PHYSICAL SCIENCES

PAPER 2 AND PAPER 1

GRADE 12

TERMS & DEFINITIONS

QUESTIONS & ANSWERS PER TOPIC

2019

AUTUMN CLASSES WEEK 1

This document consists of 33 pages.

PROGRAMME

DAY	ACTIVITY	PAGE	TIME
1	**PRE-TEST**		45 MIN
	Electrostatics: One dimension (1D)	7 - 9	1 HOUR: 15 MIN
2	**Give feedback**: pre-test (Only electrostatics)		30 MIN
	Electrostatics: One and two dimension (1D and 2D)	10 - 12	1 HOUR 30 MIN
3	**Energy graphs** (Endothermic and exothermic graphs)	16 - 19	45 MIN
	Basic concepts of mole, Empirical formula, percentage composition.	24-25 33 - 36	1 HOUR: 15 MIN
4	**Stoichiometry**	26 – 32 36 - 38	2 HOURS
5	**Summary**: Electrostatics, Energy graphs, Stoichiometry.		2 HOURS

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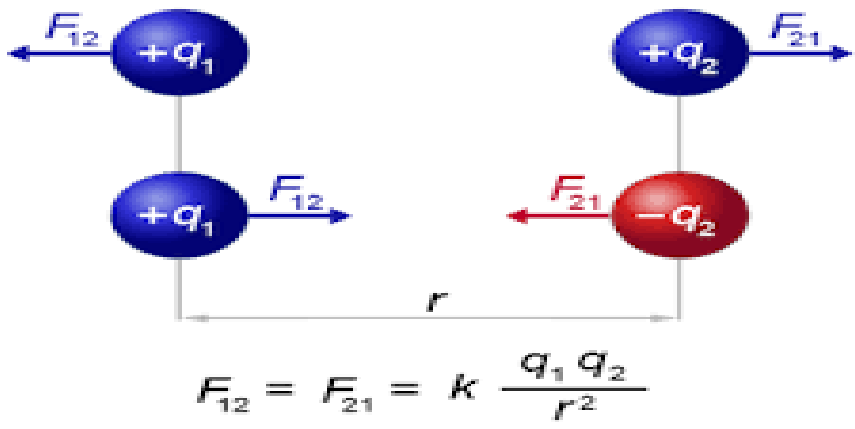
PHYSICAL SCIENCE

GRADE 12

ELECTROSTATICS



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Topic 14: Electrostatics (Grade 11)

Coulomb's law

- State **Coulomb's law**: **The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r)between them:**
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in one dimension (1D) (restrict to three charges).
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in two dimensions (2D) – for three charges in a right-angled formation (limit to charges at the 'vertices of a right- angled triangle').

Electric field

- Describe an *electric field* as a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
- Draw electric field patterns for the following configurations:
  - A single point charge
  - Two point charges (one negative, one positive OR both positive OR both negative)
  - A charged sphere
- Define the ***electric field at a point***: **The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point**. In symbols: $E = \frac{F}{q}$.
- Solve problems using the equation $E = \frac{F}{q}$.
- Calculate the electric field at a point due to a number of point charges, using the equation $E = \frac{kQ}{r^2}$ to determine the contribution to the field due to each charge. Restrict to three charges in a straight line.

ELECTRICITY AND MAGNETISM: ELECTROSTATICS	
Coulomb's law	The magnitude of the electrostatic force exerted by one point charge on another point charge is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them. In symbols: $F = \frac{kQ_1Q_2}{r^2}$
Electric field	A region of space in which an electric charge experiences a force.
Electric field at a point	The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point. In symbols: $E = \frac{F}{q}$ Unit: $N \cdot C^{-1}$
Direction of electric field	The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.

TABLE 1: PHYSICAL CONSTANTS/

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Acceleration due to gravity *Swaartekragversnelling*	g	$9,8\ m\cdot s^{-2}$
Universal gravitational constant *Universele gravitasiekonstant*	G	$6,67 \times 10^{-11}\ N\cdot m^2\cdot kg^{-2}$
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	$3,0 \times 10^{8}\ m\cdot s^{-1}$
Planck's constant *Planck se konstante*	h	$6,63 \times 10^{-34}\ J\cdot s$
Coulomb's constant *Coulomb se konstante*	k	$9,0 \times 10^{9}\ N\cdot m^2\cdot C^{-2}$
Charge on electron *Lading op elektron*	e^-	$-1,6 \times 10^{-19}\ C$
Electron mass *Elektronmassa*	m_e	$9,11 \times 10^{-31}\ kg$
Mass of Earth *Massa van Aarde*	M	$5,98 \times 10^{24}\ kg$
Radius of Earth *Straal van Aarde*	R_E	$6,38 \times 10^{3}\ km$

ELECTROSTATICS/

$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
$V = \frac{W}{q}$	$E = \frac{F}{q}$
$n = \frac{Q}{e}$ or / *of* $n = \frac{Q}{q_e}$	

ELECTROSTATICS

Study of charges at rest

Neutral (uncharged):
Number of protons = number of electrons

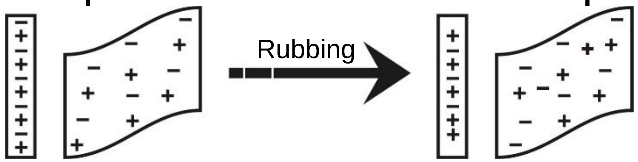
Quantisation of charge
All charges are multiples of the smallest charge i.e. the charge on one electron: $1{,}6 \times 10^{-19}$ C

Conservation of charge
Charge cannot be created or destroyed. It can only be transferred from one object to another.

Two kinds of charge

Positive: electron deficient
Negative: excess of electrons

Charging of objects
By contact: Electrons transferred from one object to another.



Rod: neutral
Cloth: neutral

Rod: positive (e^- lost)
Cloth: negative (e^- gained)

Electrostatic force

Like charges repel
Unlike charges attract

20

Coulomb's law

$F \propto Q_1Q_2$ and $F \propto \frac{1}{r^2}$

$\therefore F = \frac{kQ_1Q_2}{r^2}$ $k = 9 \times 10^9$

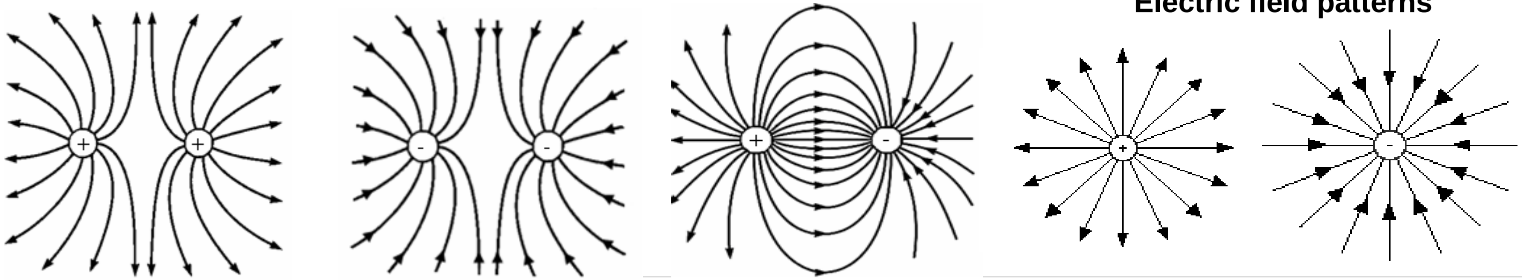
Electric field

Region in space where an electric charge experiences a force. Represented with field lines.

