

CHAPTER 11

PHYSICAL SCIENCES

The following report should be read in conjunction with the Physical Sciences question papers of the November 2020 examination.

11.1 PERFORMANCE TRENDS (2016–2020)

The number of candidates who wrote the Physical Sciences examination in 2020 increased by 9 832 in comparison to that of 2019. The performance of the candidates in 2020 reflects a tremendous decline at the 30% level from 75,5% in 2019 to 65,8% and at the 40% level from 51,7% in 2019 to 42,4%.

Table 11.1.1 Overall achievement rates in Physical Sciences

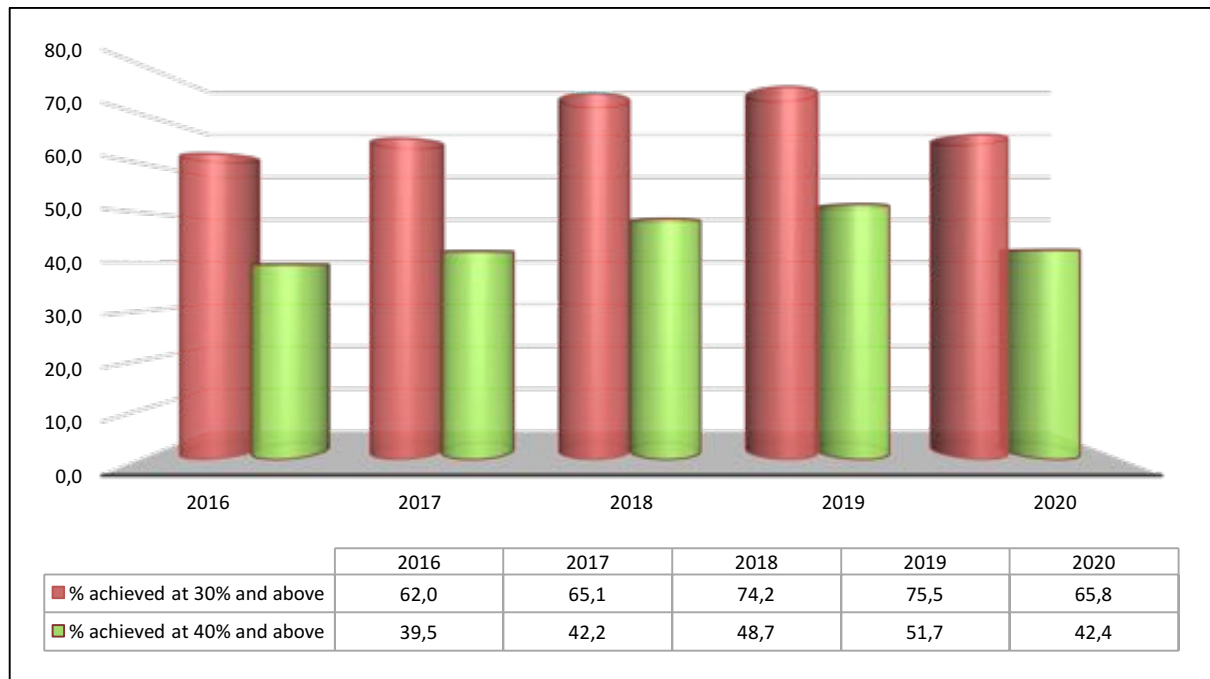
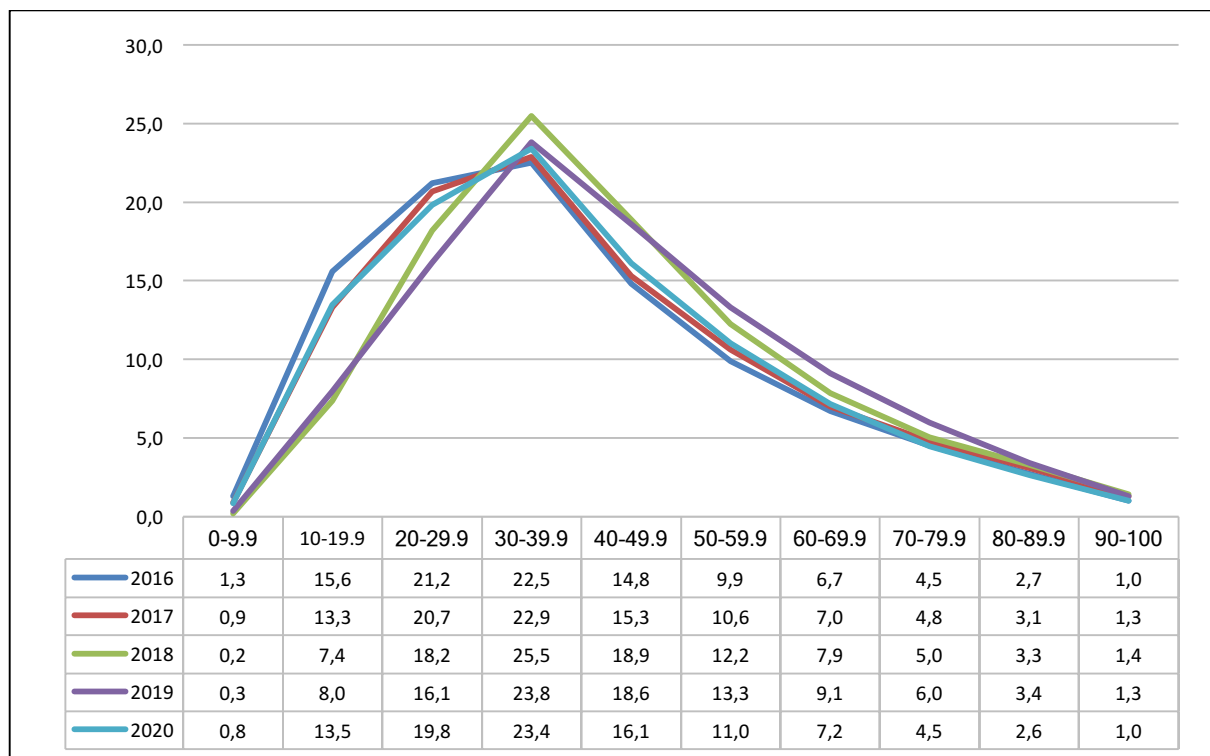
Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2016	192 710	119 467	62,0	76 068	39,5
2017	179 561	116 862	65,1	75 736	42,2
2018	172 319	127 919	74,2	84 002	48,7
2019	164 478	124 237	75,5	85 034	51,7
2020	174 310	114 758	65,8	73 982	42,4

The questions in Paper 1 on the Doppler Effect, Electrostatics, Electrodynamics and the Photoelectric Effect were generally well answered. Performance pertaining to Organic Chemistry in Paper 2 was good. The questions on reaction rate and acids and bases in Paper 2 were very poorly answered.

Questions pertaining to pure recall of content were very poorly answered because key words and phrases were omitted from definitions. Short informal assessment tasks relating to these issues will greatly assist in improving these shortcomings. This can be used to good effect in content relating to definitions and laws listed in the *CAPS* and the *Examination Guidelines*.

Interpretation of graphs is still a challenge for many learners. Problem-solving exercises that involve graphs should be done in a variety of topics. Identification of the variables in relation to the equation describing the graph should be stressed.

The application of mathematical principles is still a challenge for many learners and could have contributed to a decline in performance in 2020. Learners should be given a variety of problem-solving activities that involve mathematical knowledge pertaining to simultaneous equations, quadratic equations, binomials, factorisation, trigonometry and graphs in classwork, homework, tests and examinations.

Graph 11.1.1 Overall achievement rates in Physical Sciences (percentage)**Graph 11.1.2 Performance distribution curves in Physical Sciences (percentage)**

