



education
MPUMALANGA PROVINCE
REPUBLIC OF SOUTH AFRICA

PHYSICAL SCIENCES

PAPER 2 : GRADE 12

LEVEL 4 - 7

SURECASE

2025

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REVISION APPROACH:

90% LEARNER CENTRED

10% TEACHER CENTRED

HOW TO PREPARE FOR EXAM (STUDY TIPS)

- Prepare well in advance for all your papers and subjects.
- Planning for success in the final examination started January
- Plan your time to include study , revision and taking breaks
- Write down the date of your final exam so that you can plan and structure a study time table for all your subjects.
- Set up a study time-table according to your final Grade 12 exam time-table and stick to your study schedule.
- Your study programme should be realistic.
- Form study group to study some subjects (maximum of 4 members)
- Do not spend more time on one topic .
- When studying don't just read through your notes or textbook.
- You need to be active by making summary checklists or mind maps. Highlight the important facts that you need to memorise
- You may need to write out statements such as definitions and laws a few times to make sure you can remember these.
- **Practise questions** from previous examination papers
- Take careful note of all instructions - these do not usually change.
- Try to answer the questions without looking at your notes or the solutions.
- **Time yourself**. You need to make sure that you complete a question in time.
- Check your working against the memo. If you don't understand the answer given, asked for help.
- If you did not get the question right, try it again after a few days
- **Preparing for and writing examinations is stressful.**
- Eat regular small meals including breakfast. Include fruit, fresh vegetables, salad and protein in your diet.
- Drink lots of water while studying to prevent dehydration.

HOW TO USE THE LAST PUSH MANUAL

- Revise, read and understand the relevant content based on each topic from your preferred notes, textbooks or study guides.
- Go through the examination guidelines pasted per topic and ensure that all the points outlined in the examination guidelines you have covered, before you answer the questions in this manual.
- Read the examination guidelines carefully to also understand the exam format, duration, and assessment criteria.
- **To answer the multiple-choice questions:**
 - Read each question carefully and understand the options.
 - Eliminate the obvious incorrect options and select the correct option.
- **To answer the structured questions:**
 - Read and understand the question requirements and marks allocation.

THE DEFINITIONS, LAWS AND PRINCIPLES MUST BE STATED AS THEY APPEAR IN THE EXAMINATION GUIDELINES

FORMAT OF PAPER 2: CHEMISTRY		
TYPE OF QUESTIONS	DURATION	TOTAL MARKS
10 multiple choice questions (20 marks)	3 hours	150
9 Structured questions (130 marks)		

WEIGHTING OF PRESCRIBED CONTENT	
CONTENT	MARKS
Matter and materials • Organic nomenclature • Physical properties of organic compounds • Organic reactions	58
Chemical change • Reaction rate • Chemical equilibrium • Acids and bases • Electrochemistry	92
TOTAL	150

STRUCTURE OF PAPER 2 (CHEMISTRY)

QUESTIONS	TOPIC	Estimated marks	
1	Multiple choice (all topics)	20	
2	Nomenclature and Structures	18	
3	Physical Properties	11	
4	Organic reactions	22	
5	Rates of reactions	17	
6	Chemical Equilibrium	20	
7	Acids and Bases	17	
8	Electrochemistry (Galvanic cell)	12	
9	Electrochemistry Electrolytic cell)	13	
TOTAL MARKS		150	

NOMENCLATURE**RECOMMENDATIONS FOR IMPROVEMENT**

- **Write down the IUPAC name of the compound**

- Correct stem
- Correct substituents identified.
- IUPAC name completely correct, including numbering, sequence, hyphens and commas.

e.g. 3,3-dibromo-4,4-dimethylhexane

- **When writing the IUPAC names of haloalkanes**

- ✓ The functional group of haloalkanes do not get preference over the alkyl groups.
- numbering should start from the side giving substituents, halogen and alkyl, the lowest total number. e.g.
- 4-bromo-3,3-dimethyl : $4 + 3 + 3 = 10$
- 3-bromo-4,4-dimethyl : $3 + 4 + 4 = 11$
- Therefore, the lowest total is 10 and numbering should be such that the name is

4-bromo-3,3-dimethyl

- **When writing the IUPAC names of aldehydes and carboxylic acids**

The functional group is always on C-1, and numbering must not be used to indicate the position of the functional group e.g

- *butanal* not *butan-1-al*
- *Propanoic acid* not *1-Propanoic acid*

- **Write down the STRUCTURAL FORMULA of a compound (2 marks)**

- Functional group correct.
- Whole structural formula correct
- More than one functional group/wrong functional group: 0/2

- **marks are deducted for the following**

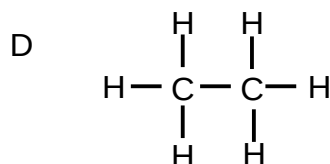
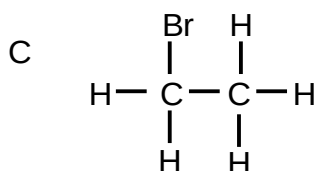
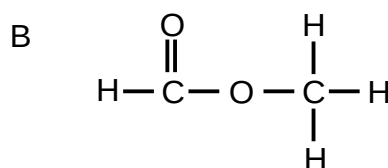
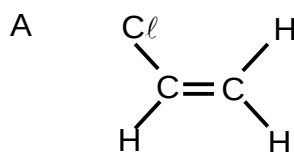
- Omitting H atoms and/or bonds between C atoms and H atoms
- Omitting hyphens between numbers and words;

- Non-alphabetical arrangement of substituents;
- Numbering of parent chain from the wrong side, resulting in the incorrect numbering of substituents
- Writing numbers of substituents as a group in front of the substituents
(2,3,4-bromochloromethylpentane).
- More than four bonds on the C atoms of the e.g. alkenes or alkynes
- Adding an H atoms on the carbonyl C atom (**no marks**)
- If two or more functional groups (**no marks**)
- Differentiate the structures of organic compounds that share carbon and oxygen in their molecule (alcohols, carboxylic acids, ketones and aldehydes)

QUESTION 1: MULTIPLE CHOICE QUESTIONS

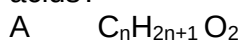
- 1.1 Which ONE of the following compounds is an aldehyde?
- A Pentanal
 - B Pentan-2-ol
 - C Pentan-2-one
 - D Ethyl propanoate (2)
- 1.2 Which one of the following compounds has the formula $C_2H_4O_2$?
- A Ethanol
 - B Methyl ethanoate
 - C Ethanoic acid.
 - D Butanol (2)

1.3 Which ONE of the following compounds can exist as an isomer?



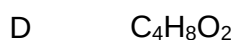
(2)

1.4 Which ONE of the following is a CORRECT GENERAL FORMULA for the carboxylic acids?



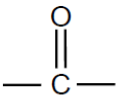
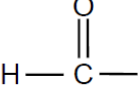
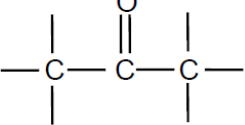
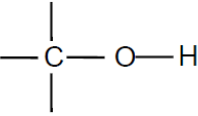
(2)

1.5 Which ONE of the following is the EMPIRICAL formula of ethyl ethanoate?



(2)

1.6 Which ONE of the following is the structural formula of the functional group of the KETONES?

A		B	
C		D	

(2)

[12]

QUESTION 2

The letters **A** to **H** in the table below represent eight organic compounds

A	$ \begin{array}{c} \text{H} \quad \quad \text{O} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array} $	B	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{C}-\text{CH}_3 \\ \quad \quad \\ \text{H} \quad \quad \text{CH}_3 \end{array} $
C	$\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_3$	D	$\text{C}_2\text{H}_6\text{O}$
E	C_2H_4	F	3-methylbutan-2-one
G	$ \begin{array}{ccccccc} \text{H} & \text{Cl} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{CH}_3 & \text{H} & \text{Cl} & \text{H} \end{array} $	H	3-methylbutanal

2.1 Define the term *unsaturated compound*. (2)

2.2 Write down the:

2.2.1 Letter that represents an UNSATURATED compound (1)

2.2.2 NAME of the functional group of compound C (1)

2.2.3 Letter that represents a CHAIN ISOMER of compound C (2)

2.2.4 IUPAC name of compound G (3)

2.2.5 General formula of the homologous series to which compound E belongs (1)

2.3 Define the term *functional isomers* (2)

2.4 For compound A, write down the:

2.4.1 Homologous series to which it belongs (1)

2.4.2 STRUCTURAL FORMULA of its FUNCTIONAL isomer (2)

2.5 Compound **D** undergoes a dehydration reaction. Write down the:

2.5.1 IUPAC name of compound **D** (1)

2.5.2 Letter that represents a product of this reaction (1)

2.5.3 NAME or FORMULA of the inorganic reactant that is used in this reaction (1)

[18]

QUESTION 3

The letters **A** to **F** in the table below represent six organic compounds.

A	Methanoic acid	B	Pentanal
C	$C_{10}H_{22}$	D	$ \begin{array}{c} \text{Br} \\ \\ \text{CH}-\text{CH}_2-\text{CH}_3 \\ \\ \text{CH}_3(\text{CH}_2)_2\text{CH}-\text{CH}_2 \\ \\ \text{Br} \end{array} $
E	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{O}-\text{H} \\ \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	F	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{O} & & \text{H} \\ & & & & & & & & & \\ \text{H} & -\text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & & & \text{H} \end{array} $

3.1 Write down the LETTER(S) that represent(s) the following: (1)

3.1.1 A ketone (1)

3.1.2 TWO compounds that are FUNCTIONAL ISOMERS (1)

3.1.3 A hydrocarbon (1)

3.2 For compound **D**, write down the:

3.2.1 Homologous series to which it belongs (1)

3.2.2 IUPAC name (3)

3.3 Write down the IUPAC name of its:

3.3.1 POSITIONAL isomer (2)

3.3.2 CHAIN isomer (2)

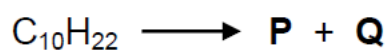
3.4 During the reaction of compound **A** with compound **E** in the presence of an acid catalyst, two products are formed.

For the ORGANIC product formed, write down the:

3.4.1 IUPAC name (2)

3.4.2 STRUCTURAL FORMULA of its FUNCTIONAL GROUP (1)

3.5 Compound **C** ($C_{10}H_{22}$) reacts at high temperatures and pressures to form a three-carbon alkene **P** and an alkane **Q**, as shown below.



Write down the:

3.5.1 Type of reaction that takes place (1)

3.5.2 Molecular formula of compound Q (2)

3.5.3 STRUCTURAL FORMULA of compound P (2)

[19]

QUESTION 4

The letters **A** to **E** in the table below represent five organic compounds

A	$ \begin{array}{ccccccc} & \text{H} & & \text{CH}_3 & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{CH}_3 & & \text{H} & & \text{Br} & & \text{H} \end{array} $	B	$\text{C}_3\text{H}_8\text{O}$
C	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & & & \text{O} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{O} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & & & & & \text{H} & & \text{H} & & \text{H} \end{array} $	D	Pentan-2-one
E	4-methylpent-2-yne		

Use the information in the table to answer the questions that follow.

4.1 For compound **D**, write down the:

4.1.1 Homologous series to which it belongs (1)

4.1.2 IUPAC name of a FUNCTIONAL ISOMER (2)

4.2 Write down the:

4.2.1 IUPAC name of compound A (3)

4.2.2 STRUCTURAL FORMULA of compound E (2)

4.3 Compound **B** is a primary alcohol

4.3.1 Write down the meaning of the term *primary alcohol* (2)

Compound **B** reacts with another organic compound **X** to form compound **C**.

Write down the:

4.3.2 Type of reaction that takes place (1)

4.3.3 IUPAC name of compound **X** (1)

[12]

QUESTION 5

The letters **A** to **H** in the table below represent organic compounds.

A		B	
C	Butanone	D	$C_4H_{10}O$
E	$CH_3C(CH_3)_2CCCH_3$	F	$CH_3COO(CH_2)_2CH_3$
G	$C_4H_8O_2$	H	$CH_3C(CH_3)_2CH_2CH_3$

- 5.1 Write down the LETTER that represents EACH of the following: (1)
- 5.1.1 An alcohol (1)
- 5.1.2 A compound with a formyl group (1)
- 5.1.3 An unsaturated compound (1)
- 5.2 Write down the IUPAC name of compound: (3)
- 5.2.1 **B** (3)
- 5.2.2 **E** (3)
- 5.3 Two different compounds in the above table are functional isomers. (2)
- 5.3.1 Define the term *functional isomer*. (2)
- 5.3.2 Write down the LETTERS that represent these functional isomers. (1)
- 5.4 Compound **F** is formed when a carboxylic acid reacts with another organic compound, **X**, in the presence of a catalyst. Write down the: (2)
- 5.4.1 NAME or FORMULA of the catalyst (1)
- 5.4.2 Type of reaction (1)
- 5.4.3 STRUCTURAL FORMULA of compound **F** (2)
- 5.4.4 IUPAC name of compound **X** (2)
- [18]**

QUESTION 6

The letters **A** to **H** in the table below represent eight organic compounds.

A	Butan-2-ol	B	$\text{CH}_3\text{C}(\text{CH}_3)_2(\text{CH}_2)_2\text{CH}_3$
C	3-ethylpent-1-yne	D	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$
E	$\begin{array}{c} \text{CH}_3 - \text{CH}_2 - \text{CH} \\ \parallel \\ \text{CH}_3 - \text{CH}_2 - \text{C} - \text{CH}_2 - \text{CH}_3 \end{array}$	F	Butan-1-ol
G	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{CH} - \text{CH}_3 \\ \quad \\ \text{Cl} \quad \text{CH}_3 \end{array}$	H	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_3 \\ \\ \text{C} = \text{O} \\ \\ \text{H} \end{array}$

- 6.1 Define the term *hydrocarbon*. (2)
- 6.2 Write down the letter(s) for: (1)
- 6.2.1 TWO compounds that are UNSATURATED hydrocarbons (2)
- 6.2.2 TWO compounds that are CHAIN ISOMERS of each other (1)
- 6.2.3 A secondary alcohol (2)
- 6.3 Write down the: (1)
- 6.3.1 STRUCTURAL formula of the FUNCTIONAL ISOMER of compound **D** (2)
- 6.3.2 General formula of the homologous series to which compound **B** belongs (1)
- 6.3.3 STRUCTURAL formula of compound **C** (2)
- 6.4 Write down the IUPAC name of compound: (3)
- 6.4.1 **E** (3)
- 6.4.2 **G** (3)
- 6.4.3 **H** (3)
- 6.5 Compound **B** undergoes complete combustion. Using MOLECULAR FORMULAE, write down the balanced equation for this reaction. (3)

[22]

PHYSICAL PROPERTIES

RECOMMENDATIONS OF IMPROVEMENT

When writing explanations related to the physical properties of compounds, the following steps need to be followed

COMPARING COMPOUNDS FROM THE SAME HOMOLOGOUS SERIES, MARKS ARE ALLOCATED FOR :

- Comparing the surface areas/chain length of the molecules.
- Comparing the strength of intermolecular forces
- Comparing the energy needed to overcome intermolecular forces

e.g.

Which compound, propane or butane, has a higher boiling point? Use the **molecular structure**, **intermolecular forces** and **energy** to explain the answer.

Butane✓

Molecular structure: The chain length / molecular size / molecular structure / molecular mass/surface area increases.

Intermolecular forces: the strength of intermolecular forces/London forces in butane. ✓

Energy: More energy is required to overcome the intermolecular forces/London forces in butane

COMPARING COMPOUNDS FROM DIFFERENT HOMOLOGOUS SERIES, MARKS ARE ALLOCATED:

- Stating the type of intermolecular force in each compound
- Comparing the strength of these intermolecular forces
- Comparing the energy needed to overcome intermolecular forces

e.g. Which one, Propan-1-ol or ethanoic acid, has the higher boiling? Explain the answer by referring to the molecular structure, **intermolecular forces** and **energy**.

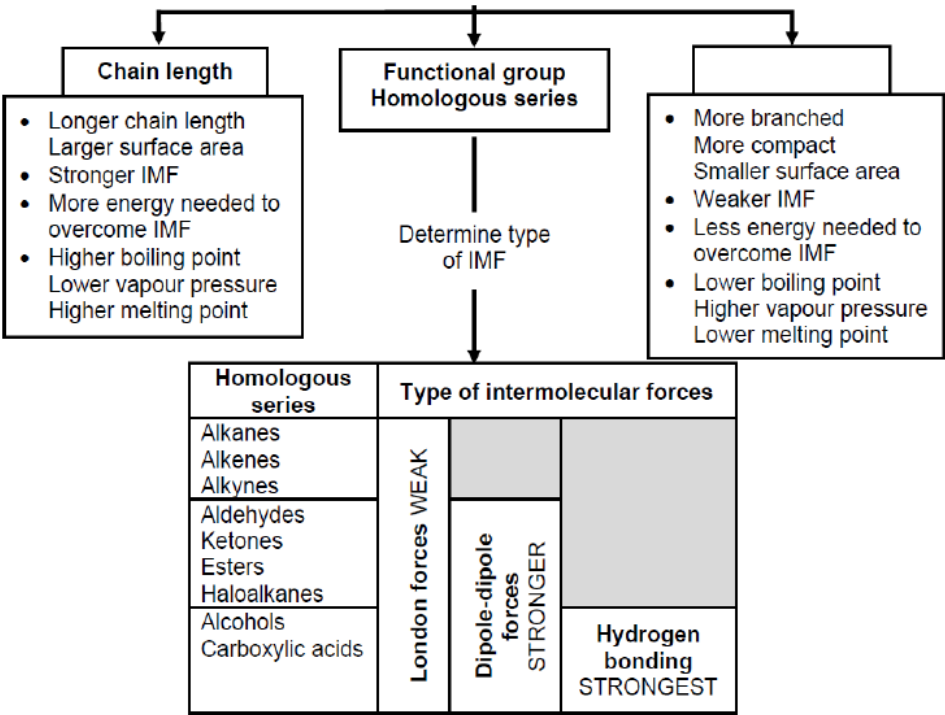
Marks are awarded for :

- ✓ Stating that carboxylic acids have two sites for hydrogen bonding.
- ✓ Stating that alcohols have one site for hydrogen bonding.
- ✓ intermolecular forces of carboxylic acids are stronger than those of alcohols
- ✓ More energy is needed to overcome/break intermolecular forces in carboxylic acids
- ensure that negative values of the melting points are correctly interpreted
e.g. $-92\text{ }^{\circ}\text{C}$ is lower than $-72\text{ }^{\circ}\text{C}$.
- Use increase or decrease when explaining the relationship between variables not the terms of proportionality (e.g. directly proportional)

NOTE

Intramolecular forces are bonds between atoms in molecules that are broken or formed during chemical reactions

Intermolecular forces are forces between molecules that are overcome (not broken) during the changes of phases



Independent	Controlled	Dependent
- Chain length/ Surface area/Branching - Molecular mass - Functional group /homologous series - Strength of intermolecular forces	- Number of Carbon atoms - Molecular mass - Functional group/ Homologous series	- Boiling Point - Melting Point - Vapour Pressure

USING THESE VARIABLES TO WRITE:

INVESTIGATIVE questions:

What is the relationship between and?

Hypothesis & Conclusion:

increase/decrease in(*independent Variable*) increases/decreases(*dependent variable*)

QUESTION 1 : _MULTIPLE CHOICE QUESTIONS

1.1 The melting points of four different straight chain (aliphatic) hydrocarbons are given

Hydrocarbon	Melting point (°C)
(i)	-182,5
(ii)	-95
(iii)	28
(iv)	-56,5

Which hydrocarbon has the strongest intermolecular forces ?

- A. (i) B. (ii) C. (iii) D. (iv) (2)

1.2 In which one of the following alternatives are the three compounds listed in order of their increasing boiling point?

- A. pentanoic acid, pentane, pentan-1-ol
B. pentan-1-ol, pentane, pentanoic acid
C. pentane, pentan-1-ol, pentanoic acid
D pentane, pentanoic acid, pentan-1-ol (2)

1.3 A scientist investigates a factor which influences the boiling points of alkanes. He determines the boiling points of the first six straight chain alkanes. Which ONE of the following is the independent variable in this investigation?

- A. Boiling point
B. Functional group
C. Branching
D. Chain length (2)

1.4 Which ONE of the following compounds has the HIGHEST vapour pressure

- A. HCOOH
B. CH₃CHO
C. CH₃CH₂OH
D. CH₃CH₂CH₃

QUESTION 2

2.1 There are two chain isomers for the organic compound with molecular formula C_4H_{10} .

2.1.1 Define the term *chain isomer*, (2)

2.1.2 Write down the structural formulae of the two chain isomers and also give their IUPAC names. (4)

2.1.3 Which ONE of the isomers mentioned in QUESTION 2.1.2 has the highest boiling point? (1)

2.2 Explain the difference in the boiling points of the chain isomers. (3)

2.3 The table below shows data collected for three organic compounds, represented by the letters **A**, **B** and **C**, during a practical investigation:

	Organic compound	Relative molecular mass	Boiling point (°C)
A	$CH_3CH_2CH_2CH_3$	58	- 0,5
B	$CH_3CH_2CH_2OH$	60	97
C	CH_3COOH	60	118

2.3.1 Which variable was controlled during this investigation? (1)

2.3.2 Write down the following for this investigation:

(a) The dependent variable (1)

(b) The independent variable (1)

2.4 Consider compound A:

2.4.1 Is compound A a saturated or an unsaturated hydrocarbon? Give a reason for your answer. (2)

2.4.2 The compound 2-methylpropane is an isomer of compound **A**. Predict whether the boiling point of 2-methylpropane will HIGHER THAN, LOWER THAN or THE SAME as the boiling point of compound **A**. (1)

2.4.3 Explain the answer in QUESTION 2.4.2 (3)

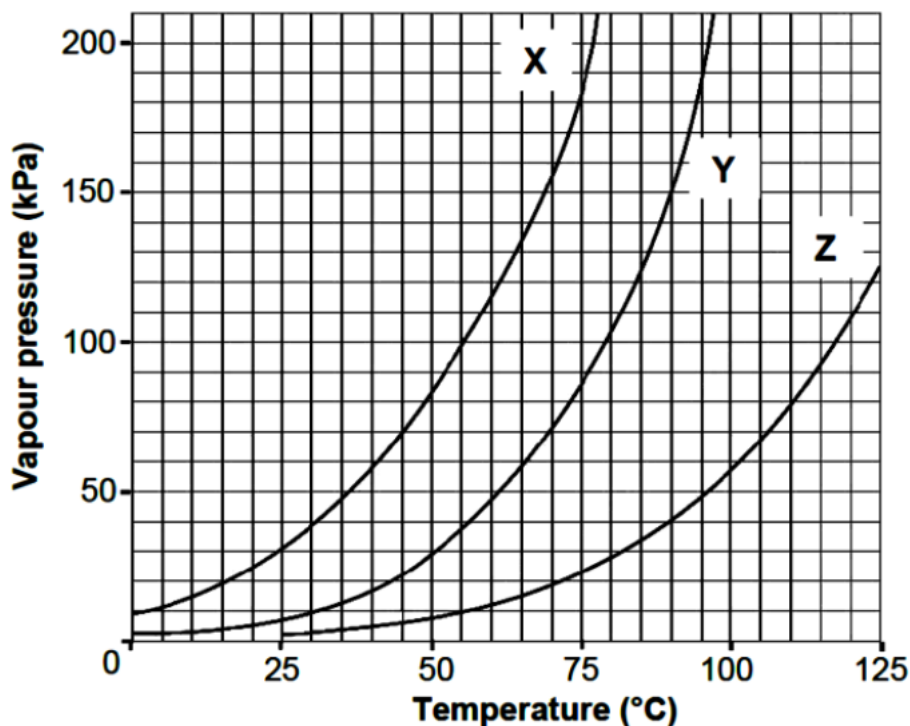
2.4.4 Refer to intermolecular forces and energy to explain why compound B will have a higher vapour pressure than compound C at 20 °C. (3)

[12]

QUESTION 3

Study the vapour pressure versus temperature graphs for three organic compounds, X, Y and Z, below which belong to different homologous series. Atmospheric pressure is 100 kPa.

Graphs of vapour pressure versus temperature



- 3.1 Write down the vapour pressure of compound Y at 90 °C. (1)
- 3.2 The graphs can be used to determine the boiling points of the three compounds.
- 3.2.1 Define *boiling point*. (2)
- 3.2.2 Determine the boiling point of compound X. (1)
- 3.3 The homologous series to which the three compounds of similar molecular masses belong, were identified in random order as: alcohol; carboxylic acid; ketone
- 3.3.1 Which compound (X, Y or Z) is the carboxylic acid? (1)
- 3.3.2 Explain the answer to QUESTION 3.3.1 by referring to the type of intermolecular forces in compounds of each of the homologous series above. (4)
- 3.3.3 Compound X has three carbon atoms per molecule. Write down its IUPAC name. (1)

[10]

QUESTION 4

The boiling points of three isomers are given in the table below.

	ISOMERS	BOILING POINT (°C)
A	2,2-dimethylpropane	9
B	2-methylbutane	28
C	pentane	36

- 4.1 Define the term *structural isomer*. (2)
- 4.2 What type of isomers (POSITIONAL, CHAIN or FUNCTIONAL) are these three compounds? (1)
- 4.3 Explain the trend in the boiling points from compound **A** to compound **C**. (3)
- 4.4 Which ONE of the three compounds (**A**, **B** or **C**) has the highest vapour pressure? Refer to the data in the table to give a reason for the answer. (2)
- 4.5 Use MOLECULAR FORMULAE and write down a balanced equation for the complete combustion of compound **B**. (3)

[11]**QUESTION 5**

The boiling points of some organic compounds are shown in the table below. The atmospheric pressure is 101,3 kPa.

