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GAUTENG PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

SECONDARY SCHOOL IMPROVEMENT PROGRAMME (SSIP) 2016

GRADE 12

PHYSICAL SCIENCE

TERM 01

VERTICAL PROJECTILES HOMEWORK

SESSION	VERTICAL PROJECTILE MOTION
2	Definition of <i>Free falling</i> objects
	<i>Acceleration due to gravity always downwards near earth's surface at $g = (9,8 \text{ m.s}^{-2})$</i>
	Definitions of : <i>Terminal velocity, Air resistance (or air friction)</i> IMPORTANT: • Provided there is no friction, the total energy of a free falling body remains constant. • Concepts: acceleration, velocity, change in position are all vectors (direction SHOULD be indicated) • "Drop" means $v_i = 0 \text{ m.s}^{-1}$ (starting from rest)
	Equations : $v_f = v_i + a\Delta t$ $v_f^2 = v_i^2 + 2a\Delta y$ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$
	GRAPHS OF MOTION: <i>velocity vs time graph,</i> <i>displacement vs time graph and</i> <i>acceleration vs time graph</i> } <i>acceleration is uniform</i>

SESSION NO: 2 (HOMEWORK)**TOPIC: VERTICAL PROJECTILE MOTION**

When introducing the section on vertical projectile motion, revise the sections from Grade 10 on Equations of Motion and Graphs of Motion. Learners must start this section by choosing a direction as positive or negative. Encourage the learners to take the initial direction of motion as positive and to stay with that convention throughout the entire question. **THEY MUST NOT CHANGE THE DIRECTION FOR EVERY SUB-QUESTION.** They must stay with the original direction selection throughout the entire question. Learners should draw a diagram of the situation and they need to place all the numerical values on the diagram and to **SELECT A**

DIRECTION AS POSITIVE OR NEGATIVE. Remind the learners that they have to convert their final + or – answer into a direction again.

- 1 Introduce session – 15 minutes
- 2 Questions – 60 minutes
- 3 Notes on Content and explanations – 15 minutes

SECTION A: TYPICAL EXAM QUESTIONS HOMEWRK SESSION2

QUESTION 1: 20 minutes Paper 1)

(Taken from NSC Feb/Mar 2013)

A ball of mass 0,2 kg is dropped from a height of 0,8 m onto a hard floor. It bounces to a maximum height of 0,6 m. The floor exerts a force of 50 N on the ball. Ignore the effects of friction.

- 1.1 Write down the magnitude and direction of the force that the ball exerts on the floor. (2)
- 1.2 Calculate the:
 - 1.2.1 Velocity at which the ball strikes the floor (4)
 - 1.2.2 Time that the ball is in contact with the floor if it bounces off the floor at a speed of $3,43 \text{ m}\cdot\text{s}^{-1}$ (4)
- 1.3 The ball takes 0,404 s from the moment it is dropped until it strikes the floor. Sketch a graph (not to scale) of position versus time representing the entire motion of the ball.

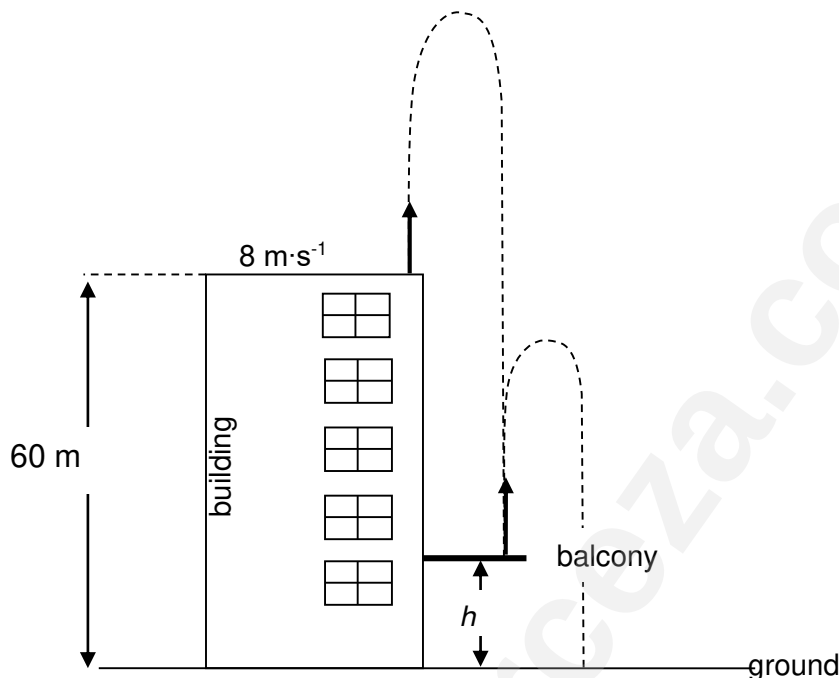
USE THE GROUND AS ZERO REFERENCE.

Indicate the following on the graph:

- ☐ Height from which the ball is dropped
 - ☐ Height reached by the ball after the bounce
 - ☐ Time at which the ball bounces off the floor
- (5)
[15]

QUESTION 2: 20 minutes
1)*(Taken from NSC Nov 2012 Paper*

An object is projected vertically upwards at $8 \text{ m}\cdot\text{s}^{-1}$ from the roof of a building which is 60 m high. It strikes the balcony below after 4 s. The object then bounces off the balcony and strikes the ground as illustrated below. Ignore the effects of friction.



- 2.1 Is the object's acceleration at its maximum height UPWARD, DOWNWARD or ZERO? (1)
- 2.2 Calculate the:
- 2.2.1 Magnitude of the velocity at which the object strikes the balcony (4)
- 2.2.2 Height, h , of the balcony above the ground (5)

The object bounces off the balcony at a velocity of $27,13 \text{ m}\cdot\text{s}^{-1}$ and strikes the ground 6 s after leaving the balcony.

- 2.3 Sketch a velocity-time graph to represent the motion of the object from the moment it is projected from the ROOF of the building until it strikes the GROUND. Indicate the following velocity and time values on the graph:
- The initial velocity at which the object was projected from the roof of the building
 - The velocity at which the object strikes the balcony
 - The time when the object strikes the balcony
- (6)

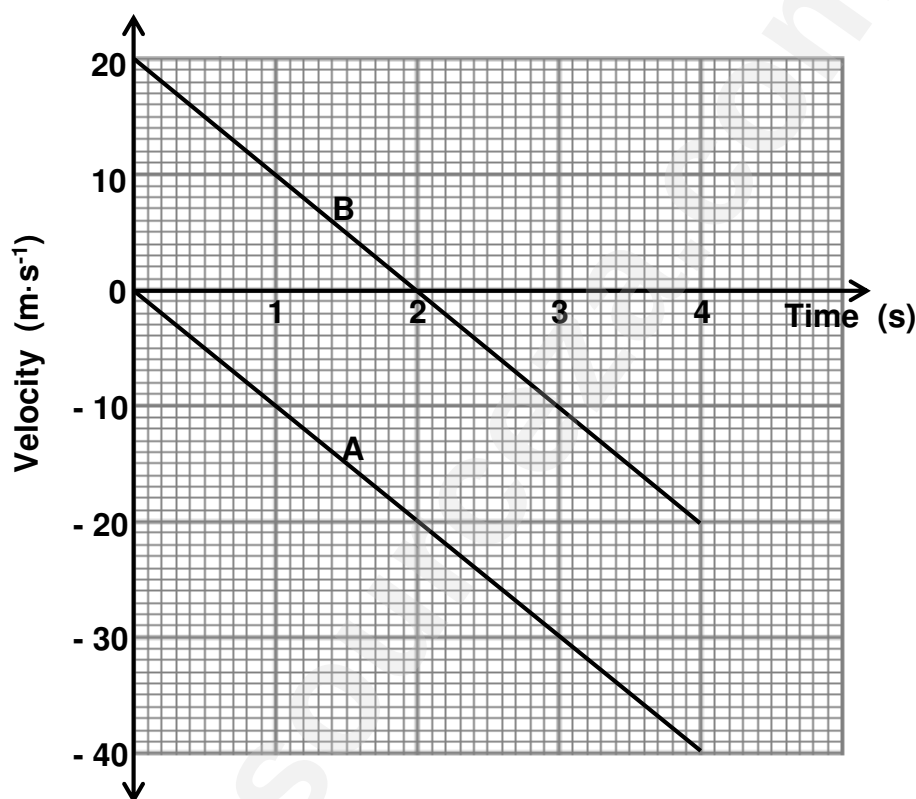
- The velocity at which the object bounces off the balcony
- The time when the object strikes the ground

[16]

QUESTION 3: 20 minutes
2011 Paper 1)

(Taken from NSC Feb/March

The velocity-time graph shown below represents the motion of two objects, **A** and **B**, released from the same height. Object **A** is released from REST and at the same instant object **B** is PROJECTED vertically upwards. (Ignore the effects of friction.)



- 3.1 Object **A** undergoes a constant acceleration. Give a reason for this statement by referring to the graph. (No calculations are required.) (2)
- 3.2 At what time/times is the SPEED of object **B** equal to 10 m·s⁻¹? (2)
- 3.3 Object **A** strikes the ground after 4 s. USE EQUATIONS OF MOTION to calculate the height from which the objects were released. (3)
- 3.4 What physical quantity is represented by the area between the graph and the time axis for each of the graphs **A** and **B** ? (2)
- 3.5 Calculate, WITHOUT USING EQUATIONS OF MOTION, the distance between objects **A** and **B** at $t = 1$ s. (5)

[17]

SECTION B: NOTES ON CONTENT

A **projectile** is an object upon which the only force acting is the force of gravity.

In the absence of air friction (which can be achieved in a vacuum chamber) all objects regardless of size, weight and shape will accelerate downward at $9,8 \text{ m}\cdot\text{s}^{-2}$. This value, known as 'the acceleration due to gravity' (symbol 'g'). The object is said to be in free-fall when there is no air resistance and the only force acting on the object is the force of gravity. Gravitational acceleration is ALWAYS downwards no matter whether the object is being thrown up or falling down.

Under normal circumstances, all falling objects are subject to air friction to varying degrees, depending on a variety of factors such as surface area, surface texture, density, velocity etc. This leads to two considerations :

- a) In reality any falling object will not accelerate indefinitely, but will reach a terminal velocity.

