

29. PHYSICAL SCIENCES (Updated September 2024)

A. MEANS OF ASSESSMENT

Paper 1	3 hours	200 marks (scaled to 150 marks)
Paper 2	3 hours	200 marks (scaled to 150 marks)
School-Based Assessment (SBA)		100 marks

400 marks

B. REQUIREMENTS

1. Examination

- Assessment tasks and questions will be based on the Subject Assessment Syllabus as outlined in Section E of this document.
- There will be two examination papers that will be written on different days.
- A variety of questioning styles will be employed in the final examination with a maximum of 10% of the marks being in the multiple-choice format.

WEIGHTING OF KNOWLEDGE AREAS

Table 1 – Physical Sciences Paper I (Physics)

Content Areas	Approximate Marks (± 10 marks)	Approximate % ($\pm 5\%$)
Kinematics (Motion in 1D)	50	25
Newton's Laws and Applications of Newton's Laws	30	15
Momentum, Impulse, Work, Energy and Power	30	15
Gravitational and Electric Fields	20	10
Electric Circuits	30	15
Electrodynamics	24	12
Photons and Electrons	16	8

Table 2 – Physical Sciences Paper II (Chemistry)

Content Areas	Approximate Marks (± 10 marks)	Approximate % ($\pm 5\%$)
Quantitative Chemistry	30	15
Chemical Bonding	20	10
Energy Change & Rates of Reactions	20	10
Chemical Equilibrium	25	12,5
Acids and Bases	25	12,5
Electrochemistry	40	20
Organic	40	20

Table 3.1 – Weighting of Examination according to Taxonomy of Cognitive Levels

Level	Description	Paper I Physics (%)	Paper II Chemistry (%)
1	Knowledge and Recall	15	15
2	Comprehensions and Routine Exercises	35	40
3	Application and Analysis	40	35
4	Synthesis and Evaluation	10	10

Information Pamphlet (Data Sheet)

Included with each of the Question Papers is a booklet containing the following information: Formulae and Equations, Physical Constants, Standard Electrode Potentials and Half-Reactions & the Periodic Table of Elements including electronegativity values.

N.B. Formulae and equations could be included for two reasons:

- (a) To be used in the numerical calculation of physical quantities.
- (b) To illustrate, in symbolic form, a scientific law or principle that should be known and applied verbally in the answer to a question.

Table 3.2 – Physical Sciences Assessment Taxonomy

COGNITIVE LEVEL	DOMAIN	EXPLANATION	EXAMPLE IN PHYSICAL SCIENCES	DISCUSSION
4	SYNTHESIS & EVALUATION	A question that requires a learner to synthesise their knowledge of a range of concepts, and to use this to evaluate some scenario would be classified as an evaluation/synthesis question.	Given a labelled diagram of a car and a truck travelling towards one another at the same speed; the truck has twice the mass of the car. Question: On impact the car exerts a force of magnitude F on the truck and experiences an acceleration of magnitude a . Both drivers are wearing identical seat belts. Which driver is likely to be more severely injured on impact? Explain the answer by referring to acceleration and velocity.	This question requires learners to analyse the diagram and evaluate the given scenario and to synthesise their knowledge of force, momentum, acceleration and velocity.

3			When given a rate vs time graph showing forward and reverse reactions for the ionisation of an acid, determine the effect of a change shown on the graph on the pH of the solution.	This question requires learners to analyse the graph and to synthesise their knowledge of reaction rates, chemical equilibrium, acids and bases and the relationship between pH and $[H_3O^+]$.
			A multi-step calculation without any scaffolding: <u>Physics</u> : A calculation requiring learners to set up simultaneous equations to calculate two unknown quantities. <u>Chemistry</u> : A K_c problem where the value of K_c is given and the initial number of moles of a reactant must be calculated.	These calculations require learners to evaluate and analyse the given information and to synthesise their knowledge in order to determine how to solve the problem.
			Explanations involving analysis of a diagram, graph or text and applying knowledge in a new context: <u>Physics</u> : Explaining how a microphone works. (IEB Nov 2015) <u>Chemistry</u> : Explaining why aluminium cannot be produced at the cathode from the electrolysis of an aqueous solution of Al^{3+} ions. (IEB Nov 2016)	These explanations require learners to evaluate and analyse the given information and to synthesise their knowledge in order to determine how to solve the problem.
	APPLICATION & ANALYSIS	A question that requires a learner to analyse and interpret a given situation, in the form of a description or a diagram , would be classified as an analysis/application question.	When given a circuit diagram determine the effect on the reading on the voltmeter across the cells (with internal resistance) if a change is made to the external circuit.	Although this question involves some level of recall, and also some comprehension of the concepts involved, the cognitive process involved in analysing the situation is a higher-order skill.
		A question that requires a learner to apply their knowledge in a given scenario would be classified as an analysis/application question.	Given a labelled diagram of a galvanic cell (metals given but polarity and anode/cathode NOT labelled), determine the emf of the cell under standard conditions.	The cognitive process involved in application of their knowledge to the scenario is a higher-order skill.
		A question that requires a learner to analyse a given scenario, diagram or structure, and to apply their knowledge would be classified as an analysis/application question.	When given the structural formula of an ester write down the IUPAC name.	The cognitive process involved in analysis and in application of their knowledge to the given scenario is a higher-order skill.
		Two- or three-step calculations (routine).	A "pendulum" type collision involving conservation of momentum and mechanical energy to find maximum height.	The cognitive process involved in analysis and in application of their knowledge to the given scenario is a higher-order skill.

		Explanations of physical properties.	Explain why butane has a higher boiling point than methyl propane.	Need to apply knowledge of the factors influencing the strength of intermolecular forces to boiling points.
2	COMPREHENSION	A question that requires a learner to explain the reason behind some observation or phenomenon would be classified as a comprehension question.	Explain why the reaction rate between zinc and HCl increases when the concentration of acid increases.	The cognitive process involved in providing the explanation is a higher-order skill, and thus the question would be categorised as a comprehension question.
		A question that requires a learner to demonstrate their understanding of scientific concepts and the relationship between them is a comprehension question.	State how the speed of photoelectrons emitted changes when the frequency of the incident radiation is increased.	The cognitive process involved in understanding the relationships between the concepts is a higher-order skill.
		A question that requires a learner to demonstrate their understanding of the scientific method is a comprehension question.	When given information about a scientific investigation ... <ul style="list-style-type: none"> Identify the independent and dependent variables Draw a conclusion Read a value off a graph 	Learners need to understand/comprehend the scientific method, and to identify variables, trends and relationships.
		One-step calculations.	Calculate the current if the voltage is 2 V and the resistance is 4 Ω .	Learners need to select appropriate formulae and half-reactions from their data sheets and need to understand how to use them correctly.
		Writing (routine) chemical equations.	Use the SEP table to write a half-equation for the anode reaction. Write a balanced chemical equation for the ionisation of HCl.	
1	RECALL	A question requiring learners to provide a word or phrase, a definition, or a learned description of a scientific phenomenon , would be a recall question.	Define acceleration. Name the component in the direct current electric motor which ensures continuous rotation of the coil in one direction.	These questions are categorised as recall because they involve straightforward memorisation and recall .
		A question involving identification of chemical species, categorisation and naming would be a recall question.	Give the chemical symbol of the carbonate ion. Name the homologous series to which the following pair of compounds belongs: CH ₃ COOH and CH ₃ (CH ₂)COOH.	

RECORDING AND REPORTING

Table 4 – Assessment tasks are reported against a seven-point rating scale:

RATING CODE	RATING	MARKS %
7	Outstanding achievement	80–100
6	Meritorious achievement	70–79
5	Substantial achievement	60–69
4	Adequate achievement	50–59
3	Moderate achievement	40–49
2	Elementary achievement	30–39
1	Not achieved	0–29

2. School-Based Assessment (SBA)

School-based assessment comprises 25% of the total assessment for the National Senior Certificate. The minimum requirements for the school-based component of the National Senior Certificate assessment are outlined in Table 5. Where schools are able to do more than the minimum requirements then the learners may select their best work for the learner file. However, where there is a choice, the tasks should be of a comparable standard.

All schools must make available the SBA evidence of all learners should it be required by IEB or Umalusi.

These Subject Assessment Guidelines must be read in conjunction with the IEB Manual for the Moderation of School-Based Assessment available at www.ieb.co.za.

Table 5 – SBA Requirements for Grade 12

Task	Time	Percentages
*2 Practical investigations (1 Physics focus; 1 Chemistry focus)	Minimum 2 hours each	2 × 15 = 30
Controlled test (Physics focus) Controlled test (Chemistry focus) <i>N.B. midyear examinations may be used</i> <i>N.B. Alternative Assessment (task) may be used in place of one test</i> <i>N.B. There must be 1 Physics focus and 1 Chemistry focus irrespective of your choice (task/test)</i>	Minimum 40 minutes each	2 × 15 = 30
Preliminary examinations	3 hours each	2 × 20 = 40
Total marks:		100

*Where applicable, there may be revisions to the method of delivery to ensure social distancing e.g., simulations.

Controlled Tests and Examinations

Controlled tests (minimum 40 minutes) and examinations are written under controlled conditions within a specified period of time. Questions in tests and examinations should assess performance at different cognitive levels. Tests may cover a specific topic or a number of topics. Preliminary examinations must mimic the final examination as closely as possible and cover almost all the prescribed topics.

Practical Investigations and the Alternative Assessment

Learners need to spend a minimum of 2 hours on each of the practical investigations and a minimum of 1 hour on the Alternative Assessment. There needs to be contact time between the learners and the teacher to facilitate guidance, support and monitoring of the achievement of specific targets.

These interactions create opportunities for teachers to:

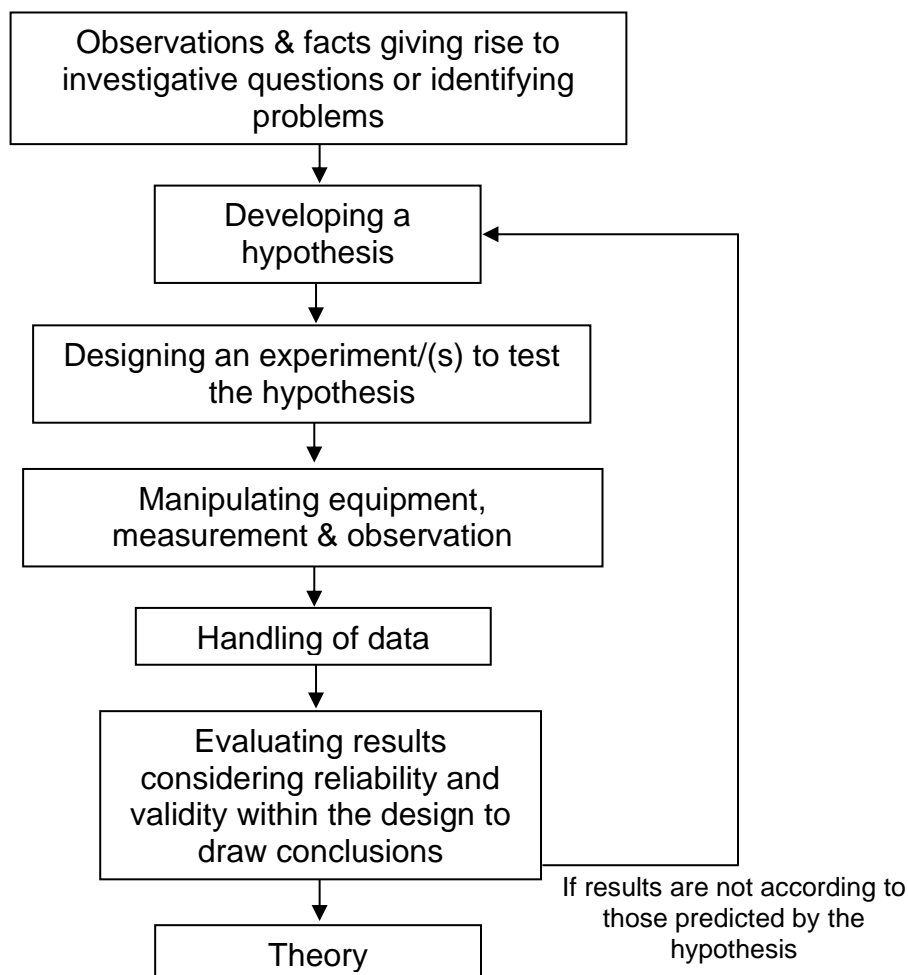
- check for plagiarism (for example by using oral questioning)
- carry out formative assessment
- monitor progress

The teacher should guard against marking the task at these times, but should question the learner about the project and respond to queries initiated by the learner. Marking occurs once, only when the task is finally submitted.

Practical investigations

The new FET focuses on teaching and assessing in an investigative approach.