11.2 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 1

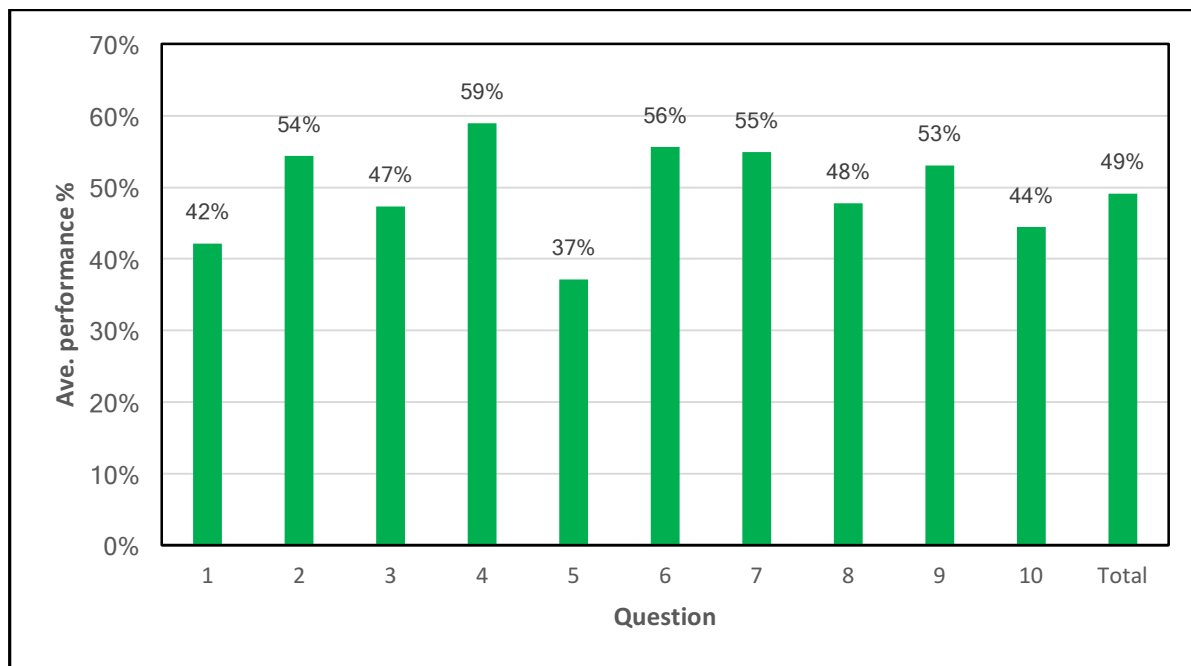
General comments

- (a) The questions on Doppler Effect, Electrostatics, Electrodynamics and the Photoelectric Effect (Q6, Q7, Q9, and Q10) were generally well answered.
- (b) In many questions, learners are making the same errors and are displaying the same poor conceptual understanding as in previous years. Provinces should mediate the effective implementation of the recommendations in this diagnostic report.
- (c) Questions pertaining to pure recall of content were very poorly answered because key words and phrases were omitted from definitions. Short informal assessment tasks relating to these issues will greatly assist in improving these shortcomings. This can be used to good effect in content relating to definitions and laws listed in the *CAPS* and the *Examination Guidelines*.
- (d) Learners are still struggling with the drawing and labelling of free-body diagrams. This skill is central to solving problems involving forces acting on objects such as in Q2 and Q5. Teachers should therefore ensure that learners are able to draw free-body diagrams for such problems in classwork, homework and tests.
- (e) Interpretation of graphs is a challenge for many learners. Problem-solving exercises that involve graphs should be done in a variety of topics. Identification of the variables in relation to the equation describing the graph should be stressed. The scale of graphs, gradient, ordered-pairs and x and y-intercepts need to be emphasised within problem-solving in science contexts.
- (f) The application of mathematical principles is still a challenge for many learners. Learners should be given a variety of problem-solving activities that involve mathematical knowledge pertaining to simultaneous equations, quadratic equations, binomials, factorisation, trigonometry and graphs in classwork, homework, tests and examinations.
- (g) It is critical that learners understand the concept of a variable that is kept constant in a particular equation and to use this information to find relationships between variables in that equation.
- (h) Some learners use correct formulae and substitute correctly but fail to get the correct final answer. It is necessary for teachers to spend some time to ensure that learners know how to operate their calculators. Learners should be encouraged to use the same calculators that they have been using during the year when they sit for their examination.

11.3 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 1

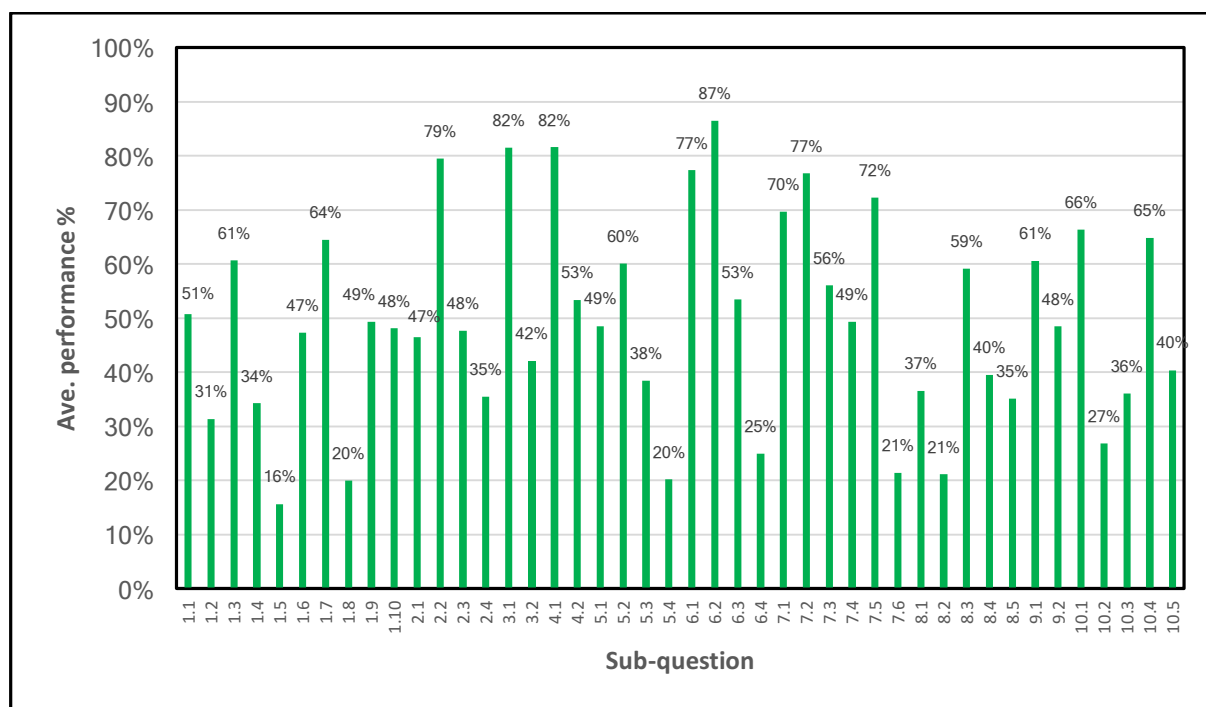
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 11.3.1 Average performance per question in Paper 1



Q	Topic/s
1	Multiple choice questions - all topics
2	Newton's laws of motion
3	Vertical projectile motion
4	Momentum
5	Work, energy and power
6	Doppler effect
7	Electrostatics (Coulomb's law & electric fields)
8	Electric circuits
9	Electrodynamics: Motors, generators and alternating current
10	Photoelectric effect

There was an improvement in performance in four topics, viz. Doppler effect (Q6), Electrostatics (Q7), Electrodynamics (Q9) and Photoelectric Effect (Q10), as compared to 2019.

Graph 11.3.2 Average performance per sub-question in Paper 1

Sub-question	Topic	Sub-question	Topic	Sub-question	Topic
1.1	Newton's 2 nd Law	5.3	Calculating the height h indicated in the diagram	8.3	Calculating the reading on the ammeter, the total external resistance and emf of the battery
1.2	Gravitational acceleration	5.4	Calculating the power delivered by the engine	8.4	Explaining whether the given statement is correct
1.3	Free fall	6.1	Definition of the Doppler Effect	8.5	How the removal of a resistor from the circuit affects the emf of the battery
1.4	Change in momentum	6.2	Interpreting the direction of motion of the train	9.1	Electrical Machine, energy conversion, component and the direction of rotation of the coil
1.5	Work	6.3	Calculating the speed of the train	9.2	Defining rms voltage, calculation of the resistance and energy dissipated by the device
1.6	Doppler Effect	6.4	Calculating the time indicated on the graph	10.1	Identifying the phenomenon displayed by the graph
1.7	Conservation of charge	7.1	Calculating the number of excess electrons	10.2	Naming the physical quantity indicated on the graph
1.8	AC Theory	7.2	Calculating the magnitude of the electrostatic force	10.3	Identifying metal with largest wavelength
1.9	Electric circuits	7.3	Description of an electric field	10.4	Definition of the work function
1.10	Photoelectric current	7.4	Calculating the magnitude of the net electric field	10.5	Calculating the work function and frequency of the incident light
2.1	Definition of the normal force	7.5	Identifying the nature of the charge		
2.2	Drawing a free-body diagram	7.6	Calculating the magnitude of the charge		
2.3	Calculation of the combined mass using Newton's 2 nd Law	8.1	Definition of the emf of a battery		
2.4	Effect on the tension in the string and the velocity of the 20 kg block	8.2	Providing a reason why the voltmeter reading decreases		
3.1	Definition of free fall				
3.2	Interpreting the graph of bouncing object				
4.1	Definition of momentum				
4.2	Calculating the velocity of the ball after collision and the impulse during the collision				
5.1	Definition of a non-conservative force				
5.2	Calculate the change in kinetic energy				

11.4 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 1

QUESTION 1 MULTIPLE CHOICE

Common errors and misconceptions

- (a) In Q1.1 many candidates did not recognise Newton's 2nd law in terms of momentum.
- (b) In Q1.2 many candidates did not understand the mathematical relationship between the physical quantities in the equation for gravitational acceleration.
- (c) In Q1.3 candidates experienced difficulty in interpreting the acceleration-time graph for an object in free-fall.
- (d) Candidates failed to relate the direction of F_{net} to the direction of the impulse which is equal to the change in momentum in Q1.4. Candidates failed to understand that the change in momentum (Δp) has a direction.
- (e) Candidates lacked an understanding of the basic concept of the Doppler Effect in Q1.6 i.e. The Doppler effect is not observed when there is no relative motion between the source and the observer.
- (f) Some candidates failed to realise in Q1.8 that each completed wave has two peak values, one with a positive amplitude and the other with a negative amplitude.

