Western Cape Government

Education

Directorate: Curriculum FET

TELEMATICS

GRADE 12

PHYSICAL SCIENCES CAPS

ENGLISH

QUESTIONS ANSWERS AND STUDY TIPS

Normal Force
Simultaneous equations in Physics
K vs f graph in Photoelectric Effect
Volume-Volume Calculations
Chemical Equilibrium
Application of the Mole

February 2019

GRADE 12 PHYSICAL SCIENCES CAPS BROADCASTING PROGRAM 2019
GRAAD 12 FISIESE WETENSKAPPE KABV UITSAAI-PROGRAM 2019

Day	Date	Time	Subject	Topic
Tuesday	12 February	16:00 – 17:00	Physical Sciences	Normal force
Wednesday	13 February	16:00 – 17:00	Fisiese Wetenskappe	Normale krag
Monday	8 April	16:00 – 17:00	Physical Sciences	Simultaneous equations in Physics
Tuesday	9 April	16:00 – 17:00	Fisiese Wetenskappe	Gelyktydige vergelykings in Fisika
Wednesday	22 May	16:00 – 17:00	Physical Sciences	Photo-Electric effect
Thursday	23 May	16:00 – 17:00	Fisiese Wetenskappe	Foto-elektriese effek
Monday	29 July	16:00 – 17:00	Physical Sciences	Volume-Volume calculations
Tuesday	30 July	16:00 – 17:00	Fisiese Wetenskappe	Volume-Volume berekeninge
Wednesday	7 August	16:00 – 17:00	Physical Sciences	Chemical equilibrium
Monday	12 August	16:00 – 17:00	Fisiese Wetenskappe	Chemiese ewewig
Tuesday	15 October	16:00 – 17:00	Physical Sciences	Application of the mol
Wednesday	16 October	16:00 – 17:00	Fisiese Wetenskappe	Toepassing van die mol

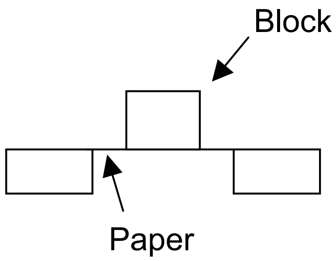
LESSON 1: NORMAL FORCE AND MOTION OF CONNECTED BODIES

Study Tips: The most important document that you should consult in order to prepare successfully for the 2016 PHYSICAL SCIENCES FINAL EXAMINATION is the EXAMINATION GUIDELINES (EG) dated 2014.

DEFINITION of a NORMAL FORCE: A normal force is the force or the component of a force which a surface exerts on an object with which it is in contact, and which is perpendicular to the surface. (EG, NSC (CAPS), page 7)

UNDERSTAND THE NORMAL FORCE:

The normal force is a contact force that a surface exerts on an object in contact with it in order to counter-act its weight, as illustrated below:



The paper is too weak to counter-act the weight of the block

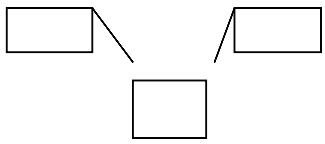


Fig. 1

The table is strong enough to counter-act the weight of the block. The force it exerts on the block is called the normal force (F_N)

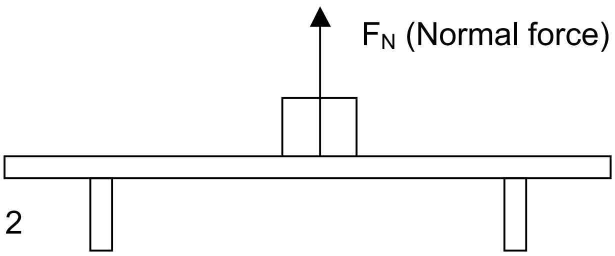
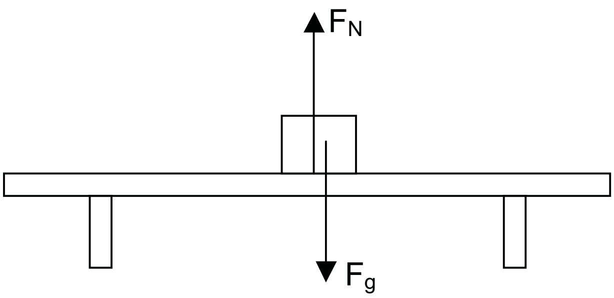


Fig. 2

EXAMPLE

Write down an equation that can be used to calculate the magnitude of the normal force (F_N) acting on the block in the diagram below. Numerical values are not required.

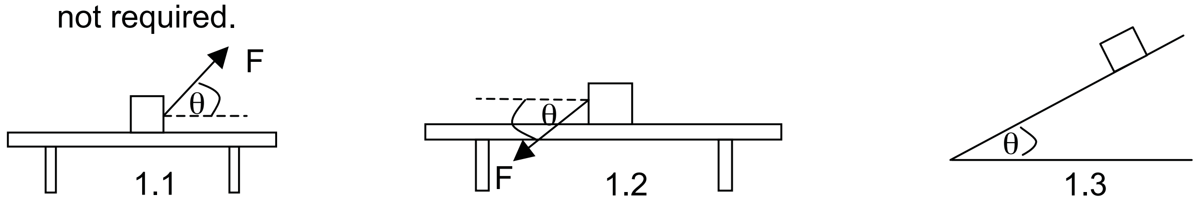


> **Study Tip:** When a body is in equilibrium, the <u>algebraic sum</u> of the upward forces equals the algebraic sum of the downward forces.
> This is the reason why $F_N = F_g$ in this example.
> This fact will be exploited to find F_N in all the examples and activities that follow.
> <u>Algebraic sum</u> means that the sum is not a vector sum.

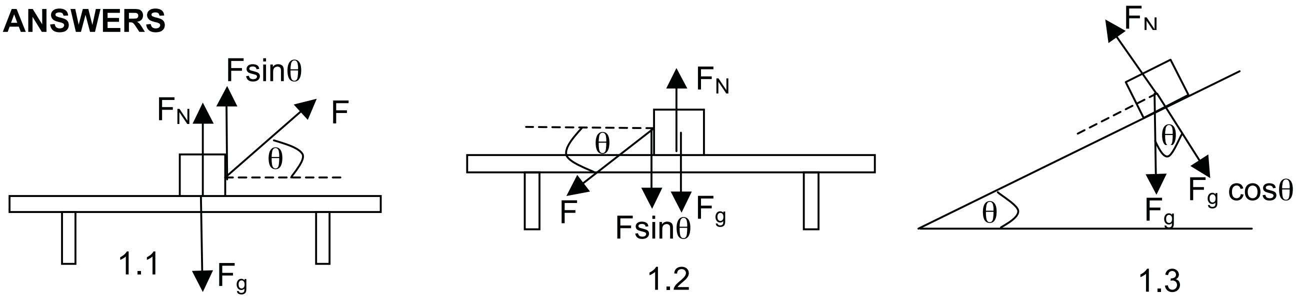
ANSWER: $F_N = F_g$ OR $F_N = w$ OR $F_N = mg$

ACTIVITY 1.1

1. Write down an equation that you can use to calculate the magnitude of the normal force (F_N) acting on the block in each of the following cases. Numerical values are not required.