A very simplified perspective of the investigative approach is represented in the flow chart that follows:



The investigations are expected to take a minimum of 2 hours. Investigations, where possible, should include the use of physical equipment.

The following is suggested as a guide to what should be assessed in a balanced way (according to cognitive levels) across an investigation.

1. Developing a hypothesis. This could include:
 - formulating a question that can be investigated.
 - combining scientific ideas with observations or recorded facts.
 - making predictions based on available knowledge and observations.
 - writing a statement of the hypothesis.
2. Manipulation of equipment, measurement and observations. This could include:
 - correct choice of equipment.
 - ability to read scales accurately.
 - safe use of equipment.
 - meaningful observations.
3. Planning and designing. This could include:
 - identifying variables to be measured and controlled.
 - organising activities in an appropriate sequence.
 - recognising whether or not an experiment is valid. (Will the results answer the investigative question?)
 - recognising the importance of the reliability of results and planning accordingly. (Are the sample size and number of readings sufficient?)
4. Presentation of data. This could include:
 - tabulating.
 - graphing.
 - use of data loggers and other software.
5. Analysing, concluding and evaluating. This could include:
 - weighing advantages and disadvantages.
 - drawing appropriate conclusions that address the hypothesis or questions.
 - making/evaluating general conclusions that go beyond the experimental or given conditions.
 - analysing problems to determine the relevant relationships, concepts, and problem-solving steps.
6. Communicating and presenting information. This could include:
 - a written report.
 - a model.
 - a role-play, song, dance, speech or presentation.
 - a poster.

Alternative Assessment

This item in the portfolio allows for creativity and opportunities to allow learners to do something unconventional. The Alternative Assessment is an ideal opportunity to extend learners. The Alternative Assessment is expected to take a minimum of 1 hour.

Appropriate referencing must be emphasised in this task.

Suggestions for Alternative Assessment tasks:

1. **Debate, discussion, short essay, e.g. on ethical issues in science**

The website www.peep.ac.uk has many ideas to engage learners in discussions and critical thinking about the impact of science on everyday life. Two to four topical articles can be provided as a resource to stimulate the debate, discussion or short essay.

2. **Translation task**

Given an article from a scientific magazine, journal, newspaper or video clip, analyse, discuss and/or answer questions and solve problems related to it.

3. **Experiment**

An experiment is a less demanding practical activity than a practical investigation in the following ways:

- The investigative question is posed for the learners.
- The procedure (method) may be stated as a series of instructions to the learners.
- The activity is set to take a minimum of 1 hour (and a maximum of 2 hours).

The recording of results, analysis and manipulation of data to draw conclusions remain as specified for a practical investigation.

The cognitive demands of this task should include all levels of performance (Levels 1–4).

4. **Simulations or video data reviews**

There are a number of simulations and recorded physics-in-action videos available online. These can be analysed and interpreted to create a meaningful Alternative Assessment.

5. **Metacognitive task**

Tasks that ask candidates to set a test, prepare marking guidelines, and/or analyse answers for misconceptions can be used as an Alternative Assessment.

Table 6 – An example of the Formal Programme of Assessment

SCHOOL-BASED ASSESSMENT (25%)			EXTERNAL ASSESSMENT (75%)
Practical Investigation (Physics Focus)	Practical Investigation (Chemistry Focus)	Alternative Assessment (Physics or Chemistry Focus)	Final Examinations
Midyear Examinations or 2 Controlled Tests		Preliminary Examinations	

Additional explanatory comments

- Table 6 describes the Formal Programme of Assessment and includes only summative assessment. However, formative assessment is integral to teaching and learning. It should take place regularly. In this process teachers will set many more tasks than are required for the SBA as described in Table 6 above. This is to the advantage of their learners. However, teachers may only submit the tasks requested in Table 5 and only these tasks can be taken into account when teachers calculate the SBA mark.
- Learner Files should be transferred with a learner from one school to another.
- The final SBA mark should be reported as a percentage.

Moderation of the assessment tasks in the Programme of Assessment

Table 7

Level	Moderation Requirements
School	<p>The Formal Programme of Assessment should be monitored at the beginning of the year to ensure compliance with requirements. Each task which is to be used as part of the Formal Programme of Assessment should be moderated before learners attempt the task. Teacher and learner files should be monitored for compliance before submission for cluster moderation. Learners and teachers must sign a letter of authenticity to be included in the learner file. The principal signs a letter, to be included in the teacher file, stating that appropriate moderation has taken place at school level.</p>
Cluster	<p>Teachers are required to attend two cluster meetings per year, the first before 15 March and the second by 15 September. The Formal Programme of Assessment should be monitored at the first meeting to ensure compliance with requirements and proposed tasks discussed to ensure they are of an appropriate standard. The second meeting should be used to complete cluster moderation of files. Portfolios may still be missing an item or two at this cluster meeting. It is suggested that the teachers discuss the tasks that they have set, the standard of those tasks and how they were marked. The second meeting is also an opportunity to share resources so that schools in a cluster can maintain a common standard.</p>
IEB	<p>Following the second cluster meeting, some schools/subjects may be regionally moderated by a moderator appointed by the IEB. A school which has been regionally moderated may not need to send portfolios for National moderation, unless either a particular problem is identified or the files are selected randomly. Complete portfolios must be submitted to Regional Moderators by mid-October.</p> <p>During the December National Senior Certificate marking session a moderating committee, appointed by the IEB, under the leadership of a National Moderator, carries out the following checks:</p> <ul style="list-style-type: none"> • monitors the teacher file and the sample of learner files (if requested), prescribed by the IEB, for compliance, from each examination centre. • monitors the standard of the SBA tasks. • moderates a sample of learner tasks (the standard of the marking is checked) to ensure comparable standards across centres across the IEB. • completes a report on the SBA work of each centre. A copy of this report is returned to the centre. • recommends mark changes to the IEB if the marks allocated for school-based assessment at a particular centre do not reflect an appropriate standard of performance.

Learner's File

- Each learner must be able to produce all the work as listed in Table 5. This work is evidence of the learner's performance and justification for the marks the learner has been allocated for SBA. This work must be collected together in some convenient format that is neither expensive nor bulky. A flat folder or file or even a set of 'treasury tags' to bind the sheets together, will suffice. This folder of work constitutes the learner's file and must be available for moderation if called for by the IEB.
- For performances or the production of models, or any other situation where it is not possible to keep the products of the task, the task assessment sheet should be retained in the file. The assessment sheet in such cases should list the criteria against which the learner was assessed and give details of the performance (marks). Photographic evidence can be included.
- All the tasks in the file must be in the same sequence as the task sheets in the teacher's file for ease of moderation.
- The first page (Appendix B) in each file must give the centre number, the learner's examination number and include an index of tasks and the mark allocation for the tasks.
- The declaration of authenticity (see Appendix B) must be completed and included as the second page of the file. Ideally, candidates should complete Appendix B themselves as this provides a further check.

Teacher's File

- Each school must submit one subject file containing the compulsory SBA requirements.
- The teacher's file must include all summative assessment task sheets or question papers with marking schemes, rubrics and marking guidelines (tests and examinations), as applicable.
- Preliminary examinations must include an Appendix A (Task Planning Sheet). Other tasks do not require an Appendix A.
- Evidence of moderation must be included for the preliminary examinations. (Evidence of moderation of all other SBA requirements must be kept at school level and available if requested for external moderation processes.)
- Teachers are expected to reference their sources on all of their Tasks and Tests.
- The teacher's file must also include a mark sheet (Appendix E) to provide evidence of all the individual marks that contribute to each component for each candidate described in Table 5. The final SBA mark should also be given as a percentage. The documentation must make it clear how the final percentage was determined. The raw score, percentage and weighted score for each task should be recorded in the mark sheet.

Learner Absence

- Learners should be given an opportunity to make up missed tasks. If necessary, an equivalent task can be done.
- An authentic reason in writing, i.e. a doctor's letter, should be produced if a learner misses an SBA task.

C. ADMINISTRATIVE AND SUPPORT DOCUMENTATION

1. Appendix A: Task Planning Sheet
2. Appendix B: SBA Cover Sheet and Declaration of Authenticity
3. Appendix C: Sample Moderation Checklist
4. Appendix D: Letter from the Principal
5. Appendix E: Summary Mark Sheet
6. Appendix F: Teacher Support Checklist (not for moderation purposes)

1. APPENDIX A: TASK PLANNING SHEET



NATIONAL SENIOR CERTIFICATE EXAMINATION

PHYSICAL SCIENCES

APPENDIX A

SAMPLE PHYSICAL SCIENCES TASK PLANNING SHEET

Title of Task		Date		
Content Knowledge				
TASK TYPE:	Place a cross in the appropriate box			
	Alternative Assessment	Physics Practical Investigation	Chemistry Practical Investigation	Controlled Test
	Examination			

Question	Topic(s) – please list	Cognitive level (for tests and examinations only)			
		1	2	3	4
Total Actual Mark					
Total maximum marks for the task					
Target % (see SAGs)					
Target Mark					
(Mark)-(Target)					

2. APPENDIX B: SBA COVER SHEET AND DECLARATION OF AUTHENTICITY



**NATIONAL SENIOR CERTIFICATE EXAMINATION
PHYSICAL SCIENCES LEARNER FILE COVER SHEET
DECLARATION OF AUTHENTICITY**

CENTRE NO. **CANDIDATE'S NO.**

NAME OF CANDIDATE: _____

NAME OF TEACHER: _____

Component	Task	Date	Out of	Mark	%	Weight	Calc. Value
Investigations	1. Physics Practical					15%	
	2. Chemistry Practical					15%	
Test/Task	1. Physics					15%	
Test/Task	2. Chemistry					15%	
Examination	Paper I: Physics					20%	
Examination	Paper II: Chemistry					20%	
FINAL MARK						100%	

DECLARATION BY THE CANDIDATE:

I, _____ (print full names)

declare that all external sources used in my Learner File have been properly referenced and that the remaining work contained in this portfolio is my own original work. I understand that if this is found to be untrue, I am liable for disqualification from the National Senior Certificate.

Signed: _____ Date: _____
Candidate

DECLARATION BY THE CANDIDATE'S TEACHER:

I _____ (print name and title of teacher) at

_____ (print name of school) declare that the work provided by this candidate has been monitored and checked for plagiarism.

Signed: _____ Date: _____
Teacher

3. APPENDIX C: SAMPLE MODERATION CHECKLIST



NATIONAL SENIOR CERTIFICATE EXAMINATION PHYSICAL SCIENCES

SAMPLE MODERATION CHECKLIST FOR REGIONAL OR NATIONAL MODERATION

To be completed and returned to the school

EXAMINATION CENTRE NUMBER: _____

Please present teacher portfolios in ring files or lever arch files. Please use dividers to separate sections and do not use plastic folders.

Records	Yes	No	Comment (if required)
Appendix D: letter from principal			
Internal mark sheet including:			
Raw score for each task			
Percentage for each task			
Weighted total for each task			
Total of 6 weighted tasks			
Accurate aggregation of marks			
Internal mark sheets – alphabetical results (Appendix E)			
IEB mark sheets – alphabetical results and rank order			
Marks on all mark sheets correlate			

Tasks set and moderated according to requirements	Task	Memo or rubric	*Evidence of moderation	Appropriate standard	Analysis grid
Physics investigation					
Chemistry investigation					
Physics controlled test/Alternative assessment					
Chemistry controlled test/Alternative assessment					
Physics preliminary examination (must include Appendix A)					
Chemistry preliminary examination (must include Appendix A)					

**Evidence of moderation of ALL tasks must be kept at school level and available if requested for external moderation processes.*

Only if learner files have been requested

Learner files should be in flat files with dividers and no plastic folders and no question papers

	Yes	No	Comment (if required)
List of learners requested by IEB			
Learner files supplied according to list from IEB			
Tasks marked in accordance with memorandum			
Appendix B correctly completed and transferred			
All tasks in learner files			

Additional comments (including descriptions of any tasks or questions of particular merit):

Moderator's Signature: _____ **Date:** _____

4. APPENDIX D: LETTER FROM THE PRINCIPAL



**NATIONAL SENIOR CERTIFICATE EXAMINATION
PHYSICAL SCIENCES
A SUGGESTION FOR THE LETTER FROM THE PRINCIPAL**

_____ SCHOOL _____
_____ ADDRESS _____

The IEB
P O Box 875
Highlands North
2037

Dear IEB Moderator

RE: SCHOOL-BASED ASSESSMENT AND MODERATION OF PHYSICAL SCIENCES
SBA IN GRADE 12

We certify that

teachers of the same subject have ensured that	Place a cross in the appropriate box	
they have met regularly to reflect on and discuss issues of standardisation	YES	NO
the assessment tasks they have set learners are of the required standard	YES	NO
the memoranda they have used for marking are accurate and functional	YES	NO
the tasks learners have completed meet the criteria described in the IEB Subject Assessment Guidelines	YES	NO
marking is complete and of the appropriate standard	YES	NO
all administrative procedures have been correctly completed	YES	NO
all information on the 1 st page of the portfolio (Appendix B) in each learner's file is complete and correct	YES	NO