Suggestions for improvement

- (a) Multiple choice questions test learners understanding of concepts, principles, laws and the relationship between the dependent, independent and constant variables. This must be demonstrated through logical reasoning and not by engaging in lengthy calculations. During teaching and learning, carefully selected concrete examples must be worked out to demonstrate these concepts, laws and principles, followed by generalisations and the making of predictions.
- (b) Learners must also be encouraged to refer to the formula sheet because it gives the summaries of laws and principles as well as the relationship between the variables.
- (c) Teachers must include the use of ICT in the teaching of the subject. Multimedia/software such as *PhET* and *Edukite* as well as YouTube videos should be used to demonstrate the answers for multiple choice questions through simulations (virtual experiments).
- (d) It is recommended that a booklet containing multiple choice questions from different topics from different sources such as previous NSC and provincial papers and text books be prepared. The booklet should also have a step-by-step explanation of how to answer multiple-choice questions.

QUESTION 2 NEWTON'S LAWS OF MOTION**Common errors and misconceptions**

- (a) In Q2.1 candidates omitted key words in their definition. Some misconceptions about the normal force were:
- Force that opposes gravitational force
 - Normal is the same as weight and perpendicular to the surface.
- (b) Many candidates labelled their free-body diagram incorrectly, also omitted arrows and labels in the free-body diagrams and drew forces that were not in contact with the body.
- (c) Some candidates failed to realise that $F_{\text{net}} = 0$ at constant velocity due to the fact that acceleration equals zero.

Suggestions for improvement

- (a) Teachers should stick to and emphasise the definitions in the *Examination Guidelines* and *CAPS*. Key words must be emphasised in these definitions.
- (b) The importance of drawing free-body diagrams for each object correctly and their usefulness in problem solving must be emphasised. A method of solving simultaneous equations can be used to solve for the unknown in the equation and this method should be taught thoroughly in class. Encourage learners to use different problem-solving strategies to solve the same problem to ensure that they gain a greater understanding of the problem and their solutions.
- (c) Furthermore, learners should also be taught to understand the relationship between the equations obtained from the free-body diagrams and the equations obtained using the system approach.
- (d) Teachers should emphasise that the net force acting on an object is the sum of all the forces acting on the object parallel to the direction of motion of the object.
- (e) Learners must be systematically exposed to different questions in which trigonometric relations must be applied.

QUESTION 3 VERTICAL PROJECTILE MOTION**Common errors and misconceptions**

- (a) Some candidates omitted the keywords 'only force' and 'gravitational force' in their definition of free fall. Some gave the definition of a projectile.
- (b) The candidates experienced problems with the signs of velocity and acceleration in their substitutions into the appropriate equations of motion.
- (c) Many candidates could not interpret the graphs properly and showed a poor understanding of the concept of time symmetry in vertical projectile motion.
- (d) Some candidates used 'sec' as the unit for time instead of 's'.

Suggestions for improvement

- (a) Learners must be advised to start every calculation in mechanics, including vertical projectile motion, by indicating the sign convention at the beginning of the problem. Emphasise that the direction of gravitational acceleration does not change in a question but remains constant. Learners should be advised to keep to ONE sign convention when solving a problem and not to change their chosen sign convention within a problem as this could lead to confusion.
- (b) Teach learners skills of interpreting graphs especially for projectiles, e.g. to have reference points and collect all relevant data before calculating any quantity.
- (c) The correct SI unit for time should be emphasised to learners.

QUESTION 4 MOMENTUM AND IMPULSE**Common errors and misconceptions**

- (a) In Q4.1 some candidates wrote the definition for the law of conservation of linear momentum. Some used the term speed instead of velocity whilst some omitted the word 'product' and also used the term 'rate'.
- (b) Many candidates erroneously used the formula $\Sigma E_{ki} = \Sigma E_{kf}$ instead of $\Sigma p_i = \Sigma p_f$ or $F_{net}\Delta t = m\Delta v$ in Q4.2.1.

Suggestions for improvement

- (a) Expose learners to many different scenarios or problems that include the application of Newton's 3rd Law, the principle of conservation of linear momentum and the impulse-momentum theorem. Teachers should also integrate topics (as and when necessary) in addition to teaching each topic in isolation. Moreover, they should expose learners to problems that integrate the application of different concepts.
- (b) Teach learners to use the data sheet and formula sheet throughout the year.
- (c) The difference between momentum and change in momentum should be made clear during teaching with a clear focus on their vector nature.

QUESTION 5 WORK, ENERGY AND POWER**Common errors and misconceptions**

- (a) Some candidates could not properly define non-conservative force while some omitted key words in their definition e.g. omitting the word 'work'.
- (b) Many candidates applied the principle of conservation of mechanical energy even though it was not an isolated/closed system.
- (c) Some candidates calculated ΔK using the formula $\Delta K = \frac{1}{2} m(v_f - v_i)^2$ instead of $\Delta K = \frac{1}{2} m(v_f^2 - v_i^2)$.
- (d) Candidates also treated energy as a vector quantity by interpreting the '-' in '-1 200J' to mean direction and therefore interpreting "-1 200J" as "1200 J" in an indicated direction.

Suggestions for improvement

- (a) Carefully selected examples and assessment tasks must be used to facilitate the understanding of why certain forces are classified as conservative or non-conservative.
- (b) Use *PhET* simulations for the identification of forces acting on objects.
- (c) Learners should know that work done by a force is always equal to a change in energy. E.g: $W_{\text{net}} = \Delta K$, $W_{\text{nc}} = \Delta U + \Delta K$, $W_g = -\Delta U$.

When using $W_{\text{nc}} = \Delta U + \Delta K$ or $W_{\text{net}} = \Delta K$ learners must draw a free body diagram to identify the forces acting in the direction of motion to determine how many forces are causing the net work to be done. Emphasise that Δ implies: final – initial.

QUESTION 6 DOPPLER EFFECT**Common errors and misconceptions**

- (a) Many candidates could not interpret the values from the graph. They mixed up the frequencies for the observer moving towards the source and away from the source.
- (b) Several candidates used the equation $v = f\lambda$ to calculate the frequency and then find its period while some simply used the equation $T = \frac{1}{f}$ to calculate the value of time t_1 .

Suggestions for improvement

- (a) Teachers need to source and expose learners to a variety of questions relating to the Doppler effect equation as the scope is very broad, given the number of variables in the equation.
- (b) Revise the use of the wave equation: $v = f\lambda$, and period equation $T = \frac{1}{f}$
- (c) Teachers must emphasise the progression of knowledge since the work done in Grade 12 cannot be seen in isolation from work done in Grade 10 and Grade 11.

QUESTION 7 ELECTROSTATICS (COULOMB'S LAW and ELECTRIC FIELDS)**Common errors and misconceptions**

- (a) Candidates defined the 'electric field at a point' instead of describing an 'electric field'.
- (b) Candidates also confused Coulomb's Law with Newton's Law of Universal Gravitation.
- (c) Candidates swapped/mixed the formulae for E and F as follows: $F = k \frac{Q}{r^2}$ and $E = k \frac{Q_1 Q_2}{r^2}$.
- (d) Candidates did not use the absolute value of the charges when substituting in the formula of Coulomb's Law or the electric field at a point.

Suggestions for improvement

- (a) Teachers need to emphasise to learners that calculations of net electrostatic force and electric field are similar in terms of their vector considerations.
- (b) Teachers need to clarify the distinction between the two equations i.e. $E = \frac{F}{q}$ and $E = \frac{kQ}{r^2}$ and explain to learners what charge the 'q' in $E = \frac{F}{q}$ represents and what charge the 'Q' in $E = \frac{kQ}{r^2}$ represents.
- (c) Expose learners to vector diagrams (1D and 2D) and vector triangles when working with forces (electrostatic and / or gravitational when determining the resultant of forces acting on a body) and net electric fields. Emphasise the integration of these concepts. Learners need more practise on 2D vector problems as they seem to be more comfortable and perform better in the 1D than the 2D problems.

QUESTION 8 ELECTRIC CIRCUITS**Common errors and misconceptions**

- (a) Many candidates were not scientifically correct in defining the emf of a battery as key words were omitted in their definitions. Some defined emf as 'the voltage of a battery when there is no flow of current in the circuit' or 'when the circuit is open'.
- (b) Many candidates had difficulty in explaining why the terminal voltage drops when the current flows through the battery with internal resistance, as well as applying the relevant principles of resistors in parallel.
- (c) Calculating R_{ext} in one step starting off with the wrong statement:

For example:
$$R_{\text{ext}} = \frac{1}{R_1} + \frac{1}{R_2} + R_s$$

Suggestions for improvement

- (a) Although the principles of series and parallel circuits are taught from Grade 9, the basic principles should be revisited and practiced constantly. The critical features of series and parallel circuits with and without internal resistance must be emphasised.
- (b) Use *PhET* simulations to demonstrate the relationship between V_{ext} and V_{int} and the effect of adding resistors in series and parallel can also be demonstrated.

QUESTION 9 ELECTRODYNAMICS**Common errors and misconceptions**

- (a) Many candidates had difficulty in defining the term 'rms voltage'.
- (b) Many candidates still omit the subscripts 'rms' and 'ave' in the equations $P_{\text{ave}} = V_{\text{rms}} I_{\text{rms}}$,
 $P_{\text{ave}} = I_{\text{rms}}^2 R$ and $P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R}$.

