

CHAPTER 11

PHYSICAL SCIENCES

The following report should be read in conjunction with the Physical Sciences question papers of the November 2018 examinations.

11.1 PERFORMANCE TRENDS (2014–2018)

The number of candidates who wrote the Physical Sciences examination in 2018 decreased by 7 242 in comparison to that of 2017. The performance of the candidates in 2018 reflects a tremendous improvement at the 30% level to 74,2% and at the 40% level to 48,7%.

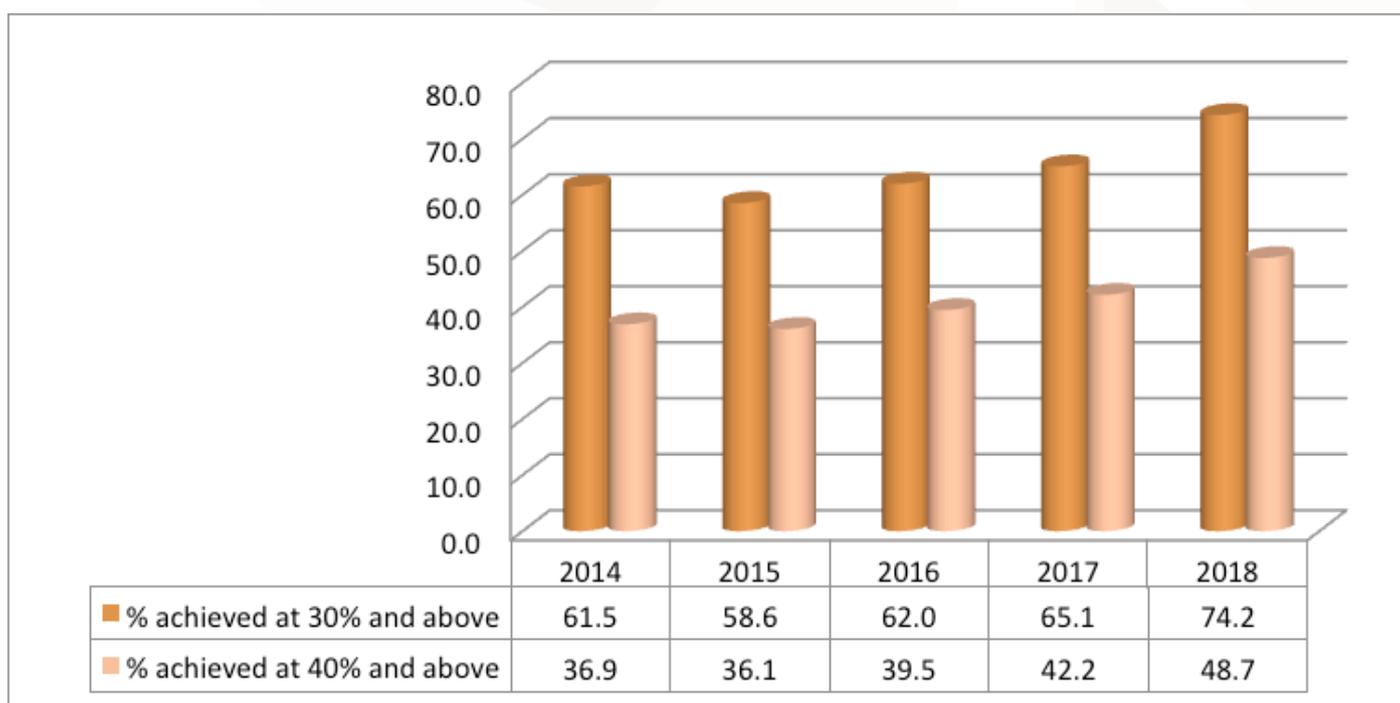
Table 11.1.1 Overall Achievement Rates in Physical Sciences

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
2014	167 997	103 348	61,5	62 032	36,9
2015	193 189	113 121	58,6	69 699	36,1
2016	192 710	119 467	62,0	76068	39,5
2017	179 561	116 862	65,1	75 736	42,2
2018	172 319	127 919	74,2	84 002	48,7

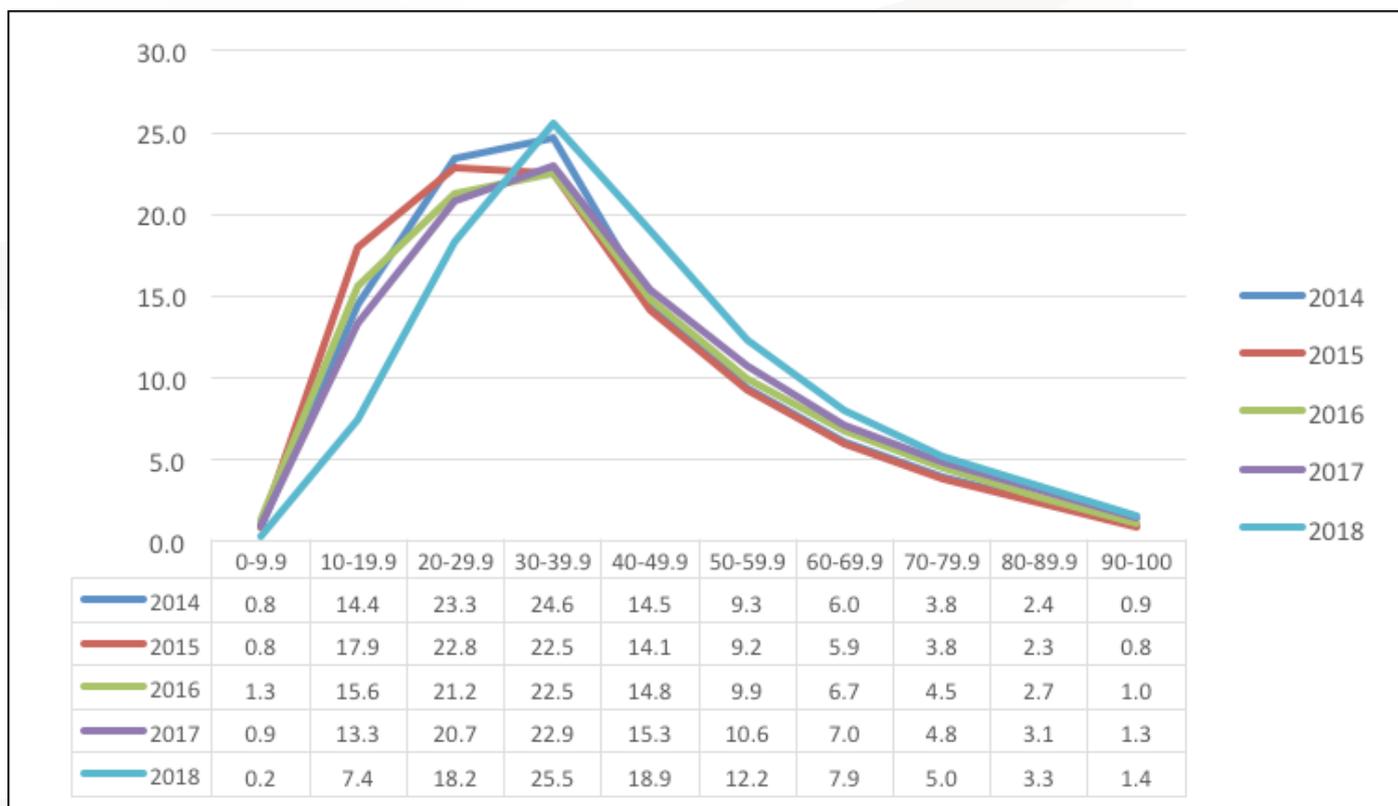
The tremendous improvement in the performance of candidates in 2018 can be attributed to the stability in the curriculum and both teachers and candidates becoming familiar with the assessment style of the subject.

However, there is still room for improvement in the performance of the candidates if the challenges surrounding problem-solving skills, mathematical skills, conceptual understanding and integration of topics are addressed. In this regard, integrated problem solving must become an integral part of teaching and learning.