Signed: _____ Date: _____
TEACHER

Signed: _____ Date: _____
PRINCIPAL

5. APPENDIX E: SUMMARY MARK SHEET



NATIONAL SENIOR CERTIFICATE EXAMINATION PHYSICAL SCIENCES

Appendix E: Summary Mark Sheet																					
Record weighted mark to 1 decimal place																					
Year	Exam Number	Name	Physics Investigation			Chemistry Investigation			Physics Test/Task			Chemistry Test/Task			Physics Prelim		Chemistry Prelim		SBA		
Total				100	15		100	15		100	15		100	15		100	20		100	20	100
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6. APPENDIX F: TEACHER SUPPORT CHECKLIST (NOT FOR MODERATION PURPOSES)



NATIONAL SENIOR CERTIFICATE EXAMINATION PHYSICAL SCIENCES SBA TEACHER SUPPORT CHECKLIST

TEACHER FILES

Lever-arch or ring files with dividers and no plastic folders

Appendix D: letter from the principal	
Appendix E: Internal summary mark sheet including: raw score, percentage and weighting for each task and total for 7 weighted tasks	
Computer generated IEB mark sheets: alphabetical results and rank order	
All student Appendix B's including declarations (not essential)	
Physics investigation task	
Physics investigation memo or rubric	
Physics investigation analysis grid (not essential)	
Chemistry investigation task	
Chemistry investigation memo or rubric	
Chemistry investigation analysis grid (not essential)	
Alternative assessment task (optional)	
Alternative assessment memo or rubric	
Alternative task analysis grid (not essential)	
Physics controlled test questions	
Physics controlled test memo	
Physics controlled test analysis grid (not essential)	
Chemistry controlled test questions	
Chemistry controlled test memo	
Chemistry controlled test analysis grid (not essential)	
Physics preliminary examination questions	
Physics preliminary examination memo	
Physics preliminary examination evidence of moderation*	
Physics preliminary examination analysis grid (Appendix A essential)	
Chemistry preliminary examination questions	
Chemistry preliminary examination memo	
Chemistry preliminary examination evidence of moderation*	
Chemistry preliminary examination analysis grid (Appendix A essential)	

* Evidence of moderation of all other SBA tasks must be kept at school level and available if requested for external moderation processes.

ONLY IF LEARNER FILES HAVE BEEN REQUESTED

flat files with dividers and no plastic folders and no question papers

List of learners requested by IEB	
All Learner files supplied according to list from IEB	
Evidence of all tasks in each learner file, in the same order as teacher file	
Appendix B correctly completed and transferred	

D. INTERPRETATION OF REQUIREMENTS

The purpose of the Assessment Syllabus is to assist IEB teachers in reaching a common understanding of the scope of the Curriculum and Assessment Standards (CAPS). The Assessment Syllabus is to make explicit the scaffolding of concepts and the enabling of learning over the grade 11 and grade 12 years. It is all the grade 11 and grade 12 content that is being assessed at the end of the grade 12 year. The Assessment Syllabus clearly enables assessment and supports teachers, assessors and moderators in the Physical Sciences.

EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES (PHYSICS)

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Acceleration due to gravity on Earth	g	$9,8 \text{ m}\cdot\text{s}^{-2}$
Speed of light in a vacuum	c	$3,0 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
Universal gravitational constant	G	$6,7 \times 10^{-11} \text{ N}\cdot\text{m}^2\cdot\text{kg}^{-2}$
Coulomb's constant	k	$9,0 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Planck's constant	h	$6,6 \times 10^{-34} \text{ J}\cdot\text{s}$
1 electron-volt	eV	$1,6 \times 10^{-19} \text{ J}$

TABLE 2 PHYSICS FORMULAE

MOTION

$v = u + at$ or $v_f = v_i + a\Delta t$	$s = \left(\frac{v+u}{2} \right) t$ or $\Delta x = \left(\frac{v_f + v_i}{2} \right) \Delta t$
$v^2 = u^2 + 2as$ or $v_f^2 = v_i^2 + 2a\Delta x$	$s = ut + \frac{1}{2} at^2$ or $\Delta x = v_i \Delta t + \frac{1}{2} a(\Delta t)^2$

FORCE AND MOMENTUM

$F_{net} = ma$	$F_{net} = \frac{\Delta p}{\Delta t}$ or $F_{net}\Delta t = m\Delta v$	$J = \Delta p = mv - mu$ or $J = \Delta p = mv_f - mv_i$
$p = mv$	$F_g = mg$	$F_{fs}^{max} = \mu_s F_N$ $F_{fk} = \mu_k F_N$

WORK, ENERGY AND POWER

$W = Fs$ or $W = F\Delta x$ or $W = F\Delta x \cos\theta$	$P = \frac{W}{t}$	$P = Fv$
$E_p = mgh$	$E_k = \frac{1}{2} mv^2$	$W_{net} = \Delta E_k$
$\% \text{ efficiency} = \frac{\text{power}_{out}}{\text{power}_{in}} \times 100$		

GRAVITATIONAL AND ELECTRIC FIELDS

$F = G \frac{m_1 m_2}{r^2}$	$g = \frac{F}{m}$	$g = G \frac{M}{r^2}$
$F = k \frac{q_1 q_2}{r^2}$	$E = \frac{F}{q}$	$E = k \frac{Q}{r^2}$

ELECTRIC CIRCUITS

$I = \frac{q}{t}$	$V = \frac{W}{q}$
$R = \frac{V}{I}$	$emf = I(R_{ext} + r)$ or $emf = V_{load} + V_{internal\ resistance}$
$R_S = R_1 + R_2 + \dots$	$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
$P = \frac{W}{t} \quad \text{or} \quad W = Pt$	
$W = VIt \quad \text{or} \quad W = I^2 R t \quad \text{or} \quad W = \frac{V^2}{R} t$	
$P = VI \quad \text{or} \quad P = I^2 R \quad \text{or} \quad P = \frac{V^2}{R}$	

ELECTRODYNAMICS

$\Phi = BA \cos \theta$	$emf = -N \frac{\Delta \Phi}{\Delta t}$	$F = IB \ell \sin \theta$
$V_p I_p = V_s I_s$	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$	

PHOTONS AND ELECTRONS

PHOTONIC ELECTRONS		
$c = f \lambda$	$E = hf$	or $E = \frac{hc}{\lambda}$
$E = W_0 + E_{K(max)}$	$W_0 = hf_0$	$E_{K(max)} = \frac{1}{2} m v_{max}^2$

EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES (CHEMISTRY)

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Standard pressure	p^θ	$1,01 \times 10^5 \text{ Pa}$
Molar gas volume at STP	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature	T^θ	$273 \text{ K (0 } ^\circ\text{C)}$
Avogadro's constant	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$
Faraday's constant	F	$96\,500 \text{ C} \cdot \text{mol}^{-1}$

TABLE 2 CHEMISTRY FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_m}$
$c = \frac{n}{V} \quad \text{OR} \quad c = \frac{m}{MV}$	$K_w = [\text{H}_3\text{O}^+] \cdot [\text{OH}^-] = 1 \times 10^{-14}$ at 25 °C (298 K)	
$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$		
$q = It$ $q = nF$	$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$	

TABLE 3 PERIODIC TABLE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 2,1 1 H					Atomic number (Z)	1 2,1 1 H	Electro- negativity										2 4 He
2	3 1,0 7 Li	4 1,5 9 Be											5 2,0 10,8 B	6 2,5 12 C	7 3,0 14 N	8 3,5 16 O	9 4,0 19 F	10 20 Ne
3	11 0,9 23 Na	12 1,2 24,3 Mg											13 1,5 27 Al	14 1,8 28 Si	15 2,1 31 P	16 2,5 32 S	17 3,0 35,5 Cl	18 40 Ar
4	19 0,8 39 K	20 1,0 40 Ca	21 1,3 45 Sc	22 1,5 48 Ti	23 1,6 51 V	24 1,6 52 Cr	25 1,5 55 Mn	26 1,8 56 Fe	27 1,8 59 Co	28 1,8 59 Ni	29 1,9 63,5 Cu	30 1,6 65,4 Zn	31 1,6 70 Ga	32 1,8 72,6 Ge	33 2,0 75 As	34 2,4 79 Se	35 2,8 80 Br	36 84 Kr
5	37 0,8 85,5 Rb	38 1,0 88 Sr	39 1,2 89 Y	40 1,4 91 Zr	41 1,6 93 Nb	42 1,8 96 Mo	43 1,9 99 Tc	44 2,2 101 Ru	45 2,2 103 Rh	46 2,2 106 Pd	47 1,9 108 Ag	48 1,7 112 Cd	49 1,7 115 In	50 1,8 119 Sn	51 1,9 121 Sb	52 2,1 128 Te	53 2,5 127 I	54 131 Xe
6	55 133 Cs	56 137,3 Ba		72 178,5 Hf	73 181 Ta	74 184 W	75 186 Re	76 190 Os	77 192 Ir	78 195 Pt	79 197 Au	80 200,6 Hg	81 204,4 Tl	82 207 Pb	83 209 Bi	84 — Po	85 — At	86 — Rn
7	87 Fr	88 Ra																

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

TABLE 4 STANDARD ELECTRODE POTENTIALS

Half-reaction			E^θ (V)
$\text{Li}^+ + \text{e}^-$	\rightleftharpoons	Li	-3,05
$\text{K}^+ + \text{e}^-$	\rightleftharpoons	K	-2,93
$\text{Cs}^+ + \text{e}^-$	\rightleftharpoons	Cs	-2,92
$\text{Ba}^{2+} + 2\text{e}^-$	\rightleftharpoons	Ba	-2,90
$\text{Sr}^{2+} + 2\text{e}^-$	\rightleftharpoons	Sr	-2,89
$\text{Ca}^{2+} + 2\text{e}^-$	\rightleftharpoons	Ca	-2,87
$\text{Na}^+ + \text{e}^-$	\rightleftharpoons	Na	-2,71
$\text{Mg}^{2+} + 2\text{e}^-$	\rightleftharpoons	Mg	-2,37
$\text{Al}^{3+} + 3\text{e}^-$	\rightleftharpoons	Al	-1,66
$\text{Mn}^{2+} + 2\text{e}^-$	\rightleftharpoons	Mn	-1,18
$2\text{H}_2\text{O} + 2\text{e}^-$	\rightleftharpoons	$\text{H}_2(\text{g}) + 2\text{OH}^-$	-0,83
$\text{Zn}^{2+} + 2\text{e}^-$	\rightleftharpoons	Zn	-0,76
$\text{Cr}^{3+} + 3\text{e}^-$	\rightleftharpoons	Cr	-0,74
$\text{Fe}^{2+} + 2\text{e}^-$	\rightleftharpoons	Fe	-0,44
$\text{Cd}^{2+} + 2\text{e}^-$	\rightleftharpoons	Cd	-0,40
$\text{Co}^{2+} + 2\text{e}^-$	\rightleftharpoons	Co	-0,28
$\text{Ni}^{2+} + 2\text{e}^-$	\rightleftharpoons	Ni	-0,25
$\text{Sn}^{2+} + 2\text{e}^-$	\rightleftharpoons	Sn	-0,14
$\text{Pb}^{2+} + 2\text{e}^-$	\rightleftharpoons	Pb	-0,13
$\text{Fe}^{3+} + 3\text{e}^-$	\rightleftharpoons	Fe	-0,04
$2\text{H}^+ + 2\text{e}^-$	\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	Sn^{2+}	+0,15
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-$	\rightleftharpoons	$\text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17
$\text{Cu}^{2+} + 2\text{e}^-$	\rightleftharpoons	Cu	+0,34
$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^-$	\rightleftharpoons	4OH^-	+0,40
$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^-$	\rightleftharpoons	$\text{S} + 2\text{H}_2\text{O}$	+0,45
$\text{I}_2 + 2\text{e}^-$	\rightleftharpoons	2I^-	+0,54
$\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^-$	\rightleftharpoons	H_2O_2	+0,68
$\text{Fe}^{3+} + \text{e}^-$	\rightleftharpoons	Fe^{2+}	+0,77
$\text{Hg}^{2+} + 2\text{e}^-$	\rightleftharpoons	Hg	+0,79
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^-$	\rightleftharpoons	$\text{NO}_2(\text{g}) + \text{H}_2\text{O}$	+0,80
$\text{Ag}^+ + \text{e}^-$	\rightleftharpoons	Ag	+0,80
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^-$	\rightleftharpoons	$\text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0,96
$\text{Br}_2 + 2\text{e}^-$	\rightleftharpoons	2Br^-	+1,09
$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^-$	\rightleftharpoons	$\text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1,21
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^-$	\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	2Cl^-	+1,36
$\text{Au}^{3+} + 3\text{e}^-$	\rightleftharpoons	Au	+1,42
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$	\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
$\text{F}_2(\text{g}) + 2\text{e}^-$	\rightleftharpoons	2F^-	+2,87

Increasing strength of oxidising agent
↓

↑
Increasing strength of reducing agent

E. SUBJECT ASSESSMENT SYLLABUS

This document aims to specify the IEB Grade 12 examination objectives for 2021 onwards as precisely as possible.