Definition of electric field: $E = \frac{F}{q}$

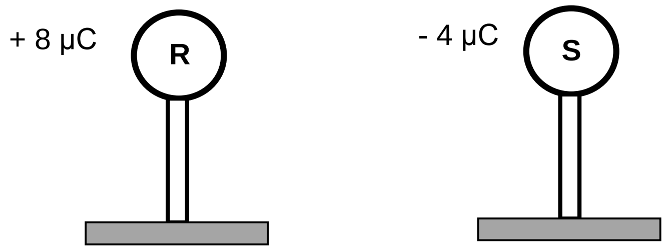
Electric field at a certain distance from a point charge
: E = kQ

Electric field patterns



QUESTION 1

The diagram below shows two small identical metal spheres, **R** and **S**, each placed on a wooden stand. Spheres **R** and **S** carry charges of + 8 μC and - 4 μC respectively. Ignore the effects of air.



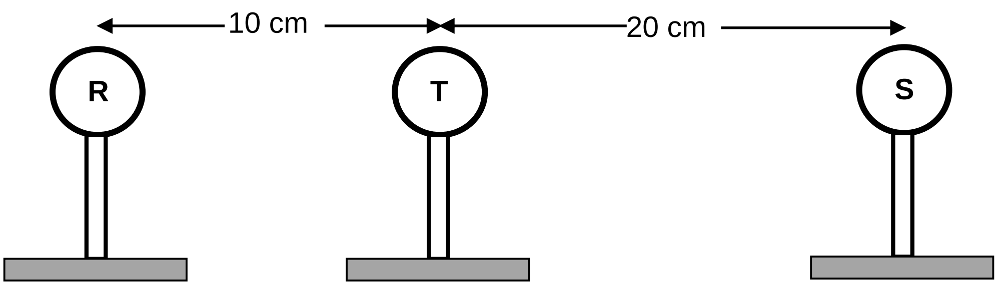
1.1 Explain why the spheres were placed on wooden stands. (1)

Spheres **R** and **S** are brought into contact for a while and then separated by a small distance.

1.2 Calculate the net charge on each of the spheres. (2)

1.3 Draw the electric field pattern due to the two spheres **R** and **S**. (3)

After **R** and **S** have been in contact and separated, a third sphere, **T**, of charge + 1 μC is now placed between them as shown in the diagram below.



1.4 Draw a free-body diagram showing the electrostatic forces experienced by sphere **T** due to spheres **R** and **S**. (2)

1.5 Calculate the net electrostatic force experienced by **T** due to **R** and **S**. (6)

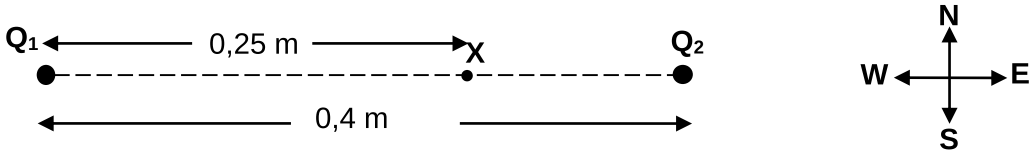
1.6 Define the *electric field at a point*. (2)

1.7 Calculate the magnitude of the net electric field at the location of **T** due to **R** and **S**. (Treat the spheres as if they were point charges.) (3)

[19]

QUESTION 2

Two charged particles, Q_1 and Q_2, are placed 0,4 m apart along a straight line. The charge on Q_1 is + 2 x 10^{-5} C, and the charge on Q_2 is – 8 x 10^{-6} C. Point **X** is 0,25 m **east** of Q_1, as shown in the diagram below.



Calculate the:

2.1 Net electric field at point **X** due to the two charges (6)

2.2 Electrostatic force that a – 2 x 10^{-9} C charge will experience at point **X** (4)

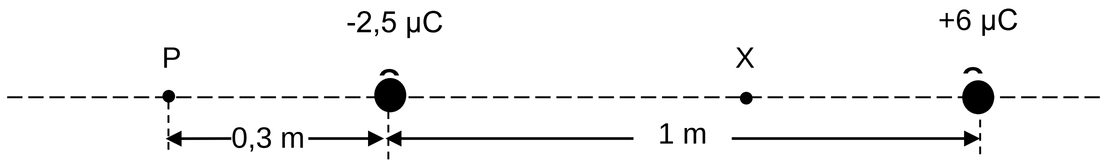
The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point **X**.

2.3 **Without any further calculation**, determine the magnitude of the force that the – 4 x 10^{-9} C charge will experience at point **X**. (1)

[11]

QUESTION 3

A sphere Q_1, with a charge of -2,5 μC, is placed 1 m away from a second sphere Q_2, with a charge +6 μC. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere Q_1, while point **X** is located between Q_1 and Q_2 . The diagram is not drawn to scale.



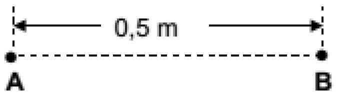
3.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** *cannot be zero.* (4)

3.2 Calculate the net electric field at point **P**, due to the two charged spheres Q_1 and Q_2. (6)

[10]

QUESTION 4

Two identical negatively charged spheres, **A** and **B**, having charges of the **same magnitude**, are placed 0,5 m apart in vacuum. The magnitude of the electrostatic force that one sphere exerts on the other is 1,44 x 10^{-1} N.



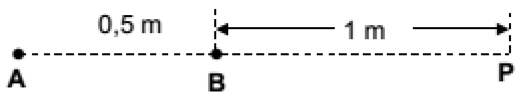
4.1 State Coulomb's law in words. (2)

4.2 Calculate the:

4.2.1 Magnitude of the charge on each sphere (4)

4.2.2 Excess number of electrons on sphere **B** (3)

4.3 **P** is a point at a distance of 1 m from sphere **B**.



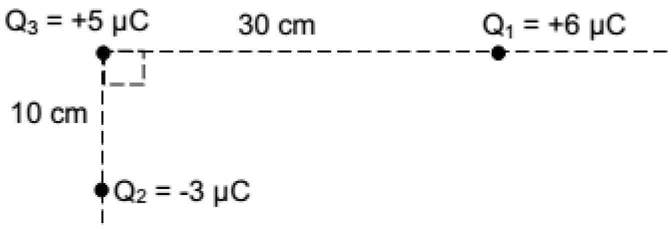
4.3.1 What is the direction of the net electric field at point **P**? (1)

B so that the net electric field at point **P** is 3 x 104 N·C^{-1} to the right. (8)

[18]

QUESTION 5

Three point charges, **Q_1**, **Q_2** and **Q_3**, carrying charges of +6 µC, -3 µC and +5 µC respectively, are arranged in space as shown in the diagram below.
The distance between **Q_3** and **Q_1** is 30 cm and that between **Q_3** and **Q_2** is 10 cm.

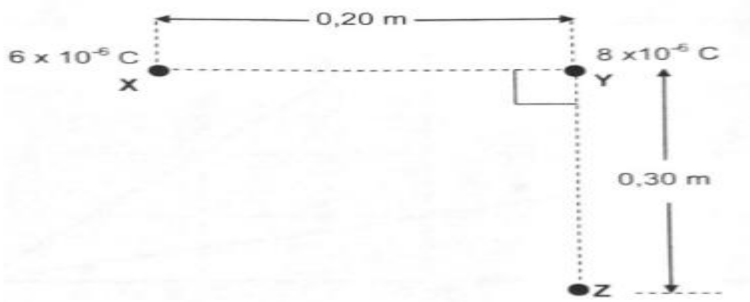


5.1 State Coulomb's law in words. (2)

5.2 Calculate the net force acting on charge **Q_3** due to the presence of **Q_1** and **Q_2**. (7)

[9]

QUESTION 6



6.1 Draw a vector diagram showing the direction of the electrostatic forces and the net force experienced charged sphere Y due to presence of charged spheres X and Z respectively. (10,70N) (3)

