Christ Church
Grammar School

Year 12 Chemistry
Trial Examination 2017

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work:	Ten minutes
Working time for the paper:	Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the candidate

Pens, pencils, calculator satisfying the conditions set by the School Curriculum & Standards Authority

To be provided by the supervisor

This Question/Answer Booklet; Multiple-choice Answer Sheet; Chemistry Data Sheet.

ANSWERS

Christ Church
Grammar School

Multiple-choice answer sheet

Course: CHEMISTRY 12

Surname: 2017 EXAM ANS.

Other names:

Student No. ☐☐☐☐☐☐☐☐

Instructions

For each question shade the box to indicate your answer. Use <u>only</u> a blue or black pen to shade the boxes.

For example, if b is your answer:

a ☐ b ■ c ☐ d ☐

If you make a mistake, place a cross through that square, then shade your new answer.
Do **not** erase or use correction fluid/tape.

For example, if b is a mistake and d is your answer:

a ☐ b ☒ c ☐ d ■

If you then want to use your first answer b, cross out d and then circle b.

a ☐ b ⓧ c ☐ d ☒

Marks will **not** be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

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☐
16	a☐	b☐	c☒	d☐
17	a☐	b☐	c☐	d☒
18	a☐	b☐	c☒	d☐
19	a☐	b☐	c☐	d☒
20	a☒	b☐	c☐	d☐
21	a☐	b☐	c☒	d☐
22	a☐	b☐	c☐	d☒
23	a☐	b☒	c☐	d☐
24	a☐	b☐	c☐	d☒
25	a☐	b☒	c☐	d☐
26	a☐	b☐	c☐	d☐
27	a☐	b☐	c☐	d☐
28	a☐	b☐	c☐	d☐
29	a☐	b☐	c☐	d☐
30	a☐	b☐	c☐	d☐

Section Two: Short answer 35% (70 marks)

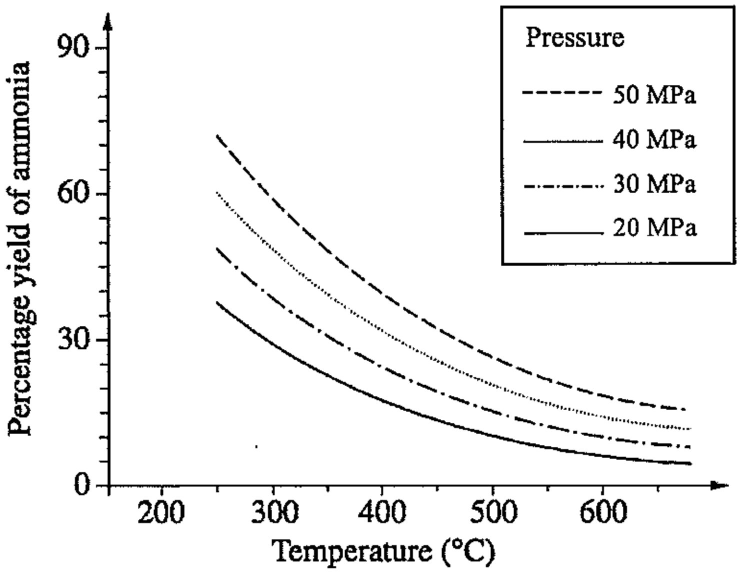
This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

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

Suggested working time: 60 minutes.

Question 26 (7 marks)

The Haber Process is the main industrial procedure for the production of ammonia. The graph below shows the percentage yield of ammonia produced from nitrogen and hydrogen at different temperatures and pressures.



(a) Write a balanced equation for the Haber Process.

$N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g)$ ✓

(1 mark)

Question 26 continued

(b) Explain with reference to the graph whether the process is exothermic or endothermic.

- Yield decreases with T ✓
- Equilibrium shifts towards the reactants as T increases. ✓
- Increase in T favours the endothermic process. The forward reaction is exothermic ✓

(3 marks)

According to the graph, the maximum percentage yield in this industrial process was achieved with a temperature of 250°C and a pressure of 50MPa.

(c) Even though the maximum yield of ammonia is achieved at high pressure and low temperature, in the actual process a higher temperature of 400 – 450°C and a lower pressure of 20 MPa is used. Explain why the manufacturers would choose these conditions.

- Low T gives high yield of ammonia but a low rate of reaction. ✓
- Compromise temperature is used. ✓
- High pressure gives high rate and high yield but a lower pressure is chosen to reduce

costs ✓

(1 mark if the answer refers to rate only)

(3 marks)

Question 27 **(6 marks)**

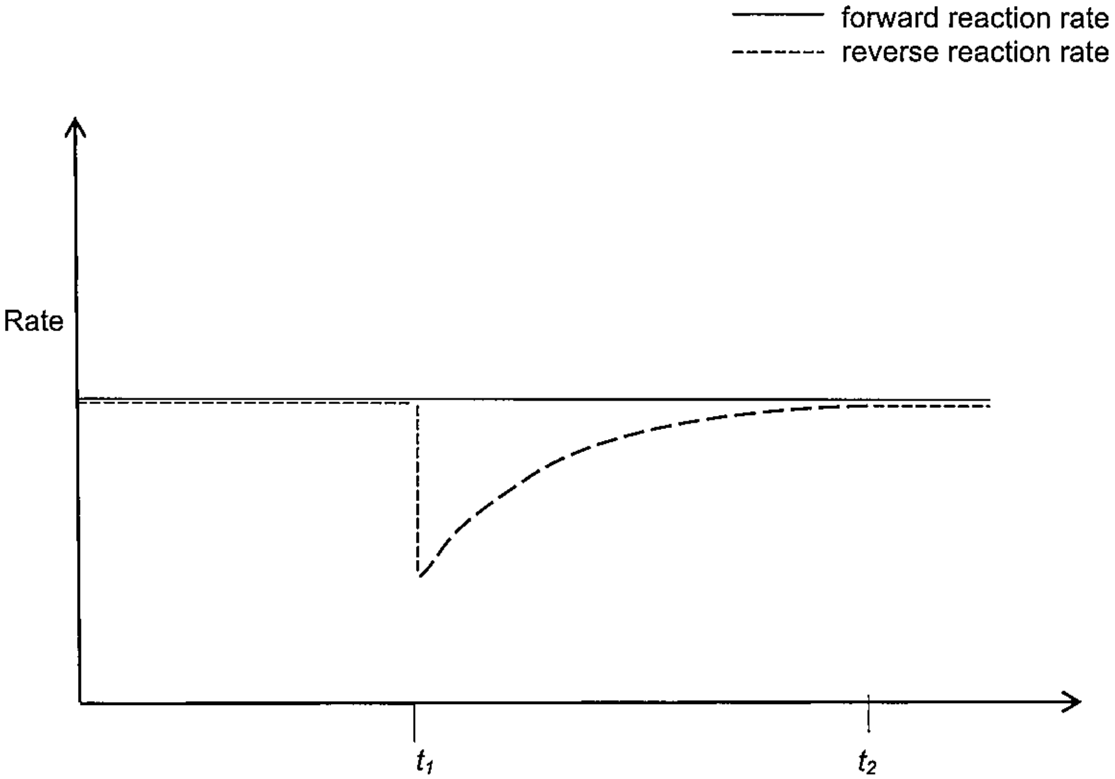
A small amount of solid lead iodide was added to a beaker of water, which was stirred. Most of the solid settled on the bottom of the beaker, but a little dissolved, establishing the equilibrium.