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

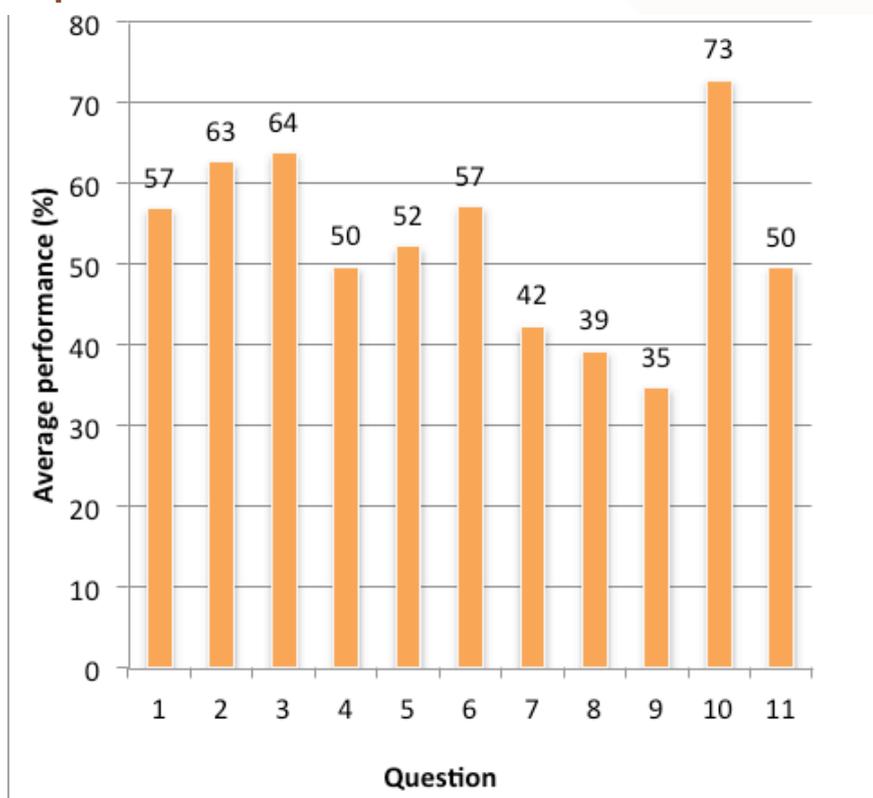
- The multiple-choice questions (Q1) and questions on Newton's Laws of Motion, Vertical Projectile Motion and Electrostatics (Q2, Q3 and Q10) were generally well answered.
- Grade 11 work is poorly understood. Grade 11 work should be included in classwork, homework and tests in Grade 12.
- Questions pertaining to pure recall of content were very poorly answered. Teachers are advised to use many short informal assessment tasks to reinforce basic concepts and principles, e.g. short speed tests (± 10 minutes). This can be used to good effect in content relating to definitions and laws listed in the CAPS and the examination guideline.
- Learners are still struggling with drawing and labelling free-body diagrams correctly. The drawing of free-body diagrams is central to solving problems involving forces acting on objects and teachers should therefore ensure that learners are able to draw free-body diagrams for such problems in classwork, homework and tests.
- 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.
- Some learners still cannot work with scientific formulae correctly. Teachers should emphasise the use of the relevant formula provided on the formula sheet, correct substitution and providing the answer with the correct unit and direction if required.

- g. 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.
- h. Problem-solving activities where different knowledge areas are integrated should be given to learners.
- i. Teachers should include at least two conceptual questions on all topics in Physics in classwork and homework exercises each week. This will assist learners to have a deeper understanding of Physics concepts.

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.

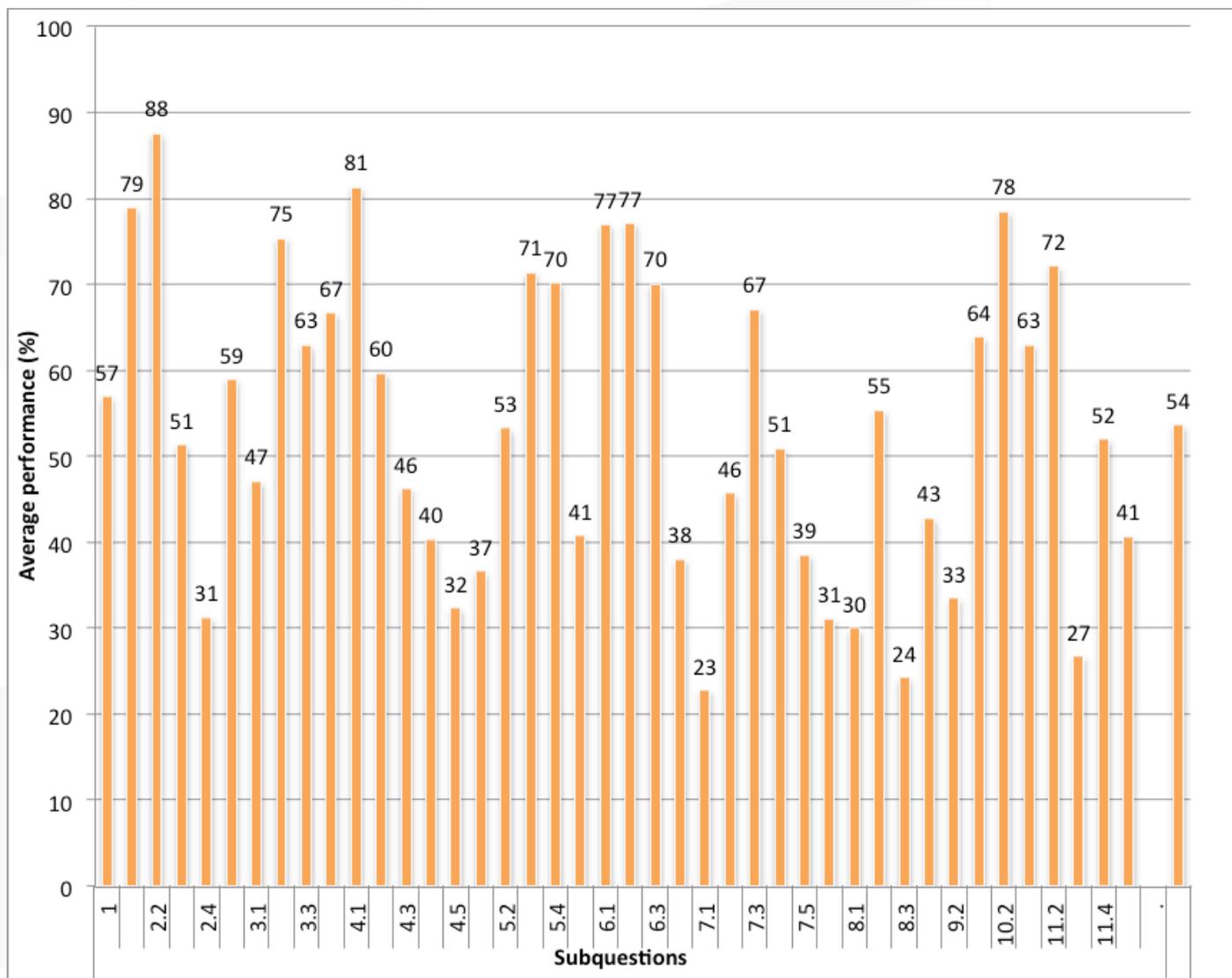
Graph 11.3.1 Average Marks per Question Expressed as a Percentage: Paper 1



Q1	Multiple-choice questions - all topics
Q2	Newton's laws of motion
Q3	Vertical projectile motion
Q4	Momentum
Q5	Work, energy and power
Q6	Doppler effect
Q7	Electrostatics (Coulomb's Law and Electric Fields)
Q8	Electric Circuits
Q9	Internal Resistance
Q10	Electrodynamics: Motors, Generators and Alternating current
Q11	Photo-electric effect

There was an improvement in performance in the multiple-choice questions (Q1) and in three topics, viz. Newton's Laws of Motion (Q2), Vertical Projectile Motion (Q3) and Electrodynamics (Q10) when compared to 2017.