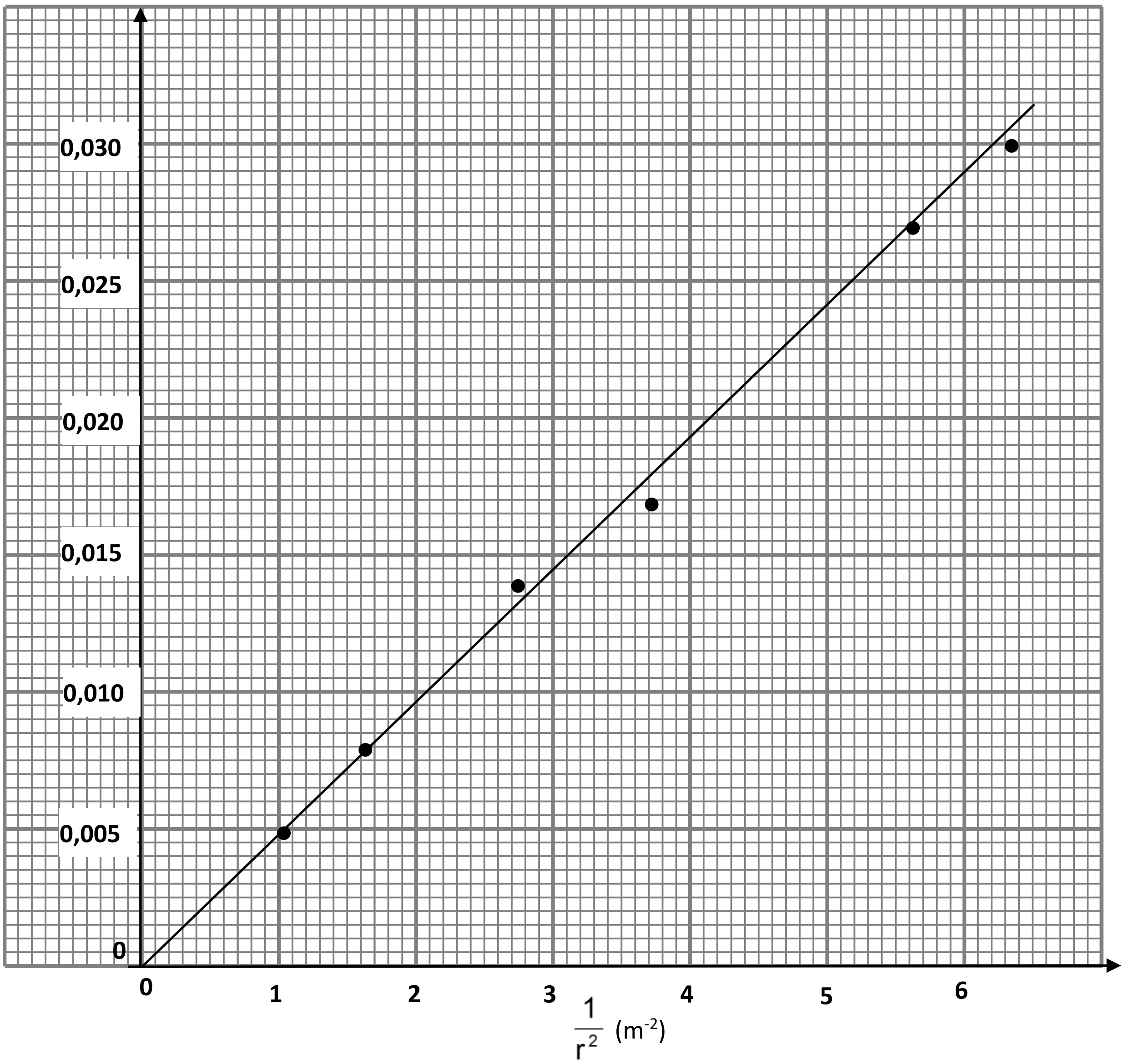
6.2 The magnitude of the net electrostatic force experienced by charged sphere Y is 15,20N. Calculate the charge on sphere Z. ($-13,37 \times 10^{-6}$C) (4)

[7]

QUESTION 7

7.1 In an experiment to verify the relationship between the electrostatic force, F_E, and distance, r, between two **identical**, positively charged spheres, the graph below was obtained.

GRAPH OF F_E VERSUS $\frac{1}{r^2}$



7.1.1 State Coulomb's law in words. (2)

7.1.2 Write down the dependent variable of the experiment. (1)

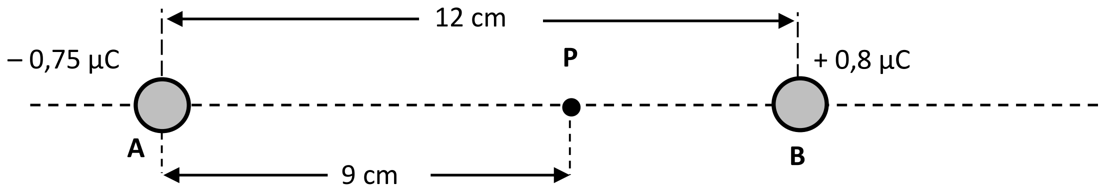
7.1.3 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

7.1.4 Use the information in the graph to calculate the charge on each sphere. (6)

7.2 A charged sphere, **A**, carries a charge of – 0,75 µC.

7.2.1 Draw a diagram showing the electric field lines surrounding sphere **A**. (2)

Sphere **A** is placed 12 cm away from another charged sphere, **B**, along a straight line in a vacuum, as shown below. Sphere **B** carries a charge of +0,8 µC. Point **P** is located 9 cm to the right of sphere **A**.



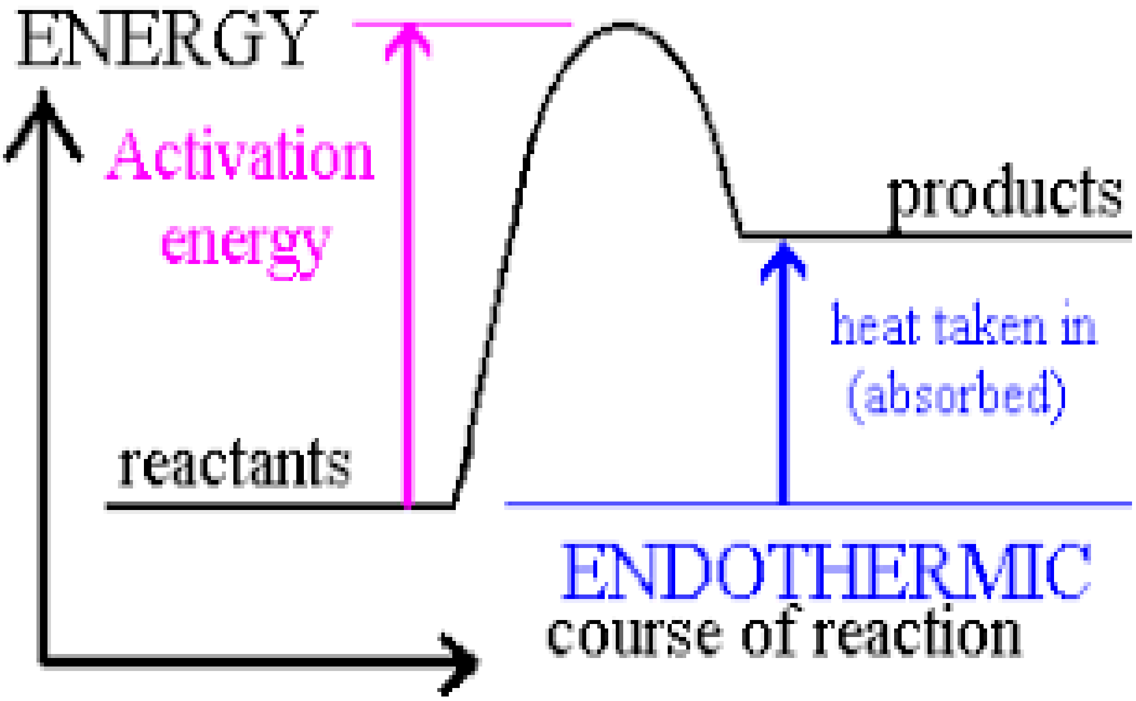
7.2.2 Calculate the magnitude of the net electric field at point **P**. (5)

[17]

PHYSICAL SCIENCE

GRADE 12

ENERGY CHANGES IN CHEMICAL REACTIONS



ENERGY AND CHEMICAL CHANGE

REVISION GRADE 11

Topic 10: Energy and Change (Grade 11)

Energy changes in reactions related to bond energy changes
- Define *heat of reaction* (ΔH) as the energy absorbed or released in a chemical reaction.
- Define ***exothermic reactions*** as **reactions that release energy**.
- Define ***endothermic reactions*** as **reactions that absorb energy**.
- Classify (with reason) reactions as exothermic or endothermic.