ANSWERS



1.1 $F_N = F_g - F\sin\theta$

Resolve F into its components. The block is in equilibrium. ∴The algebraic sum of the upward forces = the algebraic sum of the downward forces.

$F_N + F\sin\theta = F_g$
$\therefore F_N = F_g - F\sin\theta$

1.2 $F_N = F_g + F\sin\theta$

Resolve F into its components. The block is in equilibrium. ∴The algebraic sum of the upward forces = the algebraic sum of the downward forces.

$\therefore F_N = F_g + F\sin\theta$

1.3 $F_N = F_g\cos\theta$

Resolve F_g into its components. The block is in equilibrium. ∴The algebraic sum of the upward forces = the algebraic sum of the downward forces on the inclined plane.
$\therefore F_N = F_g\cos\theta$

2. Calculate the magnitude of the normal force (F_N) using the derived equations in 1.1, 1.2 and 1,3 of ACTIVITY 1.1, if m = 5 kg, F = 40 N and $\theta = 30^o$.

ANSWERS to ACTIVITY 1.1, question 2.
1.1: 29 N 1.2: 69 N 1.3: 42,43 N or 42,44 N

ACTIVITY 1.2

Application of F_N, the normal force, to the motion of connected bodies:

You already know that frictional forces oppose motion of objects. In Grade 11 you learnt about static and kinetic friction.

The normal force F_N is used in the equation to determine both static and kinetic friction.

NOTES: Instead of F_N, N is used in the formula for static and kinetic friction. N is the preferred symbol and F_N is the alternative symbol for normal force. Refer to page 25 of the EG.

Static friction

When static friction is a maximum

$$F_s = \mu_s N$$

Where:

F_s is the static frictional force
μ_s is the co-efficient of static friction
N is the normal force

Kinetic friction

When kinetic friction is a maximum

$$F_k = \mu_k N$$

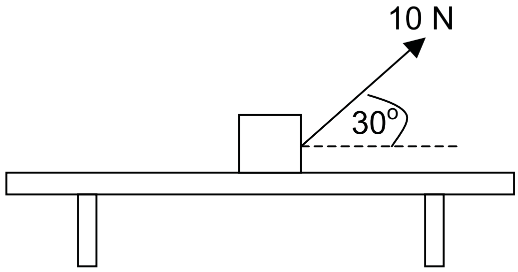
Where:

F_k is the kinetic frictional force
μ_k is the co-efficient of kinetic friction
N is the normal force

In the following examples, we apply static and kinetic frictional forces using some of the normal forces derived in ACTIVITY 1.1.

EXAMPLES

1.1 A force of 10 N acts on a block at an angle of 30° to the horizontal and the block does not move. The co-efficient of static friction between the block and the surface is 0,1.
Calculate the mass of the block.



ANSWER

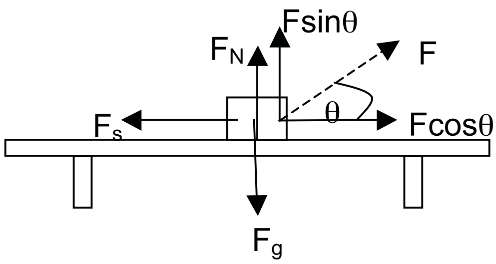
Study Tips: You must know how to obtain the mass of the block from the given data before you can solve the problem. Follow the steps below in a problem solving strategy:

PROBLEM SOLVING STRATEGY: Find F_N in terms of m using the upward and downward forces acting on the block. Then use the horizontal forces acting on the block to find the mass.

STEP 1: Understand the question and the context:
The block is in equilibrium.
This means: (1) The algebraic sum of the upward forces equals the algebraic sum of the downward forces.
(2) The algebraic sum of the horizontal forces pulling the block to the right equals the algebraic sum of the horizontal forces pulling the block to the left.

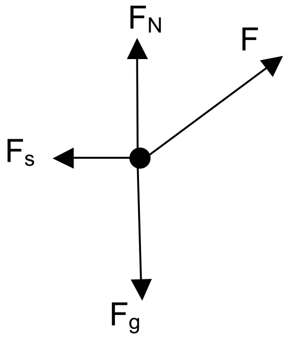
STEP 2:

Draw a diagram to show all the forces acting vertically and horizontally on the block.

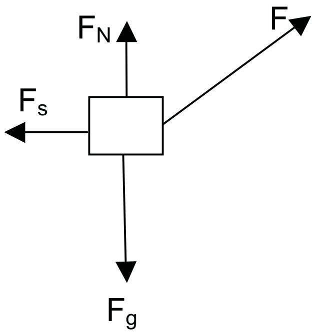


Study Tips: What is a free body diagram?
It is a diagram which is used to show all the forces that are acting on a body. The body is shown as a dot.

NOTES: In a free body diagram and a force diagram, the components of forces are not shown.



Free body diagram for STEP 2



Force diagram for STEP 2

Study Tips: The components of F are not shown in a free body diagram or a force diagram. ∴The diagram drawn in STEP 2 is not a force diagram or a free body diagram.
Study Tips: The forces shown in the free body- and force diagrams above are vectors. Vectors are shown as arrows. The head of an arrow shows its direction and its length its relative magnitude. The tails of each arrow touch the dot or the block.

Study Tips: N in μ_sN is another way of writing F_N. They have the same meaning.

Study Tips:
1. If you do not put in the arrow heads you will lose the marks for each force.
2. If you do not label each force you will lose the mark for the forces.
3. If you have additional forces that should not be included one mark is deducted per additional force.

STEP 3: Write down equations for the vertical and horizontal forces acting on the block, substitute the numerical values into them, and simplify:

Vertical forces: $F_N = F_g - F\sin30^o = m(9,8) - (10)(0,5) = 9,8m - 5$ … (1)

Horizontal forces: $F_s = \mu_sN = F\cos30^o$ … (2)

Substitute $F_N = 9,8 - 5$ into (2): $(0,1)(9,8m - 5) = (10)(0,866) = 8,66$ … (3)

STEP 3: Now use equation (3) to calculate the mass m:

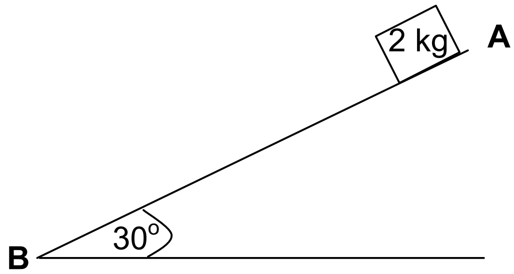
$$(0,1)(9,8m - 5) = (10)(0,866) = 8,66$$

$$\div \text{ both sides by } 0,1: \quad 9,8m - 5 = 86,6$$

$$\therefore m = \frac{91,6}{9,8} = 9,35 \text{ kg}$$

EXAMPLES

1.2 A block of mass 2 kg is released at point **A** at the top of an inclined plane and it travels to point **B** at the bottom. The length of **AB** is 5 m. If the co-efficient of kinetic friction between the surface of the block and the inclined plane is 0,05, calculate the velocity of the block when it reached **B**.