	ORGANIC COMPOUND	BOILING POINT (°C)
A	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$	78
B	$\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{Cl}$	46
C	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	118
D	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$	X

- 5.1 Define the term *boiling point*. (2)
- 5.2 Which ONE of compounds **A**, **B** or **C** is mainly in the liquid phase at 100 °C? (1)
- 5.3 Explain the difference in the boiling points of compounds A and B. (3)
- 5.4 Consider the boiling points below. (1)

75 °C	120 °C	126 °C
-------	--------	--------

- 5.4.1 Which ONE of these values represents **X**, the boiling point of compound **D**? (2)
- 5.4.2 Fully explain the answer to QUESTION 5.4.1. (2)
- 5.5 The atmospheric pressure is now changed to 83 kPa
How will the boiling points of these organic compounds be affected? Choose from INCREASE, DECREASE or REMAIN THE SAME. (1)

[10]

ORGANIC REACTIONS

RECOMMENDATIONS FOR IMPROVEMENT

- **When writing chemical equation, marks are deducted for the following :**
 - Omitting the arrow between reactants and products or using an equal sign (=) instead of an arrow
 - Omitting the plus sign (+) between the two reactants
 - Any additional reactants and/or products
 - Using condensed formulae or molecular formula instead of structural formulae, or vice versa
- **Writing down the balanced equation for the reaction, using STRUCTURAL formulae**
 - If the condensed, semi-structural or molecular formula is used: **marks are deducted**
 - If an extra product or reactant is added, **1 mark is deducted**

Type of organic reaction	Name of reaction	Reactants	Reaction conditions	Products
Substitution	Halogenation	alkane + halogen	hf/ Δ	haloalkane + hydrogen halide
	Hydrolysis	haloalkane + base (NaOH/KOH/LiOH)	• dilute strong base • mild heat	alcohol + halide salt
		haloalkane + water	• add water • mild heat	alcohol + hydrogen halide
	Substitution	alcohol + hydrogen halide	no water	haloalkane + water
Addition	Hydration	alkene + water	concentrated H_2SO_4	alcohol
	Hydrogenation	alkene + hydrogen	Pt, Pd, Ni; dissolved in non-polar solvent	alkane
	Halogenation	alkene + halogen		haloalkane
	Hydrohalogenation	alkene + hydrogen halide	no water	haloalkane
Elimination	Cracking	alkanes	high temperature and high pressure OR catalyst	alkene + hydrogen OR alkane + alkene(s)
	Dehydrohalogenation	haloalkane + base (NaOH/KOH)	• concentrated strong base • heat	alkene + salt + water
	Dehydration	alcohol	• concentrated H_2SO_4 • heat	alkene + water

OXIDATION:

- Exothermic , & Balancing
- $X \text{ (Organic molecule)} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$

SUBSTITUTION:

- **Single** bonds $\begin{array}{c} | & | & | \\ -C- & C- & C- \\ | & | & | \end{array}$ to **single** bonds $\begin{array}{c} | & | & | \\ -C- & C- & C- \\ | & | & | \end{array}$
- $A + B \rightarrow C + D$ (**two reactants to two products**)

ADDITION

- **double** bond $\begin{array}{c} | & | & | \\ -C- & C= & C- \\ | & | & | \end{array}$ to **single** $\begin{array}{c} | & | & | \\ -C- & C- & C- \\ | & | & | \end{array}$
- $A + B \rightarrow C$

. ELIMINATION

- **Single** $\begin{array}{c} | & | & | \\ -C- & C- & C- \\ | & | & | \end{array}$ to **double** $\begin{array}{c} | & | & | \\ -C- & C= & C- \\ | & | & | \end{array}$
- $A + B \rightarrow C + D + E$
- Cracking (**long chain hydrocarbon** to short useful molecules)

ESTERIFICATION

- Alcohol + Carboxylic acid $\rightarrow$ Ester + H_2O
- heat & *Conc.* H_2SO_4 (as a **catalyst** and dehydrating agent).
- Only **primary alcohols** produce esters

QUESTION 1: MULTIPLE CHOICE QUESTIONS

1.1 Which ONE of the following pairs of reactants can be used to prepare the ester ethyl butanoate in the laboratory?

- A Ethanal and butanol
- B Ethanoic acid and butanol
- C Ethanal and butanoic acid
- D Ethanol and butanoic acid

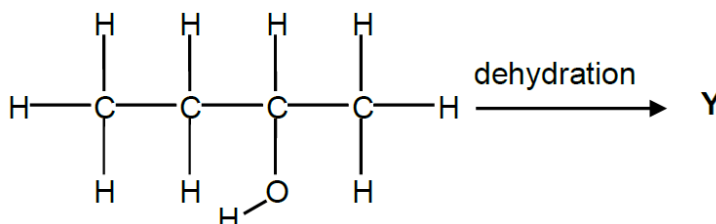
(2)

1.2 Which ONE of the following equations represents a cracking process?

- A $5\text{CH}_2 = \text{CH}_2 \rightarrow -(\text{CH}_2\text{CH}_2)_5-$
- B $\text{CH}_3(\text{CH}_2)_5\text{CH} = \text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3(\text{CH}_2)_6\text{CH}_3$
- C $\text{CH}_3(\text{CH}_2)_6\text{CH}_3 \rightarrow \text{CH}_3(\text{CH}_2)_4\text{CH}_3 + \text{CH}_2 = \text{CH}_2$
- D $\text{CH}_3(\text{CH}_2)_7\text{OH} \rightarrow \text{CH}_3(\text{CH}_2)_5\text{CH} = \text{CH}_2 + \text{H}_2\text{O}$

(2)

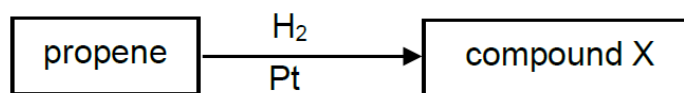
1.3 During the dehydration of butan-2-ol, represented below, compound Y forms as one of the products.



Which ONE of the following is the correct condensed structural formula for compound Y?

A	$ \begin{array}{c} \text{CH}_2 \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_3 \end{array} $	B	$ \begin{array}{c} \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH} \quad \text{CH}_3 \end{array} $
C	$ \begin{array}{c} \text{CH}_2 \quad \text{OH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH} \\ \\ \text{CH}_3 \end{array} $	D	$ \begin{array}{c} \text{CH}_3 - \text{CH}_2 \\ \\ \text{CH}_2 - \text{CH}_2 \\ \\ \text{OH} \end{array} $

1.4 Consider the flow diagram below:



The IUPAC name for compound X is:

- A Propyne
- B Propan-1-ol
- C Propan-2-ol
- D Propane

(2)

1.5 Which ONE of the following organic reactions will take place only when exposed to light?

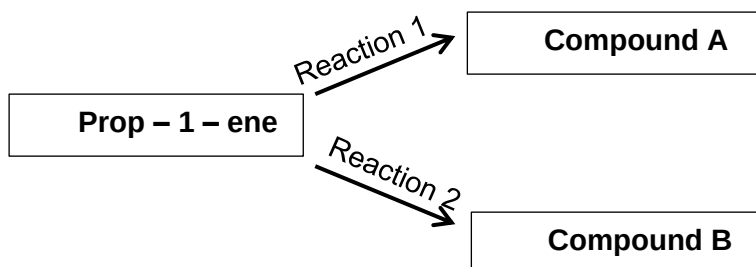
- A $\text{CH}_2\text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3\text{CH}_3$
- B $\text{CH}_3\text{CH}_3 \rightarrow \text{CH}_2\text{CH}_2 + \text{H}_2$
- C $\text{CH}_2\text{CH}_2 + \text{Cl}_2 \rightarrow \text{CH}_2\text{ClCH}_2\text{Cl}$
- D $\text{CH}_3\text{CH}_3 + \text{Cl}_2 \rightarrow \text{CH}_3\text{CH}_2\text{Cl} + \text{HCl}$

(2)

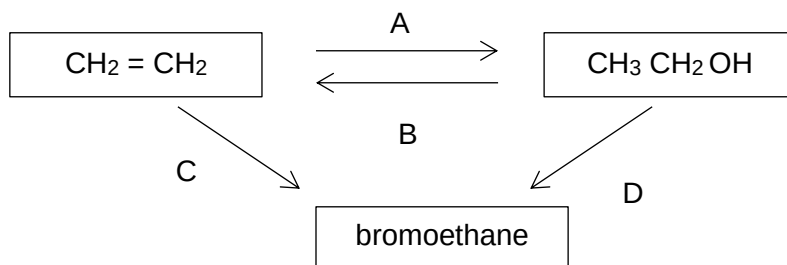
QUESTION 2

The flow diagram below shows how organic compounds can be prepared from an unsaturated hydrocarbon, prop-1-ene.

Reaction 1 takes place when prop-1-ene reacts with bromine water.



- 2.1 Write down:
- 2.1.1 The name of the type of reaction which takes place in the above Reaction 1. (1)
- 2.1.2 The structural formula of compound A. (2)
- 2.1.3 Will Reaction 1 be spontaneous at room temperature? (1)
Answer YES or NO.
- 2.1.4 Compound B is formed when prop-1-ene reacts with water in the presence of dilute sulphuric acid.
- 2.2 Write down:
- 2.2.1 the name of the type of reaction which takes place in the above Reaction 2. (1)
- 2.2.2 the IUPAC name for compound B. (2)
- 2.2.3 the homologous series to which compound B belongs. (1)
- 2.2 The letters A–D in the flow diagram below represent some organic reactions that involve ethene.

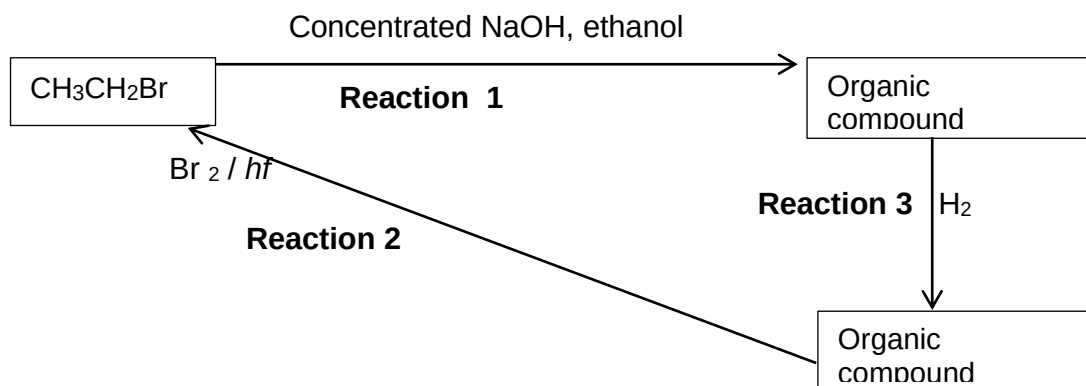


- 2.3 Name the type of reaction (addition / substitution / elimination) represented by:
- 2.3.1 A (1)
- 2.3.2 B (1)
- 2.3.3 D (1)

- 2.4 Apart from the alkene, another reactant and a catalyst are needed in Reaction **A**. Write down the NAME of the:
- 2.4.1 Other reactant (1)
- 2.4.2 catalyst which was added to the alkene. (1)
- 2.5 Use STRUCTURAL FORMULAE to write down a balanced chemical equation for the reaction represented by **C**. (4)
- 2.6 The ethanol produced in reaction **A** is made to react with a carboxylic acid in the presence of an acid catalyst. The compound formed is a STRAIGHT CHAIN ESTER which is a functional isomer of pentanoic acid. Write down the:
- 2.6.1 IUPAC NAME of the carboxylic acid that reacted with the alcohol. (2)
- 2.6.2 Name given to this type of reaction. (1)
- 2.6.3 STRUCTURAL FORMULA of the ester formed. (2)
- [22]**

QUESTION 3

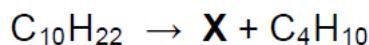
Consider the following flow diagram:



- 3.1 Write down the type of reaction that occurs in the reactions 1, 2 and 3 from the flow diagram. (3)
- 3.2 Write down the condensed structural formula for compound A. (1)
- 3.3 Why must the reaction vessel where reaction 3 takes place, be transparent? (1)
- 3.4 Write down the symbol of the catalyst that can be used instead of platinum (Pt) in Reaction 2. (1)
- 3.5 Many fruits contain organic compounds that have pleasant odours, for example ethyl ethanoate (ethyl acetate) which is responsible for the odour of pineapples.
- 3.5.1 Which group of organic compounds smells like flowers and fruit? (1)
- 3.5.2 Ethanoic acid and propanol reacts in an acidic medium while being heated over a water bath. Use structural formulae to write a balanced equation for this reaction. (6)
- 3.6 Bromine water can be used to distinguish between saturated and unsaturated compounds. Equal amounts of C_6H_{12} and C_6H_{14} are added to respective test tubes A and B at room temperature; 2cm^3 of bromine water is added to each and the test tubes shaken.
- 3.3.1 What is meant by an *unsaturated* compound? (2)
- 3.3.2 What will be observed in each of the test tubes A and B? (2)
- 3.3.3 Give a reason for the observation in test tube B. (2)
- [19]**

QUESTION 4

Butane (C_4H_{10}) is produced in industry by the THERMAL cracking of long-chain hydrocarbon molecules, as shown in the equation below. **X** represents an organic compound that is produced



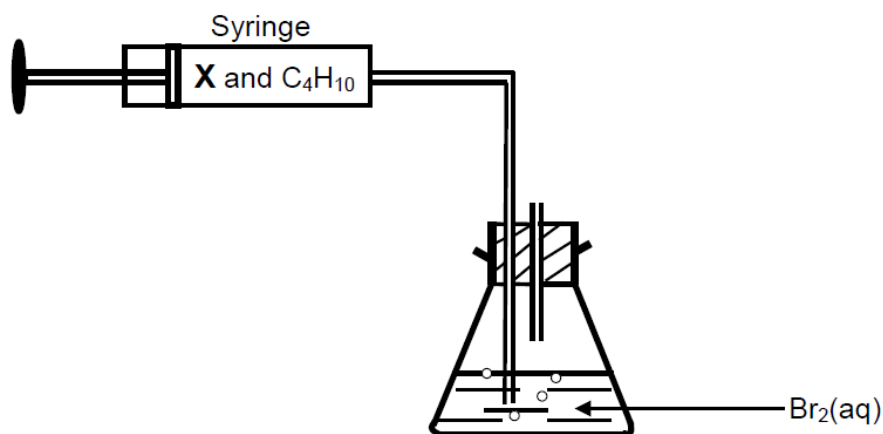
4.1 Write down:

4.1.1 ONE condition required for THERMAL cracking to take place

4.1.2 The molecular formula of compound **X**

4.1.3 The homologous series to which compound **X** belongs

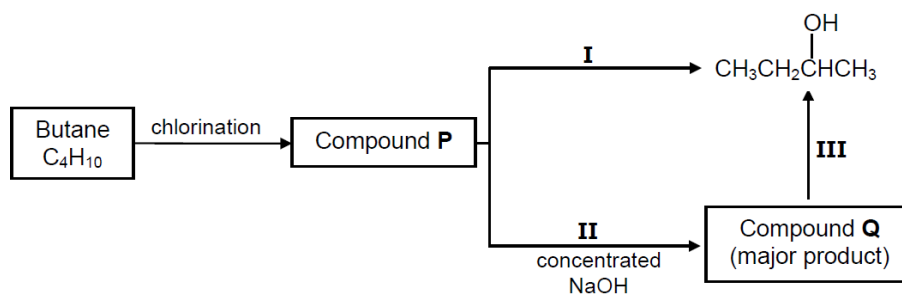
4.2 A mixture of the two gases, compound **X** and butane, is bubbled through bromine water, $Br_2(aq)$, in a conical flask, as illustrated below. THE REACTION IS CARRIED OUT IN A DARKENED ROOM.



The colour of the bromine water changes from reddish brown to colourless when the mixture of the two gases is bubbled through it.

Which ONE of the gases (**X** or BUTANE) decolorises the bromine water? Explain the answer (4)

4.2 Study the flow diagram below, which represents various organic reactions, and answer the questions that follow.

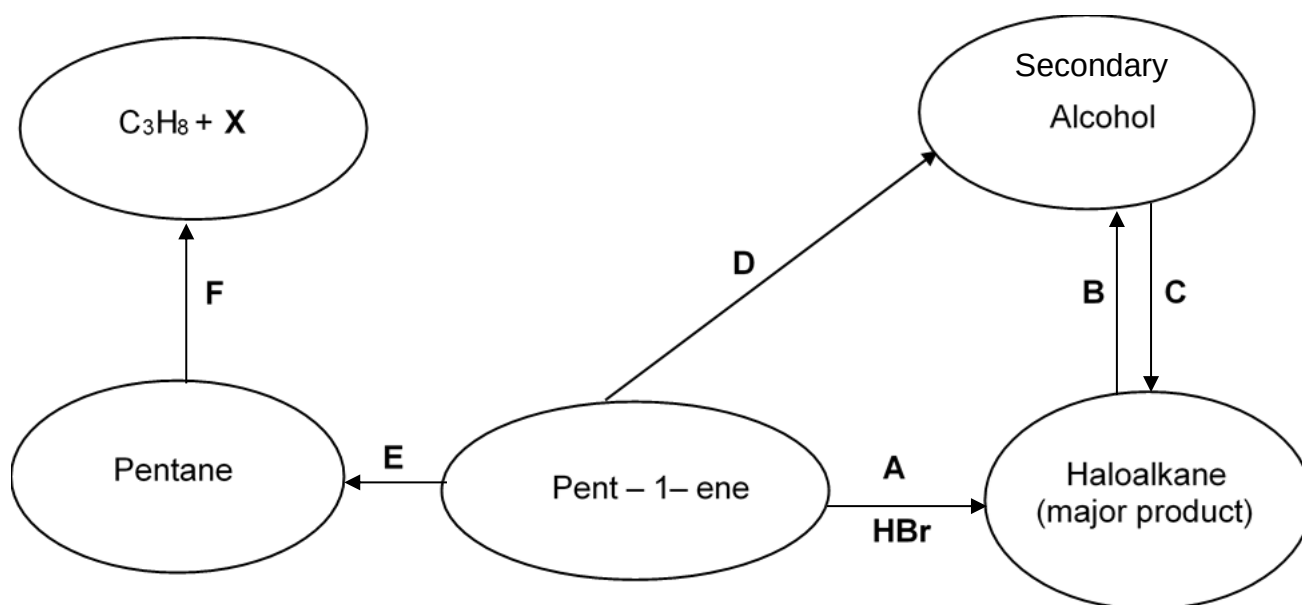


Write down the:

- 4.2.1 IUPAC name of compound **P** (2)
- 4.2.2 Type of reaction labelled **I** (1)
- 4.2.3 Structural formula of compound **Q** (2)
- 4.2.4 The type of addition reaction represented by reaction **III** (1)
- [13]**

QUESTION 5

Study the flow diagram below and answer the questions that follow.



5.1 Write down the type of:

5.1.1 Elimination reaction represented by **F**.

(1)

5.1.2 Addition reaction represented by **E**.

(1)

5.1.3 Substitution reaction represented by **B**

(1)

5.2 Write down the:

5.2.1 IUPAC name of the haloalkane formed during reaction **A**.

(2)

5.2.2 Name or formula of the catalyst needed in reaction **D**.

(1)

5.2.3 Reaction conditions required for reaction **B**.

(2)

5.3 Use structural formulae to write down an equation to show the formation of the major product formed during reaction **D**

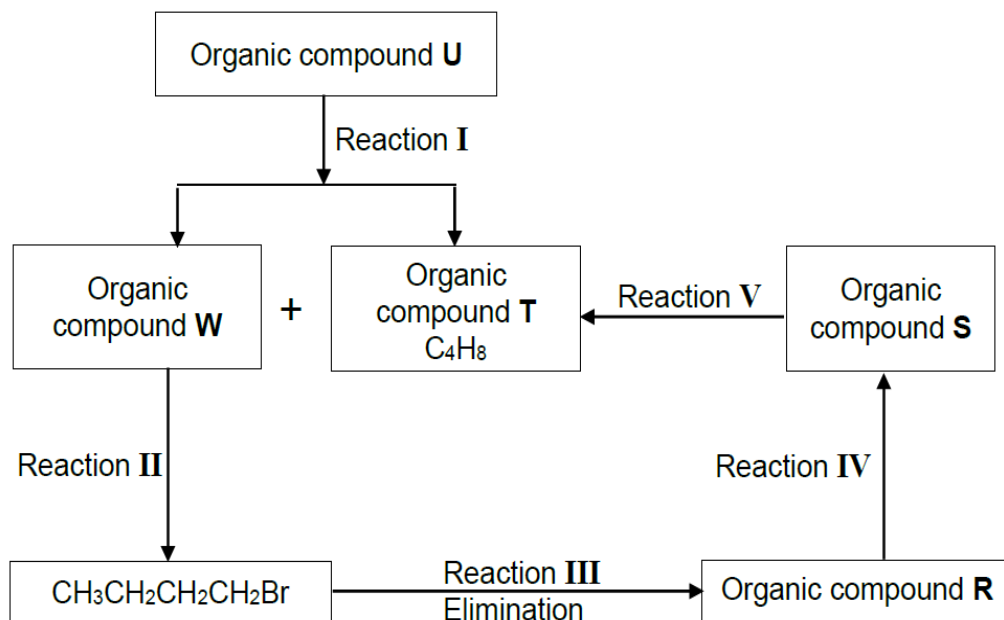
(4)

[12]

QUESTION 6

Study the flow diagram below.

Reaction I is a CRACKING REACTION forming two organic compounds, **W** and **T**, as the ONLY products.



- 6.1 Define the term *cracking reaction*. (2)
- 6.2 Is the product in reaction II a PRIMARY, SECONDARY or TERTIARY haloalkane? Give a reason for the answer. (2)
- 6.3 Write down the:
- 6.3.1 STRUCTURAL FORMULA of compound **W** (3)
- 6.3.2 MOLECULAR formula of compound **U** (1)
- 6.4 For reaction II, write down:
- 6.4.1 The NAME or FORMULA of the inorganic reactant (1)
- 6.4.2 The type of reaction (Choose from SUBSTITUTION, ADDITION or ELIMINATION.) (1)
- 6.4.3 ONE reaction condition (1)

6.5 Write down the TYPE of elimination in reaction **III**. (1)

6.6 Compounds **R** and **T** are positional isomers.

The inorganic reagents shown below are available for reactions **IV** and **V**.

Br ₂	H ₂ SO ₄ (Conc.)	NaOH(Conc.)	HBr	H ₂
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Write down:

6.6.1 The balanced equation for reaction **IV**, using STRUCTURAL FORMULAE and the correct inorganic reagent shown above (5)

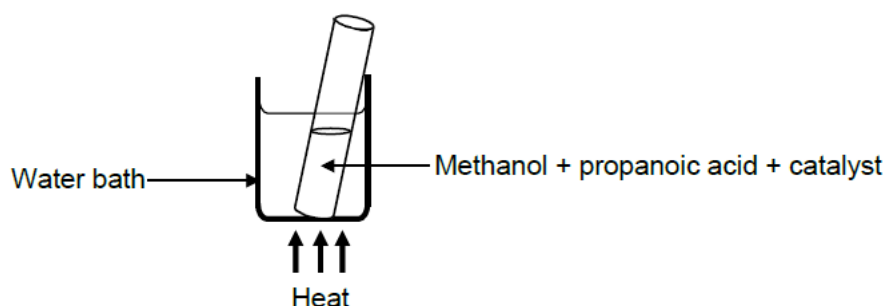
6.6.2 The balanced equation for reaction **V**, using STRUCTURAL formulae and the correct reagent shown above (3)

6.6.4 The IUPAC name of compound **T** (2)

[22]

QUESTION 7

In an experiment, a test tube containing methanol, propanoic acid and a catalyst is heated in a water bath.



Write down:

4.1.1. The NAME or FORMULA of the catalyst (1)

4.1.2 The type of reaction taking place (1)

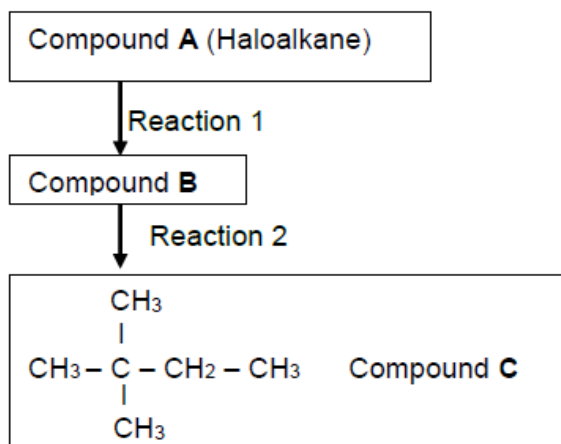
4.1.3 TWO reasons why the use of a water bath is preferred in this experiment (2)

4.1.4 The balanced equation for this reaction using STRUCTURAL FORMULAE (5)

4.1.5 The IUPAC name of the organic product for this reaction (2)

- 4.2 Compound **A**, a six-carbon branched haloalkane, is used in a two-step reaction to prepare compound **C**.

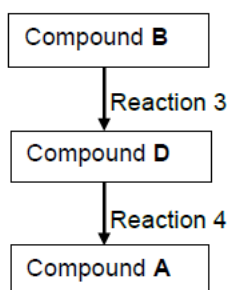
Reaction 2 is an ADDITION reaction.