It is recommended that both the grade 11 and grade 12 years are dedicated to preparing for this assessment syllabus.

Questions that test skills may be based on content which is unfamiliar to the candidate. In answering such questions, learners are required to use principles and concepts that are within the curriculum and apply them in a logical, reasoned or deductive manner to a novel situation.

A candidate should be able to:

I. PHYSICS

A. Kinematics

1. Vectors

- Define a vector as *a physical quantity that has both magnitude and direction* and give examples
- Define a scalar quantity as *a physical quantity that has magnitude only* and give examples
- Define resultant vector as *the single vector which has the same effect as the original vectors acting together*
- Determine the resultant vector of any two vectors
- Determine two perpendicular components of any vector (e.g. force at an angle, weight on an inclined plane)

2. Displacement, Velocity and Acceleration

- Describe position relative to a reference point
- Know that position is a vector quantity that points from the reference point as the origin
- Define distance as *the length of path travelled* and know that distance is a scalar quantity
- Define displacement as *a change in position*
- Know that displacement is a vector quantity that points from the initial to the final position
- Define speed as *the rate of change of distance* and know that speed is a scalar quantity
- Define velocity as *the rate of change of position or the rate of displacement or the rate of change of displacement* and know that velocity is a vector quantity
- Distinguish between average velocity and instantaneous velocity
- Define acceleration as *the rate of change of velocity*

3. Vertical Projectile Motion in One Dimension (near the surface of the Earth in the absence of air resistance)

- Know that projectiles fall freely with gravitational acceleration ' g ', where $g = 9,8 \text{ m} \cdot \text{s}^{-2}$ near the surface of the Earth
- Know that projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch

4. Graphs of Motion

For either horizontal motion or vertical motion with constant acceleration:

- Draw position vs time, velocity vs time and acceleration vs time graphs for one dimensional motion
- Interpret graphs of motion:
 - Explain the meaning of the gradient of a given graph
 - Explain the meaning of the area under a given graph
- Interpret graphs of motion:
 - Determine the velocity of an object from the gradient of a position vs time graph
 - Determine the acceleration of an object from the gradient of a velocity vs time graph
 - Determine the displacement of an object by finding the area under a velocity vs time graph

5. Equations of Motion

- Use equations of motion to solve problems involving either horizontal motion or vertical motion with constant acceleration:

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$s = \left(\frac{v + u}{2} \right) t$$

$$s = ut + \frac{1}{2} at^2$$

$$v_f = v_i + a\Delta t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\Delta x = \left(\frac{v_f + v_i}{2} \right) \Delta t$$

$$\Delta x = v_i \Delta t + \frac{1}{2} a(\Delta t)^2$$

Note: both versions of the equations will be accepted. For the purpose of this document, u, v, a, t and s will be used.

B. Newton's Laws and Application of Newton's Laws

1. Different Kinds of Forces: weight, normal force, frictional force, applied (push, pull) force, tension (strings or cables)

- Define weight F_g as *the gravitational force the Earth exerts on any object on or near its surface*
- Calculate weight using the expression $F_g = mg$ where g is the acceleration due to gravity. Near the surface of the earth the value of g is approximately $9,8 \text{ m}\cdot\text{s}^{-2}$
- Define normal force, F_N , as *the perpendicular force exerted by a surface on an object in contact with it*
- Define frictional force, F_f , as *the force that opposes the motion of an object*
- Know that the frictional force due to a surface acts parallel to the surface with which the object is in contact
- Explain what is meant by the maximum static friction
- Calculate the value of the maximum static frictional forces for objects at rest on horizontal and inclined planes using:

$$F_{fs}^{max} = \mu_s F_N$$

where μ_s is the coefficient of static friction

- Solve problems where the static frictional force is less than the maximum frictional force
- Distinguish between static and kinetic frictional forces
- Calculate the kinetic frictional force using:

$$F_{fk} = \mu_k F_N$$

where μ_k is the coefficient of kinetic friction

2. Forces and Free Body Diagrams

- Draw a labelled free-body diagram by drawing the object of interest as a dot and all the forces acting on it drawn as arrows pointing away from the dot
- The forces shown on labelled free body diagrams must be given labels that describe the force clearly in words (e.g. weight, normal force, tension, frictional force, air resistance, force of A on B). Only symbols from the data sheet will be accepted as force labels (F_N , F_f and F_g)
- Resolve forces into parallel (x) and perpendicular (y) rectangular components appropriate to the set of axes used (e.g. the weight of an object with respect to an inclined plane)
- Calculate the resultant or net force (F_{net}) in the x-direction as a vector sum of all the components in the x-direction and the resultant or net force in the y-direction as a vector sum of all the components in the y-direction
- Calculate the resultant or net force using the resultant x and y components

3. Newton's First, Second and Third laws

- State Newton's first law: *An object continues in a state of rest or uniform (moving with constant) velocity unless it is acted upon by a net or resultant force*
- Define inertia as *the property of an object that causes it to resist a change in its state of rest or uniform motion*
- State Newton's second law: *When a net force, F_{net} , is applied to an object of mass, m , it accelerates in the direction of the net force. The acceleration, a , is directly proportional to the net force and inversely proportional to the mass*
- Solve problems using: $F_{net} = ma$
- Apply Newton's laws to a variety of equilibrium and non-equilibrium problems
(e.g. Discuss, using Newton's first law, why it is important to wear seatbelts)
(e.g. Use Newton's second law to solve problems including an object moving on a horizontal/inclined plane (frictionless and rough), vertical motion (e.g. rockets, scales in lifts, hoisting masses) and also two-body systems (e.g. two masses joined by a light (negligible mass) string which may be over a pulley, two masses touching)
- State Newton's third law: *When object A exerts a force on object B, object B **simultaneously** exerts an oppositely directed force of equal magnitude on object A*
- Identify action-reaction pairs (e.g. for a donkey pulling a cart, for a book on a table)
- Demonstrate an understanding of the properties of action-reaction pairs (are equal in magnitude, act in opposite directions, act on different objects, occur simultaneously, act along the same line)

C. Momentum, Impulse, Work, Energy and Power

1. Linear Momentum (1D)

- Define linear momentum as *the product of the mass and velocity of the object*
- State that linear momentum is a vector and is the same direction as the velocity vector
- Calculate the linear momentum in one dimension of a moving object using $p = mv$

2. Newton's Second Law expressed in terms of Momentum

- State Newton's second law in terms of momentum: *The net force acting on an object is equal to the rate of change of momentum.* (Note: there are two acceptable statements of Newton's Second Law)
- Solve problems for constant mass using $F_{net} = \frac{\Delta p}{\Delta t}$

3. Conservation of Momentum and Elastic and Inelastic Collisions

- Explain that an isolated system is one that has no net external force acting on it
- Explain (when working with isolated systems) what is meant by internal and external forces
- State the law of conservation of linear momentum: *The total linear momentum of an isolated system remains constant* (is conserved)
- Solve problems by applying the law of conservation of momentum to interactions of two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention
- Define an elastic collision as *a collision in which both momentum and kinetic energy are conserved*
- Define an inelastic collision as *a collision in which only momentum is conserved*
- Identify elastic and inelastic collisions using calculations where necessary

4. Impulse

- Define impulse (J) as *the product of the net force and the contact time*
- Solve problems using $J = F_{net} \Delta t$
- Know that impulse is a vector quantity and is in the same direction as the net force vector
- Know that impulse and change in momentum are equivalent, i.e. $J = \Delta p$
- Solve problems using $\Delta p = F_{net} \Delta t$
- Apply the concept of impulse in everyday life (e.g. airbags, catching a hard ball, etc.)

5. Work, Energy and Power

(a) Definition of Work

- Define the work done on an object by a force as *the product of the displacement and the component of the force parallel to the displacement*
- Solve problems using:
 $W = Fs$ (or $W = F\Delta x$ or $W = F\Delta x \cos \theta$)
- Know that work is a scalar quantity and is measured in joules (J)
- Know that if energy is gained by the object, work done on that object is considered positive
- Know that if energy is lost by the object, work done on that object is considered negative

(b) Mechanical Energy

- Define gravitational potential energy as *the energy an object possesses due to its position relative to a reference point*
- Calculate the gravitational potential energy of an object using $E_p = mgh$
- Define kinetic energy as *the energy an object has as a result of the object's motion*
- Calculate the kinetic energy of an object using $E_k = \frac{1}{2}mv^2$
- Define mechanical energy as *the sum of gravitational potential and kinetic energy at a point*
- Use the equation: $E_M = E_p + E_k$
- State the law of conservation of energy as *the total energy in a system cannot be created nor destroyed, only transformed from one form to another*
- State the principle of conservation of mechanical energy: *In the absence of air resistance or any external forces, the mechanical energy of an object is constant*
- Apply the principle of conservation of mechanical energy and solve problems using:
 $(E_p + E_k)_i = (E_p + E_k)_f$

(c) **Work–Energy Theorem**

- State the work-energy theorem: *the work done by a net force on an object is equal to the change in the kinetic energy of the object*
- Apply the work–energy theorem to objects on horizontal and inclined planes or curved surfaces (frictionless and rough)
- Kinetic energy of a system is increased when F_{net} is in the same direction as s or Δx
- Kinetic energy of a system is decreased when F_{net} is in the opposite direction to s or Δx

(d) **Conservation of Energy with External Forces and/or Resistive Forces Present**

- Solve conservation of energy problems (with and without external forces and/or resistive forces present) by applying the law of conservation of energy

(e) **Power**

- Define power as *the rate at which work is done* or *the rate at which energy is transferred*
- Know that the unit of power is the watt (W), which is the power when one joule of work is done in one second. ($1\text{ W} = 1\text{ J}\cdot\text{s}^{-1}$)
- Calculate power using $P = \frac{W}{t}$
- If a force causes an object to move at a constant velocity, calculate the power using $P = Fv$
- Define efficiency as *the ratio of output power to input power*
- Calculate percentage efficiency using:

$$\% \text{ efficiency} = \frac{\text{power}_{out}}{\text{power}_{in}} \times 100$$

D. Gravitational and Electric Fields

1. Gravitational Fields

Newton's Law of Universal Gravitation

- State Newton's Law of Universal Gravitation: *Every particle with mass in the universe attracts every other particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres*
- Use the equation for Newton's Law of Universal Gravitation to solve problems: $F = G \frac{m_1 m_2}{r^2}$
- Define weight (F_g) as *the gravitational force the Earth exerts on any object on or near its surface*
- Describe a gravitational field as a region in space where a mass will experience a force
- Define gravitational field as *the force acting per unit mass*
- Solve problems using:

$$g = \frac{F}{m}$$
 where F is the force experienced by mass m in a gravitational field g
- Know that gravitational field and acceleration due to gravity are equivalent
- Calculate the acceleration due to gravity using the equation:

$$g = G \frac{M}{r^2}$$
 where M is the mass of a planetary body and r is the distance from its centre
- Calculate the gravitational force on an object on other planets with different values of gravitational acceleration
- Distinguish between mass and weight
- Know that the unit of weight is the newton (N) and that the unit of mass is the kilogram (kg)

2. Electrostatics

(a) Coulomb's Law

- State Coulomb's law in words: *Two point charges exert forces on each other. The force is directly proportional to the product of the charges and inversely proportional to the square of the distance between the charges*
- Know that Coulomb's law can be represented mathematically as $F = k \frac{q_1 q_2}{r^2}$ for point charges in free space or air
- Solve problems using Coulomb's law
- Determine the resultant (or net) force on a charge for a system with a maximum of three charges in one dimension or in two dimensions, restricted to charges at the vertices of a right-angled triangle

(b) **Electric Fields**

- Describe an electric field as a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point
- Draw electric field lines for various configurations of charges (point charges, two point charges, outside a charged hollow sphere, parallel plates)
- Define electric field at a point as *the force per unit positive charge*
- Solve problems using: $E = \frac{F}{q}$
 where F is the force experienced by charge q in an electric field E (no parallel plates)
- Calculate the electric field at a point due to a point charge, using the equation $E = k \frac{Q}{r^2}$
 (Convention: Q represents the charge responsible for the electric field. q represents the charge experiencing the electric field)
- Determine the resultant (or net) electric field (E_{net}) for a maximum of two charges in one dimension or in two dimensions, restricted to charges at the vertices of a right-angled triangle