This is because air friction increases with velocity, so as the object accelerates downward, the air friction gets larger and larger, until it eventually balances the weight of the object (i.e. is equal but opposite, producing a zero resultant force). From this point on, the acceleration of the object is zero and whatever downward velocity it has reached is the constant maximum velocity.

All objects are attracted to the earth by the force of gravity. This causes falling bodies to accelerate i.e. to continue falling at an ever-increasing velocity as they approach the earth.

However, it is found that a body falling to earth does not continue to accelerate indefinitely, but reaches a constant maximum velocity after a while.

- b) Not only does the air friction vary from object to object, but for a given falling object it increases gradually as the object accelerates. As a result of this, there is an enormous variety of possible values for acceleration for falling bodies and each one has an acceleration that gradually decreases and becomes zero. Thus for our calculations we will pretend there is no air friction and thus we use the value $g = 9,8 \text{ m}\cdot\text{s}^{-2}$ for gravitational acceleration.

Projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. This is known as **time symmetry**.

Projectiles can have their motion described by a single set of equations for the upward and downward motion.

Projectiles can have their motion described by graphs of motion.

PROCEDURE FOR ANSWERING A VERTICAL PROJECTILE QUESTION:

STEP 1: Select a direction as being positive or negative

STEP 2: If a diagram has not been given, draw a diagram of the situation

STEP 3: Place all information given onto the diagram

STEP 4: Identify the equation of motion to be used

STEP 5: Substitute into the equation and solve for the answer

EQUATIONS OF MOTION IN THE VERTICAL PLANE

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

$$\Delta y = v_i \Delta t + \frac{1}{2} g \Delta t^2$$

$$v_f^2 = v_i^2 + 2g\Delta y$$

$$\Delta y = \frac{(v_f + v_i) \Delta t}{2}$$

Remember:

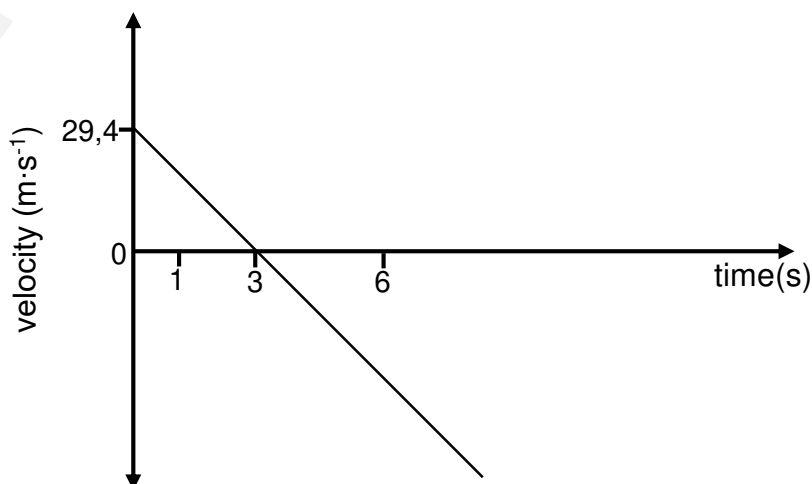
- At the greatest height of the upward motion, $v_f = 0 \text{ m}\cdot\text{s}^{-1}$
- If an object is dropped, the $v_i = 0 \text{ m}\cdot\text{s}^{-1}$
- $g = 9,8 \text{ m}\cdot\text{s}^{-2}$ which is found on the Information Sheet

SECTION C: HOMEWORK QUESTIONS

QUESTION 1: 20 minutes P1)

(Taken from NSC Nov 2010)

A man fires a projectile **X** vertically upwards at a velocity of $29,4 \text{ m}\cdot\text{s}^{-1}$ from the EDGE of a cliff of height 100 m. After some time the projectile lands on the ground below the cliff. The velocity-time graph below (NOT DRAWN TO SCALE) represents the motion of projectile **X**. (Ignore the effects of friction.)



- 1.1 Use the graph to determine the time that the projectile takes to reach its maximum height. (A calculation is not required.) (1)
- 1.2 Calculate the maximum height that projectile **X** reaches above the ground. (4)
- 1.3 Sketch the position-time graph for projectile **X** for the period $t = 0$ s to $t = 6$ s. USE THE EDGE OF THE CLIFF AS ZERO OF POSITION.

Indicate the following on the graph:

- The time when projectile **X** reaches its maximum height
 - The time when projectile **X** reaches the edge of the cliff
- (4)
- 1.4 One second (1 s) after projectile **X** is fired, the man's friend fires a second projectile **Y** upwards at a velocity of $49 \text{ m}\cdot\text{s}^{-1}$ FROM THE GROUND BELOW THE CLIFF.

The first projectile, **X**, passes projectile **Y** 5,23 s after projectile **X** is fired. (Ignore the effects of friction.)

Calculate the following:

- 1.4.1 The velocity of projectile **X** at the instant it passes projectile **Y** (5)
- 1.4.2 The velocity of projectile **X** RELATIVE to projectile **Y** at the instant it passes projectile **Y** (5)

[19]

(THIS QUESTION IS NOT REQUIRED BY CAPS)

SECTION D: SOLUTIONS FOR SECTION A

QUESTION 1

- 1.1 50 N ✓downwards✓ (2)
- 1.2

1.2.1

Downward positive:

$$v_f^2 = v_i^2 + 2a\Delta y \checkmark$$

$$\therefore v_f^2 = 0^2 + 2(9,8)(0,8) \checkmark$$

$$\therefore v_f = 3,96 \text{ m}\cdot\text{s}^{-1} \checkmark \text{ downward} \checkmark$$

Downward negative:

$$v_f^2 = v_i^2 + 2a\Delta y \checkmark$$

$$\therefore v_f^2 = 0^2 + 2(-9,8)(-0,8) \checkmark$$

$$\therefore v_f = -3,96 \text{ m}\cdot\text{s}^{-1}$$

$$\therefore v_f = 3,96 \text{ m}\cdot\text{s}^{-1} \checkmark \text{ downward} \checkmark$$

OR

$$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$$

$$0,8 = 0 + \frac{1}{2}(9,8)\Delta t^2 \checkmark$$

$$\Delta t = 0,404 \text{ s}$$

✓ Both formulae

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

$$= 0 + (9,8)(0,404)$$

$$= 3,96 \text{ m}\cdot\text{s}^{-1} \checkmark \text{ downwards} \checkmark$$

(4)

1.2.2

Downward positive

$$F_{\text{net}}\Delta t = \Delta p \text{ OR } F_{\text{net}}\Delta t = m(v_f - v_i) \checkmark$$

$$(-50)\Delta t \checkmark = 0,2(-3,43 - 3,96) \checkmark$$

$$\therefore \Delta t = 0,03 \text{ s} \checkmark (3 \times 10^{-2} \text{ s})$$

Downward negative

$$F_{\text{net}}\Delta t = \Delta p \text{ OR } F_{\text{net}}\Delta t = m(v_f - v_i) \checkmark$$

$$(50)\Delta t \checkmark = 0,2[3,43 - (-3,96)] \checkmark$$

$$\therefore \Delta t = 0,03 \text{ s} \checkmark (3 \times 10^{-2} \text{ s})$$

OR

Downward positive

$$F_{\text{net}} = ma$$

$$(-50) = 0,2a \quad \checkmark$$

$$\therefore a = -250 \text{ m}\cdot\text{s}^{-2}$$

✓ both formulae

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

$$-3,43 = 3,96 + (-250)\Delta t \quad \checkmark$$

$$\therefore \Delta t = 0,03 \text{ s} \quad \checkmark \quad (3 \times 10^{-2} \text{ s})$$

Downward negative

$$F_{\text{net}} = ma$$

$$(50) = 0,2a \quad \checkmark$$

$$\therefore a = 250 \text{ m}\cdot\text{s}^{-2}$$

✓ both formulae

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

$$3,43 = -3,96 + (250)\Delta t \quad \checkmark$$

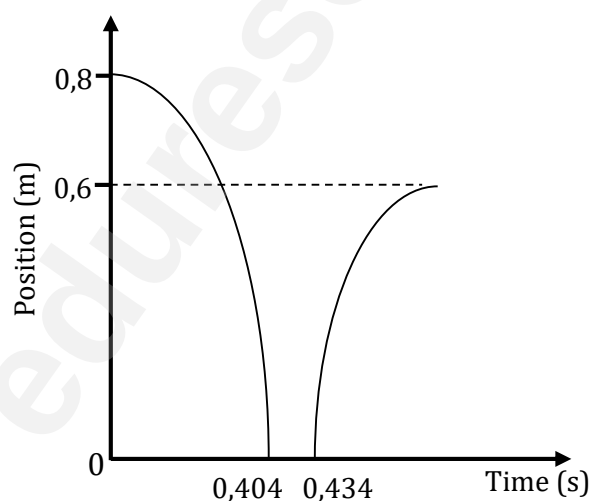
$$\therefore \Delta t = 0,03 \text{ s} \quad \checkmark \quad (3 \times 10^{-2} \text{ s})$$

(4)

1.3

Ground as zero reference and downward negative:

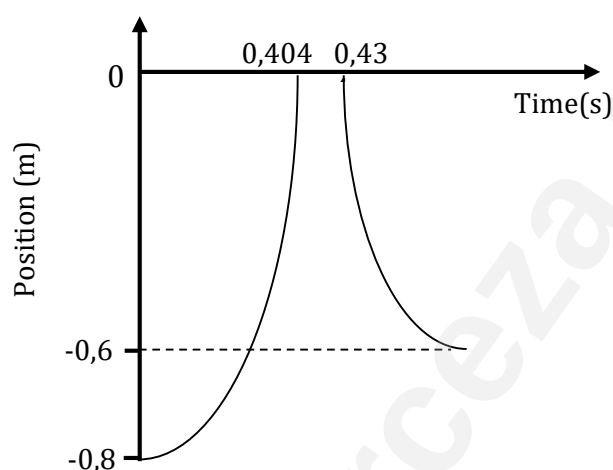
Criteria for graph	Marks
Correct shape (both curves)	✓
Graph starts at $y = 0,8 \text{ m}$ at $t = 0 \text{ s}$	✓
Second maximum height at $y = 0,6 \text{ m}$	✓
Contact time shown as space on x axis between two curves.	✓
Time at which ball leaves the floor shown as $t = 0,434 \text{ s}$.	✓