$$PbI_2 (s) \rightleftharpoons Pb^{2+} (aq) + 2I^- (aq)$$

The rates of the forward and reverse reactions were monitored over time.

At time = t_1 a small amount of water was added to the beaker at constant temperature. Equilibrium was re- established at time = t_2 and no further change took place.

(a) Complete the graph showing the reverse reaction rate up to t_2 on the diagram below.



(3 marks)

(b) Using collision theory to explain the rate of the **reverse reaction** from t_1 to t_2.

- Dilution leads to fewer collisions between Pb^{2+} and I^-. Rate of the reverse reaction decreases. ✓
- The rate of dissociation remains constant. As the concentration of Pb^{2+} and I^- increases, the rate of the reverse reaction increases. ✓
- Equilibrium is re-established at t_2. Forward rate = reverse rate. ✓

(3 marks)

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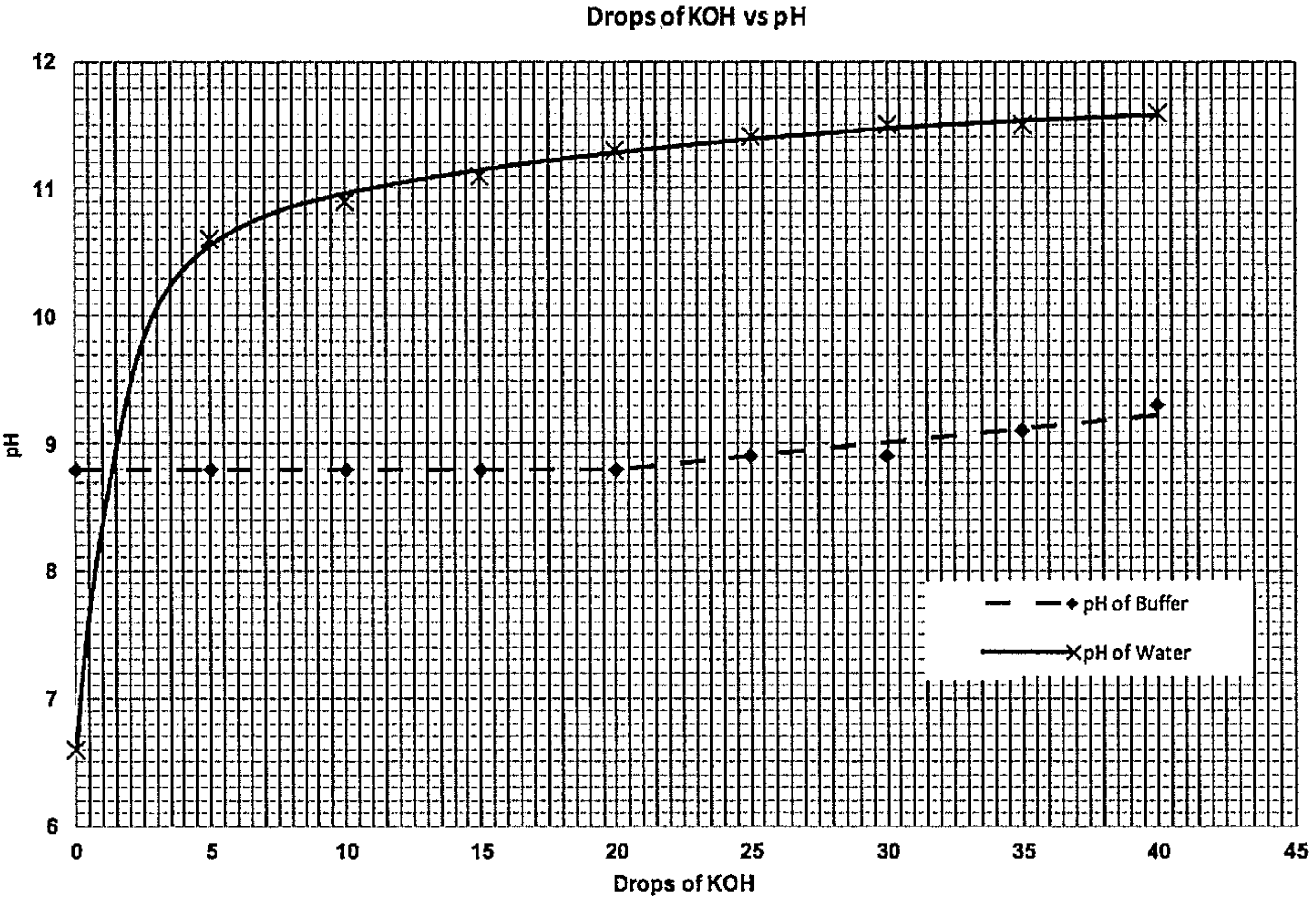
Question 28 **(7 marks)**

A student prepared a buffer by taking 150 mL of 0.13 mol L^{-1} ammonia solution and dissolving an equal number of moles of ammonium chloride in it, establishing the following equilibrium:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

The student tested the buffer by adding a 1.0 mol L^{-1} KOH solution, 5 drops at a time, and measuring the pH of the mixture with a pH meter. The student then repeated the procedure using distilled water.