E. Electric Circuits

1. Ohm's Law

- Define potential difference as *the work done per unit positive charge*

$$V = \frac{W}{q}$$
- Define current as *the rate of flow of charge* $I = \frac{q}{t}$
- Determine the relationship between current and potential difference at constant temperature
- State Ohm's Law: *The current through a conductor is directly proportional to the potential difference across the conductor at constant temperature*
- Distinguish between ohmic and non-ohmic conductors
- Know that resistance is a material's opposition to the flow of electric charge
- Know that the unit of resistance is the ohm (Ω)
- Calculate the effective resistance of resistors in series using $R_s = R_1 + R_2 + \dots$
- Calculate the effective resistance of resistors in parallel using $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
- Interpret circuit diagrams containing a source, switches, resistors, ammeters and voltmeters
- Solve problems using the mathematical expression of Ohm's Law $R = \frac{V}{I}$ for series and parallel circuits, limited to a maximum of three external resistors

2. Power and Energy

- Solve problems using electrical energy $W = Pt$
- State that electrical energy is measured in joules (J)
- Know that electrical power dissipated in a device is equal to the product of the potential difference across the device and current flowing through it
- Solve problems using $P = VI$ or $P = I^2R$ or $P = \frac{V^2}{R}$
- Solve problems using $W = VIt$ or $W = I^2Rt$ or $W = \frac{V^2}{R}t$
- Know that the kilowatt hour (kWh) is a unit of energy and that 1 kWh is the amount of energy used when 1 kilowatt of electricity is used for 1 hour
- Perform calculations involving the cost of electricity usage when given relevant information

3. Internal Resistance and Series and Parallel Networks

- Solve problems involving current, potential difference and resistance for circuits containing arrangements of resistors in series and in parallel for a maximum of three external resistors
- State that a real battery has internal resistance
- Define *emf* as *the total energy supplied per coulomb of charge by the cell*
- Know that the sum of the voltages across the external circuit plus the voltage across the internal resistance is equal to the emf:

$$emf = V_{load} + V_{internal\ resistance} \quad \text{or} \quad emf = I(R_{ext} + r)$$
- Solve circuit problems in which the internal resistance of the battery must be considered
- Solve circuit problems, with internal resistance, involving series-parallel networks of resistors to a maximum of three external resistors

F. Electrodynamics

1. Electromagnetism

- State that a magnetic field exists around a permanent magnet or a current-carrying conductor
- Draw the magnetic field lines and determine the direction of the magnetic field associated with:
 - A straight current-carrying conductor
 - A current-carrying loop (single) coil of wire
 - A solenoid
- State that a force might act on a current-carrying conductor placed in a magnetic field
- Determine the direction of the force acting on a current-carrying conductor when the current-carrying conductor is perpendicular to the magnetic field
- Qualitatively explain the factors that affect the magnitude of the force on a current-carrying conductor using the equation $F = IB\ell \sin\theta$ where ℓ is the length of the conductor experiencing the magnetic field and θ is the angle between the current and the magnetic field (no calculations required)

2. Direct-Current Motors

- State that motors convert electrical energy to mechanical energy
- Explain why a current-carrying coil placed in a magnetic field will turn by referring to the forces exerted on the sides of the coil perpendicular to the field
- Determine the direction of the rotation of a current-carrying coil in a magnetic field
- Given a diagram of a direct current (d.c.) motor, explain the basic principles of operation including why a d.c. motor has a split-ring commutator

3. Electromagnetic Induction

- Know that magnetic flux density (B) is a representation of the magnitude and direction of the magnetic field
- Know that for a loop of area (A) in the presence of a uniform magnetic flux density (B), the magnetic flux (Φ) passing through the loop is $\Phi = BA \cos \theta$ where θ is the angle between the magnetic flux density (B) and the normal to the loop of the area (A). (No calculations required)
- Define magnetic flux linkage as *the product of the number of turns on the coil and the flux through the coil ($N\Phi$)*
- Infer from appropriate experiments on electromagnetic induction:
 - That changing magnetic flux can induce an emf in a circuit
 - That the direction of the induced emf opposes the change producing it
 - The factors affecting the magnitude of the induced emf
- State Faraday's law of electromagnetic induction: *the emf induced is directly proportional to the rate of change of magnetic flux (flux linkage)*
- State Lenz's law: *the induced current flows in a direction so as to set up a magnetic field to oppose the change in magnetic flux*
- Apply Lenz's law qualitatively (e.g. for relative motion of magnets and coils, generators and transformers)
- Explain simple applications of electromagnetic induction (e.g. the induced current and its direction when a magnet is passed through a coil)
- Draw and interpret graphs of magnetic flux vs time (e.g. for an AC generator indicating how the position of the coil relative to the magnetic field relates to the magnitude of the flux)
- When given a magnetic flux vs time graph, sketch the corresponding induced emf vs time graph (and vice versa)

4. Alternating Current Generators and Transformers

- State that generators convert mechanical energy to electrical energy
- Use the equation $emf = -N \frac{\Delta \Phi}{\Delta t}$ for Faraday's law to explain qualitatively the operation of generators and transformers. (No calculations required)
- State with reasons which factors affect the emf induced
- Given a diagram, explain the basic principle of an AC generator (alternator) in which a coil is mechanically rotated in a magnetic field
- Determine the direction of the induced current in the rotating coil of an AC generator
- Know that an AC generator has slip rings
- Show an understanding of the principle of operation of a simple iron-cored transformer
- Know that for an ideal transformer, input power is equal to output power
- Solve problems using $V_p I_p = V_s I_s$ and $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ for an ideal transformer

5. Alternating Current

- Discuss the scientific and economic advantages of high voltages and low currents for the transmission of electrical energy through the national grid
- Draw a graph of potential difference vs time and current vs time for an alternating current (AC) circuit and recognise that these graphs are sinusoidal
- Relate the potential difference vs time graph to the emf produced by an AC generator (e.g. indicate how the position of the coil relative to the magnetic field relates to the magnitude of the emf)
- Define a diode as *a component that only allows current to flow in one direction*
- Distinguish graphically between half-wave and full-wave rectification
- Explain how a single diode is used for the half-wave rectification of an alternating current
- Given a circuit diagram of a bridge rectifier, explain how four diodes are used for the full-wave rectification of an alternating current

G. Photons and Electrons

1. Photoelectric Effect

- Know that the speed of light in a vacuum is constant ($3 \times 10^8 \text{ m}\cdot\text{s}^{-1}$)
- Solve problems using the equation $c=f\lambda$
- State that the energy of a photon is directly proportional to the frequency of the light
- Solve problems using the equation $E=hf$ or $E=\frac{hc}{\lambda}$
- Know that electron-volts are energy units
- Be able to convert between electron-volts and joules:
 $1 \text{ eV} = 1,6 \times 10^{-19} \text{ J}$
- Describe the photoelectric effect as the process that occurs when light shines on a metal and electrons are ejected
- Know that electrons ejected from a metal by incident light are known as photoelectrons
- State the significance of the photoelectric effect: it establishes the quantum theory and it illustrates the particle nature of light
- Define threshold (cut-off) frequency (f_0) as *the minimum frequency of incident radiation at which electrons will be emitted from a particular metal*
- Define work function (W_0) as *the minimum amount of energy needed to emit an electron from the surface of a metal*
- Know that the work function is material specific
- Know that the threshold frequency corresponds to a maximum wavelength
- Apply the photoelectric equation:
$$E=W_0+E_{K(max)}$$

where $E = hf = \frac{hc}{\lambda}$, $W_0 = hf_0$, and $E_{K(max)} = \frac{1}{2}mv_{max}^2$

- Explain why the number of electrons ejected per second increases with the intensity of the incident radiation provided the frequency is above the threshold frequency
- Explain why if the frequency of the incident radiation is above the threshold frequency, then increasing the frequency of the radiation will increase the maximum kinetic energy of the ejected electrons

2. Emission spectra

- Explain the source of atomic emission spectra (of discharge tubes) and their unique relationship to each element
- Relate the lines on the atomic emission spectrum to electron transitions between energy levels
- Calculate the energy associated with a transition and the corresponding wavelength or frequency using $E = hf = \frac{hc}{\lambda}$

II. CHEMISTRY

A. Quantitative Chemistry

1. Balanced Chemical Equations

- Represent chemical changes using balanced reaction equations, i.e. translate word equations into chemical equations with formulae
- For naming / formula purposes, know the first 20 elements and all that appear on the table of standard electrode potentials
- Interpret the meaning of and use of state symbols (when requested) to represent phases (s), (l), (g) and (aq)
- Balance reaction equations by inspection
- Know the name and formula of the following polyatomic ions: ammonium, hydronium, chlorate, ethanoate, hydroxide, nitrate, nitrite, permanganate, carbonate, hydrogen carbonate, sulfate, hydrogen sulfate, thiosulfate, sulfite, phosphate, dichromate
- When given the name of a chemical compound (which may include the use of Stock notation) write chemical formulae using the periodic table and knowledge of polyatomic ions, and vice versa

2. The Mole Concept

The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants

- Know that the mole is the SI unit for amount of substance
- Relate amount of substance to relative atomic mass
- State that one mole contains Avogadro's number of particles ($N_A = 6,02 \times 10^{23} \text{ mol}^{-1}$)
- Define molar mass as *the mass in grams of one mole of that substance*
- Calculate the molar mass of a substance given its formula
- Solve problems using the equation $n = \frac{m}{M}$

where n = number of moles, m = mass of substance and M = molar mass

3. Molar Volume of Gases

- Know and use the fact that 1 mole of gas occupies 22,4 dm³ at STP, i.e. 0 °C (273 K) and at 1 atmosphere (101,3 kPa)
- Solve problems using $n = \frac{V}{V_m}$ where $V_m = 22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$ is the molar volume at STP

4. Concentration of Solutions

- Know that a solution is a homogenous mixture of solute and solvent
- Know that the solute is the substance that is dissolved in the solution
- Know that the solvent is the substance in which another substance is dissolved, forming a solution
- Identify the solute and/or solvent for a particular solution
- Define molar concentration as *the amount of solute per unit volume of solution*
- Calculate the molar concentration of a solution using the equation

$$c = \frac{n}{V} \quad \text{or} \quad c = \frac{m}{MV}$$
- Know that the unit of molar concentration is $\text{mol} \cdot \text{dm}^{-3}$

5. Stoichiometric Calculations

- Perform stoichiometric calculations (involving moles, mass, concentration, volume of solutions and/or volume of gases at STP) using balanced equations (which may include limiting reagents)
- Know that % yield is a measure of the extent of a reaction, determined by comparing the actual amount of product to the theoretical amount of product, expressed as a percentage
- Perform stoichiometric calculations involving the percentage yield of a chemical reaction
- Perform stoichiometric calculations involving the percentage purity of an impure substance

B. Chemical Bonding

1. Covalent, Ionic and Metallic Bonding and Intermolecular Forces

- Know that an intramolecular bond is a bond between atoms within molecules
 Note: For the purposes of this document, only covalent bonds are considered to be intramolecular.
- Define electronegativity as *a measure of the tendency of an atom to attract a bonding pair of electrons*
- Know that:
 - a covalent bond involves a sharing of at least one pair of electrons by two atoms
 - a covalent bond is non-polar (pure) when the electrons are equally shared due to zero difference in electronegativity
 - a covalent bond is polar when the electrons are unequally shared due to a difference in electronegativity
 - the greater the difference in electronegativity the more polar the bond
- Know that ionic bonding involves a transfer of electrons to form cations and anions which are electrostatically attracted in an ionic crystal lattice
- Know that ionic bonding is generally between metals (or ammonium cations) and non-metals (or polyatomic anions)
- Know that metallic bonding is the attraction between positive kernels and a sea of delocalised electrons

- Identify that in a liquid or a solid there must be forces of attraction between the particles, keeping the substance in that state
 - Know that an intermolecular force is a force of attraction between molecules or between atoms of noble gases
 - Know that a polar molecule (dipole) is a molecule in which the electrons are unevenly distributed resulting in a δ^+ and δ^- end
 - Know that van der Waals forces are intermolecular forces
 - Name and explain the origin of the following different types of van der Waals forces:
 - London forces (induced dipole forces or dispersion forces)
 - Dipole-dipole forces
 - Hydrogen bonding as a special case of dipole-dipole forces
 - Know that all interactions between molecules involve London forces
 - Explain how the strength of London forces is influenced by the size of the temporary dipoles, which is influenced by:
 - the number of electrons
 - the interacting surface of the molecule (e.g. long unbranched chain vs branched chain – see *organic chemistry section*)
 - Know that hydrogen bonds:
 - Exist between polar molecules in which hydrogen is covalently bonded to either N, O or F, due to these being:
 - small atoms
 - of high electronegativity
 - with at least one lone pair of electrons
 - occur between the δ^+ H of one such molecule and the lone pair on the N, O or F of another molecule
 - are stronger than dipole-dipole forces due to:
 - the high polarity of the covalent bond formed between hydrogen and either N, O or F
 - the fact that the molecules can get close together
 - Deduce whether molecules are polar or non-polar and hence which intermolecular forces predominate (are strongest)
- Note: For the purposes of this document:
- Asymmetrical molecules are considered to be polar, while symmetrical molecules (including hydrocarbons – see *organic chemistry section*) are non-polar
 - The molecular polarity of asymmetrical molecules with non-polar bonds (e.g. PH_3 , H_2Te , NCl_3) will not be examined)

NOTE: In order to predict and explain which intermolecular forces are present between particles, knowledge of the following molecular shapes is assumed:

- linear e.g. CO_2 , CS_2 , HCN and 2-atom molecules
- angular e.g. Group 16 hydrides (e.g. H_2O) or halides (e.g. OF_2)
- trigonal planar e.g. BH_3 , BX_3 where X = halide
- tetrahedral e.g. CH_4 , CX_4 , CH_3X where X = halide
- trigonal pyramidal e.g. Group 15 hydrides (e.g. NH_3) or halides (e.g. PCl_3)

Lewis diagrams, VSEPR theory and the names of these shapes will not be directly assessed.