Graph 11.3.2 Average Marks per Subquestion Expressed as a Percentage: Paper 1



11.4 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 1

QUESTION 1: MULTIPLE CHOICE

Common Errors and Misconceptions

- In Q1.2, many candidates did not realise that the force that the scale exerts on the person is equal to the scale reading which must increase to accelerate the person upwards.
- In Q1.4, candidates failed to integrate their mathematical skills with the scientific concepts viz. velocity, momentum and kinetic energy. They also neglected the vector nature of momentum.
- Most candidates were not able to reason correctly with the formula $P = \frac{V^2}{R}$ for series and parallel circuits consisting of identical resistors in Q1.8.

Suggestions for Improvement

- a. This question tested understanding of concepts and the principles and laws that 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 laws, followed by generalizations and the making of predictions. Learners should also be exposed to more multiple-choice questions, which must be analysed to expose popular wrong choices, find out reasons for the choices, and in the process, identify and address omissions, gaps and misconceptions.
- b. Learners must also be encouraged to refer to the formula sheet because it gives the summaries of laws and principles.

QUESTION 2: NEWTON'S LAWS OF MOTION

Common Errors and Misconceptions

- a. Candidates omitted key words in their definition, especially the word 'resultant/net'. Instead of 'net force' many of the candidates simply wrote 'force'.
- b. Quite a number of candidates used the phrase: 'the net force is directly proportional to the acceleration and inversely proportional to the mass of the object'.
- c. Many candidates labelled their free-body diagram incorrectly.
- d. Candidates lack of understanding of the term 'equilibrium' was quite evident in this question. They did not understand the key words that define equilibrium, viz. acceleration, velocity and net force.
- e. Candidates did not realise that they were supposed to use the x-component of T in their calculation of the frictional force.
- f. Candidates did not use the formula sheet to check relationships between variables, and to identify key variables and the effects of their changes on the physical quantity in question. The answers provided to Q2.4 were mostly vague, and not based on the relationships between variables.

Suggestions for Improvement

- a. Teachers should stick to and emphasise the definitions in the examination guidelines.
- b. The importance of drawing free-body diagrams correctly and their usefulness in problem solving must be emphasised.
- c. In questions where more variables are involved, learners must be taught to work out reasons/explanations logically, by writing down formulae containing the physical quantity in question, identifying variables in the formulae, tracing how each variable changes, and then deducing the effect on the physical quantity in question.

QUESTION 3: VERTICAL PROJECTILE MOTION

Common Errors and Misconceptions

- a. Many candidates failed to identify the gravitational force (which is always acting downwards) as the only force that was acting on the ball.
- b. Graph sketching skills of many candidates was quite poor.
- c. The candidates experienced problems with the signs of velocity and acceleration in their substitutions into the relevant equations of motion.

Suggestions for Improvement

- Learners must be advised to start every calculation in mechanics, especially vertical 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, it remains constant.
- They must be taught the equations of motion in Physics and how these equations are related to the equations in Mathematics.

Straight line graph (velocity-time graph)

$$y = mx + c$$

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

Parabola (Position-time graph)

$$y = ax^2 \quad (+ bx + c)$$

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

Hyperbola

$$k = xy \quad y \text{ inversely proportional to } x, k \text{ is constant}$$

$$F_{\text{net}} = ma \quad a \text{ inversely proportional to } m, F_{\text{net}} \text{ is constant}$$

- The slope/gradient of graphs must be explained in terms of the physical quantity it represents as well as its significance in explaining the relationships between physical quantities.

QUESTION 4: MOMENTUM

Common Errors and Misconceptions

- The word 'speed' instead of 'velocity' was mistakenly used by candidates to define momentum. Some omitted the key word 'product' from the definition of momentum and some used the term 'sum' instead of 'product'.
- Use of the formula $\Delta p_{\text{girl}} = \Delta p_{\text{parcel}}$ instead of $\Delta p_{\text{girl}} = -\Delta p_{\text{parcel}}$
- Many candidates failed to provide the units and direction in their final answers.
- A number of candidates could not identify or differentiate between the initial and final velocities and could not apply the sign convention appropriately.

Suggestions for Improvement

- Expose learners to a variety of contexts for problem solving involving collisions and explosions, focusing on one or a few skills at a time, such as interpreting the context and identifying relevant formulae while explaining why others cannot apply.
- Use the data sheet and formula sheet throughout the year.

QUESTION 5: WORK, ENERGY AND POWER

Common Errors and Misconceptions

- Some candidates could not properly define non-conservative force while some omitted key words in their definition, e.g. omitting the word 'work' and using 'force'.
- Most candidates could not determine whether F is a non-conservative force or not.
- Many candidates defined the work-energy theorem incorrectly viz. the net work done is 'directly proportional to' instead of 'equal to the change in kinetic energy'.

Suggestions for Improvement

- Carefully selected examples and assessment tasks must also be used to facilitate the understanding of why certain forces are classified as conservative or non-conservative.
- When using $W_{nc} = \Delta U + \Delta K$ or $W_{net} = \Delta K$ learners **must draw a force diagram** to identify the forces acting in the direction of motion to determine the number of forces causing the net work to be done.
- When calculating ΔK learners used $\frac{1}{2} m(\mathbf{v}_f - \mathbf{v}_i)^2$ instead of $\frac{1}{2} m(\mathbf{v}_f^2 - \mathbf{v}_i^2)$.

QUESTION 6: DOPPLER EFFECT

Common Errors and Misconceptions

- A number of candidates struggled to state the definition correctly. Some key terms in the definition were omitted. The key phrases omitted by the candidates were: change in frequency; relative motion.
- Many candidates related the change in the pitch of sound to the loudness of the sound. Loudness of sound is related to amplitude and not frequency.
- In Q6.3, some candidates used the equation $c = f\lambda$ instead of the equation $v = f\lambda$. Further, some candidates substituted the speed of light instead of the speed of sound to determine the frequency of the sound.
- In Q6.4, candidates incorrectly used the time travelled by patrol car in x metres as the period of the sound wave and hence calculated the frequency using this time.

In addition, many candidates substituted the wrong value for the observed frequency (f_L) in the Doppler equation. From this it can be deduced that they did not understand the meaning of the statement, 'the driver ... hears a sound with frequency of 50Hz lower than the sound emitted by the alarm'.

Suggestions for Improvement

- Teachers need to source and expose learners to questions that require them to solve for different variables instead of always solving for the frequency of the detected sound or the velocity of the sound source or of the listener.
- Revise the use of the wave equation: $v = f\lambda$

QUESTION 7: ELECTROSTATICS (COULOMB'S LAW AND ELECTRIC FIELDS)

Common Errors and Misconceptions

- Many candidates treated the net/total charge as the sum of two instead of three charges in Q7.1.
- In Q7.2, candidates did not use the given information that all the charges were identical after contact. As a result, they drew field patterns for two opposite charges or for one charge only rather than for two equal charges. In addition, the directions of the field lines were omitted and some even drew magnetic field patterns.
- Candidates confused Coulomb's Law with Newton's Law of Universal Gravitation in Q7.3.
- In Q7.4 candidates swapped/mixed the formulae for E and F; $F = k \frac{Q}{r^2}$ and $E = k \frac{Q_1 Q_2}{r^2}$.
- Many candidates failed to realise that the simplest method to calculate the net electric field at a point in Q7.5, when you have the net force at that point was to use the equation $F = Eq$.
- Many candidates in Q7.6 did not realise that an electron has mass and when electrons are transferred during contact, mass is gained by a sphere.
- Candidates failed to identify the charge creating/causing the electric field and the charge experiencing the electric field.

Suggestions for Improvement

- Teachers need to emphasise to learners that calculations of net electrostatic force and electric field are similar in terms of their vector considerations.
- Teachers need to clarify the distinction between the two equations i.e. $E = \frac{F}{q}$ and $E = \frac{kQ}{r^2}$.
Learners need to understand and correctly identify the charges represented by q and Q in these two equations.
- Expose learners to vector diagrams (1D and 2D) and vector triangles when working with forces (electrostatic, gravitational when determining the resultant of forces acting on a body) and net electric fields.