OR

Ground as zero reference and downward positive:

Criteria for graph	Marks
Correct shape (both curves)	✓
Graph starts at $y = -0,8 \text{ m}$ at $t = 0 \text{ s}$	✓
Second maximum height at $y = -0,6 \text{ m}$	✓
Contact time shown as space on x axis between two curves.	✓
Time at which ball leaves the floor shown as $t = 0,434 \text{ s}$.	✓



(5)

[15]

QUESTION 2

2.1 Downward ✓ (1)

2.2

2.2.1

Upwards positive

$$\begin{aligned}
 v_f &= v_i + a\Delta t \quad \checkmark \\
 &= 8 \checkmark + (-9,8)(4) \quad \checkmark \\
 &= -31,2 \text{ m}\cdot\text{s}^{-1} \\
 \therefore v_f &= 31,2 \text{ m}\cdot\text{s}^{-1} \quad \checkmark
 \end{aligned}$$

Downwards positive

$$\begin{aligned}
 v_f &= v_i + a\Delta t \quad \checkmark \\
 &= -8 \checkmark + (9,8)(4) \quad \checkmark \\
 \therefore v_f &= 31,2 \text{ m}\cdot\text{s}^{-1} \quad \checkmark
 \end{aligned}$$

(4)

2.2.2

Upwards positive

$$\begin{aligned}
 \Delta y &= v_i\Delta t + \frac{1}{2}a\Delta t^2 \quad \checkmark \\
 &= (8)(4) \checkmark + \frac{1}{2}(-9,8)(4)^2 \quad \checkmark \\
 &= -46,4 \text{ m} \\
 \text{Height of balcony} \\
 \underline{60 - 46,4} \quad \checkmark &= 13,6 \text{ m} \quad \checkmark
 \end{aligned}$$

(5)

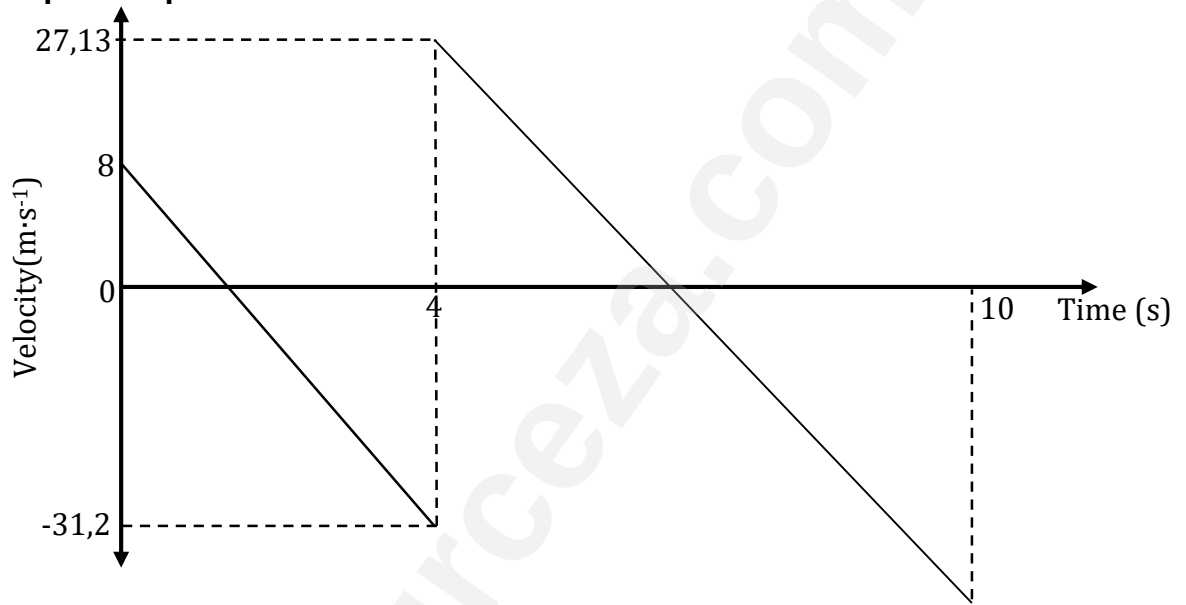
11

Downwards positive

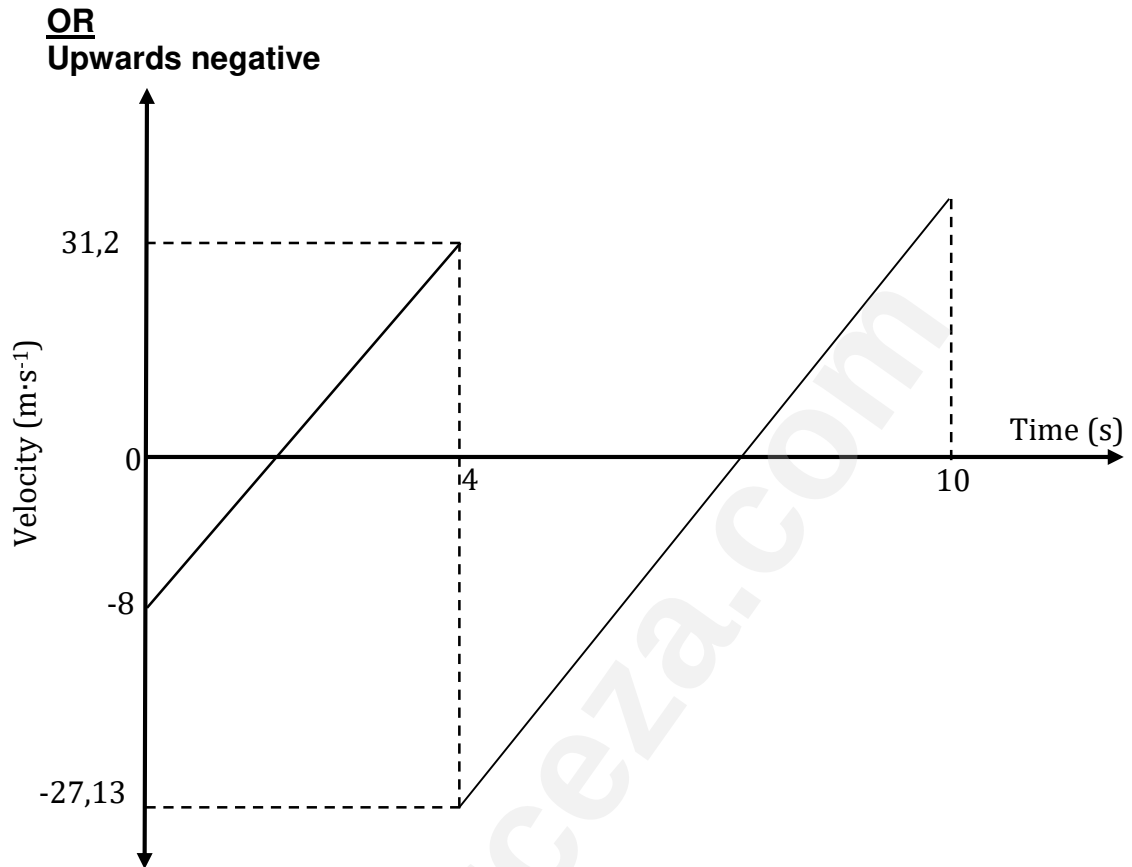
$$\begin{aligned}\Delta y &= v_i \Delta t + \frac{1}{2} a \Delta t^2 \checkmark \\ &= (-8)(4) \checkmark + \frac{1}{2}(9,8)(4)^2 \checkmark \\ &= 46,4 \text{ m} \\ \text{Height of balcony} \\ \underline{60 - 46,4 \checkmark} &= 13,6 \text{ m} \checkmark\end{aligned}$$

2.3

Upwards positive



Criteria for graph	Marks
Correct shape as shown (Two parallel lines).	✓
First part of graph starts at $v = 8 \text{ m} \cdot \text{s}^{-1}$ at $t = 0 \text{ s}$	✓
First part of the graph extends below the x axis until $v = -31,2 \text{ m} \cdot \text{s}^{-1}$ at $t = 4 \text{ s}$.	✓
Graph is discontinuous and changes direction at 4 s.	✓
Second part of graph starts at $v = 27,13 \text{ m} \cdot \text{s}^{-1}$ at $t = 4 \text{ s}$.	✓
Second part of graph extends below the x axis until $t = 10 \text{ s}$ (and a greater velocity than that at which it strikes the balcony).	✓



Criteria for graph	Marks
Correct shape as shown (two parallel lines).	✓
First part of graph starts at $v = -8 \text{ m}\cdot\text{s}^{-1}$ at $t = 0 \text{ s}$	✓
First part of the graph extends below the x axis until $v = 31,2 \text{ m}\cdot\text{s}^{-1}$ at $t = 4 \text{ s}$	✓
Graph is discontinuous and changes direction at 4 s.	✓
Second part of graph starts at $v = -27,13 \text{ m}\cdot\text{s}^{-1}$ at $t = 4 \text{ s}$.	✓
Second part of graph extends below the x axis until $t = 10 \text{ s}$ (and to a greater velocity than that at which the object strikes the balcony).	✓

(6)
[16]

QUESTION 3

- 3.1 The gradient is constant. ✓✓ (2)
- 3.2 At $t = 1 \text{ s}$ ✓ and $t = 3 \text{ s}$ ✓ (2)
- 3.3 Not required by CAPS
 $V_{AB} = V_{AG} + V_{GB}$
 $= -10 + (-10)$
 $= -20 \text{ m}\cdot\text{s}^{-1}$
 $= 20 \text{ m}\cdot\text{s}^{-1}$ downwards

$$\begin{aligned} 3.4 \quad \Delta y &= v_i \Delta t + \frac{1}{2} g \Delta t^2 \checkmark \\ &= (0)(4) + \frac{1}{2} (9,8)(4)^2 \checkmark \\ &= 78,4 \text{ m } \checkmark \end{aligned} \quad (3)$$

$$3.5 \quad \text{Displacement } \checkmark \checkmark \quad (2)$$

$$\begin{aligned} 3.6 \quad \text{Distance covered by B} &= \frac{1}{2} b h + l b \checkmark = 0,5 \times (1)(10) + (10)(1) \\ &= 15 \text{ m } \checkmark \end{aligned}$$

$$\begin{aligned} \text{Distance covered by A} &= \frac{1}{2} b h \checkmark = 0,5 \times (1)(-10) \\ &= -5 \text{ m } \checkmark \end{aligned}$$

$$\begin{aligned} \text{Distance between A and B} &= 15 - (-5) = 20 \text{ m } \checkmark \\ &\quad (5) \\ &\quad [17] \end{aligned}$$

