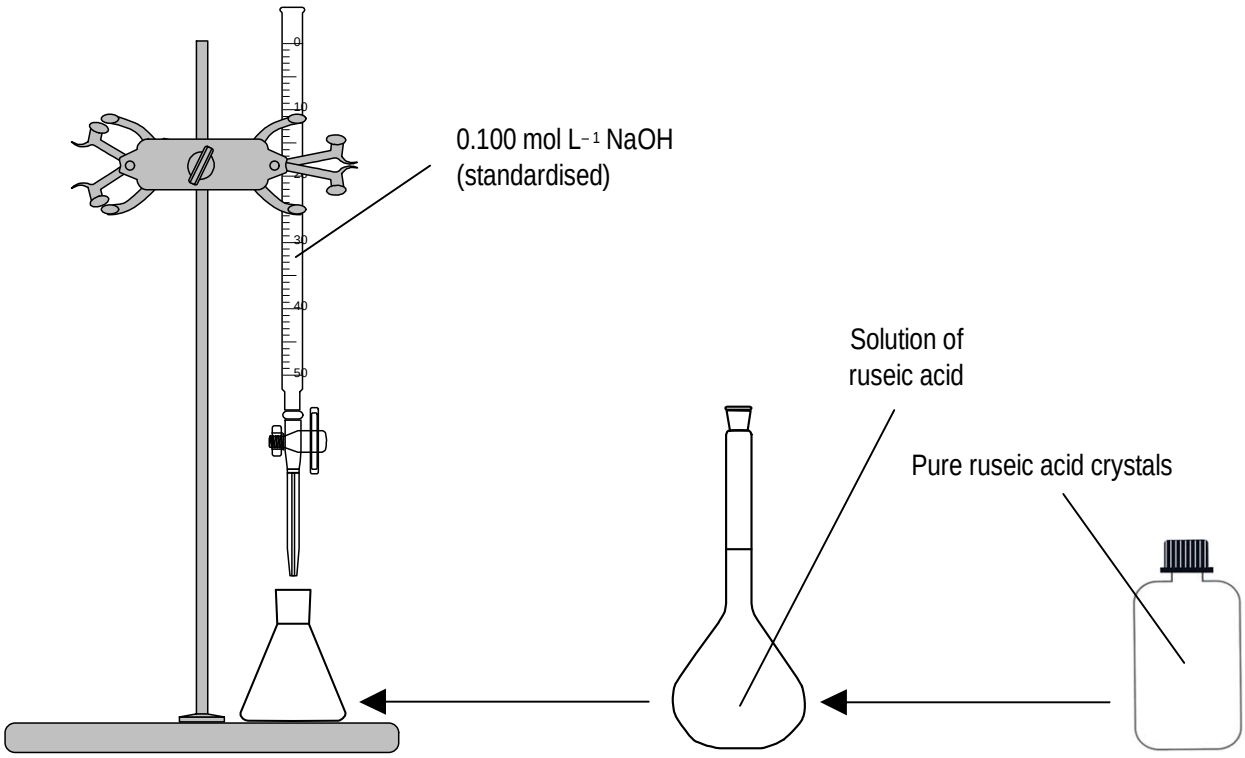
mol citric acid = m ÷ M = 1.2 g ÷ 192.124 g mol^{-1} = 0.006246 mol (limiting reactant)

volume CO_2 = 3 × mol citric acid × 24.79 L mol^{-1} = 3 × 0.006246 × 24.79 = 0.4645 = 0.46 L

Question 17 (7 marks)

Sanjay is given a research project with the aim of determining the molecular mass of ruseic acid by titration with sodium hydroxide. Ruseic acid is a weak, monoprotic acid which is a water soluble solid.

The diagram shows his titration planning procedure.



Identify the data Sanjay should record to prepare a ruseic acid solution and then titrate it; and write the sequence of calculations which he must solve to determine the molecular mass of ruseic acid.

