Western Cape Government
Education

Directorate: Curriculum FET

TELEMATICS

GRADE 12

PHYSICAL SCIENCES CAPS

ENGLISH

QUESTIONS, ANSWERS AND STUDY TIPS

REACTION RATE MECHANICAL ENERGY
ELECTROLYTIC CELLS ACIDS AND BASES

April 2015

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Term				
Date	**Time**	**Subject**	**Topic**	**Presenter**
Thursday 30 April	16:00 – 17:00	Physical Sciences	Reaction rate	D. de Storie
Monday 4 May	16:00 – 17:00	Fisiese Wetenskappe	Reaksietempo	M. Pretorius
Wednesday 17 June	16:00 – 17:00	Physical Sciences	Mechanical energy	D. de Storie
Thursday 18 June	16:00 – 17:00	Fisiese Wetenskappe	Meganiese energie	M. Pretorius

Term				
Date	**Time**	**Subject**	**Topic**	**Presenter**
Monday 3 August	16:00 – 17:00	Physical Sciences	Electrolytic cells	D. de Storie
Thursday 6 August	16:00 – 17:00	Fisiese Wetenskappe	Elektrolitiese selle	M. Pretorius
Monday 7 September	16:00 – 17:00	Physical Sciences	Acids and Bases	D. de Storie
Thursday 10 September	16:00 – 17:00	Fisiese Wetenskappe	Sure en Basisse	M. Pretorius

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LESSON 3: REACTION RATE

3.1 Consider the reaction below:

$$Cu(s) + 2Ag^{+}(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$$

Which ONE of the following about the average reaction rate for this reaction is incorrect?

A Reaction $Rate_{Av} = \frac{\Delta \text{ mass Cu}}{\Delta t}$

B Reaction $Rate_{Av} = \frac{\Delta \text{ mass Ag}}{\Delta t}$

C Reaction $Rate_{Av} = \frac{\Delta[Cu^{2+}]}{\Delta t}$

D $-(\frac{\Delta[Ag^{+}]}{\Delta t}) = \frac{\Delta[Cu^{2+}]}{\Delta t}$

(2)

Answer: 3.1 A
Study Tips: Study the equation. Note the following:

- LHS: Both the mass of Cu(s) and the $[Ag^{+}(aq)]$ decrease. This means: Δ mass Cu = (mass Cu_f – mass Cu_i) < 0 (i.e. it is negative). Similarly, $\Delta[Ag^{+}(aq)]$ is negative.
- RHS: Both $[Cu^{2+}]$ and the mass of Ag increase. This means: $\Delta [Cu^{2+}] = ([Cu^{2+}]_f - [Cu^{2+}]_i) > 0$ (i.e. it is positive). Similarly, Δ mass Ag is positive.
- Hence, if you determine the reaction rate on the LHS your answer is negative but on the RHS it is positive.
- This problem was eliminated by an international agreement that ALL REACTION RATES ARE POSITIVE (Refer to any university textbook or to IUPAC's Golden Book to verify this.)

3.2 Define the term *reaction rate* in words. (2)

Answer: The change in the concentration of a reactant or product per unit time.
Study Tips: This question is testing recall. This definition can be found on page 19 of the CAPS EG (Examination Guidelines). ALL STATEMENTS OF DEFINITIONS, LAWS AND PRINCIPLES ARE PROVIDED IN THE EG. YOU MUST BE ABLE TO REPRODUCE THEM IN THE FINAL EXAMINATION.

Activity 1
1. Use the definition of reaction rate to:

1.1 Write down a formula that can be used to calculate reaction rate.
1.2 Deduce the unit of measurement for reaction rate.

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

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

They perform four experiments under different conditions of concentration, mass and temperature as shown in the table below. They use identical apparatus in the four experiments and measure the volume of gas released in each experiment.

	EXPERIMENT			
	1	**2**	**3**	**4**
Concentration of acid ($mol \cdot dm^{-3}$)	1	0,5	1	1
Mass of impure calcium carbonate (g)	15	15	15	25
Initial temperature of acid (°C)	30	30	40	40

3.3 The results of experiments **1** and **3** are compared in the investigation.

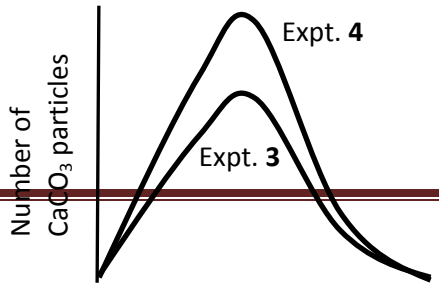
Write down the:

3.3.1 Independent variable (1)
Answer: Temperature
Study Tips: The independent variable is the one you CHANGE in the experiment. To find the answer, look at experiment 1 and 3 and find out what the CHANGE is. You will see that only the temperature is CHANGED. The answer is ∴Temperature

3.3.2 Dependent variable (1)
Answer: Reaction rate OR Volume of gas released
Study Tips: The dependent variable is the one you are MEASURING in the experiment. You have to read the text in the question to find the answer. The answer is given in the 1st sentence, immediately below Activity 1.1 viz. reaction rate OR in the 3rd sentence viz. volume of gas released.