SECONDARY SCHOOL IMPROVEMENT PROGRAMME (SSIP) 2016



GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

GRADE 12

PHYSICAL SCIENCE

TERM 01

HOME WORK-ORGANIC MOLECULES

SESSION 3

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes

(Taken from NSC Feb/Mar 2013 Paper 2)

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

A	Pent-2-ene	B	<pre> H H H H — C — C — C — O — H H C H H </pre>
C	Propyl methanoate	D	2,5-dimethylheptane
E	<pre> O CH₃CHCH₂ — — — CH CH₃ </pre>	F	<pre> CH₃ — CH₂ — CH₂ — C — CH₃ O </pre>

1.1 Write down the letter representing the compound which: (A compound may be used more than once.)

- 1.1.1 Is an aldehyde (1)
- 1.1.2 Has the general formula C_nH_{2n} (1)
- 1.1.3 Is unsaturated (1)
- 1.1.4 Is a ketone (1)
- 1.1.5 Is a hydrocarbon (1)
- 1.1.6 Can be prepared by the reaction of an alcohol with a carboxylic acid (1)

1.2 Write down the structural formula of:

- 1.2.1 Compound **A** (2)
- 1.2.2 Compound **D** (2)

1.3 Write down the:

1.3.1 NAME of the functional group of compound **F** (1)

1.3.2 IUPAC name of compound **B** (2)
[13]

QUESTION 2: 15 minutes

(Taken from NSC Feb/Mar 2013 Paper 2)

The table below shows the boiling points of four organic compounds, represented by the letters **A** to **D**, of comparable molecular mass.

	Compound	Molecular mass	Boiling point (°C)
A	Butane	58	0
B	Propanal	58	49
C	Propan-1-ol	60	97
D	Ethanoic acid	60	118

2.1 Compound **A** is used as a fuel in gas burners.

2.1.1 Is compound **A** in the GAS, LIQUID or SOLID phase at 25 °C? (1)

2.1.2 How will the boiling point of an ISOMER of compound **A** compare to that of compound **A**? Write down HIGHER THAN, LOWER THAN or EQUAL TO. Refer to MOLECULAR STRUCTURE, INTERMOLECULAR FORCES and the ENERGY needed to explain the answer. (4)

2.1.3 Compound **A** has a lower boiling point than compound **B**. Give reasons for this difference in boiling points by referring to the following:

- Structural differences between the two compounds
 - Polarity
- (2)

2.2 Consider the boiling points of compounds **C** and **D**.

2.2.1 Give a reason for this difference in boiling points by referring to the intermolecular forces present in EACH of these compounds. (2)

2.2.2 Which ONE of compound **C** or **D** has a higher vapour pressure? Refer to their boiling points to give a reason for the answer. (2)
[11]

QUESTION 3: 15 minutes

(Taken from NSC Nov 2012 Paper 2)

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

A	$\text{CH} \equiv \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$	B	$\text{CH}_3\text{CH}_2\text{CH}_2\underset{\text{OH}}{\text{CH}}\text{CH}_3$
C	$\text{CH}_2 = \underset{\text{CH}_3}{\underset{ }{\text{C}}} - \overset{\text{CH}_3}{\underset{ }{\text{CH}_2}}$	D	Pentanoic acid
E	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{O} \\ & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & \\ & \text{H} & & \text{H} - \text{C} - \text{H} & & \text{H} & & \\ & & & & & & & \\ & & & \text{H} & & & & \end{array} $	F	$\text{CH}_3 - \text{CH}_2 - \text{O} - \overset{\text{O}}{\underset{ }{\text{C}}} - \text{CH}_2 - \text{CH}_3$

3.1 Write down the letter(s) that represent(s) each of the following:
(A compound may be used more than once.)

- 3.1.1 An alkyne (1)
- 3.1.2 Two compounds that are structural isomers (2)
- 3.1.3 A compound containing a carboxyl group (1)
- 3.1.4 An aldehyde (1)
- 3.1.5 An alcohol (1)

3.2 Write down the:

- 3.2.1 IUPAC name of compound **C** (2)
- 3.2.2 Structural formula of compound **D** (2)

3.3 Compound **F** is prepared in the laboratory.

- 3.3.1 How can one quickly establish whether compound **F** is indeed being formed? (1)
- 3.3.2 Write down the IUPAC name of the alcohol needed to prepare compound **F**. (2)

3.3.3 Write down the IUPAC name of compound F. (2)
[15]

QUESTION 4: 15 minutes*(Taken from NSC Nov 2012 Paper 2)*

During a practical investigation the boiling points of the first six straight-chain ALKANES were determined and the results were recorded in the table below.

ALKANE	MOLECULAR FORMULA	BOILING POINT (°C)
Methane	CH ₄	-164
Ethane	C ₂ H ₆	-89
Propane	C ₃ H ₈	-42
Butane	C ₄ H ₁₀	-0,5
Pentane	C ₅ H ₁₂	36
Hexane	C ₆ H ₁₄	69

4.1 Write down the:

4.1.1 Most important use of the alkanes in the above table (1)

4.1.2 General formula of the alkanes (1)

Refer to the table to answer QUESTION 4.2 and QUESTION 4.3 below.

4.2 For this investigation, write down the following:

4.2.1 Dependent variable (1)

4.2.2 Independent variable (1)

4.2.3 Conclusion that can be drawn from the above results (2)

4.3 Write down the NAME of an alkane that is a liquid at 25 °C. (1)

4.4 Will the boiling points of the structural isomers of hexane be HIGHER THAN, LOWER THAN or EQUAL TO that of hexane? Refer to MOLECULAR STRUCTURE, INTERMOLECULAR FORCES and ENERGY NEEDED to explain the answer. (4)
[11]

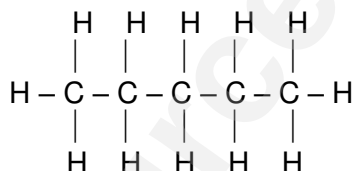
SECTION B: NOTES ON CONTENT

Organic Chemistry is the study of carbon chemistry. **Organic molecules** are molecules that contain carbon atoms. The great abundance and diversity of organic substances is due to the **unique ability of carbon to bond covalently to other carbon atoms**, and so build up **long chains** of carbon atoms. Carbon can bond to itself by direct covalent bonding to form long carbon-carbon chain structures (molecules) by the process of **catenation** with single bonds, double bonds or triple bonds.

Definitions:

Molecular formula – a chemical formula that indicates the type of atoms and the correct number of each atom in a molecule e.g. C_5H_{12} .

Structural formula - shows which atoms are attached to which within the molecule. Atoms are represented by their chemical symbols and lines represent ALL the bonds that hold the atoms together in the molecule e.g.



Condensed structural formula – This notation shows the way in which atoms are bonded together in the molecule but it does not show all the bonds e.g. $CH_3CH_2CH_2CH_2CH_3$

Hydrocarbon – organic compounds that consist of only hydrogen and carbon atoms.

Homologous series – a series of organic compounds that have the same functional group and that obey the same general formula or in which one member differs from the next with a $-CH_2$ group.

Functional group – is a bond, or bonds, an atom or group of atoms that gives an organic molecule its characteristic physical and chemical properties.

Saturated – organic molecules where there are no multiple bonds between the carbon atoms in the carbon chain.

Unsaturated – organic molecules with one or more multiple bonds between the carbon atoms in the carbon chain.

Isomer – organic molecules with the same molecular formula but different structural formulae. There are chain isomers (same molecular formula but different types of chains e.g. butane and methylpropane), positional isomers (same molecular formula but different positions of the side chain etc. e.g. but-1-ene and but-2-ene) and

functional isomers (same molecular formula but different functional group e.g. ketones and aldehydes can be isomers of each other).

NAMING OF ORGANIC COMPOUNDS

The IUPAC system is used to name organic compounds. This system sets up rules such that:

- each molecule has its own name.
- the names indicate the structure of the molecule.
- organic names are broken into a **prefix** and a **suffix**.

The **prefix** is based on the number of carbon atoms in the longest backbone of the molecule (See Table 1).

The **suffix** is determined by the functional group (See Table 4).

TABLE 1: Prefixes of organic compounds

<u>No of C-atoms (n)</u>	<u>Prefix</u>
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-

TABLE 2:

Types of C to C bonds	Type	General formulae if we have n carbons	Suffix	Saturated/unsaturated
1. All single	Alkane	C_nH_{2n+2}	-ane	Saturated
2. A double	Alkene	C_nH_{2n}	-ene	Unsaturated
3. A triple	Alkyne	C_nH_{2n-2}	-yne	Unsaturated

TABLE 3: Prefixes of alkanes

n	Name	Formula
1	Meth-ane	CH_4
2	Eth-ane	C_2H_6
3	Prop-ane	C_3H_8
4	But-ane	C_4H_{10}
5	Pent-ane	C_5H_{12}
6	Hex-ane	C_6H_{14}
7	Hept-ane	C_7H_{16}
8	Oct-ane	C_8H_{18}

TABLE 4: FUNCTIONAL GROUPS AND NAMES OF SEVERAL ORGANIC COMPOUNDS

Functional group	Homologous series	Suffix	General Formula	Pre-prefix
I. 1. All single bonds C – C 2. Double bond C = C 3. Triple bond C ≡ C	Alkane Alkene Alkyne	– ane – ene – yne	C_nH_{2n+2} C_nH_{2n} C_nH_{2n-2}	
II. 1. R – OH 2. $\begin{array}{c} \text{O} \\ \\ \text{R}^1 - \text{C} - \text{R} \\ \text{(central)} \end{array}$ 3. $\begin{array}{c} \text{O} \\ \\ \text{R} - \text{C} - \text{H} \text{ (end)} \end{array}$ 4. $\begin{array}{c} \text{O} \\ \\ - \text{C} - \text{OH} \\ \text{or} \\ - \text{COOH} \end{array}$	Alcohol / Alkanols Ketone Aldehyde Carboxylic Acids	(an) – ol (an) – one (an) – al (an) – oic acid	$C_nH_{2n+1}OH$ $C_nH_{2n}O$ $C_nH_{2n}O$ $C_nH_{2n}O_2$ or $C_nH_{2n+1}COOH$	
III. R – F R – Cl R – Br R – I	Halo Alkane / Alkyl or aryl halides		$C_nH_{2n+1}X$ where X is any halogen	Fluoro– Chloro– Bromo– Iodo–
IV $\begin{array}{c} \text{O} \\ \\ \text{R}^1 - \text{C} - \text{O} - \text{R} \end{array}$	Esters	(an) – oate	$C_nH_{2n}O_2$ (the same as carboxylic acids)	

- a) The $-C=O$ group, present in several functional groups, is called a **carbonyl group**. The $-COOH$ group is called a **carboxyl group** (a contraction of carbonyl and hydroxyl).
- b) R^1 and R are called replacement groups e.g. $-CH_3$ (methyl) or $-CH_3CH_2$ (ethyl) etc.