QUESTION 8: ELECTRIC CIRCUITS

Common Errors and Misconceptions

- In Q8.1, many candidates were not scientifically correct in explaining what an emf of 12 V of a battery means. They were:
 - * Not able to relate the terms 'maximum/greatest' or 'open circuit' when referring to 12 V
 - * Not able to relate the terms 'energy/work done per unit/coulomb charge' when referring to 12 J
- Candidates had problems applying the basic principles of series and parallel circuits.
- Candidates had great difficulty in relating the influence of the parallel branch of resistors on the total external resistance and the relationship between emf, V_{ext} and V_{int} .

Suggestions for Improvement

- Although the principles of series and parallel circuits are taught from Grade 9, the basic principles have to be revisited and practiced constantly.
- Compare parallel and series circuits when the cells have no internal resistance as opposed to when the cells have internal resistance.

- c. Teachers need to get learners to conduct practical work involving series and parallel circuits and to make observations and calculations regarding resistance, current, emf and potential difference regarding these circuits. These informal practical activities can be used as teaching tools for electric circuits.

QUESTION 9: ELECTRIC CIRCUITS (INTERNAL RESISTANCE)

Common Errors and Misconceptions

- a. Candidates failed to recognise that the given equation, $R = \frac{\epsilon}{I} - r$, was in the form of a linear equation, dealt with in Mathematics. If they did, they would have answered the question quite easily as it required them to determine the intercept on the y axis of the graph ($-r$) and the emf, which was the gradient in the equation.
- b. Several candidates also failed to see that entries on the x-axis were $\frac{1}{I}$. This meant that if they chose to use the equation, $\epsilon = I(R + r)$, they had to select the appropriate points and then take the inverse of these points on the x-axis.

Suggestions for Improvement

- a. The experiment on internal resistance must get the necessary attention. Make sure that the graph drawn is also mathematically understood. This means that learners must also be able to write the equation of the graph and be able to identify the variables in the equation as relevant physical quantities that apply.
- b. Refer to alternative graphs to the one presented in this paper. Expose learners to graphs in general. Also ensure that learners use two sets of coordinates (i.e. two ordered pairs) for calculating the gradient.
- c. Teachers must assist learners to understand the x and y variables, x-intercept, y-intercept and gradient and gradient in terms of physical quantities. Give learners exercises involving graphs on all knowledge areas in Physics. Learners should do at least two problem-solving activities involving graphs on any topic in Physics each week.

QUESTION 10: ELECTRODYNAMICS

Common Errors and Misconceptions

- a. Many candidates had difficulty in applying the right-hand rule or Fleming's right-hand rule for the generator in the diagram, in Q10.1.1.

Suggestions for Improvement

- a. Emphasise the use of subscripts in the formulae when rms calculations are done.
- b. Teachers should show learners the workings of an AC and DC generator using demonstration models of generators or also by allowing learners to build small generators that work.

QUESTION 11: PHOTO-ELECTRIC EFFECT

Common errors and misconceptions

- a. Although the definition of work function in Q11.1 was answered well, some candidates forfeited marks due to one or more of the following reasons:
- * Omitting the words 'electrons' and/or 'energy' and/or 'minimum'
 - * Defining threshold frequency instead

- b. Some candidates who chose the correct metal from the table in Q11.2 forfeited the mark for the reason because they did not compare the threshold frequencies of the two metals.
- c. Many candidates failed to analyse the data to do an appropriate calculation in Q11.3. Other common errors were:
- * Omitting a conclusion regarding the reading on the ammeter
 - * Giving a correct conclusion from an incorrect answer or without a proper calculation
- d. In Q11.4, the calculation of the kinetic energy was well attempted by many candidates.
- Common errors were:
- * Omitting the subscript *max* in the formula: $E = W_0 + K_{\max}$.
 - * Incorrect units at the final answer
 - * Using the information given for circuit B instead of that for circuit A
 - * Incorrect mathematics in the calculation
- e. Most candidates did not know that a change in intensity of light will not affect the maximum kinetic energy of the ejected electrons in Q11.5.

Suggestions for Improvement

- a. Teachers should use computer simulations (e.g. Phet) when teaching the photo-electric effect. This will assist to improve learners' understanding of the concept.
- b. Learners should be given a variety of problem solving exercises at cognitive levels 3 and 4 as both classwork and homework.
- c. Teachers should also give learners conceptual questions on all topics in Physics as classwork and homework. This will assist learners to understand concepts and to express themselves

11.5 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 2

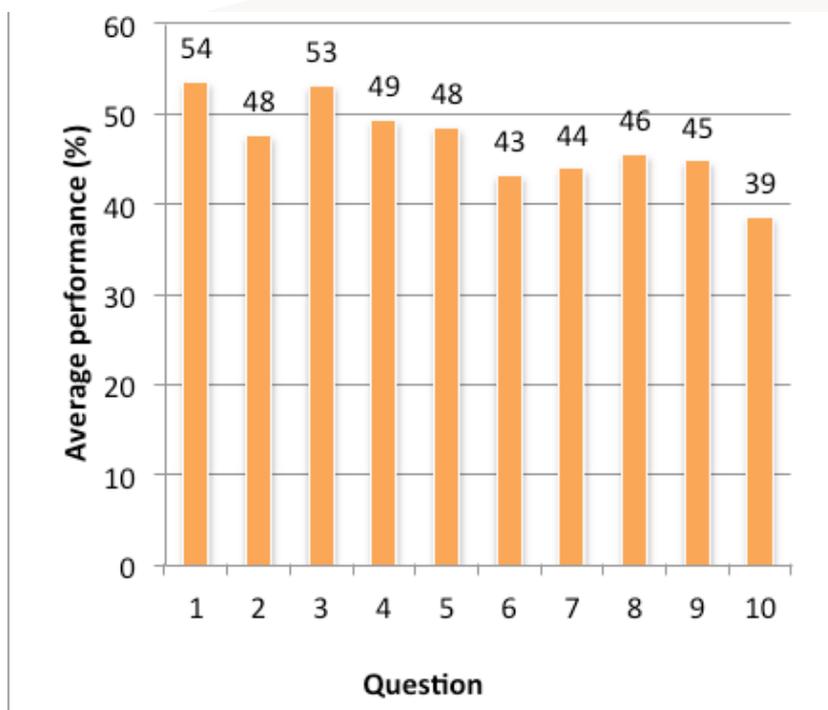
General Comments

- Q2 assessed knowledge and skills learnt in the prescribed experiment on the preparation of esters and was not answered as expected. Practical work seemed to be neglected in most schools.
- Questions on chemical equilibrium (Q6) and fertilisers (Q10) were poorly answered. Most candidates had a poor understanding of Le Chatelier's principle resulting in poor performance in Q6. Most candidates struggled to answer the calculation in Q10.
- Questions pertaining to pure recall of content were answered very poorly. Teachers are advised to use more short informal assessment tasks in order to reinforce basic concepts and principles, e.g. short speed tests (± 10 minutes). This can be used to good effect in content relating to definitions and laws listed in the CAPS and the examination guidelines.
- Grade 11 work (Stoichiometry) is poorly understood. Grade 11 work should be included in classwork, homework and tests in Grade 12.