Study Tips: Follow a similar procedure as in Example 1.1. HINT: Use the Work-Energy Theorem.

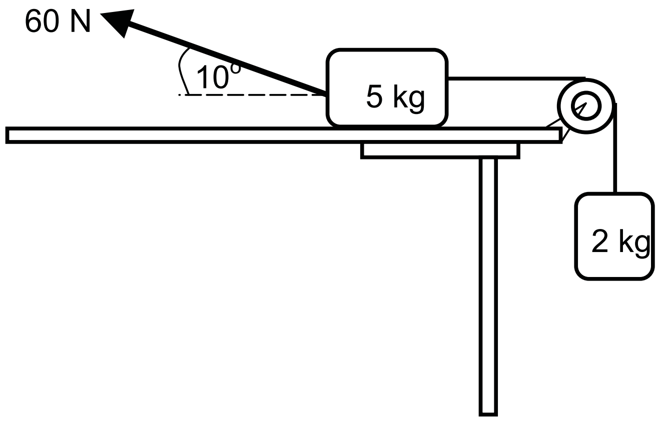
ANSWER: $6,69 \text{ m.s}^{-1}$

ACTIVITY 1.3

Solve the following problem and discuss your answers in class with your teacher:

1. A 5 kg block, resting on a rough horizontal table, is connected by a light inextensible string passing over a light frictionless pulley to another block of mass 2 kg. The 2 kg block hangs vertically as shown in the diagram below.

   A force of 60 N is applied to the 5 kg block at an angle of 10° to the horizontal, causing the block to accelerate to the left.



The coefficient of kinetic friction between the 5 kg block and the surface of the table is 0,5. Ignore the effects of air friction.

1.1 Draw a labelled free-body diagram showing ALL the forces acting on the 5 kg block. (5)

1.2 Calculate the magnitude of the:

1.2.1 Vertical component of the 60 N force (2)

1.2.2 Horizontal component of the 60 N force (2)

1.3 State Newton's Second Law of Motion in words. (2)

Calculate the magnitude of the:

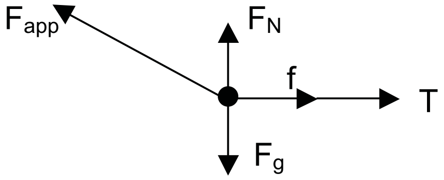
1.4 Normal force acting on the 5 kg block (2)

1.5 Tension in the string connecting the two blocks (7)

[20]

ANSWERS

1.1



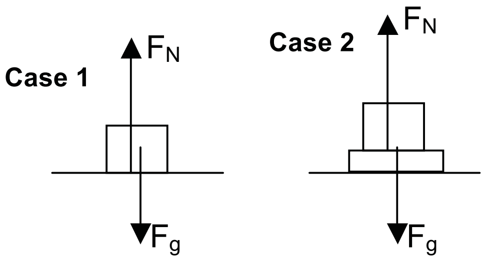
1.2.1: 10,42 N 1.2.2: 59,09 N 1.3: See EG pg. 7

1.4: 38,58 N 1.5: 25,37 N

ACTIVITY 1.4

Application of the normal force F_N in the lift problem

There are two cases:



In both cases the object experiences a normal force F_N that acts on it. Case 1 is the same as the example on page 3. In case 2, the bathroom scale registers a reading that is a reaction force to the weight of the object. According to Newton's 3rd Law, this reaction force has the same magnitude as the weight but is opposite in direction. This means the reaction force is F_N.

Case 1: An object is in direct contact with a lift floor

Case 2: An object is placed on a bathroom scale that is in direct contact with a lift floor

NOTES: The object can be a person standing in a lift. In ACTIVITY 1.4 we will use case 1 to derive the various equations. For case 2, the equations will be the same. F_{Res} and F_{net} have the same meaning. We apply Newton's 2nd Law viz. $F_{Res} = ma$ where applicable.

Study Tips: If you accelerate upwards in a lift you feel heavier. If you accelerate downwards you feel lighter. If the lift cable breaks you will feel weightless.

Case 1.1: **Lift is stationary.**

$$\mathbf{F_N = F_g}$$

(Algebraic sum of upward forces equals algebraic sum of downward forces.)

Case 1.2: **Lift moves upwards at constant velocity**.

$$\mathbf{F_N = F_g}$$

Proof: $F_{Res} = F_N – F_g = ma$
But a = 0 because v is constant.
Thus $F_N – F_g = 0$
$\therefore F_N = F_g$

Case 1.3: **Lift moves upwards at constant acceleration**.

$$\mathbf{F_N = ma + F_g}$$

Proof: $F_{Res} = ma$. $F_N > F_g$
$F_N – F_g = ma$
$\therefore F_N = ma + F_g$

Case 1.4: **Lift moves downwards at constant velocity**.

$$\mathbf{F_N = F_g}$$

Proof: $F_{Res} = F_g – F_N = ma$
But a = 0 because v is constant.
Thus $F_g – F_N = 0 \quad \therefore F_g = F_N$

Case 1.5: **Lift moves downwards at constant acceleration**.

$$\mathbf{F_N = F_g - ma}$$

Proof: $F_{Res} = ma$. $F_g > F_N$
$F_g – F_N = ma$
$\therefore F_N = F_g - ma$

Case 1.6 Lift slows down as it moves downwards.

$$\mathbf{F_N = F_g + ma}$$

Proof: $F_{Res} = ma$, $F_g > F_N$, $a<0$
$F_g – F_N = m(-a)$
$\therefore F_N = F_g + ma$

Case 1.7: **Lift slows down as it moves upwards**

$$\mathbf{F_N = F_g - ma}$$

Proof: $F_{Res} = ma$. $F_N > F_g \quad a < 0$
$F_N – F_g = m(-a)$
$\therefore F_N = F_g - ma$

Case 1.8: **Lift is free falling**

$$\mathbf{F_N = 0\ N}$$

Proof: $F_{Res} = F_g = mg$
Lift and object are in free fall.
Lift floor does not exert an upward force on the object.
$\therefore F_N = 0$ N

ACTIVITY 1.5

1.5 A man of mass 80 kg stands on a bathroom scale in a lift. Calculate the reading R on the bathroom scale in each of the following cases: (Show how you get your answers). Hint: $R = F_N$

1.5.1 The lift is stationary.
1.5.2 The lift is moving upwards with a constant velocity of 1,5 $m.s^{-1}$
1.5.3 The lift is accelerating downwards with a constant acceleration of 2 $m.s^{-2}$
1.5.4 The lift is slowing down uniformly at 2 $m.s^{-2}$ as it is moving downwards
1.5.5 The lift cable breaks

ANSWERS: 1.5.1: 784 N 1.5.2: 784 N 1.5.3: 624 N 1.5.4: 944 N 1.5.5: 0 N

LESSON 2: THE USE OF SIMULTANEOUS EQUATIONS IN PHYSICS

Study Tips: If you have two unknowns **x** and **y** and you want to find the value of each of them, you will need two equations containing **x** and **y**. To determine their values simultaneous equations are used and one of the unknown variables is eliminated.