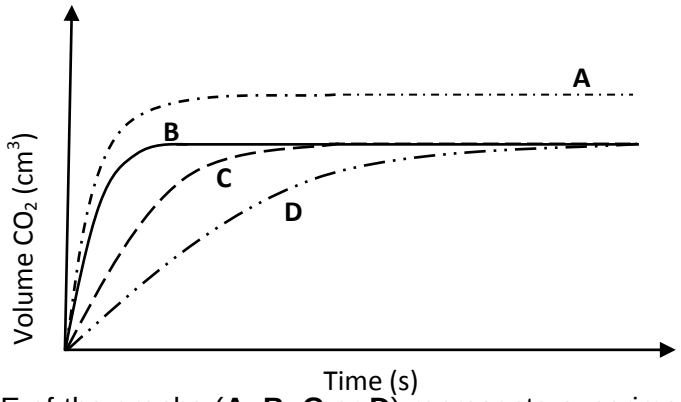
3.4 Use the collision theory to explain why the reaction rate in experiment **4** will be higher than that in experiment **3**. (3)

Answer: In experiment **4** there is a larger mass (of $CaCO_3$). There are thus more $CaCO_3$ particles that collide with the same kinetic energy and correct orientation per unit time in experiment **4** than in experiment **3**.
Study Tips: The Maxwell-Boltzmann distribution shows you better, what is happening:



Kinetic energy

The learners obtain graphs **A**, **B**, **C** and **D** below from their results.



3.5 Which ONE of the graphs (**A**, **B**, **C** or **D**) represents experiment **1**? Fully explain the answer by comparing experiment **1** with experiments **2**, **3** and **4**. (6)

Answer: C

Study Tips: Compare the reaction rate of experiment **1** with **2**, **1** with **3**, **1** with **4** and **3** with **4**, using the information given in the table. Then match them with the reaction rate given by graphs **A** to **D** respectively.

Comparison	Observation	Match observation with graph
1 with **2**	Reaction rate exp.*1* > Reaction rate exp. 2	Reaction **1** is graph **C**
1 with **3**	Reaction rate exp.**3** > Reaction rate exp. **1**	Reaction **2** is graph **D**
1 with **4**	Reaction rate exp.**4** > Reaction rate exp. **1**	Reaction **3** is graph **B**
3 with **4**	Reaction rate exp.**4** > Reaction rate exp. **3**	Reaction **4** is graph **A**

3.6 When the reaction in experiment **4** reaches completion, the volume of gas formed is 4,5 dm^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. (5)

Study Tips: Note: The "gas" in the question is CO_2 (Refer to the given equation). Write down what you are given:
Mass ($CaCO_3$) at start = m = 25 g Volume of CO_2(g) produced = V = 4,5 dm^3
Molar gas volume = V_m = 25,7 dm^3

Answer

Method:

STEP 1**:** Find the moles of CO_2(g) that were formed in the reaction.

$$n(CO_2) = \frac{V}{V_m} = \frac{4,5}{25,7} = 0,18 \text{ mol}$$

STEP 2**:** Find the moles of $CaCO_3(s)$ that reacted to form the moles of CO_2 in the reaction.
From the balanced equation:

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

$n(CaCO_3) = n(CO_2) = 0{,}18$ mol (from STEP 1)

STEP3**:** Convert the moles of $CaCO_3(s)$ in STEP 2 to mass

$n(CaCO_3) = \frac{m}{M}$ i.e. $0{,}18 = \frac{m}{100}$ i.e. $m = (0{,}18)(100) = 18$ g

STEP 4**:** Subtract the mass in STEP 3 from 25 g to obtain the answer.

$\therefore$ mass of impurities in the $CaCO_3 = 25 - 18 = 7{,}00$ g

Activity 2

1. Draw the Maxwell-Boltzmann distribution to show how concentration increases reaction rate.
2. Calculate the mass of $HC\ell$ needed to produce 0,18 mol of $CO_2(g)$.