2. Physical Properties

(a) Melting points, boiling points

- Explain that in giant structures such as diamond, graphite and silicon dioxide, melting points are high due to the large amount of energy needed to break the many strong covalent bonds
- Explain that in giant ionic solids (e.g. sodium chloride), the melting points are determined by the strength of the many electrostatic forces of attraction (ionic bonds) between the cations and the anions in the ionic crystal lattice
- Identify that for simple molecular substances the melting and boiling points are affected by the strength and the relative number per molecule (for hydrogen bonds) of the intermolecular forces
- Explain that when comparing the melting and boiling points of molecular substances in the same group on the Periodic Table (e.g. halogens, hydrides of elements in groups 15, 16 and 17) or the same homologous series (*see organic chemistry section*), the difference in melting points and boiling points is mainly due to the London forces, the exception being those that experience hydrogen bonds (e.g. H_2S vs H_2O)
- Explain that when comparing the melting and boiling points of molecular substances of similar mass in different groups on the Periodic Table or different homologous series (*see organic chemistry section*) the difference in melting and/or boiling point is due to the presence of other intermolecular forces (dipole-dipole and/or hydrogen bonds) besides the London forces which are present between all molecules
- Explain that when comparing the melting and boiling points of molecular substances that involve hydrogen bonding, the difference in melting and/or boiling point is due to the relative number of hydrogen bonds per molecule that occur between the molecules (i.e. on average, H_2O forms more H-bonds per molecule than NH_3 and HF)

(b) Electrical conductivity

- Know that metals and graphite conduct electricity due to the presence of delocalised valence electrons
- Know that ionic compounds only conduct electricity when molten or in aqueous solution, i.e. when the ions are free
- Explain that when a potential difference is applied, it is these electrons or ions that move, resulting in a current

C. Energy Change & Rates of Reactions

1. Energy Changes in Reactions (Exothermic and Endothermic Reactions)

- Define heat of reaction (ΔH) as *the net change of chemical potential energy of the system*
- Define exothermic reactions as *reactions which transform chemical potential energy into thermal energy*
- Define endothermic reactions as *reactions which transform thermal energy into chemical potential energy*
- Identify that bond breaking absorbs energy and that bond formation releases energy. (No calculations will be required)
- Identify that a stronger bond requires more energy to break and releases more energy when formed
- Predict that $\Delta H > 0$ for endothermic reactions
- Predict that $\Delta H < 0$ for exothermic reactions
- Know that exothermic reactions release heat and thus increase the temperature of the surroundings
- Know that endothermic reactions absorb heat and thus decrease the temperature of the surroundings

2. Activation Energy

- Define activation energy as *the minimum energy required to start a chemical reaction OR the energy required to form the activated complex*
- Define the activated complex as *a high energy, unstable transition state between the reactants and the products*
- Draw and interpret potential energy profile graphs (potential energy vs course of reaction) of catalysed and uncatalysed endothermic reactions and exothermic reactions (with reactants, products, activation energy, activated complex and ΔH labelled)

3. Rates of Reaction

(a) Rates of Reaction and Factors Affecting Rate

- Define reaction rate as *the change in amount or concentration per unit time of either a reactant or product*
- Calculate average reaction rate, with appropriate units, in terms of change in concentration, mass, volume, or number of moles per unit time
- Distinguish between average and instantaneous reaction rates
- List the factors that affect the rate of chemical reactions. (Nature of reacting substances, surface area of a solid, concentration of a solution, pressure of a gas, temperature and catalyst)
- Define a catalyst as *a substance that increases the rate of the reaction but remains unchanged at the end of the reaction*

- Explain that the collision theory is a model that explains that a reaction will only proceed when reactant particles collide effectively. An effective (or successful) collision is one in which the colliding reactant particles have:
 - the correct orientation
 - sufficient kinetic energy, i.e. kinetic energy equal to or greater than the activation energy
- Explain in terms of the collision theory that reaction rate is directly proportional to the number of effective collisions per unit time
- Explain in terms of the collision theory how the various factors affect the rate of chemical reactions

(b) Measuring Rates of Reaction

- Suggest and explain suitable experimental techniques for measuring the rate of a given reaction including the measuring of gas volumes, turbidity (e.g. precipitate formation), change of colour and the change of the mass of the reaction vessel
- Answer questions and interpret data (tables or graphs) on different experimental techniques for measuring the rate of a given reaction

(c) Graphs

- Apply collision theory to explain the changes in the distribution of molecular energies (number of particles against their kinetic energy, i.e. Maxwell-Boltzmann distribution) due to changes in temperature, concentration of reactants and the presence of a catalyst
- Use any other suitable graph (including e.g. energy profile graph, rate vs time or amount vs time) to show how changing concentration, pressure, surface area, or adding a catalyst affects the rate of reaction

D. Chemical Equilibrium

1. Chemical Equilibrium and Factors Affecting Equilibrium

- Define:
 - A closed system (in chemistry) as *one in which mass is conserved inside the system but energy can enter or leave the system freely*
 - An open system (in chemistry) as *one in which both energy and matter can be exchanged between the system and its surroundings*
- Explain that:
 - A reversible reaction is one in which products can be converted back into reactants
 - Dynamic chemical equilibrium refers to a reversible reaction in which the forward and the reverse reactions are taking place at the same rate, and hence the concentrations of reactants and products are constant
- List the external factors which change the equilibrium position of a particular reaction viz: temperature, pressure and concentration

2. Application of Equilibrium Principles

- State Le Châtelier's principle: *'When an external stress (change in pressure, temperature or concentration) is applied to a system in dynamic chemical equilibrium, the equilibrium point will change in such a way as to counteract the stress'*
- Use Le Châtelier's principle to predict and explain the effects of changes of pressure, temperature, and concentration (including the common ion effect) on the concentrations and/or amounts of each substance in an equilibrium mixture
- Understand and explain, in terms of the rates of the forward and reverse reactions, the effect of changes of pressure, temperature, and concentration on the concentrations and/or amounts of each substance in an equilibrium mixture
- State that the addition of a catalyst to a system in equilibrium will increase the rate of both the forward and reverse reactions equally and hence have no effect on the position of equilibrium
- Interpret the following graphs for chemical reactions in a closed system:
 - Amount (number of moles) vs time
 - Concentration vs time
 - Rate vs time
- When given chemical equations, diagrams or flow charts, apply rate and equilibrium principles to describe how yields are affected in various industrial processes
- Explain that in industrial processes the conditions chosen are those that are the most economically viable and that yield may be sacrificed for rate

3. **Equilibrium Constant**

- Write down an expression for the equilibrium constant (K_c) when given the equation for the reaction
- State that temperature is the only factor which influences the value of the equilibrium constant
- Use Le Châtelier's principle to predict and explain how temperature influences the K_c value for a particular equilibrium reaction
- Use Le Châtelier's principle to predict and explain whether a reaction is exothermic or endothermic when given relevant K_c and temperature information
- Perform calculations involving K_c using mole quantities (mass, volume, moles, concentration, etc.) and stoichiometry
- Explain the significance of high and low values of the equilibrium constant

E. Acids & Bases

1. Ionisation, dissociation and strength of acids and bases

- Define acids and bases in terms of the Lowry-Brønsted model:
 - An acid is defined as *a proton donor*
 - A base is defined as *a proton acceptor*
- Define ionisation as *the reaction of a molecular substance with water to produce ions*
- Define a strong acid as *an acid that ionises almost completely in an aqueous solution*
- Write the formula and name of the following common strong acids: HCl – hydrochloric acid, H₂SO₄ – sulfuric acid and HNO₃ – nitric acid

Note: For the purposes of this document:

- these strong acids are considered to ionise completely
- both deprotonations of H₂SO₄ will be considered strong
- Define a weak acid as *an acid that only ionises partially in an aqueous solution*
- Write the formula and name of the following weak acids: HF – hydrofluoric acid, H₃PO₄ – phosphoric acid, H₂SO₃ – sulfurous acid, H₂CO₃ – carbonic acid, (COOH)₂ – oxalic acid, CH₃COOH – ethanoic acid, and other carboxylic acids (*see organic chemistry section*)
- Identify polyprotic acids on the basis of being able to donate more than one proton
- Distinguish between monoprotic, diprotic and triprotic acids and give examples of each
- Write reaction equations for the ionisation of any known or given acids dissolving in water, using single arrows for strong acids (HCl, HNO₃, H₂SO₄) and double arrows for weak acids, for example:
 - $\text{HCl(aq)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
 - $\text{H}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O(l)} \rightarrow 2\text{H}_3\text{O}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
 - $\text{CH}_3\text{COOH(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$
 - $\text{H}_3\text{PO}_4(\text{aq}) + 3\text{H}_2\text{O(l)} \rightleftharpoons 3\text{H}_3\text{O}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$
- Define dissociation as *the splitting of an ionic compound into its ions*
- Define a strong base as *a base that dissociates almost completely in an aqueous solution*
- Name and write the formula of Group 1 metal hydroxides (common strong bases)

Note: For the purposes of this document:

- Group 1 hydroxides are considered to dissociate completely
- Metal hydroxides that are weak bases will not be examined
- Write the reaction equations (using single arrows) for the dissociation of any known or given metal hydroxides (identified as strong bases) dissolving in water
- Define a weak base as *a base that only ionises partially in an aqueous solution*
- Know that ammonia solution, NH₃(aq), is a weak base that only ionises partially in aqueous solution

- Write the reaction equation (using double arrows) for the ionisation of ammonia in water
- Classify acids and bases (other than those listed above) as strong or weak when given sufficient information, e.g. K_a or K_b values
- Know that:
 - a concentrated acid or base solution has relatively more dissolved solute than a dilute solution
 - the strength of the acid or base is independent of the concentration of the solution

2. Conjugate acid-base pairs and amphoteric substances

- Define an amphoteric (or amphiprotic) substance as *a substance that can act as either an acid or a base*
- Identify a substance as amphoteric (or amphiprotic), e.g. H_2O , HCO_3^- , HSO_3^-
- Write equations to show how an amphoteric (or amphiprotic) substance can act as an acid or a base
- Identify conjugate acid-base pairs for given compounds or reactions
- Know that the stronger the acid/base the relatively weaker its conjugate base/acid will be, and vice versa, and apply this knowledge to the hydrolysis of salts (see 4. below)

3. K_w , K_a , K_b and pH

- Interpret the strength of an acid from a given K_a value and interpret the strength of a base from a given K_b value
- Write an expression for K_a or K_b from a given ionisation reaction and calculate unknown quantities as for any equilibrium constant, K_c
- Explain how conductivity can be used as a measure of acid strength
- Explain the auto-ionisation (autoprotolysis) of water
- Know that:
 - K_w is the equilibrium constant for the auto-ionisation of water
 - $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ at 25 °C
- Perform calculations using K_w
- Explain the pH scale (0 to 14) as the measure of hydronium ion concentration, $[\text{H}_3\text{O}^+]$, in water at 25 °C
- Explain qualitatively the pH range of 0 to 14 for a solution at 25 °C
- Know that K_w and hence pH are temperature dependent
- Know that in a neutral solution $[\text{H}_3\text{O}^+] = [\text{OH}^-]$