- (c) Several candidates failed to recognise that the given voltage of the device was the rms voltage.

Suggestions for improvement

- (a) The Grade 11 work on electromagnetic induction must be revised in Grade 12 when motors and generators are discussed.
- (b) Emphasis should be placed on the use of subscripts in the formulae when rms calculations are done.
- (c) The differences and similarities between V_{rms} and V_{max} , I_{rms} and I_{max} , P_{ave} and P_{max} must be explained clearly and sufficient application type questions must be given to learners.
- (d) *Khan Academy*, *PhET* and *Edukite* are also very useful resources for teachers especially for topics that have a lot practical aspects.

QUESTION 10 PHOTO-ELECTRIC EFFECT

Common errors and misconceptions

- (a) Many candidates could not relate the straight-line graph to the equation: $E_{k(\text{max})} = hf + W_0$ which indicates that the y-intercept is the work function, W_0 .
- (b) Candidates failed to realise that the incident light with the largest wavelength corresponds to the incident light with the lowest frequency.
- (c) In Q10.4 many candidates omitted the word 'minimum' in the definition of the term work function. Important concepts are not clearly understood e.g. work function, threshold frequency and threshold wavelength.
- (d) Many candidates omitted the subscript 'max' in the equation: $E = W_0 + E_{k(\text{max})}$. Errors were made by not squaring 'v' and using the wrong value for the mass of the electron even though its value was given in the data sheet.

Suggestions for improvement

- (a) Teachers should use computer simulations (e.g. *PhET*) when teaching the photoelectric effect. This will assist in improving learners' understanding of the concept.
- (b) Learners should be given a variety of problem-solving exercises at cognitive levels 3 and 4 in both classwork and homework.
- (c) Questions on new situations where interpretation of graphs is required should be compiled and provided to the learners on the photoelectric effect. Also use graphs to highlight concepts such as work function and threshold frequency.

11.5 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 2

General comments

- (a) As in previous years performance pertaining to Organic Chemistry (Q2,Q3, Q4) was good.
- (b) The performance in the question pertaining to electrolytic cells (Q9) improved from previous years.
- (c) The questions on reaction rate (Q5) and acids and bases (Q7) were very poorly answered. The concept of hydrolysis (Q7.1.4) is poorly understood and was one of the poorest answered sub-questions in the paper.
- (d) Many candidates struggled to use their calculators correctly and failed to get the correct answer when calculating the acid concentration from the pH (Q7) and when performing calculations where small numbers are written in scientific notation (Q6).
- (e) From the performance in Q5 it is evident that practical skills did not receive much attention in 2020. Candidates could not identify dependent and independent variables and experienced difficulty in interpreting the given graph.
- (f) The writing of definitions correctly is a challenge to many candidates. Key words were often omitted or words in definitions were replaced with their own wording or explanations, resulting in partially correct definitions.
- (g) Most candidates did not know how to use the table of *Standard Reduction Potentials* correctly which caused the poor performance in some of the sub-questions in Q8 and Q9.
- (h) Rounding off answers to two decimal places in each step of a multistep calculation led to some candidates obtaining final answers that were different from the accepted ranges in those questions. Rounding off to two decimal places should only be done in the final answer to a sub-question.
- (i) There is still a high percentage of candidates who performed poorly due to common consistent mistakes that can be avoided if they prepare well for the examination. These mistakes have no bearing on the difficulty level or the content tested. Many candidates lost valuable marks due to these avoidable errors. This must be resolved through proper teaching and learning.

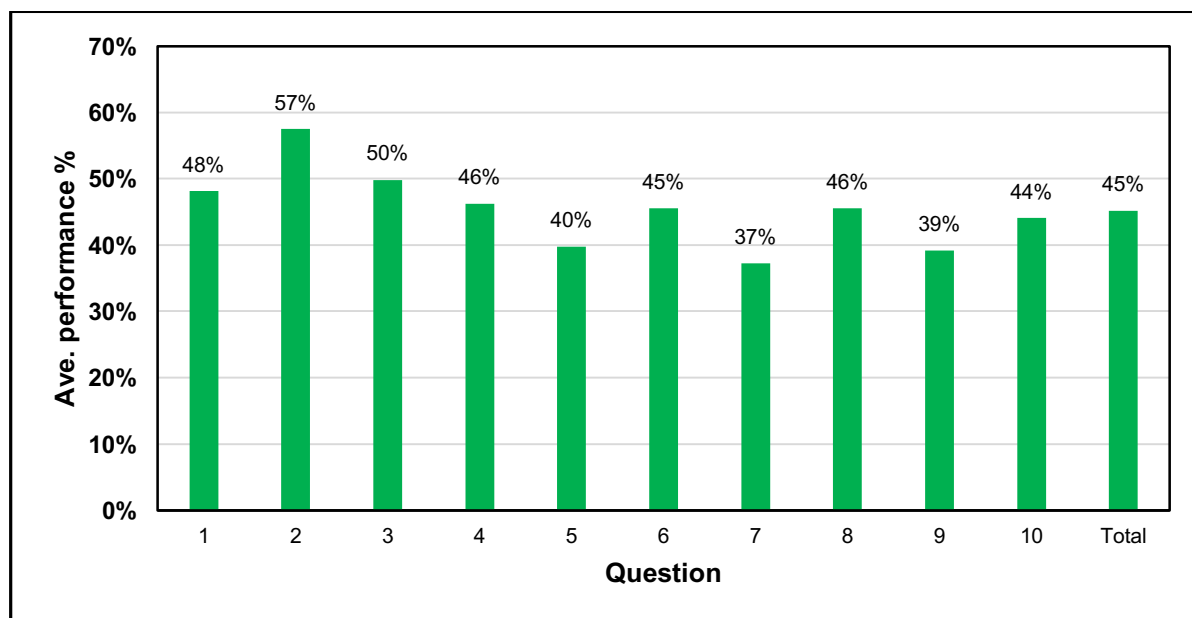
Examples of mistakes are:

- Incorrect numbering of questions
- In calculations, using values incorrectly copied from the question paper
- Incorrect copying of formulae from the data sheet
- Substituting values different from those supplied on the periodic table or constant tables
- No units provided in final answers
- Leaving final answers as fractions
- Omitting H atoms and/or bond lines when drawing structural formulae of organic compounds.

11.6 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 2

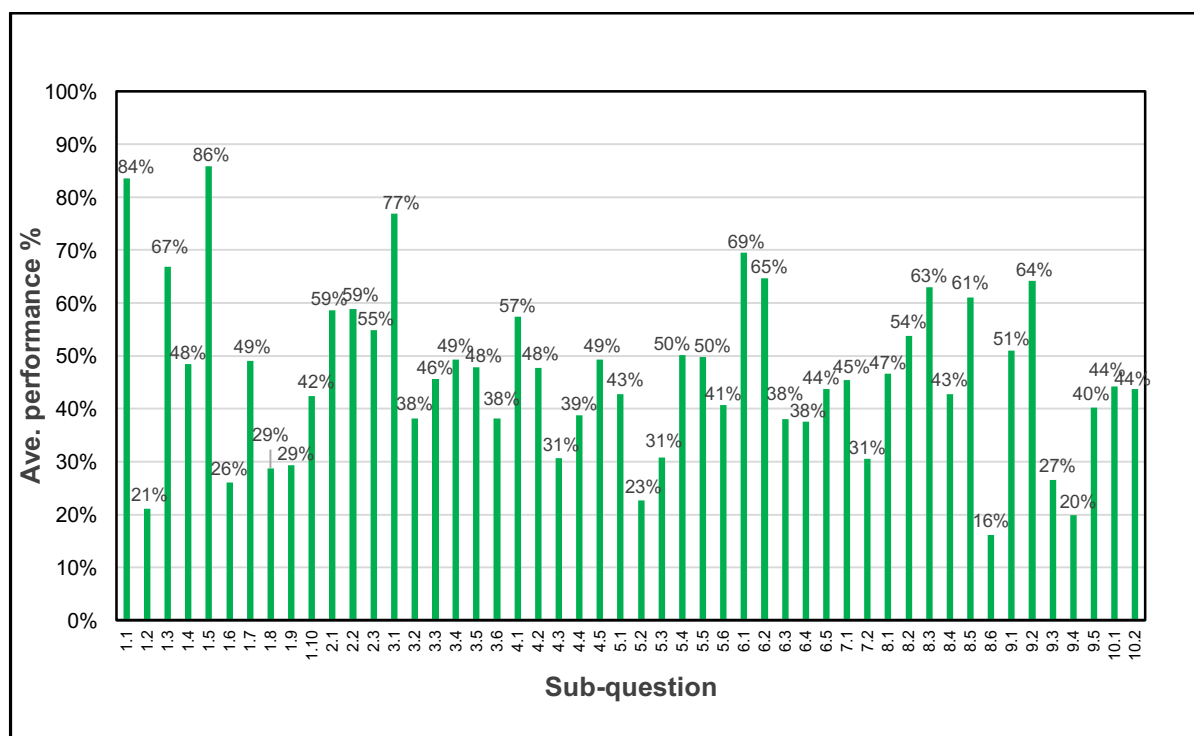
The following graph is based on data from a random sample of candidates. While this graph might not reflect national averages accurately, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 11.6.1 Average performance per question in Paper 2



Q	Topic/s
1	Multiple-choice questions
2	Organic nomenclature
3	Physical properties of organic compounds
4	Organic reactions
5	Reaction rate and stoichiometry
6	Chemical equilibrium
7	Acids and bases and stoichiometry
8	Galvanic cells
9	Electrolytic cells
10	Fertilisers

Performance improved in only four questions, namely nomenclature of organic compounds (Q2), physical properties of organic compounds (Q3), chemical equilibrium (Q6) and electrolytic cells (Q9), as compared to 2019. Whilst there was a significant improvement in the performance of Q9 (electrolytic cells), the performance in Q5 (rate of reaction) showed a decline of more than 10%.

