education

Department:
Education
PROVINCE OF KWAZULU-NATAL

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 12

PHYSICAL SCIENCES

STEP AHEAD PROGRAMME

2021

PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses as a result of the impact of COVID-19 in 2020. It also captures the challenging topics in the Grade 10 -12 work. Activities should serve as a guide on how various topics are assessed at different cognitive levels and also preparing learners for informal and formal tasks in Physical Sciences. It will cover the following topics:

	TOPIC	PAGE NUMBER
1.	Work, Energy and Power	3 – 23
2.	Reaction Rates	24 – 45
3.	Chemical Equilibrium	46 – 57
4.	Acids and Bases	58 – 72
5.	Chemical Systems (Fertilizer Industry)	73 - 85

LEARNER DOCUMENT

WORK

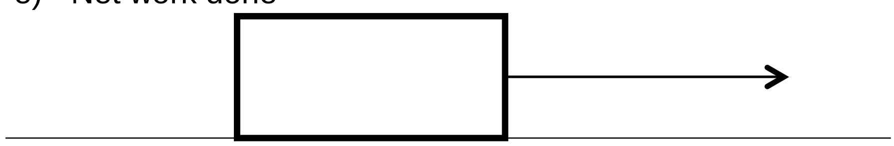
- Define the work done on an object by a constant force F as F·Δx cosθ, where F is the magnitude of the force, Δx the magnitude of the displacement and θ the angle between the force and the displacement.
- The force doing the work and the motion must be in the same direction.
- If the force **F** doing the work acts at an angle Θ, first determine the horizontal component of the force acting at an angle i.e. the force has to be resolved into its components.
- Use the horizontal component of the force to determine the amount of work.
- A force must act on the object on which work is done, all the time.
- The object must move in the direction of the force that is applied i.e Displacement must be in the same direction.
- Only the component of the applied force that is parallel to the motion does work on an object.
- Positive work is done by a force that acts in the same direction as the motion of the object.
- Negative work is done by a force that acts in the opposite direction of the motion of the object. (e.g friction).
- Zero work (no work) is done by a force that acts perpendicular to the motion of the object (e.g normal).

  For the force acting at an angle:-
- Calculate the horizontal and the vertical components.
- If an object is pulled , then $F_g = F_N + F_V$, therefore $F_N = F_g - F_V$
- If an object is pushed then $F_g = F_N - F_V$, therefore $F_N = F_g + F_V$
- This is used when given the coefficients

Worked examples

A 6kg box is pulled, to the right on a horizontal surface, by a force of 20N. The box experiences a constant frictional force of 3N during its motion. The box covers a distance of 5m. calculate the work done by:

a) The frictional force
b) Applied force
c) Normal force
d) Weight
e) Net work done



Solutions

a) $Wf = f\Delta x cos\theta$

$= (3)(5)\cos180^0$

= -15J

b) $WF = F\Delta x cos\theta$

=(20)(5)cos0^0

= 100J

c) $WN = FN\Delta x cos\theta$

= (6)(9.8)(5)cos90^0

= 0J

d) $WFg = Fg\Delta x cos\theta$

= (6)(9.8)(5)cos270^0

=0J

f) Wnet = Wf +WF+WFg+ WN

= -15J + 100J + 0J +0J

= 85J

Learner's notes

- State the **work-energy theorem**: The net work done on an object is equal to the change in the object's kinetic energy. OR The work done on an object by a net force is equal to the change in the object's kinetic energy.
- In symbols: $W_{net} = \Delta E_k = E_{kf} - E_{ki}$ *OR* $W_{net} = \frac{1}{2}m(v_f^2 - v_i^2)$, where W_{net} is Work net measured in Joules (J), E_k is Kinetic energy measured in Joules(J), m is mass measured in kilograms (kg), v is velocity measured in $m{\cdot}s^{-1}$.
- Firstly take out the given data.

METHOD ONE:

- Draw a force / free-body diagram of all the forces acting on the object.
- Determine the angle θ between each force and the direction of motion / displacement.
- Use W = FΔxcosθ to determine the work done by each force
- Then use $W_{net} = \Delta E_K$ OR $W_{net} = E_{Kf} - E_{Ki}$ OR $W_{net} = \frac{1}{2}m(v_f^2 - v_i^2)$, according to the given data and the variable you are calculating.
- Calculate the sum of the work done by all the forces (on the left hand side): $W_{net} = W_{Fa} + W_f$ equals to change in kinetic energy(on the right hand side): $\Delta E_K = E_{Kf} - E_{Ki}$ *OR* $\Delta E_K = \frac{1}{2}m(v_f^2 - v_i^2)$

METHOD TWO:

- Draw a force / free-body diagram of all the forces acting along the plane of motion of the object.
- Ignore the forces that act perpendicular to the plane, because they do zero work on the object.
- Calculate the net force / the sum of the forces acting parallel to the plane, i.e.: $F_{net} = F_a + F_{fk}$
- Calculate the net work done on the object using: $W_{net} = F_{net}\Delta x cos\theta$ (on the left hand side) equals to $\Delta E_K = E_{Kf} - E_{Ki}$ *OR* $= \frac{1}{2}m(v_f^2 - v_i^2)$ on the right hand side.

WORKED EXAMPLE (horizontal surface)

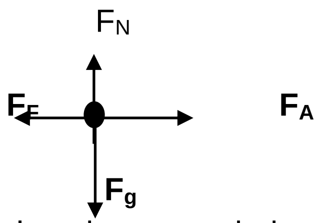
A formula 1 racing car of mass 640kg is travelling at 30m.s^{-1}. It then accelerated in a straight line down the main straight. The engine exerts an average forward force of 12000N and the racing car experiences an average frictional force of 3000N.

1. State the work-energy theorem in words.
2. Draw a labelled free- body diagram showing ALL the forces acting on a racing car.
3. Use work-energy theorem to calculate the speed of the racing car after it has travelled 30m.

Solutions

Data: m = 640 kg, V_i = 30m.s^{-1}, F_a= 12000N, f_k = 3000N

1. The net work done on an object is equal to the change in the object's kinetic energy.
2.



Firstly calculate the net work done on the car by each force :

$W_a = F_a \Delta x \cos\theta$ = (12000)(30)cos 0° = +360 000J

$W_f = F_f \Delta x \cos\theta$ = (3000)(30)cos 180° = -90000J

Find the net work done on the car by adding the work done by each force

W_{net} = +360000+ (-90000) = + 270 000J

Secondly find the initial kinetic energy of the car:

$E_{ki} = \frac{1}{2}mv_i^2 = \frac{1}{2}(640)(30)^2$ = 288000J

Use WORK-ENERGY theorem to find the final speed of the car:

$W_{net} = E_{kf} – E_{ki}$

270 000 = $\frac{1}{2}(640)v_f^2$- 288000

270000+288000 = $\frac{1}{2}(640)v_f^2$

V_f = 41.76m.s^{-1}

Second method

Firstly calculate the net force on the car : $F_{net} = F_a + F_{fk}$

= 12000-3000 = 9000N

Find the net work done on the car using the equation: $W_{net} = F_{net} \Delta x \cos\theta$

= (9000)(30)cos0°

=270000J

Secondly find the initial kinetic energy of the car:

$E_{ki} = \frac{1}{2}mv_i^2 = \frac{1}{2}(640)(30)^2$ = 288000J

Use WORK-ENERGY theorem to find the final speed of the car:

$W_{net} = E_{kf} – E_{ki}$

270 000 = $\frac{1}{2}(640)v_f^2$ - 288000

270000+288000 = $\frac{1}{2}(640)v_f^2$

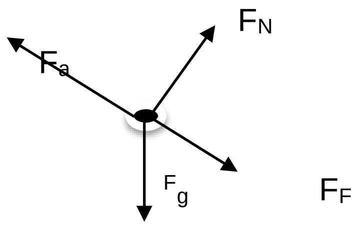
V_f = 41.76m.s^{-1}

WORKED EXAMPLE (Incline plane)

A 3kg remote-controlled car is driven up a plane inclined at 25° to the horizontal. The car motor exerts an average forward force of 60N. The car experiences a frictional force of 15N as it moves up the incline plane. The speed of the car at the bottom of the inclined plane is 5 m·s^{-1}.

1. State work-energy theorem in words.
2. Draw a free-body diagram showing all the forces acting on an object.
3. Use work-energy theorem to calculate the speed of the car after it has travelled 4m up the inclined plane.

Solutions

1. The net/total work done on an object is equal to the change in the object's kinetic energy. OR The work done on an object by a net force is equal to the change in the object's kinetic energy.
2. 

3. Wnet = ΔK

   $W_F + W_{g//} + W_f$ = ½ mvf^2 - ½ mvi^2

   FΔxcosθ°+mgsinθΔxcosθ°+fΔxcosθ°+ =½ mvf^2 - ½ mvi^2

   (60)(4)cos0°+(3)(9,8)sin25°(4)cos180°+ (15)(4)cos180° = ½(3) vf^2 - ½(3)(5)^2

   V_f = 10,58 m.s^{-1}

   Second method

   Calculate the net force / the sum of the forces acting parallel to the plane:

   $F_{net} = F_a + F_{fk} + F_{g//}$

   = 60 - 15 - (3)(9,8)sin25°

   = 32,56N

Find the net work done on the car using the equation:

$W_{net} = F_{net}$ Δxcosθ= (32,56)(4)cos0° =130,30J

Secondly find the initial kinetic energy of the car:

$E_{ki} = \frac{1}{2}mv_i^2 = \frac{1}{2}(3)(5)^2$ = 37,5J

Use WORK-ENERGY theorem to find the final speed of the car:

$W_{net} = E_{kf} – E_{ki}$

$130,30 = \frac{1}{2}(3){v_f}^2 - 37,5$

$130,30+37,5 = \frac{1}{2}3{v_f}^2$

$V_f = 10,58\ m.s^{-1}$

GRAVITATIONAL POTENTIAL ENERGY:

Gravitational potential energy (E_p) of an object is defined as the energy it has because of its position in the gravitational field relative to some reference level.

$$\mathbf{E_p = mgh}.$$

Where:

- m= mass of object, measured in kilograms(kg)
- g= acceleration due to gravity, measured in metres per second per second ($m \cdot s^{-2}$). On earth g=9.8$m \cdot s^{-2}$.
- h=vertical height of the object above some reference point, measured in metres (m)

KINETIC ENERGY:

Kinetic energy (E_k) is defined as the energy an object possess due to its motion

$$\mathbf{E_k = \frac{1}{2}mv^2}.$$

Where:

- m=mass of the object, measured in kilograms(kg)
- v=the magnitude of the velocity of the object, measured in metres per second(m/s)

MECHANICAL ENERGY:

The mechanical energy (E_m) of an object is defined as the sum of its gravitational potential energy (E_p) and kinetic energy (E_k).

$$\mathbf{E_m = E_k + E_p}.$$

Energy is a scalar quantity and is measured in joules (J).

LAW OF CONSERVATION OF MECHANICAL ENERGY:

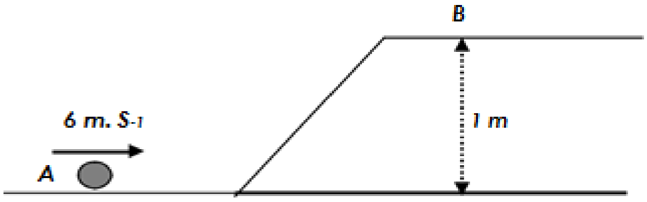
Principle of conservation of mechanical energy: The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant.

A system is isolated when the resultant/net external force acting on the system is zero.

Worked Examples:

Question 1

Given a 0.1kg bead at A sliding along a frictionless surface. Determine its speed at B if it slides up the frictionless ramp



Solution:

$E_{mech\ (A)} = E_{mech\ (B)}$.

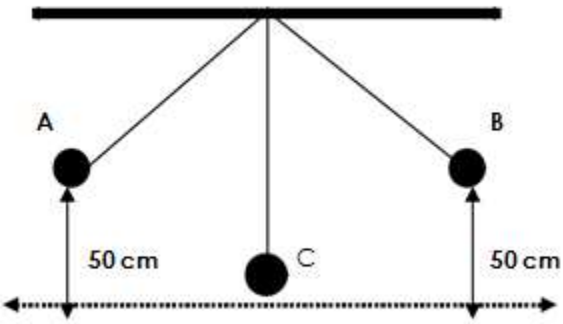
$E_{p(A)} + E_{k(A)} = E_{p(B)} + E_{k(B)}$.

$0 + \frac{1}{2}(0.1)(6^2) = (0.1)(9.8)(1) + \frac{1}{2}(0.1)(v^2)$.

$\underline{\mathbf{v = 4.05 m \cdot s^{-1}}}$.

Question 2

A pendulum of mass 800g swings to a maximum height of 50cm



a) Calculate the potential energy of the pendulum at point A. (3)
b) What is the kinetic energy of the pendulum at point A. (1)
c) Calculate the velocity of the pendulum at the lowest point of its swing. (4)

Solution

a)

$E_{p(A)} = mgh$.

$E_{p(A)} = (\frac{800}{1000})(9.8)(\frac{50}{100})$.

$\mathbf{E_{p(A)} = 3.92J}$

b) $E_{k(A)} = 0J$

c)

$E_{mech(A)} = E_{mech(C)}$.

$E_{p(A)} + E_{k(A)} = E_{p(C)} + E_{k(C)}$

$3.92 + 0 = 0 + \frac{1}{2}(0.8)(v^2)$

$\mathbf{v = 3.13 m \cdot s^{-1}}$

LAW OF CONSERVATION OF ENERGY:

The law of conservation of energy states that energy is neither created nor destroyed; it is ONLY converted from one form to another.

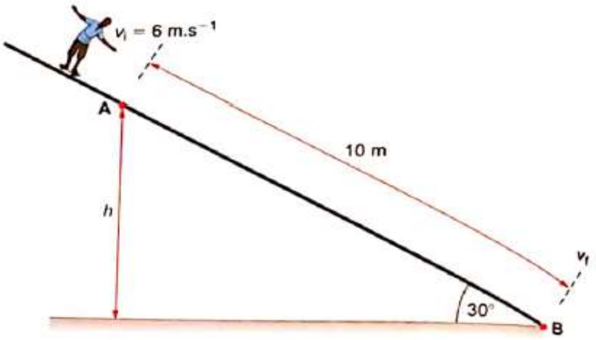
CONSERVATIVE FORCE AND NON-CONSERVATIVE FORCES:

Conservative force:

Conservative force is a force for which the work done in moving an object between two points is independent of the path taken. Examples are gravitational force, the elastic force in a spring and electrostatic forces (coulomb forces).

Worked Example:

The diagram shows a 70kg skateboarder who skates down a slope while experiencing a frictional force of 190N. The slope forms an angle of 30^0 with the horizontal. The skateboarder covers a distance of 10m between points A and B. The speed of the skateboarder at point A is $6 m \cdot s^{-1}$.



Calculate the work done by gravity.

.

Solution:

Option 1:

$W = F \cdot \Delta x Cos\theta.$

$W_g = mg \cdot \Delta x Cos\theta.$

$W_g = 70(9.8)(10)Cos60.$

$\mathbf{W_g = 3430J}.$

Option 2:

$Sin30° = \frac{opposite}{hypotenuse} = \frac{h}{10}.$

$h = 5m.$

$W = F \cdot \Delta x Cos\theta.$

$W_g = mg \cdot hCos\theta.$
$W_g = 70(9.8)(5)Cos0.$
$\mathbf{W_g = 3430J}.$

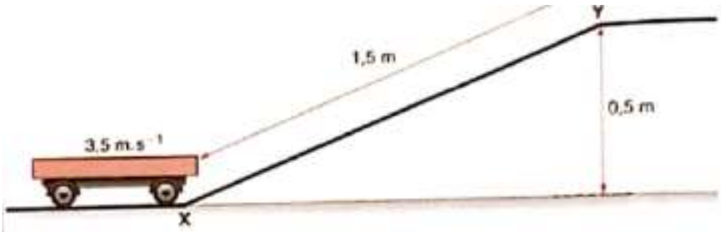
Therefore, irrespective of the path taken, work done by gravitational force does not change.

Non-conservative force:

Non-conservative force is a force for which the work done in moving an object between two points depends on the path taken. Examples are frictional force, air resistance, tension in a chord, etc.

Worked Example:

In the diagram below, a dynamics trolley of mass 1kg moving at $3.5m \cdot s^{-1}$, rolls from point X to Y along a frictionless runway. The length of the runway is 1.5m. the vertical height between points X and Y is 0.5m



1) Is the mechanical energy of the trolley conserved as it moves from X to Y? Explain your answer.
2) Calculate the speed of the trolley at point Y.
3) Now suppose the surface XY is rough and the trolley experiences a constant frictional force of 5N as it moves from X to Y. Will the trolley reach point Y? Justify your answer by means of a calculation.

Solution:

1. Yes, the system is isolated/there are no non-conservative forces present.
2.

$W_{nc} = \Delta E_k + \Delta E_p.$
$W_{nc} = E_{k(f)} - E_{k(i)} + E_{p(f)} - E_{p(i)}.$
$0 = \frac{1}{2}(1)v^2 - \frac{1}{2}(1)(3.5^2) + 1(9.8)(0.5) - 0.$
$\mathbf{v = 1.57m/s.}$

3.

$W_{nc} = \Delta E_k + \Delta E_p.$
$W_f = E_{k(f)} - E_{k(i)} + E_{p(f)} - E_{p(i)}.$
$f_k \Delta x Cos\theta = E_{k(f)} - E_{k(i)} + E_{p(f)} - E_{p(i)}.$
$5\Delta x Cos180 = 0 - \frac{1}{2}(1)(3.5^2).$
$\Delta x = 1.225m.$

The trolley will not reach Y.

Power is a rate at which work is done or energy is expended.

In symbols: $P = \frac{W}{\Delta t}$, where

P is power, the unit of power is the joule per second which is known as the watt (W).

$1\ W = 1\ J{\cdot}s^{-1}$

W is the work done, measured in joules (J)

t is time taken to do work, measured in seconds(s)

WORKED EXAMPLE 1

During a canoe race each of two different teams, A and B, exerts a net force of 80 N to pull their canoes across a distance of 70 m. Team A takes 100 s and Team B takes 95 s.

1. Calculate the net work done by both teams.
2. Determine the power of each team.

Solutions

1. $W_{net} = F_{net}\Delta x\cos\theta = (80)(70)\cos 0° = 5600J$
2. $P = \frac{W}{\Delta t} = \frac{5600}{95} = 58{,}95W$

WORKED EXAMPLE 2

A power lifter is able to lift a large weight through a vertical height of 1,5m in 3s. The weight lifter applies an average upwards force of 2700N.

1. Calculate the work done by an average upwards force.
2. Calculate the power output of the weightlifter.

Solutions

1. $W_{Fa} = F_a\Delta x\cos\theta = (2700)(1{,}5)\cos 0° = 4050J$
2. $P = \frac{W}{\Delta t} = \frac{4050}{3} = 1350W$

AVERAGE POWER

- Suppose a car moves along an even horizontal road at a constant velocity. The driving force of the engine is equal in size and opposite in direction to the frictional force and the car does not experience any acceleration.
- Distance that the car moves in time, t: $\Delta x = v\Delta t$
- Work done by the driving force: $W = F\Delta x\cos 0° = Fv\Delta t$
- $P = \frac{W}{\Delta t} = \frac{Fv\Delta t}{\Delta t} = Fv$ $P = Fv$

Use P = Fv to calculate the average power when a force F (the component of the force in the direction of the motion) acts on an object moving at an average speed v. $P_{ave} = Fv_{ave}$

WORKED EXAMPLE 1(horizontal surface)

A woman, shopping in a hurry, applies a force of 60N and moves her trolley at a constant speed of $3m.s^{-1}$. Calculate the average power of a woman.