RULES OF THE IUPAC NAMING SYSTEM

The IUPAC (International Union of Pure and Applied Chemistry) devised a system of naming which makes provision for **each organic compound having one name only**. This system is based mainly on the fact that:

- I the longest carbon chain is chosen as the basic structure
- II the branches or side chains are then specified.

Note: i) The “branches” have one hydrogen atom less than the alkane with the same

number of carbon atoms and are called **alkyl groups** or radicals.

- ii) The suffix – **ane** of the alkane is replaced by – **yl** to form the name of the corresponding alkyl group.

e.g. methyl – CH_3

ethyl – CH_2CH_3 or $-\text{C}_2\text{H}_5$

propyl – $\text{CH}_2\text{CH}_2\text{CH}_3$ or $-\text{C}_3\text{H}_7$

butyl – $\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ or $-\text{C}_4\text{H}_9$

- iii) The alkyl radicals have the homologous series $\text{C}_n\text{H}_{2n+1}$.

- iv) The letter R is used as the general symbol for an alkyl group.
The formula
 $\text{R} - \text{H}$ therefore represents any alkane.

- a) Choose the longest continuous carbon chain.
- b) Number the carbon atoms in the basic structure so that the **branches have the lowest possible number**.
- c) The names of the branches are written in alphabetical order before the name of the basic structure. (A suffix yl is used to name the branch).
- d) The number of the carbon atom to which the branch is joined appears in front of the branch name. N.B! **There must always be a number for each branch!**
- e) If a branch with the same number of carbon atoms appears more than once, the prefixes di (2), tri (3), tetra (4), penta (5), etc. are used i.e. these prefixes show the presence of multiple identical side chains.

Note: If two like groups are bonded to the same carbon atom, the number of the carbon atom is repeated for each group e.g. 2,2-dimethyl in the example indicates that there are two methyl groups and each is bonded to carbon atom number 2.

STRUCTURES AND PHYSICAL PROPERTIES (BOILING POINT, MELTING POINT, VAPOUR PRESSURE, PHYSICAL STATE, DENSITY, MOLECULAR SHAPE, FLAMMABILITY AND SMELL) RELATIONSHIPS

Molecules are held together by intermolecular forces. In order to separate these molecules from one another requires energy. The stronger the intermolecular forces are, more energy is required to separate or break these

bonds and to bring about a phase change etc. This will lead to a higher melting point, boiling point, etc

Explain the relationship between physical properties and:

- **Strength of intermolecular forces** i.e hydrogen bonds, dipole-dipole forces and Van Der Waals forces. Hydrogen bonds are stronger than dipole-dipole forces and Van Der Waals forces. Hydrogen bonds are found between alcohol molecules and carboxylic acid molecules.
- **Type of functional group** – carboxyl group has two hydrogen bonds between its molecules while the hydroxyl group from the alcohol only has one. Thus, carboxylic acids will have stronger intermolecular forces between its molecules than the corresponding alcohol.
- **Chain length** – the longer the carbon chain, the stronger the intermolecular forces between the molecules become
- **Branched chains** – the more spherical a molecule becomes, the weaker the intermolecular forces will be between the molecules as the surface area is smaller.

Boiling and melting points

The higher the melting point or boiling point, the stronger the intermolecular forces will be and thus more energy is required to break the stronger intermolecular forces.

The lower the melting or boiling points are, the weaker the intermolecular forces are and thus less energy is required to break these weaker bonds.

Vapour pressure

The definition of vapour pressure is the amount of pressure that gaseous molecules exert onto the surface of the liquid phase. The vapour pressure will decrease as the size of the molecule increases (chain length). The higher the vapour pressure, the weaker the intermolecular forces will be between the molecules present in the liquid phase.

Viscosity

Viscosity is the liquid's resistance to flow. So, a liquid that has a low viscosity will be able to flow more easily. However, where hydrogen bonds are present, there will be a much higher degree of viscosity. The opposite is true for the weak Van der Waals forces. Viscosity will also increase as the length of the carbon chain increases.

SESSION3: HOMEWORK QUESTIONS**QUESTION 1 – 20 minutes***(Taken from the DoE – exemplar 2008)*

The first six members of the alkanes occur as gases and liquids at normal temperatures. Alkanes are currently our most important fuels, but the use of alcohols as renewable energy source is becoming more and more important. Alcohols are liquids that might be a solution to the energy crisis.

- 1.1 Which chemical property of alkanes and alcohols make them suitable to be used as fuels? (2)
- 1.2 The table shows the boiling points of the first six alkanes and the first six alcohols.

Alkane	Boiling point (°C)	Alcohol	Boiling point (°C)
methane	- 164	methanol	65
ethane	- 89	ethanol	79
propane	- 42	1-propanol	97
butane	- 0,5	1-butanol	117
pentane	36	1-pentanol	138
hexane	69	1-hexanol	156

Draw a graph of boiling points versus number of carbon atoms for the first six ALCOHOLS. Choose 50 °C and 1 carbon atom as origin and use an appropriate scale. Plot the points and draw the best curve through the points. (6)

- 1.3 What trend in boiling point can be observed from the graph? (2)
- 1.4 Provide a reason for the trend mentioned in QUESTION 1.3 by referring to the type of intermolecular forces. (2)
- 1.5 Explain, referring to the type of intermolecular forces, why the boiling points of alcohols are higher than the boiling points of alkanes. (2)
- 1.6 People are always cautioned to keep liquids such as petrol (a mixture of alkanes) out of reach of children. Use the boiling points of alkanes and justify this precaution. (2)
- 1.7 Briefly explain why ethanol is a renewable energy source, while the alkanes are non-renewable. (2)

[18]

SECTION D: SOLUTIONS FOR SECTION A

QUESTION 1

1.1

1.1.1 E✓ (1)

1.1.2 A✓ (1)

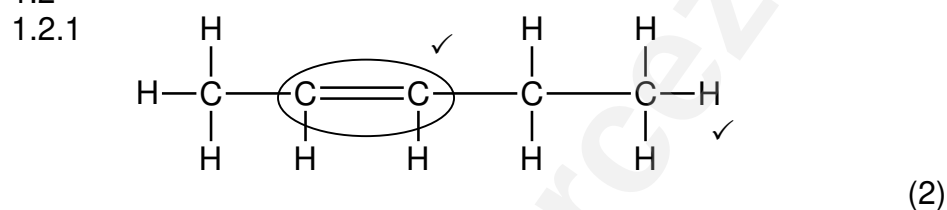
1.1.3 A✓ (1)

1.1.4 F✓ (1)

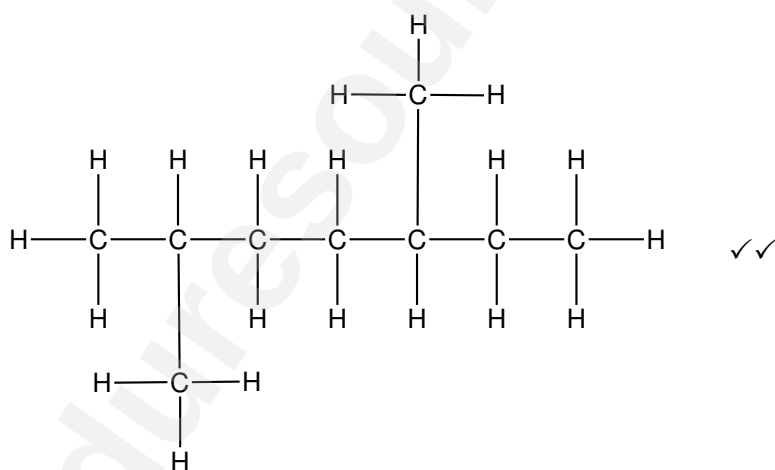
1.1.5 A✓ OR D
(1)

1.1.6 C✓ (1)

1.2



1.2.2



(2)

1.3

1.3.1 Carbonyl (group)✓ (1)

1.3.2 2-methyl✓ propan-1-ol ✓ (2)

[13]

QUESTION 2

2.1

2.1.1 Gas ✓ (1)

- 2.1.2 Lower than ✓
 Isomers of A:
More branching/Molecules more compact./Smaller surface area
 (over which the intermolecular forces act.) ✓
Weaker/less intermolecular forces. ✓
Less energy needed to overcome intermolecular forces. ✓

OR

Lower than ✓
A is less branched./has less compact molecules./has larger
surface area (over which intermolecular forces act). ✓
Stronger/more intermolecular forces. ✓
More energy needed to overcome intermolecular forces. ✓ (4)

- 2.1.3 Compound B contains a carbonyl group/O atom (bonded to C atom) ✓
 and is a polar (molecule)/dipole. ✓ (2)

2.2

- 2.2.1 Compound D: Two sites for hydrogen bonding/forms dimers ✓
 Compound C: One site for hydrogen bonding ✓

OR

Both compounds have hydrogen bonding (between molecules). ✓
 Compound D has two sites for/stronger/more hydrogen bonding ✓.
 (2)

- 2.2.2 (Compound) C ✓
 Lowest boiling point ✓ (2)
[11]