The graph of the student's results is on the axes below.



Question 28 continued

(a) Describe how the NH_3/NH_4^+ buffer is able to withstand a significant change in pH when the potassium hydroxide solution is added.

$NH_4^+ + OH^- <=> NH_3 + H_2O$

- In the buffer there is sufficient NH_4^+ to react with the additional OH^-. ✓
- The rate of the forward reaction in the equation above increases due to the additional OH^- reacting with the NH_4^+. ✓
- Once equilibrium has been re-established most of the additional OH^- has been consumed. ✓
- The pH is close to what it was initially, therefore minimal change. ✓

(4 marks)

(b) Using an appropriate equation explain why water has a very low buffering capacity for the addition of OH^-.

- $2H_2O \Leftrightarrow H_3O^+ + OH^-$ $Kw = 10^{-14}$; ✓
- $[H^+]$ is very low, so when OH^- is added to water it is not consumed by the conjugate acid ✓
- pH rises quickly ✓

(3 marks)

Question 29 **(8 marks)**

200.0 mL of a solution of sodium hydroxide with a pH of 13.7 is added to 150.0 mL of 0.200 molL^{-1} sulphuric acid. Calculate the resulting pH of the solution.

NaOH

$[H^+] = 10^{-13.7}$

✓ $[OH^-] = 10^{-14}/10^{-13.7} = 10^{-0.3}$

$[OH^-] = 0.5012$ molL^{-1}

✓ n(NaOH) = cV = 0.2 x 0.5012 = 0.10024 mol

H_2SO_4

✓ n(H_2SO_4) = cV = 0.2 x 0.15 = 0.03 mol

✓ $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

✓ 0.06 mol of NaOH is required to completely react with the H_2SO_4. NaOH is in excess.

✓ n(NaOH) remaining = 0.10024 - 0.06 = 0.0424 mol

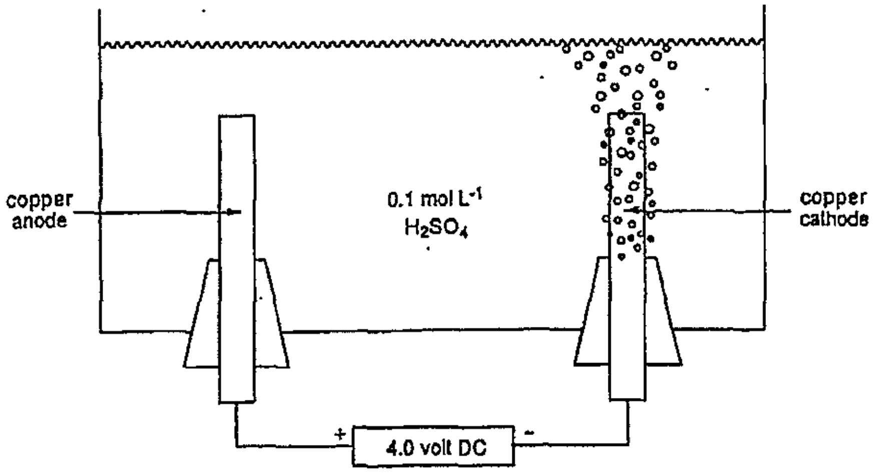
✓ $[OH^-] = 0.04024/ (0.2 + 0.15) = 0.04024/ 0.35 = 0.11497$ molL^{-1}

$[H^+] = 10^{-14}/0.11497 = 8.698 \times 10^{-14} = 10^{-13.06}$

✓ pH = 13.1

Question 30 **(5 marks)**

A student is asked to demonstrate that water is made from the elements hydrogen and oxygen. He decides to set up the following electrolytic cell to break water into its component elements by simultaneous oxidation and reduction (sulphuric acid is added as an electrolyte only).



A colourless gas is liberated from the cathode as expected, but to his surprise, no gas was liberated from the anode.

(a) Write the equation for the reaction occurring at the cathode.

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

(1 mark)

(b) Write the equation for the reaction actually occurring at the anode.

$Cu \rightarrow Cu^{2+} + 2e^-$

(1 mark)

(c) Write an observation for the reaction occurring at the anode.

The copper electrode dissolves. The solution turns blue

(1 mark)

(d) How should the student modify the apparatus so that the intended demonstration is successful?

Replace the copper anode with an inert electrode such as graphite or platinum.

(1 mark)

(e) Write an equation for the intended anode reaction.

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

(1 mark)

Question 31 **(6 marks)**

Consider the following unbalanced equation:

$$\mathbf{As_2O_3(s) + NO_3^-(aq) \rightarrow H_3AsO_4(aq) + NO(aq)}$$

(a) Identify the oxidant

oxidant: NO_3^- ✓

(1 mark)

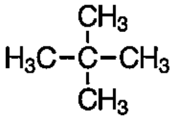
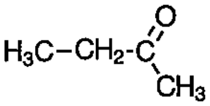
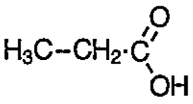
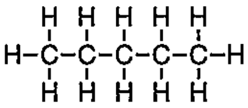
(b) Write half equations the oxidation and reduction in acidic conditions and the full balanced redox reaction.

Oxidation half equation $As_2O_3 + 5H_2O \rightarrow 2H_3AsO_4 + 4H^+ + 4e^-$	x 3	✓✓
Reduction half equation $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	x 4	✓✓
Redox equation $3As_2O_3 + 7H_2O + 4NO_3^- + 4H^+ \rightarrow 6H_3AsO_4 + 4NO$		✓

(5 marks)

Question 32 **(10 marks)**

Complete the following table. Note that the molar masses (M) of all substances are in the range of 70-74 $gmol^{-1}$, and that any differences are insignificant.