Graph 11.6.2 Average performance per sub-question in Paper 2

Sub-question	Topic
1.1	General formulae
1.2	Empirical formulae
1.3	Structural formulae
1.4	Factors affecting reaction rate
1.5	Role of a catalyst
1.6	pH and application of Le Chatelier's principle
1.7	Conjugate acid-base pairs
1.8	Redox reaction
1.9	Electrolytic cells
1.10	Eutrophication
2.1	Homologous series' and IUPAC names
2.2	IUPAC names and structural formulae
2.3	Primary alcohols and esterification
3.1	Boiling point
3.2	Functional groups
3.3	Boiling points vs number of C atoms
3.4	Boiling point vs functional groups
3.5	Boiling point vs functional groups
3.6	Vapour pressure and boiling point
4.1	Halogenation
4.2	Organic reactions
4.3	Organic reactions
4.4	Organic reactions
4.5	Hydrolysis reaction
5.1	Identification of variables
5.2	Interpretation of a graph
5.3	Calculation of average rate

Sub-question	Topic
5.4	Interpretation of data in a table and on a graph
5.5	Collision theory
5.6	Stoichiometric calculation
6.1	Reversible reaction
6.2	Effect of change in pressure on K_c and the equilibrium position
6.3	Explanation in terms of Le Chatelier's principle
6.4	Explanation in terms of Le Chatelier's principle
6.5	K_c calculation
7.1	Weak acid; pH calculation; hydrolysis of a salt
7.2	Stoichiometric calculation
8.1	Functions of a salt bridge
8.2	Anodes
8.3	Anode in a galvanic cell
8.4	Reduction half-reaction and reducing agent
8.5	Cell potential
8.6	Explanation in terms of relative strengths of reducing agents
9.1	Electrolysis
9.2	Electrolytic cell
9.3	Electrolytic cell
9.4	Change in concentration in an electrolytic cell
9.5	Half-reaction in an electrolytic cell
10.1	Fertilisers
10.2	NPK

11.7 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 2

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common errors and misconceptions

- (a) In Q1.1 the most common incorrect answer was A, which represents the general formula for alkenes.
- (b) In Q1.2 most candidates incorrectly chose the molecular formula of hexanoic acid as the answer and did not determine its empirical formula, possibly because they did not know what an empirical formula was.
- (c) The most common incorrect answer in Q1.3 was A, which represents the structural formula of a carboxylic acid (the only distractor which is NOT an ester)
- (d) Most candidates did not know that volume will not affect the reaction rate (Q1.4). Many chose A as the answer, possibly reasoning that a smaller volume has a larger concentration and therefore resulting in a higher reaction rate.
- (e) Q1.5 was the best answered sub-question. The minority who had it wrong, mainly chose B (activation energy) as answer.
- (f) In Q1.6 most candidates could not relate an increase in $[H^+]$ to pH to determine the effect of pH on the given equilibrium. They mainly chose A as the answer.
- (g) The most common incorrect answers in Q1.7 were A and C. Many candidates did not know that the conjugate base can be obtained by removing H^+ from the given ion.
- (h) Failure to use the *Table of Standard Reduction Potentials* correctly led to poor performance in Q1.8. Candidates could not identify the half-reactions on the table to determine the spontaneous reaction.
- (i) In Q1.9 most candidates showed poor understanding of the functioning of an electrolytic cell. Those who knew that the anode, where oxidation takes place, will show a mass decrease, did not realise that the initial mass of the anode cannot begin at 0 on graph.
- (j) Many candidates failed to differentiate between the process of eutrophication and its causes (Q1.10).

Suggestions for improvement

- (a) The answering of multiple-choice questions is a skill that needs to be developed. Learners must be guided to eliminate the wrong answers through regular practice and assessment. Multiple-choice questions should be used in assessments on a regular basis for all topics covered.
- (b) Subject advisors should compile a booklet with multiple choice questions arranged according to topics to supply to schools. These questions can be used for weekly assessments. Through discussions, learners can then be shown how to approach such questions.

- (c) Although definitions from the Grade 11 section 'Quantitative aspects of Chemical Change' are not assessed in the Grade 12 examinations, applications thereof are examinable. Concepts from this section such as empirical formula, percentage composition, stoichiometric calculations and molar mass should be revised.
- (d) Learners should be taught how to determine the conjugate base or conjugate acid from a given species.

Conjugate acid: ADD H^+ to the given compound or ion.

Example: Conjugate acid of HPO_4^{2-} : $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$

Conjugate base: REMOVE H^+ from the given compound or ion.

Example: Conjugate base of HPO_4^{2-} : $HPO_4^{2-} - H^+ \rightarrow PO_4^{3-}$

- (e) The correct use of the *Table of Standard Reduction Potentials* cannot be emphasised enough. The meaning of reduction potentials (E^\ominus values in Tables 4A and 4B) needs more attention in class. Learners should be taught that the values listed are reduction potentials applicable to each reduction half-reaction which gives a comparative indication of the strength of oxidising agents listed in the table. When two half-reactions are compared, the one with the more positive E^\ominus value has the greater tendency to be a reduction and the substance undergoing reduction is the stronger oxidising agent. The one with the less positive E^\ominus value has the greater tendency to be an oxidation and the substance undergoing oxidation is the stronger reducing agent.

Learners must know where on the *Table of Standard Reduction Potentials* are the oxidising agents and reducing agents and in which direction (upwards or downward) is the strength of each increasing.

The following steps can be followed to determine whether a reaction is spontaneous:

- Identify the two half-reactions that together will give the net equation, on the *Table of Standard Reduction Potentials*.
 - Identify the reducing agent in each half-reaction on the table and determine which one is the stronger reducing agent.
 - Identify the oxidising agent in each half-reaction on the table and determine which one is the stronger oxidising agent.
 - The spontaneous reaction will be between the stronger reducing agent and the stronger oxidising agent.
- (f) Learners must be taught to differentiate between electrolytic and galvanic cells. In an electrolytic cell, the electrode connected to the positive terminal of the battery will always be the anode where oxidation takes place. When a metal is oxidised to form ions, its mass decreases. The electrode connected to the negative terminal of the battery is always the cathode where reduction takes place, resulting in an increase in mass if a solid is formed.

QUESTION 2: ORGANIC NOMENCLATURE**Common errors and misconceptions**

- (a) Most candidates identified the homologous series in Q2.1.1 correctly. For some candidates spelling was a problem and *keytone* instead of *ketone* was used.
- (b) Many candidates numbered the functional group of the aldehyde (*pentan-1-al* instead of *pentanal*) in Q2.1.2 and forfeited one mark. A number of candidates did not know what a functional isomer was and failed to identify the compound as an aldehyde.
- (c) In Q2.2.1 most candidates lost a mark due to incorrect numbering and/or sequencing of substituents. Most candidates gave preference to the halogen (*2-bromo-4,5-dimethylhexane* instead of *5-bromo-2,3-dimethylhexane*) in the haloalkane instead of treating all substituents equally and thus numbered from the side that will result in the lowest numbers.

When drawing the structural formula of the alkyne (Q2.2.2), some placed the triple bond between C1 and C2 instead of between C2 and C3. Other common errors were as follows:

- More than four bonds on the C atoms of the triple bond
- Omitting H atoms
- Using a double bond instead of a triple bond
- Using condensed structural formulae

The definition of a *primary alcohol* (Q2.3.1) was poorly answered for a recall question. Common errors were:

- One C atom is bonded to the *-OH* group instead of one C atom is bonded to the C atom bonded to the *OH* group
 - Referring to the *O atom* instead of the *-OH group* e.g. in a primary alcohol, the C atom attached to the O atom is attached to only one other C atom
 - Referring to the *homologous series* instead of to the *functional group* e.g. the alcohol is bonded to a C atom bonded to only one other C atom
 - Referring to the *hydroxyl group* as a *hydroxide ion*.
- (d) In Q2.3.3 many candidates wrote the IUPAC name of the compound C or another ester instead of the carboxylic acid needed to prepare ester. Some of those who knew that the carboxylic acid needed is *butanoic acid*, only wrote *butanoic* and forfeited the mark.

Suggestions for improvement

- (a) It should be emphasised that halogens do not get preference when naming haloalkanes. All substituents, halogens and alkyl groups should be treated as equals and numbering should be such that the substituents have the lowest numbers. For example, 2,3,5 is smaller than 2,4,5.