4. Acid-base reactions, titrations and hydrolysis

- Define a salt as *a substance in which the hydrogen of an acid has been replaced by a cation*
- Know the following acid reactions and be able to write the balanced chemical equations:
 - acid + active metal \rightarrow salt + hydrogen (NB: A redox reaction)
 - acid + metal oxide \rightarrow salt + water
 - acid + metal hydroxide (or ammonia) \rightarrow salt + water (or ammonium salt)
 - acid + metal carbonate \rightarrow salt + carbon dioxide + water
 - acid + metal hydrogen carbonate \rightarrow salt + carbon dioxide + water
- Identify the acid and base (metal hydroxide or ammonia) that could react to produce a given salt
- Define hydrolysis of a salt as *a reaction of an ion (from a salt) with water*
- Write equations (using double arrows) for the hydrolysis reactions of NH_4^+ and the anions of weak acids in order to predict the approximate pH range of salt solutions
- Know that the conjugate ions of strong acids and bases do not undergo hydrolysis i.e. Cl^- , NO_3^- , HSO_4^- and SO_4^{2-} and Group 1 metal ions
- Define neutralisation as *a chemical reaction in which an acid and a base react so that neither is in excess*
- Define a standard solution as *a solution of known concentration*
- Describe quantitatively and qualitatively how to make up a standard solution
- Describe and explain the physical process of performing a titration to ensure the appropriate precision
- Perform calculations based on titration reactions using mole quantities and stoichiometry
- Select suitable indicators for the relevant titrations from a table of given indicators and their pH ranges. Titrations between strong acid / strong base; strong acid / weak base; weak acid/strong base are considered to be relevant
- Know that the equivalence point in a titration is the point where neither reactant is in excess, while the end point is the point where the indicator changes colour
- Identify indicators as weak acids and use Le Châtelier's principle to predict and explain the colour of the indicator in different acidic and basic media

F. Electrochemistry

1. Redox Reactions

- Define the following in terms of electron transfer:
 - Redox reaction as *a reaction involving the transfer of electrons*
 - Oxidation as *the loss of electrons*
 - Reduction as *the gain of electrons*
 - An oxidising agent as *a substance that accepts electrons*
 - A reducing agent as *a substance that donates electrons*
 - Anode as *the electrode where oxidation takes place*
 - Cathode as *the electrode where reduction takes place*
- Define an electrolyte as *a substance that can conduct electricity due to the presence of free (mobile) ions when molten or dissolved in solution*

2. Writing of Equations Representing Oxidation and Reduction Half Reactions and Redox Reactions

- Use single arrows when writing equations for any half-reactions and redox reactions from the table of standard electrode potentials (Table 4 on the Data Sheet)
- Use the table of standard electrode potentials or other given half-reactions to:
 - Predict the chemical species which is oxidised in a redox reaction and write an equation for the oxidation half-reaction
 - Predict the chemical species which is reduced in a redox reaction and write an equation for the reduction half-reaction
 - Write the overall balanced ionic reaction equation by combining the two half-reactions
 - Identify the oxidising agent and the reducing agent for a redox reaction
 - Determine the spontaneity of a redox reaction under standard conditions
- Explain whether or not a redox reaction is spontaneous under standard conditions using the relative strengths of the oxidising / reducing agents or by referring to the half-cell potentials (E^θ)
- Identify spectator ions in a redox process and know that the spectator ions do not take part in the electron transfer

3. Galvanic Cells

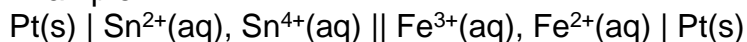
- Describe a galvanic cell as an electrochemical cell that converts the chemical energy of spontaneous redox reactions into electrical energy

(a) Understanding of the Processes and Redox Reactions

- Predict the half-cell in which oxidation will take place and identify the anode
- Predict the half-cell in which reduction will take place and identify the cathode
- Use the standard electrode potential table (or other given half-reactions and relevant information) to write equations for half-reactions taking place at the anode and cathode
- Write the overall ionic cell reaction by combining two half-reactions
- Describe:
 - the movement of ions through the solutions
 - the electron flow in the external circuit of the cell
 - the observations in the half-cells
- State the functions of the salt bridge as
 - completing the circuit
 - maintaining electrical neutrality in the half-cells
- Describe how the salt bridge maintains electrical neutrality in the half-cells by referring to the movement of ions in and out of the salt bridge
- Explain when it is necessary to use an inert electrode in a galvanic cell
- Identify or suggest suitable inert electrodes for use in galvanic cells and give reasons for their suitability
- Use cell notation to represent a galvanic cell, using the following conventions:
 - Electrodes, including inert electrodes, are written on the outside of the cell notation
 - A single vertical line (|) represents a phase boundary and is drawn between two chemical species that are in different phases but in contact with each other
 - The salt bridge is represented by two vertical lines (||). The identity of the salt bridge electrolyte need not be shown in the cell notation
 - Cell notation is written using the following order convention:
 reducing agent | product of oxidation || oxidising agent | product of reduction
 Examples:
 $\text{Zn} | \text{Zn}^{2+} || \text{Cu}^{2+} | \text{Cu}$
 $\text{Pt} | \text{Cl}^- | \text{Cl}_2 || \text{F}_2 | \text{F}^- | \text{Pt}$
 - When both chemical species in a half-cell are in the same phase then they are separated by a comma

- State symbols need only be shown when requested

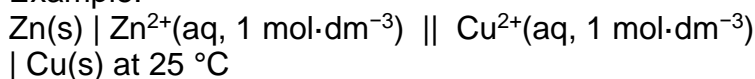
Example:



- If requested, standard conditions are given in brackets after:

- o Aqueous solutions of ions (aq, 1 mol·dm⁻³)
- o Gases (g, 1 atm)
- o Temperature (at 25 °C) is shown at the end of the cell notation

Example:



(b) Standard electrode potentials

- State the relevant specific standard conditions under which standard electrode potentials are determined for different cells
- Describe the standard hydrogen electrode and explain its role as the reference electrode
- Know that when used as a reference electrode the standard hydrogen electrode is connected as the anode (to the negative terminal of a voltmeter) even though it may not spontaneously act as the anode
- Write the cell notation for a cell in which the standard hydrogen electrode is used as a reference electrode and is therefore shown as the anode, i.e. $\text{Pt} \mid \text{H}_2 \mid \text{H}^+ \parallel \text{cathode}$
- Explain how standard electrode potentials can be determined using the reference electrode and state the convention regarding positive and negative values

NOTE: The standard hydrogen electrode will only be assessed in the context of its use as a **reference electrode** and therefore it will always be shown to be connected as the **anode** and must be shown as the anode in the cell notation for the cell. A negative emf thus indicates that the reaction does not occur spontaneously in the direction given in the cell notation. The anode half-reaction, cathode half-reaction and net cell reaction must always be written for the spontaneous reaction regardless of how the standard hydrogen electrode is connected.

(c) Relation of Current and Potential to Rate and Equilibrium

- State that the galvanic cell has the capacity to deliver current until the reaction reaches chemical equilibrium or has run to completion
- State that once a galvanic cell reaches chemical equilibrium or has run to completion the voltage of the cell equals zero
- Qualitatively, using Le Châtelier's principle, predict the effect of changing concentration on the voltage of a galvanic cell. (i.e. all the factors that favour the forward reaction increase the voltage of the galvanic cell and factors that favour the reverse reaction decrease the voltage. E.g. Increasing the concentration of the reactants or decreasing the concentration of the products increases voltage)
- Know that internal resistance is opposition to the flow of charge through the electrodes and electrolytes in a cell
- State that increased surface area of the electrodes increases the rate of the reaction by lowering the internal resistance and increasing the maximum current that the cell can deliver, but does not affect the emf of the cell
- State that the wider, shorter and/or more conductive salt bridge lowers internal resistance thereby increasing the maximum current that the cell can deliver, but does not affect the emf of the cell

4. Electrolytic Cells

- Describe an electrolytic cell as an electrochemical cell that uses electrical energy to cause a non-spontaneous redox reaction to occur. Thus, electrical energy is converted into chemical energy

(a) Understanding of the Processes and Redox Reactions

- Identify the anode and cathode
- Write equations for half-reactions taking place at the anode and cathode using the standard electrode potential table or other given half-reactions
- Write the overall ionic cell reaction by combining two half-reactions
- Identify the oxidising agent and the reducing agent for an electrolytic reaction
- Identify or suggest suitable inert electrodes for use in electrolysis and give reasons for their suitability
- Identify the predominant half-reaction taking place at the anode and cathode during electrolysis of an AQUEOUS solution
 - Explain the role of concentration when predicting the predominant anode half-reaction during electrolysis
 - Explain under what circumstances the anode itself will be oxidised in preference to the ions in the solution
 - Explain that the inherent reactivity (electrode potentials/strength of agents) will determine which half-reaction will be predominant at the cathode

(b) **Applications of Electrolytic Cells**

- When given a diagram of a cell or other relevant information, predict and explain features of the following electrolytic processes:
 - The electrolysis of an aqueous solution or molten ionic compound
 - Simple electroplating of objects in aqueous solutions of metal ions, demonstrating an understanding of why it is not possible to electroplate using metals ions which are weaker oxidising agents than water (H_2O) under standard conditions
 - The electrorefining of copper, including the possible competitive reactions that can take place at the electrodes due to the presence of impurities
 - The electrolysis of a concentrated solution of sodium chloride (brine) and its use in the chlor-alkali industry using the membrane cell

5. **Calculations involving Redox Reactions**

- Apply mole relationships and stoichiometry to electrochemical reactions
- Perform mole calculations involving the Faraday constant (F) and the formulae $q = It$ and $q = nF$ (where n is the number of moles of electrons) to determine unknown quantities
- Use the table of standard electrode potentials to calculate the emf of a redox reaction under standard conditions, which may or may not be taking place in a cell, using

$$E_{\text{cell}}^{\theta} = E_{\text{cathode}}^{\theta} - E_{\text{anode}}^{\theta}$$

OR

$$E_{\text{cell}}^{\theta} = E_{\text{oxidising agent}}^{\theta} - E_{\text{reducing agent}}^{\theta}$$

- Use a positive value of the standard emf (E_{cell}^{θ}) as an indication that a redox reaction is spontaneous under standard conditions
- Use a negative value of the standard emf (E_{cell}^{θ}) as an indication that a redox reaction is non-spontaneous under standard conditions
- Know that cell potentials will differ when conditions are not standard

G. Organic Chemistry

1. Organic Molecular Structures – Functional Groups, Saturated and Unsaturated Structures

- Describe organic molecules as molecules containing carbon atoms with the exception of carbon dioxide, carbon monoxide, diamond, graphite, carbonates (or bicarbonates), carbides (e.g. CaC_2) and cyanides (e.g. KCN)
- Define:
 - a hydrocarbon as *a compound containing only carbon and hydrogen atoms*
 - a saturated compound as *a compound in which all of the bonds between carbon atoms are single bonds*
 - an unsaturated compound as *a compound in which there is at least one double and/or triple bond between carbon atoms*
- Identify compounds that are hydrocarbons
- Identify compounds that are saturated and unsaturated
- Define
 - a functional group as *an atom or a group of atoms that form the centre of chemical activity in the molecule*
 - a homologous series as *a series of similar compounds which have the same functional group and have the same general formula, in which each member differs from the previous one by a single CH_2 unit*
- Identify the functional group of compounds belonging to the following homologous series:

Homologous Series	Functional Group	
	Structure	Name/Description
Alkanes	$\begin{array}{c} \quad \\ -\text{C}-\text{C}- \\ \quad \end{array}$	Only C-H and C-C single bonds
Alkenes	$\begin{array}{c} \diagup \quad \diagdown \\ \text{C}=\text{C} \\ \diagdown \quad \diagup \end{array}$	Carbon-carbon double bond
Haloalkanes	$\begin{array}{c} \\ -\text{C}-\text{X} \\ \end{array}$ Where X = F, Cl, Br, or I	Halogen atom bonded to a saturated C atom
Alcohols	$\begin{array}{c} \\ -\text{C}-\text{O}-\text{H} \\ \end{array}$	Hydroxyl group bonded to a saturated C atom
Carboxylic acids	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}-\text{H} \end{array}$	Carboxyl group
Esters	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}-\text{C}- \\ \end{array}$	Ester group

Note: Identification of primary, secondary, and tertiary carbons will not be assessed.