11.6 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 2

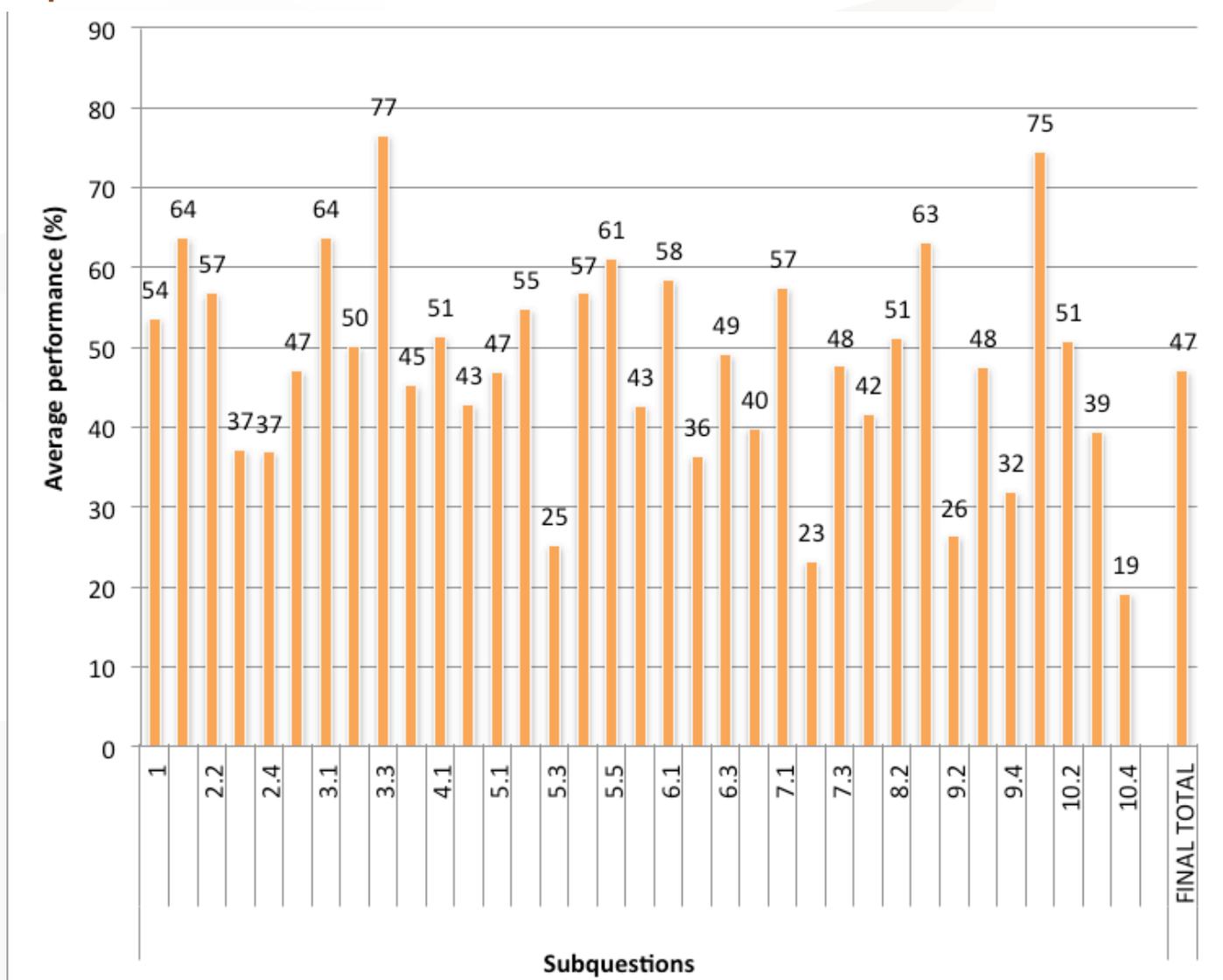
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 11.6.1 Average Marks per Question Expressed as a Percentage: Paper 2



Q1	Multiple-choice questions; all topics
Q2	Preparation and nomenclature of esters
Q3	Physical properties of organic compounds
Q4	Organic reactions
Q5	Reaction rate & stoichiometry
Q6	Chemical equilibrium
Q7	Acids and bases & stoichiometry
Q8	Galvanic cells
Q9	Electrolytic cells
Q10	Fertilisers

Graph 11.6.2 Average Marks per Subquestion Expressed as a Percentage: Paper 2



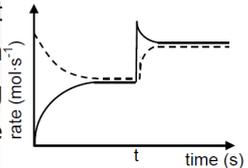
11.7 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 2

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

- In Q1.4, candidates failed to find the correct description of activation energy, i.e. the minimum energy required to cause effective collisions. For a reaction to take place, molecules must collide effectively and not just collide as represented by distractor B which was the most common incorrect choice.
- Many candidates had misconceptions regarding the definition of chemical equilibrium in Q1.5 and 'the forward reaction is equal to the reverse reaction' was the incorrect choice made by most.
- In Q1.6, candidates could not interpret the rate versus time graph correctly due to one or more of the following misconceptions:
 - * The dotted line on a graph is always the reverse reaction.
 - * An increase in temperature increases the rate of only the endothermic reaction.
 - * An increase in temperature increases the rate of only the forward reaction.

- d. Many candidates failed to interpret the K_c values and to link them to the extent of ionisation of the acids in Q1.7, to allow them to arrange acids in order of increasing strength.
- e. In Q10, candidates failed to identify the stage in which the catalyst is used in the Contact process.

Suggestions for Improvement

- a. Learners should understand the meaning of definitions rather than just memorising them. This will enable them to interpret questions in which definitions are assessed using different wording than in formal definitions. Time should be spent on the importance of key words, as well as their meaning, in definitions.
- b. In graphs of reaction rate or chemical equilibrium versus time, the dotted line does not necessarily represent the reverse reaction. Learners should be taught that the graph with the highest initial rate represents the forward reaction. For example, in the accompanying graph the dotted line represents a higher initial rate than the solid line and thus the dotted line represents the forward reaction.
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- c. The difference between the effect of temperature on reaction rate (how fast) and on chemical equilibrium (how much) should be emphasised. An increase in temperature increases the rate of any reaction regardless of whether it is exothermic or endothermic. However, an increase in temperature increases the rate of the endothermic reaction more than that of the exothermic reaction and therefore an increase in temperature favours the endothermic reaction.
- d. The meaning of a low or high value of the equilibrium constant (K_c) for acids and bases should be addressed. If $K_c > 1$ for the ionisation of an acid, this acid is a stronger acid than the acid formed as one of the products.
- e. Subject advisors are advised to prepare a booklet containing multiple-choice questions on different topics from different sources such as previous NSC and provincial papers, and text books. Strategies to deal with multiple-choice questions, like comparison and elimination, should be discussed in cluster meetings to assist teachers to help learners in tackling multiple-choice questions.
- f. Learners should be encouraged to learn the conditions of all the reactions as well as the reactions themselves.

QUESTION 2: PREPARATION AND NOMENCLATURE OF ESTERS

Common Errors and Misconceptions

- a. Candidates referred to the test tube instead of its contents in Q2.1 as a reason why the test tube is heated in a water bath. Many candidates indicated that the carboxylic acid, instead of the alcohol, is flammable.
- b. Failure to recognise the experimental setup illustrated as that of the preparation of an ester resulted in incorrect answers in Q2.2.1, Q2.2.2 and Q2.2.3. In Q2.2.3 spelling was also a problem.
- c. Determination of the molecular formula from an empirical formula in Q2.3 is a concept from Grades 10 and 11 and most candidates did not know how to solve the problem. Apart from not knowing that the product is an ester, other common errors were:
- * Incorrect or no calculation of the molar mass of C_4H_8O
 - * Drawing of the structural formula of a carboxylic acid
 - * Giving a molecular formula of an alkane or an alcohol
 - * Giving the general formulae of an alkane, an alkene or alcohols

- d. In Q2.4, candidates did not know that it should be an *ethyl ester* because the alcohol used in the experiment is *ethanol*. Some candidates used a number when writing the IUPAC name of the ester to indicate the ethyl substituent on the molecule in question e.g. 1-ethyl hexanoate.
- e. A 5th bond was used around the C atom of the functional group or bond lines between carbon atoms were omitted when drawing the structural formula of the carboxylic acid in Q2.5.

Suggestions for Improvement

- a. Practical work forms an important part of the teaching of the subject. Teachers are advised to expose learners to practical work and safety precautions related to particular experiments.
- b. Molecular formulae and the mole concept should form part of daily assessments throughout the chemistry topics.
- c. IUPAC rules for the naming of products formed in reactions should be emphasised.