- (b) When writing IUPAC names:
- The correct use of hyphens and commas should be emphasised.
 - Functional groups of aldehydes, carboxylic acids and esters are not numbered.
 - Numbering is only used for substituents when naming alkanes.
- (c) When drawing structural formulae, learners should be encouraged to count the number of bonds drawn around atoms to eliminate unnecessary errors. They need to be reminded that a carbon atom cannot have less than or more than 4 bonds around it.
- (d) Frequent informal tests should be used to ensure that learners write definitions correctly. Often, learners write different interpretations of a definition and they usually end up with incorrect or partially correct statements.
- (e) Emphasise the difference between molecular formulae, structural formulae and condensed structural formulae.

QUESTION 3: PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Common errors and misconceptions

- (a) The omission of the word *temperature* in the definition of boiling point (Q3.1) was a common error e.g. boiling point is the point where the vapour pressure of a liquid equals atmospheric pressure.

Some stated that the vapour pressure is *in equilibrium with*, instead of *equal to*, the atmospheric pressure.

Most candidates could not write the structural formula of the functional group of aldehydes in Q3.2. Common errors were:

- Omitting the fourth bond line on the carbon atom
 - Drawing the structural formula of an aldehyde e.g. propanal
 - Adding another C atom to the C atom of the functional group
 - Using an *X* instead of a *R* to indicate an alkyl group.
- (b) In Q3.3 many candidates compared the different types of intermolecular forces in alkanes, aldehydes and alcohols when explaining the increase in boiling points as the number of C atoms increases. Other common errors were:
- The chain increases (instead of chain length)
 - Energy needed to break the bonds (instead of intermolecular forces)
 - Energy needed to break the intermolecular forces between atoms (instead of molecules)
 - In a longer chain there are more bonds to break requiring more energy
 - More energy is needed to break the chains (instead of intermolecular forces).
- (c) The explanation in Q3.4.2 was a challenge to many candidates. Common errors were:
- Referring to *bonds between atoms* instead of *intermolecular forces*
 - Referring to the double bond between the C atom and the O atom in aldehydes as being dipole-dipole forces or even hydrogen bonds which are stronger than the London forces in alkanes

- Comparing the types of intermolecular forces in alkanes, alcohols and aldehydes without comparing the strength of these forces
 - Failure to compare the three graphs – although the aldehyde was correctly identified, only two of the graphs were compared.
- (d) In Q3.5 many candidates numbered the functional group of the aldehyde and *butan-1-al* instead of *butanal*.
- (e) Most candidates did not number the position of the functional group (Q3.6) and *pentanol* instead of *pentan-1-ol* was a common incorrect answer when writing the IUPAC name of the alcohol with five C atoms. Some of those who numbered the functional group of the alcohol correctly, wrote the IUPAC name as *pent-1-ol* instead of *pentan-1-ol*.

Some did not know the relationship between boiling point and vapour pressure and thought that pentane has the lowest vapour pressure.

Suggestions for improvement

- (a) When discussing intermolecular forces, the concepts atoms, molecules and ions should be revised. Emphasise the difference between bonds between atoms in molecules (intramolecular) and forces between molecules (intermolecular) and that the strength of intermolecular forces are responsible for the different phases. Interatomic or intramolecular forces, which are much stronger than intermolecular forces, are formed/broken during chemical reactions when new compounds are formed. Intermolecular forces are overcome (not broken) during phase changes.
- (b) Emphasise that functional groups of carboxylic acids and aldehydes are not numbered when writing IUPAC names. In both carboxylic acids and aldehydes, the functional group is always on the first C atom and is not numbered. However, functional groups of alcohols, alkenes, alkynes and ketones should be numbered because the functional group can be on different C atoms.
- (c) Ensure that learners know the different types of intermolecular forces when comparing boiling points of compounds from different homologous series and can compare the strength of these forces.

Homologous series	Type and strength of intermolecular forces		
Alkanes Alkenes Alkynes	London forces WEAK		
Aldehydes Ketones Esters Haloalkanes		Dipole-dipole forces STRONGER	
Alcohols Carboxylic acids			Hydrogen bonding STRONGEST

QUESTION 4: REACTIONS OF ORGANIC COMPOUNDS**Common errors and misconceptions**

- (a) Although well answered, some candidates were not sure of the meaning of hydrohalogenation (Q4.1) and used substitution or elimination as key words instead of addition. Some candidates swapped the wording around and wrote that halogenation is the addition of an alkene to a hydrogen halide instead of the addition of a hydrogen halide to an alkene. Other common errors were:
- The addition of a hydrogen and a haloalkane
 - The reaction between hydrogen and a halogen
 - The addition of water
 - The addition of water and a halogen
- (b) In Q4.2 the structural formula of propane was a common incorrect answer. Several the candidates obtained only 1 mark which was for the functional group whilst the rest of the structure was incorrect. Other common errors were:
- Adding more than four H atoms around each C atom
 - Drawing the structural formula of ethene or but-1-ene
 - Addition of two functional groups to the structural formula, for example a halogen and a double bond or else two Cl substituents
- (c) Most candidates confused cracking (Q4.3.1) with other types of elimination reactions and wrote dehydrogenation, dehydration or dehydrohalogenation.
- (d) In Q4.3.2 many candidates drew the structural formula instead of writing the molecular formula of the alkane. Such learners did not read the question properly or did not know the difference between a structural formula and a molecular formula. Some candidates gave the general formula of alkanes as answer.
- (e) When writing the IUPAC name in Q4.4, most candidates numbered incorrectly. Common incorrect answers were 2,3-dibromopropane or 1,1-dibromopropane or 2,2-dibromopropane. Other common errors were:
- Omitting hyphens between numbers and words
 - Using a semi-colon instead of a comma between numbers
 - Omitting the *di* to indicate two bromine atoms
- (f) Many learners confused *hydrolysis* (Q4.5.1) with *hydrogenation* and therefore used H₂ as reactant to produce propane. Such learners added HCl as a second product. Others thought it was similar to hydration and obtained an alkene as a product. Other common errors were:
- Adding extra reactants or products
 - Omitting the arrow between reactants and products
 - Adding an additional functional group to the product e.g. the -OH group as well as a Cl atom
 - Writing incorrect structural formulae for inorganic reactants e.g. H₂O was written as H – H – O and NaOH as Na – O – H
- (g) In Q4.5.2 many candidates only stated that a dilute base is needed instead of a dilute strong base (or water), whilst others omitted the word dilute and only wrote strong

base. Those who thought that hydrolysis is similar to hydration or hydrogenation, stated that an acid catalyst or a catalyst should be used. For the second reaction condition, many learners referred to temperature or strong heat instead of mild heat.

Suggestions for improvement

- (a) Chemical bonding in Grade 10 and 11 should receive more attention. The valency of different elements, e.g. carbon forming only four bonds and hydrogen only one bond, should be revised.
- (b) Emphasise the difference between structural, molecular, general and empirical formulae.
- (c) Ensure that learners know that the rules applicable to the writing of balanced equations are also valid when writing balanced equations using structural formulae. Learners should also be made aware that structural formulae are required only for organic compounds and not for inorganic reactants when writing equations using structural formulae.
- (d) Learners must be exposed to more questions based on flow diagrams.
- (e) Conditions under which reactions of organic compounds occur should be emphasised.

QUESTION 5: REACTION RATE

Common errors and misconceptions

- (a) Candidates could not identify the dependent (Q5.1.1) and the independent (Q5.1.2) variables correctly. Most of them selected one of the headings of the columns in the table given, therefore *volume* and *concentration* were common incorrect answers. Others swapped the dependent and independent variables. Many thought that time (on the axis) was the independent variable.
- (b) Most candidates did not know that the gradient of the graph represented reaction rate (Q5.2.1). The increase in volume between 20 s and 40 s was interpreted as an increase in reaction rate. Although the total volume of gas was increasing, it was increasing with a smaller volume per second.
- (c) In Q5.2.2 many candidates interpreted the graph parallel to the x axis (from 60 s to 120 s) as representing a reaction that reached equilibrium. They did not know that the gradient of the graph represented reaction rate. Consequently, very few candidates concluded that the constant volume shown in the graph represented a reaction that was complete or the gradient of the graph was zero and therefore the reaction rate was zero.

Common incorrect answers were:

- The reaction reached equilibrium.
 - The rate of the forward reaction equals the rate of the reverse reaction.
 - Reaction rate is constant.
- (d) In Q5.3 candidates did not interpret the graph correctly and therefore did not know that the reaction takes place only for 60 s. Many calculated the average rate, substituting (120 – 0) as the time.

Other common errors were:

- Using an incorrect formula e.g. $n = \frac{V}{V_m}$ or $c = \frac{n}{V}$
- Substituting incorrect values from the graph e.g. $\frac{500 - 0}{120 - 60}$, $\frac{500 - 300}{60 - 20}$, $\frac{500 - 300}{120 - 60}$
- Substituting $\frac{0 - 500}{60 - 0}$ thus obtaining a negative answer

- (e) Many candidates failed to interpret the table to conclude that the reaction in experiment C will take place at a faster rate (Q5.5) and therefore the gradient of the graph will be steeper.