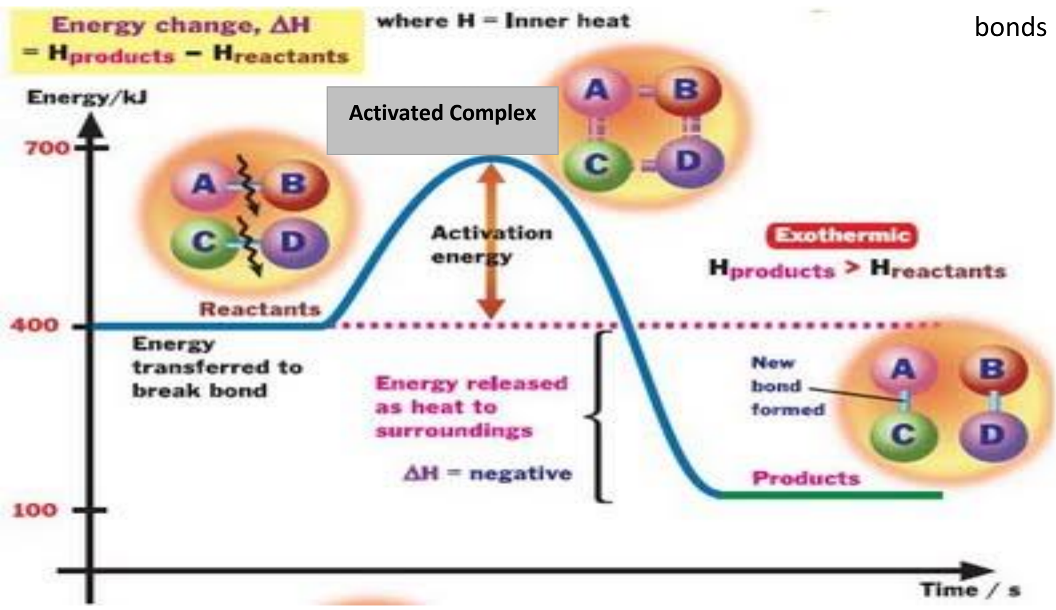
Exothermic and endothermic reactions
- **State that ΔH > 0 for endothermic reactions, i.e. reactions in which energy is absorbed.**
- **State that ΔH < 0 for exothermic reactions, i.e. reactions in which energy is released.**

Activation energy
- Define ***activation energy*** as **the minimum energy needed for a reaction to take place**.
- Define an ***activated complex*** as **the unstable transition state from reactants to products**.
- Draw or interpret fully labelled sketch graphs (potential energy versus course of reaction graphs) of catalysed and uncatalysed endothermic and exothermic reactions.

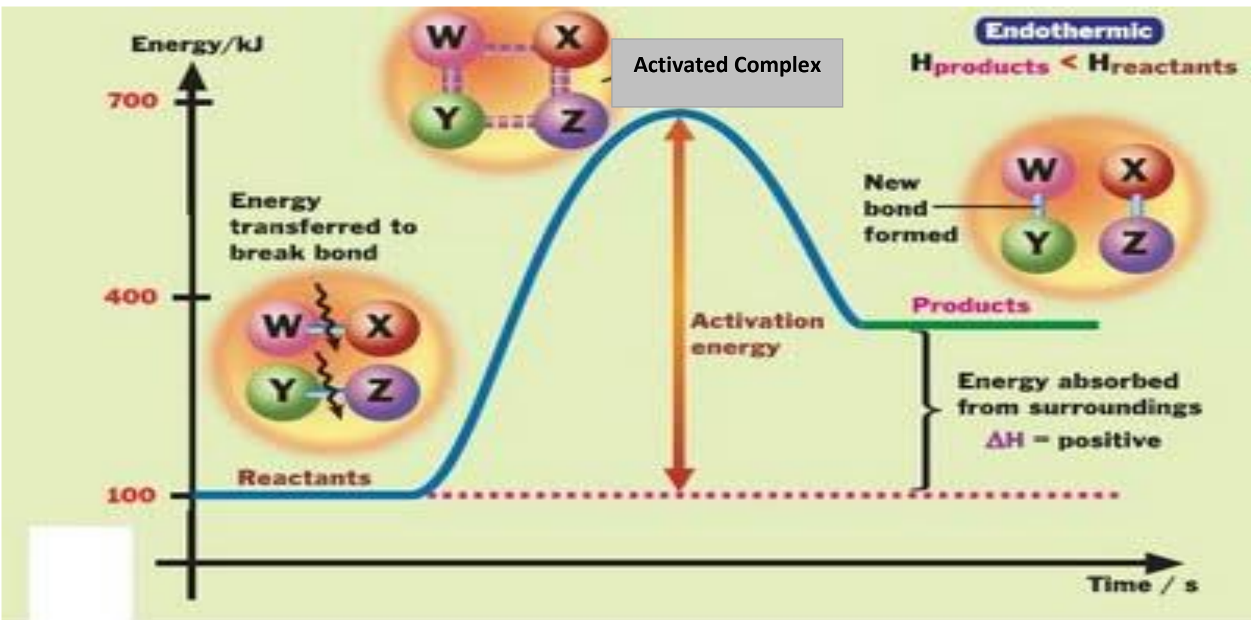
CHEMICAL CHANGE: ENERGY AND CHANGE	
Heat of reaction (ΔH)	The energy absorbed or released in a chemical reaction.
Exothermic reactions	Reactions that release energy. (ΔH < 0)
Endothermic reactions	Reactions that absorb energy. (ΔH > 0)
Activation energy	The minimum energy needed for a reaction to take place.
Activated complex	The unstable transition state from reactants to products.

ENERGY LEVEL DIAGRAMS OF EXOTHERMIC REACTION

In activated complex bonds in reactants are breaking while new bonds (in products) are formed.



ENERGY LEVEL DIAGRAM OF ENDOTHERMIC REACTION



QUESTION 1

Hydrogen gas and oxygen gas react to form water according to the following balanced equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 241{,}8\ kJ{\cdot}mol^{-1}$$

The activation energy (E_A) for this reaction is 1 370 kJ·mol^{-1}.

1.1 Define the term *activation energy*. (2)

1.2 Sketch a potential energy versus reaction coordinate graph for the above reaction. Clearly label the axes and indicate the following on the graph:

- ΔH
- E_A for the forward reaction
- Reactants (**R**) and products (**P**)
- Activated complex (**X**)

(5)

1.3 Write down the value of the:

1.3.1 Heat of reaction (1)

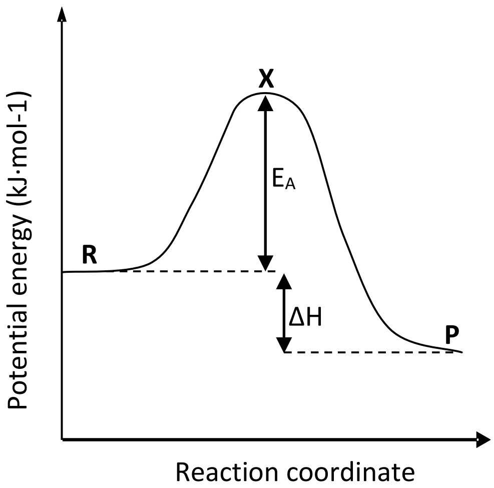
1.3.2 Activation energy for the following reaction:

$2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$ (2)