Solution

$P_{ave} = Fv_{ave} = (60)(3) = 180$ W

WORKED EXAMPLES (inclined plane)

A cyclist rides up the rough inclined plane at a constant speed of 3m.s^{-1}, as shown in figure 4.96. The combined mass of the cyclist and bicycle is 90kg. The cycle experiences a frictional force of 250N.

- Firstly identify all the forces acting parallel to the plan.
  There are two forces acting on down the slope(frictional force and the parallel weight component to the slope)
  $F_{g//} = mg\sin\theta° = (90)(9,8)\sin 20° = 301.7$N
  $F_{g//} + f = 301,7 + 250 = 551,7$ N

In order for the cyclist to maintain the constant speed up the slope, he must exert an equal forward force of 551,7N up the slope.

$P_{ave} = Fv_{ave} = (551,7)(3) = 1655,1$W

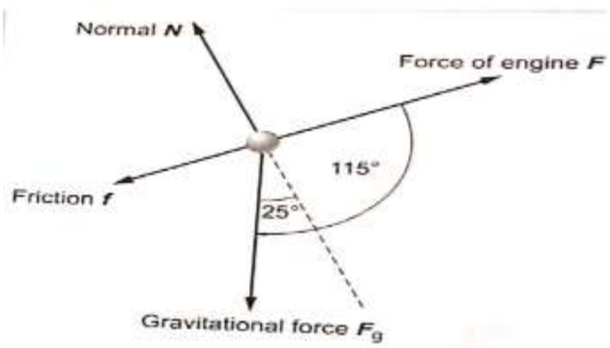
WORKED EXAMPLE 2

A vehicle of mass 2000kg travels up a plane inclined at 25° to the horizontal, at a constant speed of 8m.s^{-1}. The vehicle experiences a frictional force of 1500N.

1. Draw a labelled free body diagram showing all the forces acting on a vehicle on an inclined plane.
2. Calculate the force exerted by the vehicles engine.
3. Calculate the average power developed by the vehicles engine.

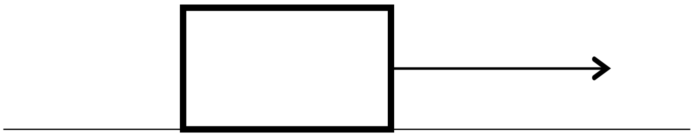
Solution

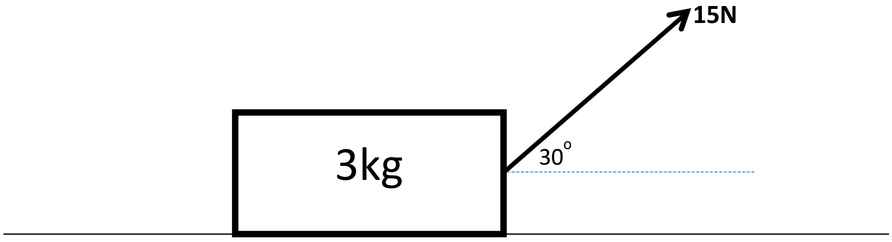
1.



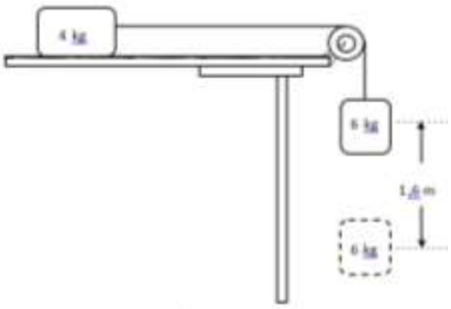
2. $F = F_{g//} + f = mg\sin\theta° + f = (2000)(9,8)\sin 25° + 1500 = 9783,3$N
3. $P_{ave} = Fv_{ave} = (9783,3)(8) = 78267$ W

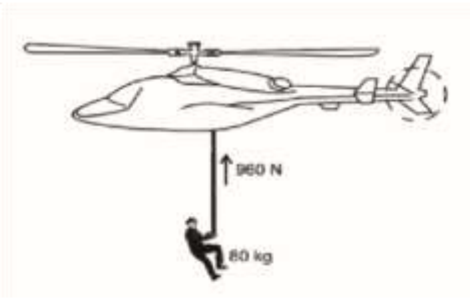
ACTIVITIES

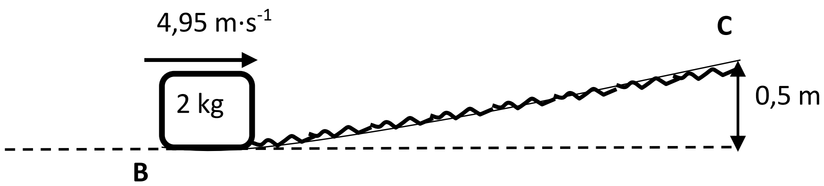
Question 1 A 10kg box is pulled, to the right on a horizontal surface, by a force of 50N for 10m. The box experiences a constant frictional force of 5N during its motion.  1.1 Draw a free body diagram, show all the forces acting on the object	
1.2 Name two physical quantities needed for the work to be done.	
1.3 Calculate work done by the 1.3.1 Applied force 1.3.2 Frictional force 1.3.3 Net work done by the two forces on an object **QUESTION 2**	

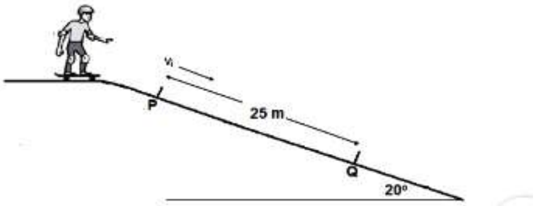
A 3kg block is pulled 8m to the right, by a 15N force, applied at an angle of 30° to the horizontal. The surface has a coefficient of kinetic friction of 0.2.  2.1.1 Drawing a free-body diagram of all the forces acting on the block 2.1.2 Calculate the work done by each force 2.1.3 Calculate the net work done by all the forces	
2.1.1	
2.1.2	
2.1.3	

LEARNER'S WORKSHEET

	ACTIVITY 1	
	In the diagram below, a 4 kg block lying on a rough horizontal surface is connected to a 6kg block by a light inextensible string passing over a light frictionless pulley. Initially the blocks are HELD AT REST. When the blocks are released, the 6 kg block falls through a vertical distance of 1,6 m. 	
1.	State the work-energy theorem in words.	(2)
2.	Draw a labelled free-body diagram for the 6 kg block.	(2)
3.	Calculate the work done by the gravitational force on the 6 kg block. The coefficient of kinetic friction between the 4 kg block and the horizontal surface is 0,4. Ignore the effects of air resistance.	(3)
	The coefficient of kinetic friction between the 4 kg block and the horizontal surface is 0,4. Ignore the effects of air resistance.	
4.	Use **WORK-ENERGY THEOREM** to calculate the speed of the 6 kg block when it falls through 1,6 m while still attached to the 4 kg block.	(5)

	ACTIVITY 2	
	A rescue helicopter is stationary (hovers) above a soldier. The soldier of mass 80 kg is lifted vertically through a height of 20 m by a cable at a CONSTANT SPEED of 4 $m \cdot s^{-1}$. The tension in the cable is 960 N. Assume that there is no sideways motion during the lift. Air friction is not to be ignored.  	
1.	State the work-energy theorem in words.	(2)
2.	Draw a labelled free body diagram showing ALL the forces acting on the soldier while being lifted upwards.	(3)
3.	Write down the name of a non-constant force that acts on the soldier during the upward lift.	(1)
4.	Use the WORK-ENERGY THEOREM to calculate the work done on	(5)

	the soldier by friction after moving through the height of 20 m.	
5.	Identify TWO forces which do negative work.	(2)
	ACTIVITY 3	
	The block moves from point **B** at a velocity of 4,95 m·s^{-1} up a rough inclined plane to point **C**. The speed of the block at point **C** is 2 m·s^{-1}. Point **C** is 0,5 m above the horizontal, as shown in the diagram below. During its motion from **B** to **C** a uniform frictional force acts on the block. The total work done by force F that moves the vehicle from point A to point B is 4,80 x 10^{6} J. 	
1.	State the work-energy theorem in words.	(2)
2.	Draw a labelled free- body diagram showing ALL the forces acting on an object.	(3)
3.	Use work-energy theorem to calculate the work done by the frictional force when the 2 kg block moves from point **B** to point **C**.	(5)

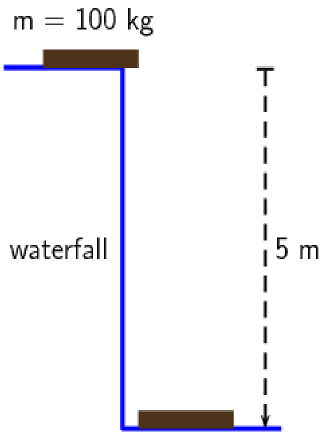
	Activity 4	
	The diagram below shows a boy skate boarding on a ramp which is inclined 20° to the horizontal. A constant frictional force of 50N acts on the skate board as it moves from point P to Q. consider the boy and the skateboard as a single unit of mass 60kg. ignore the effect of air friction  	
1.	Draw a labelled free- body diagram, showing ALL the forces acting on the boy-skateboard unit while moving down the ramp from P to Q.	(3)
	Point P and Q on the ramp are 25m apart. The skate board passes point P at a speed of v_i and passes point Q at a speed of 15 $m \cdot s^{-1}$.	
2.	State work-energy theorem in words.	(2)
3.	Use work-energy theorem to calculate the speed v_i of the skateboarder at point P.	(5)

WORK SHEET:

ACTIVITY 1

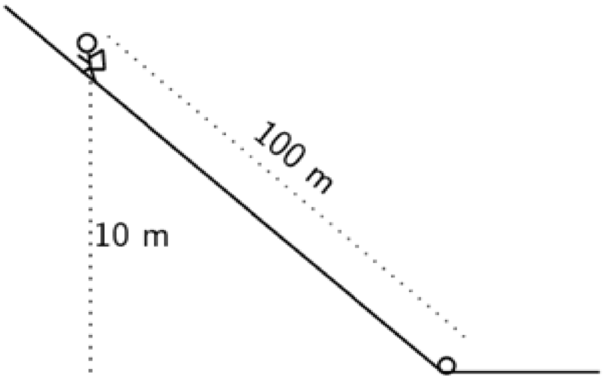
Question 1

During a flood a tree trunk of mass 100 kg falls down a waterfall. The waterfall is 5 m high.



If air resistance is ignored, calculate:

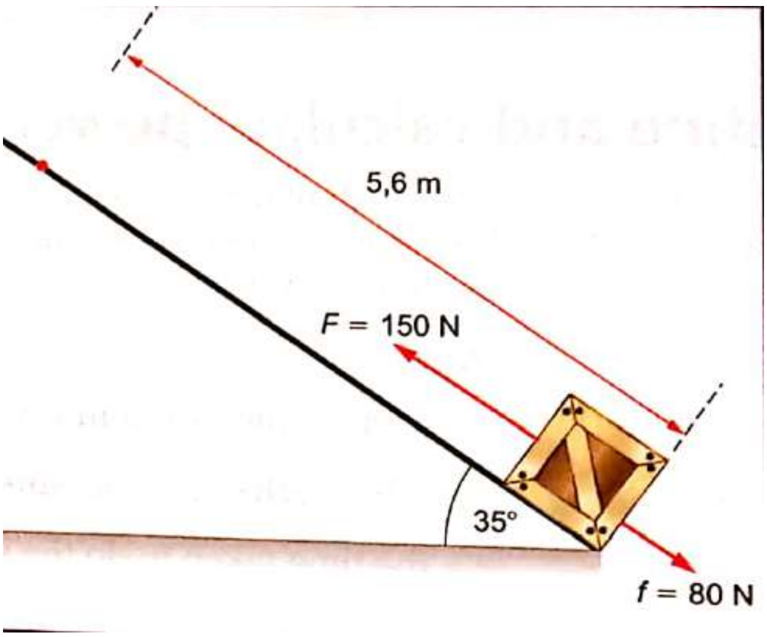
1.1	the potential energy of the tree trunk at the top of the waterfall.	(3)
1.2	the kinetic energy of the tree trunk at the bottom of the waterfall.	(4)
1.3	the magnitude of the velocity of the tree trunk at the bottom of the waterfall.	(4)
	Question 2 A mountain climber who is climbing a mountain in the Drakensberg during winter, by mistake drops her water bottle which then slides 100 m down the side of a steep icy slope to a point which is 10 m lower than the climber's position. The mass of the climber is 60 kg and her water bottle has a mass of 500 g	

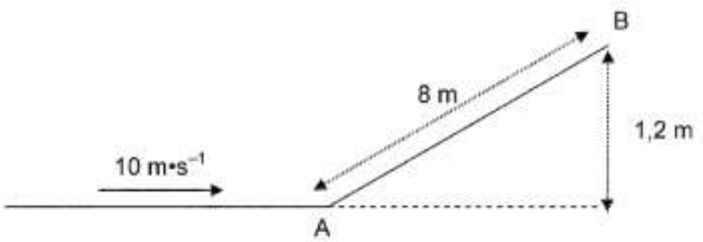
		
2.1	If the bottle starts from rest, how fast is it travelling by the time it reaches the bottom of the slope? (Neglect friction.)	(4)
2.2	What is the total change in the climber's potential energy as she climbs down the mountain to fetch her fallen water bottle? i.e. what is the difference between her potential energy at the top of the slope and the bottom of the slope?	(5)

ACTIVITY 2

	Question 1	
1.1	Sate the law of conservation of energy.	(2)
1.2	State the law of conservation of mechanical energy	(2)
1.3	Define a conservative force and give an example of such a force.	(3)
1.4	A child of mass 38kg slides from rest down a slide at the playground. The height of the slide is 2m. the speed of the child at the bottom of the slide is 3m/s	
a)	Is mechanical energy of the child conserved? Explain your answer.	(2)
b)	Calculate the work done by gravity on the child.	(4)

ACTIVITY 3

	Question 1 In the diagram below, a 10kg crate is pushed up an inclined ramp with a force of 150N being applied parallel to the ramp. The ramp is inclined at 350 to the horizontal. The crate experiences a constant frictional of 80N. 	
(a)	Draw a labelled free-body diagram showing all the forces acting on the crate as it moves up the ramp.	(4)
(b)	From your free-body diagram above, identify conservative and non-conservative forces.	(3)

	Question 2 Ronald, a cyclist, is free-wheeling (moving without peddling) along a horizontal surface at a constant speed of $\mathbf{10 m \cdot s^{-1}}$. He reaches the bottom of the ramp (position A). The ramp has a height of **1.2m** and a length of 8m. While free-wheeling up the ramp, he experiences a frictional force of **8N**. The total mass of the cyclist and cycle is **55kg** 	
2.1	Is the cyclist's mechanical energy conserved as he moves from point A to point B? Give a reason for your answer.	(2)
2.2.1	What is a conservative force?	(2)
2.2.2	Name the conservative force acting on the cyclist as he moves.	(1)
2.3	Calculate the kinetic energy of the cyclist:	
2.3.1	at position A	(3)
2.3.2	at the top of the ramp, using $W_{nc}=\Delta E_k + \Delta E_p$	(6)
2.3.3	Verify your answer 1.3.2 above using the WORK-ENERGY THEOREM.	(6)

ACTIVITY

	Question 1 Define power:	(2)
	Question 2 What are the two possible units for measuring power.	(2)
	Question 3 A girl pushes a 30kg box with a horizontal force of 120N along a horizontal floor a distance of 3m in 5s. the force of friction between the box and the floor in 20N	
3.1	Calculate the power of the girl	(4)
3.2	Calculate the rate at which energy id dissipated as heat.	(4)
	Question 4 A car maintains a constant speed of $110Km \cdot h^{-1}$ on a straight, level road. The total resistive force acting on the car is 750N. Calculate:	
4.1	The work done against friction over a distance of of 10Km.	(3)
4.2	The power output of the car.	(4)

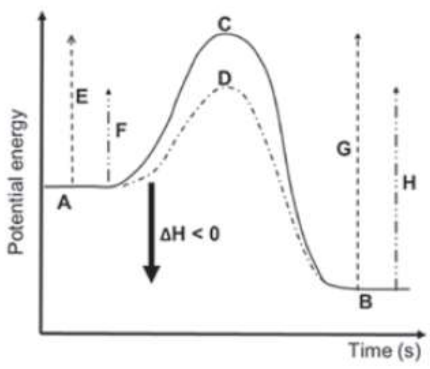
Reaction mechanisms, Collision Theory and the Rates of Reaction

Reaction mechanisms

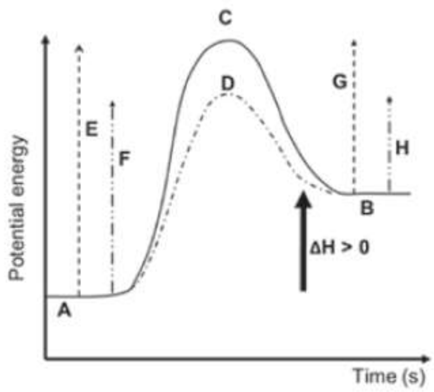
Key Concepts In this session we will focus on summarising what you need to know about:

- Activation energy and activation complex
- Energy profile of a reaction
- Enthalpy (ΔH)
- Endothermic and exothermic reactions
- Energy changes during a reaction

Graphic representation:



Graphic representation:



Key to the symbols on the graphs:

A: reactants (for the forward reaction) / products (for the reverse reaction)
B: products (for the forward reaction) / reactants (for the reverse reaction)
C: activated complex (without a catalyst)
D: activated complex (with a catalyst)
E: activation energy for the forward reaction (without a catalyst)
F: activation energy of the forward reaction (with a catalyst)
G: activation energy of the reverse reaction (without a catalyst)
H: activation energy of the reverse reaction (with a catalyst)

Most reactions do not begin until an amount of energy (activation energy) has been added to the reaction mixture.

The activation energy is often called the 'energy hill' which must be 'overcome' by the addition of this amount of energy before a reaction can take place.