- ***Mass of ruseic acid (RA) dissolved***
- ***Volume of ruseic acid solution prepared***
- ***Volume of ruseic acid aliquot pipetted***
- ***Volumes of NaOH titres***

- $c_{NaOH} \times V_{NaOH\ (mean\ titre)} = c_{RA} \times V_{RA\ aliquot}$ ***(Solve for c_{RA})***
- $n_{RA} = c_{RA} \times V_{RA\ (total\ solution\ volume\ in\ volumetric\ flask)}$ ***(Solve for n_{RA})***
- $n_{RA} = m_{RA} \div M_{RA}$ ***(Solve for M_{RA})***

Question 18 (3 marks)

All natural bodies of water contain this buffer system…

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

(a) Qualitatively describe the effect of this buffer when acid rain falls on a small lake. **(1 mark)**

The buffer will effectively stabilise the pH of the water, i.e. the pH will fall very slightly.
► ***No change in pH is deemed wrong.***

(b) The hydrogen carbonate ion is an amphiprotic species.
Write balanced chemical reactions showing it acting as an acid and a base. **(2 marks)**

HCO_3^- (acid) + OH^- → CO_3^{2-} + H_2O

HCO_3^- (base) + H_3O^+ → H_2CO_3 (or CO_2 + H_2O) + OH^-

► ***Must show four species per reaction.***

Question 19 (4 marks)

The table shows comparative data for 1–propanol and acetic acid.

	Molecular mass (g mol $^{-1}$)	*Boiling Point (°C)*
1–propanol	60.094	97.2
acetic acid	60.052	117.9

(a) Explain the difference in the boiling points. **(2 marks)**

Both 1–propanol and acetic acid engage in <u>hydrogen bonding</u>. (1)
Acetic acid forms two hydrogen bonds, while 1–propanol forms one.
Thus acetic acid has stronger IMFs, hence higher boiling point. (1)

(b) Write the balanced chemical equation for the reaction between 1–propanol and acetic acid and state the conditions required for the reaction. Give the IUPAC name for the organic product. **(3 marks)**

$CH_3CH_2CH_2OH + CH_3COOH \rightleftharpoons CH_3COOCH_2CH_2CH_3 + H_2O$

► ***Use of molecular formulas OK. Omission of $\rightleftharpoons$ and states OK.***

Reaction conditions ~ conc. H_2SO_4 + heat (or refluxing)

$CH_3COOCH_2CH_2CH_3$ = propyl ethanoate

Question 20 (3 marks)

Describe the benefits and problems associated with the use of one named radioactive isotope in medicine.

Radioisotopes are useful in medicine. They may be used to diagnose and treat certain illnesses. For example, technetium-99m is used to study blood flow in the circulatory system. This can help in diagnosing circulation disorders. However, there are potential problems with using radioisotopes such as technetium-99m. The radiation emitted by the isotope may damage living tissue.

(1) named isotope (medical)
(1) benefit
(1) problem

Question 21 (3 marks)

Describe the conditions and chemistry associated with the preparation of ethanol.

$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$ (requires dilute $H_2SO_4(aq)$ as a catalyst)

Or,

$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2CO_2$ (requires yeast enzymes)

(1): reactants
(1): products
(1): conditions ("requires dilute $H_2SO_4(aq)$ as a catalyst"; "yeast enzymes and anaerobic conditions")

Question 22 (4 marks)

A spirit burner containing 1-propanol was used to heat water in an aluminium can in order to determine the heat of combustion per mole of the alkanol. The empty can had a mass of 177.1 g and when filled with water had a mass of 347.8 g. The spirit burner containing 1-propanol had a mass of 235.6 g at the beginning of the investigation. The initial temperature of the water in the can was 23.5°C. The spirit burner was lit and extinguished when the water temperature reached 33.5°C. On reweighing, the spirit burner weighed 235.0 g.