QUESTION 3

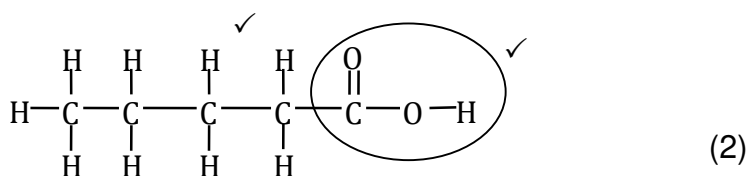
3.1

- 3.1.1 A ✓ (1)
 3.1.2 D ✓ & F ✓ (2)
 3.1.3 D ✓ (1)
 3.1.4 E ✓ (1)
 3.1.5 B ✓ (1)

3.2

- 3.2.1 2-methylbut-1-ene ✓ (2)

3.2.2



3.3
3.3.1 (Pleasant) odour/smell ✓ (1)

3.3.2 Ethanol ✓ (2)

3.3.3 Ethyl propanoate ✓

(2)
[15]

QUESTION 4

4.1
4.1.1 Fuels/Energy ✓ (1)

4.1.2 C_nH_{2n+2} ✓ (1)

4.2
4.2.1 Boiling point ✓ (1)

4.2.2 Chain length/Molecular size/Molecular mass ✓ (1)

4.2.3

Criteria for conclusion	Mark
Dependent and independent variables correctly identified.	✓
Relationship between the independent and dependent variables correctly stated.	✓

Example:

- Boiling point increases with increase in chain length/molecular size/molecular mass. (2)

4.3 Pentane ✓ (1)

4.4 Lower than ✓



Structure:

Isomers have more branching/less compact molecules/smaller surface areas (over which the intermolecular forces act.) ✓

- Intermolecular forces:**
Weaker intermolecular forces. ✓

- Energy:**
Less energy needed to overcome intermolecular forces. ✓

OR

Lower than ✓
• **Structure:**

Hexane is less branched/has less compact molecules/has a Larger surface area (over which intermolecular forces act.) ✓

- **Intermolecular forces:**
Stronger intermolecular forces. ✓
- **Energy:**
More energy needed to overcome intermolecular forces. ✓ (4)
[11]

SESSION NO: 4 HOMEWORK

TOPIC: ORGANIC REACTIONS AND POLYMERISATION

When teaching and revising this section please make sure that the learners know that the reactants are on the left hand side of the arrow ($\longrightarrow$) and that the products are on the right hand side. Make sure that learners know what to do when the question asks for the use of structural formulae, or condensed structural formulae or molecular formulae. Spend time on teaching the different types of reactions and the reaction conditions to ensure that the learners understand the difference between substitution, addition and elimination reactions.

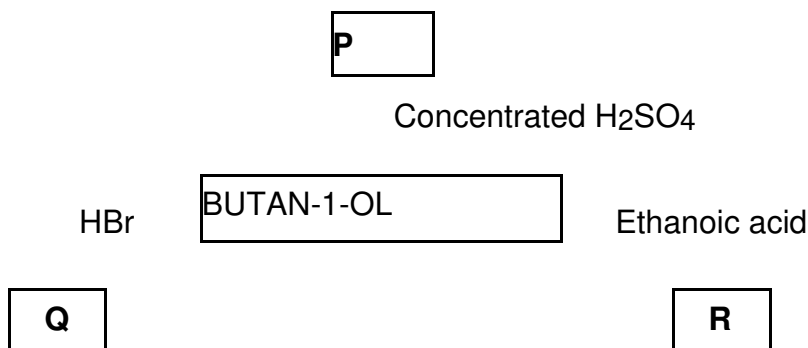
- 1 Introduce session – 5 minutes
- 2 Questions – 60 minutes
- 3 Notes on Content and explanations – 25 minutes

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes

(Taken from NSC Feb/Mar 2013 Paper 2)

Some of the reactions of BUTAN-1-OL are represented in the flow diagram below. **P**, **Q** and **R** represent the organic products formed.

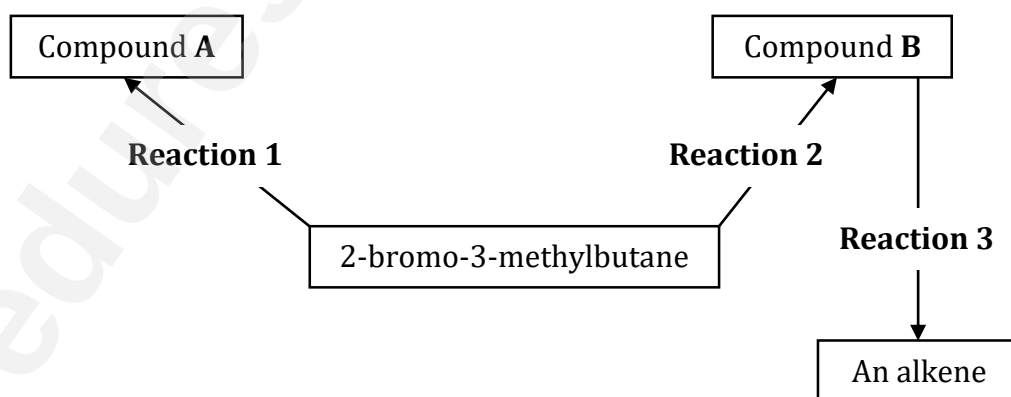


- 1.1 Is butan-1-ol a PRIMARY, SECONDARY or TERTIARY alcohol? (1)
- 1.2 Product **P** is formed when butan-1-ol is heated in the presence of concentrated sulphuric acid.
Write down the:
- 1.2.1 Name of the type of reaction that takes place (1)
- 1.2.2 Balanced equation for the reaction that takes place using structural formulae (5)
- 1.3 Product **R** is formed when butan-1-ol reacts with ethanoic acid in the presence of an acid catalyst.
Write down the:
- 1.3.1 Name of the type of reaction that takes place (1)
- 1.3.2 Structural formula of the organic product formed (2)
- 1.4 When HBr reacts with butan-1-ol, compound **Q**, a haloalkane, is formed.
Write down the:
- 1.4.1 Name of the type of reaction that takes place (1)
- 1.4.2 IUPAC name of the haloalkane formed (2)
- [13]

QUESTION 2: 15 minutes

(Taken from NSC Nov 2012 Paper 2)

The flow diagram below shows how three organic compounds can be prepared from 2-bromo-3-methylbutane.



- 2.1 Write down the:
- 2.1.1 Homologous series to which 2-bromo-3-methylbutane belongs (1)
- 2.1.2 Structural formula of 2-bromo-3-methylbutane (2)

2.2 **Reaction 2** takes place in the presence of a dilute sodium hydroxide solution.

Write down the:

2.2.1 Name of the type of reaction which takes place (1)

2.2.2 Structural formula of compound **B** (2)

2.3 **Reaction 1** takes place in the presence of concentrated sodium hydroxide.

Write down:

2.3.1 Another reaction condition needed for this reaction (1)

2.3.2 The name of the type of reaction which takes place (1)

2.3.3 The structural formula of compound **A**, the major product formed (2)

2.4 **Reaction 3** takes place when compound **B** is heated in the presence of concentrated sulphuric acid. Write down the IUPAC name of the major product formed. (2)

[12]

QUESTION 3: 22 minutes

(Taken from NSC Feb/March 2011 Paper 2)

3.1 Prop-1-ene, an UNSATURATED hydrocarbon, and compound **X**, a SATURATED hydrocarbon, react with chlorine, as represented by the incomplete equations below.

Reaction I :
 Prop-1-ene + Cl₂ →

Reaction II: X + Cl₂ → 2-chlorobutane + Y

3.1.1 Give a reason why prop-1-ene is classified as unsaturated. (1)

3.1.2 What type of reaction (ADDITION or SUBSTITUTION) takes place in the following:

(a) Reaction I (1)

(b) Reaction II (1)

3.1.3 Write down the structural formula of the product formed in Reaction I. (2)

3.1.4 Write down the reaction condition necessary for Reaction II to take place. (1)

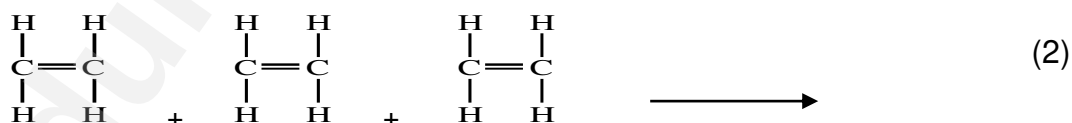
31

- 3.1.5 Write down the IUPAC name of reactant **X**. (1)
- 3.1.6 Write down the name or formula of product **Y**. (1)
- 3.2 2-chlorobutane can either undergo ELIMINATION or SUBSTITUTION in the presence of a strong base such as sodium hydroxide.
- 3.2.1 Which reaction will preferably take place when 2-chlorobutane is heated in the presence of CONCENTRATED sodium hydroxide in ethanol? Write down only SUBSTITUTION or ELIMINATION. (1)
- 3.2.2 Write down the IUPAC name of the major organic compound formed in QUESTION 3.2.1. (2)
- 3.2.3 Use structural formulae to write down a balanced equation for the reaction that takes place when 2-chlorobutane reacts with a DILUTE sodium hydroxide solution. (6)
- 3.2.4 Write down the name of the type of substitution reaction that takes place in QUESTION 3.2.3. (1)
- 3.3 Haloalkanes are used in insecticides (insect killers).
- 3.3.1 Write down ONE POSITIVE impact of insecticides on human development. (2)
- 3.3.2 Write down ONE NEGATIVE impact of insecticides on humans. (2)
- [22]**

QUESTION 4: 8 minutes*(Taken from DGC 2008 Paper 2)*

Alkenes, such as ethene, can be made into polymers.

- 4.1 Complete the following to show how the given ethene molecules bond to form part of a polymer.



- 4.2 Name the type of polymerization reaction taking place in 4.1. (1)
- 4.3 Name the polymer formed from ethene. (1)
- 4.4 Give **one** important problem caused by the everyday use of this polymer. (2)

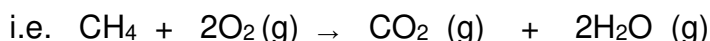
[6]

SECTION B: NOTES ON CONTENT

ORGANIC REACTIONS

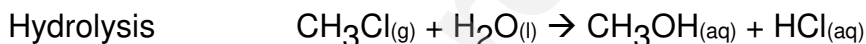
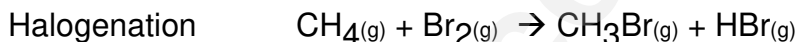
1 Combustion reactions

Hydrocarbons can undergo combustion reactions e.g.