QUESTION 3: PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Common Errors and Misconceptions

- a. Candidates omitted one or more of the key words in the definition of *boiling point* in Q3.1. Common errors were:
- * Vapour pressure and atmospheric pressure are at equilibrium.
 - * It is a point where vapour pressure equals atmospheric pressure.
 - * The temperature when liquid turns into a gas.
- b. In Q3.2.1, candidates wrote the name of the homologous series (carboxylic acids) instead of the name of the functional group namely the *carboxyl group*. Another common incorrect answer was *carbonyl group*.
- c. Some candidates included a number for the functional group in the IUPAC name of the carboxylic acid, e.g. *1-propanoic acid*, in Q3.2.2.
- d. Many candidates showed poor understanding of the term *functional isomer* in Q3.2.3 and wrote the structural formula of compound B instead of that of its functional isomer.
- e. In Q3.3, candidates made general statements on the relationship between boiling point and vapour pressure instead of being specific when giving a reason. For example, instead of giving 'lowest boiling point' as the reason why compound A has the highest vapour pressure, many stated that 'as boiling point decreases, vapour pressure increases'.
- f. In Q3.4.1, most candidates wrote that both compounds have the 'same intermolecular forces' or 'both have hydrogen bonding' as the reason for the comparison being fair. To compare the boiling points of the two compounds (which is determined by the strength of intermolecular forces), the molecules should be of similar size. The two compounds have the same molecular mass which indicates similar size.
- g. For a reason as to why compound X is a primary alcohol in Q3.4.2 many candidates wrote that 'the –OH group is bonded to only one carbon atom' instead of 'the –OH group is bonded to a carbon atom that is bonded to only one other carbon atom'. Some candidates referred to *it* instead of to the *–OH group* and forfeited the mark.

- h. In the explanation of the difference in boiling points between compounds **B** and **X** in Q3.4.3, many candidates omitted one or more of the four steps needed in the explanation. Common errors were:
- * Omitting the comparison between the number of sites for hydrogen bonding in the two compounds
 - * Carboxylic acids have hydrogen bonding and alcohols have dipole-dipole forces
 - * Carboxylic acids have a double bond and alcohols have a single bond
 - * Not specifying whether intermolecular forces in compound B are stronger than those in compound X
 - * Compound B needs more energy instead of compound B needs more energy to overcome intermolecular forces
 - * Using abbreviations such as HB for hydrogen bonding

Suggestions for Improvement

- a. Learners should be taught to write definitions correctly including all necessary key words. Informal tests should be used to assess definitions on a weekly basis.
- b. Learners should be made aware that a direct proportionality between two variables implies that a graph plotted of the two variables on the x and y axis respectively will be a straight line through the origin. If the vapour pressures of substances are plotted against the inverse of the boiling points of the substances, it will not be a straight line through the origin. Therefore, it is incorrect to state that 'vapour pressure is inversely proportional to boiling point'. Learners should rather be taught that 'substances with high boiling points have low vapour pressures or when boiling point increases, vapour pressure decreases'.
- c. When explaining the difference in strength of intermolecular forces in a carboxylic acid and an alcohol, learners should be taught that the carboxylic acid has two 'sites' and NOT two 'sides' for hydrogen bonding. Furthermore the carboxylic acid does not have a double bond and the alcohol a single bond. The comparison is that 'the carboxylic acid has two sites for hydrogen bonding and the alcohol has one site for hydrogen bonding'.
- d. IUPAC rules should be emphasised regularly. Learners should be made aware that a number is not used to indicate the position of the carboxyl group when naming carboxylic acids.

QUESTION 4: REACTIONS OF ORGANIC COMPOUNDS

Common Errors and Misconceptions

- a. Instead of the definition of a *homologous series* in Q4.1.1, many wrote the definition of a *functional group*.
- b. Some candidates wrote the formula of the inorganic compound in Q4.1.3 as *BrH* instead of *HBr*.
- c. Instead of the structural formula of the POSITIONAL isomer of 2-bromobutane in Q4.1.4, candidates drew the structural formula of 2-bromobutane. Such candidates either did not know the meaning of *positional isomer* or else they did not read the question properly. Other common errors were:
- * Using br or BR instead of Br as the symbol for bromine
 - * Using Br₂ as substituent on C1
 - * Omitting H atoms
 - * Using h instead of H as symbol for hydrogen

- d. Candidates experienced difficulty in writing a balanced equation for the combustion reaction in Q4.1.5. Common errors were:
- * Incorrect balancing
 - * Incorrect molecular formula for pentane
 - * Writing of the structural formula or condensed structural formula of pentane
 - * Incorrect products, e.g. organic compounds other than CO_2 and H_2O
- e. The definition of cracking in Q4.1.6 was poorly answered. Most candidates omitted one or more key words in the definition. The following incorrect or partially correct definitions were used:
- * 'Longer chains are broken into shorter chains' instead of 'longer hydrocarbon/ alkane chains are broken into shorter chains'
 - * 'Hydrocarbons are broken into smaller hydrocarbons' instead of 'long chain hydrocarbons/alkanes are broken into smaller hydrocarbons'
- f. Instead of butan-2-ol as the IUPAC name in Q4.2.1, the following incorrect or partially incorrect IUPAC names were used: but-2-ol; butan-1-ol; buta-2-nol; butanol.
- g. Many of those who drew the structural formula of an alkene in Q4.2.2 placed the double bond between C1 and C2 (1 out of 2 marks) instead of between C2 and C3. Other common errors were:
- * Drawing the structural formula of an incorrect alkene e.g. ethene
 - * Drawing the structural formula of butan-2-ol/compound R which is the reactant
 - * Writing phosphorous (from H_3PO_4) as part of the structural formula

Suggestions for Improvement

- a. Learners should be taught that the products in any complete combustion reaction are CO_2 and H_2O . Then they can at least obtain one mark if they cannot write the correct molecular formula of the organic compound.
- b. Learners should have ample exercises in drawing structural formulae from names of molecules and vice versa. Booklets containing a variety of molecules should be developed and learners should draw molecules as part of homework, self-study and classwork.
- c. The correct writing of formulae of inorganic molecules should be emphasised.

QUESTION 5: REACTION RATE

Common Errors and Misconceptions

- a. In Q5.1, candidates had a poor understanding of the concepts *independent variable*, *dependent variable* and *controlled variable* which are taught from grade 10.
- b. The definition of reaction rate is still a challenge to many candidates (Q5.2). Key words in the definition such as *per unit time* and *change* were often omitted. Common incorrect definitions were:
- * The rate at which reactants are changed into products (no mentioning of amount, volume, mass, concentration)
 - * The speed at which reactants convert to products

- c. In Q5.3, candidates failed to realise that the only difference between experiment 2 and experiment 4 was the volume (in excess) of HCl. Therefore the average reaction rate and thus the reactions times would be the same.

The most common incorrect answers were:

- * 7 s (half of 14 s)
 - * 28 s i.e. $14 \text{ s} \times 2$, possibly because the volume of acid in experiment 4 was double that in experiment 2
- d. Most candidates obtained marks for the interpretation of the Boltzmann distribution curves in Q5.4, but failed to give correct reasons for their answers.
- e. The calculation of the average rate of the reaction in Q5.6 was a challenge to many candidates. Common errors were:
- * Substituting the mass of Zn in the numerator when calculating the reaction rate
 - * Calculating the concentration of Zn using the volume of acid and then using this concentration to calculate reaction rate
 - * Swapping the initial and final moles of Zn and/or swapping the initial and the final times
 - * Obtaining a negative answer for reaction rate

Suggestions for Improvement

- a. When calculating reaction rate for a reaction using the number of moles of reactants, the following expression should be used: Average rate = $-\left(\frac{\Delta n}{\Delta t}\right) = -\left(\frac{n_f - n_i}{t_f - t_i}\right)$

The number of moles of reactants decreases because reactants are used and therefore $n_f - n_i$ will be negative. The minus sign ensures that a positive value is obtained for reaction rate.

When calculating reaction rate for a reaction using the number of moles of products, the following expression should be used: Average rate = $-\left(\frac{\Delta n}{\Delta t}\right) = -\left(\frac{n_f - n_i}{t_f - t_i}\right)$. The number of moles of products increases because products are formed and $n_f - n_i$ will be positive.