(a) Calculate the molar heat of combustion for 1-propanol. (3 marks)

Mass of water = 170.7 g
$\Delta T = 10^oC$
Mass of 1-propanol = 0.60 g

$\Delta H = mC\Delta T = (170.7g)(4.18\ J.K^{-1}.g^{-1})(10^oC) = 7135.26\ J$

0.60 g of 1-propanol = 0.00998 moles

$\Delta H_c^\theta = -714.6$ kJ/mole or "heat of combustion = 714.64 kJ/mole"

(1): correct values derived from data supplied in question (mass of water, temperature change, specific heat capacity of water)
(1): for using the relationship: $\Delta H = mC\Delta T$
(1): correct value obtained for ΔH_c^θ = – kJ/mole and for dividing by 0.00998

(b) State one reason why the molar heat of combustion determined from this investigation would not be the same as that found in a standard chemical reference book. **(1 mark)**

Limitations of method:
no stirring; heat loss from calorimeter; spirit burner may not have been close to the base of the can.

Question 23 (6 marks)

The dry cell and lead-acid cell have been useful commercial galvanic cells.
With reference to ONE of these cells:

(a) Write half-equations to describe the chemistry occurring at the anode and cathode. **(2 marks)**

(b) Write an overall equation for the cell. **(1 mark)**

(c) Describe the electrolyte used. **(1 mark)**

(d) Describe one use of this particular cell. **(1 mark)**

(e) Describe one limitation of using this cell. **(1 mark)**

	Dry cell	***Lead-acid cell***
Anode	$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$	$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$
Cathode	$NH_4^+(aq) + MnO_2(s) + H_2O(l) + e^- \rightarrow Mn(OH)_3(s) + NH_3(aq)$	$PbO_2(s) + 4H^+ + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$
Overall	$Zn(s) + 2NH_4^+(aq) + 2MnO_2(s) + 2H_2O(l) + e^- \rightarrow 2Mn(OH)_3(s) + 2NH_3(aq) + Zn^{2+}(aq)$	$Pb(s) + 2SO_4^{2-}(aq) + 4H^+ + PbO_2(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$
Electrolyte	NH_4Cl ***paste***	$H_2SO_4(aq)$
Use	***Widely used in e.g., torches***	***Car batteries***
Disadvantage	***Cannot provide large stable currents.***	***Pb is toxic to the environment.*** $H_2SO_4(aq)$ ***is hazardous.***

**** Students must explicitly identify the anode and cathode reactions.***

Question 24 (4 marks)

Justify the synthesis and use of a named biopolymer.

Poly(3-hydroxybutanoate): used as a plastic for items such as disposable nappies and packaging for medical and hospital supplies. It has the advantage of being biodegradable. Since it is formed from a microorganism, it is considered as being renewable. This is an advantage over petroleum-based polymers.

(1): named biopolymer
(1): use
(1): advantage – biodegradable
(1): advantage – formed from renewable resources

Question 25 (3 marks)

(a) Write two balanced chemical equations showing the combustion of a fuel under different conditions.

(b) Identify one harmful product formed.

R1 $C_8H_{18} + 25/2\ O_2 \rightarrow 8CO_2 + 9H_2O$

R2 $C_8H_{18} + 21/2O_2 \rightarrow 4CO_2 + 4CO + 9H_2O$

Incomplete combustion, reaction 2, can cause C and toxic CO to form.

Marking criteria	*Marks*
• *Gives two relevant equations AND identifies one harmful product*	*3*
• *Gives two relevant equations OR* • *Gives one relevant equation AND identifies a harmful product*	*2*
• *Gives one relevant equation OR identifies a harmful product*	*1*

Question 26 (6 marks)

You performed first hand investigations to analyse water samples using qualitative and quantitative analysis.

(a) Distinguish between qualitative and quantitative analysis. **(2 marks)**

Quantitative analysis tries to find out the amounts of each chemical present.

Qualitative analysis tries to identify the chemicals present.