SOLUTION

2.1 The minimum energy needed for a reaction to take place. (2)

2.2



2.3.1 - 241,8 kJ•mol^{-1}

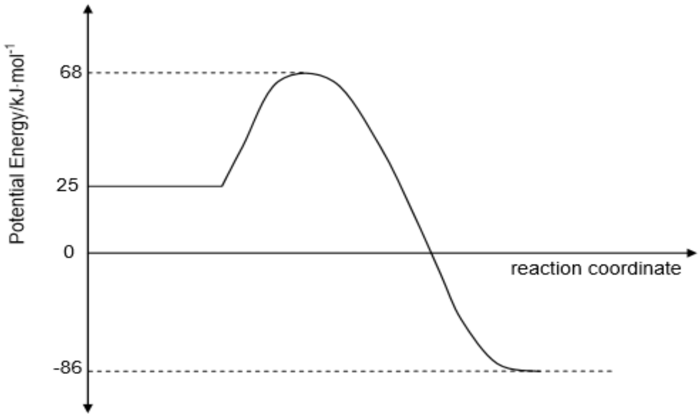
2.3.2 1 611,8 kJ•mol^{-1}

QUESTION 2

One of the steps in the preparation of sulphuric acid in the industry is represented by the following reversible reaction:

$$2SO_2(g) \quad + \quad O_2(g) \quad \rightleftharpoons \quad 2SO_3(g)$$

The graph below shows the energy change during this reaction.



2.1 Write down the type of reaction represented by above graph. Choose from EXOTHERMIC or ENDOTHERMIC. Explain your answer. (2)

2.2 Calculate the enthalpy change of this reaction. (3)

At 68 kJ·mol^{-1} an activated complex is formed.

2.3 Define the term activated complex. (2)

2.4 Calculate the activation energy for the reverse reaction. (2)

SOLUTION

2.1 Exothermic

Products have a lower energy than the reactants

so that more molecules will have an energy equal or greater than the activation energy to take part in the reaction.

2.2 $\Delta H = E_P - E_R$

$= -86 - 25$

$= -111$ kJ·mol^{-1}

2.3 An unsatble (transition) state from reactants to products

2.4 Δ Ea = 68 – (-86) = 154 kJ.mol^{-1}

ACTIVITY

QUESTION 1

The following reaction takes place in a flask:

$$Ba(OH)2.8H_2O(s) + 2NH_4NO_3(aq) \rightarrow Ba(NO_3)2(aq) + 2NH_3(aq) + 10H_2O(l)$$

Within a few minutes, the temperature of the flask drops by approximately 20°C.

1.1 Is the above reaction endothermic or exothermic? Explain. (2)

(Endothermic drop in temperature /Δ H > 0)

1.2 Define the term heat of reaction. (2)

1.3 Define activation energy? (2)

1.4 Draw a labelled potential energy curve for this reaction. Indicate the following:

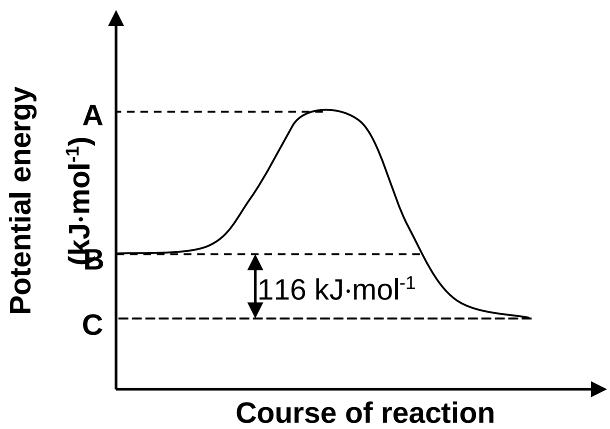
- Labelled x-axis and y-axis
- Position of reactants (R) and products (P)
- Activation energy
- Heat of reaction
- On the graph, indicate the effect of a catalyst with a dotted line. (6)

QUESTION 2

A barium hydroxide solution, $Ba(OH)_2(aq)$, reacts with a nitric acid solution, $HNO_3(aq)$, according to the following balanced equation:

$$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(\ell)$$

The potential energy graph below shows the change in potential energy for this reaction.



2.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (EXOTHERMIC $\Delta H < 0$) (2)

2.2 Use energy values A, B and C indicated on the graph and write down an expression for each of the following:

2.2.1 The energy of the activated complex (A) (1)

2.2.2 The activation energy for the forward reaction.(B - A) (1)

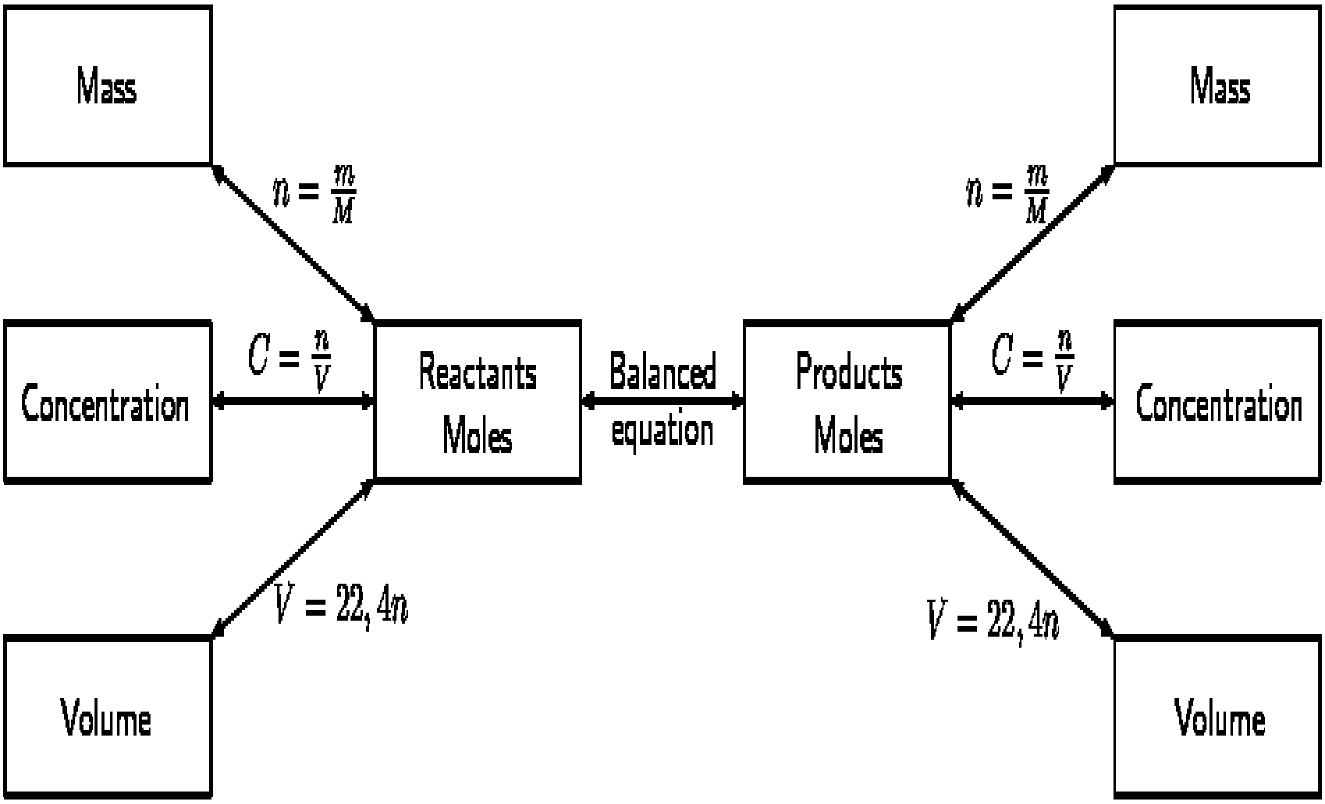
2.2.3 ΔH for the reverse reaction. (C – B) (1)

2.3 Calculate the amount of energy released during the reaction if 0,18 moles of $Ba(OH)_2(aq)$ reacts completely with the acid.(20,88KJ) (3)

PHYSICAL SCIENCE

GRADE 12

QUANTITATIVE AS ASPECTS OF CHEMICAL CHANGE



QUANTITATIVE AS ASPECTS OF CHEMICAL CHANGE

REVISION GRADE 11

Topic 9: Quantitative Aspects of Chemical Change (Grade 11)

Molar volume of gases
- 1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa).