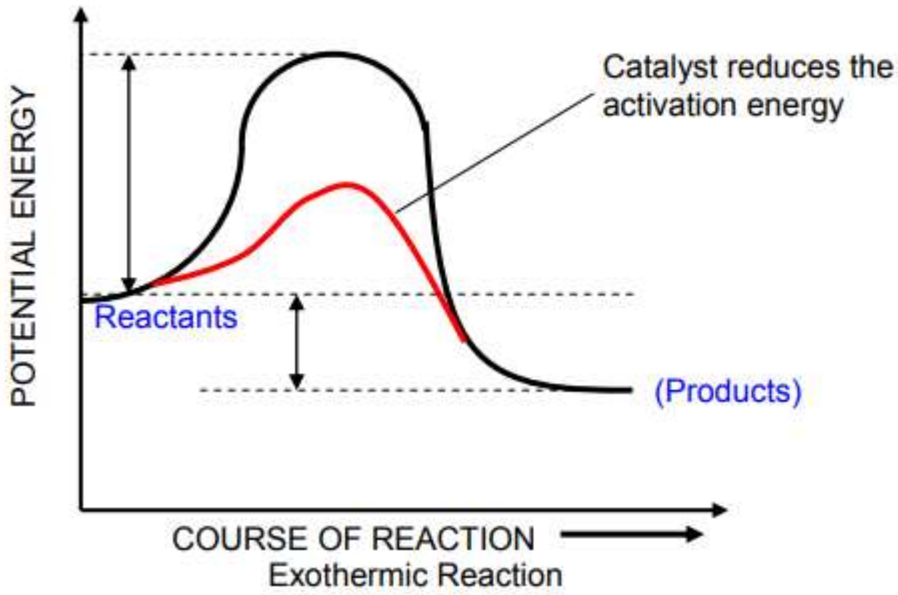
When activation energy is added to the reactants, a so-called activated complex is formed.

Activated complex is a temporary, unstable, high-energy composition of atoms, which represents a transition state between reactants and the products.

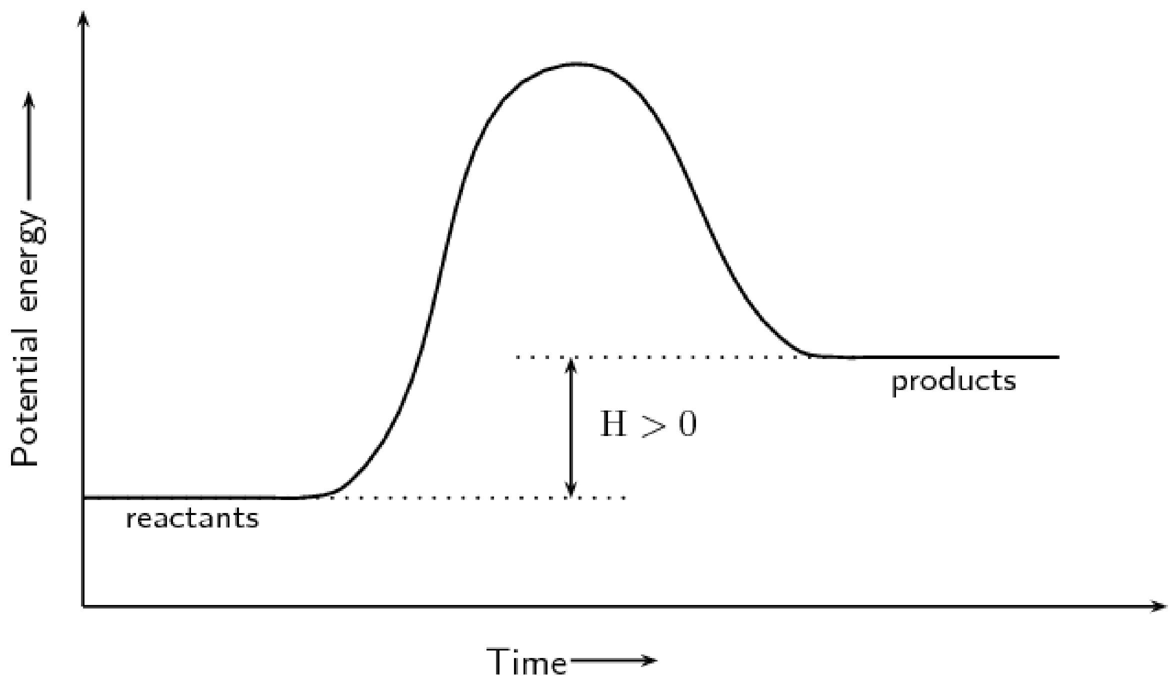
When the activated complex is formed during a reaction, this complex can lead either to the formation of new bonds, i.e. molecules of the products, or to re-formation of the old bonds, thereby returning to being reactants.

The peak of the energy hill indicates the energy of the activated complex. When an activated complex is formed during a reaction, this complex can lead either to the formation of new bonds, i.e. molecules of the products, or to the re-formation of the old bonds thereby returning to being the reactants. This is reversibility for the reaction.

ENTHALPY (HEAT OF REACTION) • Enthalpy (ΔH) is the difference between the energy of the products and the energy of the reactants.
ΔH = Energy of products – Energy of reactants



For an endothermic reaction, Energy of products > Energy of reactants, therefore, ΔH is positive. For an exothermic reaction, Energy of products < Energy of reactants, ΔH is negative. A **catalyst mechanism**: the function of a catalyst is to provide an alternate route for the reaction to take place. This route has a lower activation energy and the rate of the reaction increases. A catalyst forms part of the activated complex and when this decomposes, the catalyst is released unchanged.



Collision Theory

Collision theory provides an explanation for how particles interact to cause a reaction and the formation of new products. According to the collision theory, the following criteria must be met in order for a chemical reaction to occur:

- Molecules must collide with sufficient energy, known as the activation energy, so that chemical bonds can break.
- Molecules must collide with the proper orientation.
- A collision that meets these two criteria, and that results in a chemical reaction, is known as a successful collision or an **effective collision**.

Factors affecting Reaction Rates

Reaction rate, in chemistry is the speed at which a chemical reaction proceeds. It is often expressed in terms of either the concentration (amount per unit volume) of a product that is formed in a unit of time or the concentration of a reactant that is consumed in a unit of time. Alternatively, it may be defined in terms of the amounts of the reactants consumed or products formed in a unit of time.

Nature of Reactants

Certain substances are more reactive than others based on their chemical properties. Example: Lithium is more reactive than Gold. The more bonds that need to be broken the slower the reaction rate will be.

Concentration

Increasing the concentration of the reactants will result in more effective collisions because there are more particles. More effective collisions = a faster reaction rate (shorter time)

Surface area

Increasing the surface area of a reactant increases the number of sites where a collision can take place. Greater surface area = more effective collisions = faster reaction rate (shorter time)

Temperature

Increasing temperature causes an increase in the average kinetic energy of molecules. Higher kinetic energy means the particles move faster. This results in more effective collisions and a faster reaction rate.

Pressure

A change in pressure only affects gases! Increase pressure by decreasing the volume. Less space between particles results in more effective collisions per unit time. More collisions gives a faster reaction rate.

Catalyst

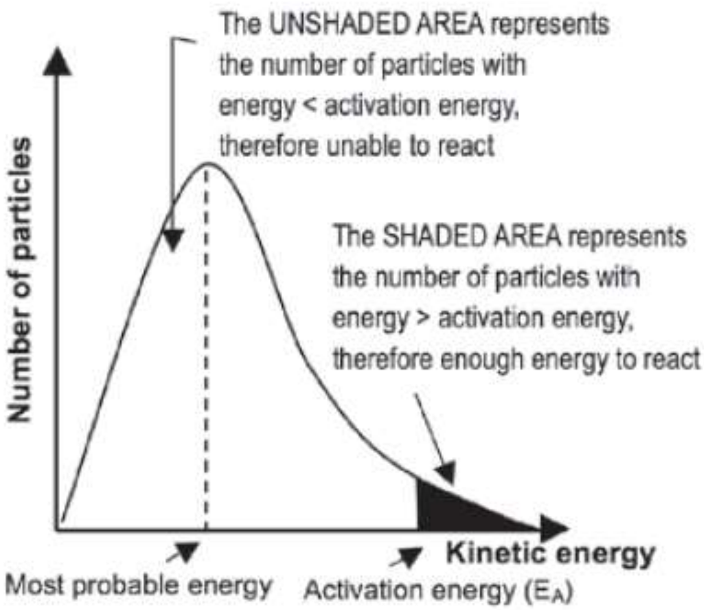
Catalyst: a substance that speeds up a reaction but IS NOT A PART of the reaction. The catalyst lowers the activation energy. (Less energy needed for an effective collision)

• The nature of the reactants.	• The higher the reactivity of a reactant, the higher the reaction rate (E.g. reactive metals like Mg react faster than metals like Cu). • Inorganic reactions are faster than organic reactions.
• The concentration of the reactants for gases (g) and aqueous (aq) solutions. • The pressure of gas (g) reactants.	• The higher the concentration of a reactant, the higher the reaction rate. • The higher the pressure of a gas reactant, the higher its concentration and the higher the reaction rate.
• The surface area (state of division) of solid reactants (marked (s)).	• A powder has a large surface area. • Lumps and strips have a smaller surface area. • The larger the surface area, the higher the reaction rate.
• The temperature of the reaction system.	• The higher the temperature of the reaction system, the higher the reaction rate. However, if the temperature goes too high, a different reaction might take place (e.g. the reactants might burn up instead of reacting as expected).
• The presence of a suitable catalyst.	• A suitable positive catalyst increases the reaction rate.

The Maxwell-Boltzmann distribution Curve

The Maxwell-Boltzmann distribution diagram shown below shows the distribution of the kinetic energy of the particles in a reaction system. The distribution of the kinetic energies of the reactant particles is used to explain the reaction rate in the system.

- The graph shows the number of particles (on the vertical axis) versus their kinetic energy (on the horizontal axis).



- The curve always passes through the origin – this means that no molecules have zero kinetic energy since all molecules are in motion – unless they reach the temperature of 0 K or –273 ˚C.
- The curve does not touch the x-axis at high kinetic energy i.e. there are always some molecules with very high kinetic energy.
- The energy value that corresponds with the **peak** of the curve represents the **most probable energy**.
- The **area** below the curve is equal to the **total number of molecules**

a. The effect of increasing the temperature of the reaction mixture

If the temperature increases:

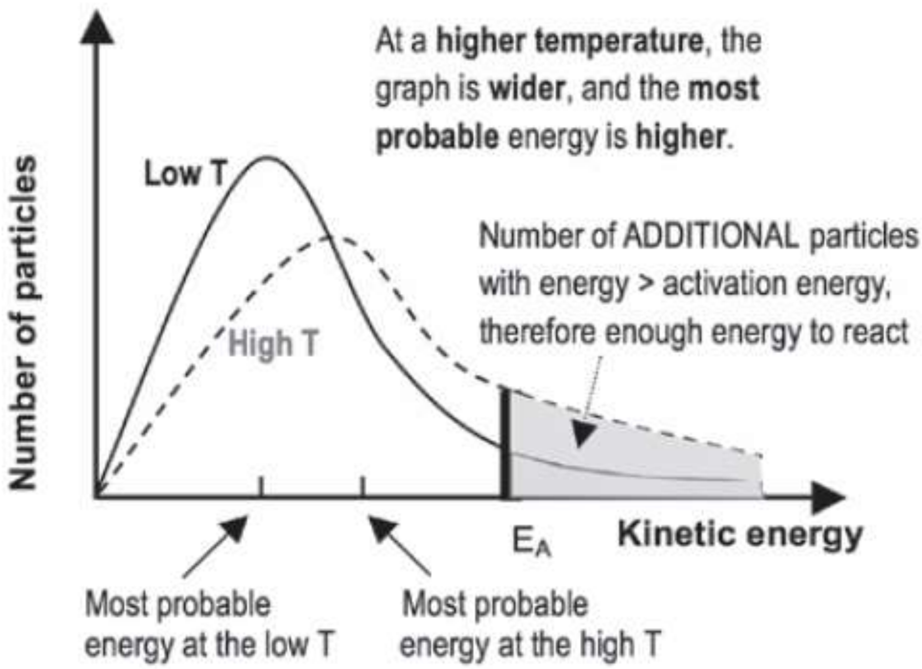
• The particles in the sample have a higher average kinetic energy and the most probable energy is higher than at a low temperature.

• The graph is wider and the peak is lower.

• The total number of particles is the same, so the total area below the graph is the same.

• More particles have kinetic energy greater than the activation energy (the shaded area is bigger)

• More effective collisions take place per second and the collisions are more energetic the reaction rate increases.

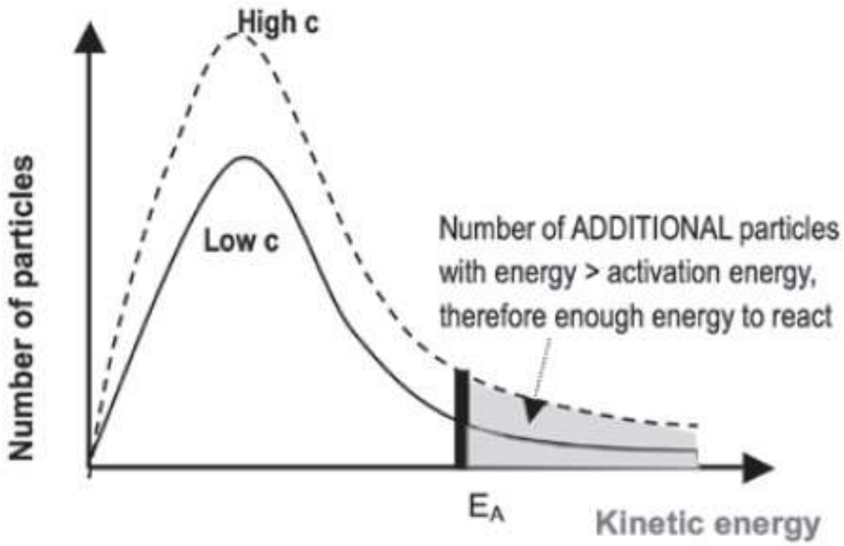


b. The effect of increasing the concentration of the reactants.

If the concentration of the reactants increases:

• The particles in the sample have the same average kinetic energy and the most probable energy is the same the graph has the same curve/shape

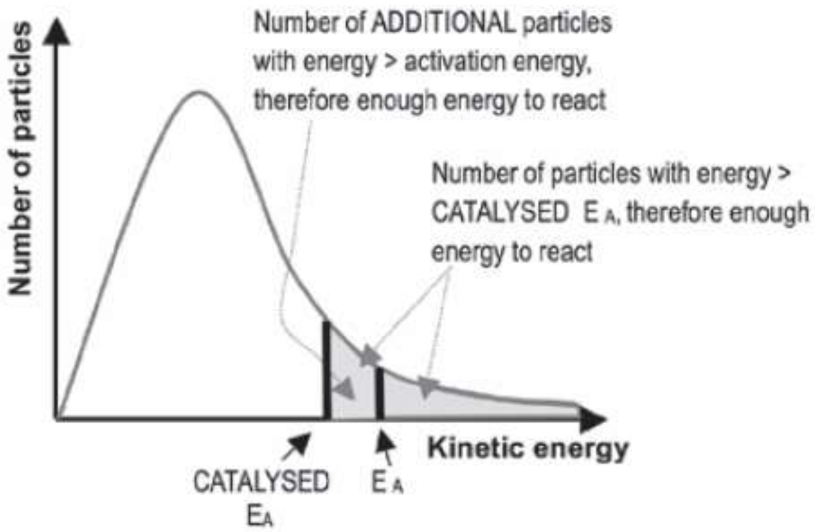
• The graph is higher as there are now more particles per unit volume;
• The total number of particles is greater, so the total area below the graph is bigger.
• More particles have energy greater than the activation energy (the shaded area is bigger)
• More effective collisions take place per second
• The reaction rate increases.



c. The effect of adding a catalyst

Adding a **suitable positive catalyst:**

- **decreases** the **activation energy** needed to change the reactants into an activated complex so
- **more** particles have **enough energy** to form an activated complex
- ∴ the **number** of possible **effective collisions per second increases** and
- ∴ the reaction **rate increases**.



Worked examples

1.1 Define each of the following terms

1.1.1 Activation energy (2)

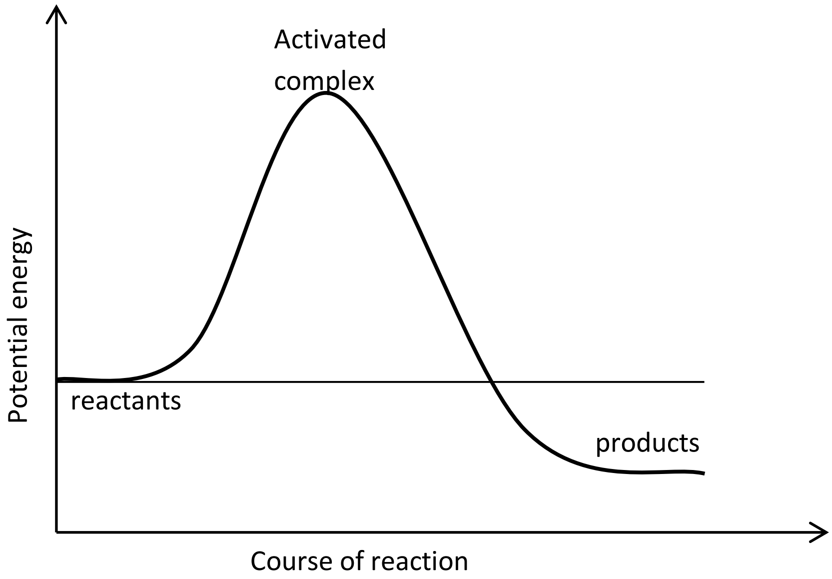
1.1.2 Exothermic reaction (2)

1.1.3 Endothermic reaction (2)

1.1.4 Activated complex (2)

1.2 In a limited supply of oxygen, such as in a car which is not tuned properly, octane burns incompletely to produce, amongst others, carbon monoxide. The following balanced chemical equation represents the reaction during which carbon monoxide forms:

$$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g) \qquad \Delta H < 0$$



1.2.1 Is this graph representing an exothermic or endothermic reaction? Explain your answer (3)

1.2.2 Is the reaction homogeneous or heterogeneous (1)

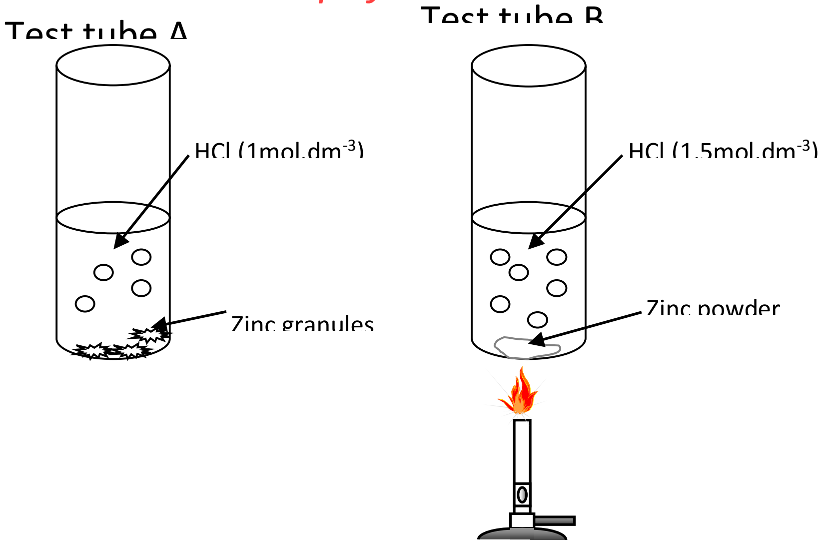
1.2.3 On the same set of axis draw a catalyzed pathway (2)