Question 26 (continued)

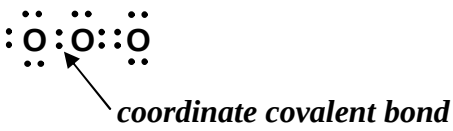
(b) Complete the following table to show how the ions listed can be identified. **(4 marks)**

Ion	*Test used*	*Observation if ion is present*
CO_3^{2-}	*Add HCl*	*Bubbling*
Cl^-	*Add $AgNO_3$*	*White precipitate is formed*
Ca^{2+}	*Flame test*	*Brick red flame colour*
Fe^{3+}	*Add KSCN*	*Solution becomes a blood red colour*

Marking criteria	*Marks*
• *Four correct tests and correct observations*	*4*
• *Four correct tests and two correct observations OR* • *Three correct tests and three correct observations*	*3*
• *Four correct tests OR* • *Two correct tests AND two correct observations*	*2*
• *Two correct tests OR* • *One correct test AND one correct observation*	*1*

Question 27 (2 marks)

Draw the Lewis electron dot structure for ozone and indicate the coordinate covalent bond on the diagram.



Question 28 (4 marks)

Identify two additives in town water supplies and give reasons for their addition.

Chlorine is added to disinfect the water by killing harmful coliforms that can cause disease.

Fluoride ions are added to provide potable drinking water that will help to reduce tooth decay by hardening tooth enamel.

Marking criteria	*Marks*
• *Identifies two correct additives and gives one reason for each addition*	*4*
• *Identifies two correct additives and gives one reason for its addition*	*3*
• *Identifies two correct additives OR* • *Identifies one correct additive and gives a reason for its addition*	*2*
• *Identifies one correct additive*	*1*

Question 29 (5 marks)

Discuss problems associated with the uses of CFCs and analyse their effects on the atmosphere using appropriate chemical equations.

CFCs are non-toxic, easily compressed to liquids and unreactive. They became the gas used in refrigeration, air conditioners, propellants for spray cans and solvents in dry cleaning . By the 1980s thousands of tonnes of CFCs were being used each year and they were released to the atmosphere.

The problem caused by CFCs relate to ozone depletion and the subsequent thinning of the ozone layer in the stratosphere. Ozone is important to life on Earth as it absorbs high energy ultra violet radiation that is damaging to living things.

When CFCs reach the stratosphere they are broken down by UV radiation to produce reactive chlorine radicals. These radicals disrupt the ozone cycle by breaking down ozone and then reform as radicals to continue the process.

$CH_3Cl \rightarrow CH_3 + Cl^{\cdot}$ ► *Free radical dots not required*

$Cl^{\cdot} + O_3 \rightarrow ClO + O_2$

$ClO + O^{\cdot} \rightarrow Cl^{\cdot} + O_2$

Marking criteria	*Marks*
• *Describes uses of CFCs and their impact on the atmosphere* • *Includes chemical equations to show the release of chlorine radicals; the reaction of this radical on ozone and the re-formation of the chlorine radical to continue the process*	*4-5*
• *Describes uses of CFCs and their impact on the atmosphere, may include one equation*	*3*
• *Identifies uses of CFCs and their impact on the atmosphere*	*2*
• *Identifies uses of CFCs OR their impact on the atmosphere*	*1*

Section II

25 marks
Attempt Question 30
Allow about 45 minutes for this section

Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 30 — Industrial Chemistry (25 marks)

(a) While developing his process, Haber started one experiment with a mixture consisting of 0.500 mol nitrogen gas and 0.800 mol hydrogen gas in a 1.00 L container. He found that, at equilibrium at a certain temperature, 0.150 mol of ammonia gas was present.

(i) Write a balanced chemical equation for the reaction. **(1 mark)**

$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$ ► *Must include ⇋ and (g) states.*

(ii) Calculate the equilibrium constant for the reaction at that temperature. **(2 marks)**

	Species		
	N_2	H_2	NH_3
initial moles	0.500	0.800	0
change in moles	-0.075	-0.225	+ 0.150
equilibrium moles	0.425	0.575	0.150
equilibrium concentration	0.425	0.575	0.150

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.150)^2}{0.425\ X\ (0.575)^3} = 0.278$$