Write down:

- 4.2.1 The NAME or FORMULA of the inorganic reactant in reaction 2 (2)
- 4.2.2 The IUPAC name of compound B (2)
- 4.2.3 The type of reaction represented by reaction 1 (2)
- 4.2.4 Compound **B** is now used in two-step reaction to prepare compound **A**. (2)

Reaction 4 is a SUBSTITUTION reaction.



Write down:

- 4.2.4 The NAME or FORMULA of the catalyst used in reaction 3 (1)
- 4.2.5 The IUPAC name of compound D (2)
- 4.2.6 The type of reaction represented by reaction 3 (1)
- 4.2.7 The type of haloalkane represented by compound **A** (Choose from primary, secondary or tertiary.) (1)

[20]

RATE OF REACTIONS**RECOMMENDATIONS FOR IMPROVEMENT**

- The following formulas, which are not on the data sheet, can be used to calculate the rate of reaction

Determine rate in terms of products	$\text{Rate} = \frac{\Delta c}{\Delta t}$	$\text{Rate} = \frac{\Delta m}{\Delta t}$	$\text{Rate} = \frac{\Delta V}{\Delta t}$	$\text{Rate} = \frac{\Delta n}{\Delta t}$
Determine rate in terms of reactants	$\text{Rate} = -\frac{\Delta c}{\Delta t}$	$\text{Rate} = -\frac{\Delta m}{\Delta t}$	$\text{Rate} = -\frac{\Delta V}{\Delta t}$	$\text{Rate} = -\frac{\Delta n}{\Delta t}$

- The gradient of the graph represents the reaction rate. when the reaction is complete, the gradient of the graph is zero (the reaction is not at equilibrium)
- Stoichiometric calculations:**
 - the yield (amount) of product formed is determined by the limiting reagent, not by an substance which is in excess
 - When investigating factors affecting the rate of the reaction, identify the dependent (reaction rate) and the independent variable (factor)

ASPECTS OF THE REACTION RATES		
Definition & calculations of reaction rates	Factors affecting reaction rates (x5)	Collision theory
- Definitions from examination guidelines - Formula used to calculate the reaction rates	- Temperature - Concentration - Catalyst - State of division - Nature of reacting substance	Effective collision per unit time e.g. Effect of increasing temperature; increasing concentration or adding a catalyst on the reaction rates.

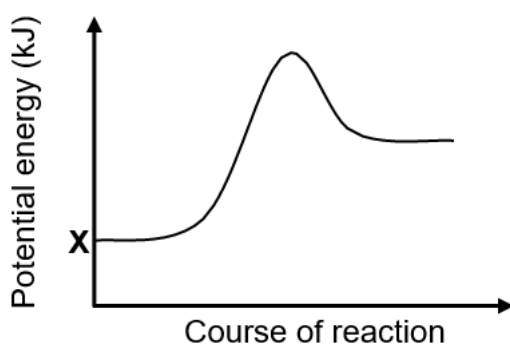
According to collision theory

e.g.

Catalyst	Temperature	Concentration	Surface area
Addition of catalyst creates an alternative path with lower E_a	Increase in temp. increases the average E_k of particles	Increase in conc. Increases the no. of particles per unit volume	Usage of powder increases the surface area of particles
- More particles have enough E_k ($E_k \geq E_a$) - More effective collisions per unit time - Reaction rate increases		- More particles collide with correct orientation - More effective collisions per unit time - Reaction rate increases	

QUESTION 1 : MULTIPLE CHOICE QUESTIONS

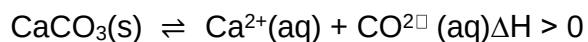
1.1 The potential energy diagram for a chemical reaction is shown below.



Consider the following statements regarding the graph above:

Consider the following statements regarding the graph above:

- I. X represents the potential energy of the products formed during the reverse reaction.
- II. The graph could be a representation of the change in potential energy for the following reaction:



- III. The graph could be a representation of the change in potential energy for the combustion of methane.

Which of the statements above are TRUE?

- A. I and II only
- B. II and III only
- C. I and III only
- D. I, II and III

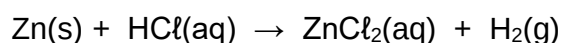
(2)

1.2 Activation energy can best be described as the minimum energy required to ...

- A. cause effective collisions.
- B. make reactant molecules collide.
- C. change the orientation of reactant molecules.
- D. increase the kinetic energy of reactant molecules.

(2)

1.3 Zinc (Zn) granules react as follows with EXCESS hydrochloric acid solution, HCl(aq) :



Which ONE of the following combinations of volume and concentration of HCl(aq) will result in the highest INITIAL reaction rate for the same mass of zinc granules used? (Assume that the zinc granules are completely covered by the acid in all cases.)

	VOLUME HCl(aq) (cm^3)	CONCENTRATION HCl(aq) ($\text{mol}\cdot\text{dm}^{-3}$)
A	50	0,5
B	100	1,0
C	200	0,1
D	200	0,5

(2)

1.4 The role of a catalyst in a chemical reaction is to increase the ...

- A. yield.
- B. activation energy.
- C. heat of reaction.
- D. rate of the reaction.

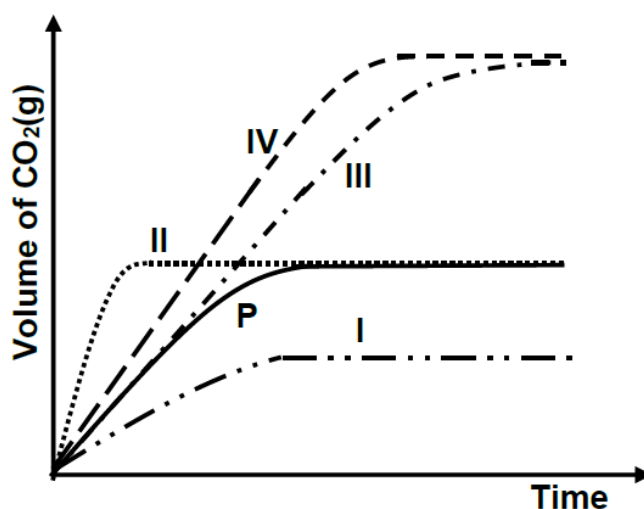
(2)

1.5 In an experiment 5 g of calcium carbonate, $\text{CaCO}_3\text{(s)}$, reacts with EXCESS hydrochloric acid, HCl(aq) , at a temperature of 40°C .



The volume of $\text{CO}_2\text{(g)}$ produced versus time is shown by CURVE **P** in the graph below

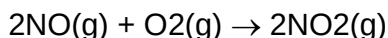
The experiment is repeated with 10 g of the same $\text{CaCO}_3\text{(s)}$ sample and an excess of HCl(aq) with the same concentration at 40°C . Which ONE of the curves will now be obtained



- A Curve I
- B Curve II
- C Curve III
- D Curve IV

(2)

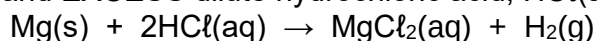
1.6 Consider the balanced equation for a chemical reaction below.



The activation energy of the forward and reverse reactions are $156 \text{ kJ}\cdot\text{mol}^{-1}$ and $175 \text{ kJ}\cdot\text{mol}^{-1}$ respectively. The heat of reaction, in $\text{kJ}\cdot\text{mol}^{-1}$, for this reaction is ...

- A +19
- B -331
- C -19
- D +331

1.7 Consider the balanced equation for the reaction between magnesium powder and EXCESS dilute hydrochloric acid, $\text{HCl}(\text{aq})$:



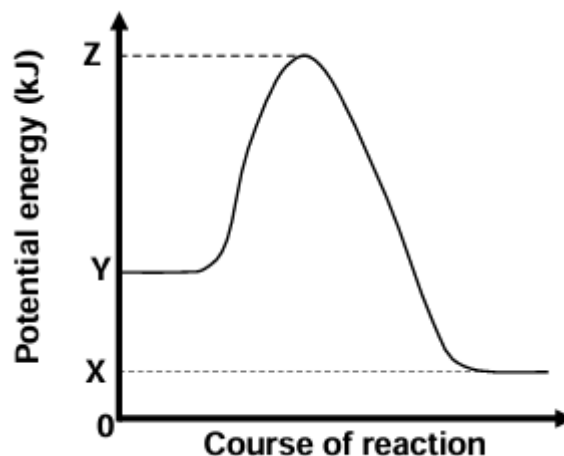
- A Increasing the volume of $\text{HCl}(\text{aq})$
- B Increasing the temperature of $\text{HCl}(\text{aq})$
- C Increasing the concentration of $\text{HCl}(\text{aq})$
- D Adding more magnesium powder

(2)

1.9 EXCESS $\text{HCl}(\text{aq})$ of concentration $0,1 \text{ mol}\cdot\text{dm}^{-3}$ reacts with 2 g of Mg under different conditions. Which ONE of the following combinations of conditions will produce the largest volume of $\text{H}_2(\text{g})$ in the FIRST MINUTE of the reaction?

	STATE OF DIVISION OF Mg	TEMPERATURE OF $\text{HCl}(\text{aq})$ (°C)
A	Powder	20
B	Granules	20
C	Powder	50
D	Granules	50

1.10 The potential energy diagram for a chemical reaction is shown below.



Which ONE of the following combinations is CORRECT for the FORWARD reaction?

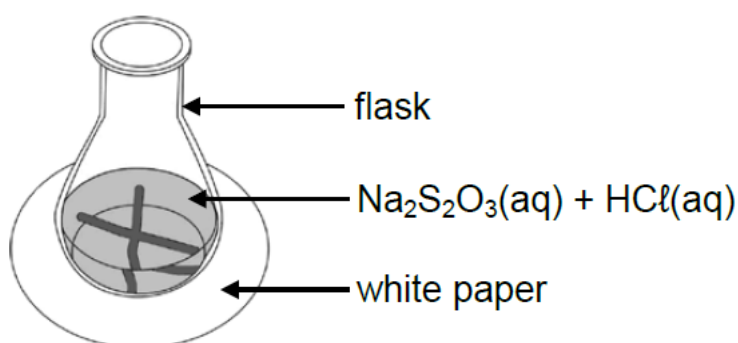
	ΔH	ACTIVATION ENERGY	POTENTIAL ENERGY OF THE ACTIVATED COMPLEX
A	$Y-X$	$Z+Y$	Z
B	$Y-X$	$Z-Y$	$Z+Y$
C	$X-Y$	$Z-Y$	Z
D	$X-Y$	Z	$Z-Y$

QUESTION 2

Learners use the reaction between sodium thiosulphate and hydrochloric acid to investigate one of the factors that affects reaction rate. The balanced equation for the reaction is:



The diagram below shows the experimental setup.



In the first experiment, 50 cm³ of the sodium thiosulphate solution is added to 100 cm³ of a 2 mol·dm⁻³ dilute hydrochloric acid solution in a flask that is placed over a cross drawn on a sheet of white paper. The hydrochloric acid is in EXCESS.

The time taken for the cross to become invisible, when viewed from the top, is recorded

The experiment is then repeated four times with different volumes of the sodium thiosulphate solution. The results obtained are shown in the table below

EXPERIMENT	VOLUME OF $\text{Na}_2\text{S}_2\text{O}_3$ (cm^3)	VOLUME OF H_2O (cm^3)	TIME (s)	AVERAGE RATE $\left(\frac{1}{\text{time}}\right)$ ($\times 10^{-2} \text{ s}^{-1}$)
1	50	0	22,7	4,4
2	40	10	28,6	3,5
3	30	20	38,5	2,6
4	20	30	58,8	1,7
5	10	40	111,1	0,9

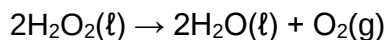
- 2.1 Define *reaction rate*. (2)
- 2.2 How does the concentration of the sodium thiosulphate solution used in experiment **2** compare to that used in experiment **5**? Choose from MORE THAN, LESS THAN or EQUAL TO. (1)
- 2.3 Draw a graph of average reaction rate versus volume of sodium thiosulphate used on the attached GRAPH SHEET. (3)
- 2.4 Use the information in the graph to answer the following questions. (2)
- 2.4.1 Determine the volume of dilute sodium thiosulphate solution that needs to react in order for the cross to become invisible in 40 seconds.
USE DOTTED LINES ON THE GRAPH TO SHOW HOW YOU ARRIVED AT THE ANSWER. (3)
- 2.4.2 Write down a conclusion for this investigation. (2)
- 2.5 Use the collision theory to explain the effect of an increase in concentration on reaction rate. (3)
- 2.6 The mass of sulphur produced in experiment **1** is 1,62 g. Calculate the mass of the sodium thiosulphate used in experiment **1**. (4)

[18]

QUESTION 3

Three experiments, **A**, **B** and **C**, are carried out to investigate some of the factors that affect the rate of decomposition of hydrogen peroxide, $\text{H}_2\text{O}_2(\ell)$.

The balanced equation for the reaction is:

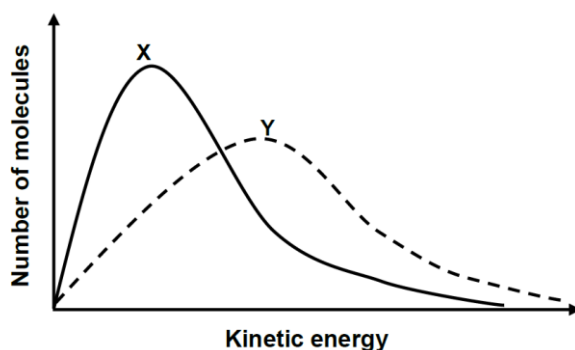


Identical samples of hydrogen peroxide are used in each experiment.

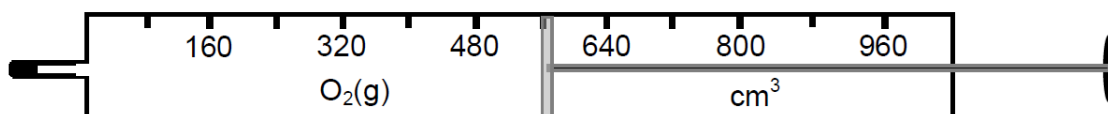
The conditions used in each experiment are summarised in the table below.

EXPERIMENT	TEMPERATURE (°C)	
A	25	Without catalyst
B	25	With catalyst
C	35	Without catalyst

- 3.1 In which experiment, **A** or **B**, is the reaction rate higher? Use the collision theory to explain the answer. (4)
- 3.2 The Maxwell-Boltzmann distribution curves, **X** and **Y**, for two of the above experiments are shown below.

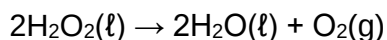


- Identify the curve (**X** or **Y**) that represents experiment **C**. (2)
- 3.3 The volume of oxygen gas, $\text{O}_2(\text{g})$, produced in experiment **B** during the first 3,6 s is collected in a syringe, as shown below.



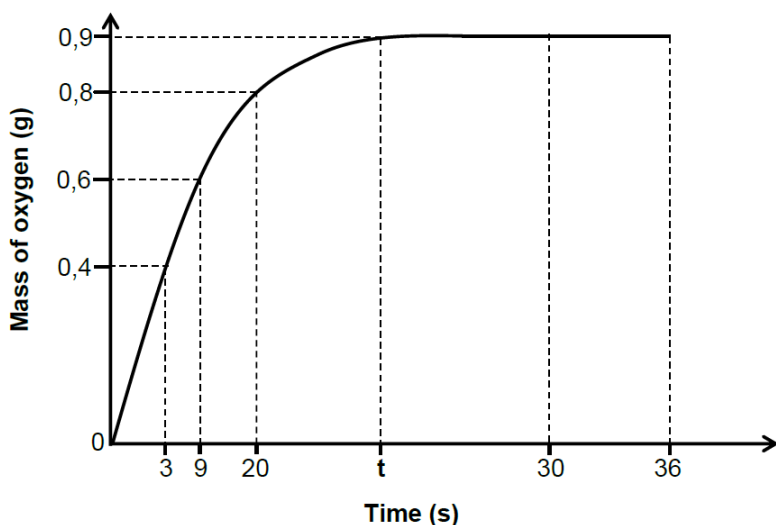
- 3.3.1. Write down the volume of $\text{O}_2(\text{g})$ collected in the syringe. (2)

The balanced equation for the reaction is:



- 3.3.2 Calculate the mass of water, $\text{H}_2\text{O}(\ell)$, that was produced during the first 3,6 s. Take the molar gas volume to be $24\,000\text{ cm}^3\cdot\text{mol}^{-1}$ at $25\text{ }^\circ\text{C}$. (4)

- 3.4 The graph below, NOT drawn to scale, is obtained for the mass of oxygen gas produced over a period of time in experiment A.



Use the information in the graph to answer the following questions:

- 3.4.1 Write down the rate of production of oxygen gas for the interval 30 s to 36 s. (1)
- 3.4.2 Will the rate of the reaction in the interval 3 s to 9 s be GREATER THAN, SMALLER THAN or EQUAL TO the rate of the reaction in the interval 9 s to 20 s? (1)
- 3.4.3 The average rate of decomposition of hydrogen peroxide is $2,1 \times 10^{-3}\text{ mol}\cdot\text{s}^{-1}$. Calculate the value of time t on the graph. (5)

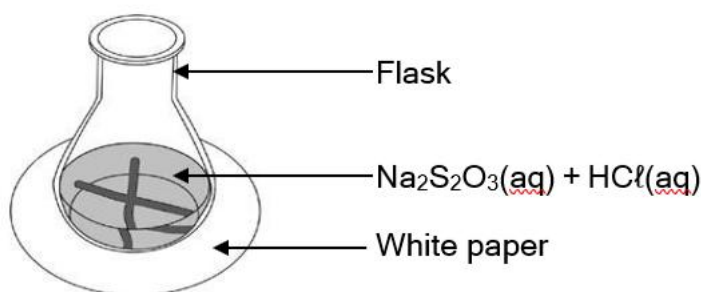
[19]

QUESTION 4

The reaction between EXCESS dilute hydrochloric acid and sodium thiosulphate is used to investigate factors that influence reaction rate.



The concentration of $\text{HCl}(\text{aq})$ used is $1 \text{ mol} \cdot \text{dm}^{-3}$. The same volume of $\text{HCl}(\text{aq})$ is used in each run. The time taken for the cross on the paper under the flask to become invisible is measured.



The table below summarises the reaction conditions and results of the experiment.

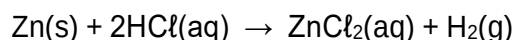
RUN	VOLUME $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ (cm^3)	VOLUME $\text{H}_2\text{O}(\text{l})$ ADDED (cm^3)	CONCENTRATION $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ ($\text{mol} \cdot \text{dm}^{-3}$)	TIME (s)
1	50	0	0,13	20,4
2	40	10	0,10	26,7
3	30	20	P	33,3

- 4.1 Define *reaction rate*. (2)
- 4.2 Write down the independent variable for this investigation. (1)
- 4.3 Calculate the value of **P** in the table. (3)
- 4.4 When 0,21 g of sulphur has formed in Run **1**, the cross becomes invisible. Calculate the average reaction rate with respect to sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$, in $\text{g} \cdot \text{s}^{-1}$. (5)
- Another investigation is performed at different temperatures
- 4.5 Sketch the Maxwell-Boltzmann distribution curve for the reaction at 20°C . Label this curve as **A**. On the same set of axis, draw the curve that will be obtained at 35°C and label it as **B**. (4)
- 4.6 Explain the effect of temperature on reaction rate in terms of the collision theory. (4)

[19]

QUESTION 5

A group of learners uses the reaction between powdered zinc and EXCESS dilute hydrochloric acid to investigate one of the factors that affects the rate of a chemical reaction. The balanced equation for the reaction is:

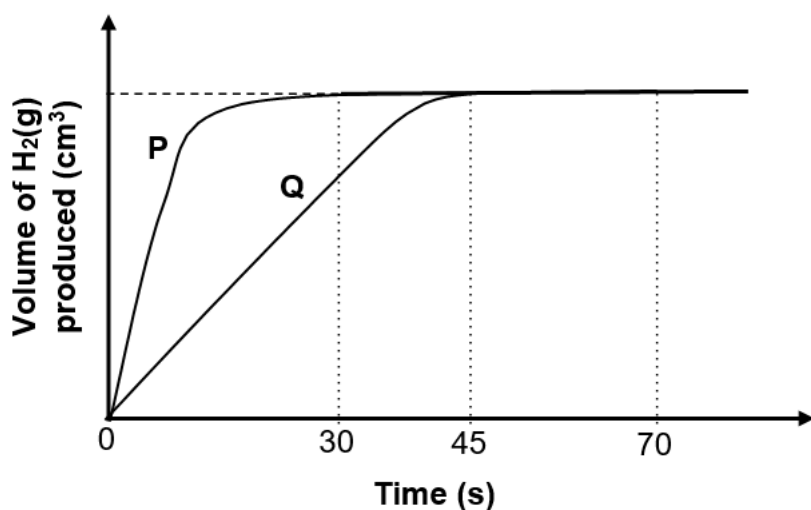


They conduct two experiments. The reaction conditions used are summarised in the table below.

EXPERIMENT	TEMPERATURE (°C)	VOLUME OF HCl (cm ³)	CONCENTRATION OF HCl (mol·dm ⁻³)	MASS OF Zn (g)
I	25	200	0,25	x
II	25	200	0,40	x

The results obtained are shown in the graph (not drawn to scale) below.

Graph of volume of H₂(g) produced versus time



- 5.1 Define *reaction rate*. (2)
- 5.2 Write down an investigative question for this investigation. (2)
- 5.3 Which curve, **P** or **Q**, represents the results of experiment I? Explain the answer.
- 5.4 The average rate of the production of hydrogen gas, as represented by graph **P**, was $15 \text{ cm}^3 \cdot \text{s}^{-1}$. Calculate the mass of zinc used. **Take the molar gas volume at 25 °C as 24 000 cm³.** (5)
- 5.5 In a third experiment (experiment **III**), 200 cm³ of a 0,25 mol·dm⁻³ dilute hydrochloric acid solution at 35 °C reacts with the same amount of zinc powder as in experiment I and experiment II.

- 5.5.1 How will the heat of reaction of experiment II compare with that of experiment III? Choose from MORE THAN, LESS THAN or EQUAL TO.
- 5.5.2 How will the activation energy of the reaction in experiment I compare with that of the reaction in experiment III? Choose from MORE THAN, LESS THAN or EQUAL TO.
- 5.6 The rate of the reaction in experiment III is higher than that of experiment I. Fully explain this statement by referring to the collision theory.

QUESTION 6

The reaction of calcium carbonate (CaCO_3) and EXCESS dilute hydrochloric acid (HCl) is used to investigate one of the factors that affects reaction rate. The balanced equation for the reaction is:



The same mass of CaCO_3 is used in all the experiments and the temperature of the hydrochloric acid in all experiments is 40°C .

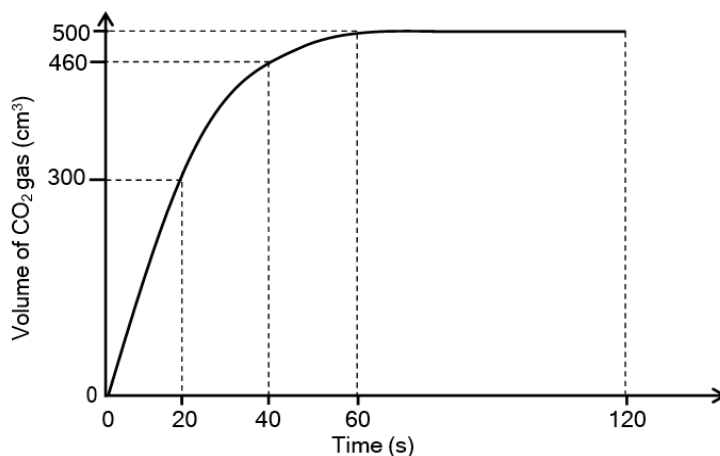
The reaction conditions for each experiment are summarised in the table below.

EXPERIMENT	VOLUME OF HCl (aq) (cm^3)	CONCENTRATION OF HCl (aq) ($\text{mol}\cdot\text{dm}^{-3}$)	STATE OF DIVISION OF CaCO_3
A	500	0,1	granules
B	500	0,1	lumps
C	500	0,1	powder

6.1 For this investigation write down the

- 6.1.1 Dependent variable (1)
- 6.1.2 Independent variable (1)

The carbon dioxide gas, $\text{CO}_2(\text{g})$, produced during EXPERIMENT **A**, is collected in a gas syringe. The volume of gas collected is measured every 20 s and the results obtained are shown in the graph below.

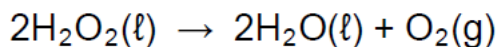


- 6.2 What can be deduced from the graph regarding the RATE OF THE REACTION during the time interval:
- 6.2.1 20 s to 40 s (1)
- 6.2.2 60 s to 120 s (1)
- 6.3 Calculate the average rate (in $\text{cm}^3 \cdot \text{s}^{-1}$) at which $\text{CO}_2(\text{g})$ is produced in the experiment.
- 6.4 How will the volume of $\text{CO}_2(\text{g})$ produced in experiment **B** compare to that produced in experiment **A**? Choose from GREATER THAN, SMALLER THAN or EQUAL TO.
- 6.5 A graph is now drawn for experiment **C** on the same set of axes. How will the gradient of this graph compare to the gradient of the graph for experiment **A**? Choose from GREATER THAN, SMALLER THAN or EQUAL TO.

Use the collision theory to fully explain the answer.

QUESTION 7

Hydrogen peroxide, H_2O_2 , decomposes to produce water and oxygen according to the following balanced equation



- 7.1 The activation energy (E_A) for this reaction is 75 kJ and the heat of reaction (ΔH) is -196 kJ.