EXAMPLE
If x + y = 10 and 2x – y = -4, determine the values of x and y that satisfy these equations.
Problem solving strategy:

STEP 1: Write down the two equations. Call one equation (1) and the other equation (2):

$$x + y = 10 \qquad \ldots (1)$$
$$2x - y = -4 \qquad \ldots (2)$$

STEP 2: Eliminate either x or y to obtain an equation with only x or y in it. If you add (1) and (2), y will be eliminated because +y – y = 0. The resulting equation only has x in it viz.

(1) + (2): $x + 2x = 10 - 4$
i.e. $3x = 6 \qquad \ldots (3)$

STEP 3: Calculate the value of x in equation (3): $x = \frac{6}{3} = 2$

STEP 4: Substitute x = 2 into equation (1) (or (2)) to obtain an equation for y:
$$2 + y = 10$$

STEP 5: Calculate the value of y: y = 10 – 2 = 8

STEP 6: Check the correctness of the values of x and y: Substitute x = 2 and y = 8 into equation (1) (or (2)): The value you get on the LHS must equal the value you get on the RHS viz.

LHS: 2 + 8 = 10 RHS: 10
i.e. LHS = RHS
i.e. 10 = 10

Study Tips: There will be more than one way to eliminate a variable such as x or y from both equations.
For example: To eliminate x:

Multiply (1) by 2: $2x + 2y = 20$ … (3).
Subtract: (2) – (3): $-3y = -24$
Then: $y = 8$.
Substitute $y = 8$ into (2) gives $x = 2$.

NOTES
In ACTIVITY 1.2 you also used simultaneous equations to determine the tension, T.
You should follow STEP 1 to STEP 6 to verify that your answer is correct.

Study Tips: If there are three, four, five, … unknown variables, they can be determined if there are respectively, three, four, five, … different equations to determine them.

ACTIVITY 2.1
Study the example and answer the following question.

A traffic officer **T** is stationary at a robot situated on a long straight road. A car **X** goes through the red robot travelling at a constant velocity of 10 $m.s^{-1}$. One second later the traffic officer takes off and chases the car, travelling uniformly at 2 $m.s^{-2}$. Calculate the:

2.1.1 Time it takes the traffic officer **T** to overtake the car **X**
2.1.2 Distance both travelled from the robot at overtake.

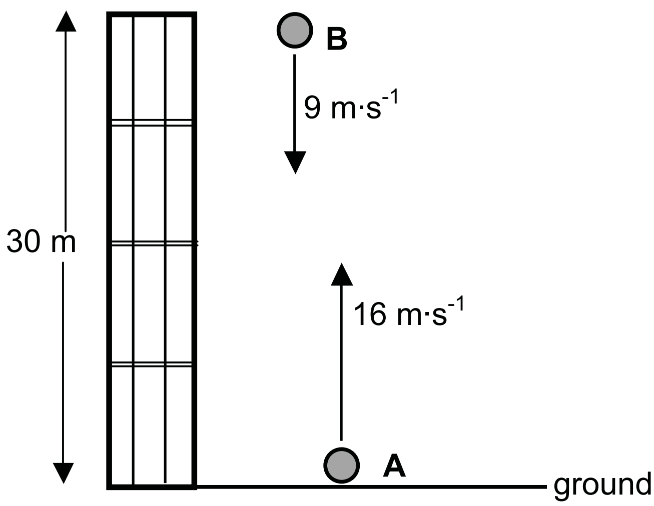
HINT: $\Delta x = 10\,t$ … (1) $\Delta x = (t-1)^2$ … (2)

ANSWERS: 2.1.1: 11,92 s 2.1.2: 119,20 m

ACTIVITY 2.2
There is another way to use simultaneous equations to find unknown values viz. treating variables as vector quantities.

EXAMPLE

ONE SECOND after ball **A** is projected upwards, a second ball, **B**, is thrown vertically downwards at a velocity of 9 $m{\cdot}s^{-1}$ from a balcony 30 m above the ground. Refer to the diagram below. **Use the ground as zero reference.**

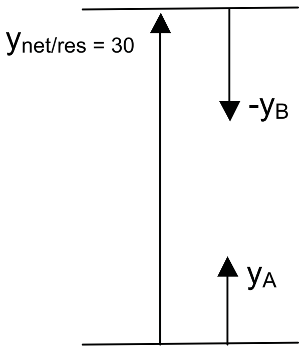


Calculate how high above the ground ball **A** will be at the instant the two balls pass each other.

ANSWER

Study Tips: Because there is both upward and downward motion, a SIGN CONVENTION must be used. In this problem either motion upwards is positive or negative (or motion downwards is negative or positive)

To solve this problem we will take MOTION UPWARDS AS POSITIVE.
Draw a diagram to understand the vectors involved:



The following PRINCIPLE is used to solve this problem:

Net (Resultant) displacement = sum of displacements of A and B

i.e. $30 = y_A + (-y_B)$

Study Tips: Anywhere where **A** and **B** meet, $30 = y_A + (-y_B)$

Now we can go into the actual equations.
Let **A** take t seconds to pass **B**, then **B** will take (t-1) seconds to pass **A**.

$y_A = v_i\Delta t + \frac{1}{2} a\Delta t^2$
$= 16\Delta t + \frac{1}{2}(-9,8)\Delta t^2$
$= 16\Delta t - 4,9\Delta t^2 \quad \ldots(1)$

$Y_B = v_i\Delta t + \frac{1}{2} a\Delta t^2$
$= -9(\Delta t-1) + \frac{1}{2}(-9,8)(\Delta t-1)^2$
$= 0,8\Delta t - 4,9\Delta t^2 + 4,1 \ldots(2)$

$y_A + (-y_B) = 16\Delta t - 4,9\Delta t^2 - (0,8\Delta t - 4,9\Delta t^2 + 4,1) = 30$
$15,2\Delta t = 34,1 \quad \therefore \Delta t = 2,24$ s.
Substitute $\Delta t = 2,24$ s into equation (1). Then
$y_A = 16(2,24) - 4,9(2,24)^2 = 11,25$ m

Complete the table below to check your answer:

	$y_A = 16\Delta t - 4,9\Delta t^2$	$y_B = 0,8\Delta t - 4,9\Delta t^2 + 4,1$	$y_A + (-y_B)$
t=1 s			
t=2 s			
t=2,24s			

ACTIVITY 2.3

Taking MOTION DOWNWARDS AS POSITIVE, solve the problem in the EXAMPLE in ACTIVITY 2.2.
HINT: $-30 = (-y_A) + y_B$

ANSWER: y = 11,25 m

LESSON 3: THE RELATIONSHIP BETWEEN K AND f IN THE PHOTOELECTRIC EFFECT

Study Tips: To understand the relationship between K (kinetic energy) and f (frequency) in the Photoelectric effect, you need to know the relationship y = mx + c for the straight line.