2. IUPAC Naming and Formulae; Isomers

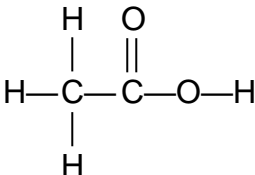
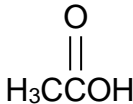
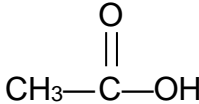
- Write the IUPAC name when given the formula of compounds in the following homologous series: alkanes, alkenes, haloalkanes, alcohols, carboxylic acids and esters (up to 8 carbon atoms in the parent chain)

NOTE the following for naming purposes:

- Naming and drawing of organic compounds is restricted to one type of functional group per compound and to a maximum of two functional groups of the same type per compound, except for haloalkanes, where a maximum of two different halogen substituents (e.g. bromo- and chloro-) are allowed per molecule.
- The only substituent chains that are allowed in naming and reactions are: methyl- and ethyl- groups.
- A maximum of THREE substituent chains (alkyl substituents) are allowed on the alkane, alkene, haloalkane, alcohol or carboxylic acid parent chain. No substituent chains are allowed on esters.
- When naming haloalkanes, the halogen atoms do not get preference over alkyl groups – numbering should start from the end nearest to the first substituent, either the alkyl group or the halogen. In haloalkanes, where e.g. a Br and a Cl have the same number when numbered from different ends of the chain, Br gets alphabetical preference.
- When writing IUPAC names, substituents appear as prefixes written alphabetically (bromo-, chloro-, ethyl-, methyl-), ignoring the prefixes di- and tri-.
- When writing IUPAC names, the following conventions must be followed:
 - Numbers are separated from letters using an en dash (-).
 - Numbers are separated from numbers using a comma (,).
 - Letters are not separated at all (i.e. no space is used), with the exceptions being esters (e.g. methyl ethanoate) and carboxylic acids (e.g. propanoic acid).
- In some (especially smaller) molecules numbering becomes redundant, but redundancy will not be penalised. For example, methylbut-2-ene may be written as 2-methylbut-2-ene without penalty. The only exception to this is if numbering is always redundant, e.g. for a carboxylic acid: butan-1-oic acid will be penalised, as it must be written as butanoic acid.
- For euphonic purposes, the vowel "e" is generally removed from the name before the suffix, e.g. butan-1-ol instead of butane-1-ol. However, this is not done for diols, e.g. butane-1,2-diol is correct, and not butan-1,2-diol.
- For euphonic purposes, the vowel "a" must be added to the name before the suffix for dienes, e.g. buta-1,3-diene is correct, and not but-1,3-diene.

- Write down, identify and apply the general formula for alkanes (C_nH_{2n+2}) and alkenes (C_nH_{2n})
Note: Only one double bond will be considered when assessing general formulae of alkenes
- Draw structural, condensed structural and molecular formulae for compounds belonging to the following homologous series: alkanes, alkenes, haloalkanes, alcohols, carboxylic acids and esters (up to 8 carbon atoms in the parent chain)

Examples of different types of formulae for ethanoic acid

Structural	Condensed structural	Molecular
Atoms are represented by their chemical symbols and lines are used to represent ALL of the bonds between atoms.	Represents the way in which atoms are bonded, but NOT ALL bond lines are shown.	This is a chemical formula that indicates the type of atoms and the correct number of each in a molecule.
	CH_3COOH or  or 	$C_2H_4O_2$ Order is C, H, then alphabetical

- Define structural isomers as *compounds having the same molecular formula but different structural formulae*
- Identify compounds that are structural isomers (up to 8 carbon atoms in the parent chain)
Structural isomers are restricted to:
 - (1) chain isomers;
 - (2) positional isomers; and
 - (3) functional isomers
 Note: No cis-, trans- or stereo-isomerism will be assessed

Examples of types of structural isomerism

Type of isomer	Description	Examples
(1) Chain isomers	Different type of chain structure, i.e. branching	butane and methylpropane
(2) Positional isomers	Different positions of the same functional group or alkyl substituent on the parent chain	i. 1-chloropropane and 2-chloropropane ii. but-1-ene and but-2-ene iii. ethyl methanoate and methyl ethanoate iv. 2-methylpentane and 3-methylpentane
(3) Functional isomers	Different functional groups	propanoic acid and ethyl methanoate

3. Relationship between Physical Properties and Structure

- Know that all hydrocarbon molecules are non-polar and thus have only London intermolecular forces
- Recognise and explain the relationship between melting point/boiling point and the strength of the intermolecular forces (see *intermolecular forces section*)

Note: Dimer formation in carboxylic acids and its subsequent effect on the strength of London forces will not be examined.

4. Organic Chemical Reactions (ONLY alkanes, alkenes, haloalkanes, alcohols, carboxylic acids and esters)

- Know that, since many organic compounds are flammable, a water bath is used for gentle heating of organic reaction mixtures
- Classify and identify the following reaction types: combustion, substitution, addition, elimination and esterification

(a) Combustion Reactions

- State that combustion reactions are exothermic and hence explain the importance of fossil fuels in terms of their ability to transform chemical potential energy into thermal energy
- Write balanced chemical equations to represent the complete combustion of alkanes, alkenes and alcohols with excess oxygen to produce water and carbon dioxide

(b) **Substitution Reactions (GENERAL type)**

- When given the appropriate reaction conditions, write balanced equations to show the formation of substitution products in the following SPECIFIC types of substitution reactions:
 - **Halogenation:** alkanes to haloalkanes
 - e.g. $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$
(Reaction condition: in the presence of ultraviolet light or heat)
 - **Hydrolysis:** haloalkanes to alcohols
 - e.g. $\text{CH}_3\text{Cl} + \text{NaOH(aq)} \rightarrow \text{CH}_3\text{OH} + \text{NaCl}$
(Reaction conditions: heat under reflux in a dilute aqueous alkali solution)
 - Know what 'heating under reflux' entails and explain why this is necessary

(c) **Addition Reactions (GENERAL type)**

- When given the appropriate reaction conditions write balanced equations to show the formation of addition products in the following SPECIFIC types of addition reactions:
 - **Hydrogenation:** addition of H_2 to any alkene
 - e.g. $\text{CH}_2=\text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3-\text{CH}_3$
(Reaction condition: alkene dissolved in an organic solvent with a Pt, Pd or Ni catalyst in a H_2 atmosphere)
 - **Halogenation:** addition of X_2 ($\text{X} = \text{Cl}, \text{Br}$)
 - e.g. $\text{CH}_2=\text{CH}_2 + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}-\text{CH}_2\text{Cl}$
Know that rapid decolourisation of bromine water by an alkene at room temperature is used to distinguish an alkene from an alkane (test for unsaturation). Since alkenes are more reactive than alkanes, addition reactions occur faster than substitution reactions
 - **Hydrohalogenation:** addition of HX to any alkene
 - e.g. $\text{CH}_2=\text{CH}_2 + \text{HCl} \rightarrow \text{CH}_3-\text{CH}_2\text{Cl}$
(Reaction condition: no water may be present)
 - **Hydration:** addition of H_2O to any alkene
 - e.g. $\text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3-\text{CH}_2\text{OH}$
(Reaction condition: steam and a suitable catalyst, e.g. H_3PO_4)

Note: When two addition products are possible, either will be accepted.

(d) Elimination Reactions (GENERAL type)

- When given the appropriate reaction conditions write balanced equations to show the formation of elimination products in the following SPECIFIC types of elimination reactions:
 - **Dehydrohalogenation:** elimination of HX from any haloalkane
 - e.g. $\text{CH}_3\text{--CH}_2\text{Cl} \rightarrow \text{CH}_2=\text{CH}_2 + \text{HCl}$
 OR: $\text{CH}_3\text{--CH}_2\text{Cl} + \text{KOH} \rightarrow \text{CH}_2=\text{CH}_2 + \text{KCl} + \text{H}_2\text{O}$
 (Reaction condition: hot concentrated solution of NaOH or KOH in an ethanol solvent i.e. in the absence of water; the amount of water produced in the second reaction is insufficient to cause hydrolysis)
 - **Dehydration:** elimination of H_2O from any alcohol
 - e.g. $\text{CH}_3\text{--CH}_2\text{OH} \rightarrow \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O}$
 (Reaction condition: acid catalysed dehydration – heating of alcohol with an excess of concentrated H_2SO_4 or H_3PO_4)
 - **Cracking of hydrocarbons:** breaking up large alkane molecules to form a mixture of smaller and more useful alkane and alkene molecules
 (Reaction conditions:
 - thermal cracking – high pressures and temperatures without a catalyst
 - catalytic cracking – lower temperatures and pressures in the presence of a catalyst)

Note: When two elimination products are possible, either will be accepted.

(e) Esterification Reactions

- Know that esterification is an acid-catalysed reaction between an alcohol and a carboxylic acid that produces an ester and water
- State or identify the appropriate reaction conditions (acid catalyst and gentle heating)
- Identify the alcohol and carboxylic acid used to prepare any given ester
- Identify the ester produced when given any alcohol and carboxylic acid
- Write balanced equations to represent the preparation of an ester

Note: For combustion and esterification reactions, there is no distinction between the general and specific reaction type.

III. SCIENTIFIC SKILLS

These skills may be assessed under any Physics and/or Chemistry content

1. Arithmetic and algebra

Candidates should be able to:

- Recognise and use expressions in decimal and scientific notation
- Use a calculator for addition, subtraction, multiplication and division, and find arithmetic means, powers (including reciprocals and n^{th} -roots), sines, cosines, tangents (and the inverse functions)
- Substitute physical quantities into physical equations using consistent units
- Solve simple algebraic equations
- Recall and use Pythagoras' theorem
- Recall and use formulae for the area of rectangles and triangles
- Additional trigonometric rules may be used to solve problems, but will not be required. Trigonometric rules will not be supplied
- Solve a system of two linear simultaneous equations
- Solve quadratic equations where the solution may not always be a whole number. The quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ may be helpful in solving a quadratic equation but is not supplied

2. Conversion of Units

Candidates should be able to:

- Identify common conversion factors in mass, length, volume and pressure
- Recognise and convert various metric scales of measurement
- Translate data into the correct units and dimensions using conversion factors and scientific notation
- Recall orders of magnitude (10^{-9} , 10^{-6} , 10^{-3} , 10^{-2} , 10^{-1} , 10^1 , 10^2 , 10^3 , 10^6 , 10^9)

3. Mathematical Relationships and graphical representation

Candidates should be able to:

- Identify independent, dependent and fixed variables in an investigation
- Comment on the accuracy and the precision of experimental results
- Describe and recognise certain relationships between two variables:
 - y is directly proportional to x ($y/x = \text{constant}$)
 - y is inversely proportional to x ($yx = \text{constant}$)
 - y is directly proportional to x^2 ($y/x^2 = \text{constant}$)
 - y is inversely proportional to x^2 ($yx^2 = \text{constant}$)
- Organise observations in a data table, analyse the data for trends or patterns, and interpret the trends or patterns, using scientific concepts
- Select appropriate variables and scales for graph plotting and construct a graph
- Interpret a graph constructed from experimentally obtained data to identify relationships:
 - y is directly proportional to x ($y/x = \text{constant}$)
 - y is inversely proportional to x ($yx = \text{constant}$)
 - y is directly proportional to x^2 ($y/x^2 = \text{constant}$)
 - y is inversely proportional to x^2 ($yx^2 = \text{constant}$)

- Calculate the gradient of a best-fit line using two points on the line (rather than given data points)
- Derive the units of the quantity represented by the gradient
- Identify the physical quantity represented by the gradient of a graph
- Relate a straight-line graph to an equation in the form $y = mx + c$ and determine the meaning of the y-intercept and/or the x-intercept where appropriate
- Read off a value that corresponds on the best fit line to a given variable
- Select appropriate units and scales for situations involving proportional reasoning
- Determine the value of the area below a curve where the area has physical significance and identify the physical quantity that the area represents

4. **Skills needed to analyse Practical Investigations**

- Identify an answerable question and formulate a hypothesis to guide a scientific investigation
- Design a simple experiment including appropriate controls
- Identify independent, dependent and fixed variables in an investigation
- Perform and understand laboratory procedures directed at testing a hypothesis
- Select appropriate tools and technology to collect precise and accurate quantitative data
- Correctly read a thermometer, a balance, metric ruler, voltmeter, ammeter, graduated cylinder, pipette, and burette
- Record observations and data using the correct scientific units
- Export data into the appropriate form of data presentation (e.g. equation, table, graph, or diagram)
- Analyse information in a table, graph or diagram (e.g. compute the mean of a series of values or determine the slope of a line, manipulate data to draw a straight-line graph e.g. plot F vs $1/r^2$ to establish mathematical relationships)
- Show an understanding of the distinction between precision and accuracy
- Comment on the accuracy and the precision of experimental results
- Analyse experimental results and identify possible sources of bias or experimental error
- Recognise, analyse and evaluate alternative explanations for the same set of observations
- Formulate a mathematical model that can be used for further investigation based on the relationship between variables (which has been established experimentally)
- Distinguish between qualitative and quantitative analysis of data