7.1.1 Define the term *activation energy*.

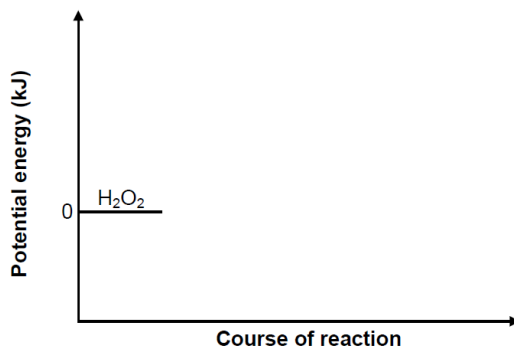
(2)

7.1.2 Redraw the set of axes below in your ANSWER BOOK and then complete the potential energy diagram for this reaction.

Indicate the value of the potential energy of the following on the y-axis:

- Activated complex
- Products

(The graph does NOT have to be drawn to scale.)



When powdered manganese dioxide is added to the reaction mixture, the rate of the reaction increases.

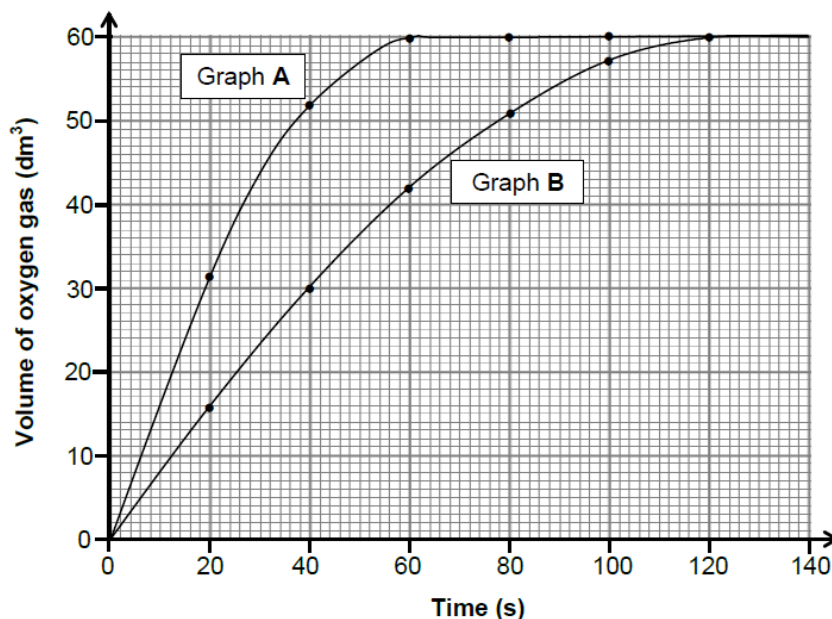
7.1.3 On the graph drawn for QUESTION 7.1.2, use broken lines to show the path of the reaction when the manganese dioxide is added.

(2)

7.1.4 Use the collision theory to explain how manganese dioxide influences the rate of decomposition of hydrogen peroxide

(3)

7.2 Graphs **A** and **B** below were obtained for the volume of oxygen produced over time under different conditions.



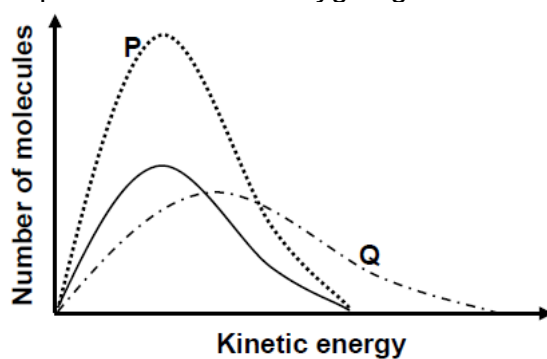
7.2.1 Calculate the average rate of the reaction (in $\text{dm}^3 \cdot \text{s}^{-1}$) between $t = 10 \text{ s}$ and $t = 40 \text{ s}$ for graph **A**. (3)

7.2.2 Use the information in graph **A** to calculate the mass of hydrogen peroxide used in the reaction. Assume that all the hydrogen peroxide decomposed. Use $24 \text{ dm}^3 \cdot \text{mol}^{-1}$ as the molar volume of oxygen. (3)

7.2.3 How does the mass of hydrogen peroxide used to obtain graph **B** compare to that used to obtain graph **A**? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. (1)

7.3 Three energy distribution curves for the oxygen gas produced under different conditions are shown in the graph below.

The curve with the solid line represents 1 mol of oxygen gas at 90°C .



Choose the curve (**P** or **Q**) that best represents EACH of the following situations:

7.3.1 1 mol of oxygen gas produced at 120°C (1)

7.3.2 2 moles of oxygen gas produced at 90°C (1)
[20]

QUESTION 8

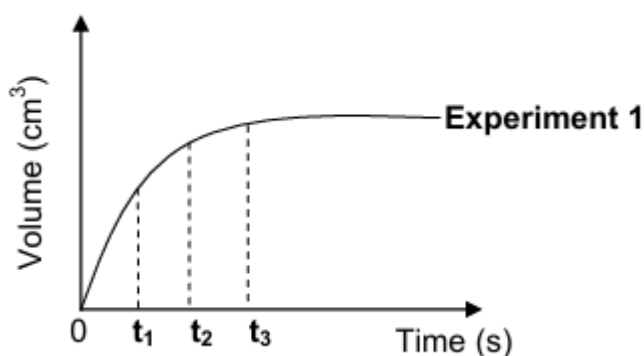
Dilute acids, indicated in the table below, react with EXCESS zinc in each of the three experiments to produce hydrogen gas. The zinc is completely covered with the acid in each experiment.

EXPERIMENT	DILUTE ACID
1	100 cm ³ of 0,1 mol·dm ⁻³ H ₂ SO ₄
2	50 cm ³ of 0,2 mol·dm ⁻³ H ₂ SO ₄
3	100 cm ³ of 0,1 mol·dm ⁻³ HCl

The volume of hydrogen gas produced is measured in each experiment.

8.1 Name TWO essential apparatuses needed to determine the rate of hydrogen production. (2)

8.2 The graph below was obtained for Experiment 1.



Use this graph and answer the questions that follow.

8.2 At which time (t_1 , t_2 or t_3) is the:

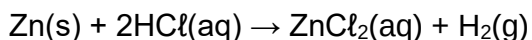
8.2.1 Reaction rate the highest (1)

8.2.1 Mass of zinc present in the flask the smallest (1)

8.3 In which time interval, between t_1 and t_2 OR between t_2 and t_3 , does the largest volume of hydrogen gas form per second? (1)

8.4 Redraw the graph for Experiment 1 in the ANSWER BOOK
On the same set of axes, sketch the graphs that will be obtained for Experiments 2 and 3. Clearly label the three graphs as EXPERIMENT 1, EXPERIMENT 2 and EXPERIMENT 3 (4)

- 8.5 The initial mass of zinc used in each experiment is 0,8 g. The balanced equation for the reaction in Experiment 3 is:

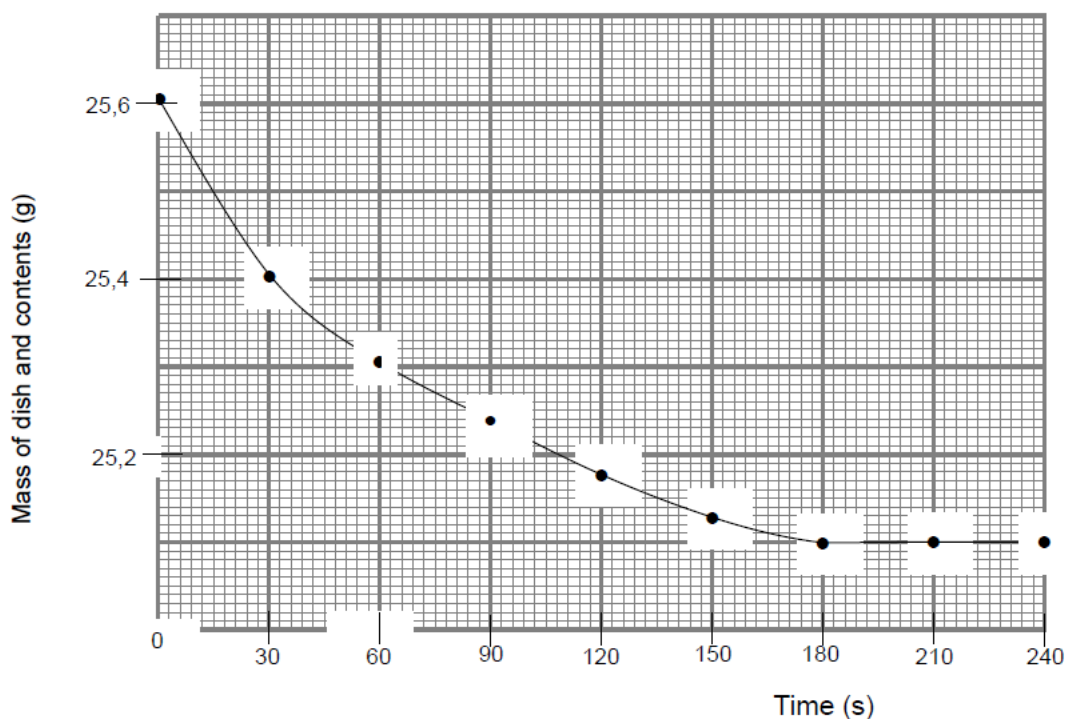


- 8.5.1 Calculate the mass of zinc present in the flask after completion of the reaction in Experiment 3. (5)
- 8.5.2 How will the mass of zinc present in the flask after completion of the reaction in Experiment 2 compare to the answer to QUESTION 5.5.1? Write down only LARGER THAN, SMALLER THAN or EQUAL TO. (1)

[15]

QUESTION 9

An excess of hydrochloric acid (HCl) at 25 °C is added to some calcium carbonate chips in an evaporating dish that is placed on an electronic balance. The mass of the dish and its contents are recorded every 30 seconds. The results are shown in the graph below.



- 9.1 Why does the mass of the dish and its contents decrease with time? (2)
- 9.2 How long did the reaction take to reach completion? (2)
- 9.3 During which time interval was the reaction rate the fastest? (2)
(Choose from: 0 – 30 s; 60 – 90 s or 180 – 210 s)
- 9.4 Make a rough sketch of the graph above, not to scale, in your answer book and label it **Q**. On the same set of axes, sketch the curve that would be obtained if calcium carbonate powder instead of chips had been used. Label this graph **R**. (2)

[08]

CHEMICAL EQUILIBRIUM

RECOMMENDATIONS FOR IMPROVEMENT

- Use the following steps, when explaining in terms of Le Chatelier's principle the Identify the disturbance.
 - State that the system will act to oppose this disturbance
 - State which reaction (forward or reverse) will be favoured when opposing the disturbance.
 - State the effect on, for example, the number of moles of products.
- *reverse reaction will be favoured* instead of the *equilibrium position shifts to the left*
- At equilibrium, the reaction stops, but that both forward and reverse reactions proceed at the same rate.
- Increase in volume leading to a decrease in pressure, which favours a reaction yielding more moles of gas, and the K_c remains constant because only temperature affects
- **Calculation of K_c value.**
 - K_c calculations can be assessed in various ways. Learners must be exposed to a
 - A range of question types so that the context and the requirement of the question is understood.
- In some questions,
 - the K_c value needs to be calculated using these equilibrium concentrations, and in other questions,
 - the K_c value is given, and unknown concentrations or amounts need to be calculated
- The use of the table for K_c calculations is recognized as a convenient way to arrive at equilibrium concentrations.
- Use the correct labels when using a table to solve K_c calculations, and write the correct values next to each label.
 - $[n(\text{initial})$,
 - $n(\text{change})$,
 - $n(\text{equilibrium})$,
 - $c(\text{equilibrium})]$
- When writing K_c expression avoid the use of

$$K_c = \frac{[\text{products}]}{[\text{reactants}]}$$

- **Common MISTAKES when writing K_c expression were**
 - No K_c expression
 - Incorrect K_c expression
 - Using a correct K_c expression with **ROUND BRACKETS INSTEAD OF SQUARE BRACKETS**

The formula for K_c has:

- the concentration of the products in the numerator and the concentration of reactants in the denominator.
- a K_c value **greater than 1** means that the equilibrium lies to the right **there are more products than reactants**.
- a K_c value **between 0 and 1** means that the equilibrium lies to the left **more reactants than products**.

Note that K_c cannot be 0 or less.

Yield describes the quantity of product in the container relative to the maximum product possible.

K_c value	Equilibrium	Yield
$K_c > 1$	forward reaction favoured	more products than reactants
$0 < K_c < 1$	Reverse reaction favoured	more reactants than products

A high K_c value means that:

- the concentration of products is high.
- the equilibrium lies far to the right.
- the reaction has a high yield.

A low K_c value (close to 0) means that:

- the concentration of reactants is high.
- the equilibrium lies far to the left.
- the reaction has a low yield.

- The teacher must list the factors that influence the value of the equilibrium constant.

Concentration, **pressure**, and **temperature** all affect the equilibrium position of a reaction, and a catalyst affects reaction rates. However, only **temperature** affects the value of K_c .

❖ Changing **concentration**:

- Changing the concentration of a reactant or product results in one of the reactions (forward or reverse) being favoured.
- This change in reaction rate minimizes the effect of the change and restores the concentration ratio between reactants and products. There will just be more reactants and products.
- **K_c will remain the same.**

❖ Changing **pressure**:

- Changing the pressure of the system will change the ratio between the reactant and product concentrations.
- The equilibrium then shifts to minimise the effect of the change and restores the ratio between reactant and product concentrations.

- **K_c will remain the same.**

❖ Adding a **catalyst** to the system:

- Both the forward and reverse reactions rates are increased.
- Therefore the ratio between reactant and product concentrations will remain the same.
- **K_c will remain the same.**

❖ Changing **temperature**:

- Changing the temperature will favour either the endothermic or exothermic reaction.
- The ratio between the concentration of the reactants and products will change.
- **K_c will change.**

❖ **Le Chatelier' principle** state that when the equilibrium in a close system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

❖ Remember there are three factors that modify the equilibrium state.

- **Concentration** of the reactants or the products.
- **Pressure.**
- **Temperature.**

QUESTION 1: MULTIPLE CHOICE QUESTIONS

- 1.1 A certain chemical reaction reaches equilibrium at 25 °C. The equilibrium constant, K_c , for the reaction at this temperature is $1,0 \times 10^{-4}$.

Which ONE of the following statements regarding this reaction at equilibrium is CORRECT?

- A. The concentration of the products is equal to that of the reactants.
- B. The concentration of the products is higher than that of the reactants.
- C. The concentration of the products is lower than that of the reactants.
- D. The rate of the forward reaction is lower than the rate of the reverse reaction. (2)

- 1.2 Consider the following chemical reaction at equilibrium in a closed container: $2\text{HgO(s)} \rightleftharpoons 2\text{Hg(l)} + \text{O}_2\text{(g)}$

More HgO(s) is now added to the container at constant temperature.

How will the number (in moles) of $\text{O}_2\text{(g)}$ and the value of K_c be affected at equilibrium?

	NUMBER OF MOLES OF O_2	K_c
A	Increases	Increases
B	Increases	Remains the same
C	Remains the same	Remains the same
D	Remains the same	Increases

(2)

- 1.3 Consider the following equation of the equilibrium reaction taking place in a closed container:



According to **Le Chatelier's principle**, the conditions of temperature and pressure under which the **highest yield** of nitrogen (N_2) will be obtained are:

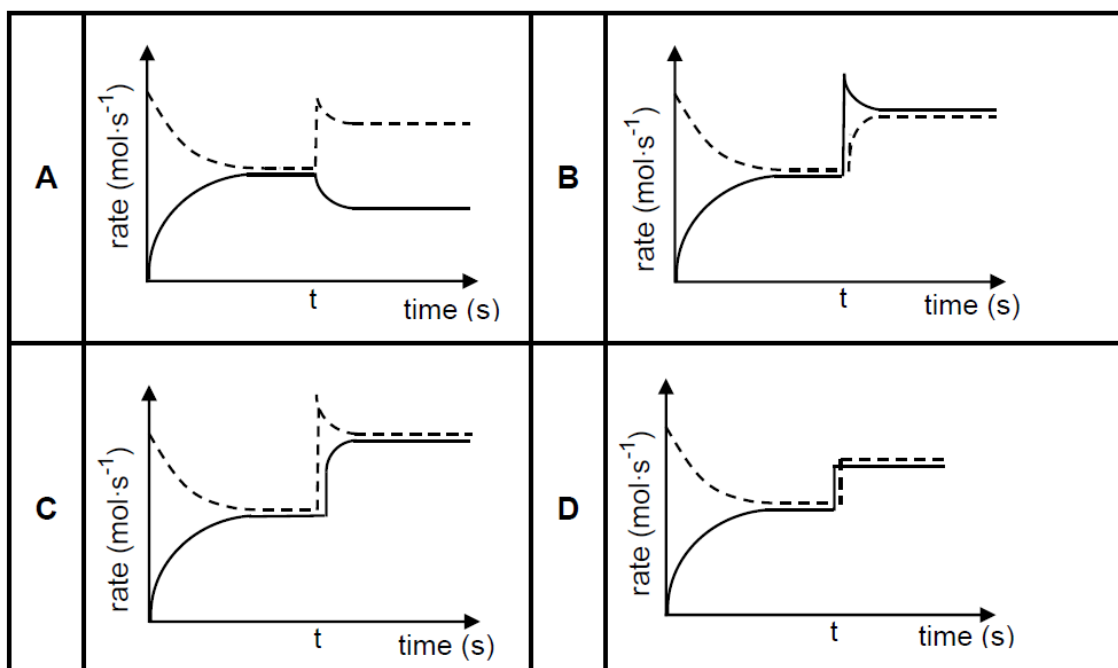
	Temperature	Pressure
A	Low	High
B	High	High
C	High	Low
D	Low	Low

- 1.4 Initially, a certain amount of P(g) was placed in an empty container. The hypothetical reaction reaches equilibrium in a closed container according to the following balanced equation:



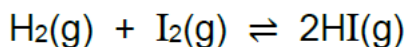
At time t , the temperature is increased.

Which graph below best illustrates the resulting changes in the rates of the forward and reverse reactions after the temperature is increased?



(2)

- 1.5 Initially, an equal number of moles of hydrogen gas, $\text{H}_2(\text{g})$, and iodine gas, $\text{I}_2(\text{g})$, are mixed in a closed container. The reaction reaches equilibrium at a constant temperature according to the balanced equation.

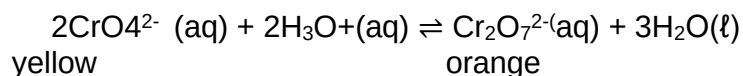


Which ONE of the following is ALWAYS TRUE at equilibrium?

- A $[\text{H}_2] = [\text{I}_2]$
- B $[\text{HI}] = [\text{I}_2]$
- C $[\text{HI}] = 2[\text{H}_2]$
- D $[\text{H}_2] = [\text{I}_2] = [\text{HI}]$

(2)

1.6 The balanced equation below represents a reaction at equilibrium

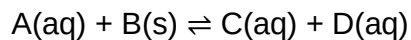


Which statement(s) is/are TRUE when a few drops of concentrated hydrochloric acid, $\text{HCl}(\text{conc})$, are added to the mixture?

- (i) The reverse reaction will be favoured.
- (ii) The concentration of $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ increases.
- (iii) The colour of the solution changes from yellow to orange

- A (i) only
- B (i) and (ii) only
- C (i) and (iii) only
- D (ii) and (iii) only (2)

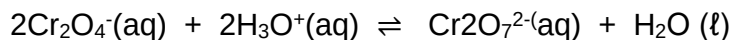
1.7 Consider the equation below for a hypothetical reaction.



If the equilibrium constant $K_c = 1 \times 10^{-4}$, then ...

- A $[\text{A}][\text{B}] < [\text{C}][\text{D}]$
- B $[\text{A}][\text{B}] > [\text{C}][\text{D}]$
- C $[\text{A}] > [\text{C}][\text{D}]$
- D $[\text{A}] < [\text{C}][\text{D}]$ (2)

1.8 Consider the following reaction that reaches equilibrium in a beaker

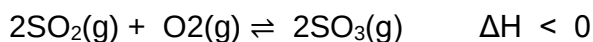


A few drops of concentrated $\text{NaOH}(\text{aq})$ are now added to the beaker. Which ONE of the following combinations correctly identifies the DISTURBANCE ON THE SYSTEM and the SYSTEM'S RESPONSE to the disturbance?

	DISTURBANCE ON THE SYSTEM	SYSTEM'S RESPONSE
A	$[\text{H}^+]$ decreases	Forward reaction favoured
B	$[\text{H}^+]$ decreases	Reverse reaction favoured
C	$[\text{CrO}_4^{2-}]$ decreases	Reverse reaction favoured
D	$[\text{CrO}_4^{2-}]$ increases	Forward reaction favoured

(2)

1.9 The reaction given below reaches equilibrium in a closed container. The K_c value is 0,04 at a certain temperature.



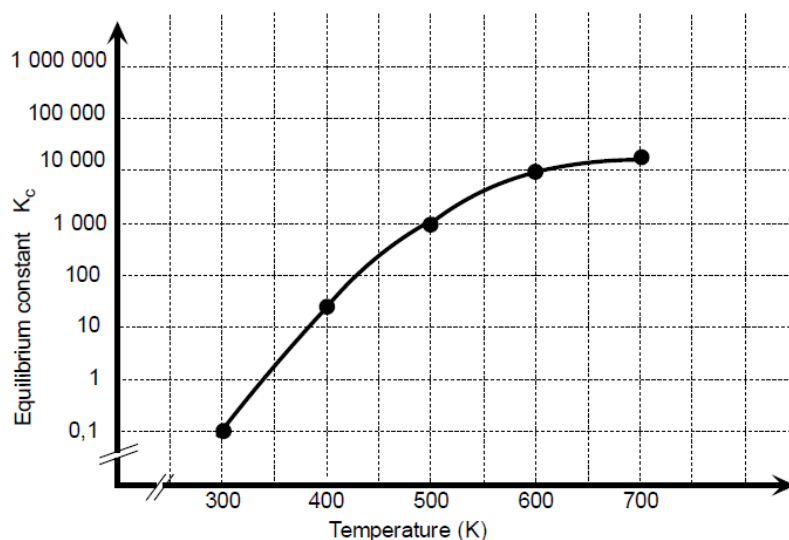
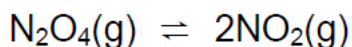
Which ONE of the following factors will change the K_c value to 0,4?

- A Increase in pressure
- B Decrease in pressure
- C Increase in temperature
- D Decrease in temperature

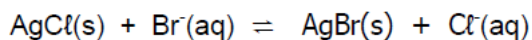
(2)
[18]

QUESTION 2

- 2.1 The graph below shows the effect of a temperature change on the value of K_c for the following reaction taking place in a closed container



- 2.1.1 What effect does an increase in temperature have on the value of K_c ? (1)
- 2.1.2 Which reaction was favoured due to an increase in temperature? Write only FORWARD or REVERSE. (1)
- 2.1.3 Using Le Chatelier's principle, explain whether the forward reaction is exothermic or endothermic (4)
- 2.1.4 Write down two factors, other than temperature, that can be used to increase the rate of the forward reaction at 500 K. (2)
- 5.2 The equilibrium constant K_c is 360 at 298 K for the reaction:

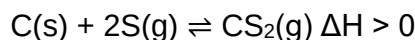


- If a $0.2 \text{ mol}\cdot\text{dm}^{-3}$ solution of $\text{Br}^-(\text{aq})$ is added to solid AgCl , what will the equilibrium concentrations of $\text{Br}^-(\text{aq})$ and $\text{Cl}^-(\text{aq})$ at 298 K be? (8)

[16]

QUESTION 3

Carbon, C(s), reacts with sulphur, S(g), according to the following balanced equation:



The system reaches equilibrium at temperature T in a sealed 2 dm³ container.

The K_c value is 9,4 at temperature T.

3.1 State Le Chatelier's principle. (2)

At equilibrium, 1 mole of carbon disulphide, CS₂(g), is present in the container.

3.2 Calculate the concentration of S(g) present at equilibrium. (4)

The volume of the container is now DOUBLED at temperature T. After a while, a NEW equilibrium is established.

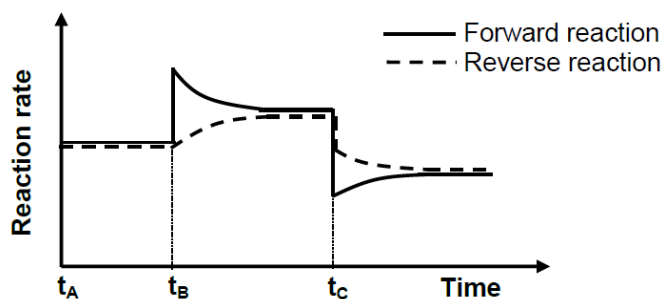
3.3 How will the amount of S(g) change as this new equilibrium is established? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

3.4 Explain the answer to QUESTION 2.3 in terms of Le Chatelier's principle. (3)

3.5 If the concentration of CS₂(g) CHANGES by x mol·dm⁻³, write down an expression for the equilibrium constant, K_c, in terms of x.

Show ALL your workings. NO simplification or solving for x is required. (5)

3.6 The reaction rate-time graph below represents further changes made to the equilibrium mixture. The volume of the container is kept constant.