QUESTION 2

2.1 State TWO requirements for effective collision according to the collision theory (2)

QUESTION 3

3. Consider the following two ways of producing hydrogen (H_2) gas in the laboratory:



3.1 Define rate of reaction (2)

3.2 In test tube B, H_2 (g) is produced at a faster rate than in test tube A.
Give three reasons why H_2(g) is produced at a faster rate in test-tube B. (6)

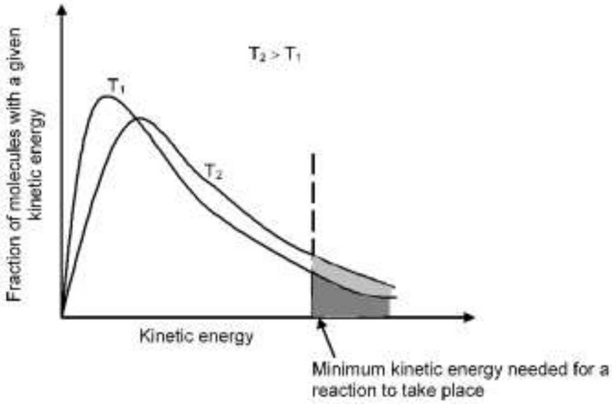
3.3 Mention 2 ways, other than those mentioned in 3.2 above, of increasing the rate of the reaction in test-tube B (2)

4. The rate of the reaction between methanol and hydrochloric acid is investigated. The concentration of HCl(aq) was measured at different time intervals. The following results were obtained:

TIME (minutes)	HCl CONCENTRATION ($mol \cdot dm^{-3}$)
0	1,90
15	1,45
55	1,10
100	0,85
215	0,60

Calculate the average rate, in $(mol \cdot dm^{-3}) \cdot min^{-1}$ during the first 15 minutes. (3)

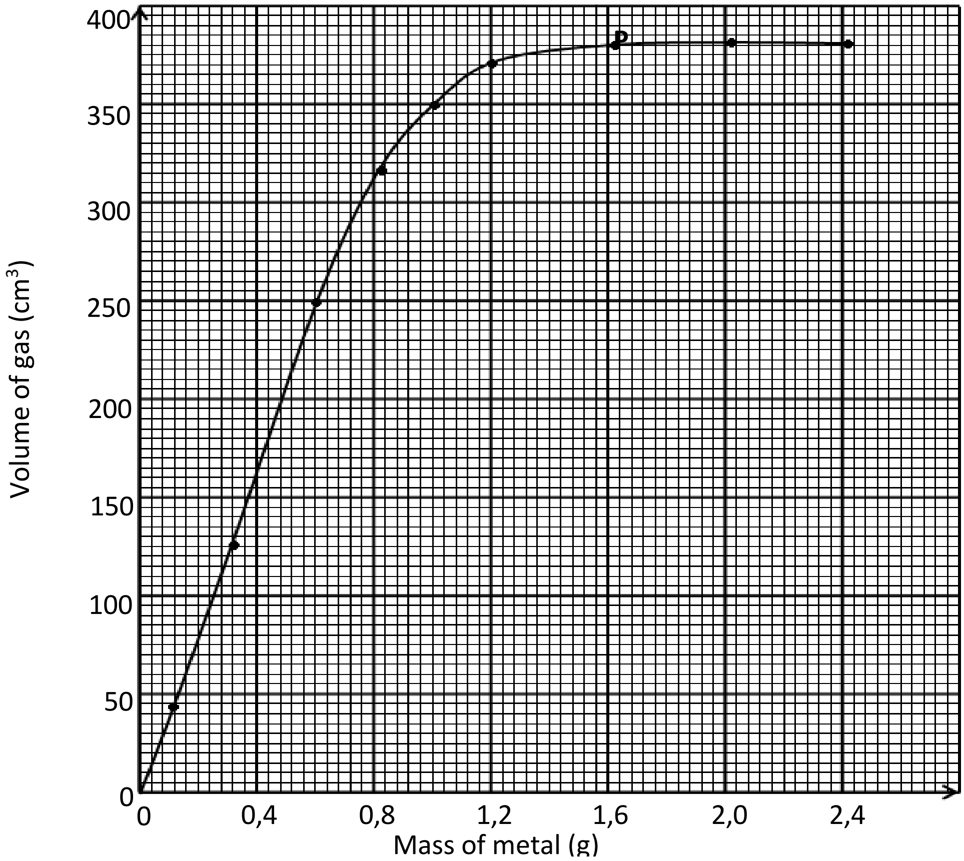
5. In general, a teaspoonful of sugar dissolves much quicker in hot water than in the same amount of cold water. Use the graph below and your knowledge of the collision theory to explain this observation.



(5)

6. A learner investigates the relationship between the mass of a metal and the volume of the gas produced when the metal reacts with dilute hydrochloric acid. During the investigation the learner adds the metal in amounts of 0,4 g to a certain volume of acid in a container. After the complete reaction between the metal and the acid, the learner measures the volume of gas that forms after each addition of the metal. (2)

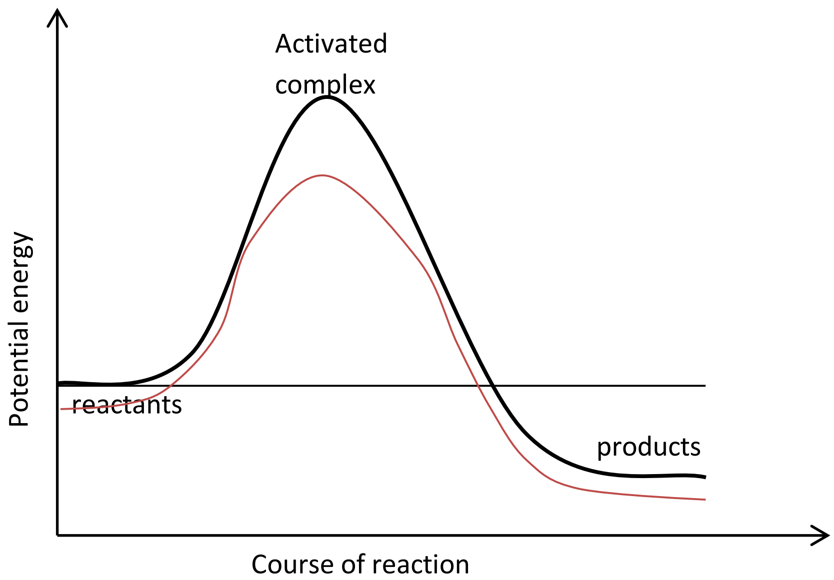
6.1 State the hypothesis of this investigation (2)



6.2 Name TWO variables that must be controlled during this investigation (2)

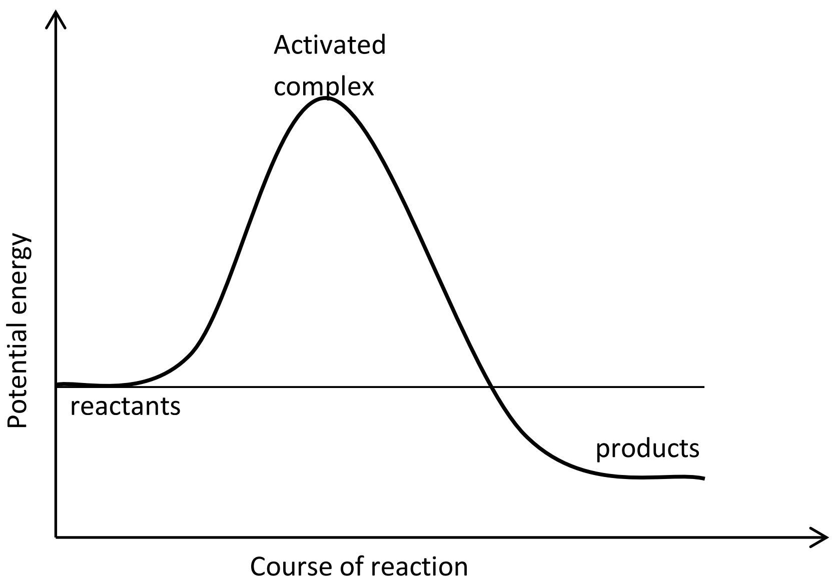
6.3 What conclusion can be drawn from the section PQ on this investigation (2)

6.4 Use the graph to predict the volume of the gas that will be produced when 0,4g of the metal results with the acid (2)

SOLUTIONS			
QUESTION 1			
1.1			
	1.1.1	Minimum energy needed for the chemical reaction to start	(2)
	1.1.2	Reaction that releases energy during chemical reaction	(2)
	1.1.3	Reaction that absorbs energy during the chemical reaction	(2)
	1.1.4	Unstable transition state from reactants to products	(2)
1.2			
	1.2.1	Exothermic reaction, ΔH < 0 or energy of products is less tan energy or reactants	(3)
	1.2.2	Heterogeneous	(1)
	1.2.3		(2)
QUESTION 2			
2.1		Sufficient kinetic energy of particles Correct orientation of particles	(2)

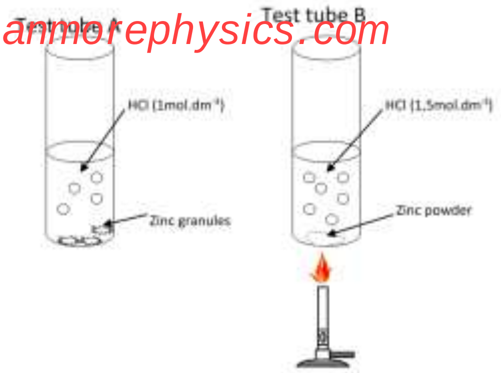
	QUESTION 3		
3.			
	3.1	Change in concentration of reactants or products	(2)
	3.2	HCl has a higher concentration Reaction mixture is heated thus temperature is higher Zinc powder has been used resulting to a larger surface area	(6)
	3.3	Addition of positive catalyst Nature of a reactant	(2)
4.		Average rate = $\frac{\Delta c}{\Delta t}$ $= \frac{1{,}45 - 1{,}90}{15 - 0}$ $= -0{,}03\ mol \cdot dm^{-3}$ $= 0{,}03\ mol \cdot dm^{-3}$	
5.		The more water gets hotter the higher the temperature, according to collision theory, • The speeds of the particles increase • The average kinetic energy of the particles increases • More particles have sufficient kinetic energy • Which increases the number of effective collisions taking place per unit time • Thus, rate of reaction increases	
6.			
	6.1	The higher the amount of the metal, the higher the volume of the hydrogen gas produced	(2)
	6.2	Concentration of HCl Volume of HCl Temperature	(2)
	6.3	The reaction has reached completion/ reaction has stopped/ reactants has been used up	(2)
	6.4	125 cm^3	(2)

Worksheet: Reaction rate

QUESTION 1			
1.1		Define each of the following terms	
	1.1.1	Activation energy	(2)
	1.1.2	Exothermic reaction	(2)
	1.1.3	Endothermic reaction	(2)
	1.1.4	Activated complex	(2)
1.2		In a limited supply of oxygen, such as in a car which is not tuned properly, octane burns incompletely to produce, amongst others, carbon monoxide. The following balanced chemical equation represents the reaction during which carbon monoxide forms:	
		$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$ ΔH < 0 	

	1.2.1	Is this graph representing an exothermic or endothermic reaction? Explain your answer	(3)
	1.2.2	Is the reaction homogeneous or heterogeneous	(1)
	1.2.3	On the same set of axis draw a catalyzed pathway	(2)
QUESTION 2			
2.1		State TWO requirements for effective collision according to the collision theory	(2)
QUESTION 3			

3. Consider the following two ways of producing hydrogen (H_2) gas in the laboratory:



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3.3 Mention 2 ways, other than those mentioned in 3.2 above, of increasing the rate of the reaction in test-tube B (2)

4. The rate of the reaction between methanol and hydrochloric acid is investigated. The concentration of HCl(aq) was measured at different time intervals. The following results were obtained:

TIME (minutes)	HCl CONCENTRATION ($\boldsymbol{mol \cdot dm^{-3}}$)
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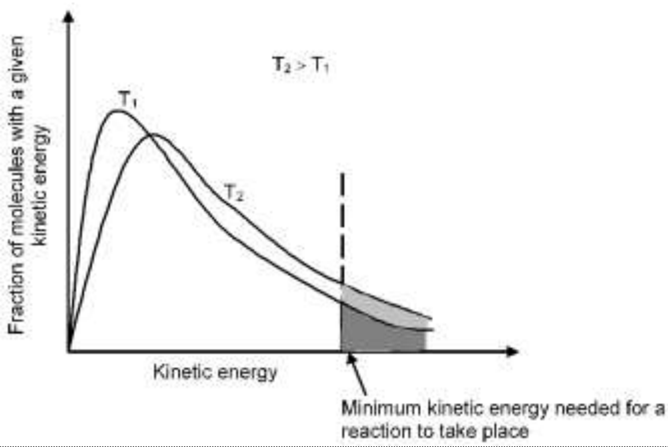
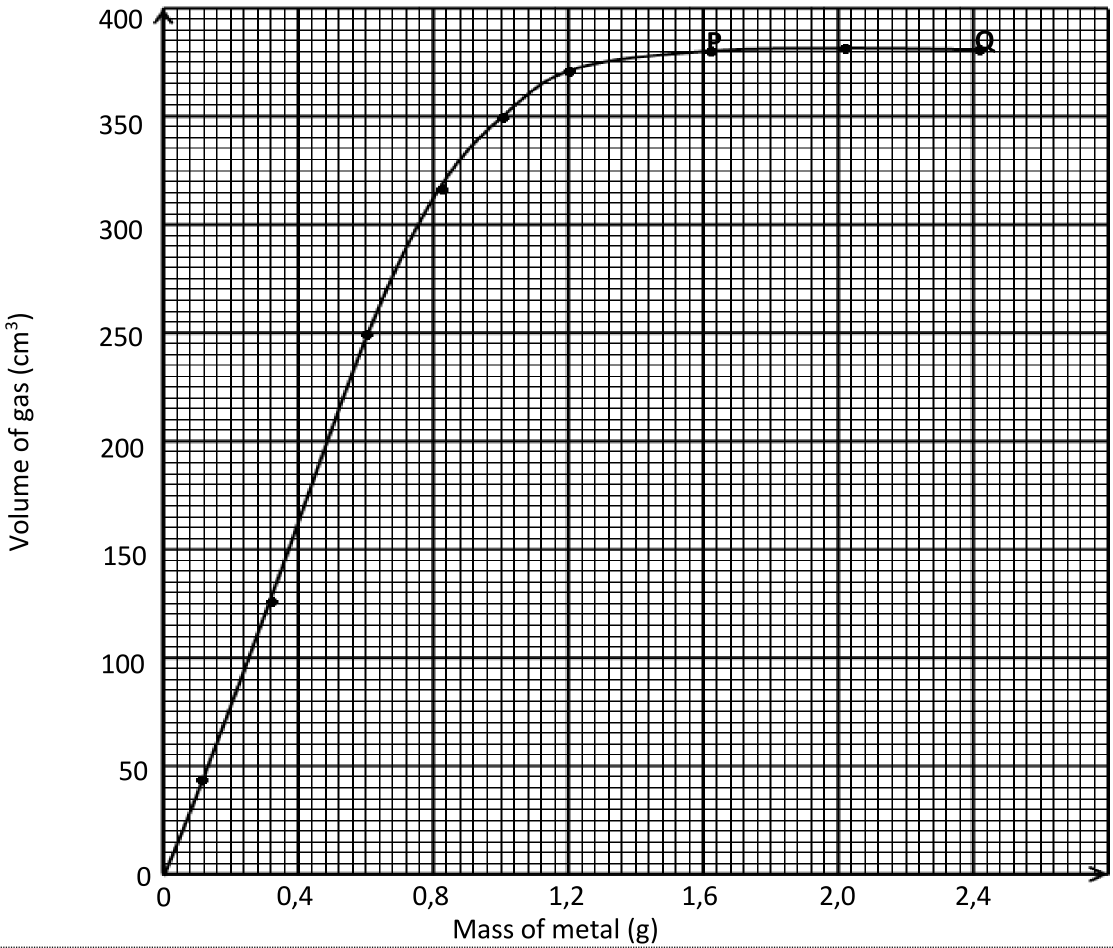


6. A learner investigates the relationship between the mass of a metal and the volume of the gas produced when the metal reacts with dilute hydrochloric acid. During the investigation the learner adds the metal in amounts of 0,4 g to a certain volume of acid in a container. After the complete reaction between the metal and the acid, the learner measures the volume of gas that forms after each addition of the metal. (2)

6.1 State the hypothesis of this investigation (2)



6.2 Name TWO variables that must be controlled during this investigation (2)

6.3 What conclusion can be drawn from the section PQ on this investigation (2)

6.4 Use the graph to predict the volume of the gas that will be produced when 0,4g of the metal results with the acid (2)

CHEMICAL EQUILIBRIUM SUMMARY NOTES

Definitions

Open system – reactants or products can escape from reaction vessel
(An open system continuously interacts with its environment)
Closed system – reactants or products can escape from reaction vessel
(A closed system is isolated from its surroundings)
Macroscopic changes – measurable or visible changes, eg. changes in colour, temperature, pressure, volume, concentration
Yield – the amount of product formed during a chemical reaction
Endothermic reaction – a reaction which absorbs more energy than is released
Exothermic reaction – a reaction which releases more energy than is absorbed
Reversible reaction – reaction that does not go to completion and occurs in both the the forward and reverse directions (products can be converted back to reactants)
Dynamic chemical equilibrium – the rate of the forward reaction equals the rate of reverse reaction and they occur simultaneously
Homogeneous equilibrium – all the substances in the system are in the same phase
Heterogeneous equilibrium – substances of different phases occur in the system
Equilibrium constant – ratio of the concentration of products to the concentration of reactants

FACTORS AFFECTING EQUILIBRIUM

- concentration
- temperature
- pressure (in the case of gases)

If any of the conditions (factors) are changed, the forward or reverse reaction will be favoured (will occur faster) until a new equilibrium is established.

NB: *Adding a catalyst has NO EFFECT on the equilibrium position, a catalyst only increases the rate of both the forward and the reverse reactions equally.
*If a catalyst is added initially, then the equilibrium position is reached much quicker.
*The addition of an inert gas does not alter the equilibrium position.