Molecule	Major type of intermolecular attraction.(choose from dispersion forces, dipole-dipole forces or hydrogen bonding)	Boiling point ranking (1=highest, 4=lowest)
 dimethylpropane	Dispersion ✓	4
 butanone	Dipole – Dipole ✓	2 ✓
 propanoic acid	Hydrogen bond ✓	1 ✓
 pentane	Dispersion ✓	3 ✓

(7 marks)

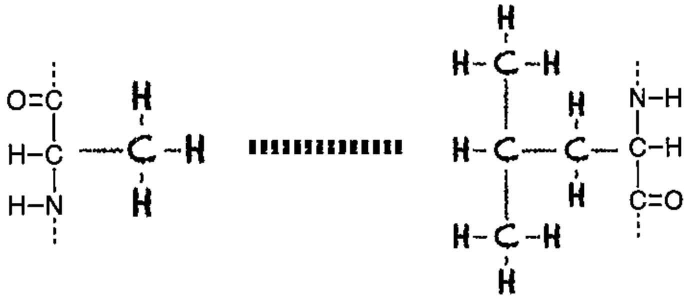
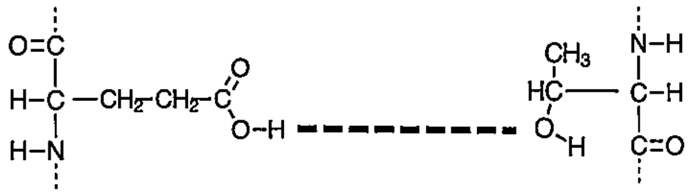
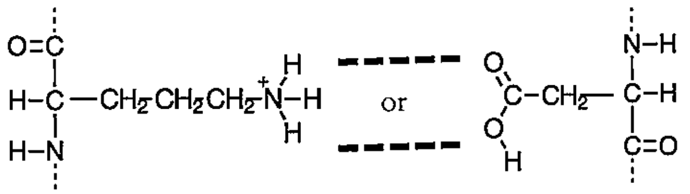
Explain the difference in the boiling points of dimethylpropane and pentane.

- Same number of e- ✓
- More surface area in contact between molecules in pentane due to their shape (or pentane molecules pack more tightly together) ✓
- Dispersion forces are stronger between pentane molecules and require more energy to break. Therefore pentane has a higher BP. ✓

(3 marks)

Question 33 **(6 marks)**

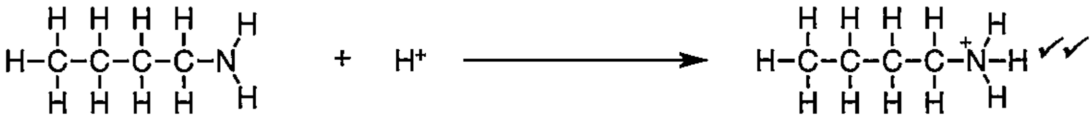
Complete the table below by adding sidechains corresponding to the alpha amino acid residues given on each line in the table below. Show the main intermolecular force present by drawing a dashed line between the atoms involved in each side chain. Name the intermolecular force you have drawn. An example of what is required is given as the first entry in the table.

Diagram	Name of intermolecular force
Example: Alanine and leucine residues. 	Dispersion
Glutamic acid and threonine residues. ✓ 	Hydrogen bond ✓
Serine and methionine residues. ✓ 	Dipole-dipole ✓
Lysine and aspartic acid residues in acidic conditions. ✓ 	Ion – dipole ✓

Question 34 **(6 marks)**

An amine can be regarded as an alkyl substituted ammonia. Butan-1-amine ($CH_3CH_2CH_2CH_2NH_2$) is a liquid with a low boiling point and a strong ammonia-like fishy smell.

(a) When a sample of butan-1-amine is shaken with an equimolar quantity of 0.1 molL^{-1} hydrochloric acid the resulting solution has no odour. Using full structural formula write an equation below that shows how the butan-1-amine has reacted with the hydrochloric acid.



(-1) for not using full structural formula

(2 marks)

(b) When a small quantity of 0.1 molL^{-1} sodium hydroxide is shaken with the resulting mixture the strong fishy smell returns. Use an equation to show what has happened.

(2 marks)

(c) Why was an equimolar quantity of dilute hydrochloric acid needed to get rid of the odour but only a small amount sodium hydroxide solution needed to bring it back?

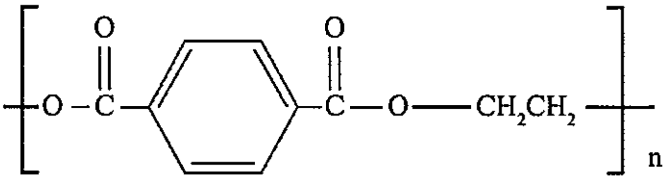
- All of the $CH_3CH_2CH_2CH_2NH_2$ needs to be reacted to get rid of the odour. ✓
- Only a small amount needs to be regenerated for the odour to return. ✓

(2 marks)

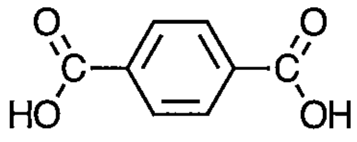
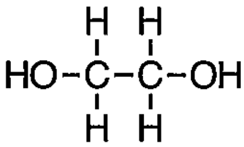
Question 35 **(4 marks)**

Condensation polymers appear in biological contexts such as polypeptides in protein chemistry and are also found in many industrial and domestic applications. PET (polyethylene terephthalate) plastic is an example.

(a) The structure below shows a repeating unit of a polyethylene terephthalate polymer.

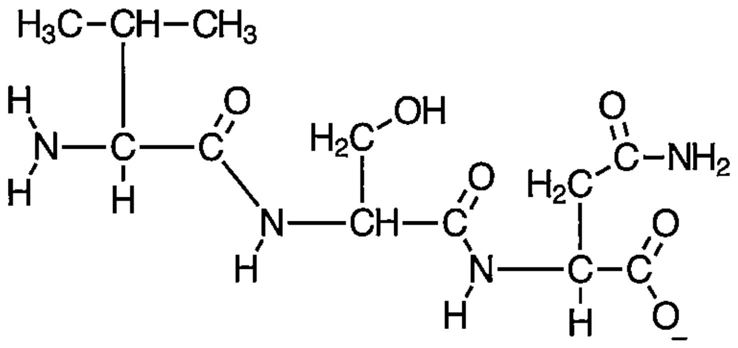


Draw the structures of the monomers that were used to make this polymer.