3.2.1 What do the parallel lines between t_A and t_B represent? (1)

3.2.2 What change was made to the equilibrium mixture at t_B? (1)

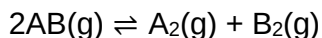
3.2.3 Give a reason for the sudden change in the reaction rate at t_C. (1)

3.2.4 Fully explain the answer to QUESTION 2.2.3. (3)

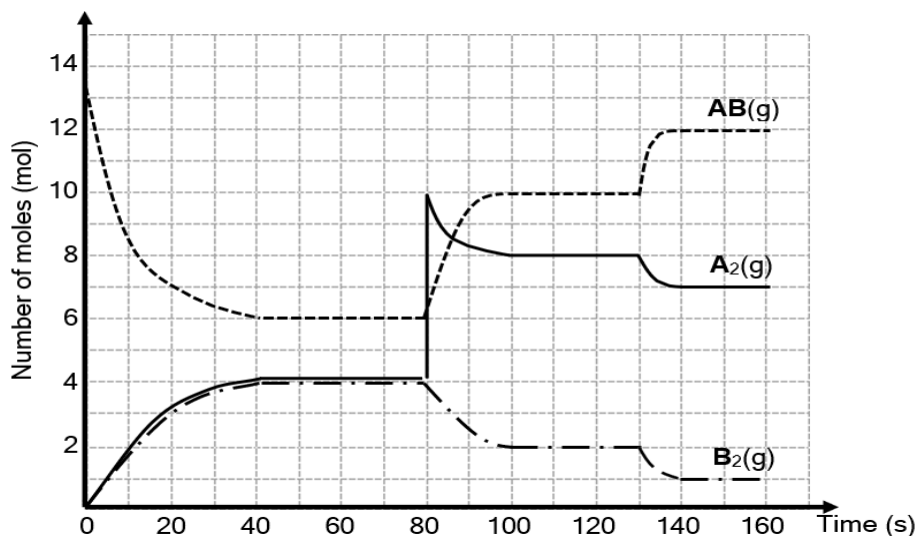
[21]

QUESTION 4

Consider the following hypothetical reaction reaching equilibrium in a 4 dm³ closed container at 150 °C.



The graph below shows the changes in the amounts of reactants and products over time.

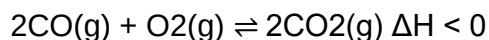


- 4.1 Write down the meaning of the term *reversible reaction*. (1)
- 4.2 State Le Chatelier's principle. (2)
- 4.3 A change was made to the equilibrium mixture at $t = 80$ s.
 - 4.3.1 Write down the change made at $t = 80$ s. (1)
 - 4.3.2 Use Le Chatelier's principle to explain how the system reacts to this change. (2)
- 4.4 Calculate the equilibrium constant, K_c , at $t = 120$ s. (2)
- 4.5 At $t = 130$ s the temperature of the system is decreased to 100 °C. (3)
 - 4.5.1 Draw a potential energy diagram for this reaction. (3)
 - 4.5.2 Will the equilibrium constant, K_c , at 100 °C be GREATER THAN, LESS THAN or EQUAL TO the K_c at 150 °C? Explain the answer. (3)
- 4.6 The initial reaction now takes place in the presence of a catalyst at 150 °C. Describe the changes that will be observed on the graph between $t = 0$ s and $t = 60$ s. (3)

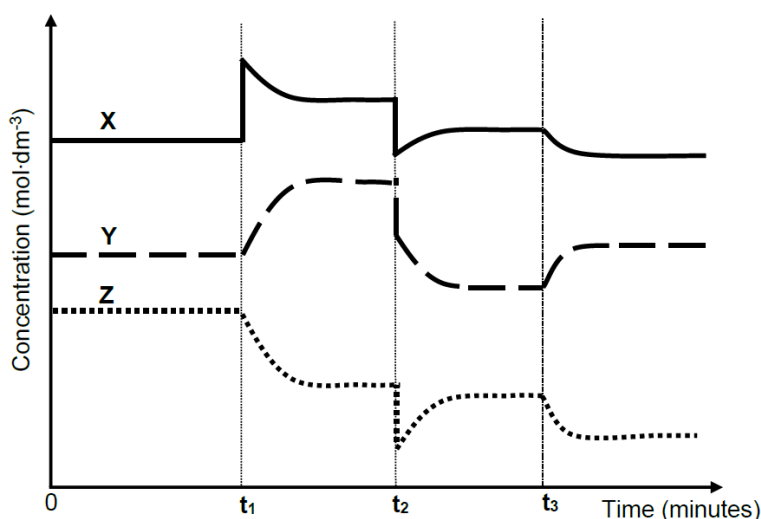
[19]

QUESTION 5

- 5.1 The reaction of carbon monoxide gas, CO(g) , with oxygen gas, $\text{O}_2\text{(g)}$, is investigated. The reaction reaches equilibrium in a closed container at constant temperature $T\text{ }^\circ\text{C}$, according to the balanced equation



Changes to the conditions of equilibrium are made at different times. The graph shows the results obtained. **X**, **Y** and **Z** represent the gases in the above reaction.

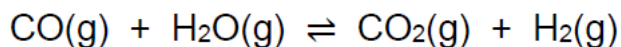


- 5.1.1 Define the term *chemical equilibrium* (2)

Use the graph to answer the questions below.

- 5.1.2 At **t₁**, oxygen, $\text{O}_2\text{(g)}$, was added to the container. Write down the letter that represents $\text{O}_2\text{(g)}$. Choose from **X**, **Y** or **Z**. (1)
- 5.1.3 At **t₂**, the pressure is adjusted by changing the volume of the container. Was the pressure INCREASED or DECREASED? (1)
- 5.1.4 Give a reason for the answer to QUESTION 5.1.3. (1)
- 5.1.5 Write down the NAME or FORMULA of the gas that is represented by the letter **Z**. (1)
- 5.1.6 Give a reason for the answer to QUESTION 5.1.5. (1)
- 5.1.7 What change in temperature is made at **t₃**? Choose between INCREASED or DECREASED (1)
- 5.1.8 Use Le Chatelier's principle to explain the answer to QUESTION 5.1.7. (1)

- 5.2 Carbon monoxide gas, CO(g) , reacts with water vapour, $\text{H}_2\text{O(g)}$, at $T\text{ }^\circ\text{C}$. The reaction reaches chemical equilibrium according to the balanced equation



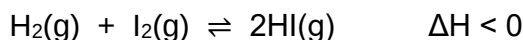
Initially, 0,6 moles of CO(g) , 0,6 moles of $\text{H}_2\text{O(g)}$, 0,1 moles of carbon dioxide gas, $\text{CO}_2\text{(g)}$, and 0,1 moles of hydrogen gas, $\text{H}_2\text{(g)}$, were mixed and sealed in a 2 dm^3 flask.

If the equilibrium constant, K_c , for this reaction at $T\text{ }^\circ\text{C}$ is 4, calculate the mass of CO(g) present in the flask at equilibrium. (9)

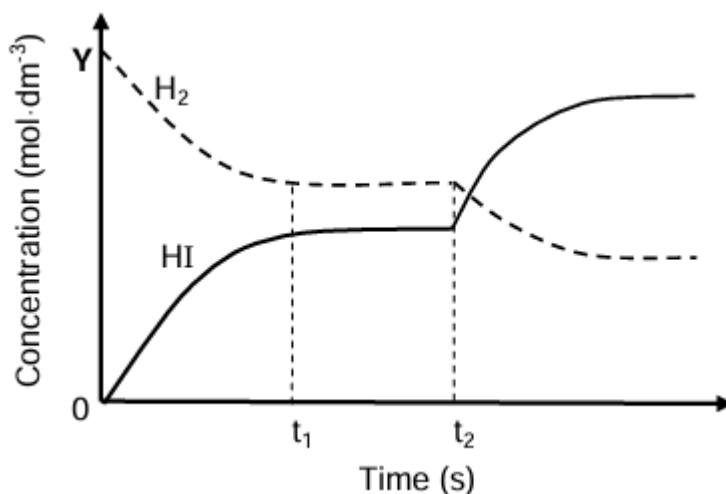
[20]

QUESTION 6

- 6.1 Initially, 4 moles $\text{H}_2\text{(g)}$ and 4 moles $\text{I}_2\text{(g)}$ are allowed to react in a sealed 2 dm^3 flask according to the following balanced equation:



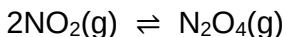
The graph below shows the concentrations of $\text{H}_2\text{(g)}$ and HI(g) versus time during the reaction.



- 6.1.1 Write down the value of Y. (1)
- 6.1.2 State Le Chatelier's principle. (2)
- 6.1.3 Changes were made to the temperature of the flask at time t_2 . Was the flask HEATED or COOLED? (1)
- 6.14 Fully explain the answer to QUESTION 6.1.3. (2)

6.2 The equation below represents the reversible reaction that takes place when

$\text{NO}_2(\text{g})$ is converted to $\text{N}_2\text{O}_4(\text{g})$.



Initially, x mol of $\text{NO}_2(\text{g})$ is sealed in a 1 dm^3 container at 350 K. When equilibrium is established at this temperature, 0,81 mol $\text{N}_2\text{O}_4(\text{g})$ is present in the container.

6.2.1 Write down the meaning of the term reversible reaction. (1)

6.2.2 Show that the equilibrium constant for this reaction is given by

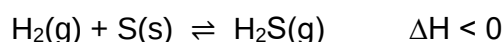
$$\frac{0,81}{(x - 1,62)^2} \quad (5)$$

0,79 moles of $\text{N}_2\text{O}_4(\text{g})$ is now added to the equilibrium mixture above. When the NEW equilibrium is established at 350 K, it is found that the amount of $\text{NO}_2(\text{g})$ increased by 1,2 moles.

6.2.3 Calculate the value of x . (6)
[19]

QUESTION 7

Hydrogen gas, $\text{H}_2(\text{g})$, reacts with sulphur powder, $\text{S}(\text{s})$, according to the following balanced equation:



The system reaches equilibrium at 90°C .

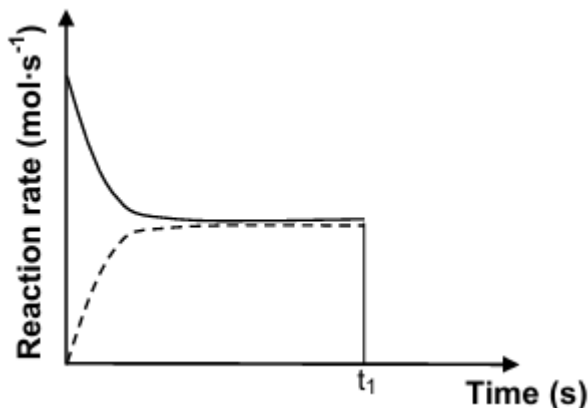
7.1 Define the term chemical equilibrium. (2)

7.2 How will EACH of the following changes affect the number of moles of $\text{H}_2\text{S}(\text{g})$ at equilibrium?
Choose from INCREASES, DECREASES or REMAINS THE SAME

7.2.1 The addition of more sulphur (1)

7.2.2 An increase in temperature
Use Le Chatelier's principle to explain the answer. (4)

7.3 The sketch graph below was obtained for the equilibrium mixture.



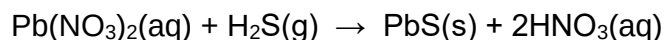
A catalyst is added to the equilibrium mixture at time t_1

Redraw the graph above in your ANSWER BOOK. On the same set of axes, complete the graph showing the effect of the catalyst on the reaction rates.

(2)

Initially 0,16 mol $\text{H}_2(\text{g})$ and excess $\text{S}(\text{s})$ are sealed in a 2 dm³ container and the system is allowed to reach equilibrium at 90 °C.

An exact amount of $\text{Pb}(\text{NO}_3)_2$ solution is now added to the container so that ALL the $\text{H}_2\text{S}(\text{g})$ present in the container at EQUILIBRIUM is converted to $\text{PbS}(\text{s})$ according to the following balanced equation:



The mass of the PbS precipitate is 2,39 g.

7.4 Calculate the equilibrium constant K_c for the reaction $\text{H}_2(\text{g}) + \text{S}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g})$ at 90 °C.

(9)

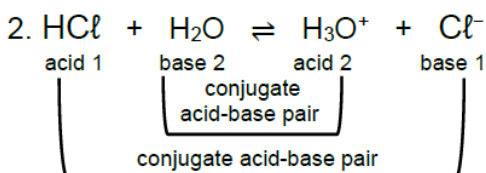
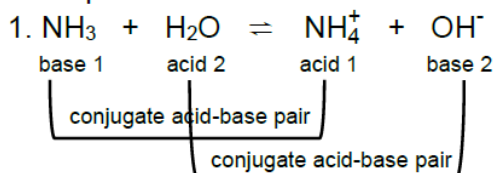
[18]

ACIDS AND BASES

RECOMMENDATIONS FOR IMPROVEMENT

- Determine the conjugate base or conjugate acid from a given species:

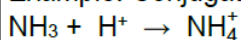
Examples:



Conjugate acid of a base:

ADD H^+ to the given compound or ion

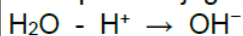
Example: Conjugate acid of NH_3



Conjugate base of an acid:

REMOVE H^+ from the given compound or ion

Example: Conjugate base of H_2O :



Salt of		Nature of solution	pH	Example
Acids	bases			
Strong	Strong	neutral	pH = 7	no hydrolysis of NaCl (aq) ions
				$\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$
				$\text{Na}^+ + \text{H}_2\text{O} \rightarrow \text{No reaction}$
				$\text{Cl}^- + \text{H}_2\text{O} \rightarrow \text{No reaction}$
weak	weak	neutral	pH = 7	$\text{CH}_3\text{COONH}_4(\text{aq})$
				$\text{CH}_3\text{COONH}_4(\text{aq}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{NH}_4^+(\text{aq})$
				$\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$
				$\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{NH}_3(\text{g}) + \text{H}_3\text{O}^+(\text{aq})$
				Salt is neutral, OH^- and H_3O^+ produced.
strong	weak	acidic	pH < 7	the hydrolysis of NH_4Cl
				$\text{NH}_4\text{Cl}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$
				$\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{NH}_3(\text{g}) + \text{H}_3\text{O}^+(\text{aq})$
				Salt is acidic, H_3O^+ produced
weak	strong	basic	pH > 7	the hydrolysis of $\text{CH}_3\text{COONa}(\text{aq})$:
				$\text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{Na}^+(\text{aq})$
				$\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$
				Salt is basic, OH^- produced

K_w is called **equilibrium constant for ionization of water** or **ionic product of water**

$[\text{H}_3\text{O}^+] \propto \frac{1}{[\text{OH}^-]}$ as one increases, the other decreases

Relationship between K_a and K_b values

$[K_a] \propto \frac{1}{[K_b]}$ as one increases, the other decreases

ACID	BASE	INDICATOR	pH COLOURCHANGE RANGE
strong	weak	Bromothymol blue	6,0 – 7,6
strong	weak	Methyl orange	3,2 – 4,4
weak	strong	Phenolphthalein	8,2, - 10

IMPORTANT TIPS FOR ACID-BASE STOICHIOMETRIC CALCULATIONS

- Ensure you know stoichiometry from grades 10 and 11.
- You must be able to calculate:
 - Number of moles (n) from a given mass (m) using $n = \frac{m}{M}$ where M is the molar mass
 - Number of moles (n) from a given concentration (c) using $c = \frac{n}{V}$ where V is the volume in dm^3
 - Number of moles from a given number of particles N using $n = \frac{N}{N_A}$ where N_A is the Avogadro constant ($N_A = 6,02 \times 10^{23} \text{ mol}^{-1}$)
 - Number of moles for **gases only** from a given gas volume using $n = \frac{V}{V_M}$ where V_M is the molar gas volume. **Only at STP the molar gas volume is $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$.**
- After calculating number of moles of acid/base that has reacted, **use the ratio of the acid to the base** to find the number of moles of base/acid that reacted.
- When either the acid or base is in **excess**, calculate the:
 - The number of moles in excess through subtraction:
 $n(\text{excess}) = n(\text{initial}) - n(\text{reacted})$
 - The number of moles reacted through subtraction:
 $n(\text{reacted}) = n(\text{initial}) - n(\text{excess})$
 - The initial number of moles through addition:
 $n(\text{initial}) = n(\text{excess}) + n(\text{reacted})$

QUESTION 1 : MULTIPLE CHOICE QUESTIONS

- 1.1 Which ONE of the following solutions, each of concentration $0,1 \text{ mol}\cdot\text{dm}^{-3}$, has the highest pH?)
- A. $\text{HNO}_3(\text{aq})$
 - B. $\text{NH}_4\text{Cl}(\text{aq})$
 - C. $\text{Na}_2\text{CO}_3(\text{aq})$
 - D. $\text{CH}_3\text{COOH}(\text{aq})$
- (2)
- 1.2 Four solutions of different acids of the same concentration are compared. Which ONE of the following K_a values represents the WEAKEST acid at 25°C ?
- A $4,5 \times 10^{-6}$
 - B $2,5 \times 10^{-5}$
 - C $1,8 \times 10^{-2}$
 - D $6,5 \times 10^{-2}$
- (2)
- 1.3 Consider the statements below regarding an alkaline substance.
An alkaline substance:
- (i) Reacts with an acid to form a neutral solution
 - (ii) Turns red litmus blue
 - (iii) Forms a salt when it reacts with an acid
- A (i), (ii) and (iii)
 - B (i) and (ii) only
 - C (i) and (iii) only
 - D (ii) and (iii) only
- (2)
- 1.4 Which ONE of the following salts, when dissolved in water, will NOT change the pH of the water?
- A Na_2CO_3
 - B $(\text{COO})_2\text{Na}_2$
 - C NH_4Cl
 - D NaCl
- (2)

- 1.5 A dilute acid is titrated against a potassium hydroxide solution, KOH(aq) . At the equivalence point the pH is 7. Which ONE of the following combinations correctly identifies the acid and the MOST SUITABLE indicator for this titration?

	ACID	INDICATOR
A	$(\text{COOH})_2(\text{aq})$	Phenolphthalein
B	$(\text{COOH})_2(\text{aq})$	Bromothymol blue
C	HCl(aq)	Phenolphthalein
D	HCl(aq)	Bromothymol blue

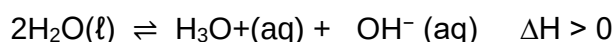
(2)

- 1.6 During a titration to determine the concentration of an acid using a standard base, a learner pipettes the base into a conical flask. She then uses a small amount of water to rinse the inside of the flask so that all the base is part of the solution in the flask. How will the extra water added to the flask affect the results of this titration? The concentration of the acid ...

- A cannot be determined.
 B will be lower than expected.
 C will be higher than expected.
 D will be the same as expected.

(2)

- 1.7 The following equilibrium exists in pure water at 25 °C.



At this temperature, the $\text{pH} = 7$ and $K_w = 1 \times 10^{-14}$. The temperature of the water is now increased to 90°C.

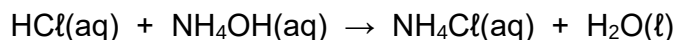
Which ONE of the following is TRUE at the new temperature?

- A $\text{pH} = 7$
 B $[\text{H}_3\text{O}^+] = [\text{OH}^-]$
 C $[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}$
 D $[\text{H}_3\text{O}^+] = 10^{-7} \text{ mol}\cdot\text{dm}^{-3}$

(2)

- 1.9 A hydrochloric acid solution is titrated against an ammonia solution.

The balanced equation for the reaction is:



Which ONE of the following gives the pH of the solution at the end point and the reason for this pH?

	pH	REASON
A	3	$\text{H}_3\text{O}^+(\text{aq})$ is formed during the ionisation of HCl(aq) .
B	5	$\text{H}_3\text{O}^+(\text{aq})$ is formed during hydrolysis of $\text{NH}_4^+(\text{aq})$.
C	7	Neutralisation takes place at the end point.
D	9	$\text{OH}^-(\text{aq})$ is formed during hydrolysis of $\text{NH}_4^+(\text{aq})$.

(2)

- 1.10 The pH of a solution increases from 8,5 to 9,5 at 298 K when a base is added to it. Which ONE of the statements below is TRUE for the original solution?

- A Its $[\text{OH}^-]$ increases by a factor of 10.
- B Its $[\text{H}^+]$ increases by a factor of 10.
- C Its $[\text{OH}^-]$ increases by 1 mol.dm⁻³.
- D Its $[\text{H}^+]$ increases by 1 mol.dm⁻³.

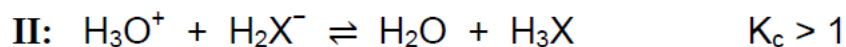
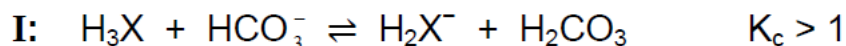
(2)

- 1.11 When sodium carbonate (Na_2CO_3) dissolves in water, the pH of the solution is 9,82. Which one of the following equations offers the best explanation for this?

- A $2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$
- B $\text{Na}_2\text{CO}_3 \rightleftharpoons 2\text{Na}^+ + \text{CO}_3^{2-}$
- C $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$
- D $\text{H}_3\text{O}^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O}$

(2)

1.12 Reactions I and II below have equilibrium constants (K_c) greater than 1.



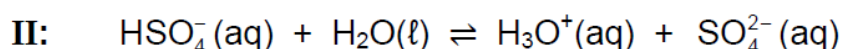
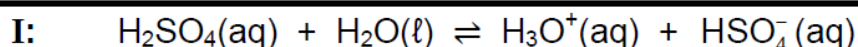
Based on the reactions above, the ACIDS in order of INCREASING STRENGTH (weakest to strongest) are ...

- A H_3X , H_2X^- , H_3O^+
- B H_2CO_3 , H_3X , H_3O^+
- C H_3X , H_2CO_3 , H_3O^+
- D H_3X , H_3O^+ , H_2CO_3

(2)
[22]

QUESTION 2

2.1 Sulphuric acid is a strong acid present in acid rain. It ionises in two steps as follows:



2.1.1 Define an *acid* in terms of the Lowry-Brønsted theory. (3)

2.1.2 Write down the FORMULA of the conjugate base of $\text{H}_3\text{O}^+(\text{aq})$. (1)

2.1.3 Write down the FORMULA of the substance that acts as an ampholyte in the ionisation of sulphuric acid. (3)

2.2 Acid rain does not cause damage to lakes that have rocks containing limestone (CaCO_3). Hydrolysis of CaCO_3 results in the formation of ions, which neutralise the acid.

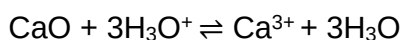
2.2.1 Define *hydrolysis* of a salt. (3)

2.2.2 Explain, with the aid of the relevant HYDROLYSIS reaction, how limestone can neutralise the acid. (3)

2.3 The water in a certain lake has a pH of 5.

2.3.1 Calculate the concentration of the hydronium ions in the water. (3)

The volume of water in the lake is $5 \times 10^9 \text{ dm}^3$. Lime, CaO , is added to the water to neutralise the acid according to the following reaction:



- 2.3.2 If the final amount of hydronium ions is $1,37 \times 10^3$ moles, calculate the mass of lime that was added to the lake.

(7)

[20]

QUESTION 3

- 3.1 Sulphuric acid is a diprotic acid.

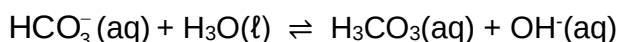
3.1.1 Define an *acid* in terms of the Lowry-Brønsted theory.

(2)

3.1.2 Give a reason why sulphuric acid is referred to as a *diprotic acid*.

(1)

- 3.2 The hydrogen carbonate ion can act as both an acid and a base. It reacts with water according to the following balanced equation:



3.2.1 Write down ONE word for the underlined phrase.

(1)

3.2.2 $\text{HCO}_3^-(\text{aq})$ acts as base in the above reaction. Write down the formula of the conjugate acid of $\text{HCO}_3^-(\text{aq})$.

(1)

- 3.3 A learner accidentally spills some sulphuric acid of concentration $7 \text{ mol} \cdot \text{dm}^{-3}$ from a flask on the laboratory bench. Her teacher tells her to neutralise the spilled acid by sprinkling sodium hydrogen carbonate powder onto it. The reaction that takes place is: (Assume that the H_2SO_4 ionises completely.)



The fizzing, due to the formation of carbon dioxide, stops after the learner has added 37 g sodium hydrogen carbonate to the spilled acid.

3.3.1 Calculate the volume of sulphuric acid that spilled. Assume that all the sodium hydrogen carbonate reacts with all the acid.

(7)

The learner now dilutes some of the $7 \text{ mol} \cdot \text{dm}^{-3}$ sulphuric acid solution in the flask to $0,1 \text{ mol} \cdot \text{dm}^{-3}$.

3.3.2 Calculate the volume of the $7 \text{ mol} \cdot \text{dm}^{-3}$ sulphuric acid solution needed to prepare 1 dm^3 of the dilute acid.

(3)

During a titration 35 cm^3 of the $0,1 \text{ mol} \cdot \text{dm}^{-3}$ sulphuric acid solution is added to an Erlenmeyer flask and titrated with a $0,1 \text{ mol} \cdot \text{dm}^{-3}$ sodium hydroxide solution.

3.3.3 The learner uses bromothymol blue as indicator. What is the purpose of this indicator?

(1)

3.3.4 Calculate the pH of the solution in the flask after the addition of 30 cm^3 of sodium hydroxide. The endpoint of the titration is not yet reached at this point.