Examples:
1. Equilibrium mixtures of solutions (**temperature and concentration** play a role)
Equation: $CoC\ell_4^{2-}(aq) + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4C\ell^-$ $\Delta H < 0$

Disturbance	Effect on equilibrium	Colour change
1. Temperature		
○ increase	○ favours endothermic (reverse) reaction	○ turns blue
○ decrease	○ favours exothermic (forward) reaction	○ turns pink
2. Concentration		
○ $[H_2O]$ is increased by adding H_2O	○ favours forward reaction (which uses up water)	○ turns pink
○ $[C\ell]$ is increased by adding $HC\ell$/$NaC\ell$ (with common $C\ell^-$ ion)	○ favours reverse reaction (which will decrease $C\ell^-$)	○ turns blue
○ $[C\ell^-]$ is decreased by adding Ag^+ ($Ag^+ + C\ell^- \rightarrow AgC\ell_{(s)}$)	○ favours forward reaction (which produces more $C\ell^-$)	○ turns pink
○ $[H_2O]$ is decreased by adding a dehydrating agent, eg. H_2SO_4	○ favours reverse reaction (which will decrease $C\ell^-$)	○ turns blue

2. Gaseous equilibrium mixtures (**temperature and pressure** play a role)

Equation: $NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H < 0$

	Disturbance	Effect on equilibrium	Colour change
1. Temperature	○ increase	○ favours endothermic (reverse) reaction	○ colourless to brown
	○ decrease	○ favours exothermic (forward) reaction	○ brown to colourless
2. Pressure	○ increase	○ favours forward reaction (less moles of gas molecules)	○ brown to colourless
	○ decrease	○ favours reverse reaction (more moles of gas molecules)	○ colourless to brown

FACTORS AFFECTING EQUILIBRIUM

CONCENTRATION

If the concentration of a reactant increases, more of that reactant reacts, and so the concentration of the reactants on the other side of the equation increases.
Removing a reactant lowers the concentration of the reactant and so less of that reactant reacts and so t The rates of the forward and reverse reactions will not be equal for a short while.
The concentrations are restored to the original values.
The reaction rates once again become equal and equilibrium is restored.
he concentration of the reactants on the other side of the equation decreases
The value of K_{equ} is unaffected by adding or removing reactants, providing the temperature does not change.

Worked examples:

1. Consider the following reaction that is at equilibrium in a closed container
   $N_2O_4(g) \leftrightarrows 2\,NO_2\,(g)$

CHANGE OF FACTOR	EFFECT ON REACTION RATE	REACTION FAVOURED	CHANGE IN THE AMOUNT OF PRODUCTS	CHANGE IN THE AMOUNT OF REACTANTS	CHANGE IN KC
Increase in concentration of a reactant [NO_2]	Overall reaction rate increases BUT rate of forward	Forward reaction	Amount of product (N_2O_4) increases	Amount of reactants (NO_2) decreases	Remains the same

	reaction is faster				
Increase in concentration of a product [N_2O_4]	Overall reaction rate increases BUT rate of reverse reaction is faster	Reverse reaction	Amount of product (N_2O_4) decreases	Amount of reactants (NO_2) increases	Remains the same
Decrease in concentration of a reactant [NO_2]	Overall reaction rate decreases BUT rate of reverse reaction is faster	Reverse reaction	Amount of product (N_2O_4) decreases	Amount of reactants (NO_2) increases	Remains the same
Decrease in concentration of a product [N_2O_4]	Overall reaction rate decreases BUT rate of forward reaction is faster	Forward reaction	Amount of product (N_2O_4) increases	Amount of reactants (NO_2) decreases	Remains the same

PRESSURE

Changes in pressure only affect the equilibrium if the reactants or products are in the gas phase.
A change in pressure can be brought about by changing the volume of the container.
Adding or removing one of the reacting gases changes the partial pressure of that gas and disturbs the equilibrium
Adding or removing a non-reacting gas has no effect on the equilibrium.

TEMPERATURE

Increasing the temperature of an equilibrium system increases the rate of both the forward and the reverse reactions as more particles have sufficient energy to make effective collisions.
However, in order to counteract the increase in temperature, the endothermic reaction rate increases even more.
After a time the rates adjust and equilibrium is restored.
However, as both rates are higher, the equilibrium has a new value for E_{equ}.
ΔH values given with the equation for a reversible reaction refer to the forward reaction.
Worked example: The following reversible reaction reaches equilibrium in a closed container:

$2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$ $\Delta H<0$

1.1 What is meant by " dynamic equilibrium"
1.2 State Le Chatelier's principle
1.3 How will the equilibrium concentration of the sulphur trioxide be affected by:
1.3.1 an increase in temperature
1.3.2 an increase in pressure
1.3.3 an increase in $[SO_2]$

SUGGESTED SOLUTIONS

1.1 In a closed system dynamic equilibrium the rate of the forward reaction is equal to the rate of the reverse reaction.
1.2 Le Chatelier's principle state that in a closed system when equilibrium is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.
 1.3.1 DECREASE
 1.3.2 INCREASE
 1.3.3 INCREASE

A CATALYST
A catalyst affects the rate of both the forward and the reverse reactions equally and so has no effect on the position of the equilibrium or the value of K_{equ}
These observations and explanations can be summed up in le Chatelier's principle
If a system in chemical equilibrium is subjected to a change of temperature, pressure or concentration, processes occur within the system which tend to counteract the change imposed.

Imposed change	System response	Change in K_{equ}
Increase concentration of reactants	Favour forward reaction to increase concentration of products	none
Decrease concentration of reactants	Favour reverse reaction to decrease concentration of products	None

Increase pressure	Favour the reaction that produces fewer particles	none
Decrease pressure	Favour the reaction that produces more particles	none
Increase temperature	Favour the endothermic reaction	Yes
Decrease temperature	Favour the exothermic reaction	Yes

Worked example 2:

For the reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad H = 180\ kJ$$

state the effect on the reaction equilibrium if you use

1.1. Higher concentration of O_2.

Increase in [O_2], increases the overall reaction rates but forward reaction will be favoured, amount of reactants increase amounts of product decreases

1.2. Lower concentration of NO.

Decrease in [NO], overall reaction rates decrease, forward reaction is favoured, amount of reactants decrease, amount of products decreases

1.3. Presence of a catalyst.

The rate of both the forward reaction and reverse reaction increases equally. Equilibrium is not disturbed, amounts remain constant

Worked example 3:

1. State Le Chatelier's principle.

When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

2. Study the following equation : $2CO\ (g) + O_2\ (g) \rightleftharpoons 2CO_2\ (g)$

Use Le Chatelier's principle to predict what effect the following changes will have on the equilibrium.

2.1 increase in the concentration of O_2

overall rates of reaction increases, forward reaction is favoured, amount of reactants decreases , amount of products decreases until new equilibrium is re- instated

2.2 Besides concentration state TWO ways in which the rate of the forward reaction can be increased.

Increase pressure, increase temperature

CHEMICAL EQUILIBRIUM _quantity and concentration of substances at equilibrium

- Remember these equations from grade 10 and 11

$c = {}^{n}/_{V}$, $n = {}^{m}/_{M}$,$n = {}^{N}/_{N_A}$, $n = {}^{V}/_{V_m}$ these are mostly used to find or convert the amount of substances at equilibrium

- $c = {}^{n}/_{V}$ _used when you have a solution

C=concentration (mol/dm^3) and V = volume of solution (dm^3)

- $n = {}^{m}/_{M}$ _used when given the mass of a substance

m=mass (g) and M=molar mass (g/mol)

- $n = {}^{V}/_{V_m}$_used when given gases and specific temperatures and pressure most cases STP

V= volume of a gas (dm^3) and Vm= molar volume of a gas(dm^3/mol) 22.4 ONLY at STP

- $n = {}^{N}/_{N_A}$_used when amount is given as number of particles/atoms/molecules

N= number of particles/atoms/molecules and NA =Avogadro's number : 6.022×10^{23}

- Equilibrium concentration is the amount of substance per unit volume the instant the reaction reaches equilibrium, the amount of substance at equilibrium can be achieved by :
-

$$nEquilibrium = nInitial + nChange \; / \; nEquilibrium = nInitial - nChange$$

- Note: [ ] mean concentration of
- Summarise the 1st column of the equilibrium table as R.I.C.E

Reactant ⇌ Product

Ratio		
*n***I**nitial (mol)		
n**C**hange (mol)		
n**E**quilibrium (mol)		
Volume (dm^3)		
[equilibrium] mol/dm^3		

- Explain that the concentration of liquids and solids remains constant, for volume of liquids and solids on the table put a cross**.**
- Use the following steps to fill in the table

  Step 1_Set up the **RICE** table as shown above

  Step 2_write each Change moles in terms of an unknown (eg. *x, y, a, b*) in pencil using the stoichiometric ratio of each substance as the the coefficient of the chosen unknown

  Step 3_fill in quantities given on the table in ink if quantities are given as mass, concentration, volume convert to number of moles

  Step 4_ fill in the volume (dm^3) of the reaction vessel on the volume row, put a cross for liquids and solids.

  Step 5_ put + in change in moles of substance formed and – for the substance that decreases or is used up

Step6_ Solve for the unknown and substitute actual values of the Change
To do this find one substance in the reaction with all I.C.E values (including the unknown)
Step 7_ find moles at equilibrium
Step 8_ calculate equilibrium concentration using $c = {}^{n}/_{v}$

Examples

1. A mixture of 5 moles of H_2 and 6 moles of I_2(g) is placed in a sealed container of $2dm^3$ at a temperature of 430ºC.The balanced chemical equation for this reaction is:

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

Equilibrium is reached in a certain period. At equilibrium, there are 4 moles of HI(g) in the container. Calculate the concentrations of H_2(g) and I_2(g) at equilibrium.

SOLUTION:

Table

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

Ratio	1	1	2
*n***I**nitial (mol)	5	6	0
n**C**hange (mol)	(-1a) -2	(-1a) -2	(+2a) +4
n**E**quilibrium (mol)	3	4	4
Volume (dm^3)	2	2	2
[equilibrium] mol/dm^3	1,5	2	2

2. The following reaction takes place in a 250 cm^3 container at 150°C
   $2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$

The reaction initially contains 0.25moles of NO and 0.1 moles Br_2. When equilibrium is reached, it is found that 80% of NO remained at, calculate the concentrations at equilibrium

$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$

Ratio	2	1	2
*n***I**nitial (mol)	0.25	0.1	0
n**C**hange (mol)	(-2y) -0.5	(-1y) -0.25	(+2y) +0.5
n**E**quilibrium (mol)	0.2	0.75	0.5
Volume (dm^3)	0.25	0.25	0.25

[equilibrium] mol/dm^3	0.8	0.3	0.2

NO at equilibrium

$$\frac{80}{100} \times 0.25 = 0.2$$

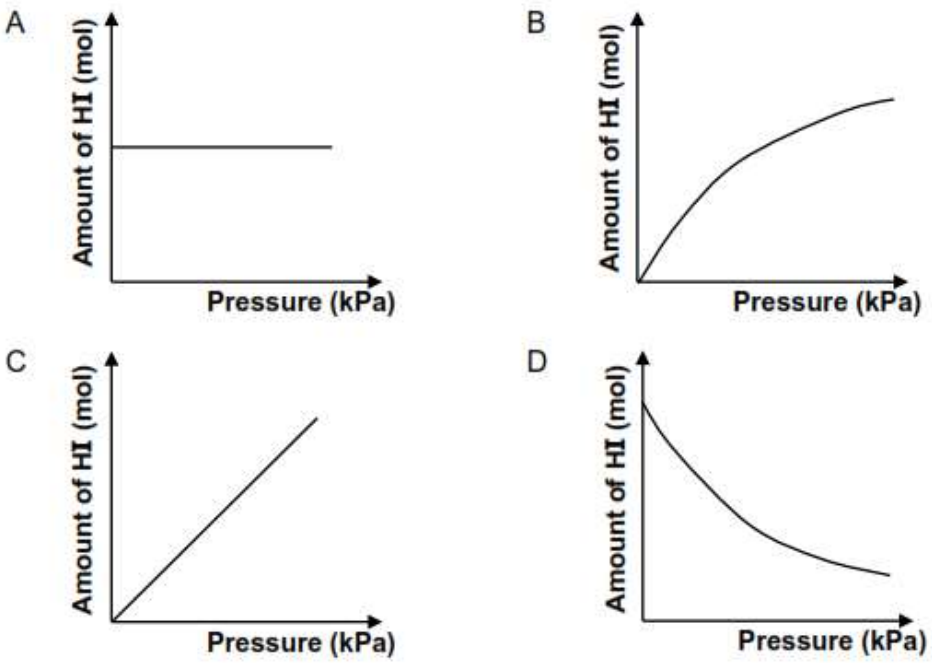
QUESTION 1

1.1

1.1.1 The reaction between hydrogen gas and iodine gas reaches equilibrium in a closed container according to the following balanced equation:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

Which ONE of the graphs below shows the relationship between the amount of HI(g) at equilibrium and the pressure in the container at constant temperature?



(2)

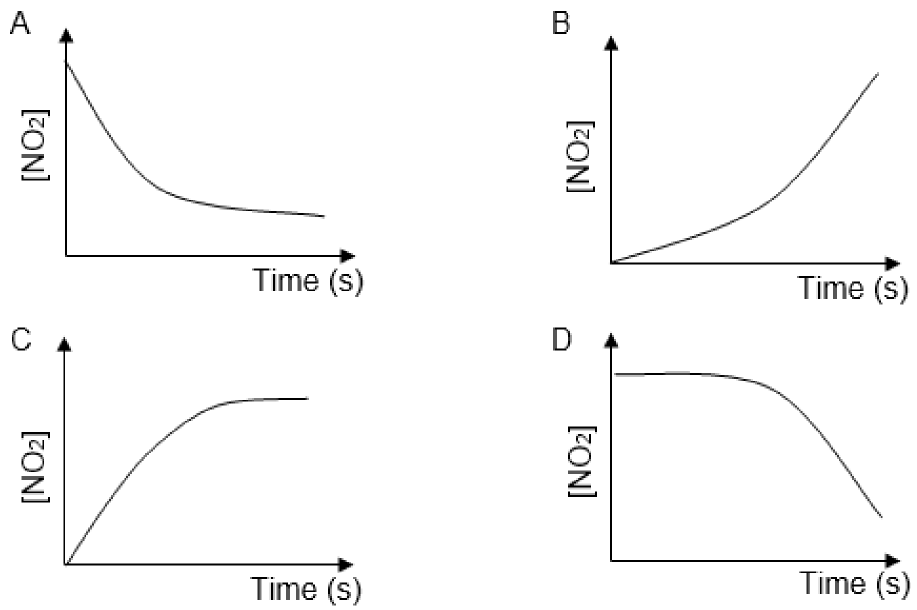
1.1.2 N_2O_4(g) is placed in an evacuated, sealed container. c

The following reaction takes place in the container at constant temperature:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

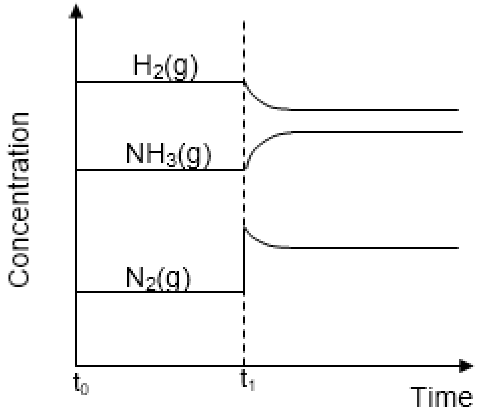
The concentration of the product is measured over time.

Which ONE of the following graphs correctly illustrates the relationship between the nitrogen dioxide (NO_2) concentration and time?



1.1.3 The graph below shows a change made to a chemical equilibrium in a closed container at time t_1. The equation for the reaction is: (2)

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$



Which ONE of the following is the change made at time t_1?

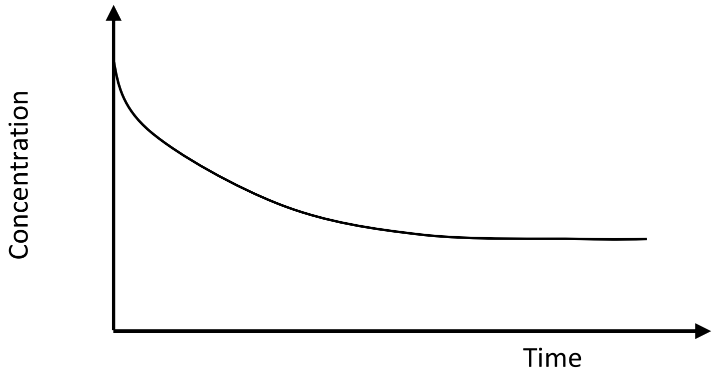
A Addition of a catalyst

B Increase in temperature

C Increase in the concentration of $N_2(g)$

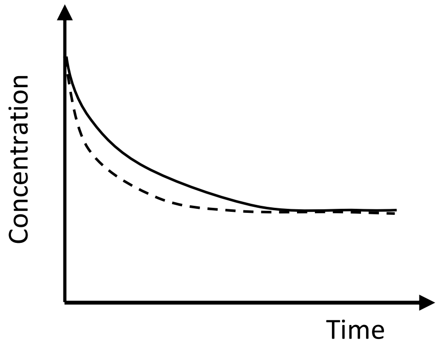
D Increase in pressure by decreasing the volume

1.1.4 The graph below represents the change in concentration of a reactant against time for a chemical reaction

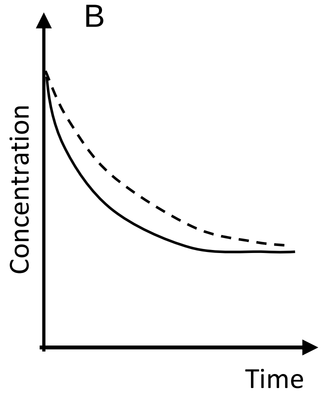


In which ONE of the following graphs does the dotted line show the effect of catalyst on this reactant?