QUESTION 6: CHEMICAL EQUILIBRIUM

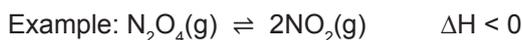
Common Errors and Misconceptions

- a. Candidates who did not obtain full marks for stating Le Chatelier's principle in Q6.1, omitted one or more of the following keywords: When the 'equilibrium is disturbed', the system will 're-instate a new equilibrium' by 'opposing the disturbance'.
- b. In the explanation using Le Chatelier's principle in Q6.2, many candidates could not identify the forward reaction as endothermic. Other common errors were:
- * Omitting the statement that a decrease in temperature will favour the exothermic reaction
 - * Not stating that the reverse reaction is favoured
- c. Most candidates could not apply Le Chatelier's principle in Q6.3.1 to a situation where the pressure of a gas increases due to a decrease in volume.
- d. Many candidates missed the effect of an increase in pressure due to a decrease in volume of a gas on the rate of the forward and reverse reactions in Q6.3.3. Due to the increase in concentration, the rates of both reactions will increase.
- e. The K_c calculation in Q6.4 was poorly answered due to one or more of the following reasons:
- * Not using 20% of X to find the moles of $[N_2O_4]$ that have reacted
 - * Using the 20% of X as the amount left at equilibrium instead of the amount used
 - * Ignoring the 20% of X
 - * No K_c expression (Note that $\frac{[\text{Products}]}{[\text{reactants}]}$ is NOT a K_c expression!)
 - * Incorrect K_c expression e.g. $\frac{[2NO_2]}{[N_2O_4]}$ or $\frac{[N_2O_4]}{[NO_2]^2}$
 - * Splitting the N_2O_4 into N_2 and O_4 resulting in three columns in the table followed by the following K_c expression: $= \frac{[2NO_2]}{[N_2O_4]}$

Suggestions for Improvement

- a. Content and methodology training of teachers on the application of Le Chatelier's principle will assist inexperienced teachers to teach this topic. Experienced teachers can also share methodology in the teaching of the topic with others.
- b. More emphasis should be placed in class 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 practise such explanations.

c. When explaining whether a reaction is exothermic or endothermic, the following steps are important:



1. Identify the disturbance e.g. a decrease in temperature
 2. State the effect of the disturbance on the system e.g. a decrease in temperature favours the exothermic reaction.
 3. State which reaction will be favoured when opposing the disturbance e.g. the reverse reaction will be favoured.
 4. State, if required, the effect of the above on the number of moles of products/reactants e.g. the number of moles of N_2O_4 will increase.
- d. Teachers should avoid the use of $K_c = \frac{[\text{Products}]}{[\text{reactants}]}$ in class. Use chemical equations to teach the writing of K_c expressions.
- e. For learners to clearly understand the above calculations, it might be prudent to use excess and limiting reagents as a precursor to dynamic chemical equilibrium to help learners track and calculate the moles in excess and the limiting moles.

QUESTION 7: ACIDS AND BASES

Common Errors and Misconceptions

- a. Instead of the definition of *an* acid in terms of the Lowry-Brønsted theory in Q7.1.1, many gave the definition in terms of the Arrhenius theory.
- b. In Q7.1.3, most candidates assumed that H_2O acts as ampholyte in the ionisation of sulphuric acid without looking at its role in the given reactions. Some of those who knew that the ampholyte is HSO_4^- , omitted the charge on the ion.
- c. Common errors when stating the definition of hydrolysis in Q7.2.1 were:
 - * The salt dissolves in water instead of reacts with water
 - * The salt ionises in water (a salt already consists of ions)
- d. In Q7.2.2, very few candidates wrote the equation of a hydrolysis reaction to show how CaCO_3 neutralises the acid. Most of those who attempted the equation, did not write an equation in which one the ions of the salt (CO_3^{2-}) reacts with water, but CaCO_3 itself was reacted with water instead. Other errors were:
 - * Using *dissolves* instead of the keyword *reaction* in the definition
 - * Stating that hydrolysis is the dissolution/ionisation/dissociation of a salt in water
 - * Stating the definition of neutralisation instead
- e. Many candidates could not use their calculators correctly to calculate $[\text{H}_3\text{O}^+]$ from pH in Q7.3.1. Common errors were:
 - * Using an incorrect pH formula e.g. $\text{pH} = -\log[\text{OH}^-]$
 - * Using round brackets instead of square brackets in the pH formula
 - * Omitting the + on H_3O^+ in the pH formula

- * Omitting the pH formula and just starting with $5 = -\log[\text{H}_3\text{O}^+]$
- * Omitting the unit ($\text{mol}\cdot\text{dm}^{-3}$) or using an incorrect unit ($\text{mol}\cdot\text{dm}^3$)
- * Obtaining 0,69 which is the log of 5 after substituting 5 for pH in a correct formula

f. Most candidates skipped one or more steps in the calculation in Q7.2.3.

Some candidates used the ratio $\text{H}_3\text{O}^+ : \text{H}_2\text{O} = 2 : 3$ and then the ratio $\text{CaO} : \text{H}_2\text{O} = 1 : 3$ from the reaction given instead of the ratio $\text{H}_3\text{O}^+ : \text{CaO} = 2 : 1$. Such candidates multiplied by 3 and then later divided by 3 and thus still obtained the correct answer, but sometimes used the concentration of water to arrive at $n(\text{CaO})$. Common errors were:

- * Using an incorrect formula e.g. $n = \frac{V}{V_m}$ Skipping the subtraction step i.e. $n(\text{H}_3\text{O}^+)_{\text{reacted}} = n(\text{H}_3\text{O}^+)_{\text{initial}} - n(\text{H}_3\text{O}^+)_{\text{final}}$
- * Swapping the initial and final moles of H_3O^+ when subtracting - a negative answer should have been obtained
- * Using the final number of moles of H_3O^+ given in the paper as the number of moles that have reacted
- * Calculating the mass of H_3O^+ and CaO and then applying mole ratios on the masses
- * Using the initial concentration of H_3O^+ to calculate the concentration of water

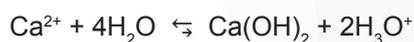
Suggestions for Improvement

- Teachers need support in the teaching of hydrolysis of salts. Very few candidates could answer the question on hydrolysis.
- 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 CaCO_3 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 CaCO_3 i.e. Ca^{2+} and
- * The positive ion (Ca^{2+}) comes from a base and the negative ion (CO_3^{2-}) comes from an acid. Determine the base and acid that can be used to prepare the salt, for example: - the acid is H_2CO_3 which is a weak acid Ca^{2+} - the base is $\text{Ca}(\text{OH})_2$ which is a strong base (From this, learners can already deduce that only the CO_3^{2-} will undergo hydrolysis as it comes from a weak acid. Ca^{2+} will not undergo hydrolysis as it comes from a strong base.)
- * Determine the ion that will undergo hydrolysis:

- A weak acid ionises incompletely and therefore its negative ion will hydrolyse: $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$
When the negative ion reacts with water, OH^- is always one of the products. H_2CO_3 is a weak acid and is incompletely ionised. Therefore CO_3^{2-} 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 Ca^{2+} will not undergo hydrolysis.



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. in this case, the reaction of this ion with water should be written down as the hydrolysis reaction. $+ \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 + \text{OH}^-$
 - * 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 and will neutralise an acid.
- c. Ensure learners know how to use their calculators to calculate $[\text{H}_3\text{O}^+]$ from the pH.
- d. Learners should be taught to label formulae when doing multistep calculations e.g. when calculating the number of moles of H_3O^+ , the formula should be as follows: $n(\text{H}_3\text{O}^+) = cV$.