2 Substitution reactions

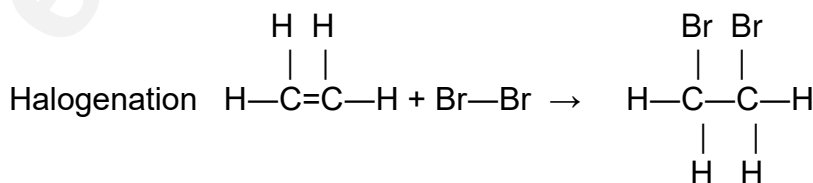
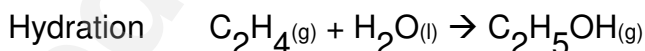
Alkanes, alcohols and haloalkanes can also undergo slow substitution reactions requiring activation energy (i.e. heat or sunlight) whereby a hydrogen atom or hydroxyl group or halogen atom respectively is replaced during the reaction by another element, usually a halogen or a hydroxyl group.



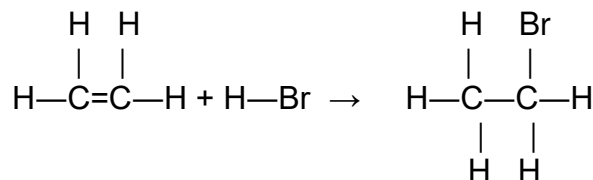
The process whereby an H-atom in a hydrocarbon is replaced by one Or more atoms of a halogen are called **halogenation**. If the halogen atom is chlorine, the particular halogenation process is called **chlorination**, if it is bromine then **bromination**.

3 Addition reactions

Because of the unstable double bond, alkenes undergo chiefly **addition reactions** ('adding on' of extra atoms or groups of atoms to the molecule) with the subsequent breaking of the double bond. An addition reaction always takes place across a double or triple bond. Addition reactions generally occur faster than substitutions reactions.

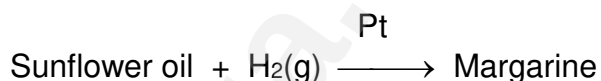


Hydrohalogenation



Hydrogenation is the addition of H_2 onto the alkene or alkyne in the presence of a catalyst (Pt or Ni together with heat). Edible liquid vegetable oils (long chain molecules) with large numbers of double bonds (polyunsaturates) (e.g. sunflower oil) are “hardened” (converted into solid fats which contain less double bonds than oils) by bubbling $\text{H}_2(\text{g})$ through the oil.

Hydrogenation converts the oil to fat by opening the double bonds and adding hydrogen. The intermolecular forces increase and the oil is hardened into a more solid form.



By controlling the amount of hydrogenation the fat is made ‘hard’ or ‘soft’. Upon addition of H_2O , colourant, salt, flavouring agents and vitamins margarine results.

4 Test for unsaturated compounds – Addition of a halogen (halogenation)

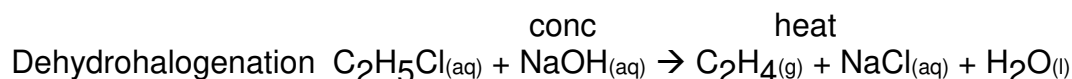
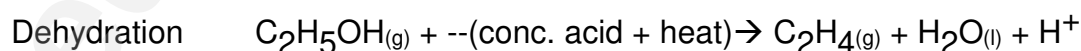
To test for double bond (or triple bond) (unsaturated compounds), add a few drops of a bromine – carbon tetrachloride solution. If the colour disappears $\text{Br}_2(\text{l})$ has been removed by addition. This serves as a positive test for unsaturated compounds.

i.e. the bromine test is the standard laboratory test for unsaturation.

When bromine water is added to an alkane it undergoes a very slow substitution reaction and the colour disappears over a period of time.

5 Elimination reactions

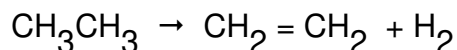
This reaction is the opposite to addition reactions. A single bond is ELIMINATED and a double bond forms.



Dehydrogenation is the removal of hydrogen. Dehalogenation is the removal of a halogen molecule.

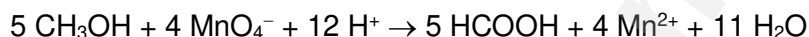
6 Cracking

Organic molecules like $C_{20}H_{42}$ are heated to very high temperatures and then it is broken down into smaller fragments such as ethane etc i.e. alkenes and alkynes are formed.

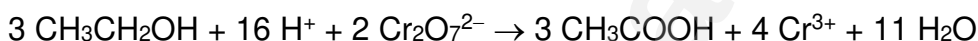


7 Oxidation

When an alcohol undergoes oxidation of an alcohol by using strong oxidising agents like $KMnO_4$ or $K_2Cr_2O_7$ in acid medium, carboxylic acids are formed. Methanoic acid is prepared by the oxidation of methanol i.e.



Oxidation of a primary alcohol using $K_2Cr_2O_7$ as a catalyst and oxidising agent forms an aldehyde. Oxidation of a secondary alcohol using $K_2Cr_2O_7$ as a catalyst and a dehydrating agent forms a ketone. Ethanoic acid is prepared by the oxidation of ethanol i.e.



8 Esterification

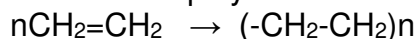
An ester is formed when an alcohol reacts with a carboxylic acid when using sulphuric acid as a dehydrating agent and catalyst. The ester is formed as well as water.

9 Polymerisation

Polymers are very large organic molecules (macromolecules) that are made up of hundreds of atoms or long chains of monomers that are covalently bonded together. Polymers are found in nature, e.g. rubber found in rubber trees; as well as wool, silk and cellulose found in wood and paper. Plastics are synthetic polymers that are made by man.

A polymer is made up of a large number of similar units called monomers that are bonded together. There are two basic types of polymerization: addition polymerization and condensation polymerization.

Addition polymerization reactions involve alkenes that, under correct conditions i.e. high temperature and very high pressure, will combine to form a very long polymer molecule. This polymer is called polythene.



Condensation polymerization *occurs when two molecules react with the elimination of a water molecule.*

The two main differences between addition polymerization and condensation polymerization are:

- Condensation polymers form more slowly than addition polymers.
- Water is formed in condensation polymerization and no by-products are formed in addition polymerization.

- The monomers of addition polymers contain carbon-carbon double bonds, whilst the monomers of condensation polymers contain functional groups, such as alcohols and carboxylic acids.

The formation of a polyester is the same as that for an ester. The only difference is that in the polyester there is a diol- that is an alcohol with two –OH groups and a dicarboxylic acid- a carboxylic acid with two –COOH groups.

Poly(lactic acid) (PLA) is a polyester that is produced from renewable resources such as corn starch and sugar cane. The monomer is lactic acid and it has the formula $C_3H_6O_3$. Many monomers of lactic acid molecules will react together, water will be eliminated and poly(lactic acid) will be formed.

SECTION C: HOMEWORK QUESTIONS

QUESTION 1 – 20 minutes

(Taken from the DoE – exemplar 2008)

The first six members of the alkanes occur as gases and liquids at normal temperatures. Alkanes are currently our most important fuels, but the use of alcohols as renewable energy source is becoming more and more important. Alcohols are liquids that might be a solution to the energy crisis.

- 1.1 Which chemical property of alkanes and alcohols make them suitable to be used as fuels? (2)
- 1.2 The table shows the boiling points of the first six alkanes and the first six alcohols.

Alkane	Boiling point (°C)	Alcohol	Boiling point (°C)
methane	- 164	methanol	65
ethane	- 89	ethanol	79
propane	- 42	1-propanol	97
butane	- 0,5	1-butanol	117
pentane	36	1-pentanol	138
hexane	69	1-hexanol	156

Draw a graph of boiling points versus number of carbon atoms for the first six ALCOHOLS. Choose 50 °C and 1 carbon atom as origin and use an appropriate scale. Plot the points and draw the best curve through the points. (6)

- 1.3 What trend in boiling point can be observed from the graph? (2)
- 1.4 Provide a reason for the trend mentioned in QUESTION 1.3 by referring to the type of intermolecular forces. (2)

- 1.5 Explain, referring to the type of intermolecular forces, why the boiling points of alcohols are higher than the boiling points of alkanes. (2)
- 1.6 People are always cautioned to keep liquids such as petrol (a mixture of alkanes) out of reach of children. Use the boiling points of alkanes and justify this precaution. (2)
- 1.7 Briefly explain why ethanol is a renewable energy source, while the alkanes are non-renewable. (2)

[18]

SECTION D: SOLUTIONS FOR SECTION A

QUESTION 1

1.1

1.1.1 E✓ (1)

1.1.2 A✓ (1)

1.1.3 A✓ (1)

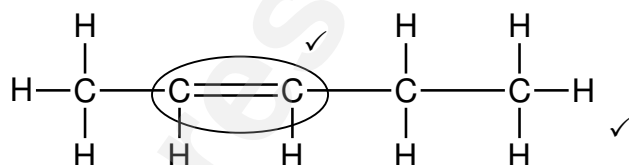
1.1.4 F✓ (1)

1.1.5 A✓OR D
(1)

1.1.6 C✓ (1)

1.2

1.2.1



(2)

1.2.2

✓✓

1.3

- 1.3.1 Carbonyl (group)✓ (1)
- 1.3.2 2-methyl✓propan-1-ol ✓ (2)
- [13]

QUESTION 2

2.1

- 2.1.1 Gas ✓ (1)

- 2.1.2 Lower than ✓

Isomers of A:

More branching/Molecules more compact./Smaller surface area
(over which the intermolecular forces act.) ✓

Weaker/less intermolecular forces. ✓

Less energy needed to overcome intermolecular forces. ✓

OR

Lower than ✓

A is less branched./has less compact molecules./has larger
surface area (over which intermolecular forces act). ✓

Stronger/more intermolecular forces. ✓

More energy needed to overcome intermolecular forces. ✓ (4)