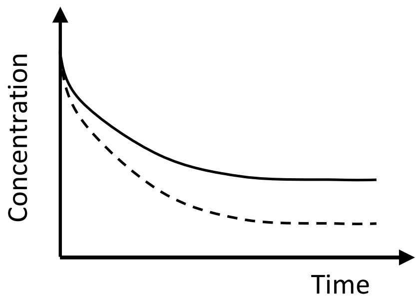
A


Concentration
Time

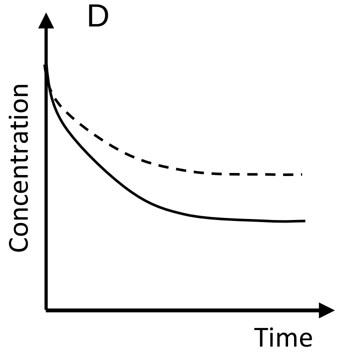
B

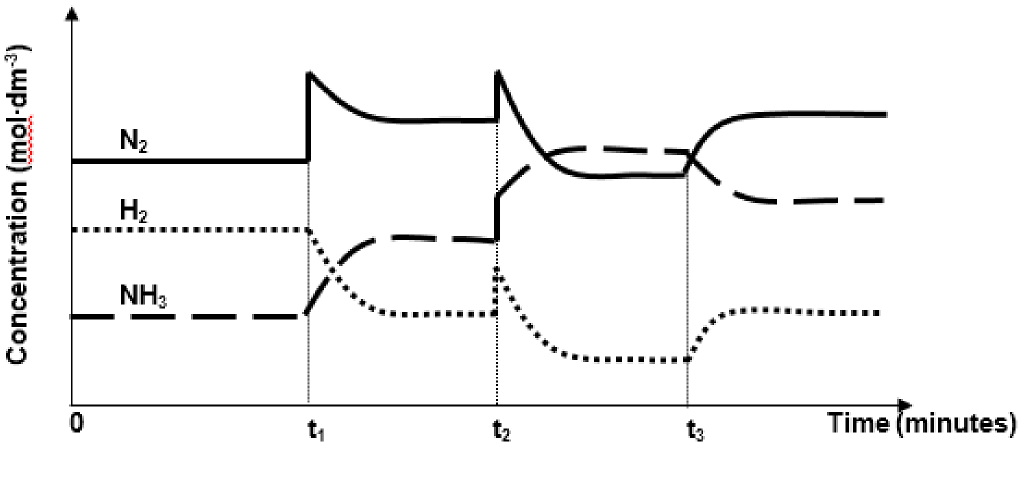

Concentration
Time

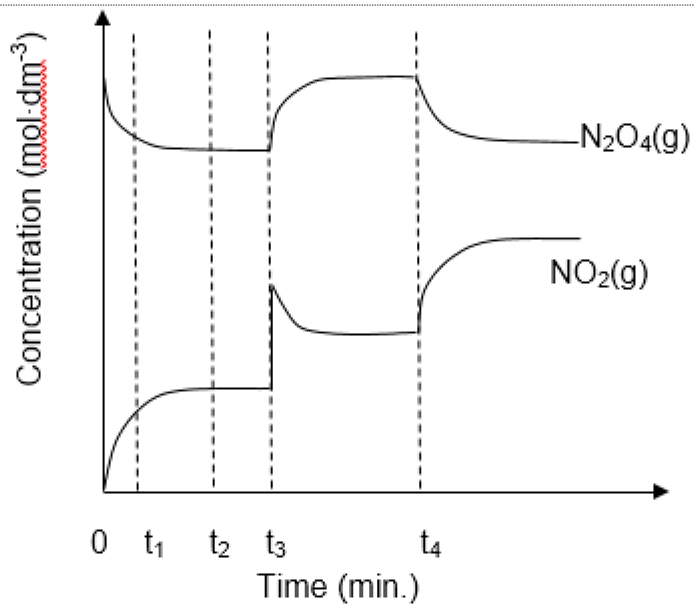
C

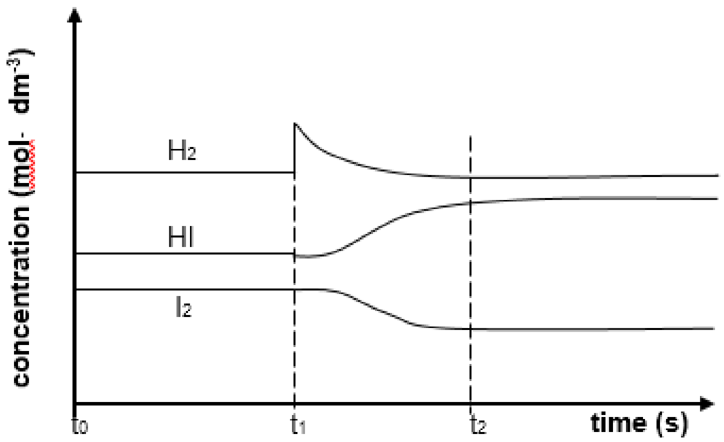

Concentration
Time

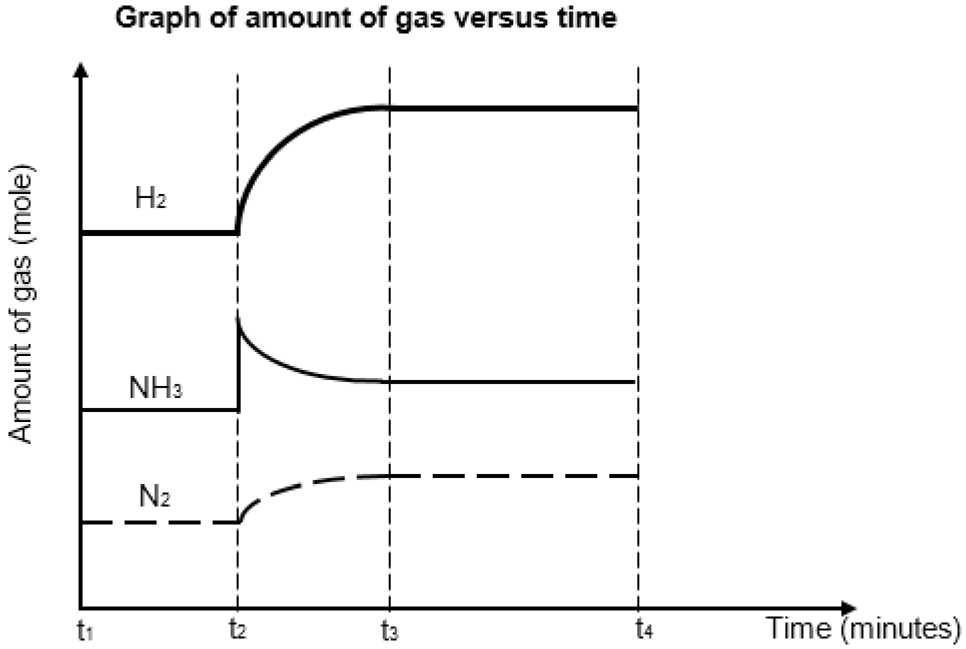
D


Concentration
Time

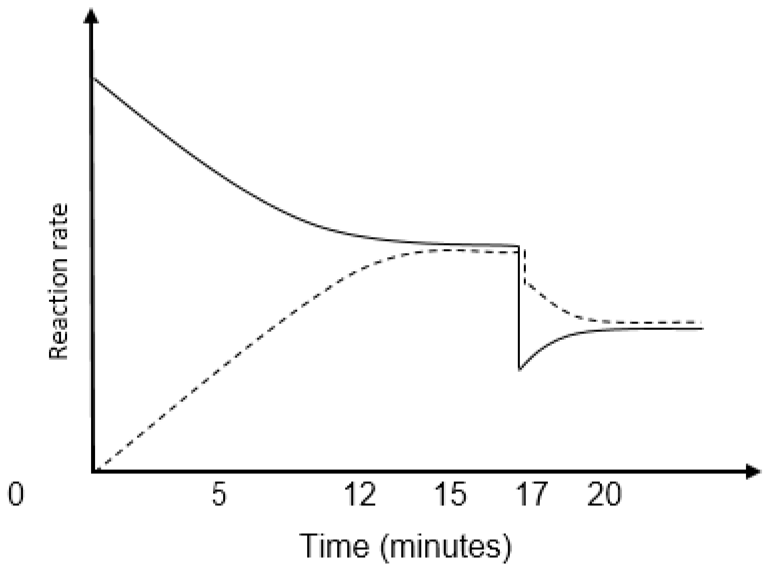
2.1		The substance that lowers the activation energy in a reaction.	(1)
2.2		The measure of the average kinetic energy in a system.	(1)
2.3		Rate of forward reaction equals rate of reverse reaction.	(1)
2.4		A reaction in which products can be converted back to reactants	(1)
2.5		The ratio of concentration of products to the ratio of concentration of reactants at equilibrium.	(1)
3		A fertiliser company produces ammonia on a large scale at a temperature of 450 °C. The balanced equation below represents the reaction that takes place in a sealed container.	
		$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H < 0$	
		To meet an increased demand for fertiliser, the management of the company instructs their engineer to make the necessary adjustments to increase the yield of ammonia. In a trial run on a small scale in the laboratory, the engineer makes adjustments to the TEMPERATURE, PRESSURE and CONCENTRATION of the equilibrium mixture. The graphs below represent the results obtained.	
			
3.1		Identify the changes made to the equilibrium mixture at each of the	

		following times:	
	3.1.1	t_1	(2)
	3.1.2.	t_2	(2)
	3.1.3	t_3	(2)
3.2		At which of the above time(s) did the change made to the reaction mixture lead to a higher yield of ammonia? Write down only t_1 and/or t_2 and/or t_3	(2)
4		A sample of N_2O_4 gas is sealed in a container and heated. The N_2O_4 gas decomposes to NO_2 gas and the reaction reaches equilibrium according to the following balanced equation:	
		$N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H > 0$	
		The graph below shows how the concentrations of the two gases change as a result of changes made to the reaction conditions	
			
4.1		Define the term *chemical equilibrium*.	(2)
4.2		How does the rate of the forward reaction compare to that of the reverse reaction at each of the following times? Only write down HIGHER THAN, LOWER THAN or EQUAL TO.	
	4.2.1	t_1	(1)
	4.2.2	t_2	(1)
4.3		What change was made to the reaction conditions at each of the following times? In both instances, the equilibrium constant for the reaction did not change	

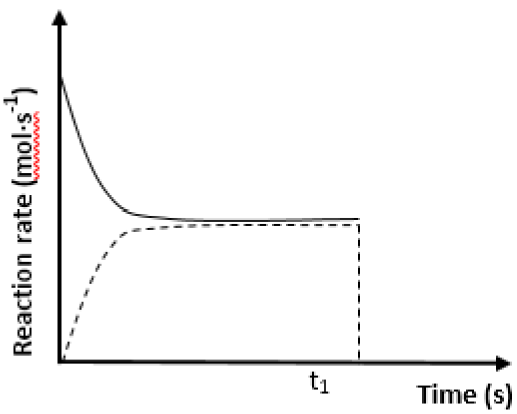
	4.3.1	t3	(1)
	4.3.2	t4	(1)
4.4		How will an increase in temperature influence the yield of $NO_2(g)$? Write down INCREASES, DECREASES or REMAINS THE SAME. Use Le Chatelier's principle to explain the answer.	(3)
5		Hydrogen and iodine are injected into a closed container at constant temperature. The reaction reaches equilibrium according to the following equation: $$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$ The graph below illustrates changes that were then made to the equilibrium mixture.	
			
5.1		What information about the reaction can be obtained from the graph between times t_0 and t_1?	(1)
5.2		Describe all the changes that occurred in the system between t_1 and t_2	(4)
6		The following equation represents a reversible reaction that has reached equilibrium at 470 °C in a closed container: $$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$	
		A change was then made to the NH_3 in the equilibrium mixture at t_2. A graph showing the effect of this change is drawn below. (The graph is not drawn to scale.)	

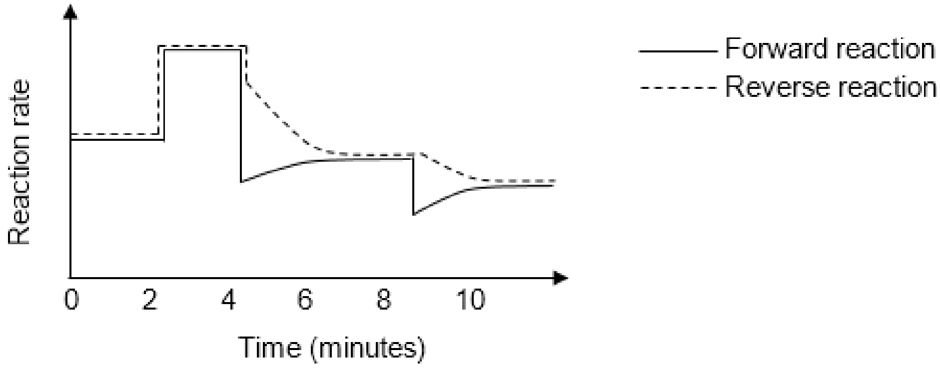


6.1		What is the meaning of the horizontal lines between t_1 and t_2?	(1)
6.2		State the change that was made to the NH_3 in the mixture at time t_2	(1)
6.3		Explain how the change mentioned in QUESTION 6.2 affected the concentration of H_2 and N_2 gases as shown in the graph.	(3)
7		Pure hydrogen iodide, sealed in a 2 dm^3 container at 721 K, decomposes according to the following balanced equation: $2HI(g) \rightleftharpoons H_2(g) + I_2(g) \quad \Delta H = +26\ kJ\cdot mol^{-1}$ The graph below show how reaction rate changes with time for this reversible reaction.	



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

7.2		How does the concentration of the reactant change between the 12th and the 15th minute? Write down only INCREASES, DECREASES or NO CHANGE.	(1)
7.3		The rates of both the forward and the reverse reactions suddenly change at t = 15 minutes.	
	7.3.1	Give a reason for the sudden change in reaction rate	(1)
	7.3.2	Fully explain how you arrived at the answer to QUESTION 7.3.1	(3)
8		Hydrogen gas, $H_2(g)$, reacts with sulphur powder, S(s), according to the following balanced equation: $H_2(g) + S(s) \rightleftharpoons H_2S(g) \quad \Delta H < 0$	
		The system reaches equilibrium at 90^0C	
	8.1	Define the term *chemical equilibrium*.	(2)
	8.2	The sketch graph below was obtained for the equilibrium  A catalyst is added to the equilibrium mixture at time t_1 Redraw the graph above in your ANSWER BOOK. On the same set of axes, complete the graph showing the effect of the catalyst on the reaction rates.	(2)
9		Hydrogen and iodine are sealed in a 2 dm^3 container. The reaction is allowed to reach equilibrium at 700 K according to the following balanced equation: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	
9.1		Give a reason why changes in pressure will have no effect on the equilibrium position.	(1)
		The reaction rate versus time graph below represents different changes made to the equilibrium mixture.	

			
9.2		What do the parallel lines in the first two minutes indicate?	(1)
9.3		State TWO possible changes that could be made to the reaction conditions at t = 2 minutes.	(2)
9.4		The temperature of the equilibrium mixture was changed at t = 4 minutes	
	9.4.1	Is the forward reaction EXOTHERMIC or ENDOTHERMIC? Fully explain the answer	(3)
	9.4.2	How will this change influence the K_c value? Choose from INCREASES, DECREASES or REMAINS THE SAME	(1)
9.5		What change was made to the equilibrium mixture at t = 8 minutes?	(1)

ACIDS AND BASES

Properties of acids

1. sour to taste
2. temperature rises when reacting with water-shows that reaction is taking place
3. Ability to neutralise bases
4. Have a pH less than 7
5. Conduct electricity in solution

Properties of bases

1. Bitter to taste
2. Have a soapy feel
3. temperature rises when reacting with water-shows that reaction is taking place
4. Ability to neutralise acids
5. Have a pH greater than 7

Acid	Formula	Strength
Hydrochloric acid	HCl	strong
Sulphuric acid	H_2SO_4	strong
Nitric acid	HNO_3	strong
Phosphoric acid	H_3PO_4	Weak
Carbonic acid	H_2CO_3	weak
Oxalic acid	$(COOH)_2$ $H_2C_2O_4$	weak
Acetic acid (etanoic acid)	CH_3COOH	weak

Base	Formula	Strength
Sodium hydroxide	NaOH	strong
Potassium hydroxide	KOH	strong
Lithium hydroxide	LiOH	strong
Calcium hydroxide	$Ca(OH)_2$	Strong
Magnesium hydoxide	$Mg(OH)_2$	Strong
Ammonia	NH_3	weak
Potassium carbonate	K_2CO_3	weak
Sodium bicarbonate	$NaHCO_3$	weak
Sodium carbonate	Na_2CO_3	weak

WORKED EXAMPLES

Acid-Base reactions (Common acids and bases)

Eg1) Complete and balance the following chemical equations

a) 2 HCl + $Ca(OH)_2$ → __$CaCl_2$____ + __2_H_2O___

b) 2 HNO_3 + K_2O → __2 KNO_3____ + __H_2O__

c) $MgCO_3$ + H_2SO_4 → _ $MgSO_4$__ + _ H_2O _ + __CO_2__

% Purity composition and Yield

eg1) Determine the % composition of Na in 2,5 g of Na_3PO_4

Mr (Na_3PO_4) = 3(23) +31 + 4(16) = 164 $gmol^{-1}$

% of Na = $\frac{69}{164}$ X 100 = 42,073 %

Mass of Na = $\frac{42,073}{100}$ X 2,5 g = 1,052 g

eg2) A sample consisting of 3,25 g of Impure Potassium oxide reacts completely with excess nitric acid as shown by following balanced chemical equation.

$$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_20$$

During the reaction, 2,56 g of Potassium sulphate was formed.

Calculate the % purity of Potassium oxide

Solution : 2 KOH : 1 K_2SO_4

112g : 174 g

x : 2,56

Mass of pure KOH = 1,648 g

% purity of KOH = $\frac{1,648}{3,25}$ x 100

= 0,51 %

DISCUSSION: Complete and balance the following chemical equations:

a) 2 HCl + $Ca(OH)_2$ → _________ + _________

b) 2 HNO_3 + K_2O → ___________ + ___________

c) $MgCO_3$ + H_2SO_4 → ________+ _______ + _________

% Purity composition and Yield

eg1) Determine the % composition of Na in 2,5 g of Na_3PO_4

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NOTES

Acids and Bases

- Acids and bases are chemicals that exhibit their chemical behaviour when dissolved in water. Hence, when dealing with them the word aqueous will be repeatedly used, so is in the chemical equation for acids and bases. Acids and bases produces ions when dissolved in water; therefore, are called **electrolytes**.
- An electrolyte is an **ionic** solution that is able to conduct electricity.
- There are different types of acids and bases that occur naturally; however, there also others which are derived in the laboratory.
- Acids and bases are defined based of two theories i.e. Lowry-Bronsted and Arrhenius

Acids and bases are defined based of two theories i.e. Lowry-Bronsted and Arrhenius

Table1: Illustrates acid and base definition using different theories.

Definition	**Acid**	**Base**
Lowry-Bronsted theory	An acid is a proton donor (H^+)	A base is a proton acceptor (H^+)
	$HCl + H_2O \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$	$NH_3 + H_2O \rightleftharpoons NH_4^+_{(aq)} + OH^-_{(aq)}$
Arrhenius theory	An acid liberates hydrogen ions (H^+) in aqueous solutions	A base liberates hydroxyl ions (OH^-) in aqueous solutions
	$HCl \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$	$NaOH \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Discuss Conjugate Acid- base pairs

Conjugate acid- formed when a base accepts a proton
Conjugate base- formed when an acid loses a proton(H^+)

.a_1 b_2 a_2 b_1

$$HCl + H_2O \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Discuss Ampholyte/Amphiprotic substances

a_1 b_2 a_2 b_1

$$H_2O + HSO_4^- \rightarrow H_2SO_4 + OH^-$$

a_1 b_2 a_2 b_1

$HSO_4^- + H_2O \rightarrow H_3O^+ + SO_4^{2-}$

An **ampholyte** is a substance that can act as an acid and a base.
$HSO_4^- + H_2O \rightleftharpoons H_2SO_4 + OH^-$ HSO_4^- acts as a base
$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$ HSO_4^- acts as an acid
Activity 1 & 2 are educator facilitated:

Activity 1

1.1 Which one of the following substances may be regarded as an ampholyte

A. H_2O

B. CO_3^{2-}

C. SO_4^{2-}

D. Cl^-

1.2 Use the relevant Equations to show that the following substances are ampholytes.

1.2.1 $H_2PO_4^-$

1.2.2 H_2O

Activity 2

2 For each of the following equations, write down the conjugate base:

2.1 $NH_3 + HCl \longrightarrow NH_4^+ + Cl^-$

2.2 $HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$

2.2	For each of the following equations, write down the TWO acids:
2.2.1	$H_2SO_4 + H_2O \longrightarrow H_3O^+ + SO_4^{2-}$
2.2.2	$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

NOTES

Types of acids

Strong Acid(HCl, H_2SO_4, HNO_3)	Weak Acid(CH_3COOH)
1. Ionises completely in water to form high concentration of hydronium ions	1. Ionises partially in water to form low concentration of hydroxide ions
2. Has a lower pH value	2. Has pH value closer to 7
3. Has bigger K_a	3. Has smaller K_a
4. Stronger electrolytes, high conductivity	4. Weak electrolytes, lower conductivity

Dilute acid – acid where the ratio of the number of moles of acid to volume of solution is small.	**Concentrated acid** – acid in which the ratio of the number of moles of the acid to volume is large. This applies to both strong and weak acids .