LESSON 4: MECHANICAL ENERGY

4.1 Which one of the following is false if mechanical energy is conserved?

A: $\Delta M_E = 0$

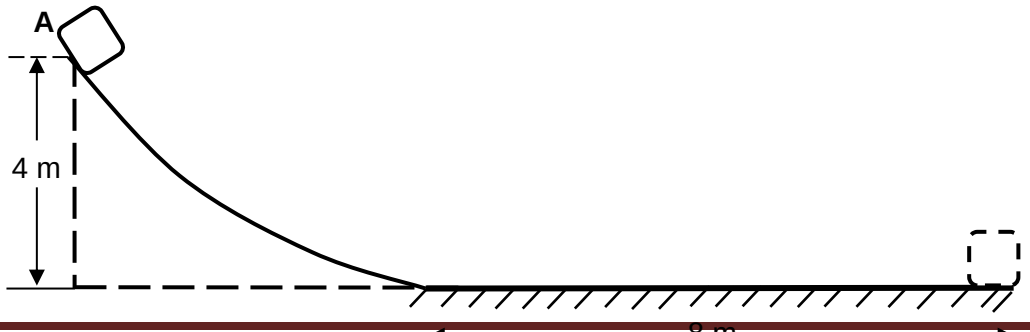
B: $\Delta U + \Delta K = 0$

C: $\Delta U + \Delta K = W_{nc}$

D: $(U + K)_i = (U + K)_f$

Answer: 4.1 C
ME is conserved if the change in ME is zero. In the case of C, the change in ME ≠ 0

4.2 The diagram below shows a track, **ABC**. The curved section, **AB**, is frictionless. The rough horizontal section, **BC**, is 8 m long.



An object of mass 10 kg is released from point **A** which is 4 m above the ground. It slides down the track and comes to rest at point **C**.

4.2.1 State the *principle of conservation of mechanical energy* in words. (2)

Answer: Total mechanical energy remains constant in a closed system.
Study Tips: All principles, definitions and laws are stated in words in the EG, and these you should study for your Final Examination. Do not study those in your text book.

4.2.2 Where Is mechanical energy conserved as the object slides from **A** to **C**? (1)

Answer: only between **A** and **B**.
Study Tips: The following are reasons for this answer:

- There is no friction along **AB** or The system is closed along **AB**
- F_g or w (weight), a conservative force, is the only force acting on the object

4.2.3 Using ENERGY PRINCIPLES only, calculate the magnitude of the frictional force exerted on the object as it moves along **BC**. (6)

Study Tips: Follow the following steps to answer this question:

STEP 1: Calculate the velocity of the object at **B**

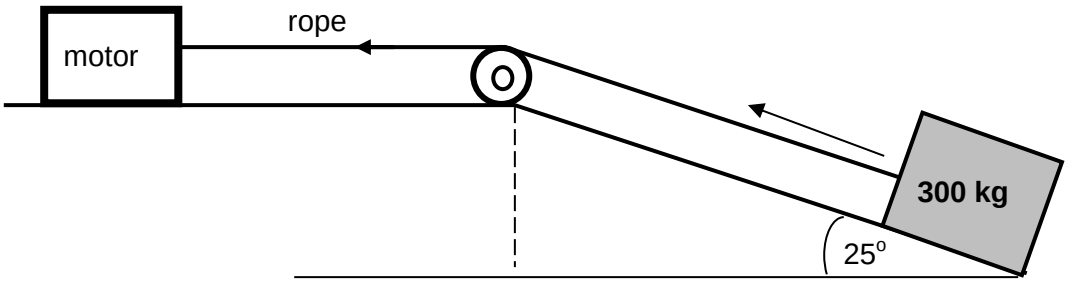
$ME_A = ME_B$
$(U + K)_A = (U + K)_B$
$mgh_A + 0 = 0 + ½ mv_B^2$
$(10)(9,8)(4) + 0 = 0 + ½ (10)v_B^2$
$\therefore v_B^2 = 78,4$

STEP 2: Use the velocity calculated in STEP 1 to calculate the frictional force, f.

$W_{net} = \Delta K$
$W_f = K_f - K_i$
$f\Delta x\cos 180 = 0 - ½ mv_B^2$
$f(8)(-1) = -½ (10)(78,4)$
$\therefore f = 49$ N

OR Use $W_{nc} = \Delta U + \Delta K$
Then $W_f = \Delta K$ because $\Delta U = 0$

4.3 A motor pulls a crate of mass 300 kg with a constant force by means of a light inextensible rope running over a light frictionless pulley as shown below. The coefficient of kinetic friction between the crate and the surface of the inclined plane is 0,19.