- 2.1.3 Compound B contains a carbonyl group/O atom (bonded to C
atom) ✓
and is a polar (molecule)/dipole. ✓ (2)

2.2

- 2.2.1 Compound D: Two sites for hydrogen bonding/forms dimers ✓
Compound C: One site for hydrogen bonding ✓

OR

Both compounds have hydrogen bonding (between molecules). ✓

Compound D has two sites for/stronger/more hydrogen bonding.
✓. (2)

- 2.2.2 (Compound) C ✓
Lowest boiling point ✓ (2)
- [11]

QUESTION 3

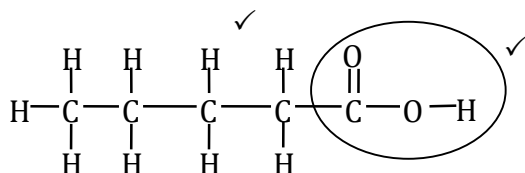
3.1

- 3.1.1 A ✓ (1)
- 3.1.2 D ✓ & F ✓ (2)
- 3.1.3 D ✓ (1)
- 3.1.4 E ✓ (1)
- 3.1.5 B ✓ (1)

3.2

3.2.1 2-methylbut-1-ene ✓ (2)

3.2.2



3.3

3.3.1 (Pleasant) odour/smell ✓ (1)

3.3.2 Ethan✓ol ✓ (2)

3.3.3 Ethyl ✓ propanoate ✓ (2)
[15]

QUESTION 4

4.1

4.1.1 Fuels/Energy ✓ (1)

4.1.2 $\text{C}_n\text{H}_{2n+2}$ ✓ (1)

4.2

4.2.1 Boiling point ✓ (1)

4.2.2 Chain length/Molecular size/Molecular mass ✓ (1)

4.2.3

Criteria for conclusion	Mark
Dependent and independent variables correctly identified.	✓
Relationship between the independent and dependent variables correctly stated.	✓

Example:

- Boiling point increases with increase in chain length/molecular size/molecular mass. (2)

4.3 Pentane ✓ (1)

4.4 Lower than ✓

- Structure:**
Isomers have more branching./less compact molecules./smaller surface areas (over which the intermolecular forces act.) ✓

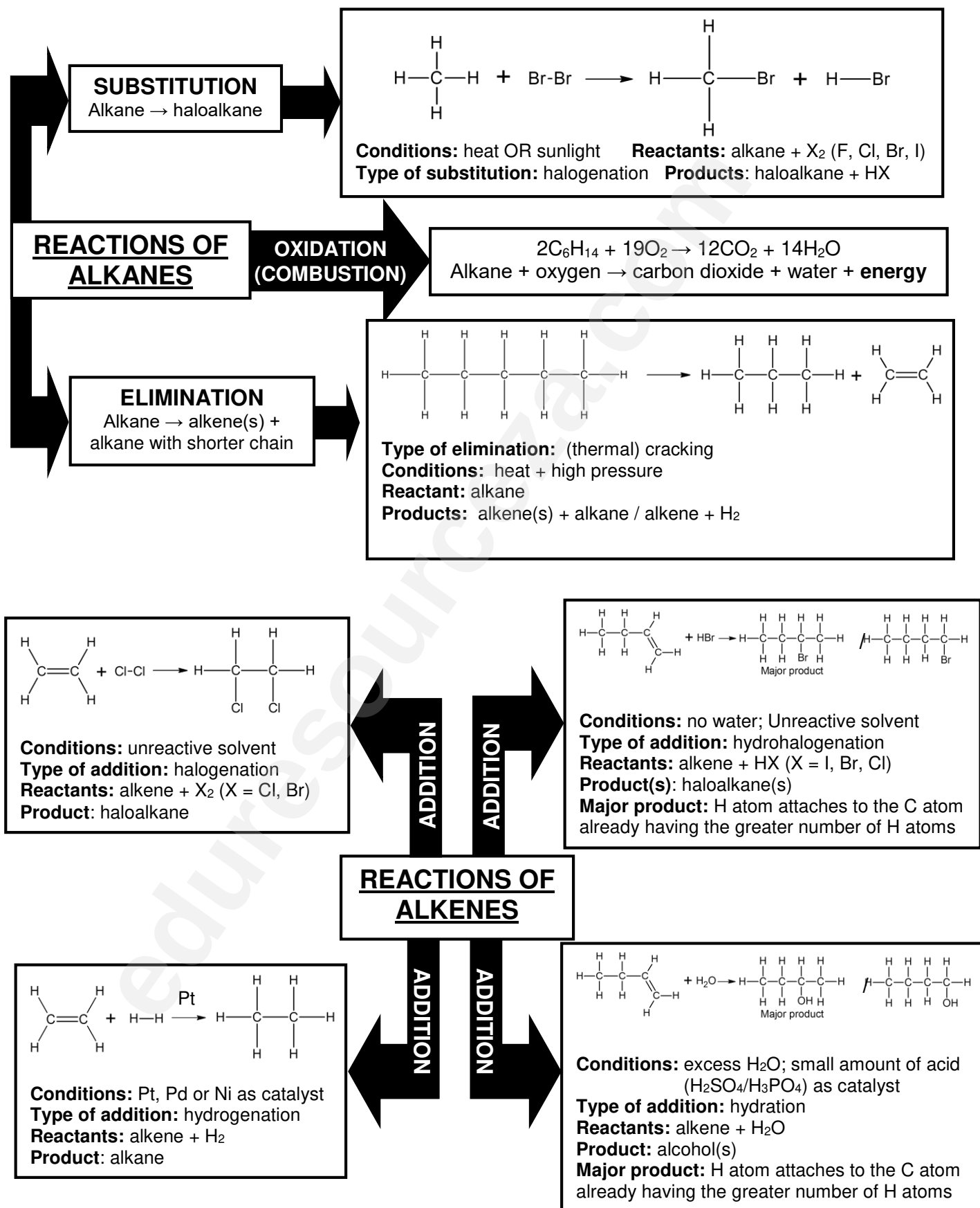
- Intermolecular forces:**
Weaker intermolecular forces. ✓

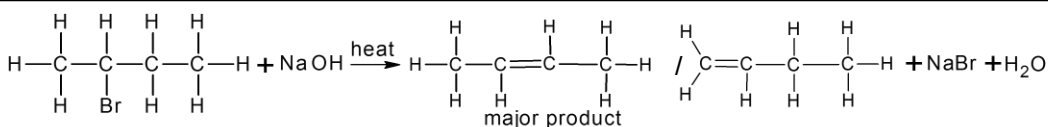
- **Energy:**
Less energy needed to overcome intermolecular forces. ✓

OR

- ⓪ Lower than ✓
- **Structure:**
Hexane is less branched./has less compact molecules./has a larger surface area (over which intermolecular forces act.) ✓
 - **Intermolecular forces:**
Stronger intermolecular forces. ✓
 - **Energy:**
More energy needed to overcome intermolecular forces. ✓ (4)
[11]

ORGANIC REACTIONS GRADE 12





Conditions: concentrated strong base (NaOH, KOH, LiOH) in ethanol + heat

Type of elimination: dehydrohalogenation

Reactants: haloalkane + concentrated strong base

Products: alkene + NaBr + H₂O

Major product: The one where the H atom is removed from the C atom with the least number of H atoms (most substituted double bond forms i.e. double bond with most alkyl groups)

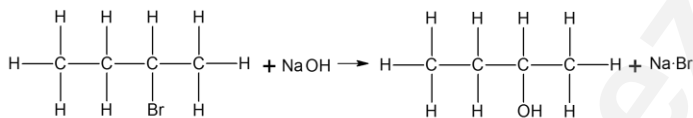
ELIMINATION

Haloalkane → alkene

REACTIONS OF HALOALKANES

SUBSTITUTION

Haloalkane → alcohol

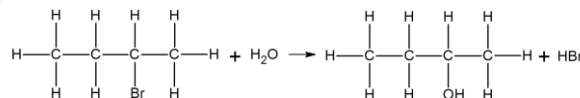


Conditions: dilute strong base (NaOH/KOH/LiOH) + mild heat

Type of substitution: hydrolysis

Reactants: haloalkane + dilute strong base

Products: alcohol + NaBr/KBr/LiBr

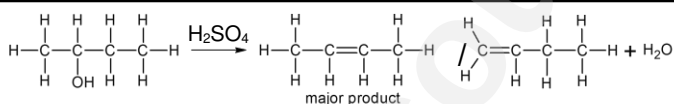


Conditions: excess H₂O + mild heat

Type of substitution: hydrolysis

Reactants: haloalkane + H₂O

Products: alcohol + HBr



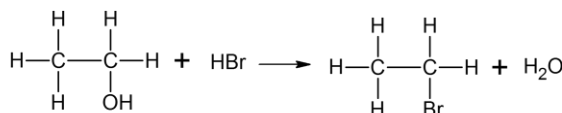
Conditions: dehydrating agent (H₂SO₄/H₃PO₄) + heat

Type of elimination: dehydration

Reactants: alcohol + H₂SO₄

Products: alkene(s) + H₂O

Major product: The one where the H atom is removed from the C atom with the least number of H atoms



Conditions: heat

Reactants needed: alcohol + HX

Primary & secondary alcohols:

NaBr + H₂SO₄ used to make HBr in reaction flask

Tertiary alcohols: HBr (or HCl) directly

Products: haloalkane + H₂O

ELIMINATION

Alcohol → alkene

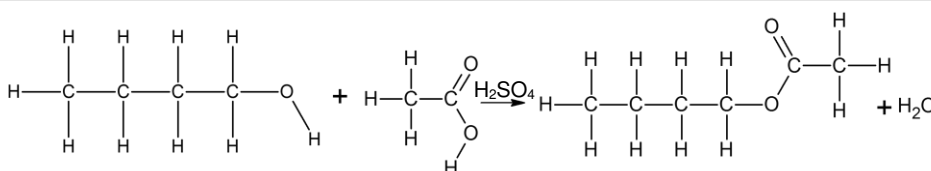
SUBSTITUTION

Alcohol → haloalkane

REACTIONS OF ALCOHOLS

ESTERIFICATION

Acid catalysed condensation



Conditions: acid as catalyst + heat

Reactants: alcohol + carboxylic acid + H₂SO₄

Type: esterification

Products: ester + water