Consider the equation for the straight line: y = mx + c … (1)

The following information can be read directly from this equation:

- The gradient of the straight line is given by the co-efficient of x viz. m
- When x = 0, y = c i.e. the line cuts the y-axis at c.
- When y = 0, x = $\frac{-c}{m}$ i.e. the line cuts the x-axis at $\frac{-c}{m}$

Now consider the equation used in the photoelectric effect: $hf = w_0 + K_{max}$ … (2)

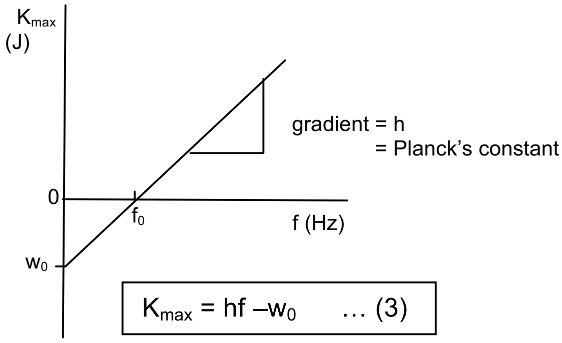
Equation (2) cannot be used directly in the K vs f graph. Because the K vs f graph is a straight line, it obeys equation (1). ∴You need to convert equation (2) into the same form as equation (1), the straight line.

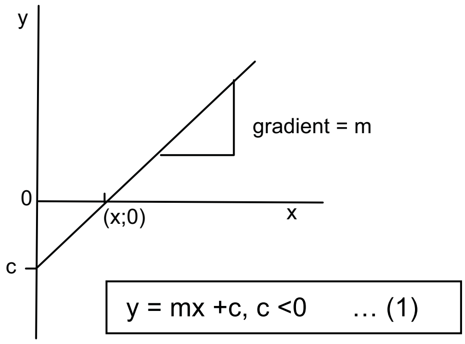
The conversion gives: $K_{max} = hf - w_0$ … (3)

We can now read information directly from equation (3) just like we did for equation (1):

- The gradient of this straight line is given by h (Planck's constant), the co-efficient of f i.e. THE GRADIENT OF THE K_{max} vs f graph gives h, Planck's constant.
- When f = 0, $K_{max} = -w_0$ i.e. the line cuts the K_{max} -axis at $-w_0$ i.e. THE WORK FUNCTION (w_0) is where the line cuts the K_{max} -axis.
- When $K_{max} = 0$, $f = \frac{w_0}{h} = \frac{hf_0}{h} = f_0$ i.e. the line cuts the f-axis at f_0.
  ∴THE THRESHOLD FREQUENCY is where the line cuts the f-axis.

The graphs given by equation (3) and (1) are sketched below:





NOTES: In the K_{max} vs f graph w_0 will always be a negative number because of equation (3). But if you convert equation (3) back to equation (2), it will become a positive number.

Prove without calculations that the gradient of the K_{max} vs f graph is h.
Proof: From equation (3):

$$\text{Gradient} = \frac{K_{max} + w_0}{f} = \frac{(hf - w_0) + w_0}{f} = \frac{hf}{f} = h$$

ACTIVITY 3.1

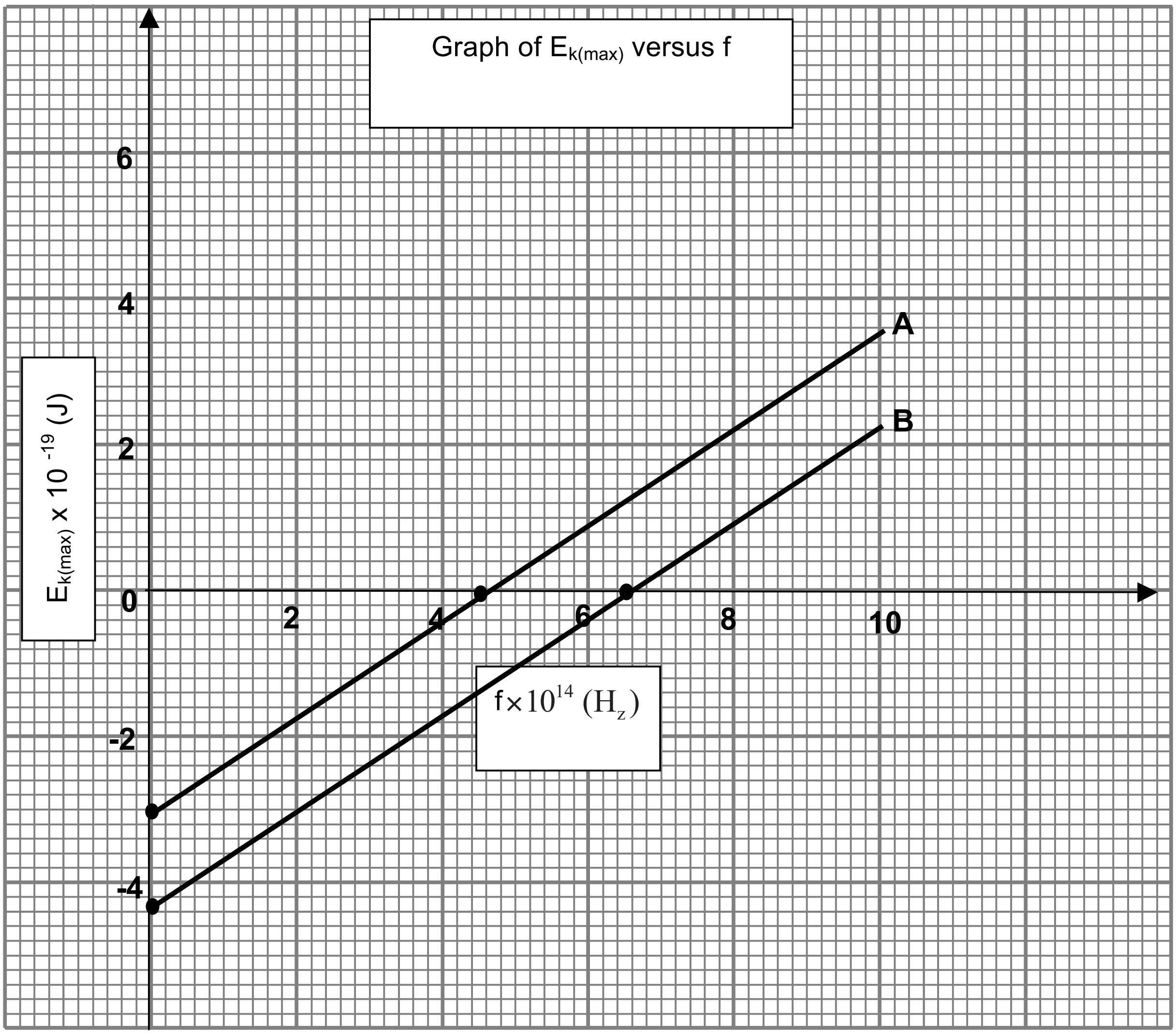
1. Complete Table 1 below by filling in the missing values:

Table 1

Element	W_0 (J)	f_o (Hz)	λ_o (nm)
Sodium	3.8×10^{-19}	5.8×10^{14}	520
Caesium	3.0×10^{-19}	4.5×10^{14}	666
Lithium		5.6×10^{14}	560
Calcium	4.3×10^{-19}	6.5×10^{14}	462
Magnesium	4.3×10^{-19}		337
Silver	7.6×10^{-19}	11.14×10^{14}	
Platinum	10.0×10^{-19}		199

ANSWERS: Lithium: $w_0 = 3{,}7 \times 10^{-19}$ J Magnesium: $f_0 = 8{,}9 \times 10^{14}$ Hz
Silver: $\lambda_0 = 263$ nm ($2{,}63\times10^{-7}$ m) Platinum: $f_0 = 15{,}1 \times 10^{14}$ Hz ($1{,}51\times10^{15}$ Hz)

GRAPH FOR ACTIVITY 3,1: Question 2

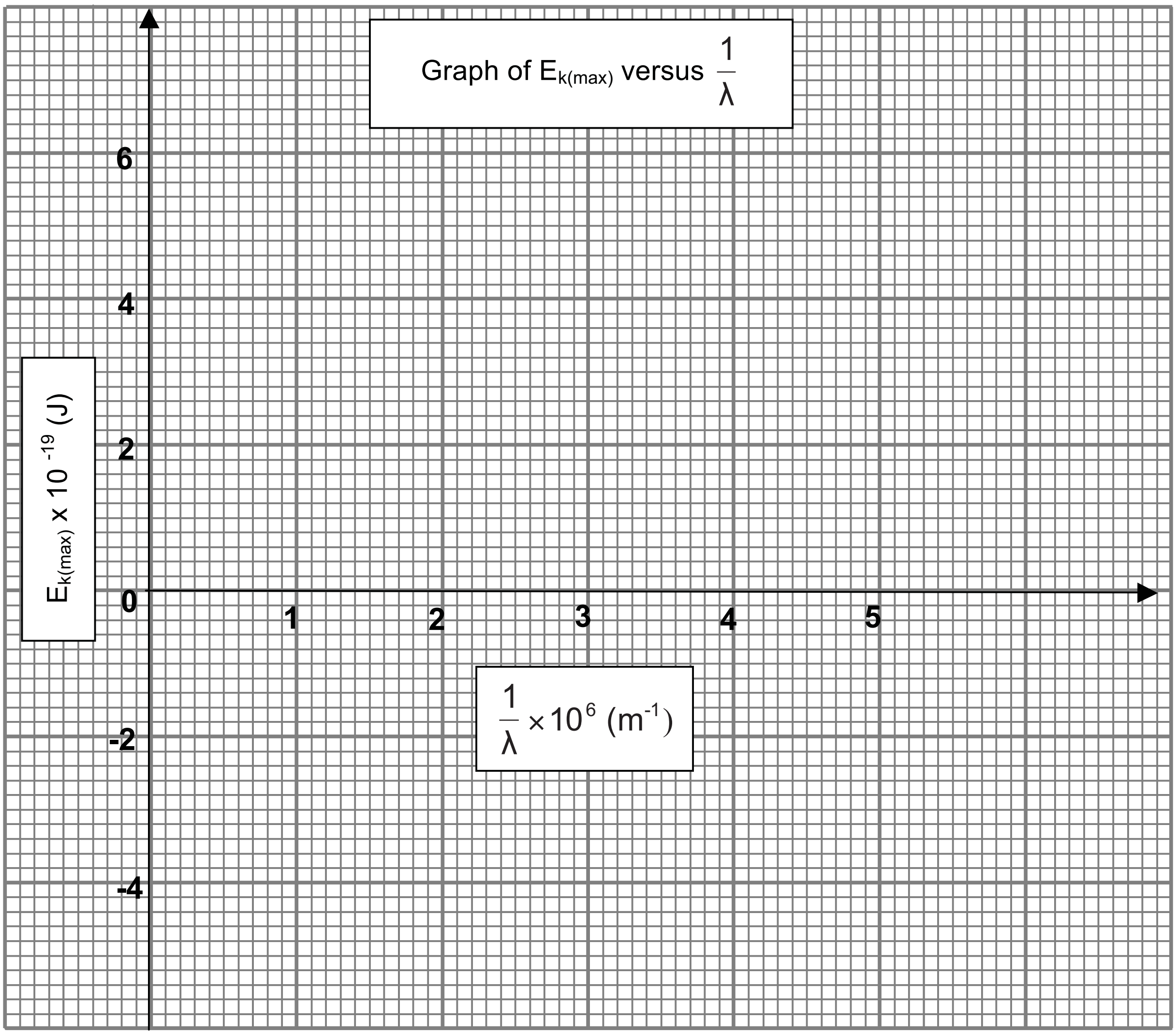


2. Study the graphs on the graph paper provided on this page.

2.1 Identify the element whose graph is:
2.1.1 **A** **ANSWER:** Caesium
2.1.2 **B** **ANSWER:** Calcium Reason: $w_0 = 4{,}3 \times 10^{-19}$ J and $f_0 = 6{,}5 \times 10^{14}$ Hz
2.2 Give a reason for your answer in 2.1.1: Reason: $w_0 = 3{,}0 \times 10^{-19}$ J and $f_0 = 4{,}4 \times 10^{14}$ Hz
2.3 Use graph **A** to calculate Planck's constant **ANSWER:** $6{,}55 \times 10^{-34}$ J.s
2.4 Draw the graph of sodium on the same set of axes for **A** and **B**. Label it **C**.

ACTIVITY 3.2

GRAPH PAPER FOR ACTIVITY 3.2: Question 3.2.2 and 3.2.3 below



In an experiment to demonstrate the photoelectric effect, light of different wavelengths was shone onto a metal surface of a photoelectric cell. The maximum kinetic energy of the emitted electrons was determined for the various wavelengths and recorded in the table on page 15.

INVERSE OF WAVELENGTH $\frac{1}{\lambda}$ **(× 10^6 m^{-1})**	**MAXIMUM KINETIC ENERGY** $E_{k(max)}$ **(× 10^{-19} J)**
5,00	6,60
3,30	3,30
2,50	1,70
2,00	0,70

3.2.1 What is meant by the term *photoelectric effect?* (2)

3.2.2 Draw a graph of $E_{k(max)}$ (y-axis) versus $\frac{1}{\lambda}$ (x-axis) ON THE GRAPH PAPER PROVIDED ON PAGE 14. (3)

3.2.3 USE THE GRAPH to determine:

3.2.3.1 The threshold frequency of the metal in the photoelectric cell (4)

HINT: $f_0 = c\,\frac{1}{\lambda_0}$

ANSWER: $4{,}8 \times 10^{14}$ Hz

3.2.3.2 Planck's constant

HINT: hc = gradient

(4)

ANSWER: $6{,}47 \times 10^{-34}$ J.s or $6{,}67 \times 10^{-34}$ J.s or $6{,}53 \times 10^{-34}$ J.s **[13]**

LESSON 4: VOLUME-VOLUME CALCULATIONS

Study Tips: Volume-volume calculations in chemical equations involving gases depend on the following principle: If temperature (T) and pressure (P) are constant, then volume (V) is directly proportional to moles (n) for each gas in the balanced chemical equation.