(8)

[24]

QUESTION 4

4.1 Nitric acid (HNO_3), an important acid used in industry, is a strong acid.

4.1.1 Give a reason why nitric acid is classified as a strong acid. (1)

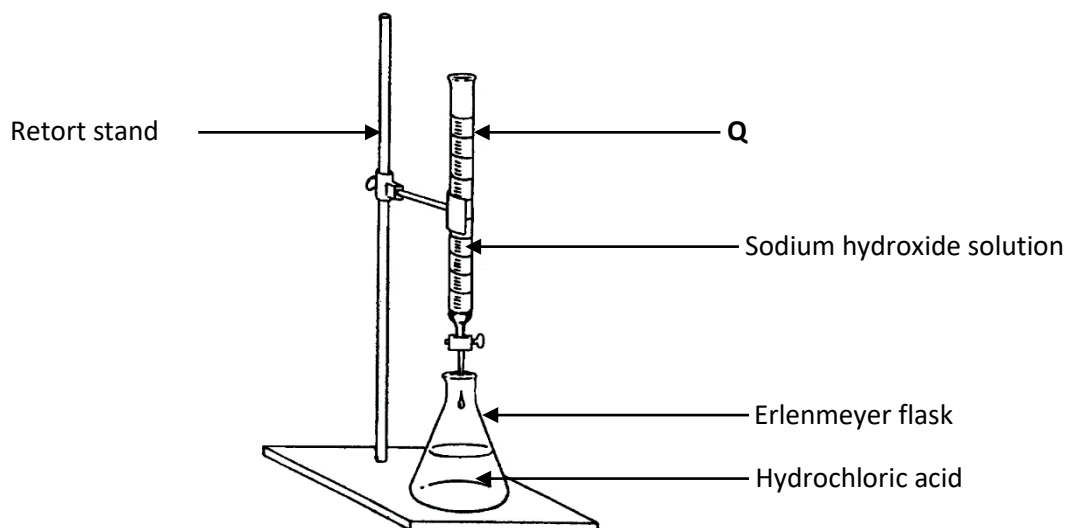
4.1.2 Write down the NAME or FORMULA of the conjugate base of nitric acid. (1)

4.1.3 Calculate the pH of a $0,3 \text{ mol}\cdot\text{dm}^{-3}$ nitric acid solution. (3)

4.2 A laboratory technician wants to determine the percentage purity of magnesium oxide. He dissolves a $5,5 \text{ g}$ sample of the magnesium oxide in 100 cm^3 hydrochloric acid of concentration $3 \text{ mol}\cdot\text{dm}^{-3}$.

4.2.1 Calculate the number of moles of hydrochloric acid added to the magnesium oxide. (3)

He then uses the apparatus below to titrate the EXCESS hydrochloric acid in the above solution against a sodium hydroxide solution.



4.2.2 Write down the name of apparatus Q in the above diagram. (1)

4.2.3 The following indicators are available for the titration:

INDICATOR	pH RANGE
A	3,1 – 5,5
B	7,0 – 7,7
C	8,3 – 10,0

Which ONE of the above indicators (**A**, **B** or **C**) is most suitable to indicate the exact endpoint in this titration? Give a reason for the answer. (3)

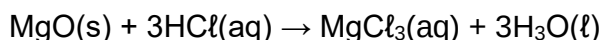
4.2.4 During the titration, the technician uses distilled water to wash any sodium hydroxide spilled against the sides of the Erlenmeyer flask into the solution.

Give a reason why the addition of distilled water to the Erlenmeyer flask will not influence the results.

4.2.5 At the endpoint of the titration he finds that 31 cm³ of a 0,3 mol dm⁻³ sodium hydroxide solution has neutralised the EXCESS hydrochloric acid.

Calculate the number of moles of hydrochloric acid in excess.

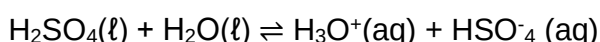
4.2.6 The balanced equation for the reaction between hydrochloric acid and magnesium oxide is:



Calculate the percentage purity of the magnesium oxide. Assume that only the magnesium oxide in the 5,5 g sample reacted with the acid.

QUESTION 5

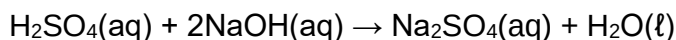
5.1 The balanced equation below represents the first step in the ionisation of sulphuric acid (H₂SO₄) in water:



5.1.1 Write down the FORMULAE of the TWO bases in the equation above. (2)

5.1.2 Is sulphuric acid a STRONG or a WEAK acid? Give a reason for the answer. (2)

5.2 Learners use the reaction of a 0,15 mol·dm⁻³ sulphuric acid solution with a sodium hydroxide solution in two different experiments. The balanced equation for the reaction is:



5.2.1 They use 24 cm³ of H₂SO₄(aq) in a titration to neutralise 26 cm³ of NaOH(aq).

Calculate the concentration of the NaOH(aq). (5)

5.2.2 In another experiment, 30 cm³ of the H₂SO₄(aq) is added to 20 cm³ of a 0,28 mol·dm⁻³ NaOH solution in a beaker.

Calculate the pH of the final solution. (8)

[17]

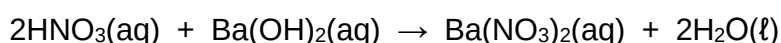
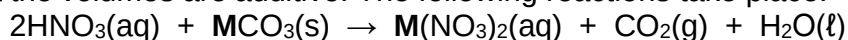
QUESTION 6

To identify metal **M** in an unknown metal carbonate, MCO_3 , the following procedure is carried out:

Step 1: 0,198 g of IMPURE MCO_3 is reacted with 25 cm³ of 0,4 mol·dm⁻³ nitric acid, $\text{HNO}_3(\text{aq})$.

Step 2: The EXCESS $\text{HNO}_3(\text{aq})$ is then neutralised with 20 cm³ of 0,15 mol·dm⁻³ barium hydroxide, $\text{Ba}(\text{OH})_2(\text{aq})$.

Assume that the volumes are additive. The following reactions take place:

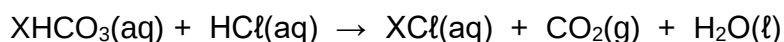


- 6.1 Define the term *strong base*. (2)
- 6.2 Calculate the:
- 6.2.1 Number of moles of $\text{Ba}(\text{OH})_2(\text{aq})$ that reacted with the excess $\text{HNO}_3(\text{aq})$ (3)
- 6.2.2 pH of the solution after Step 1 (5)
- 6.3 The percentage purity of the $\text{MCO}_3(\text{s})$ in the sample is 85%. Identify metal **M**. (8)
- [18]**

QUESTION 7

- 7.1 Define a *base* in terms of the Arrhenius theory. (2)
- 7.2 Explain how a *weak base* differs from a *strong base*. (2)
- 7.3 Write down the balanced equation for the hydrolysis of NaHCO_3 . (3)
- 7.4 A learner wishes to identify element **X** in the hydrogen carbonate, XHCO_3 . To do this she dissolves 0,4 g of XHCO_3 in 100 cm³ of water. She then titrates all of this solution with a 0,2 mol dm⁻³ hydrochloric acid (HCl) solution. Methyl orange is used as the indicator during the titration.
- 7.4.1 Calculate the pH of the hydrochloric acid solution. (3)
- 7.4.2 Give a reason why methyl orange is a suitable indicator in this titration. (1)

At the endpoint she finds that 20 cm³ of the acid neutralised ALL the hydrogen carbonate solution. The balanced equation for the reaction is:



7.4.3 Identify element **X** by means of a calculation.

(6)
[17]

QUESTION 8

8.1 Ammonia ionises in water to form a basic solution according to the following balanced equation:

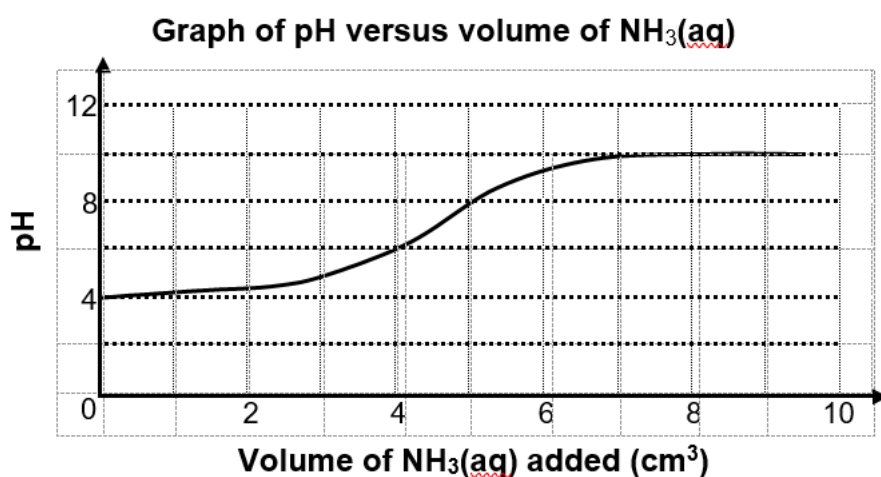


8.1.1 Is ammonia a WEAK or a STRONG base? Give a reason for the answer. (2)

8.1.2 Write down the conjugate acid of NH₃(g). (1)

8.1.3 Identify ONE substance in this reaction that can behave as an ampholyte in some reactions. (1)

8.2 A learner adds distilled water to a soil sample and then filters the mixture. The pH of the filtered liquid is then measured.

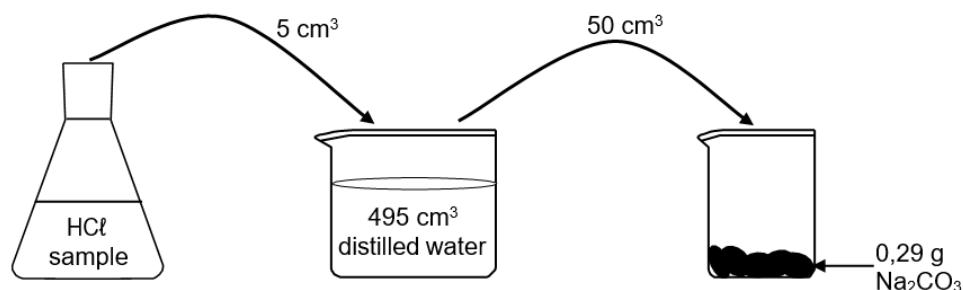


8.2.1 Is the soil sample ACIDIC or BASIC? Refer to the graph above and give a reason for the answer. (2)

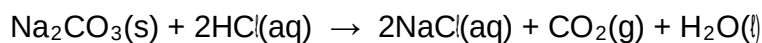
8.2.2 Calculate the concentration of the hydroxide ions (OH⁻) in the reaction mixture after the addition of 4 cm³ of NH₃(aq). (4)

- 8.3 A laboratory technician wants to determine the concentration of a hydrochloric acid (HCl) sample. He adds 5 cm^3 of the HCl sample to 495 cm^3 of distilled water to give 500 cm^3 of dilute hydrochloric acid, $\text{HCl}(\text{aq})$.

During a reaction 50 cm^3 of this dilute hydrochloric acid solution, $\text{HCl}(\text{aq})$, reacts completely with $0,29 \text{ g}$ of sodium carbonate, $\text{Na}_2\text{CO}_3(\text{s})$.



The balanced equation for the reaction is:



Calculate the concentration of the hydrochloric acid sample.

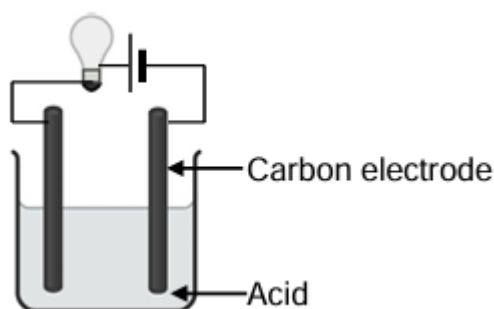
(7)
[17]

QUESTION 9

- 9.1 The conductivity of three acid solutions, A, B and C, as shown below is investigated at the same temperature.

A	$0,1 \text{ mol} \cdot \text{dm}^{-3} \text{H}_2\text{SO}_4(\text{aq})$
B	$0,1 \text{ mol} \cdot \text{dm}^{-3} \text{HNO}_3(\text{aq})$
C	$0,1 \text{ mol} \cdot \text{dm}^{-3} \text{CH}_3\text{COOH}(\text{aq})$

The brightness of the bulb in the apparatus shown below is used as a measure of the conductivity of the solutions.



The acid solutions are electrolytes.

- 9.1.1 Define the term electrolyte.

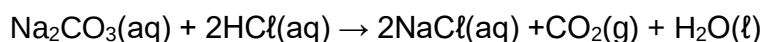
(2)

The brightness of the bulb for each of the solutions is compared.

9.1.2 In which solution, A or B, will the bulb be brighter? Give a reason for the answer by referring to the types of acids. (2)

9.1.3 In which solution, **B** or **C**, will the bulb be brighter? Give a reason for the answer by referring to the types of acids. (2)

9.2 A hydrochloric acid solution, HCl(aq) , is standardised by titrating it against 25 cm^3 of a $0,04 \text{ mol} \cdot \text{dm}^{-3}$ sodium carbonate solution $\text{Na}_2\text{CO}_3(\text{aq})$. At the endpoint, it is found that $19,5 \text{ cm}^3$ of HCl(aq) has reacted. The balanced equation for the reaction is:



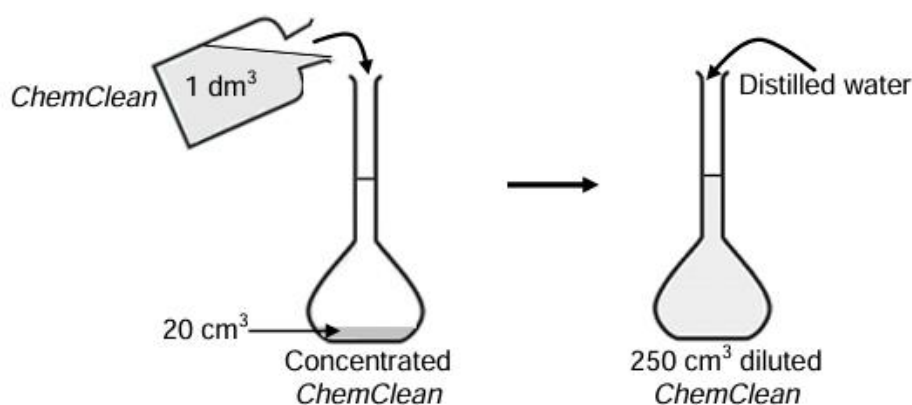
9.2.1 Calculate the concentration of the HCl(aq) . (3)

9.2.2 Suppose a few drops of water were present in the burette before it was filled with the hydrochloric acid solution. How will the volume of the HCl solution needed to reach the endpoint be affected?.

Choose from GREATER THAN, SMALLER THAN or REMAINS THE SAME. Give a reason for the answer (2)

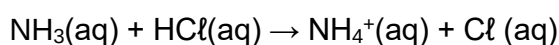
A concentrated household product, ChemClean, contains ammonia as the main cleaning agent. To determine the amount of ammonia present in 1 dm^3 of ChemClean, the following procedure is followed:

20 cm^3 of ChemClean is added to a 250 cm^3 flask. The flask is then filled to the 250 cm^3 mark with distilled water.



The diluted solution is titrated against the hydrochloric acid solution of the concentration as calculated in QUESTION 9.2.1.

During the titration, 22 cm^3 of the diluted ChemClean solution is neutralised by $18,7 \text{ cm}^3$ of the HCl solution. The balanced equation for the reaction is:



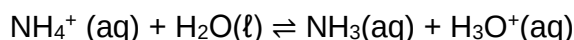
9.2.3 Calculate the mass of ammonia in 1 dm^3 of ChemClean. (7)

- 7.2.4 Will the pH of the solution at the end of the titration be GREATER THAN 7, EQUAL TO 7 or LESS THAN 7? Write down the relevant equation as motivation for the answer. (3)

[21]

QUESTION 10

- 10.1 Ammonium chloride crystals, $\text{NH}_4\text{Cl}(\text{s})$, dissolve in water to form ammonium and chloride ions. The ammonium ions react with water according to the balanced equation below:



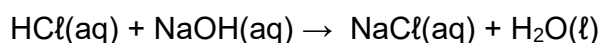
- 10.1.1 Write down the name of the process described by the underlined sentence. (1)
- 10.1.2 Is ammonium chloride ACIDIC or BASIC in aqueous solution? Give a reason for the answer. (2)

- 10.2. A certain fertiliser consists of 92% ammonium chloride. A sample of mass x g of this fertiliser is dissolved in 100 cm^3 of a $0,10 \text{ mol} \cdot \text{dm}^{-3}$ sodium hydroxide solution, $\text{NaOH}(\text{aq})$. The NaOH is in excess. The balanced equation for the reaction is:



- 7.2.1 Calculate the number of moles of sodium hydroxide in which the sample is dissolved. (3)

During a titration, 25 cm^3 of the excess sodium hydroxide solution is titrated with a $0,11 \text{ mol} \cdot \text{dm}^{-3}$ hydrochloric acid solution, $\text{HCl}(\text{aq})$. At the endpoint it is found that $14,55 \text{ cm}^3$ of the hydrochloric acid was used to neutralise the sodium hydroxide solution according to the following balanced equation:



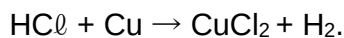
- 7.2.2 Calculate the mass x (in grams) of the fertiliser sample used. (8)
- 7.3 Calculate the pH of a $0,5 \text{ mol} \cdot \text{dm}^{-3}$ sodium hydroxide solution at 25°C . (5)

[18]

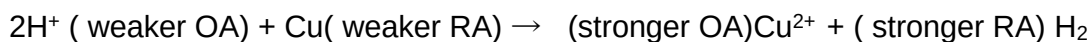
ELECTROCHEMISTRY

RECOMMENDATIONS FOR IMPROVEMENTS

- **When the strengths of reducing agents are compared,**
 - compare the atoms with atoms and not with ions
- **To determine whether the reaction can occur or not, check the reducing and oxidising strengths of the given substances.**
 - A reaction will take place between a stronger reducing agent and a stronger oxidising agent.
 - A reaction will not take place between a weaker reducing agent and a weaker oxidising agent.e.g.



(after removing spectator ions)

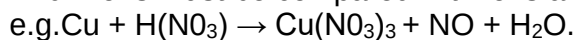


in terms of reducing ability:

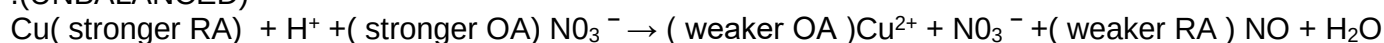
Cu is a weaker reducing agent than H₂, so it cannot reduce H⁺ to H₂, so the above reaction WILL NOT TAKE PLACE

- **When the strengths of oxidising agents are compared**

- ions must be compared with ions and not atoms.



.(UNBALANCED)



in terms of oxidising ability:

- NO₃⁻ is a stronger oxidising agent than Cu²⁺ so it oxidises Cu to Cu²⁺

How to read Table 4B Table of standard reduction potentials

Half-reaction			E ^θ (V)
Li ⁺	+ e ⁻	⇌ Li	- 3.05 V

Strength of Oxidising Agent
Increases

Oxidation half-reaction

Reduction half-reaction

Reducing Agent

Oxidising Agent

Strength of Reducing Agent
Increases

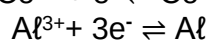
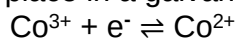
F ₂ + 2e ⁻	⇌ 2F ⁻	+ 2.87 V
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QUESTION 1: MULTIPLE CHOICE

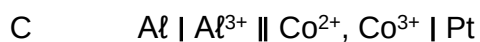
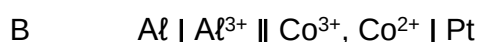
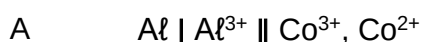
1.1 Which ONE of the following CANNOT act as a reducing agent?



1.2 The following half-reactions take place in a galvanic cell:



Which ONE of the following is the cell notation for this cell?



1.3. An electrochemical cell is set up using the following half-reactions:



The reducing agent in the cell reaction is ...



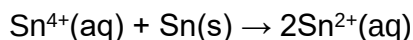
- 1.4 Consider the galvanic cell represented below.



Which ONE of the following half-reactions takes place at the cathode?

- A $\text{H}_2(\text{g}) \rightarrow 2\text{H}^{+}(\text{aq}) + 2\text{e}^{-}$
- B $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Mg(s)}$
- C $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-}$
- D $2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$ (2)

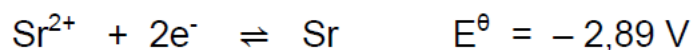
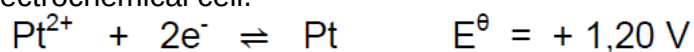
- 1.5 Consider an electrochemical cell based on the following reaction:



Which ONE of the following statements regarding this cell is CORRECT?

- A Sn is the anode of the cell.
- B Sn is the cathode of the cell.
- C $\text{Sn}^{4+}(\text{aq})$ is the reducing agent.
- D Sn is the oxidising agent. (2)

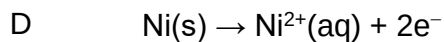
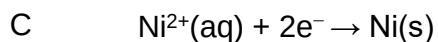
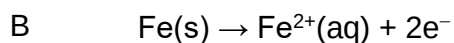
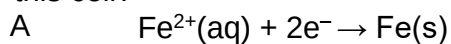
- 1.6 The two equations below represent the half-cell reactions in an electrochemical cell.



Which one of the statements below is TRUE for this cell when it is delivering current?

- A The mass of the Sr electrode will increase.
- B Pt undergoes oxidation more easily than Sr.
- C Pt^{2+} undergoes reduction more easily than Sr^{2+} .
- D Electrons will flow from the Pt electrode to the Sr electrode in the external circuit. (2)

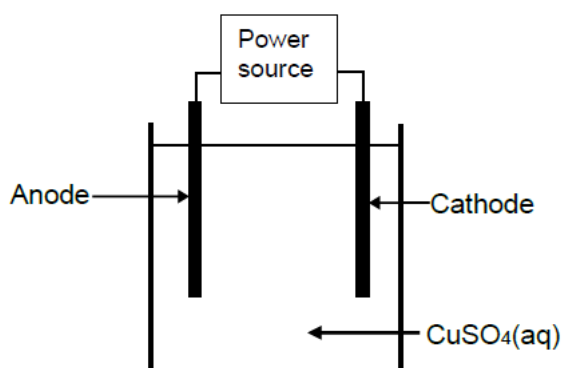
- 1.7 An electrochemical cell is used to electroplate an iron spoon with nickel. Which ONE of the following half-reactions takes place at the positive electrode of this cell?



(2)

- 1.8 Copper is purified by electrolysis.

Which ONE of the following combinations is CORRECT for the changes occurring at the anode, cathode and in the electrolyte when the cell is in operation?



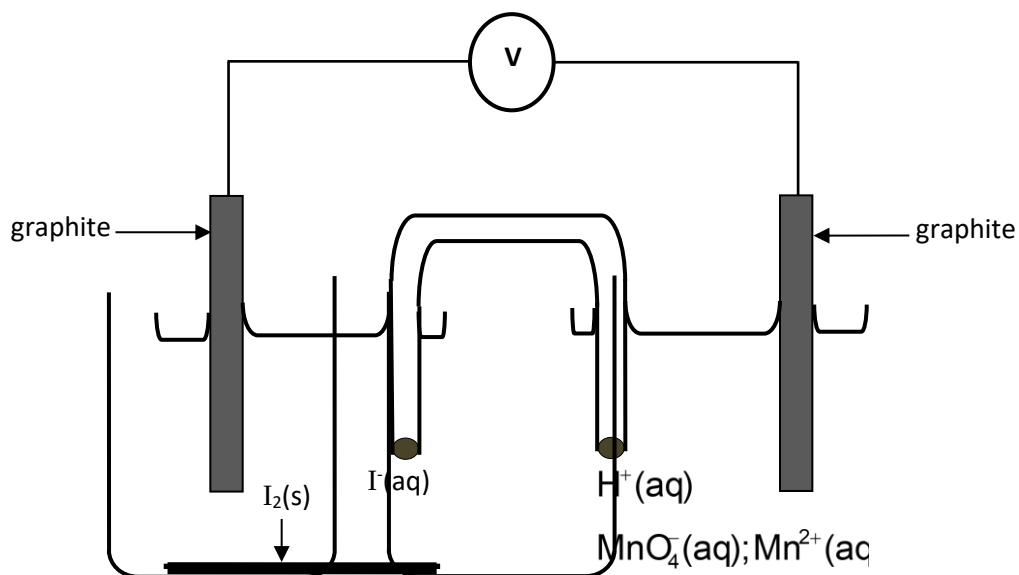
(2)

	MASS OF THE ANODE	MASS OF THE CATHODE	COLOUR OF THE ELECTROLYTE
A	Increases	Decreases	No change
B	Decreases	Increases	No change
C	Increases	Decreases	Becomes darker
D	Decreases	Increases	Becomes lighter

[18]

QUESTION 2

The voltaic cell represented below functions at standard conditions.



- 2.1. Write down the concentration of the $H^+(aq)$ in the one half-cell. (1)
- 2.2. Solids present in half-cells are usually used as electrodes. Give a reason why $I_2(s)$ is not suitable to be used as electrode. (1)
- 2.3. Write down ONE property, other than being a solid, of graphite that makes it suitable to be used as an electrode in the above voltaic cell. (1)
- 2.4. For the above voltaic cell, write down the:
 - 2.4.1 NAME of the oxidising agent (1)
 - 2.4.2 Net cell reaction (3)
 - 2.4.3 Cell notation (3)
- 2.5. Calculate the cell potential of the above cell. (4)
- 2.6. How will the reading on the voltmeter be affected if the concentration of MnO_4^- increases ? Write down INCREASES, DECREASES or NO EFFECT, explain. (3)

[17]

QUESTION 3

Learners are given the following two unknown half-cells:

Half-cell 1: $\text{Q}^{2+}(\text{aq}) \mid \text{Q}(\text{s})$

Half-cell 2: $\text{Pt} \mid \text{R}_2(\text{g}) \mid \text{R}^-(\text{aq})$

During an investigation to identify the two half-cells, the learners connect each half-cell alternately to a $\text{Cd}^{2+}(\text{aq}) \mid \text{Cd}(\text{s})$ half-cell under standard conditions. For each combination of two half-cells, they write down the net cell reaction and measure the cell potential.