Strengths of acids :

In decreasing order of strength

→

$HClO_4$, HCl ,HNO_3, H_2SO_4, $(COOH)_2$, H_2SO_3 , HSO_4^-, H_3PO_4, HF, HNO_2,CH_3COOH, H_2CO_3, H_2S ,NH_4^+

Strengths of bases :

In decreasing order of strength

→

OH^- , HCO_3^- , CO_3^{2-} , O^{2-}

Define pH as:

pH is a measure of concentration of H^+ ions in a solution.it is indication of the acidity or basicity of a solution.

pH is mathematically defined as:

$pH = -\log[H_3O^+]$ OR $pH = -\log[H^+]$

$[H_3O^+][OH^-] = 1 \times 10^{-14}$

Conversion for Volumes:

1 l = 1 dm^3

1 ml = 1 cm^3

1 cm^3 = 1×10^{-3} dm^3

1000ml = 1dm^3 = 1l = 1000cm^3

pH is measured with a pH meter; for grade 12, pH meter ranges from 0 to 14

- ◦ Acidic pH is less than 7
- ◦ Neutral pH is equal to 7
- ◦ Basic pH is greater than 7

Auto-ionisation of water

- Water has tendency to ionise itself by transferring a proton (H+) from one water molecule to the other. This ionisation is shown in the equation below:

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

- Since, the above reaction shows an equilibrium nature, then one can write the equilibrium constant expression for water auto-ionisation as follows:

Worked Examples

1. Calculate the concentration of H_3O^+ and OH^- ions in H_3PO_4 of concentration
   0,1 mol.dm^{-3} when it ionizes in water.(assume complete ionization)

   $$H_3PO_4 \rightleftharpoons 3H^+ + PO_4^{3-}$$

	H_3PO_4	$3H^+$	PO_4^{3-}
Ratio:	1	3	1
	0,1	0,3	0,1

   $[H_3O^+] = 3(0,1)$
   $= 0,3$ mol.dm^{-3}

   $[H_3O^+][OH^-] = 1 \times 10^{-14}$
   $(0,3)[OH^-] = 1 \times 10^{-14}$
   $[OH^-] = 3,33 \times 10^{-14}$ mol.dm^{-3}

2. Calculate the pH of the solution of H_3PO_4 in *question 1* above.
   pH = $-\log[H_3O^+]$
   $= -\log(0,3)$
   $= 0,52$

NOTES

Hydrolysis- reaction of salt with water

Solubility Table

Soluble compounds		Exceptions
Almost all salts of Na^+, K^+ and NH_4^+		
All salts of Cl^-, Br^- and I^-	⇔	Halides of Ag^+, Hg_2^{2+} and Pb^{2+}
Compounds containing F^-	⇔	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} and Pb^{2+}
Salts of nitrate, NO_3^- chlorate, ClO_3^- perchlorate, ClO_4^- acetate, CH_3COO^-		$KClO_4$
Salts of sulphate, SO_4^{2-}	⇔	Sulphates of Sr^{2+}, Ba^{2+} and Pb^{2+}

Insoluble compounds		Exceptions
All salts of carbonate, CO_3^{2-} phosphate, PO_4^{3-} oxalate, $C_2O_4^{2-}$ chromate, CrO_4^{2-} sulphide, S^{2-} Most metal hydroxides OH^- and oxides, O^{2-}	⇔	Salts of NH_4^+ and alkali metal cations

TEST

Dissociate the following salts in water

a) $NaCl \rightarrow$ _____ + _____ (2)

b) $NH_4Cl \rightarrow$ _______ + _______ (2)

c) $CH_3OONH_4 \rightarrow$ _______ + _______ (2)

d) $NH_4NO_3 \rightarrow$ _______ + _______ (2)

(10 minutes)

Reaction of salts with water

Acidic salts - The hydrolysis of a salt derived from a strong acid and a weak base result in an acidic solution.

eg) $NH_4Cl + H_2O \longrightarrow NH_4^+ + Cl^-$

$\downarrow$ $\downarrow$

derived from NH_3 HCl

Basic salts - The hydrolysis of a salt derived from a strong base and weak acid results in a basic solution

eg) $Na_2CO_3 + H_2O \longrightarrow 2Na^+ + CO_3^{2-}$

$\downarrow$ $\downarrow$

derived from NaOH H_2CO_3

Neutral salts - The hydrolysis of a salt derived from a strong acid and a strong base results in a neutral solution

eg) $NaCl + H_2O \longrightarrow Na^+ + Cl^-$

derived from NaOH (from Na^+) and HCl (from Cl^-)

The effect of salts on pH

- The salt that is formed in a neutralization reaction should be neutral, with a pH equal to 7. But if the acid is much stronger than the base, or the base is much stronger than the acid, the pH is not 7, but just above or below 7.
- If the ***acid is much stronger*** than the base, the salt is acidic, with a pH just lower than 7.
- If the ***base is much stronger*** than the acid, the salt is alkaline/basic, with a pH just higher than 7.

Acidic salt		**Alkaline salt**	
$NH_4C\ell$	ammonium chloride	Na_2CO_3	sodium carbonate
		CH_3COONa	sodium ethanoate
		$(COOH)_2Na_2$	sodium oxalate

	Example	**Hydrolysis of salt**	**pH of salt**
strong a + strong b	$NaOH + HC\ell \rightarrow \mathbf{NaC\ell} + H_2O$	none	7 (neutral)
	$KOH + H_2SO_4 \rightarrow \mathbf{Na_2SO_4} + 2H_2O$	none	
	$LiOH + HNO_3 \rightarrow \mathbf{LiNO_3} + H_2O$	none	
strong a + weak b	$NH_3 + HC\ell \rightarrow \mathbf{NH_4C\ell}$	$\mathbf{NH_4^+} + H_2O \rightarrow NH_3 + H_3O^+$	< 7 (acidic)
weak a + ***strong b***	$NaOH + H_2CO_3 \rightarrow \mathbf{Na_2CO_3} + H_2O$	$\mathbf{CO_3^{2-}} + H_2O \rightarrow HCO_3^- + OH^-$	> 7 (basic/ alkaline)
	$NaOH + CH_3COOH \rightarrow \mathbf{CH_3COONa} + H_2O$	$\mathbf{CH_3COO^-} + H_2O \rightarrow CH_3COOH + OH^-$	
	$NaOH + (COOH)_2 \rightarrow \mathbf{(COOH)_2Na_2} + H_2O$	$\mathbf{(COO^-)_2} + 2H_2O \rightarrow (COOH)_2 + 2OH^-$	

ACTIVITIES-LESSON 1

ACTIVITY 1

1.Complete the following table of salts formed during acid-base reactions

1.

Acid/Base	**HCl**	**HNO_3**	**H_2SO_4**
KOH			
NaOH			
Na_2O			
MgO			
$NaHCO_3$			
$CaCO_3$			

2.	**NAME THE FOLLOWING ACIDS, BASES OR IONS**	
2.1	NaOH	
2.2	CH_3COOH	
2.3	$(COOH)_2$	
2.4	$Ca(OH)_2$	
2.5	HNO_3	
2.6	H_2SO_4	
2.7	$NaHCO_3$	
2.8	H_3O^+	
2.9	HSO_4^-	
2.10	CO_3^{2-}	
2.11	NH_4^+	
2.12	HCO_3^-	
2.13	NH_3	

3.		**DATA SHEET:**	

		$n = \frac{V}{V_m}$ $n = \frac{m}{M}$ $c = \frac{n}{V}$ $c = \frac{m}{MV}$	
	3.1	Calculate the concentration of a 0,2 mol solution of Na_2CO_3 with a volume of 150 cm^3.	(3)
	3.2	Calculate the number of mol of NaOH in 250 cm^3 solution of concentration of 0,25 $moldm^{-3}$	(3)
	3.3	Calculate the mass of NaCl(s) needed to prepare a solution of concentration 0,2 $moldm^{-3}$ in a 150 ml flask.	(3)
	3.4	Calculate the concentration of H^+ ions in 0,25 $moldm^{-3}$ H_2SO_4.	(3)
	3.5	1,2 g of impure sodium hydrogen carbonate reacts with excess hydrochloric acid to form 44,8 dm^3 of carbon dioxide gas at STP .The balanced equation for this reaction is given below.	
		$NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$	
		Calculate the % purity of sodium hydrogen carbonate in this mass.	(5)
	3.6	Calcium carbonate reacts completely with excess nitic acid according to the following balanced chemical equation.	
		$\mathbf{CaCO_3 + 2\ HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O}$	
		Calculate the mass of $CaCO_3$ needed to completely react with 30 cm^3 solution of nitric acid of concentration 0,0125 $moldm^{-3}$.	(5)

		HOMEWORK ACTIVITY-LESSON 1	
1		If 20g of impure Na_2CO_3 produces 14,625 g of pure NaCl according to the reaction: $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$ What is the percentage purity of Na_2CO_3 used?	
2		***Sulphuric acid is a strong diprotic acid.***	
	2.1	Define the term strong acid	(2)
	2.2	Give a reason why sulphuric acid is referred to as a diprotic acid.	(1)

3		The hydrogen carbonate ion can act as both an acid and a base. It reacts with water according to the following balanced equation: $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3\,(aq) + OH^-(aq)$	
	3.1	Write down ONE word for the underlined phrase.	(1)
	3.2	$HCO^-_3(aq)$ acts as base in the above reaction. Write down the formula of the conjugate acid of $HCO^-_3(aq)$	(1)
4		Ammonia can readily dissolve in water according to the equation below: $NH_3(g) + H_2O(\ell) \rightarrow NH^+_4(aq) + OH^-(aq)$	
	4.1	Explain why a hydroxide ion is regarded as a Lowry-Brønsted base	(2)
	4.2	Write a balanced equation to show how the ampholyte in the above equation will act as a base when it reacts with hydrochloric acid (HCℓ)	(2)
5		5 $dm^3$of nitric acid (HNO_{3_3}), with a concentration of 0,75 $mol{\cdot}dm^{-3}$, is spilled accidentally in a small pond of water. The acid and water has a total volume of 1 000 dm^3. To neutralise the acid, calcium hydroxide is added to the water $2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2H_2O$	
	5.1	Define concentration of a solution	(2)
	5.2	Calculate the concentration of the acid AFTER it was spilled in the pond.	(4)
	5.3	Use calculations to determine if 120 g of calcium hydroxide will be sufficient to react completely with ALL the acid in the pond.	(6)

NOTES/ACTIVITIES-LESSON 2

Acids and Bases

- Acids and bases are chemicals that exhibit their chemical behaviour when dissolved in water. Hence, when dealing with them the word aqueous will be repeatedly used, so is in the chemical equation for acids and bases. Acids and bases produces ions when dissolved in water; therefore, are called **electrolytes**.
- An electrolyte is an **ionic** solution that is able to conduct electricity.
- There are different types of acids and bases that occur naturally; however, there also others which are derived in the laboratory.

- Acids and bases are defined based of two theories i.e. Lowry-Bronsted and Arrhenius

Acids and bases are defined based of two theories i.e. Lowry-Bronsted and Arrhenius

Table1: Illustrates acid and base definition using different theories.

Definition	**Acid**	**Base**
Lowry-Bronsted theory	An acid is a proton donor (H^+)	A base is a proton acceptor (H^+)
	$HCl + H_2O \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$	$NH_3 + H_2O \rightleftharpoons NH_4^+_{(aq)} + OH^-_{(aq)}$
Arrhenius theory	An acid liberates hydrogen ions (H^+) in aqueous solutions	A base liberates hydroxyl ions (OH^-) in aqueous solutions
	$HCl \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$	$NaOH \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Discuss Conjugate Acid- base pairs

Conjugate acid- formed when a base accepts a proton
Conjugate base- formed when an acid loses a proton(H^+)

.a_1 b_2 a_2 b_1

$HCl + H_2O \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

Discuss Ampholyte/Amphiprotic substances

a_1 b_2 a_2 b_1

$H_2O + HSO_4^- \rightarrow H_2SO_4 + OH^-$

a_1 b_2 a_2 b_1

$HSO_4^- + H_2O \rightarrow H_3O^+ + SO_4^{2-}$

An **ampholyte** is a substance that can act as an acid and a base.

$HSO_4^- + H_2O \rightleftharpoons H_2SO_4 + OH^-$	HSO_4^- acts as a base
$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$	HSO_4^- acts as an acid

Activity 1 & 2 are educator facilitated:

Activity 1

1.1 Which one of the following substances may be regarded as an ampholyte

A. H_2O

B. CO_3^{2-}

C. SO_4^{2-}

D. Cl^-

1.2 Use the relevant Equations to show that the following substances are ampholytes.

1.2.1 $H_2PO_4^-$

1.2.2 H_2O

Activity 2

2 For each of the following equations, write down the conjugate base:

2.1 $NH_3 + HCl \longrightarrow NH_4^+ + Cl^-$

2.2 $HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$

2.2	For each of the following equations, write down the TWO acids:
2.2.1	$H_2SO_4 + H_2O \longrightarrow H_3O^+ + SO_4^{2-}$
2.2.2	$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

ACTIVITIES

1.	**Define the following terms:**	
1.1	Strong acid	(2)
1.2	Strong base	(2)
1.3	Concentrated acid	(2)
1.4	Dilute base	(2)

2.	Calculate the concentration of H_3O^+ and OH^- ions in the following solutions:	
2.1	NaOH of concentration 0,00001 $mol.dm^{-3}$	(4)
2.2	HCl of concentration 0,5 $mol.dm^{-3}$	(4)
3.	Calculate the pH of:	
3.1	0,2 $mol.dm^{-3}$ of HNO_3	(3)
3.2	0,04 $mol.dm^{-3}$ of H_2SO_4	(4)
3.3	0,2 $mol.dm^{-3}$ of $Ba(OH)_2$	(5)
4.	The pH of a solution of HCl is 3. Calculate the concentration of HCl.	(3)
5.	Calculate the concentration of phosphoric acid(H_3PO_4) if the pH of the acid is 4.92. (Assume complete dissociation of the acid)	(5)

HOMEWORK/CLASSWORK ACTIVITY-LESSON 4

1		Define the term End point	(2)
2		45 cm^3 of sodium hydroxide solution is pipetted into a conical flask and titrated with a 0,12 $mol{\cdot}dm^{-3}$ oxalic acid ($H_2C_2O_4$). Using a suitable indicator, it was found that 20,3 cm^3 of acid was needed to neutralise the base. $2NaOH + H_2C_2O_4 \longrightarrow Na_2C_2O_4 + 2H_2O$	
	2.1	Write down the name an indicator that would be suitable for the above titration. Give a reason for your answer	(3)
	2.2	How many grams of oxalic acid is necessary to make 150cm^3 of standard solution?	(4)
	2.3	Calculate the concentration of the sodium hydroxide solution.	(4)
3		A learner accidentally spills some sulphuric acid of concentration 6$mol{\cdot}dm^{-3}$ from a flask on the laboratory bench. Her teacher tells her to neutralise the spilled acid by sprinkling sodium hydrogen carbonate powder onto it. The reaction that takes place is: (Assume that the H_2SO_4 ionises completely.) $H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell) + 2CO_2(g)$ The fizzing, due to the formation of carbon dioxide, stops after the learner has added 27 g sodium hydrogen carbonate to the spilled	

		acid.	
	3.1	Calculate the volume of sulphuric acid that spilled. Assume that all the sodium hydrogen carbonate reacts with all the acid.	(6)
		The learner now dilutes some of the 6 $mol \cdot dm^{-3}$ sulphuric acid solution in the flask to 0,1 $mol \cdot dm^{-3}$.	
	3.2	Calculate the volume of the 6 $mol \cdot dm^{-3}$ sulphuric acid solution needed to prepare 1 dm^3 of the dilute acid.	(2)
4		During a titration 25 cm^3 of the 0,1 $mol \cdot dm^{-3}$ sulphuric acid solution is added to an Erlenmeyer flask and titrated with a 0,1 $mol \cdot dm^{-3}$ sodium hydroxide solution.	
		Calculate the pH of the solution in the flask after the addition of 30 cm^3 of sodium hydroxide. The endpoint of the titration is not yet reached at this point	(8)

THE CHEMICAL SYSTEM
FERTILIZERS

NOTES - LESSON 1
Fertilizer is a substance that is used to make the soil fertile.

A fertilizer consists of an organic or chemical substance with the aim of improving the quality or amount of plant growth. When correctly applied, fertilizer makes plants more vigorous, helps leaves grow larger, helps to develop strong root system and makes plants stronger.

TYPES OF FERTILIZERS
ORGANIC FERTILIZER
These are fertilizers that are derived mainly from plant remains and animal excretion.
Examples: Plant compost; animal manure; guano and bone meal
INORGANIC FERTILIZERS These are artificial fertilisers manufactured chemically in the laboratory.
The sample of inorganic fertilizer

Example of a bag of inorganic fertiliser

Examples: Urea; ammonia; ammonium phosphate; ammonium nitrate; superphosphate; and NPK fertilizers.

WHY FERTILIZERS ARE NEEDED?

- To produce more food
- To fertilize soil faster than naturally
- To increase the rate of food production in a given space of land
- Land available for agriculture decrease.

NUTRIENTS NEEDED BY PLANTS

There are 16 nutrients. They are divided into two. Mineral and non-mineral nutrient.

Mineral nutrients.

- There are three primary nutrients:
    - Nitrogen (N) ; Phosphorus(P) and Potassium (K).
- NPK ratio is the proportion of nitrogen, phosphorus and potassium.
- Mineral nutrients are derived from organic sources and inorganic sources.
- NITROGEN is derived from:
    - organic sources like guano and manure and
    - inorganic sources: urea; ammonium nitrate and ammonia
- Functions:-
    - promotes growth of the leaves
    - stimulates growth of the plants
- POTASSIUM is derived from:
    - organic sources:- potash
    - inorganic sources:- Potassium Chloride; Potassium Nitrate and Potassium Sulphate
    - Function improves quality of fruits and flowers.
- PHOSPHORUS comes from:
    - organic sources :- guano and bone meal.
    - Inorganic sources:- superphosphate; triple superphosphate and ammonium phosphate
    - Function- promotes growth of roots and stems.
- **Non-mineral nutrients (CHO)**

  Carbon (C) – from carbon dioxide in the atmosphere
  Hydrogen (H) – from rain

Oxygen (O) – from rain and air in the atmosphere.

LESSON 2 NOTES

INTERPRETATION OF NPK RATIO

- Interpret the N: P: K fertiliser ratio and perform calculations based on the ratio.
- N P K is the ratio of Nitrogen(N),Phosphorus(P) and Potassium(K) in a certain fertilizer.
- This can be expressed as
  3:1:5 (36) 20kg
  - 36 percentage fertilizer in the bag.(NB In this bag 64% will be the fillers)
  - 3 parts of 9 parts is Nitrogen
  - 1 part of 9 parts is Phosphorus
  - 5 parts of 9 parts is Potassium
- Calculate the total percentages and mass of Nitrogen, Phosphorus and Potassium.