QUESTION 8: REDOX REACTIONS AND GALVANIC CELLS

Common Errors and Misconceptions

- a. Some candidates wrote that 'oxidation is reduction of electrons' in Q8.1.1. Reduction is an ambiguous term to use in this context! It can mean electrons get less which implies a loss of electrons, but in this context reduction is also a gain of electrons. Common errors when writing the definition of oxidation in Q8.1.1 were:
- * Oxidation is a gain of electrons
 - * Oxidation is a substance that is oxidised or a substance that loses electrons
- b. In Q8.1.2, many candidates used the Fe/Fe^{2+} instead of the Fe/Fe^{3+} half-reaction. The question stated that iron(III) ions are formed when iron rusts. Common errors were:
- * Using $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ instead of $\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-$
 - * Using the reduction half-reaction i.e. $\text{Fe}^{3+} + 3\text{e}^- \rightarrow \text{Fe}$
 - * Using double arrows in the correct half-reaction i.e. $\text{Fe} \rightleftharpoons \text{Fe}^{3+} + 3\text{e}^-$
 - * Writing an incomplete half-reaction e.g. $\text{Fe} \rightleftharpoons \text{Fe}^{3+} + 3\text{e}^-$
- c. The use of the Table of Standard Reduction Potentials in Q8.1.4 is still poorly understood by many candidates. Many still have the perception that if an element is a weak reducing agent, it implies that the element is a strong oxidising agent. Therefore, statements like 'Fe has a stronger reducing ability and Cu has a stronger oxidising ability, therefore Fe will be oxidised and Cu will be reduced' were often made. Common incorrect or partially incorrect explanations were:
- * The iron nail has a higher oxidising ability than the copper and the iron nail will react with oxygen and be oxidised.
 - * Copper is a stronger oxidising agent than Fe and Fe will be reduced
 - * Fe is a stronger reducing agent than O_2 and Fe will be oxidised
- NOTE:** O_2 is an oxidising agent and not a reducing agent.

d. Although they were not required to show the two half-reactions in Q8.2.1, many candidates wrote the correct half-reactions, but failed to combine them to obtain a balanced cell reaction. Answers of most candidates showed lack of understanding of the use of the Table of Standard Reduction Potentials. For example, some candidates used the Cu/Cu^{2+} half-reaction as the oxidation Q8.2.1 and then as the reduction when calculating the cell potential in Q8.2.2 Common errors were:

- * Using the two metals as reactants or as products e.g.



- * Swapping the reactants and products e.g. $3\text{Cu} + 2\text{Fe}^{3+} \rightarrow 3\text{Cu}^{2+} + 2\text{Fe}$

- * Writing the cell notation instead of the cell reaction

e. Common errors when calculating the cell potential in Q8.2.2 were:

- * Using abbreviations in the formula e.g. $E_{\text{cell}} = E_{\text{red}} - E_{\text{ox}}$ or using an incorrect formula e.g. $E_{\text{cell}} = E_{\text{oxidation}} - E_{\text{reduction}}$

- * Using the reduction potential of the Fe^{2+}/Fe half-reaction (-0,44 V) instead of that of the Fe^{3+}/Fe half-reaction

- * Using the reduction potential of the $\text{Cu}^{+}/\text{Cu}^{2+}$ half-reaction (+0,52 V) instead of that of the Cu^{2+}/Cu half-reaction

- * Swapping the reduction potential of the anode with that of the cathode when substituting

- * Omitting the unit in the final answer

Suggestions for Improvement

a. The Table of Standard Reduction Potentials is still not well understood by most learners. Time should be spent in class to thoroughly explain how to use the table to determine relative strengths of oxidising and reducing agents in order to decide which substance will be oxidised and which one will be reduced. A weaker reducing agent is NOT a strong oxidising agent!

Learners should be taught that oxidising agents are listed to the left in the Table of Standard Reduction Potentials and reducing agents to the right (see the section of Table 4B below).

Section of the TABLE OF STANDARD REDUCTION POTENTIALS (4B)

Most negative reduction potential Weakest oxidising agent	$\text{Ni}^{2+} + 2\text{e}^{-} = \text{Ni}$	-0,27	Most negative reduction potential Strongest reducing agent
	$\text{Sn}^{2+} + 2\text{e}^{-} = \text{Sn}$	-0,14	
	$\text{Pb}^{2+} + 2\text{e}^{-} = \text{Pb}$	-0,13	
	$\text{Fe}^{3+} + 3\text{e}^{-} = \text{Fe}$	-0,06	
Most positive reduction potential Strongest oxidising agent	$2\text{H}^{+} + 2\text{e}^{-} = \text{H}_2(\text{g})$	0,00	Most positive reduction potential Weakest reducing agent
	$\text{S} + 2\text{H}^{+} + 2\text{e}^{-} = \text{H}_2\text{S}(\text{g})$	+0,14	
	$\text{Sn}^{4+} + 2\text{e}^{-} = \text{Sn}^{2+}$	+0,15	
	$\text{Cu}^{2+} + \text{e}^{-} = \text{Cu}^{+}$	+0,16	
	$\text{SO}_4^{2-} + 4\text{H}^{+} + 2\text{e}^{-} = \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17	
	$\text{Cu}^{2+} + 2\text{e}^{-} = \text{Cu}$	+0,34	
	$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^{-} = 4\text{OH}^{-}$	+0,40	
	$\text{SO}_2 + 4\text{H}^{+} + 4\text{e}^{-} = \text{S} + 2\text{H}_2\text{O}$	+0,45	

- b. Content training for teachers on how to explain the use of the Table of Standard Reduction Potentials to learners is essential. Learners continually fail to use the table correctly.
- c. Terms such as reduction, reducing agent, oxidation and oxidising agent need to be understood well. For example a reducing agent is a substance that causes reduction of another substance whilst it is oxidised or loses electrons.

QUESTION 9: ELECTROLYTIC CELLS

Common Errors and Misconceptions

- a. In Q9.1, some candidates confused an electrolytic cell with a galvanic cell whilst others thought electrical energy is transferred to mechanical energy.
- b. Most candidates failed to write a correct formula for a suitable electrolyte in the cell in Q9.2.
- c. Many candidates could not identify the cathode in Q9.3, but wrote the correct half-reaction. They knew reduction takes place at the cathode, but either did not read the question properly or did not realise that copper is deposited on the cathode which is electrode B.
- d. In Q9.4, candidates again failed to use the Table of Standard Reduction Potentials to compare the relative strengths of reducing agents. Pt and Ag are weaker reducing agents than Cu and will not be oxidised to Pt^{2+} and Ag^+ respectively, whilst Fe, Co and Ni are stronger reducing agents than Cu and will be, together with Cu, oxidised at the anode to form Fe^{2+} , Co^{2+} and Ni^{2+} .

Suggestions for Improvement

- a. Learners should be supplied with a summary of the five different types of electrolytic cells prescribed. Ensure that learners understand the reactions at the electrodes in these cells. The five types are: electrolysis of concentrated NaCl , electrolysis of concentrated CuCl_2 , the aluminium cell, an example of the cell used for electroplating and the purification of copper.
- b. The galvanic cell and the electrolytic cell should be contrasted so that learners can see the differences and similarities between the two cells.
- c. The use of the Table of Standard Reduction Potentials should also be emphasised when teaching electrolytic cells.
- d. Teachers should ensure that learners understand the differences between galvanic and electrolytic cells.

QUESTION 10: FERTILISERS

Common Errors and Misconceptions

- a. Spelling was a huge problem in Q10.1.1 and Q10.1.2. Instead of Haber process the following names were often used: *Hamba*, *Heyber*, *Hamper*, *Harbour* Instead of Ostwald process the following were often used: *Ostwalt*, *Oswayd*, *Oshwald*
- b. In Q10.2.2, many candidates failed to give the correct catalyst used in the Haber process. Common incorrect answers were: *Pt*; H_2SO_4 ; V_2O_5

- c. Most candidates could not write the correct equation for the reaction of NH_3 to form ammonium sulphate in Q10.3. Common errors were:
- * Using $(\text{NH}_3)_2\text{SO}_4$ or NH_3SO_4 or NH_4SO_4 as the formula for ammonium sulphate instead of $(\text{NH}_4)_2\text{SO}_4$
 - * Incorrect balancing
 - * Adding an extra product to the equation
- a. The calculation in Q10.4 was poorly answered. Many candidates did not use the molar masses of the three substances in the bag in their calculations and obtained zero. Common errors were:
- * Calculating some of the molar masses incorrectly
 - * Failure to calculate the correct ratio
 - * Failure to calculate the mass of each primary nutrient using the molar mass of each
 - * Using the number of moles instead of masses to calculate the NPK ratio

Suggestions for Improvement

- More attention should be given to fertilisers as a topic. Learners should be encouraged to study the topic as they can obtain marks easily if they know their work.
- The mole concept and stoichiometry should form part of daily assessment across all chemistry topics.
- Teachers are encouraged to ensure that enough time is set aside to teach this topic.