Proof: pV = nRT. If p and T are constant, then $V \propto n$ since R is also constant.
i.e. $\frac{V}{n} = R$ = a constant

EXAMPLES

1. If 7 g of N_2(g) occupy a volume of 11, 2 dm^3 at constant temperature and pressure, then 22 g of CO_2(g) will also occupy 11,2 dm^3 at the same temperature and pressure. Reason:

$$n(N_2) = \frac{m}{M} = \frac{7}{14} = 0,5 \quad \text{and} \quad n(CO_2) = \frac{m}{M} = \frac{22}{44} = 0,5$$

2. During the catalytic oxidation of ammonia in the Ostwald process, 8 cm^3 of NH_3(g) react with 20 cm^3 of O_2(g). Assume that the temperature and pressure remain constant. The balanced equation for the reaction taking place is:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

2.1 Determine which reactant is the limiting reagent.

ANSWER: NH_3
Explanation:

$$\underset{4\text{ moles}}{4NH_3(g)} + \underset{5\text{ moles}}{5O_2(g)} \rightarrow 4NO(g) + 6H_2O(g)$$

Since $V \propto n$,
4 moles of NH_3 are equivalent to 8 cm^3 of NH_3
1 mole of NH_3 is equivalent to $\frac{1}{4} \times 8cm^3$ = 2 cm^3 of NH_3
The volume of O_2 that is required to react with 8 cm^3 of NH_3 is:

$$2\ cm^3 \times 5 = 10\ cm^3 < 20\ cm^3$$

$\therefore$ The O_2 is in excess (because the NH_3 can react only with 10 cm^3 of O_2)

Study Tips: Determining a reactant that is the limiting reactant is not easy. The technique used in the explanation of the answer to 2.1, first finds the volume of NH_3 that is equivalent to ONE MOLE of NH_3. It then uses this volume of NH_3 to find the volume of the other reactant as follows: volume of 1 mole NH_3 x number of moles of the other reactant.

This technique is also used to answer 2.2 and 2.3 below

Calculate:

2.2 The volume of NO(g) and H_2O(g) that are formed
Answer: Volume of NO = volume of 1 mole NH_3x mol NO = 2 cm^3 x 4 = 8 cm^3.
Similarly: Volume of H_2O = 2 cm^3 x 6 = 12 cm^3

2.3 The volume of the reactant molecule that is in excess.
Volume in excess = 20 – 10 = 10 cm^3

ACTIVITY 4.1

4.1 During a combustion reaction, 8 cm^3 of butane react in excess oxygen according to the following balanced equation:

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

Assume that temperature and pressure remains constant. If the initial volume of the oxygen was 60 cm^3, calculate the:

4.1.1 Volume of O_2(g) that is in excess. ANSWER: 8 cm^3
4.1.2 Volume of CO_2(g) that is produced. ANSWER: 32 cm^3
4.1.3 Volume of H_2O(g) that is produced. ANSWER: 40 cm^3

LESSON 5: CHEMICAL EQUILIBRIUM

An unknown gas, X_2(g), is sealed in a container and allowed to form X_3(g) at 300 °C. The reaction reaches equilibrium according to the following balanced equation:

$$3X_2(g) \rightleftharpoons 2X_3(g)$$

5.1 How will the rate of formation of X_3(g) compare to the rate of formation of X_2(g) at equilibrium? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

ANSWER: EQUAL TO

REASON: Because the reaction is at equilibrium, the rate of the forward and reverse reactions must be EQUAL. (Refer to the definition of chemical equilibrium on page 20 of the EG)

Study Tips: Every definition, principle and law that is examinable is in the EG. You need to remember them and reproduce them in the Final examination. In each question paper, P1 and P2, 15% (23 marks) is allocated to statements of definitions, principles and laws. DO NOT LEARN DEFINITIONS THAT ARE NOT IN THE EG. THEY MAY NOT BE ACCEPTED.

The reaction mixture is analysed at regular time intervals. The results obtained are shown in the table below.

Table 2

TIME (s)	**[X_2] ($mol \cdot dm^{-3}$)**	**[X_3] ($mol \cdot dm^{-3}$)**
0	0,4	0
2	0,22	0,120
4	0,08	0,213
6	0,06	0,226
8	0,06	0,226
10	0,06	0,226

5.2 Calculate the equilibrium constant, K_c, for this reaction at 300 °C. (4)

ANSWER

$$K_c = \frac{[X_3]^2}{[X_2]^3} = \frac{(0{,}226)^2}{(0{,}06)^3} = 236{,}46$$

Study Tips: You must be able to interpret information in tables. You must be able to use your knowledge of chemical equilibrium to obtain the correct data from the table for the K_c calculation. The principle used to obtain the data from the table is: IF A REACTION IS IN EQUILIBRIUM, THE CONCENTRATION OF EACH REACTANT AND EACH PRODUCT WILL REMAIN CONSTANT.

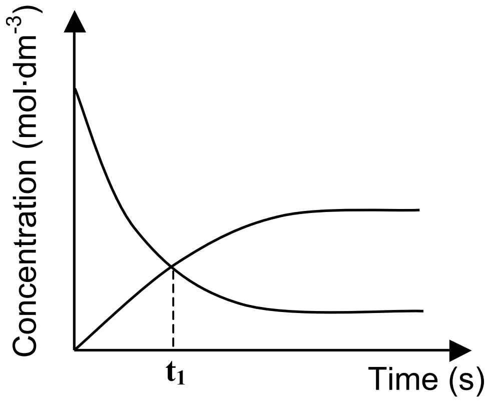
5.3 More $X_3(g)$ is now added to the container.

5.3.1 How will this change affect the amount of $X_2(g)$? Write down INCREASES, DECREASES or REMAINS THE SAME. (1)

5.3.2 Use Le Chatelier's principle to explain the answer to QUESTION 5.3.1. (2)

ANSWER: 5.3.1 INCREASES
ANSWER: 5.3.2: The reverse reaction that reduces (opposes) this increase is favoured.

The curves on the set of axes below (not drawn to scale) were obtained from the results in Table 2.