Volume relationships in gaseous reactions
- Interpret balanced equations in terms of volume relationships for gases, i.e. under the same conditions of temperature and pressure, equal number of moles of all gases occupy the same volume.

Concentration of solutions
- Calculate the molar concentration of a solution.

More complex stoichiometric calculations
- Determine the empirical formula and molecular formula of compounds.
- Determine the percentage yield of a chemical reaction.
- Determine percentage purity or percentage composition, e.g. the percentage $CaCO_3$ in an impure sample of seashells.
- Perform stoichiometric calculations based on balanced equations.
- Perform stoichiometric calculations based on balanced equations that may include limiting reagents.

CHEMICAL CHANGE: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE	
Mole	One mole of a substance is the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
Molar gas volume at STP	The volume of one mole of a gas. (1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa).
Molar mass	The mass of one mole of a substance. Symbol: M Unit: $g{\cdot}mol^{-1}$
Avogadro's Law	Under the same conditions of temperature and pressure, the same number of moles of all gases occupy the same volume.
Concentration	The amount of solute per litre/cubic decimeter of solution. In symbols: $c = \frac{n}{V}$ Unit: $mol{\cdot}dm^{-3}$
Empirical formula	The simplest positive integer ratio of atoms present in a compound.
Percentage yield	Yield is the amount of product obtained from a reaction. $\text{percentage yield} = \frac{\text{actual mass obtained}}{\text{calculated mass}} \times 100$
Percentage purity	$\text{percentage purity} = \frac{\text{mass of pure chemical}}{\text{total mass of sample}} \times 100$
Percentage composition	The percentage of each of the components in a substance. $\text{Percentage of component} = \frac{\text{mass contribute d by component}}{\text{mass of all components}} \times 100$
Limiting reagents	The substance that is totally consumed when the chemical reaction is complete.

TABLE 1: PHYSICAL CONSTANTS/

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Standard pressure *Standaarddruk*	p^{θ}	$1{,}013 \times 10^{5}$ Pa
Molar gas volume at STP *Molêre gasvolume by STD*	V_m	$22{,}4\ dm^{3}\cdot mol^{-1}$
Standard temperature *Standaardtemperatuur*	T^{θ}	273 K
Charge on electron *Lading op elektron*	e	$-1{,}6 \times 10^{-19}$ C
Avogadro's constant *Avogadro-konstante*	N_A	$6{,}02 \times 10^{23}\ mol^{-1}$

TABLE 2: FORMULAE/

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$c = \frac{n}{V}$ or/*of* $c = \frac{m}{MV}$	$n = \frac{V}{V_m}$

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

KEY/*SLEUTEL*

- Atomic number / *Atoomgetal*: 29
- Electronegativity / *Elektronegatiwiteit*: 1,9
- Symbol / *Simbool*: Cu
- Approximate relative atomic mass / *Benaderde relatiewe atoommassa*: 63,5

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Aℓ 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cℓ 35,5	18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tℓ 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															

58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175
90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

MOLAR GAS VOLUME OF GASES

QUESTION 1

The airbags in motor vehicles contain the compound sodium azide (NaN_3). When a car crashes into an object, the compound decomposes and the nitrogen inflates the airbag. The balanced equation for the reaction is as follows:

$$2\ NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

In one such decomposition, 2,53 x 10^8 molecules of nitrogen are generated.

Calculate the:

1.1 Number of moles of NaN_3(s) that decomposed (4)

1.2 Volume of N_2(g) produced Assume that the reaction occurs at standard pressure. (3)

SOLUTION

1.1

$$n(N_2) = \frac{N}{N_A} \checkmark$$

$$= \frac{2{,}53 \times 10^8}{6{,}02 \times 10^{23}} \checkmark$$

$$= 4{,}2 \times 10^{-16} \text{ mol}$$

2 mol NaN_3 produces/*lewer* 3 mol N_2

$$\therefore n(NaN_3) = \frac{2}{3}(4{,}2 \times 10^{-16}) \checkmark$$

$$= 2{,}80 \times 10^{-16} \text{ mol} \checkmark$$

1.2

$$n(N_2) = \frac{V}{V_m} \checkmark$$

$$\therefore 4{,}2 \times 10^{-16} = \frac{V}{22{,}4} \checkmark$$

$$\therefore V = 9{,}41 \times 10^{-15} \text{ dm}^3 \checkmark$$

QUESTION 2

During a combustion reaction in a closed container of adjustable volume, 8 cm^3 of compound A (butane) reacts in excess oxygen according to the following balanced equation:

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

If the initial volume of the oxygen in the container was 60 cm^3, calculate the TOTAL volume of the gases that are present in the container at the end of the reaction. All the gases in the container are at the same temperature and pressure.

	C_4H_{10}	O_2	CO_2	H_2O
Initial V (cm^3)	8	60	0	0
Change in V (cm^3)	8	52	32	40
Final V (cm^3)	0	8	32	40

Total volume = 8 + 32 + 40 = 80 cm^3

ACTIVITY

QUESTION 1

What volume of oxygen is needed for the complete combustion of 300 cm^3 of propane (C_3H_8) according to the following equation at the same temperature and pressure? (1500cm^3/ 1,5 dm^3)

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O\ (g)$

QUESTION 2

Learners use the reaction between 25g IMPURE POWDERED calcium carbonate and excess hydrochloric acid to investigate reaction rate. The balanced equation for the reaction is:

$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell) + CO_2(g)$

When the reaction reaches completion, the volume of gas formed is 4,5dm^3. Assume that the molar gas volume at 40 °C is equal to 25,7 dm^3. Calculate the mass of the impurities present in the calcium carbonate. (7,49 g)

CONCENTRATION OF SOLUTIONS

QUESTION 1

Aluminium sulphate is used as a coagulant in water purification. It reacts with sodium hydroxide to form aluminium hydroxide which drags the impurities as it settles.

The balanced equation for the reaction is:

$A\ell_2(SO_4)_3(aq) + 6NaOH(aq) \rightarrow 2A\ell(OH)_3(s) + 3Na_2SO_4(aq)$

A chemist at a water purification plant adds 700 g of $A\ell_2(SO_4)_3$ to a sample of water.

1.1 Calculate the maximum mass of $A\ell(OH)_3$ that can be produced from this mass of $A\ell_2(SO4)_3$. (5)

The chemist now dissolves 0,85 mol of Na_2SO_4 in 250 cm^3 of distilled water. He then tops it up with enough distilled water to make a 1 litre solution.

1.2 Define, in words, the term concentration of a solution. (2)

1.3 Calculate the concentration of this Na_2SO_4 solution. (3)

SOLUTION

1.1

$$n[A\ell_2(SO_4)_3] = \frac{m}{M} = \frac{700}{342} \checkmark = 2{,}05 \text{ mol}$$

$$n[A\ell(OH)_3] = 2(2{,}05) \checkmark = 4{,}09 \text{ mol}$$

$$m[A\ell(OH)_3] = nM = (4{,}09)(78) \checkmark = 319{,}30 \text{ g} \checkmark$$

1.2 Amount of solute/dissolved substance per cubic decimetre of solution.

1.3

$$c(Na_2SO_4) = \frac{n}{V} \checkmark$$
$$= \frac{0,85}{250 \times 10^{-3}} \checkmark$$
$$= 3,40\ mol \cdot dm^{-3}$$

QUESTION 2

2.1 Sodium thiosulphate, $Na_2S_2O_3(s)$, reacts with 200 cm^3 of a hydrochloric acid solution, HCℓ(aq), of concentration 0,2 mol•dm^{-3} according to the following balanced equation:

$$Na_2S_2O_3(s) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + S(s) + SO_2(g) + H_2O(\ell)$$