Monomer 1	Monomer 2
	

(2 marks)

(b) Draw the structure of the tripeptide Val – Ser – Asn in basic conditions.



(2 marks)

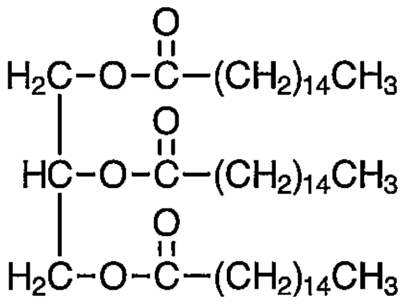
Question 36 **(5 marks)**

(a) A product derived from palm tree oil is used as an alternative fuel in diesel engines. Palm oil is converted to biodiesel by transesterification with methanol in either a base catalysed or lipase catalysed reaction.

In one batch of biodiesel, methyl palmitate was the only biodiesel molecule produced. The condensed structural formula for methyl palmitate is:

$$CH_3(CH_2)_{14}COOCH_3$$

Draw the structure of the triglyceride molecule found in the palm oil below.



✓ ester linkages drawn correctly

✓general structure

(2 marks)

(b) Give 3 advantages of the lipase catalysed process for the production of biodiesel over the base catalysed method.

- Lower operating temperature: lower energy use.
- Lower operating pressure (atmospheric pressure); lower energy use.
- The catalyst can be recycled
- The wastes are biodegradable
- No soap byproduct

(any 3 of the above) ✓✓✓

(3 marks)

Section 3: Extended answer 40% (80 Marks)

This section contains **six (6)** questions. You must answer **all** questions. Write your answers in the spaces provided.

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

Suggested working time for this section is 70 minutes.

Question 37 (11 marks)

Hydrogen bromide is a toxic, colourless gas. A reaction for its synthesis is:

$$2\ H_2O(g) + 2\ Br_2(g) \rightleftharpoons 4\ HBr(g) + O_2(g) \qquad \Delta H\ \text{-ve}$$

The manufacturer of this chemical investigates reaction conditions that could affect the reaction rate and the percentage yield.

(a) Predict the effect of increasing the temperature on the **rate of reaction** and the **percentage yield** of hydrogen bromide. Explain your reasoning.

- As temperature increases the frequency of collisions and the proportion of collisions with E>Ea increases. ✓
- Both the forward and reverse reaction rates increase. ✓
- Equilibrium favours the endothermic process as temperature is increased. ✓
- The equilibrium shifts to the reactant side. ✓
- % yield of HBr decreases. ✓

(5 marks)

Question 37 continued

(b) A change was made to the system. After equilibrium was re-established the concentration of HBr had increased and the mass of HBr had decreased.

(i) What change was made to the system? The volume was decreased ✓ (1 mark)

(ii) Explain your answer.

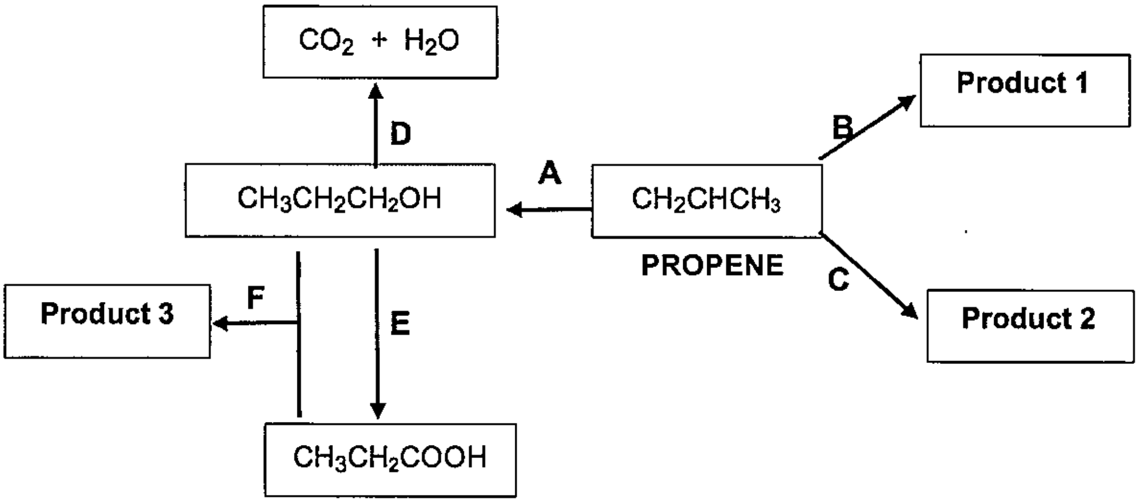
- As the volume decrease the concentration/ pressure of the reactants and products increases ✓
- The frequency of collisions between reacting particles increase. The rate of the forward and reverse reactions increase. ✓
- There is a greater proportion of particles on the product side of the reaction, therefore the rate of the reverse reaction increases by more than the rate of the forward reaction. Equilibrium shifts to the reactant side. ✓
- When equilibrium is re-established the mass of HBr has decreased. ✓
- The increase in pressure has only been partially counteracted so [HBr] is greater. ✓

(5 marks)

(Discussion of Le Chatelier's Principle only; max 3 marks)

Question 38 **(17 marks)**

Propene is a versatile chemical, which can be used to produce several other chemicals by a range of reactions. Some of these are represented in the diagram below.

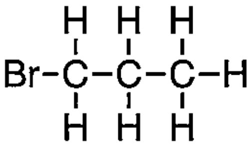


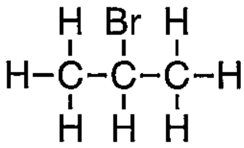
(a) (i) What type of reaction is reaction **A**? Addition or hydration (1 mark)

(ii) What other reactant is needed in **A**? H_2O (1 mark)

(b) (i) Propene is reacted with hydrogen bromide to give **product 1**. Draw a possible structural formula of **product 1** and name it.