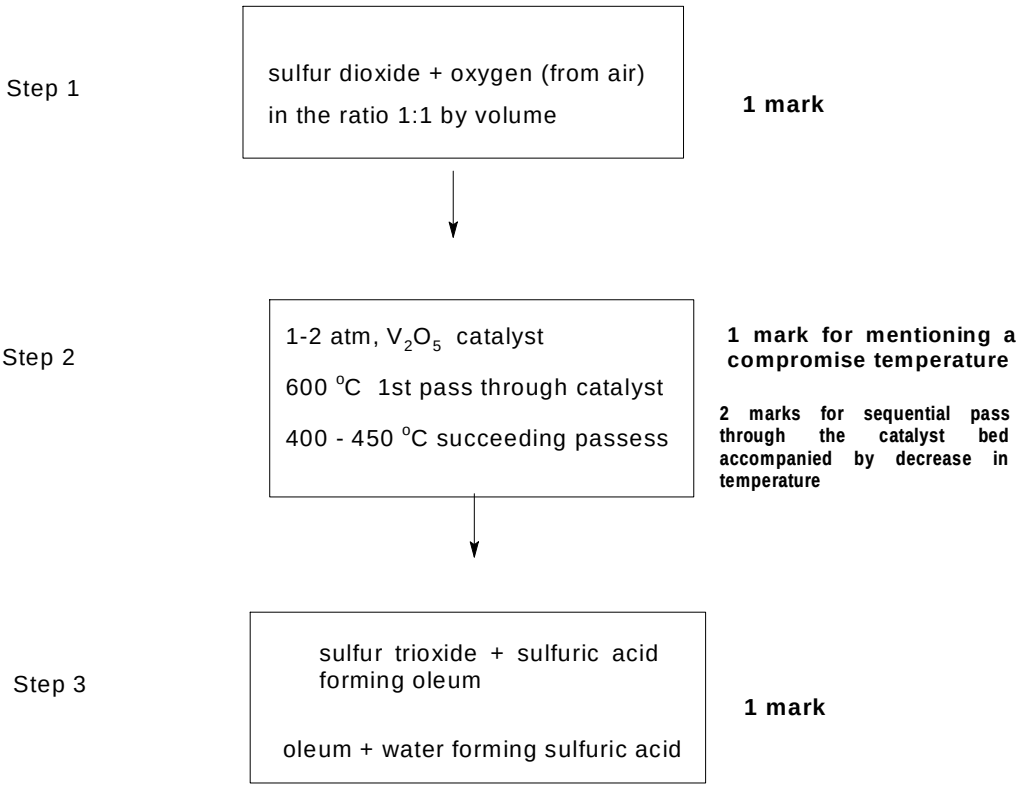
►*equilibrium concentration for both N_2 and H_2* **(1 mark)**

► *K expression* **and** *Evaluation of K expression* **(1 mark)**

(b) Describe and justify the conditions for the industrial production of sulfuric acid. **(7 marks)**

$2SO_2\ (g) + O_2(g) \rightleftharpoons 2SO_3\ (g) \qquad \Delta H = -196\ kJ\ mol^{-1}$

Possible answers:

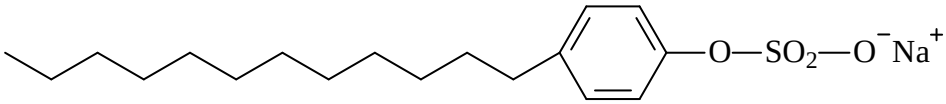
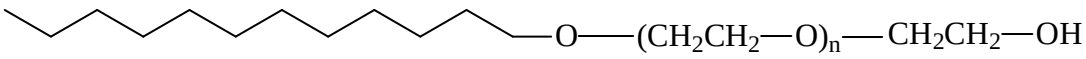