The results obtained for the two half-cell combinations are given in the table below.

COMBINATION	NET CELL NOTATION	CELL POTENTIAL
I	$\text{Q}^{2+}(\text{aq}) + \text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + \text{Q}(\text{s})$	0,13 V
II	$\text{R}_2(\text{g}) + \text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{R}^-(\text{aq})$	1,76 V

3.1 Write down THREE conditions needed for these cells to function as standard cells. (3)

3.2 For **Combination I**, identify:

3.2.1 The anode of the cell (1)

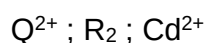
3.2.2 **Q** by using a calculation (5)

3.3 For **Combination II**, write down the:

3.3.1 Oxidation half-reaction (2)

3.3.2 NAME or FORMULA of the metal used in the cathode compartment. (1)

3.4 Arrange the following species in order of INCREASING oxidising ability: (4)

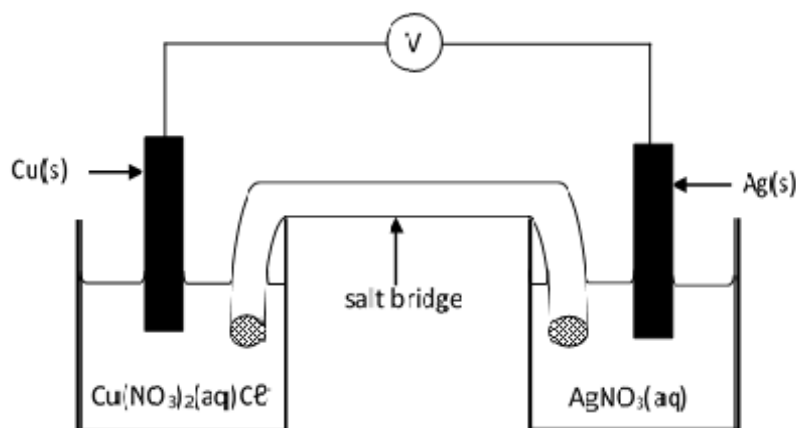


Explain fully how you arrived at the answer. A calculation is NOT required

[16]

QUESTION 4

The diagram below represents a galvanic cell operating under standard conditions.



- 4.1 Write down:
- 4.1.1 The energy conversion which takes place in this cell (1)
 - 4.1.2 A balanced equation for the overall cell reaction. (3)
 - 4.1.3 The cell notation for this cell (3)
- 4.2 Calculate the initial emf of this cell. (4)
- 4.3 In which direction will electrons flow? Write down only 'from Ag to Cu' or 'from Cu to Ag'. (1)
- 4.4 The cell is allowed to discharge for a period of time during which the mass of the copper electrode changes by 3,2 g. Calculate the expected mass change of the silver electrode. (Assume that the change in mass is only a result of the oxidation-reduction reaction occurring as the cell discharges.) (4)
- 4.5 The silver half-cell is now replaced with the standard hydrogen half-cell.
- 4.5.1 Is the copper electrode the POSITIVE or the NEGATIVE electrode? Refer to the relative strength of reducing agents to explain the answer. (4)
 - 4.5.2 Write down the emf of this cell. (1)

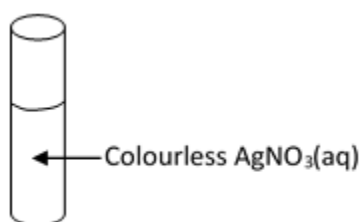
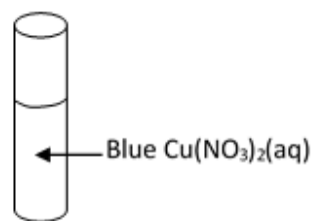
[21]

QUESTION 5

A learner conducts two experiments to investigate the reaction between copper (Cu) and a silver nitrate solution, $\text{AgNO}_3(\text{aq})$.

EXPERIMENT 1

The learner adds a small amount of copper (Cu) powder to a test tube containing silver nitrate solution, $\text{AgNO}_3(\text{aq})$. The solution changes from colourless to blue after a while.

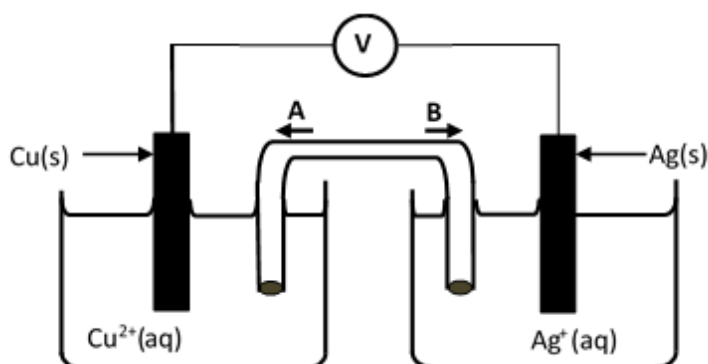
Before addition of Cu(s)**After addition of Cu(s)**

5.1 Define the term *oxidising agent* in terms of electron transfer. (2)

5.2 Explain why the solution turns blue by referring to the relative strength of oxidizing agents. (4)

EXPERIMENT 2

The learner now sets up a galvanic cell as shown below. The cell functions under standard conditions.



5.3 Write down the energy conversion that takes place in this cell. (1)

5.4 In which direction (**A** or **B**) will ANIONS move in the salt bridge? (1)

5.5 Calculate the emf of the above cell under standard conditions. (4)

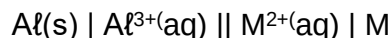
5.6 Write down the balanced equation for the net cell reaction that takes place in this cell. (3)

5.7 How will the addition of 100 cm^3 of a $1 \text{ mol} \cdot \text{dm}^{-3}$ silver nitrate solution to the silver half-cell influence the initial emf of this cell? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

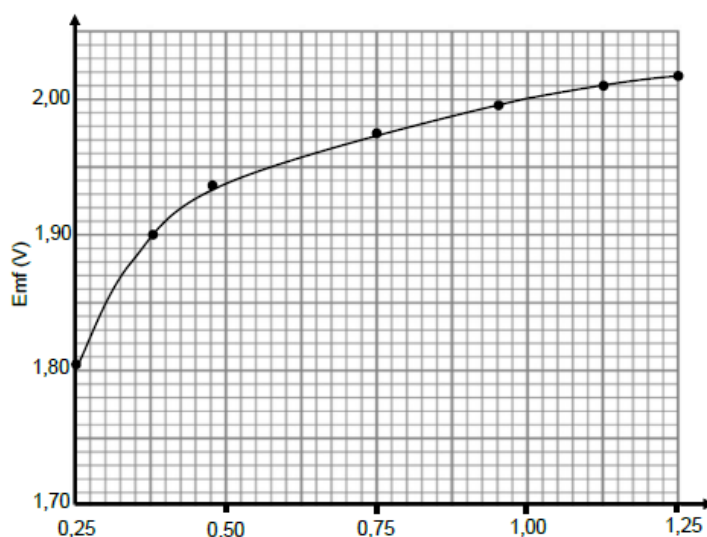
[16]

QUESTION 6

The relationship between the concentration of the electrolyte and the cell potential is investigated using the following electrochemical cell represented by the cell notation



The concentration of M^{2+} is changed and the corresponding emf is measured. The concentration of $\text{Al}^{3+}(\text{aq})$ and the temperature are at standard conditions. The graph below shows the results of this investigation



- 6.1 Identify the reducing agent in this cell. (1)
- 6.2 Determine the concentration of $\text{M}^{2+}(\text{aq})$ that will produce an emf of 1,87 V. (2)
- 6.3 How will the concentration of $\text{M}^{2+}(\text{aq})$ be affected as the cell operates? Choose from INCREASES, DECREASES or REMAINS THE SAME. (2)
- 6.4 Potassium nitrate, $\text{KNO}_3(\text{aq})$, is used in the salt bridge of this cell.
To which electrode will the K^+ ions move in the salt bridge (Al or M)? (1)
- 6.5 Identify metal **M** with the aid of a calculation. (1)
- 6.6 Metal **M** is now replaced with magnesium, Mg.
 - 6.6.1 Which electrode, Al or Mg, will be the anode? (1)
 - 6.6.2 Refer to the relative strengths of the oxidising agents to explain the answer. (2)

[15]

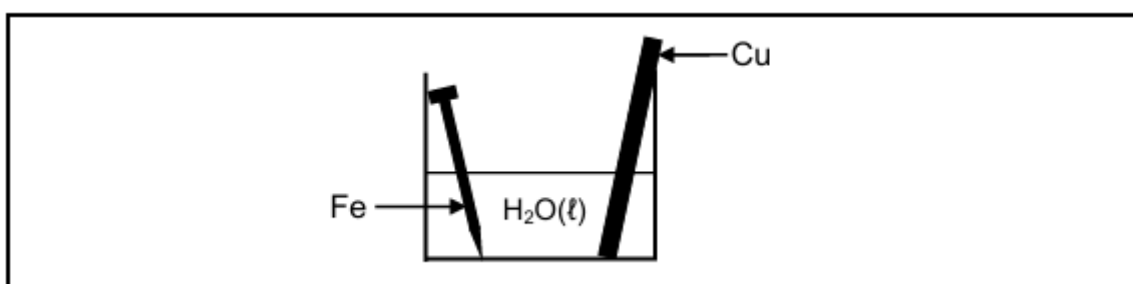
QUESTION 7

- 7.1 Corrosion is a redox reaction that takes place in the presence of oxygen and water. Rusting is the corrosion of iron leading to the formation of iron(III) ions.

7.1.1 Define oxidation in terms of oxidation number .

(2)

A cleaned copper rod and a cleaned iron nail are placed in a beaker containing water at 25°C, as shown below.



After a while it was observed that the iron nail was coated with rust. The copper rod showed no visible signs of corrosion.

7.1.2 Write down the half-reaction for the iron nail.

(2)

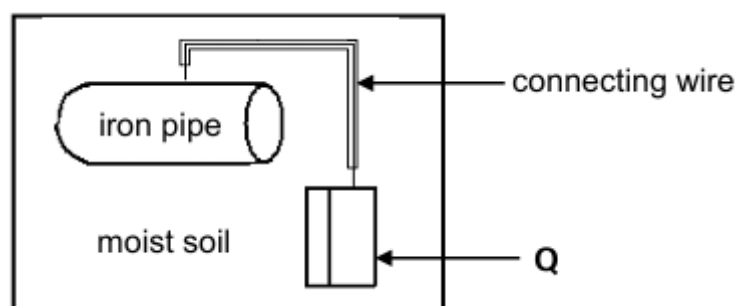
7.1.3 Does iron act as REDUCING AGENT or OXIDISING AGENT in the beaker?

(1)

7.1.4 Explain the above observation by referring to the Table of Standard Reduction Potentials.

(3)

To prevent rusting of an underground iron pipe, the pipe is connected to a metal (Q) that corrodes easily.



7.1.5 You are given two metals, Zn and Cu, to use as metal Q. Which metal would more suitable? Give a reason.

(2)

7.2 A galvanic cell is constructed using a $Fe | Fe^{3+}$ half-cell and a $Cu | Cu^{2+}$ half-cell.

7.2.1 Write down the overall (net) cell reaction that takes place when the cell is functioning.

(3)

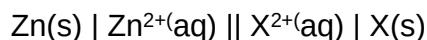
7.2.2 Calculate the cell potential of this cell under standard conditions.

(4)

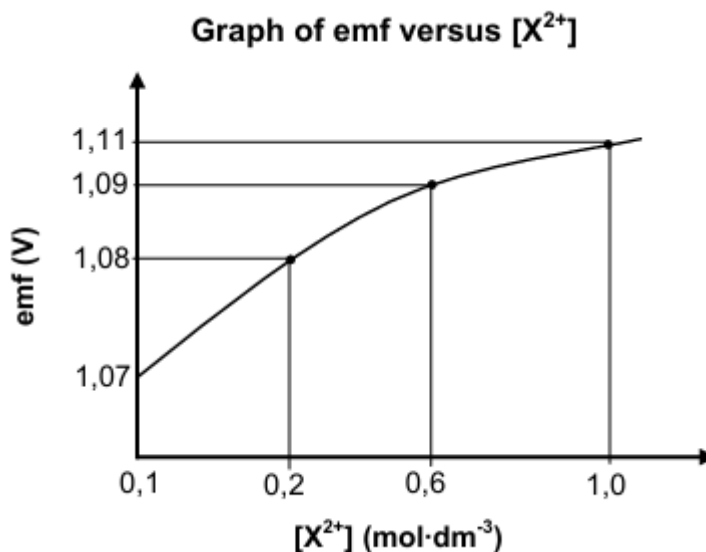
[17]

QUESTION 8

the relationship between the concentration of $X^{2+}(aq)$ and the emf of the cell. The concentration of $Zn^{2+}(aq)$ and the temperature are kept at standard conditions.



The graph below shows the results obtained.



- 8.1 For this investigation, write down the:
- 8.1.1 Dependent variable (1)
 - 8.1.2 Name of an instrument needed to measure the emf of the cell (1)
 - 8.1.3 Name of the component of the cell that ensures electrical neutrality (1)
 - 8.1.4 Values of TWO standard conditions needed to ensure that the standard emf is obtained (2)
- 8.2 Write down the conclusion that can be drawn from the results. (2)
- 8.3 Identify electrode X with the aid of a calculation. (5)
- 8.4 Write down the overall (net) cell reaction that takes place when this cell is in operation. (3)

[15]

ELECTROLYTIC CELL

RECOMMENDATIONS FOR IMPROVEMENT

Stoichiometric calculations

Step 1: Calculate number of moles

Step 2: Mole ratio

e.g $\text{Ni} \rightarrow \text{Ni}^{2+} + 2\text{e}^-$

$$n(\text{Ni}) : 2 n(\text{e}^-)$$

Step 3: Calculate number of particles

$$n = \frac{N}{N_A}$$

Where N is equal to number of electrons ($N = n \text{ e}^-$)

Step 4: Calculate the charge

$$n = \frac{Q}{q_e}$$

Where n represent number of electrons not number of moles

Step 5: Calculate the current

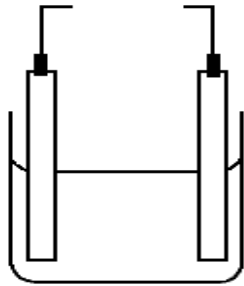
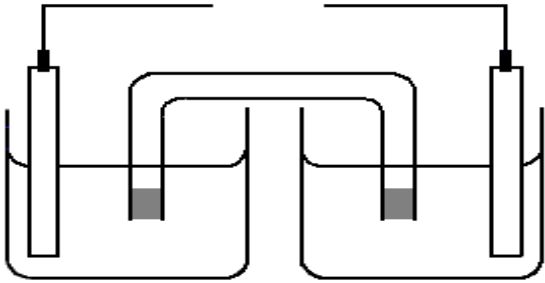
$$I = \frac{Q}{\Delta t}$$

Note that the time must be in seconds

1hr : 3600s

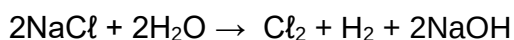
1min : 60s

Remember: you can be given a question where by you are supposed to Calculate change in mass or initial mass given the current and time

COMPARISON OF ELECTROLYTIC CELL AND GALVANIC / VOLTAIC CELL	
Electrolytic cell	Galvanic / voltaic cell
	
Electric energy → chemical energy	Chemical energy → electric energy
No salt bridge	Salt bridge
Non-spontaneous redox reactions	Spontaneous redox reactions
Endothermic reaction	Exothermic reaction
Positive electrode → anode → oxidation takes place	Negative electrode → anode → oxidation
Negative electrode → cathode → reduction takes place	Positive electrode → cathode → reduction

QUESTION 1 : MULTIPLE CHOICE QUESTIONS

1.1 Consider the following balanced equation of a chemical reaction:



Which ONE of the following statements about the reaction is correct?

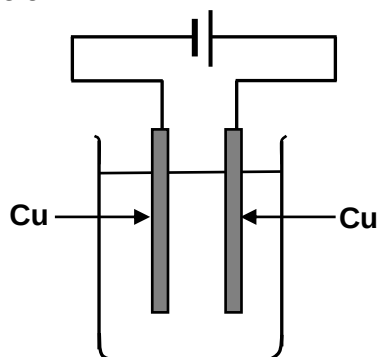
The reaction takes place in a/an ...

- A galvanic cell and absorbs energy.
- B galvanic cell and releases energy.
- C electrolytic cell and absorbs energy.
- D electrolytic cell and releases energy.

(2)

- 1.2 Which ONE of the following statements regarding an electrolytic cell is CORRECT?
- A An electric current causes a chemical change to occur.
- B Reduction occurs at the anode.
- C A spontaneous chemical reaction produces an electric current.
- D Electrons flow to the electrode where oxidation occurs (2)
- 1.3 Which ONE of the following is formed at the cathode in a electrolytic cell involving concentrated NaCl?
- A Chlorine
- B Hydrogen
- C Sodium chloride
- D Oxygen (2)
- 1.4 Which ONE of the following half-reactions occurs at the cathode during the electrolysis of an aqueous CuCl_2 solution?
- A $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$
- B $\text{Cu}^+ + \text{e}^- \rightarrow \text{Cu}$
- C $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$
- D $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ (2)
- 1.5 Which ONE of the following substances can be used as an electrolyte?
- A Mercury
- B Molten copper
- C Sugar dissolved in distilled water
- D Table salt dissolved in distilled water (2)

- 1.6 Copper is purified through electrolysis as represented in the simplified diagram below.



Which ONE of the following statements is CORRECT for this process?

- A Cu is oxidised at the negative electrode.
- B Cu is reduced at the positive electrode.
- C Cu^{2+} ions are reduced at the positive electrode.
- D Cu^{2+} ions are reduced at the negative electrode. (2)

- 1.7 The following characteristics may be used to describe an electrochemical cell (electrolytic or galvanic):

- I The chemical reaction is self-sustaining.
- II The reaction requires energy from an electrical source.
- III The anode is the positive electrode of the cell.

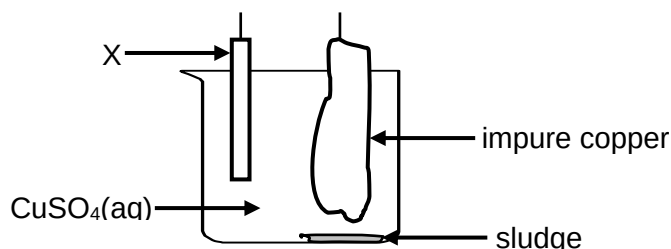
Which of these characteristics are specific to an electrolytic cell?

- A Only I
- B Only II
- C I and III
- D II and III (2)

- 1.8 Which ONE of the following statements about the extraction of aluminium is TRUE?

- A The ore of aluminium oxide is called cryolite.
- B When the cell is in operation, aluminium forms at the anode.
- C Aluminium oxide is dissolved in cryolite.
- D When the cell is in operation, carbon dioxide gas forms at the cathode. (2)

- 1.9 The diagram below represents a cell that may be used for refining copper. The impure copper contains silver metal and zinc metal.



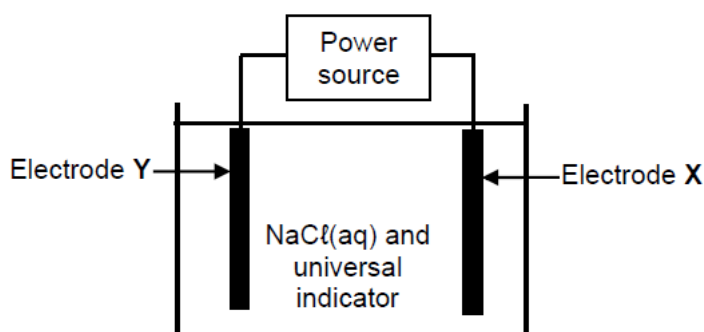
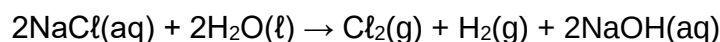
Which ONE of the following half-reactions will take place at electrode X?

- A $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$
- B $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
- C $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$
- D $\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}$

(2)

QUESTION 2

The apparatus below is used to demonstrate the electrolysis of a concentrated sodium chloride solution. Both electrodes are made of carbon. A few drops of universal indicator are added to the electrolyte. The equation for the net cell reaction is:



Initially the solution has a green colour. Universal indicator becomes red in acidic solutions and purple in alkaline solutions.

- 2.1 Define the term *electrolyte*.

(2)

When the power source is switched on, the colour of the electrolyte around electrode Y changes from green to purple.

- 2.2 Write down the:

- 2.2.1 Half-reaction that takes place at electrode Y.

(2)

2.2.2 NAME or FORMULA of the gas released at electrode **X**.

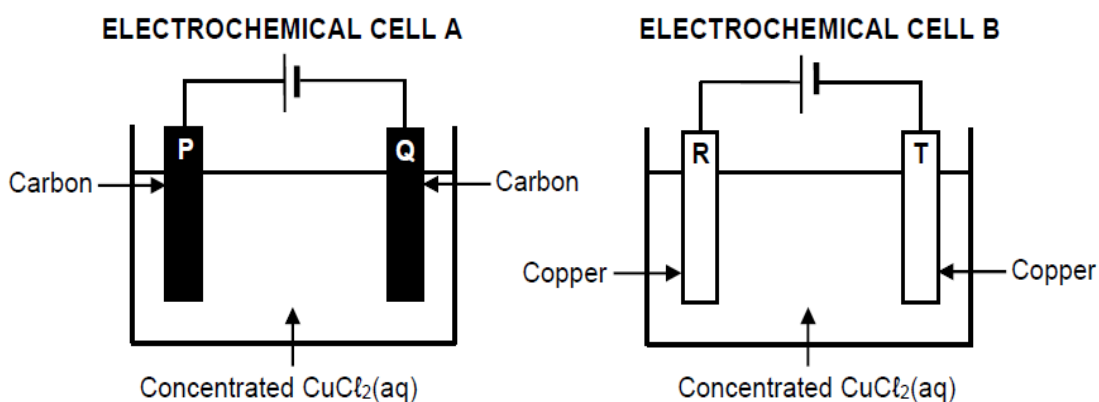
(1)

2.3 Refer to the Table of Standard Reduction Potentials to explain why hydrogen gas, and not sodium, is formed at the cathode of this cell.

(2)

[7]**QUESTION 3**

The simplified diagrams below represent two electrochemical cells, **A** and **B**. A concentrated copper(II) chloride solution is used as electrolyte in both cells.



3.1 Are **A** and **B** ELECTROLYTIC or GALVANIC cells?

(1)

3.2 Which of the electrodes (**P**, **Q**, **R** or **T**) will show a mass increase? Write down a half-reaction to motivate the answer.

(4)

3.3 Write down the NAME or FORMULA of the product formed at:

3.3.1 Electrode **P**

(1)

3.3.2 Electrode **R**

(1)

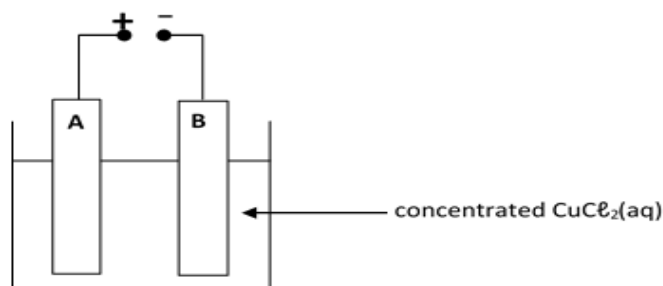
3.4 Fully explain the answer to QUESTION 3.3.2 by referring to the relative strengths of the reducing agents involved.

(3)

[10]

QUESTION 4

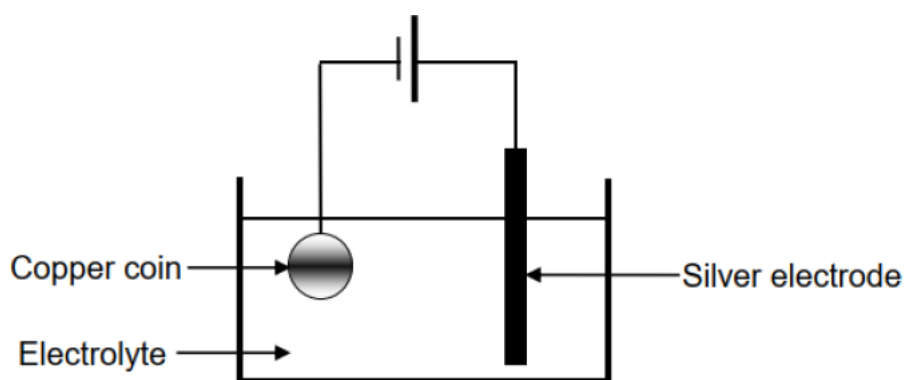
The diagram below represents the apparatus used in the electrolysis of a concentrated CuCl_2 solution. **A** and **B** are two carbon electrodes connected to a power supply.



- 4.1 Which electrode (**A** or **B**) is the anode? (1)
- 4.2 Is the electrolytic process endothermic or exothermic? (1)
- 4.3 Write down THREE observations that can be made during this process. (3)
- 4.4 Write down the overall cell reaction. (3)
- 4.5 Give ONE reason why the salt needs to be in solution in this process. (1)

[9]**QUESTION 5**

The simplified diagram below represents an electrolytic cell used to electroplate a copper (Cu) coin with silver (Ag).