2.1.1 Define the term concentration of a solution. (2)

2.1.2 Calculate the number of moles of HCℓ(aq) added to the sodium thiosulphate. (3)

2.1.3 Calculate the volume of $SO_2(g)$ that will be formed if the reaction takes place at STP. Assume the molar gas volume at STP is equal to 22,4dm^3 (3)

SOLUTION

2.1.1 Amount of solute/dissolved substance per cubic decimetre of solution.

2.1.2 C(HCl) = $\frac{n}{V}$

0,2 = $\frac{n}{0,2}$

n(HCl) = 0,04mol

2.1.3 2mol HCl reacts with 1 mol SO_2

n(SO_2) = $\frac{0,04}{2}$ = 0,02mol

n(SO_2) = $\frac{V}{V_M}$

0,02 = $\frac{V}{22,4}$

= 0, 45 dm^3

ACTIVITY

QUESTION 1

1.1 Define the term concentration. (2)

1.2 8 grams of $Na_2S_2O_3$ is dissolved in water to prepare 500 cm^3 of solution. Calculate the concentration of the $Na_2S_2O_3$ solution. (0,12mol.dm^{-3}) (3)

QUESTION 2

130 g of magnesium chloride ($MgCl_2$) is dissolved in 300 cm^3 of water.

2.1 Calculate the concentration of the solution. (4,56 mol.dm^{-3}) (3)

2.2 What mass of magnesium chloride would need to be added for the concentration to become 6,7 mol·dm^{-3}? (190,95g) (3)

STOICHIOMETRIC CALCULATIONS

LIMITING REACTANT AND PERCENTAGE YIELD

QUESTION 1

The chemical reaction for the production of the drug, aspirin, from two compounds, X and Y, is represented by the balanced equation below.

$2C_7H_6O_3 + C_4H_6O_3 \rightarrow 2C_9H_8O_4 + H_2O$

A chemist reacts 14 g of compound X with 10 g of compound Y.

1.1 Define the term limiting reactant in a chemical reaction. (2)

1.2 Perform the necessary calculations to determine which one of compound X or compound Y is the limiting reactant. (5)

The actual mass of aspirin obtained is 11,5 g.

1.3 Calculate the percentage yield of the aspirin. (5)

SOLUTION

1.1 The reactant that produces the least amount of product.

The reactant that will be used up first during a chemical reaction.

A reactant whose amount limits/determines the amount of product obtained in a chemical reaction.

1.2

$$n(X) = \frac{m}{M}$$
$$= \frac{14}{138} \checkmark$$
$$= 0{,}10 \text{ mol}$$

$$n(Y) = \frac{m}{M}$$
$$= \frac{10}{102} \checkmark$$
$$= 0{,}10 \text{ mol}$$

From balanced equation:

2mol (X) reacts with 1mol(Y)

∴ 0,1 mol of X needs0,05 mol of Y

The limiting reactant is X.

1.3 n(aspirin produced) = n(X) = 0,10 mol

$$n(\text{aspirin}/\textit{aspirien}) = \frac{m}{M}$$

$$\therefore 0{,}1 = \frac{m}{180} \checkmark$$

$$\therefore m(\text{aspirin}/\textit{aspirien}) = 18 \text{ g} \quad (18{,}26 \text{ g})$$

$$\% \text{ yield} = \left(\frac{\text{actual yield}}{\text{theoretical yield}}\right)100$$
$$= \frac{11{,}5}{18} \checkmark (100) \checkmark$$
$$= 63{,}90\% \checkmark \quad (62{,}98\%)$$

QUESTION 2

2.2 Iron (Fe) reacts with sulphur (S) to form iron sulphide (FeS) according to the following balanced equation:

$Fe(s) + S(s) \rightarrow FeS$

2.2.1 Calculate which of the two substances will be used up completely if 20 g of Fe and 10 g of S are mixed and heated. (5)

2.2.2 How many grams of the other substance are in excess? (2)

2.3 Magnesium burns in air to form magnesium oxide according to the following balanced equation:

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

If the percentage yield of this reaction is only 80%, calculate the mass of magnesium that needs to be burned to produce 30 g of magnesium oxide. (6)

SOLUTION

2.2.1

$$n(Fe) = \frac{m}{M}$$
$$= \frac{20}{56} \checkmark$$
$$= 0{,}357 \text{ mol Fe}$$

$$n(S) = \frac{m}{M}$$
$$= \frac{10}{32} \checkmark$$
$$= 0{,}313 \text{ mol S}$$

From balanced equation:

1 mol Fe reacts with1 mol S ✓

n(S) < n(Fe)

The limiting reactant is S. ✓

(5)

2.2.2

(3)

$$n(Fe\ used) = \frac{m}{M}$$

$$0,313 = \frac{m}{56} \checkmark$$

$\therefore$ m(Fe used) = 17,5 g

m(excess) = 20 – 17,5 ✓ = 2,5 g ✓

OPTION 1	OPTION 2
$n(MgO) = \frac{m}{M}$ $= \frac{30}{40} \checkmark$ $= 0,75$ mol From balanced equation n(Mg) = n(MgO) = 0,75 mol ✓ $n(Mg) = \frac{m}{M}$ $0,75 = \frac{m}{24} \checkmark$ $m(Mg) = 18$ g If 18 g Mg gives 80% yield, then mass Mg needed for 100% yield: 18 g ……………24 g MgO ✓ x g ……………..30 g ✓ $\therefore m(Mg) = \frac{(18)(30)}{24} = 22,5$ g ✓	$n(MgO) = \frac{m}{M}$ $= \frac{30}{40} \checkmark$ $= 0,75$ mol From balanced equation n(Mg) = n(MgO) = 0,75 mol ✓ If 0,75 mol Mg gives 80% yield, then mol Mg needed for 100% yield: 0,75 mol Mg …………80% ✓ x mol Mg……………..100% $n(Mg) = \frac{(0,75)(100)}{80} \checkmark$ = 0,9375 mol $n(Mg) = \frac{m}{M}$ $0,9375 = \frac{m}{24} \checkmark$ $\therefore m(Mg) = 22,5$ g

QUESTION 3

Hydrochloric acid reacts with an excess of magnesium chunks according to the following balanced equation:

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g) \qquad (\Delta H < 0)$$

Initially 200 cm^3 of a 3 $mol \cdot dm^{-3}$ HCℓ solution is added to 20 g of magnesium chunks. Calculate the mass of magnesium in excess.

SOLUTION

$$c = \frac{n}{V}$$

$$3 = \frac{n}{200 \times 10^{-3}} \checkmark$$

$\therefore n = 0,6$ mol

n(Mg reacted) = ½n(HCℓ) = 0,3 mol ✓

OPTION 1	Option 2	
m(Mg reacted $n(Mg) = \frac{m}{M}$ $\therefore 0,3 = \frac{m}{24}$ ✓ $\therefore m = 7,2$ g m(Mg) in excess: m = 2 0–7, 2✓ = 12,8 g ✓	n(Mg initially): $n = \frac{m}{M}$ $= \frac{20}{24}$ ✓ = 0,83 mol n(Mg in excess): n = 0,83 – 0,3 ✓ = 0,53 mol	m(Mg in excess): $n = \frac{m}{M}$ $0,53 = \frac{m}{24}$ $\therefore$ m = 12,72 g ✓

ACTIVITY

QUESTION 1

The fizz produced when an antacid dissolves in water is caused by the reaction between sodium hydrogen carbonate ($NaHCO_3$) and citric acid ($H_3C_6H_5O_7$). The balanced equation for the reaction is:

$3NaHCO_3(aq) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3CO_2(g) + 3H_2O(\ell)$

1.1 Write down the FORMULA of the substance that causes the fizz when the antacid dissolves in water. (1)

A certain antacid contains 1, 8 g of $H_3C_6H_5O_7$ and 3, 36 g of $NaHCO_3$. The antacid is dissolved in 100 cm^3 distilled water in a beaker.