Step	*Explanation of the processes*
1	***The ratio of SO_2 to O_2 is 1:1 which amounts to a slight excess of O_2. According to Le Chatelier's principle, the slight excess of oxygen helps to push the equilibrium to the right. Air is a cheap source of oxygen and an aid to increase conversion of SO_2 to SO_3 (1 mark)***
	► Must mention excess of oxygen and the shifting of the equilibrium to the right according to Le Chatelier's principle. (1 mark) ►*The slight increase in system pressure as a way of shifting the equilibrium to the right (as predicted by Le Chatelier's principle may also be mentioned instead of or in addition to the use of excess oxygen.*
2	***According to Le Chatelier's, conversion to SO_3 is favoured by a low temperature. However, low temperature results in a slow approach to equilibrium. A high temperature is used initially to increase the rate of the reaction and produce a substantial amount of SO_3, then the temperature is lowered to 400 – 450^{o}C to produce sulfur trioxide at a fairly high proportion.*** ***The catalyst has no effect on the position of equilibrium but it ensures that the reaction is fast enough for a dynamic equilibrium to be set up within the short time that the gases are actually in the reactor. (1 mark)***
3	***Water is not added directly to the sulfur trioxide since the reaction is uncontrollable and produces a lot of sulfuric acid mist. The amount of sulfuric acid produced is twice the amount used originally to produce oleum. (1 mark)***

Criteria	***Marks***
Detailed description of conditions	*3*
Evaluation of each described condition	*4*

(c) The table shows diagrammatically the structure of anionic and nonionic detergents.
Using the structures in the table, explain how anionic detergents and nonionic detergents act to clean oily materials. **(2 marks)**

Possible answer: (1 mark each)

Structure of anionic detergent 
The polar sulfate group is attracted to water while the non-polar hydrocarbon part is attracted to the oil. The detergent therefore, forms a link between the oil and the water, allowing the oil to be washed away.
Structure of nonionic detergent 
Although not charged, the polar group is attracted strongly to water while the hydrocarbon part is attracted to oil. The nonionic detergent forms a link between the oil and the water allowing the oil to be washed away.

(d) Define saponification. **(1 mark)**

Saponification is the conversion in basic solution of fats and oils to glycerol and salts of fatty acids. (or any other acceptable definition)

► ***Basic medium must be emphasised***

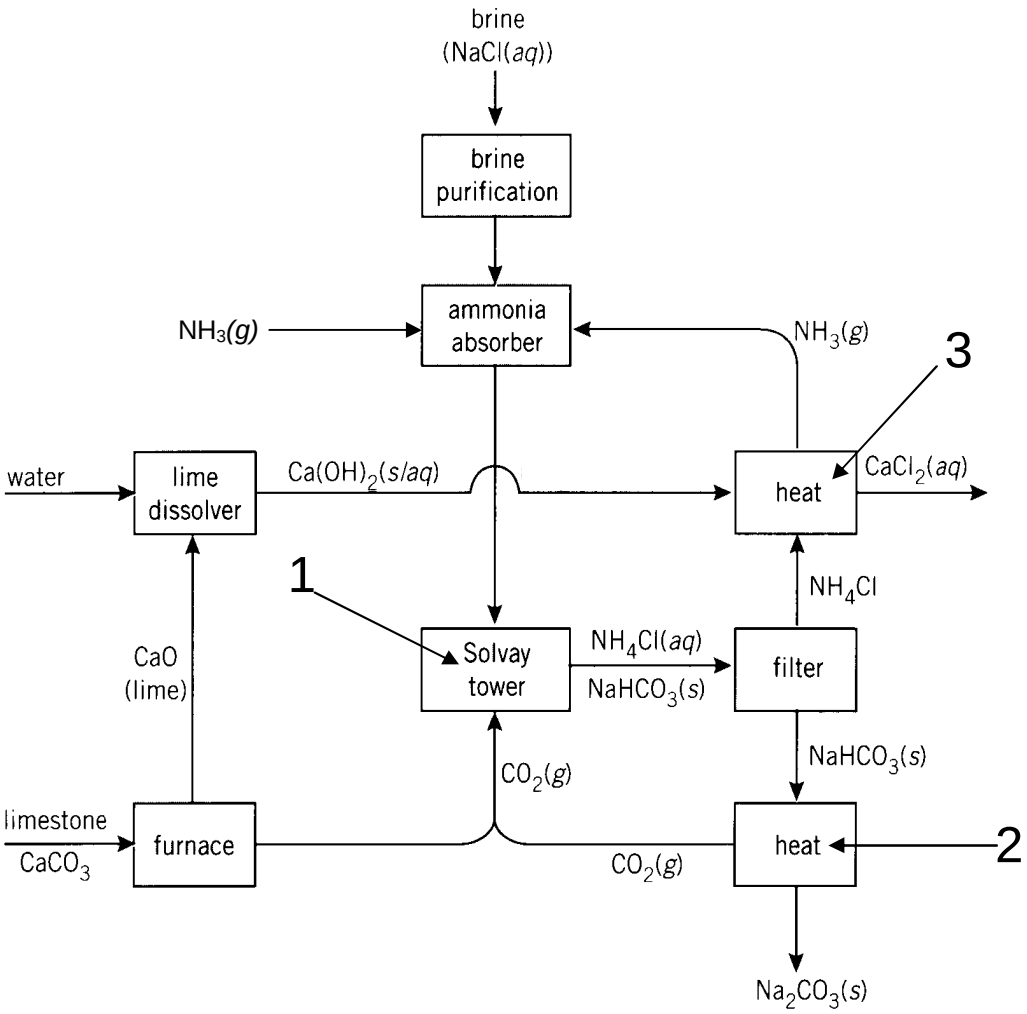
(e) Compare the three electrolysis methods used to produce sodium hydroxide in terms of their cathode reactions and the technical difficulties associated with each process. **(4 marks)**