Structural formula ✓





Name 1-bromopropane or 2-bromopropane ✓

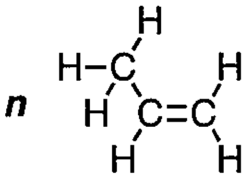
(2 marks)

Question 38 continued

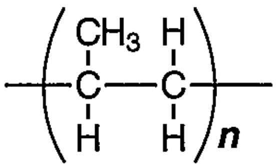
(c) Reaction **C** is a polymerisation reaction.

Write an equation for the production of the polymer (**product 2**) from the propene monomer showing repeating units and name the polymer.

Equation:



$\longrightarrow$



✓✓

Name: polypropene ✓

(3 marks)

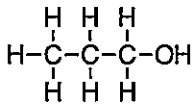
(d) Write a fully balanced equation for reaction **D**.

$2CH_3CH_2CH_2OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$ ✓✓

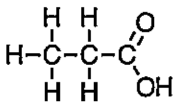
(2 marks)

(e) In reaction **E** propan-1-ol is converted to propanoic acid in a redox reaction. As the reaction occurred the colour of the solution went from orange to deep green. Write the oxidation and reduction half equations and the full redox reaction for the conversion. Use full structural formula for the organic reactant and product.

Oxidation:



$+ H_2O \longrightarrow$



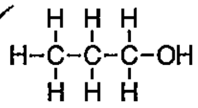
$+ 4H^+ + 4e^-$ x 3 ✓✓

Reduction:

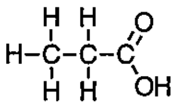
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ x 2 ✓

Full redox reaction:

✓✓ 3



$+ 2Cr_2O_7^{2-} + 16H^+ \longrightarrow$ 3



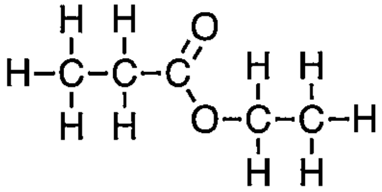
$+ 4Cr^{3+} + 11H_2O$

(5 marks)

Question 38 continued

(f) Write the full structural formula and name of the product(s) of reaction **F**.

Structural formula:



+ H_2O ✓✓

Name of product(s): propyl propanoate ✓

(3 marks)

Question 39 **(14 marks)**

A certain organic compound is known to contain only carbon, hydrogen and oxygen.
The compound was analysed as follows.

A 2.149 g sample was burned and the carbon dioxide produced was bubbled through a barium hydroxide solution, producing 11.27 g of barium carbonate ($BaCO_3$).

$$CO_2(g) + Ba(OH)_2(aq) \rightarrow BaCO_3(s) + H_2O(l)$$

The mass of water produced by burning of the sample was 0.7721 g.

(a) Determine the empirical formula of the compound. (8 marks)

$M(BaCO_3)$= 137.3 + 12.01 + 48 = 197.31gmol^{-1}

$n(BaCO_3)$ = 11.27/197.31 = 0.0571 mol

$n(C) = n(BaCO_3)$ = 0.0571 mol

m(C) 0.0571 x 12.01 = 0.6860g ✓✓

$n(H_2O)$ = 0.7721 / 18.016 = 0.0429 mol

n(H) = 2 x 0.0429 = 0.08571 mol

m(H) = 0.0858 x 1.008 = 0.08639 g ✓✓

m(O) = 2.149 – 0.6860 – 0.08639 = 1.3766g

n(O) = 1.3766/16 = 0.0860 mol ✓✓

	C	H	O
mole	0.0571	0.0858	0.0860
ratio	1	1.5	1.5
	2	3	3

EF = $C_2H_3O_3$ ✓✓

Question 39 continued

(b) A further 2.149g of the compound was vapourised at 100^{0}C and 105kPa and was found to occupy a volume of 423.1 mL. Determine the molar mass of the compound and its molecular formula.

n = PV/RT = 105 x 0.4231/ 8.314 x 373.15 = 0.01432 mol

M = m/n = 2.149/ 0.01432 = 150.07 ✓

M($C_2H_3O_3$) = 75.044gmol^{-1}

M(MF)/M(EF) = 150.07/ 75.044 = 2 ✓

MF = $C_4H_6O_6$ ✓

(3 marks)

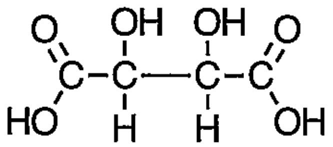
(c) Further tests were carried out to determine the structure of the compound.

Test #1:
A small quantity of sodium carbonate was added to a sample of the compound. A colourless gas was produced which turned limewater milky.

Test#2:
When the compound was mixed ethan-1,2- diol (HO-CH_2CH_2-OH) and a suitable catalyst a polymer was produced.

Test #3:
When a few drops of acidified potassium permanganate was added to the compound it changed colour from purple to pale pink.

Draw the structural formula of the unknown compound in the space below showing all bonds.



(3 marks)

Question 40 **(13 marks)**

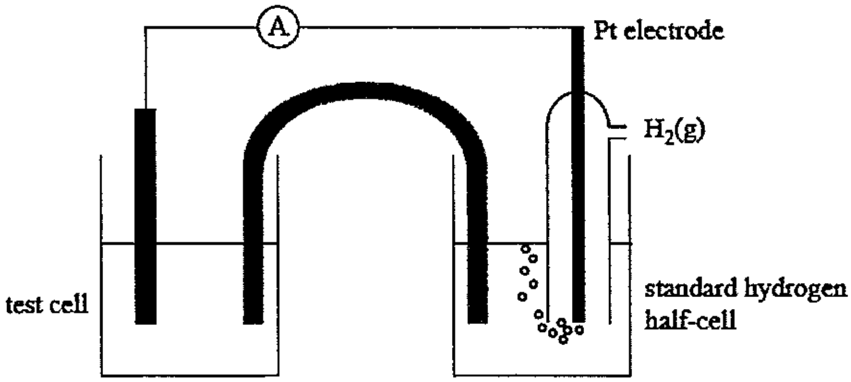
In a problem-solving activity a group of students were given the task of arranging the 3 equations below so that the metals can be arranged in order of increasing strength of reducing agent (reductant). The students are given the E^0 values for the reduction of the metal ions in the table below but in the incorrect order. They are to perform 3 experiments to be able to assign the correct E^0 to the equations. The half equations and E^0 values are given tin the tables below. **The E^0 values are in no specific order.**

Half-equations
$X^{2+}(aq) + 2e^- \rightleftharpoons X(s)$
$Y^{2+}(aq) + 2e^- \rightleftharpoons Y(s)$
$Z^{3+}(aq) + 3e^- \rightleftharpoons Z(s)$

E^0 values in no specific order
-1.56 V
+0.85 V
-1.63 V

The students prepared 1.0 $molL^{-1}$ solutions of $X(NO_3)_2$, $Y(NO_3)_2$, and $Z(NO_3)_3$ by weighing 0.1 mole of each of the solid nitrates and dissolving them in 100 mL of water using a measuring cylinder. They then constructed standard half-cells for each of the half reactions by placing solid samples of the metals X,Y and Z in the solutions of their salts.