4.3.1 Calculate the magnitude of the frictional force acting between the crate and the surface of the inclined plane. (3)

Study Tips: The following steps can be followed to calculate f (frictional force).

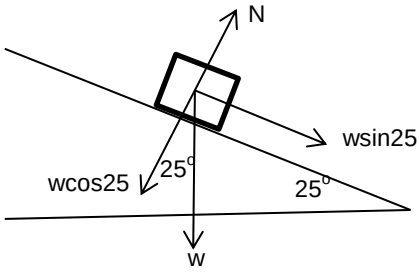
STEP 1: Write down an expression to obtain f viz. $f_k = \mu_k N$

STEP 2: Use the equation in STEP 1 to calculate f_k

$f_k = \mu_k N = \mu_k w\cos\Theta = (0,19)(300)(9,8)(0,906) = 506,09$ N

NOTES: Why is the (normal force) N = wcosΘ? The diagram below shows why.

Procedure:
Resolve w into rectangular components along the inclined plane.



The crate moves up the incline at a constant speed of 0,5 $m \cdot s^{-1}$.

4.3.2 Calculate the average power delivered by the motor while pulling the crate up the incline. (6)

Study Tips: The following STEPS can be used to calculate the average power:

STEP 1: If the crate is moving at constant speed, then $F_{net} = 0$.

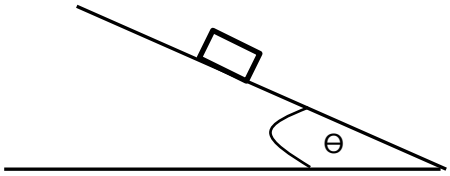
$$F_{net} = F + (-mg\sin\Theta) + (-f) = 0$$

STEP 2: Use $F_{net} = 0$ to find F, the force that pulls the crate

$$F - (300)(9,8)(0,423) - (506,09) = 0$$
$$F = 300)(9,8)(0,423) + (506,09) = 1749,71 \text{ N}$$

STEP 3: Use the formula P = Fv to calculate the average power:
$\therefore P_{av} = P = Fv = (1749,71)(0,5) = 874,86$ W

Activity 4.1: Prove that $\mu_k = \tan\Theta$ for an object sliding down an inclined plane at constant velocity, where Θ is the angle the incline plane makes with the horizontal.



LESSON 5: ELECTROLYTIC CELLS

5.1 An electrochemical cell is used to electroplate an iron spoon with nickel.

Which ONE of the following half-reactions takes place at the positive electrode of this cell?

A $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$

B $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

C $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

D $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ (2)

Answer: D
Study Tips: How do you know that the cell in Q5.1 is an electrolytic cell? The word "electroplate" tells you that the cell is electrolytic. Which electrode is the "positive" electrode? The anode is ALWAYS the positive electrode and at the anode, oxidation occurs.

The answer can be B or D. It can't be B because the Fe spoon is the cathode i.e. reduction takes place at the Fe spoon. Therefore, the answer is D.

Galvanic and electrolytic cells are compared in the Table 1 below.

Table 1: Comparison of Galvanic and Electrolytic cells

	Galvanic cell	Electrolytic cell
Similarities:	Oxidation occurs at anode	Reduction occurs at cathode
Differences:	Anode is negative (-) electrode	Anode is positive (+) electrode
	Cathode is positive (+) electrode	Cathode is negative (-) electrode
	Net reaction is exothermic	Net reaction is endothermic

Study Tip: You only need to know the information in one of the columns e.g. the shaded column. The information in the unshaded column on the RHS is just the opposite i.e. it can be deduced from the shaded column.

Activity 5.1:

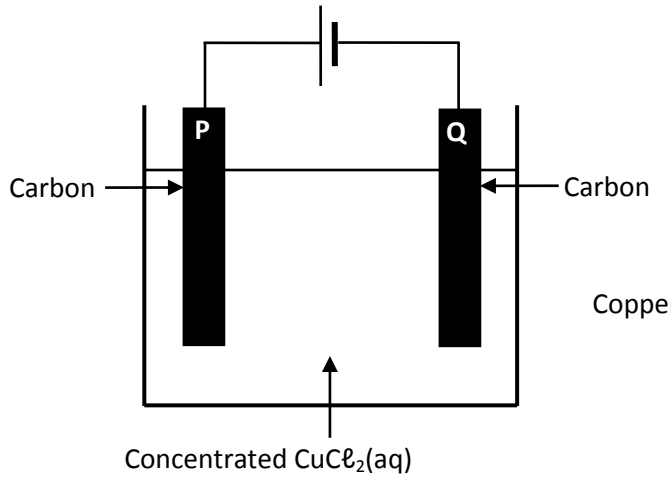
5.1.1 Write down the net cell reaction taking place in electrochemical cell **A** and **B** on page 9.