Process	*Cathode reactions*	*Technical difficulties*
mercury	$2Na^+(aq) + 2e^- \rightarrow 2Na(Hg)$	***Mercury transfers mechanically to the brine and can escape to the environment. Requires larger amount of electricity to operate.***
diaphragm	$2H_2O + 2e^- \rightarrow H_2 + 2\ OH^-$	***NaOH product is contaminated with NaCl.***
membrane	$2H_2O + 2e^- \rightarrow H_2 + 2\ OH^-$	***Membrane separator is expensive and easily damaged, and has a shorter lifetime than diaphragm and mercury separators.***

Number of correct answers	**6**	**5**	**4**	**3**	**2**	**1**
Marks	**4**	**3**	**2**	**1**	**1**	**0**

(f) (i) The flow chart shows the Solvay process.

Explain the processes occurring at labelled stages 1, 2, and 3 including the relevant chemical equations. **(6 marks)**



Criteria	*Marks*
Explanation of the step	*1 mark*
Correct equation	*1 mark*

Stage 1, ammoniated brine reacts with carbon dioxide producing sodium hydrogen carbonate (1 mark)

$$Na^+(aq) + H_2O(l) + CO_2(g) + NH_3(aq) \rightarrow NH_4^+(aq) + NaHCO_3(s) \quad \textbf{(1 mark)}$$

Stage 2, Na_2CO_3 (s) is produced by heat decomposition of $NaHCO_3$(s) (1 mark)

$$2\,NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Stage 3, NH_3 is regenerated by reacting the NH_4Cl (aq) with $Ca(OH)_2$ (aq) (1 mark)

$$Ca(OH)_2(aq) + NH_4Cl(aq) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$$

(ii) Discuss an environmental issue associated with the Solvay process and explain how this issue is addressed. **(2 marks)**

Possible Answers (any of the following)

- ***The Solvay process is exothermic, so waste water must be cooled before it is returned to rivers or ocean. This is done with the use of cooling ponds.***

- ***Calcium chloride is a waste that is difficult to dispose of. Some uses have been developed, e.g. as a drying agent, as an additive for concrete and to melt ice on roads. It has also been disposed of in the ocean.***

- ***Dust is a problem and this is being addressed by improved truck loading facilities, upgrading of dust suppression, and the installation of dust scrubbing systems.***

Marking guidelines	*Mark*
Any issue and how they are addressed	*2*
Any issue no explanation on how it is addressed	*1*