Although most candidates attempted the explanation in terms of the collision theory, many forfeited marks for one or more of the following reasons:

- Stating that the powder has a smaller surface area instead of a larger surface area
- Stating that the powder has a larger surface area and therefore the kinetic energy will increase
- Stating that more effective collisions take place instead of more effective collisions per unit time
- Stating that effective collisions take place per unit time instead of more effective collisions per unit time
- Omitting the last statement i.e. reaction rate will increase

Very few candidates obtained full marks for the stoichiometric calculation (Q5.6). Many candidates forfeited marks for one or more of the following errors:

- Using the molar gas volume of $25,7 \text{ dm}^3 \cdot \text{mol}^{-1}$ given in the paper as the volume of the gas and then dividing it by $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
- Using the ratio between CO_2 and HCl (1:2) instead of that between CaCO_3 and CO_2 (1:1)
- Using *kg* as the unit at the final answer
- Using an incorrect formula e.g. $c = \frac{m}{MV}$ and then substituting $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$ or $25,7 \text{ dm}^3 \cdot \text{mol}^{-1}$ as the volume of gas.

Suggestions for improvement

- (a) Practical skills should receive more attention in schools. Learners have a poor understanding of skills such as identifying variables and interpreting graphs. Ensure that learners know how to distinguish between the independent variable (factor that is manipulated/changed during an experiment), the dependent variable (factor affected by the change made and that is measured) and the controlled (factors that are kept constant) variables.

Graphs such as the one in Q5 should be used to explain to learners how to analyse the different stages of a chemical reaction, for example:

- Initially, the gradient of the graph is steepest, and the reaction rate is high.
- When the gradient becomes less steep, due to reactants being used up, the reaction rate decreases.
- Finally, when the gradient becomes zero, the reaction is complete because one or more reactants are used up and the reaction rate is zero.

- (b) Emphasis should be placed on the difference between reversible and non-reversible reactions. Reversible reactions can reach equilibrium, whilst non-reversible reactions take place in one direction and cannot reach equilibrium. Furthermore, a reversible reaction can only reach equilibrium in a closed system. If gases are released it implies that the container should be closed to prevent the gases from escaping. When written, equilibrium reactions are indicated with double arrows. Single arrows indicate non-reversible reactions.
- (c) When teaching reaction rate calculations, it should be emphasised that the formula is not on the data sheet. Rate can be calculated as a change in concentration/mass/volume/number of moles per time. Therefore, any one of the following can be used:

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

- (d) Ensure that learners know the different scenarios, namely change in surface area, change in temperature, change in concentration and addition of a catalyst, that should be explained in terms of the collision theory. Use previous marking guidelines to give learners assistance on how to explain each of these scenarios in terms of the collision theory.
- (e) Stoichiometry needs more attention in class. Learners struggle to use ratios correctly and are very uncertain when selecting formulae for a specific calculation.
- (f) It should be emphasised that the molar gas volume of $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$ is only applicable to STP.

QUESTION 6: CHEMICAL EQUILIBRIUM

Common errors and misconceptions

- (a) Although this question was well answered, some candidates confused *reversible* with *reverse* (Q6.1). Many candidates seemed not to know that a reversible reaction is one in which both a forward and a reverse reaction can take place. A common incorrect answer was: 'A reaction that can be reversed or a reaction in which products react to form reactants'.
- (b) Many candidates did not know that only temperature can change the value of K_c (Q6.2.1).
- (c) In their explanation in Q6.3, many candidates stated Le Chatelier's principle instead of using it. Some stated that the reaction with the lower pressure will be favoured instead of the reaction that forms the smaller number of moles of gas. Instead of stating that the reverse reaction is favoured, many stated that the equilibrium shifts to the left.
- (d) Many candidates could not interpret the K_c values in answering Q6.4. Some thought that $5,6 \times 10^{-12}$ is a greater K_c value than $3,76 \times 10^{-3}$ and then deduced that K_c decreased with an increase in temperature.

When explaining why the reaction is endothermic, many candidates omitted to state that 'an increase in temperature favours an endothermic reaction' or 'a decrease in temperature favours an exothermic reaction'.

- (e) In the K_c calculation (Q6.5), many candidates used a table without fully understanding how to use the table.

Common errors were:

- No K_c expression (Note: $\frac{[\text{products}]}{[\text{reactants}]}$ is NOT a K_c expression!)
- Incorrect K_c expression e.g. $K_c = \frac{[I_2]}{[I]^2}$ or $\frac{[2I]}{[I_2]}$
- Using a correct K_c expression with round brackets instead of square brackets
- Starting to complete the table without calculating $[I_2]$
- Substituting the equilibrium concentration of the iodine atoms, $[I]$ for the equilibrium concentration of the iodine molecules $[I_2]$
- Using incorrect labels in the table e.g. equilibrium concentrations are written next to the label for equilibrium number of moles
- Substituting the molar mass of I_2 as $127 \text{ g} \cdot \text{mol}^{-1}$ instead of $254 \text{ g} \cdot \text{mol}^{-1}$

Suggestions for improvement

- (a) Place more emphasis on explanations requiring Le Chatelier's principle. Learners struggle to express themselves when explaining in terms of Le Chatelier's principle. They should be exposed to more exercises to practice such explanations.
- (b) Correct scientific language should be used in class. For example, it is better to state that the 'reverse reaction will be favoured' instead of the 'equilibrium shifts to the left'.
- (c) When answering questions that require explanations in terms of a change in temperature of an equilibrium system, the first step should be to state how the change in temperature influences either an exothermic or an endothermic reaction i.e. 'an increase in temperature favours an endothermic reaction or a decrease in temperature favours an exothermic reaction'.
- (d) Teachers should avoid the use of $K_c = \frac{[\text{products}]}{[\text{reactants}]}$ in class. Instead, use chemical equations to teach the writing of K_c expressions.
- (e) When using a table to solve K_c calculations, learners should be taught to use correct labels $[n(\text{initial})]$, $[n(\text{change})]$, $[n(\text{equilibrium})]$, $[c(\text{equilibrium})]$ in the table and write the correct values next to each label. Use previous marking guidelines to show learners the labelling in such tables.

QUESTION 7: ACIDS AND BASES

Common errors and misconceptions

- (a) Many candidates did not use the definition to explain why ethanoic acid is a weak acid (Q7.1), but instead just stated that it is used in the house or in food or that it can be swallowed, and it is therefore a weak acid. Another common error was referring to a weak acid as an acid with a low concentration of hydronium ions. Some also referred to an acid that is incompletely dissolved instead of incompletely ionized.

- (b) It was obvious that many candidates did not know how to use their calculators to calculate the concentration from the pH value (Q7.1.2). Consequently, most candidates forfeited the mark for the answer.

Other common errors were:

- Using an incorrect pH formula e.g. $\text{pH} = -\log[\text{H}_3\text{O}]$ or $\text{pH} = -\log(\text{H}_3\text{O}^+)$ or $\text{ph} = -\log[\text{H}_3\text{O}^+]$ or $\text{pH} = -\log[\text{CH}_3\text{COOH}]$
 - Incorrect substitution of the pH value i.e. $\text{pH} = -\log(3,85)$
 - Omitting the unit of concentration at the final answer or using an incorrect unit e.g. $\text{mol}\cdot\text{dm}^3$
- (c) In Q7.1.3 some candidates incorrectly indicated that the $\text{pH} = 7$ and then further explained incorrectly in the next question that the acid neutralises the base.
- (d) Most candidates did not attempt to write the equation in Q7.1.4 and reasoned that the solution will be basic because it is the salt of a weak acid and a strong base. Others wrote the equation for the reaction of CH_3COOH and NaOH given in Q7.2, instead of the equation for the reaction of the CH_3COO^- with H_2O . Candidates had a poor understanding of the term hydrolysis i.e. the reaction of a salt with water.
- (e) Most candidates substituted the data given for NaOH (Q7.2.1) in the question paper in the formula $c = \frac{n}{V}$ without any reference to CH_3COOH to obtain the final answer. There was no indication that $n(\text{CH}_3\text{COOH}) = n(\text{NaOH})$.
Other common errors were:
- Incorrect or no conversion from cm^3 to dm^3
 - Rounding off of the value given in the question paper before substitution e.g. after converting $14,5 \text{ cm}^3$ to dm^3 , candidates rounded it to 0,01 or 0,015 or even 0,014 instead of using $0,0145 \text{ dm}^3$.
- (f) In Q7.2.2 many candidates forfeited the mark for subtraction of the unreacted moles of CH_3COOH from the initial moles to determine the number of moles that have reacted. Many candidates started by calculating the $n(\text{CaCO}_3)$ using the 1,2 g from which they determined the $n(\text{CH}_3\text{COOH})$. Such candidates missed several steps in the multistep calculation and obtained a maximum 3 of the 8 marks.

Other errors were:

- Incorrect calculation of the molar mass of CH_3COOH or CaCO_3
- Multiplying instead of dividing by 1,2 g when calculating the percentage of CaCO_3 in the impure sample

Suggestions for improvement

- (a) There is a serious need for teacher development in the content and skills needed to teach acids and bases.
- (b) Learners should be taught to copy formulae correctly from the data sheet.
- (c) Learners should be taught to label formulae when doing multistep calculations e.g. when calculating the number of moles of NaOH , the formula should be as follows: $n(\text{NaOH}) = cV$.