1.2 Define 1 mole of a substance. (2)

1.3 Calculate the number of moles of $NaHCO_3$ in the antacid. (0,04mol) (3)

1.4 Using calculations, which substance is the limiting reagent? ($H_3C_6H_5O_7$) (4)

1.5 Calculate the mass of the reactant in excess. (0,84g) (3)

1.6 Calculate the mass decrease of the beaker contents on completion of the reaction. (1,32g) (3)

QUESTION 2

Learners made a mini volcano in a science laboratory by adding sodium bicarbonate to ethanoic acid. They added 100 mℓ of a 0,2 $mol.dm^{-3}$ ethanoic acid solution to 10 g of $NaHCO_3$ to start the reaction of the volcano.

The balanced equation for this reaction is:

$CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COONa(aq) + H_2O(\ell) + CO_2(g)$

2.1 Define the term limiting reagent. (2)

2.2 Determine the limiting reagent in this reaction. (CH_3COOH) (6)

2.3 Calculate the mass of the other substance in excess. (1,6g) (3)

2.4 Calculate the volume of CO_2 produced at STP. (0,45dm^3) (4)

EMPIRICAL AND MOLECULAR FORMULAE

QUESTION 1

1.1 Define the term molar mass of a substance. (1)

1.2 Calculate the number of moles of water in 100 g of water. (3)

1.3 Methyl benzoate is a compound used in the manufacture of perfumes. It is found that a 5,325 g sample of methyl benzoate contains 3,758 g of carbon, 0,316 g of hydrogen and 1,251 g of oxygen.

1.3.1 Define the term empirical formula. (2)

1.3.2 Determine the empirical formula of methyl benzoate. (7)

1.3.3 If the molar mass of methyl benzoate is 136 g·mol-1, what is its molecular formula? (2)

SOLUTION

1.1 The mass of one mole (of the substance).

1.2

$$n(H_2O) = \frac{m}{M} \checkmark$$

$$= \frac{100}{18} \checkmark$$

$$= 5{,}56 \text{ mol} \checkmark$$

1.3.1 Smallest whole number ratio of the elements that make up the substance.

1.3.2

$$\left.\begin{aligned} \%C &= \left(\frac{3{,}758}{5{,}325}\right)(100) = 70{,}573 \\ \%H &= \left(\frac{0{,}316}{5{,}325}\right)(100) = 5{,}934 \\ \%O &= \left(\frac{1{,}251}{5{,}325}\right)(100) = 23{,}493 \end{aligned}\right\} \checkmark$$

$$n = \frac{m}{M} \checkmark$$

$$n(C) = \frac{70{,}573}{12 \checkmark} = 5{,}881 \text{ mol}$$

$$n(H) = \frac{5{,}934}{1 \checkmark} = 5{,}934 \text{ mol}$$

$$n(O) = \frac{23{,}493}{16 \checkmark} = 1{,}468 \text{ mol}$$

mol C : mol H : mol O = 4 : 4 : 1 ✓

∴ C_4H_4O ✓

1.3.3 $M(C_4H_4O) = 4(12) + 4(1) + 16 = 68 \text{ g·mol}^{-1}$

$$\frac{136}{68} = 2$$

∴ Molecular formula: $C_8H_8O_2$

QUESTION 2

An ester contains 6,67% hydrogen (H), 40% carbon (C) and 53,33% oxygen(O). The molar mass of the ester is 60 g·mol^{-1}.

Use a calculation to determine its:

2.1 Empirical

2.2 Molecular formula

SOLUTION

2.1

$n(C) = \frac{40}{12} = 3{,}33$ mol

$n(H) = \frac{6{,}67}{1} = 6{,}67$ mol ✓

$n(O) = \frac{53{,}33}{16} = 3{,}33$ mol ✓

mol C : mol H : mol O = 1 : 2 : 1 ✓

∴ CH_2O ✓

2.2 $M(CH_2O) = (12) + 2(1) + 16 = 30$ g·mol^{-1}

$\frac{60}{30} = 2$

∴ Molecular formula: $C_2H_4O_2$

ACTIVITY

QUESTION 1

Vinegar, which is used in our homes, is a dilute form of acetic acid. A sample of acetic acid has the following percentage composition:

- 39,9 % carbon
- 6,7 % hydrogen
- 53, 4 % oxygen

1.1 Determine the empirical formula of acetic acid. (CH_2O) (5)

1.2 Determine the molecular formula of acetic acid if the molar mass of acetic acid is 60, 06 g•mol^{-1}. ($C_2H_4O_2$) (3)

QUESTION 2

Menthol, the substance we can smell in mentholated cough drops, is composed of carbon (C), hydrogen (H) and oxygen (O).

During combustion of a 9,984 g sample of menthol, it is found that

28,160 g of CO_2(g) and 11,520 g of H_2O(g) is produced.

2.1 Calculate the mass of carbon (C) in the CO_2.(7,68g) (4)

2.2 Calculate the empirical formula of menthol. ($C_{10}H_{20}O$) (7)

2.3 The molar mass of menthol is 156 g•mol^{-1}. Determine the molecular formula of menthol. ($C_{10}H_{20}O$) (2)

VOLUME RELATIONSHIPS IN GASEOUS REACTIONS

QUESTION 1

Sodium azide is sometimes used in airbags. When triggered, it has the following reaction:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

If 55 g of sodium azide is used, what volume of nitrogen gas would we expect to produce?

Solution

number of moles of sodium azide used is:

$$n = \frac{m}{M}$$

$$= \frac{55}{85}$$

$$= 0,85 \text{ mol}$$

mole ratio of NaN_3 to N_2 is 2:3. So the number of moles of N_2 is:

$$n(N_2) = \frac{0,85\ X\ 3}{2}$$

= 1,27 mol

V =(22,4)n =(22,4)(1,27) = 28,4 dm^3

QUESTION 2

Calcium carbonate chips are added to an excess dilute hydrochloric acid solution in a flask placed on a balance as illustrated below. The cotton wool plug in the mouth of the flask prevents spillage of reactants and products, but simultaneously allows the formed gas to escape. The balanced equation for the reaction that takes place is:

$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$

Calculate the mass of calcium carbonate needed to produce 4g of carbon dioxide when the reaction is completed. Assume that all the gas that was formed, escaped from the flask.

SOLUTION

$n(CO_2) = \frac{m}{M}$

$= \frac{4}{44}$

= 0,09 mol

$n(CaCO_3) = n(CO_2)$ = 0,09 mol

$m(CaCO_3)$ = nM

= (0,09) (100)

= 9 g

ACTIVITY

QUESTION 1

Consider the following reaction:

$CaCO_3 (s) + 2HCl (aq) \longrightarrow CaCl_2 (aq) + H_2O (l) + CO_2 (g)$

The reaction of calcium carbonate with excess of hydrochloric acid is determined by measuring the loss of mass of the reaction components in an open container. The following results were obtained:

Time **(min)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Lost mass **(g)**	**0,5**	**1,0**	**1,5**	**1,8**	**2,0**	**2,0**	**2,0**	**2,0**

2.1 Give the NAME of the gas that is liberated. (Carbon dioxide) (1)

2.2 What does the loss of mass represent? (CO_2 formed) (2)

2.3 Give a reason why the loss of mass remains constant after 5 minutes. (2)

(Reaction has stopped/ reached completion)

2.4 Calculate the volume of the gas liberated during the reaction. Assume the molar gas volume at 25^0C is equal to 24 dm^3.(1,09dm^3) (5)

QUESTION 2

Annalize is making a mini volcano for her science project. She mixes baking soda (mostly $NaHCO_3$) and vinegar (mostly CH_3COOH) together to make her volcano erupt. The reaction for this equation is:

$NaHCO_3(s) + CH_3COOH\ (aq) \rightarrow CH_3COONa\ (aq) + H_2O\ (l) + CO_2(g)$

What volume of carbon dioxide is produced if Annalize uses 50 cm^3 of 0,2 $mol{\cdot}dm^{-3}$ acetic acid?(0,24dm^3)