5.4 How does the rate of the forward reaction compare to that of the reverse reaction at t_1? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

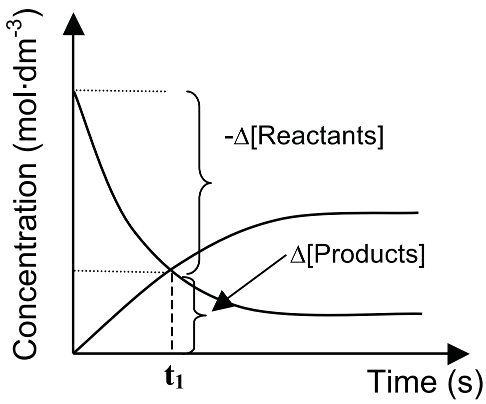
ANSWER: HIGHER THAN

EXPLANATION:

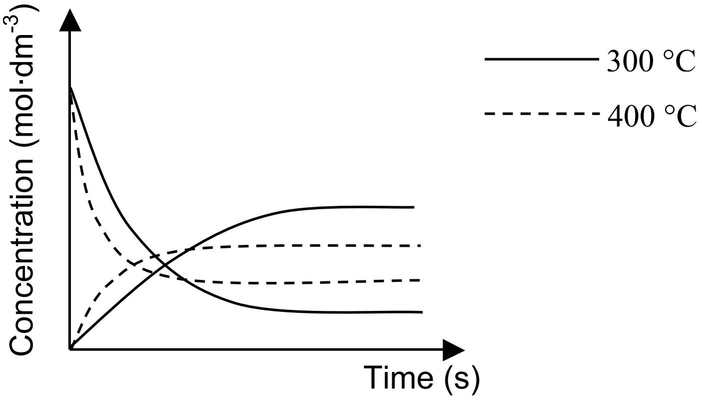
Use the definition of reaction rate:

$$\text{Reaction rate} = \frac{-\Delta[\text{Reactants}]}{\Delta t} = \frac{\Delta[\text{Products}]}{\Delta t}$$

You can see from the diagram on the right that:
$-\Delta$[Reactants] > Δ[Products] for the same time t_1.



The reaction is now repeated at a temperature of 400 °C. The curves indicated by the dotted lines below were obtained at this temperature.



5.5 Is the forward reaction EXOTHERMIC or ENDOTHERMIC? Fully explain how you arrived at the answer. (4)

ANSWER: Exothermic

EXPLANATION
At the higher temperature (dotted lines) the concentration of the reactants increased and the concentration of the products decreased. The reverse reaction is favoured. Increase in temperature favours the endothermic reaction.

LESSON 6: APPLICATION OF THE MOLE

Study Tips: In this lesson you need to have a good understanding of the mole concept. In particular you need to know how to convert:

- Volume and concentration to moles: Use $n = cV$ or $c = \frac{n}{V}$**.** REMEMBER: V must be in dm^3.

> How to convert cm^3 to dm^3: Divide by 1000.
>
> Technique to use:
>
> STEP 1: Write down how many cm equals 1 dm viz. 10 cm = 1 dm
> STEP 2: Cube both sides: $(10\ cm)^3 = (1\ dm)^3$
> STEP 3: Simplify: $10^3\ cm^3 = 1^3\ dm^3$ i.e. $1000\ cm^3 = 1\ dm^3$
> **NOTES**: Apply the indice law: $(ab)^n = a^n \times b^n$ in STEP 2 to get to STEP 3.
> APPLY THE SAME PROCEDURE TO CHANGE UNITS OF MEASUREMENT TO OTHER UNITS OF MEASREMENT.

- Moles to mass and mass to moles: Use $m = nM$ or $n = \frac{m}{M}$ where n represents moles, m represents mass and M represents molar mass.

EXAMPLE

8 g of commercial caustic soda are made into an aqueous solution of volume 200 cm^3.
10 cm^3 of this solution are neutralised by 14,5 cm^3 of a nitric acid solution of concentration 0,52 $mol.dm^{-3}$. Calculate the percentage purity of the commercial caustic soda.

Study Tips: If you look at any CAPS Grade 12 Chemistry question paper (those from November 2014 onwards) you must see a question similar to this one. Therefore you need to master this type of problem.

PROBLEM SOLVING STRATEGY

STEP 1: Understand the problem and have a method to get to the answer. The 8 g will form the denominator of a fraction that you will multiply by 100% to obtain the answer. You need to determine the mass that will form the numerator of the fraction using the given information. This mass should be smaller than 8 g.

Study Tips: General procedure: Start from the last sentence: Calculate … caustic soda. Work your way back to the first sentence. Remove the obstacle “caustic soda” by replacing it with NaOH.

STEP 2: Use the volume and concentration of the HNO_3 to find the moles of HNO_3 that reacted with 10 cm^3 NaOH(aq) solution. Use the formula: n = cV
STEP 3: Write down a balanced chemical equation for the reaction between NaOH and nitric acid. Deduce the moles of NaOH that reacted with the moles of HNO_3 in STEP 2 from the balanced equation.
STEP 4: The moles of NaOH in 10 cm^3 of the NaOH(aq) solution was determined in STEP 3. Find the moles of NaOH in 200 cm^3 of the NaOH(aq) solution. Use SIMPLE PROPORTION.
STEP 5: Calculate the mass of the moles of NaOH in STEP 4. Use the formula m = nM. This will be the numerator of the fraction mentioned in STEP 1.
STEP 6: Calculate the percentage purity of the commercial NaOH.

ANSWER

Begin at the last sentence and work your way to the first sentence.
First calculate the mass of NaOH that forms the numerator of the fraction in STEP 1:

$$n(HNO_3) = cV = (0{,}52)(\frac{14{,}5}{1000}) = (0{,}52)(0{,}0145) = 0{,}00754 \text{ mol.}$$

$$\underset{\text{1 mole}}{NaOH} + \underset{\text{1 mole}}{HNO_3} \rightarrow NaNO_3 + H_2O$$

Since the mol ratio NaOH : HNO_3 = 1:1 in the balanced chemical equation,
$n(HNO_3) = n(NaOH) = 0{,}00754$ mol
Using SIMPLE PROPORTION, determine the n(NaOH) in 200 cm^3 NaOH(aq):
If 10 cm^3 of the NaOH(aq) contains 0,00754 moles of NaOH
Then 200 cm^3 of NaOH(aq) will contain $\frac{200}{10} \times 0{,}00754 = 0{,}1508$ mol of NaOH

$\therefore$ The mass of NaOH in the 200 cm^3 NaOH(aq) solution = m(NaOH)
= nM
= (0,1508)(40)
= 6,03 g (accept 6,032 g)

Finally, multiply the fraction by 100%:

Percentage purity of the commercial NaOH = $\frac{6{,}03}{8} \times 100\%$ = 75,38%

STUDY TIPS:

- Only approximate your final answer correct to the 2^{nd} decimal place.
- Do not approximate any other decimal numbers in your calculations.

ACTIVITY 6.1

Follow the steps in the example to solve the following problem:

6.1 A certain fertiliser consists of 92% ammonium chloride. A sample of mass x g of this fertiliser is dissolved in 100 cm^3 of a 0,10 $mol{\cdot}dm^{-3}$ sodium hydroxide solution, NaOH(aq). The NaOH is in excess.

The balanced equation for the reaction is:

$$NH_4C\ell(s) + NaOH(aq) \rightarrow NH_3(g) + H_2O(\ell) + NaC\ell(aq)$$

6.1.1 Calculate the number of moles of sodium hydroxide in which the sample is dissolved. (3)

During a titration, 25 cm^3 of the excess sodium hydroxide solution is titrated with a 0,11 $mol{\cdot}dm^{-3}$ hydrochloric acid solution, HCℓ(aq). At the endpoint it is found that 14,55 cm^3 of the hydrochloric acid was used to neutralise the sodium hydroxide solution according to the following balanced equation:

$$HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$$

6.1.2 Calculate the mass x (in grams) of the fertiliser sample used. (8)

ANSWERS: 6.1.1 0,01 mol 6.1.2 0,21 g