These cells are connected, one at a time (as test cells), to a standard hydrogen half-cell as indicated in the diagram below.



Question 40 continued

The following observations were made either during or after the electrochemical cell was discharged for several minutes.

Experiment	Half-Cells	Experimental notes
1.	$X^{2+}(aq) / X(s)$ and $H^+(aq)/H_2(g)$	The ammeter measured electron flow from the the half-cell containing the metal X electrode to standard hydrogen half-cell.
2.	$Y^{2+}(aq) / Y(s)$ and $H^+(aq)/H_2(g)$	The pH of the solution in the standard hydrogen half-cell decreased.
3.	$Z^{3+}(aq) / Z(s)$ and $H^+(aq)/H_2(g)$	The mass of the electrode Z decreased.

(a) The above information can only be used to assign **ONE** of the E^0 values to its corresponding half-equation. Write the reduction half-equation and the E^0 value in the space below:

Half-Equation: $Y^{2+} + 2e^- \rightarrow Y$ ✓

E^0 value: +0.85 V ✓

(2 marks)

(b) Would the mass of metal X increase or decrease in **Experiment 1**?

decrease

(1 mark)

(c) Write the equation for the anode reaction in **Experiment 2.**

$H_2 \rightarrow 2H^+ + 2e^-$

(1 mark)

Question 40 continued

(d) Consider **Experiment 3.** Label the diagram below showing the following:

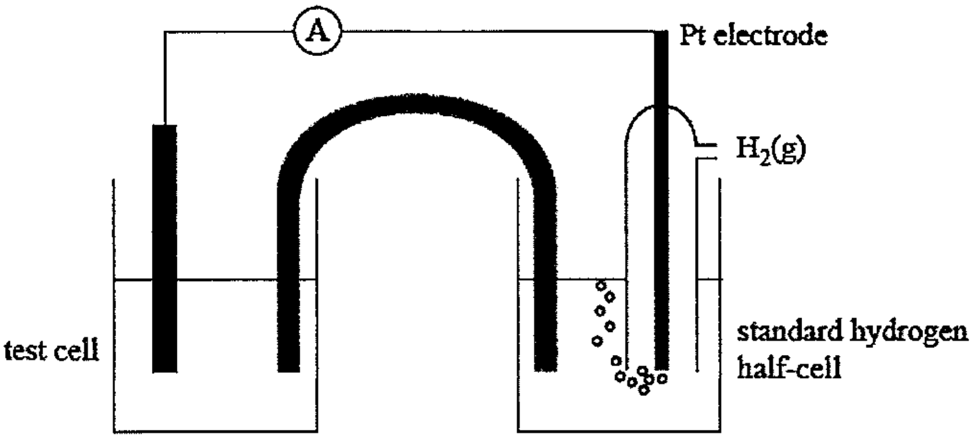
(i) the anode and cathode;

(ii) the polarity of each electrode (+ or -);

(iii) the electron flow (← or →), and;

(iv) the ion flow (← or →) through the salt bridge.

Anode (-)✓✓ e- → ✓ cathode (+)



positive ion flow →

negative ion flow ← ✓

(4 marks)

Question 40 continued

The cell was left to operate for some time. It was found that 0.100 moles of metal Z dissolved from the electrode.

(e) Calculate the change in mass of hydrogen gas in the cell.

$Z \rightarrow Z^{3+} + 3e^-$

$2H^+ + 2e^- \rightarrow H_2$

$2Z + 6H^+ \rightarrow 2Z^{3+} + 3H_2$ ✓✓

$n(H_2)$ produced = 3/2 x 0.1 = 0.15mol

$m(H_2)$ produced = .15 x 2.016 = 0.3024 g ✓

(3 marks)

(f) Even though the E^0 values for the remaining two cells are very close, the rate of the reactions appeared to be different. The students made the conclusion that the cell with the fastest reaction rate contained the metal that is the strongest reductant. This may or may not be a valid conclusion.

Describe one further experiment that the students could perform using the half cells they have prepared to improve the **validity** of their conclusion.

- Connect the 2 remaining cells together in an electrochemical cell ✓
- The anode will be the stronger reductant ✓

(2 marks)

Question 41 **(17 marks)**

Global levels of carbon dioxide in the atmosphere are rising, causing more carbon dioxide to dissolve in the ocean producing carbonic acid and leading to increased ocean acidity. Acidification shifts the equilibrium of carbonate chemistry in seawater, decreasing the rate and amount of calcification among a wide range of marine organisms, particularly seashell organisms.

(a) Write the ionic equation for the reaction of acid with calcium carbonate.

$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$ ✓✓

(2 marks)

Seashells contain a mixture of carbonates. A group of marine scientists set out to measure the percentage by mass of carbonate in a sample of seashell.

The concentration of a solution of hydrochloric acid was determined by titration against a standard sodium carbonate solution using the following procedure.

- All glassware was rinsed to remove possible contaminants;
- Hydrochloric acid was placed in the burette;
- 25.00 mL aliquots of the standard sodium carbonate solution were taken from the volumetric flask and placed in a conical flask;
- an appropriate indicator was added.

The titration was performed and the concentration of the hydrochloric acid was found to be 0.200 $molL^{-1}$.

(b) The scientist performing the titration rinsed the burette with distilled water only. Which one of the following applies? (Circle the number of the correct alternative).