- (d) Ensure that stoichiometric calculations are properly taught in Grade 11. Expose learners to stoichiometric calculations involving limiting reagents from the beginning of their Grade 12 year to give them enough practice.
- (e) Rounding off should only be done at the final answer of a calculation. Learners should be taught not to round off in each step as it leads to an incorrect answer.
- (f) Learners should be taught to use values given in a question paper when substituting. Such values are fixed and should not be rounded before substitution.
- (g) When teaching hydrolysis, learners should be taught to split the given salt into ions and then each ion should be reacted with water. For example, when CH_3COONa undergoes hydrolysis the following steps should be followed to determine whether an acidic or basic solution will form:
- Determine the two ions in the salt e.g. in CH_3COONa i.e. Na^+ and CH_3COO^-
 - The positive ion (Na^+) comes from a base and the negative ion (CH_3COO^-) comes from an acid. Determine the base and acid that can be used to prepare the salt, for example:
 CH_3COO^- - the acid is CH_3COOH which is a weak acid
 Na^+ - the base is NaOH which is a strong base
 (From the above, learners can already deduce that only the CH_3COO^- will undergo hydrolysis as it comes from a weak acid. Na^+ will not undergo hydrolysis as it comes from a strong base.)
 - Determine which ion will undergo hydrolysis:
 - A weak acid ionises incompletely and therefore its negative ion will hydrolyse: $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$ (equilibrium position lies to right).

 When the negative ion reacts with water, OH^- is always one of the products.
NOTE: CH_3COOH is a weak acid and is incompletely ionised, therefore CH_3COO^- undergoes hydrolysis.
 - A strong base dissociates completely and therefore its ion will NOT hydrolyse. If the ion reacts with water, a strong base will be the product and will immediately dissociate because a strong base is completely ionised/dissociated. The following reaction will not take place and therefore Na^+ will not undergo hydrolysis.
 $\text{Na}^+ + \text{H}_2\text{O} \rightleftharpoons \text{NaOH} + \text{H}_3\text{O}^+$ (equilibrium position lies to the left)
 When the positive ion reacts with water, H_3O^+ is always one of the products.
- After determining the ion that will undergo hydrolysis i.e. CH_3COO^- in this case, the reaction of this ion with water should be written down as the hydrolysis reaction: $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{OH}^-$
- The product of this reaction (OH^- or H_3O^+) should be used to explain whether hydrolysis of the salt forms an acidic or basic solution. In this case OH^- is formed and therefore the solution will be basic.

QUESTION 8: REDOX REACTIONS AND GALVANIC CELLS

Common errors and misconceptions

- (a) When stating another function of the salt bridge (Q8.1), many candidates just repeated the function given in the question paper, i.e. 'it completes the circuit'. Common misconceptions were as follows:
- The salt bridge transfers electrons from one half-cell to the other or conducts electricity.
 - The salt bridge transfers ions from the one half-cell to the other (**NOTE:** Ions do not move from one half-cell to the other. Cations move from the salt bridge to the cathode and anions move from the salt bridge to the anode).
 - The salt bridge connects the two half-cells.
 - The salt bridge separates the electrodes and prevent them from touching.
- (b) Many candidates incorrectly defined the anode (Q8.2) as the electrode that undergoes oxidation. This statement excludes anodes that are inactive electrodes and will not undergo oxidation. Some candidates confused the word *electrolyte* with *electrode* and then stated that an anode is the electrolyte where oxidation takes place.
- (c) In Q8.3 many candidates failed to use the *Table of Standard Reduction Potentials* correctly to identify the anode in the cell. Mg^{2+} , a solution, and *Pt*, an inert electrode, were common incorrect answers.
- (d) Failure to use the *Table of Standard Reduction Potentials* correctly resulted in candidates writing the oxidation half-reaction for the hydrogen half-cell (Q8.4.1) instead of the reduction half-reaction. Other common errors were:
- Copying the reduction half-reaction with a double arrow from the *Table of Standard Reduction Potentials*
 - Writing either the reduction half-reaction ($Mg^{2+} + 2e^- \rightarrow Mg$) or the oxidation half-reaction ($Mg \rightarrow Mg^{2+} + 2e^-$) for magnesium
 - Writing the platinum half-reaction: $Pt^{2+} + 2e^- \rightarrow Pt$
- (e) In Q8.4.2 many candidates wrote the formula for the oxidising agent (Mg^{2+}). Some candidates wrote either the oxidation half-reaction or the reduction half-reaction for magnesium instead of the formula of the reducing agent.
- (f) When calculating cell potential (Q8.5) common errors were:
- Using abbreviations in the formula e.g. $E_{cell} = E_{red} - E_{ox}$ or $E_{cell} = E_{oxidising} - E_{reducing}$
 - Swapping the reduction potential of the anode with that of the cathode when substituting
 - Substituting the reduction potential for the Pt^{2+}/Pt half-reaction instead of that for the H^+/H_2 half-reaction
- (g) In Q8.6 most candidates compared the relative strengths of Cu and Zn instead of that of H_2 and Cu. Others stated that H^+ , instead of H_2 , is a stronger reducing agent than Cu^{2+} , instead of Cu. Candidates failed to identify the oxidising agents and reducing agents on the *Table of Standard Reduction Potentials*.

Suggestions for improvement

- (a) Concepts such as reducing agent, oxidation, oxidising agent and reduction should be taught with understanding. Learners must be able to identify, for example the reducing agent in a reaction. Regular assessment on this identification is needed to ensure that learners fully understand these concepts and how to identify them on the *Table of Standard Reduction Potentials*.
- (b) Learners should be taught how to use the *Table of Standard Reduction Potentials* to identify the anode, cathode, reducing agent, oxidising agent, reduction half-reaction and oxidation half-reaction in a galvanic cell. Regular assessment on this identification is needed to ensure that learners understand the use of the *Table of Standard Reduction Potentials*.

QUESTION 9: ELECTROLYTIC CELLS**Common errors and misconceptions**

- (a) Candidates did not know the difference between *electrolysis*, an *electrolytic cell* and an *electrolyte*. In Q9.1 many candidates wrote the definition of an electrolyte instead of the definition of electrolysis.
- (b) A common incorrect response to Q9.2 was that the absence of a salt bridge indicates that it is an electrolytic cell. Some candidates thought the coin or electrodes show that it is an electrolytic cell.
- (c) Most candidates could not identify the electrolyte in Q9.3 and wrote the formula of an insoluble silver salt or just silver (Ag). Some wrote the silver ion with a +2 charge instead of a +1 charge.

Although many candidates knew that the concentration of the electrolyte will remain constant (Q9.4), most of them failed to give a correct reason. A common incorrect response was that 'the rate of the forward reaction equals the rate of the reverse reaction'. Such candidates did not understand that the oxidation and reduction half-reactions together form the forward reaction – there is no reverse reaction in the cell. Another misconception was that the electrolyte is NOT part of the reaction (or is a spectator ion) and therefore remains the same.

- (d) Most candidates wrote the reduction half-reaction for silver (Q9.5) instead of the oxidation half-reaction. They copied the half-reaction as it is written on the *Table of Standard Reduction Potentials*. Other common errors were the omission of the charge on the $\text{Ag}^+(\text{aq})$ or the use of double arrows in the half-reaction.

Suggestions for improvement

- (a) The difference between the definitions of *electrolysis*, an *electrolytic cell* and an *electrolyte* should be emphasised. Although there is a similarity in that the definition of both electrolysis and an electrolytic cell contains 'electrical energy is converted to chemical energy', there is a difference in that electrolysis is a process, while an electrolytic cell is a cell in which the energy change takes place. An electrolyte is a solution that conducts electricity through the movement of ions.
- (b) When copying either the oxidation or the reduction half-reaction from the *Table of Standard Reduction Potentials*, single arrows should be used to represent either the oxidation or the reduction.

QUESTION 10: FERTILISERS**Common errors and misconceptions**

- (a) The interpretation of the flow diagram (Q10.1) to identify the unknown items was poorly done. In Q10.1.1 and Q10.1.2 most candidates probably did not know what a raw material was. Common errors were as follows:
- Q10.1.1: Most candidates thought that the raw material from which N_2 is obtained is manure or plants. Some of those who answered in terms of the process only wrote 'fractional distillation' without mentioning air.
 - Q10.1.2: A common incorrect answer was water. From the poor performance in this sub-question it is clear that most candidates were not familiar with the raw material (coal or earth gases) from which H_2 is obtained.
 - Q10.1.3: Many candidates did not know the catalyst and therefore NH_3 was a common incorrect answer.
 - Q10.1.5: The most common incorrect answer was 'Haber process' or 'Contact process'.
 - Q10.1.6: Many candidates wrote the reaction of ammonia with sulphuric acid instead of the reaction of ammonia with nitric acid. Some of those who used the correct reactants, provided the incorrect product. There was also a tendency to use $N_2H_4O_3$ or NH_3HNO_3 instead of NH_4NO_3 in the equation. Some candidates wrote the formula of nitric acid (HNO_3) in strange ways e.g. NO_3H or $HONO_2$.
- (b) In Q10.2.1 many candidates wrote nutrients without stating that NPK represents the primary nutrients.
- (c) In the calculation in Q10.3.2, most candidates managed to get one mark for the ratio $\frac{4}{9}$, but did not know how to finally get to the percentage fertiliser. A common error was that candidates listed the three ratios without specifying which one is the ratio for phosphorous.

Suggestions for improvement

- (a) Fertilisers will NOT be assessed in the final examination from November 2021 onwards.