3+1+5=9
% N =3/9 x36
=12%
% P = 1/9x36
=4%
%K= 5/9x36
=20%

Mass of Nitrogen =12% x 20kg
=2,4kg
Mass of Phosphorus= 4% x 20kg
=0,8 kg
Mass of Potassium = 20% x 20kg

=4kg

LESSON 3 NOTES

Fractional distillation of liquid air
Industrial preparation of nitrogen from air.

Steam reforming Preparation of hydrogen from earth gas (methane)

Reaction: $CH_4 + H_2O \rightarrow 3H_2 + CO$

Haber process Industrial preparation of **ammonia**
Reaction: $N_2 + 3H_2 \rightleftharpoons 2NH_3$
Iron (Fe) catalyst

Ostwald process Industrial preparation of **nitric acid**
Reactions:
1. **Catalytic oxidation of ammonia**; catalyst: Pt

$4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$

$2NO + O_2 \rightarrow 2NO_2$

$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ OR $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

Contact process Industrial preparation of **sulphuric acid**
Reactions:

1. $S + O_2 \rightarrow SO_2$
2. $2SO_2 + O_2 \rightarrow 2SO_3$ Contact catalyst: vanadium pentoxide (V_2O_5)
3. $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$
   ($H_2S_2O_7$: fuming sulphuric acid OR pyro sulphuric acid OR oleum)
4. $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

Preparation of **ammonium sulphate**
Ammonia + sulphuric acid → ammonium sulphate

$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

Preparation of **ammonium nitrate**
Ammonia + nitric acid → ammonium nitrate

$NH_3 + HNO_3 \rightarrow NH_4NO_3$

LESSON 4 NOTES

Excessive use of fertiliser and the environment

- The correct application of fertiliser to crops is essential for high quality, fast growing crops but using too much or unnecessary fertiliser has a negative effect on the environment.
- Fertiliser leaching (spreading by water) into the ground contaminates groundwater.
- Soil becomes acidic (pH decreases). Many plants do not grow in acidic soil.

- Invasive plants grow excessively while indigenous plants die. Invasive plants are undesirable non-indigenous (foreign) plants that grow too fast and out-compete local plants.
- Fertiliser in dams and rivers leads to "**eutrophication**", defined below.
- High nitrate concentrations in drinking water decreases the ability of haemoglobin in the blood to carry oxygen and leads to '**blue baby syndrome'**
- **Eutrophication** The process by which an ecosystem, e.g. a river or dam, becomes enriched with inorganic plant nutrients, especially phosphorus and nitrogen, resulting in excessive plant growth. As plant growth becomes excessive, the amount of dead and decaying plant material increases rapidly.

Alternatives to inorganic fertilisers

Although fertilisers are essential for the fast growth of high-quality crops, the negative effects of inorganic compounds on the environment must be taken into account. **Alternative sources of organic nutrients** that can be used to ensure good crops are:

- Bone meal;
- Animal manure;
- Natural plant compost;
- Bat guano (faeces);
- Fish emulsions;
- Kelp meal

Advantages of organic fertilisers:

- Break down and release nutrients more slowly than inorganic fertilisers, so there is less chance of the fertiliser leaching into the soil and causing contamination of groundwater;
- Usually cost less and Are often available free.

Disadvantages of organic fertilisers:

- Not enough is available for large scale usage;
- Provide less nutrients – more has to be used;
- Slow release of nutrients sometimes harms plants;
- Slow release may cause nutrients to be available too late in the plant's growth cycle.

QUESTION 1			
1.1		Which of the following is a primary mineral nutrient that is needed by plants	
	1.1.1	A. N B. C C. Mg D. Na	
			(2)
	1.2	The rapidly increasing human population is resulting in an ever-increasing demand for food. To meet this demand, farmers apply fertilizer to the same cultivated land EACH YEAR.	
	1.2.1	Explain why farmers have to apply fertilizers to the land each year.	(1)
	1.2.2	Write down one negative impact that over- fertilization can have on humans.	(1)
	1.2.3	Write down one positive impact of fertilizer on humans.	(1)

QUESTION 2(Lesson 2)			
1.1		A 10 kg bag of NPK fertilizer is labeled 6:1:5 (22)	

	1.1.1	What is the meaning of NPK?	**(1)**
	1.1.2	What is the meaning of (22) on the label	(1)
	1.1.3	Calculate the mass of potassium in the bag	(4)
1.2		A 2 kg bag of fertilizer is labeled as follows: 2:3:2 (22) . Calculate the mass of the : 1.2.1 Phosphorus in the bag 1.2.2 Filler in the bag	(3) (3)
1.3	1.3.1	Two 50kg bags containing fertilisers P and Q respectively, are labeled as follows: **Fertiliser P: 5:2:3 (25)** **Fertiliser Q: 1:3:4 (20)** What do the numbers (25) and (20) on the labels represent?	
	1.3.2	Using calculations,determine which fertiser (P or Q) contains the greater mass of potassium	(4)
1.4	1.4.1	The following substances are present in a bag of fertilizer: 20kg Ammonium nitrate,12kg sodium phosphate,18 kg potassium chloride. Calculate the NPK ratio of the fertilizer.	(5)

QUESTION 1

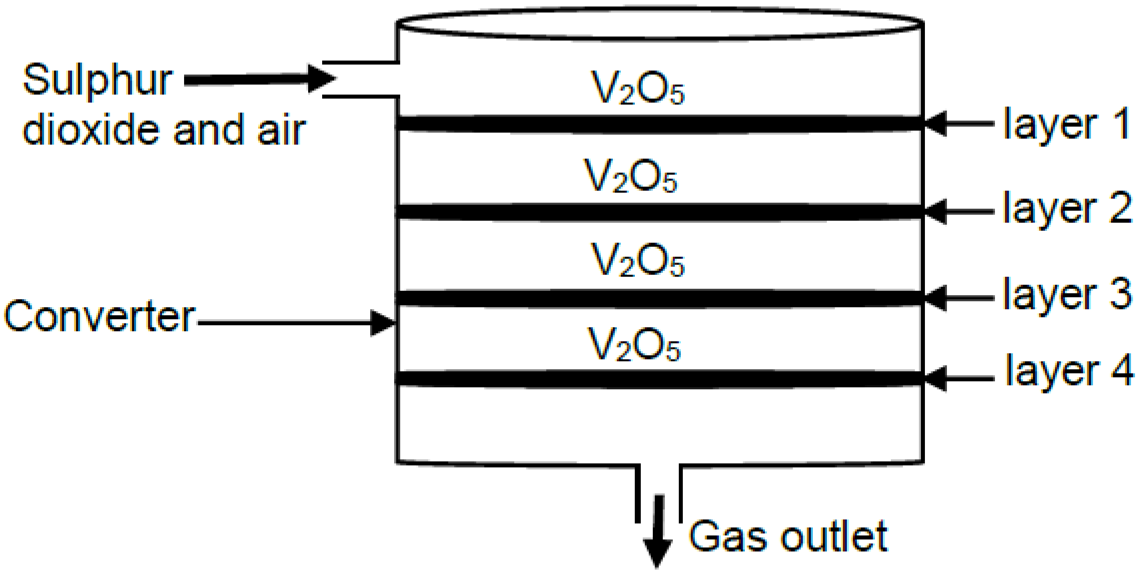
1.1		The reaction represented below take place during one of the industrial processes used in the fertilizer industry.
		1. $4NH_3(g) + 5O_2(g)$ ----Pt------ $4NO(g) + 6H_2O(g)$ 11. $NO(g) + O_2(g)$ X 111.$NO_2 + H_2O(l)$ --------------$HNO_3(aq)$ + -------- Write down: 1.1.1 The name of this industrial process 1.1.2 The function of Pt in reaction 1 1.1.3 The NAME of product X
		1.1.4 A balanced equation for reaction 111 1.1.5 Two ways in which the yield of the NO(g) obtained in reaction 1 can be increased Without changing the amount of reactants and products.
1.2		The four steps in the manufacture of an inorganic fertilizer are listed below. These steps are NOT written in the order in which they occur. Step 1: Sulphuric acid reacts with ammonia to produce ammonium sulphate' Step 2: Sulphur dioxide reacts with oxygen to produce Sulphur trioxide Step 3: Oleum is diluted with water to produce sulphuric acid Step 4: Sulphur trioxide is bubbled in concentrated sulphuric acid to produce oleum.
		Write down the : 1.2.1 Correct order in which the steps occur in the preparation of the inorganic fertilizer by using the numbers 1 to 4.
		1.2.2 Balance chemical equation for step 2
		1.2.3 NAME of the catalyst used in step 2
		1.2.4 Balanced chemical equation for step 4
		1.2.5 Reason why Sulphur trioxide is NOT dissolved in water in step 4.
		Worksheet 3 (Lesson 3) Activity 2
2.1		
	2.1.1	Ammonium Nitrate is often mixed with Potassium Chloride and Ammonium Phosphate. Give a reason why it is mixed with these compounds

2.2		
	2.2.1	The letters A to F below represent some fertilisers and raw materials used in the preparation of fertilisers. A Sulphur B Methane C Ammonium Sulphate D Air E Potassium Chloride F Ammonium Nitrate
	2.2.1.1	LETTERS representing TWO raw materials used in the preparation of compound F
	.2.2.1.2	NAME or FORMULA of the acid needed to prepare compound F
	2.2.1.3	LETTER representing the solid raw material used in the contact process
	2.2.1.4	Balanced equation for the preparation of compound E
	2.2.1.5	LETTER representing the raw material that supplies the primary nutrients needed for development of flowers

REVISION QUESTIONS

Question 1

The industrial process for the preparation of sulphuric acid involves a series of stages. The second stage in this process involves the conversion of sulphur dioxide into sulphur trioxide in a converter as illustrated below. In the converter the gases are passed over vanadium pentoxide(V_2O_5) placed in layers as shown below.



1.1 Write down the:
1.1.1 Balanced equation for the reaction taking place in the converter (3)
1.1.2 Function of the vanadium pentoxide (1)

The table below shows data obtained during the second stage

VANADIUM PENTOXIDE LAYER	TEMPERATURE OF GAS BEFORE THE REACTION (°C)	TEMPERATURE OF GAS AFTER THE REACTION (°C)	PERCENTAGE OF REACTANT CONVERTED TO PRODUCT
1	450	600	66
2	450	518	85
3	450	475	93
4	450	460	99,5

1.2 Is the reaction in the second stage EXOTHERMIC or ENDOTHERMIC? Refer to the data in the table to give a reason for the answer. (2)
1.3 After the conversion at each layer the gases are cooled down to 450 °C. Fully explain why the gases must be cooled to this temperature. (3)
1.4 During the third stage sulphur trioxide is dissolved in sulphuric acid rather than in water to produce oleum.
1.4.1 Write down the FORMULA of oleum. (1)
1.4.2 Give a reason why sulphur trioxide is not dissolved in water. (1)
1.5 Sulphuric acid reacts with ammonia to form a fertiliser. Write down a balanced equation for this reaction. (3) **[14]**

QUESTION 2

Ammonia is an important fertiliser. Large amounts are prepared from hydrogen and nitrogen in industry.

2.1 For the industrial preparation of ammonia, write down:

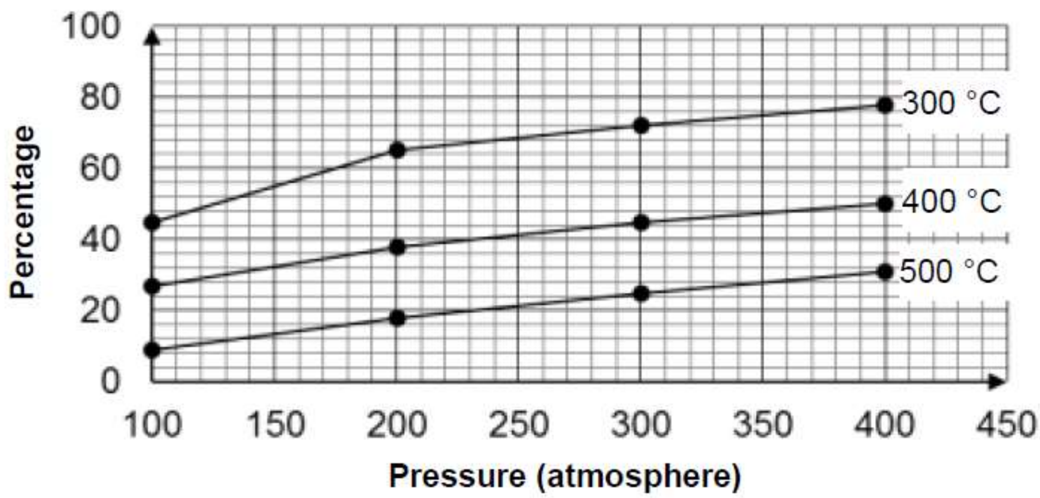
2.1.1 The name of the process used (1)

2.1.2 A balanced equation for the reaction that occurs (3)

2.1.3 The source of nitrogen (1)

2.2 The yield of ammonia changes with temperature and pressure during its industrial preparation. The graphs below show how the percentage of ammonia in the reaction mixture that leaves the reaction vessel varies under different conditions.

GRAPHS OF THE PERCENTAGE OF AMMONIA IN THE REACTION MIXTURE VERSUS PRESSURE



2.2.1 Use the appropriate graph to estimate the percentage of ammonia present in the reaction mixture at 240 atmosphere and 400 °C (1)

2.2.2 State TWO advantages of using high pressure in the preparation of ammonia. (2)

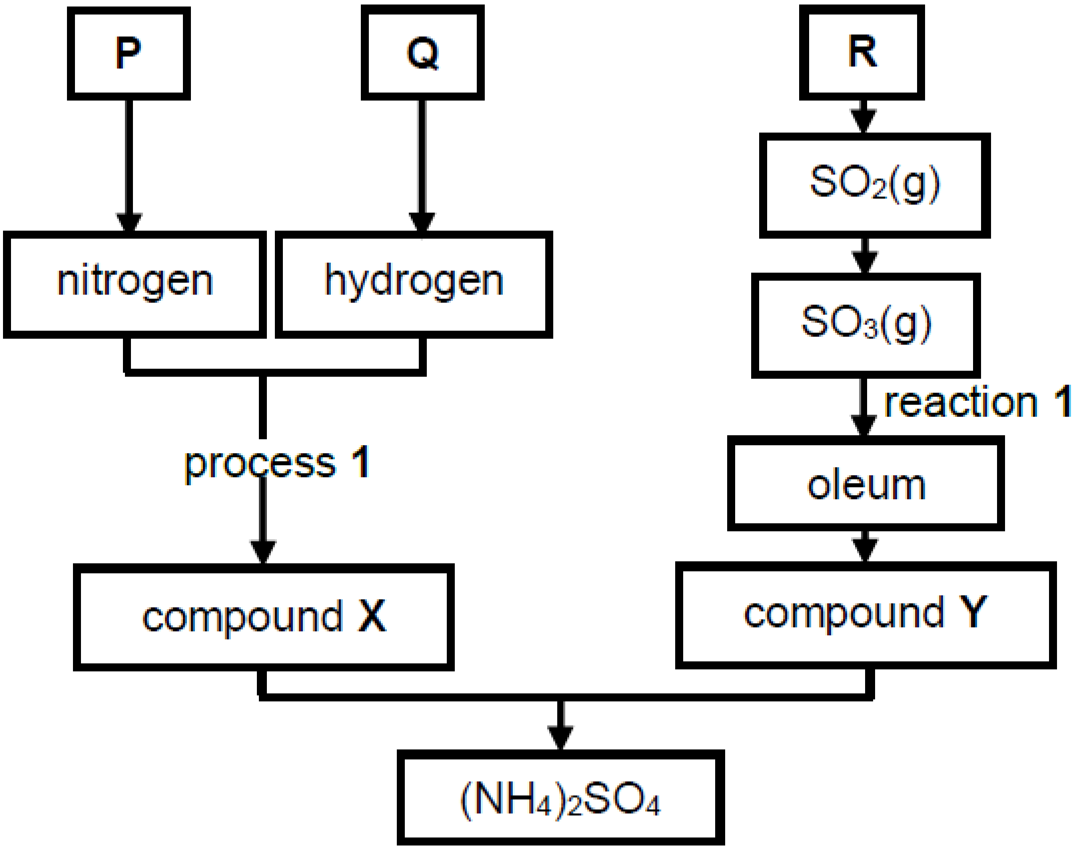
2.2.3 The advantage of using a low temperature is the large percentage of ammonia formed. What is the disadvantage of using a low temperature? (1)

2.3 Ammonia is also used in the preparation of other fertilisers such as ammonium nitrate. Calculate the mass of nitrogen in a 50 kg bag of pure ammonium nitrate fertiliser. (3)

[12]

Question 3

A chemical company produces ammonium sulphate, $(NH_4)_2SO_4$, starting from the raw materials **P**, **Q** and **R**, as
shown in the flow diagram below.



3.1 Write down the NAME of raw material:
3.1.1 **P** (1)
3.1.2 **Q** (1)
3.1.3 **R** (1)

3.2 Write down the:
3.2.1 NAME of **process 1** (1)
3.2.2 NAME of compound **X** (1)
3.2.3 FORMULA of compound **Y** (1)
3.2.4 Balanced equation for **reaction 1** (3)

3.3 The company compares the nitrogen content of ammonium sulphate with that of ammonium nitrate, NH_4NO_3.

3.3.1 Determine, by performing the necessary calculations, which ONE of the two fertilisers has the higher percentage of nitrogen per mass. (4)

3.3.2 Write down the name of the process that should be included in the flow diagram above if the company wants to prepare ammonium nitrate instead of ammonium sulphate. (1)
[14]

ACTIVITY 4 (FS September 2014)

Thabo wants to start a vegetable garden in his community. The department of agriculture donates the four fertilisers described below.

FERTILISER **A**: 7:1:3 (21)

FERTILISER **B**: 3:2:1 (28)

FERTILISER **C**: 2:3:4 (22)

FERTILISER **D**: Ammonium sulphate

4.1 What is the meaning of (21) indicated at fertiliser **A**? (1)

4.2 From FERTILISERS **A**, **B** and **C**, choose a fertilizer which is most suitable for:

4.2.1 Spinach (1)

4.2.2 Tomatoes (1)

4.2.3 Maize (1)

4.3 Calculate the:

4.3.1 Percentage of nitrogen in fertiliser **B** (2)

4.3.2 Mass of potassium present in a 20 kg bag of fertiliser **C.** (3)

4.4 Write down a balanced equation for the preparation of fertiliser **D** from ammonia and a suitable acid. (3) **[12]**

ACTIVITY 5 (Gauteng 2014)

In the CONTACT process for the manufacture of sulphuric acid the second step of the process produces sulphur (VI) oxide as in the following equation:
2SO2(g) + O2 (g) ⇌ 2 SO3 (g) □H = -197 kJ·mol^{-1}

The rate of the formation of SO3 is increased in a number of ways using rate and equilibrium principles.

5.1 Name the catalyst used in the Contact Process. (1)
5.2 Ammonia compounds are necessary for the production of fertiliser.
It is manufactured in the Haber process.
Give a balanced equation for the Haber process (3)
5.3 Calculate the ***number of moles*** of nitrogen in a bag of fertiliser that has a ratio of 7:1:3 (22). The mass of the bag is 5 kg. (5)
5.4 The abuse of large amounts of fertiliser can result in the enrichment of inorganic plant nutrients in water sources. Explain how this leads to dead and decaying plant material. (1) **[10]**