1. **The scientist should have rinsed the burette with hydrochloric acid and has introduced random errors into the analysis;**

2. **The scientist should have rinsed the burette with hydrochloric acid and has introduced systematic errors into the analysis;**

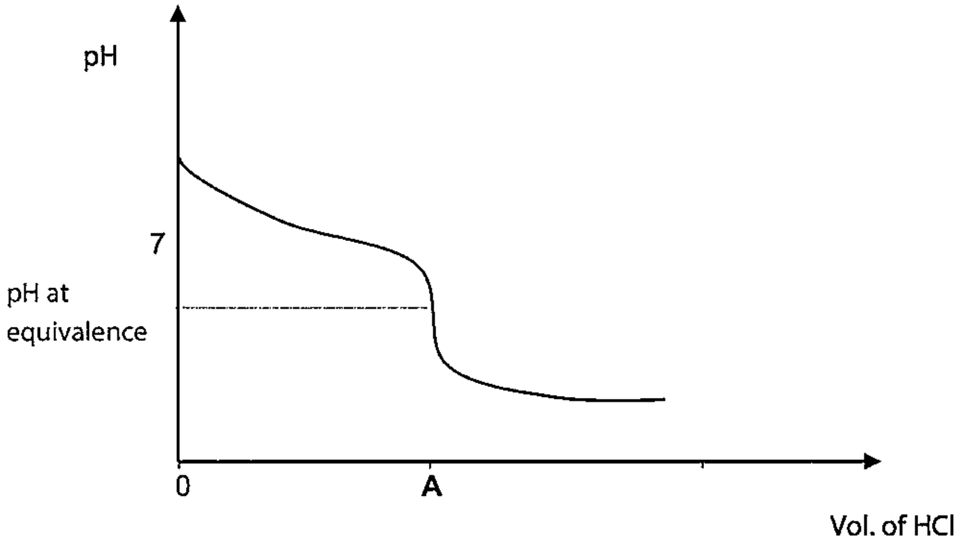
3. **The scientist used the correct procedure.**

(1 mark)

Question 41 continued

(c) On the axes below draw the titration curve (pH vs volume of HCℓadded) showing the approximate pH at the equivalence point. The volume of HCℓ used at equivalence is marked at point **A** (no calculation required).

(2 marks)



(d) (i) An indicator that changes colour in the acidic pH region (3-5) was chosen for the titration. Using an appropriate equation, show that this was the correct choice.

$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$

CO_2 is acidic. Solution is acidic at equivalence ✓

Indicator chosen must change colour in the acidic range ✓

(2 marks)

(ii) What would the effect on the calculated concentration of HCℓ be if an indicator was chosen that changed colour in in the basic pH region (8-10)?

Volume of HCl used would be less ✓

Calculated concentration of HCl would be greater ✓

(2 marks)

Question 41 continued

Seashells contain a mixture of carbonate compounds. The standardised hydrochloric acid was used to determine the percentage by mass of carbonate in a seashell using a back titration procedure.

- A 0.145 g sample of the seashell was placed in a conical flask;
- 50.0 mL of the standardized hydrochloric acid is added to the conical flask;
- at the completion of the reaction, the mixture in the conical flask was titrated with 0.250 $molL^{-1}$ sodium hydroxide.

The scientists performed a rough titration and then recorded the results of a further 4 titrations in the table below:

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**
Final volume (mL)	29.80	29.90	29.70	29.80
Initial volume (mL)	0.25	0.50	0.15	0.30
Volume titrated (mL)	29.55	29.4	29.55	29.5

(e) Complete the table and calculate the average volume of sodium hydroxide used in the titration sequence.

Vav = 29.55 + 29.55 + 29.5 /3 = 29.53 mL (1 mark)

Question 41 continued

(f) Calculate the percentage by mass of carbonate ions in the sample of the seashell.

$n(OH^-) = 0.25 \times 29.53 \times 10^{-3} = 7.383 \times 10\text{-}3$ mol ✓

$n(H^+)$ in x.s = 8.383 x 10-3 mol ✓

$n(H^+)$ initially = 0.05 x 0.2 = 10 x 10^{-3} mol ✓

n(HCl) reacted with CO_3^{2-} = (10 – 7.383) x 10-3 = 2.622 x 10-3 mol ✓

n (CO_3^{2-}) = 0.5 x n(HCl) = 1.311 x 10^{-3} ✓

$m(CO_3^{2-})$ = 1.311 x 10-3 x 60.01 = 0.07868g ✓

%(CO_3^{2-}) = 0.07868/0.145 x 100 = 54.3% (3 sf) ✓

(7 marks)

Question 42 **(8 marks)**

Each year, millions of tonnes of iron ore, impure iron (III) oxide, are mined. This ore is converted to iron in the blast furnace. The overall reaction which leads to the production of iron in the blast furnace is given by the following equation:

$$Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(l) + 3\,CO_2(g)$$

In a blast furnace, 25.0 tonnes of iron ore (containing 87% Fe_2O_3) and 1.53×10^7 L of carbon monoxide are reacted together at 110 kPa and 750 K.

(a) Determine the limiting reactant. (5 marks)

$m(Fe_2O_3) = 0.87 \times 25 \times 10^6$ g $= 2.175 \times 10^7$g ✓

$n(Fe_2O_3) = 2.175 \times 10^7/159.7 = 1.3619 \times 10^5$ mol ✓

$n(CO) = PV/RT = 110 \times 1{,}53 \times 10^7 / 8.314 \times 750 = 2.699 \times 10^5$ mol ✓

1 mole of Fe_2O_3 requires 3 mole of CO for complete reaction

1.3619×10^5 mole of Fe_2O_3 requires 4.0867×10^5 mole of CO for complete reaction ✓

n(CO) < the number of mole required. CO is the LR ✓

(b) The mass of iron produced in the process was 8.32 tonnes. Calculate the % efficiency of the reaction. (3 marks)

n(Fe) theoretical = $2/3 \times 2.699 \times 10^5$ mol $= 1.7993 \times 10^5$ mol ✓

n(Fe) actual = $8.32 \times 10^6/55.85 = 1.4897 \times 10^5$ mol ✓

% efficiency = actual/ theoretical x 100
= $1.4987 \times 10^5 / 1.7993 \times 10^5 \times 100$
= 82.80 % ✓

Question 42 continued

END OF EXAMINATION