- 5.1 Define the term *electrolysis*. (2)
- 5.2 Which component in the diagram indicates that this is an electrolytic cell? (1)
- 5.3 Write down the NAME or FORMULA of the electrolyte. (1)

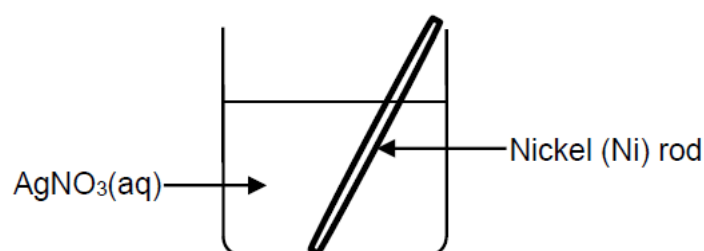
5.4 How will the concentration of the electrolyte change during electroplating? Choose from INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

5.5 Write down the balanced equation of the half-reaction that takes place at the silver electrode. (2)

[8]

QUESTION 6

6.1 A nickel (Ni) rod is placed in a beaker containing a silver nitrate solution, $\text{AgNO}_3(\text{aq})$ and a reaction takes place.

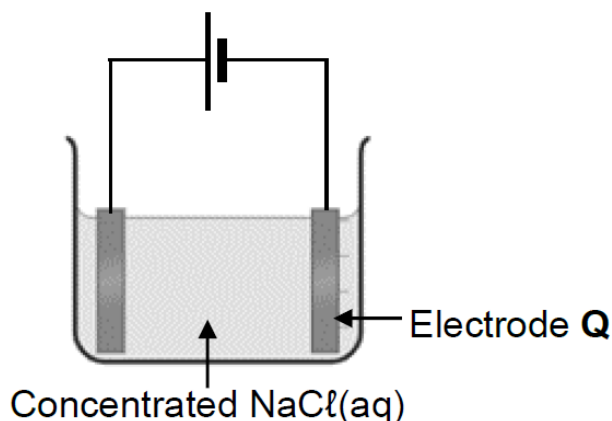


6.1.1 NAME or FORMULA of the electrolyte (1)

6.1.2 Oxidation half-reaction that takes place (2)

6.1.3 Balanced equation for the net (overall) redox reaction that takes place (3)

6.2 The simplified diagram below represents an electrolytic cell. The electrodes are made of carbon.



6.2.1 Define an *electrolyte*. (2)

6.2.2 Write down the oxidation half-reaction that takes place in this cell. (2)

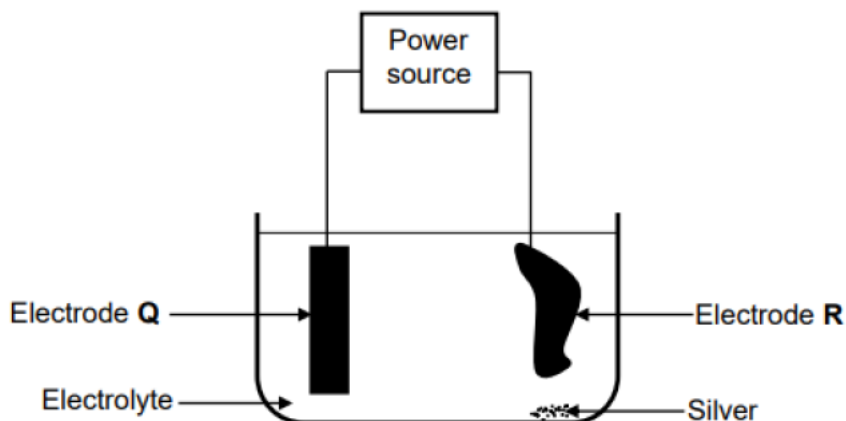
6.2.3 Write down the NAMES or FORMULAE of the products formed at electrode Q. (2)

6.2.4 Explain the answer to QUESTION 9.2.3 by referring to the relative strengths of the oxidising agents involved.

[14]

QUESTION 7

An electrolytic cell is set up to purify a piece of copper that contains silver and zinc as impurities. A simplified diagram of the cell is shown below. Electrode **R** is impure copper.

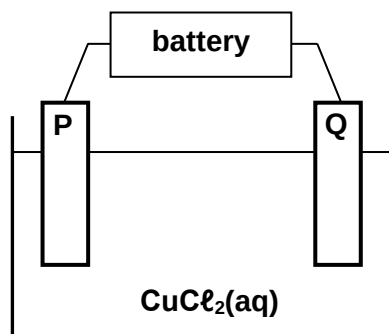


- 7.1 What type of power source is used to drive the reaction in this cell? Write down only AC or DC. (1)
- 7.2 Define the term *electrolysis* (2)
- 7.3 Write down the reaction taking place at electrode Q. (2)
- 7.4 In which direction do the electrons flow in the external circuit? Choose from **Q** to **R** or **R** to **Q**. (1)
- 7.5 Calculate the current needed to form 16 g of copper when the cell operates for five hours. (5)
- 7.6 During this electrolysis, only copper and zinc are oxidised. Give a reason why the silver is not oxidised. (2)

[13]

QUESTION 8

In the electrolytic cell, represented below, two CARBON RODS are used as electrodes and a concentrated copper (II) chloride solution is used as electrolyte.



When the cell is functioning, a gas is released at electrode **P**, whilst electrode **Q** is coated with a reddish-brown layer.

8.1 Define the term *electrolyte*. (2)

8.2 Write down a half-reaction to explain the observation made at:

8.2.1 Electrode **P** (2)

8.2.2 Electrode **Q** (2)

8.3 Which electrode, **P** or **Q**, is the cathode? Give a reason for the answer. (2)

8.4 The carbon rods in the above cell are now replaced with COPPER RODS.

The following observations are made at electrode **P**:

- No gas is released.
- Its surface appears rough and eroded.

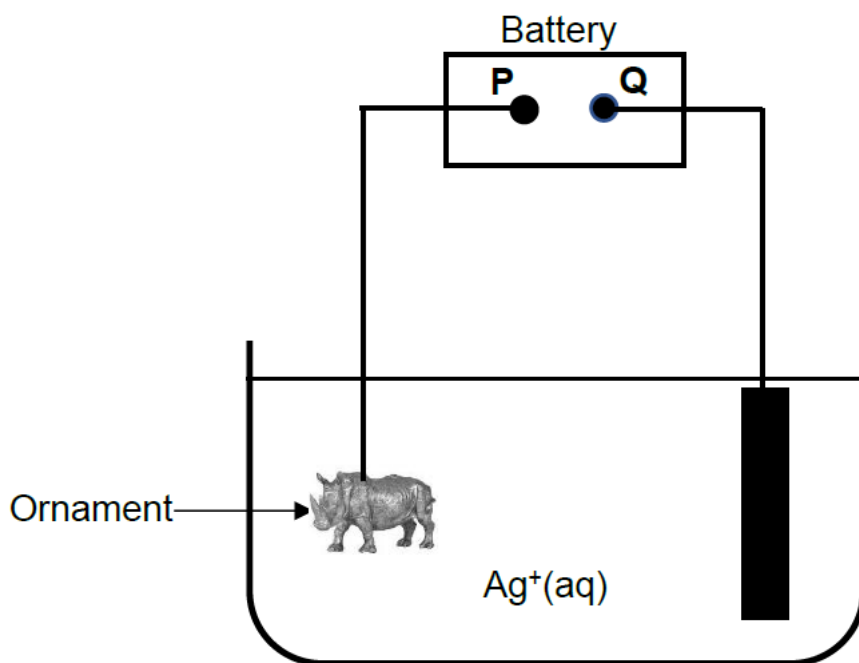
8.4.1 Refer to the RELATIVE STRENGTHS OF REDUCING AGENTS to explain this observation. (3)

8.4.2 This cell can be used for the refining of copper. Which electrode (**P** or **Q**) will be replaced with impure copper during the refining process? (1)

[12]

QUESTION 9

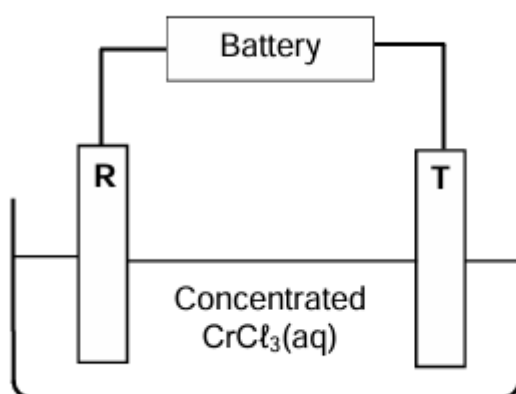
The simplified diagram below represents the cell used for electroplating ornaments with silver, Ag. **P** and **Q** are the two terminals of the battery.



- 9.1 State the energy conversion that takes place in this cell. (1)
- 9.2 Which terminal of the battery (**P** or **Q**) is negative? (1)
- 9.3 Write down the equation for the half-cell reaction that takes place at the cathode. (2)
- 9.4 Calculate the current needed to electroplate the ornament with 3,25 g of silver in 30 minutes. (5)

[9]**QUESTION 10**

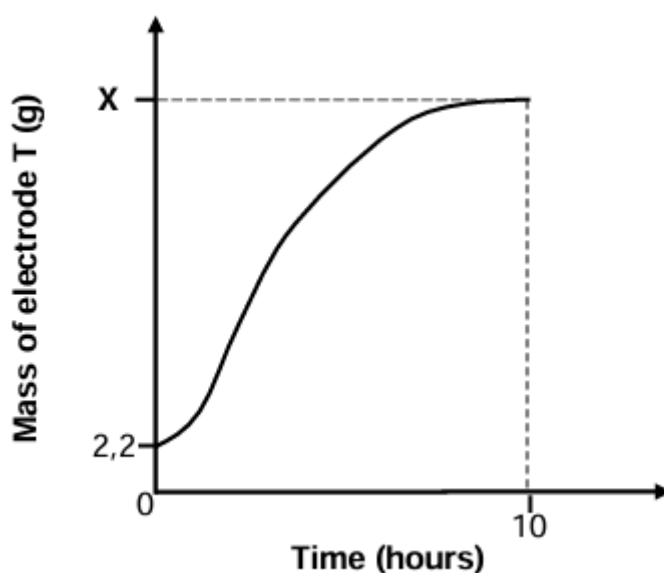
The diagram below represents a simplified cell used for the electrolysis of CONCENTRATED chromium(III) chloride, $\text{CrCl}_3(\text{aq})$. Electrodes R and T are made of carbon.



The net cell reaction is: $2\text{CrCl}_3(\text{aq}) \rightarrow 2\text{Cr}(\text{s}) + 3\text{Cl}_2(\text{g})$

10.1 Define the term electrolysis. (2)

10.2 The graph below, NOT drawn to scale, represents the changes in the mass of electrode T during electrolysis.



10.2.1 Write down the half-reaction that takes place at electrode T. (2)

A current of 2,5 A passes through the cell for 10 hours. Calculate the:

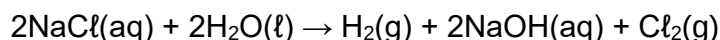
10.2.2 Value of X as shown on the graph (7)

[11]

QUESTION 11

Chlorine is produced industrially by the electrolysis of a concentrated sodium chloride solution, $\text{NaCl}(\text{aq})$.

The balanced equation for the net (overall) cell reaction is as follows:



11.1 Define the term electrolysis. (2)

11.2 For the above reaction, write down the:

11.2.1 Half-reaction that takes place at the anode (2)

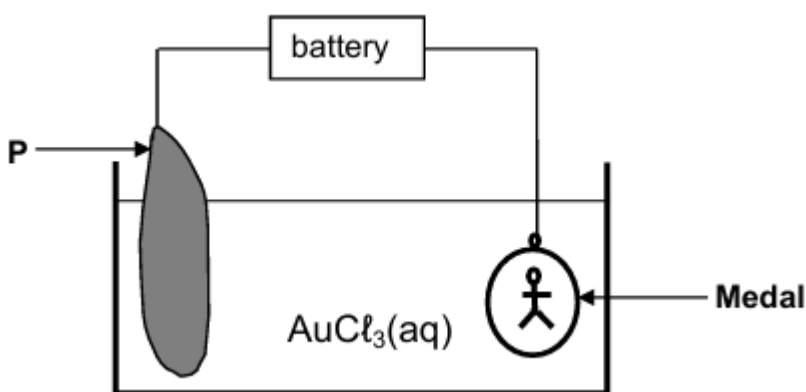
9.2.2 NAME or FORMULA of the oxidising agent (1)

11.3 Refer to the Table of Standard Reduction Potentials to explain why sodium ions are not reduced during this process. (3)

- 11.4 Is the solution in the cell ACIDIC or ALKALINE (BASIC) after completion of the reaction? Support your answer using a relevant equation. (3)
- 11.5 How will the mass of the electrodes during the electrolysis? Choose from INCREASES, DECREASES or REMAIN THE SAME. Explain your answer. (2)

[13]**QUESTION 12**

The simplified diagram below represents a cell used to electroplate an iron medal with a thin layer of gold.

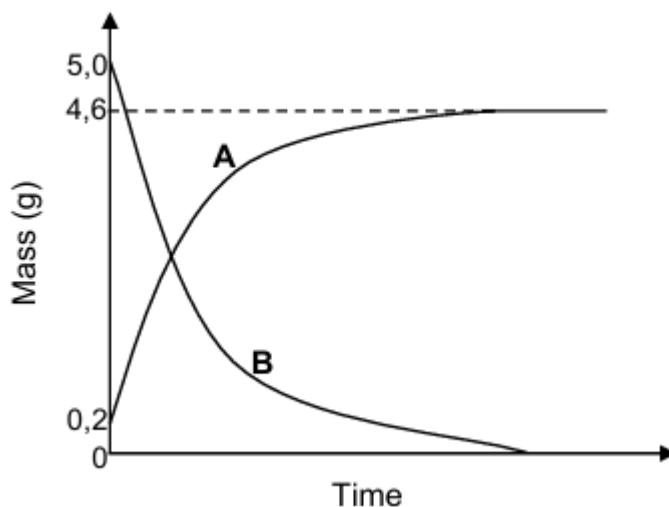


- 12.1 Is this an ELECTROLYTIC or a GALVANIC cell? (1)
- 12.2 Which electrode, P or the Medal, is the anode? (1)
- 12.3 Write down the:
- 12.3.1 Half-reaction that takes place at electrode P (2)
 - 12.3.2 Oxidation number of gold (Au) in the electrolyte (1)
 - 12.3.3 Energy change that takes place in this cell (1)
 - 12.3.4 Visible change that occurs on electrode P after the cell functions for a while (1)
- 12.4 Besides improving appearance, state ONE other reason why the medal is electroplated. (1)
- 12.5 State ONE of the two possible changes that should be made to the cell above to electroplate the medal with silver instead of gold. (1)

[9]

QUESTION 13

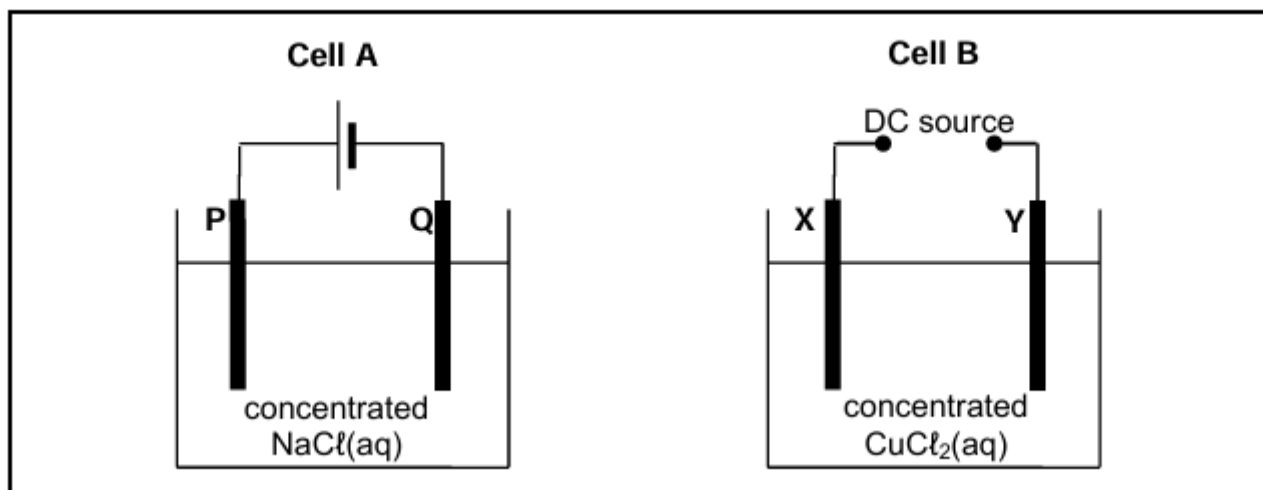
The graph below represents the changes in mass that occur at electrode A and electrode B in an electrolytic cell during the purification of copper.



- 13.1 Which graph, A or B, represents the change in mass of the anode during electrolysis? Give a reason for your answer. (2)
- 13.2 Write down the equation of the half-reaction which takes place at the cathode of this cell. (2)
- 13.3 Use the information in the graph and calculate the percentage purity of the impure copper. (4)
- 13.4 Calculate the amount of charge transferred during the purification of copper. (4)
- 13.5 Hence calculate the current needed to purify the copper in 30 minutes (3)

QUESTION 14

The diagrams below represent two electrochemical cells. P, Q, X and Y are carbon electrodes.



When cell B is functioning, the mass of electrode X increases.

- 14.1` What type of electrochemical cell, GALVANIC or ELECTROLYTIC, is illustrated above? Give a reason for your answer. (2)
- 14.2 Write down the half-reaction that takes place at electrode Q. (2)
- 14.3 The products formed in the two cells are compared.
- 14.3.1 Name ONE substance that is produced in BOTH cells. (1)
- 14.3.2 Write down the LETTERS of the TWO electrodes where this product is formed. Choose from P, Q, X and Y. Support your answer using a relevant equation. (4)
- 14.4 Besides gas bubbles write down other observable change at electrode P (1)
- 14.5 Is electrode X the CATHODE or the ANODE? Give a reason for the answer. (1)
- 14.6 Write down the net (overall) cell reaction that takes place in cell B. (3)
- 14.7 How will the concentration of the electrolyte in cell B change? Choose from INCREASES, DECREASES or REMAIN THE SAME. Explain your answer. (2)

[16]

**DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 2 (CHEMISTRY)**

**GEGEWENS VIR FISIESTE WETENSKAPPE GRAAD 12
VRAESTEL 2 (CHEMIE)**

TABLE 1: PHYSICAL CONSTANTS/TABEL 1: FISIESTE KONSTANTES

NAME/NAAM	SYMBOL/SIMBOOL	VALUE/WAARDE
Standard pressure <i>Standaarddruk</i>	p^{θ}	$1,013 \times 10^5 \text{ Pa}$
Molar gas volume at STP <i>Molêre gasvolume by STD</i>	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature <i>Standaardtemperatuur</i>	T^{θ}	273 K
Charge on electron <i>Lading op elektron</i>	e	$-1,6 \times 10^{-19} \text{ C}$
Avogadro's constant <i>Avogadro-konstante</i>	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$

TABLE 2: FORMULAE/TABEL 2: FORMULES

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$c = \frac{n}{V}$ or/of $c = \frac{m}{MV}$	$n = \frac{V}{V_m}$
$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$	$\text{pH} = -\log[\text{H}_3\text{O}^+]$
$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ at/by } 298 \text{ K}$	
$E_{\text{cell}}^{\theta} = E_{\text{cathode}}^{\theta} - E_{\text{anode}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{katode}}^{\theta} - E_{\text{anode}}^{\theta}$ or/of $E_{\text{cell}}^{\theta} = E_{\text{reduction}}^{\theta} - E_{\text{oxidation}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{reduksie}}^{\theta} - E_{\text{oksidasie}}^{\theta}$ or/of $E_{\text{cell}}^{\theta} = E_{\text{oxidising agent}}^{\theta} - E_{\text{reducing agent}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{oksideermiddel}}^{\theta} - E_{\text{reduseermiddel}}^{\theta}$	
$I = \frac{Q}{\Delta t}$	$n = \frac{Q}{q_e}$ where n is the number of electrons/ waar n die aantal elektrone is

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TABLE 3: THE PERIODIC TABLE OF ELEMENTS
TABEL 3: DIE PERIODIEKE TABEL VAN ELEMENTE

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9																10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24																18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 1,6 Nb 92	42 1,8 Mo 96	43 1,9 Tc 98	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 1,3 La 139	72 1,6 Hf 179	73 1,6 Ta 181	74 1,8 W 184	75 1,8 Re 186	76 2,2 Os 190	77 2,2 Ir 192	78 2,2 Pt 195	79 1,9 Au 197	80 1,8 Hg 201	81 1,8 Tl 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po 209	85 2,5 At 210	86 Rn 222
87 0,7 Fr 223	88 0,9 Ra 226	89 1,3 Ac 227															
58 Ce 140	59 Pr 141	60 Nd 144	61 Pm 147	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175				
90 Th 232	91 Pa 231	92 U 238	93 Np 237	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262				

KEY/SLEUTEL

Atomic number
Atoomgetal

Electronegativity
Elektronegatiwiteit

Approximate relative atomic mass
Benaderde relatiewe atoommassa

Symbol
Simbool

TABLE 4A: STANDARD REDUCTION POTENTIALS
TABEL 4A: STANDAARD-REDUKSIEPOTENSIALE

Half-reactions/Halfreaksies	E° (V)
$F_2(g) + 2e^- \rightleftharpoons 2F^-$	+ 2,87
$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+ 1,81
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1,77
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+ 1,51
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-$	+ 1,36
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+ 1,33
$O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+ 1,23
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	+ 1,23
$Pt^{2+} + 2e^- \rightleftharpoons Pt$	+ 1,20
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-$	+ 1,07
$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	+ 0,96
$Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$	+ 0,85
$Ag^+ + e^- \rightleftharpoons Ag$	+ 0,80
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2(g) + H_2O$	+ 0,80
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+ 0,77
$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+ 0,68
$I_2 + 2e^- \rightleftharpoons 2I^-$	+ 0,54
$Cu^+ + e^- \rightleftharpoons Cu$	+ 0,52
$SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$	+ 0,45
$2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$	+ 0,40
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+ 0,34
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+ 0,16
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+ 0,15
$S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$	+ 0,14
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	0,00
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	- 0,06
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	- 0,13
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	- 0,14
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	- 0,27
$Co^{2+} + 2e^- \rightleftharpoons Co$	- 0,28
$Cd^{2+} + 2e^- \rightleftharpoons Cd$	- 0,40
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	- 0,41
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	- 0,44
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	- 0,74
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	- 0,76
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	- 0,83
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	- 0,91
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	- 1,18
$Al^{3+} + 3e^- \rightleftharpoons Al$	- 1,66
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	- 2,36
$Na^+ + e^- \rightleftharpoons Na$	- 2,71
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	- 2,87
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	- 2,89
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	- 2,90
$Cs^+ + e^- \rightleftharpoons Cs$	- 2,92
$K^+ + e^- \rightleftharpoons K$	- 2,93
$Li^+ + e^- \rightleftharpoons Li$	- 3,05

Increasing strength of oxidising agents /Toenemende sterkte van oksideermiddels

Increasing strength of reducing agents /Toenemende sterkte van reduceermiddels

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TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARD-REDUKSIEPOTENSIALE

Half-reactions/Halfreaksies	E°(V)
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$	-3,05
$\text{K}^+ + \text{e}^- \rightleftharpoons \text{K}$	-2,93
$\text{Cs}^+ + \text{e}^- \rightleftharpoons \text{Cs}$	-2,92
$\text{Ba}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ba}$	-2,90
$\text{Sr}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sr}$	-2,89
$\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca}$	-2,87
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$	-2,71
$\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$	-2,36
$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$	-1,66
$\text{Mn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mn}$	-1,18
$\text{Cr}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cr}$	-0,91
$2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-$	-0,83
$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$	-0,76
$\text{Cr}^{3+} + 3\text{e}^- \rightleftharpoons \text{Cr}$	-0,74
$\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe}$	-0,44
$\text{Cr}^{3+} + \text{e}^- \rightleftharpoons \text{Cr}^{2+}$	-0,41
$\text{Cd}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cd}$	-0,40
$\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$	-0,28
$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$	-0,27
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	-0,14
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$	-0,13
$\text{Fe}^{3+} + 3\text{e}^- \rightleftharpoons \text{Fe}$	-0,06
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0,00
$\text{S} + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0,14
$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}$	+0,15
$\text{Cu}^{2+} + \text{e}^- \rightleftharpoons \text{Cu}^+$	+0,16
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17
$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$	+0,34
$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$	+0,40
$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{S} + 2\text{H}_2\text{O}$	+0,45
$\text{Cu}^+ + \text{e}^- \rightleftharpoons \text{Cu}$	+0,52
$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$	+0,54
$\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2$	+0,68
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0,77
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}$	+0,80
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	+0,80
$\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}(\text{l})$	+0,85
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0,96
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	+1,07
$\text{Pt}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pt}$	+1,20
$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1,23
$\text{O}_2(\text{g}) + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1,23
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1,33
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1,36
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1,51
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1,77
$\text{Co}^{3+} + \text{e}^- \rightleftharpoons \text{Co}^{2+}$	+1,81
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-$	+2,87

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Increasing strength of reducing agents / Toenemende sterkte van reduseermiddels

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