5.1.2 Calculate the standard emf of cell **A.**

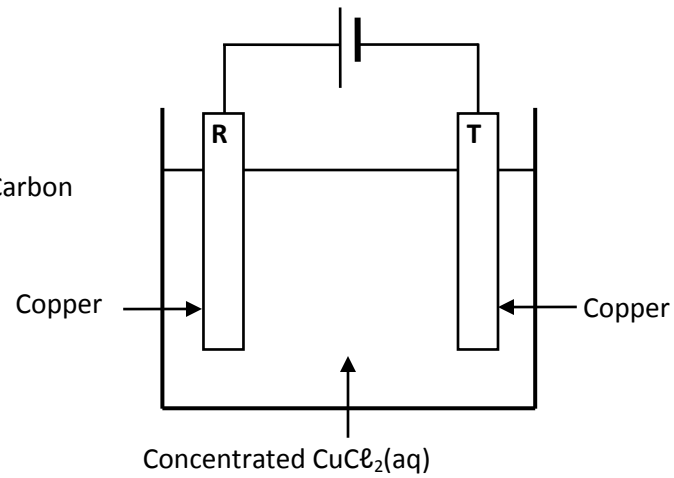
5.1.3 Is the net reaction in cell **A** exothermic or endothermic? Give a reason for your answer.

The simplified diagrams below represent two electrochemical cells, **A** and **B**. A concentrated copper(II) chloride solution is used as electrolyte in both cells.

ELECTROCHEMICAL CELL A



ELECTROCHEMICAL CELL B



5.2 Are **A** and **B** ELECTROLYTIC or GALVANIC cells? (1)

Answer: Electrolytic

Study Tip: The two electrodes are connected to a battery/cell or power supply i.e. they need electrical energy to function. A galvanic cell does not need external electrical energy to function. ∴the symbol ⊣|⊢ is not part of its circuit.

5.3 Which of the electrodes (**P**, **Q**, **R** or **T**) will show a mass increase? Write down a half-reaction to motivate the answer. (4)

Study Tip: "mass increase" means the electrode where REDUCTION occurs. From Table 1 it is the cathode (-) electrode. In the given circuits, the electrodes connected to the negative terminals are the cathodes. ∴**Answer** is **Q** and **T**

5.4 Write down the NAME or FORMULA of the product formed at:

5.4.1 Electrode **P** (1)

Answer: $C\ell_2$ or Chlorine gas
Study Tips:

- **P** is the positive electrode and negative ions ($C\ell^-$) from the electrolyte are attracted to it.
- According to Table 1, **P** is the anode. Oxidation ALWAYS takes place at the anode i.e. $2\ C\ell^- \rightarrow C\ell_2 + 2\bar{e}$
- Therefore the product formed at **P** is $C\ell_2$

5.4.2 Electrode **R** (1)

Answer: Cu^{2+} or Copper (II) ions
Study Tips: R is also a positive electrode like **P.** Now explain how you got to your Answer. Refer to the Study Tips in 5.4.1.

5.5 Fully explain the answer to QUESTION 5.4.2 by referring to the relative strengths of the reducing agents involved. (3)

Study Tips:

- Reducing agents are substances that undergo oxidation
- There are two reducing agents that compete to get oxidised viz. Cu from the anode **R** and $C\ell^-$ ions from the electrolyte that are attracted to **R**, the positive electrode.
- When there is more than one reducing agent available, the strongest reducing agent is oxidized first.
- Since Cu is a stronger reducing agent than $C\ell^-$ (Refer to the table of Standard Reduction Potentials to verify this), it is oxidized to Cu^{2+}, first.

LESSON 6: ACIDS AND BASES

6.1 Nitric acid (HNO_3), an important acid used in industry, is a strong acid.

6.1.1 Give a reason why nitric acid is classified as a strong acid. (1)

Answer: It ionizes completely (100%) in water. Refer to EG page 20.
Study Tips: The following acids are also strong acids that ionize completely (100%) in water: $HC\ell$, HBr, H_2SO_4 (1^{st} ionization)

6.1.2 Write down the NAME or FORMULA of the conjugate base of nitric acid. (1)

Answer: NO_3^- or Nitrate ion
Study Tips:

- A conjugate base is obtained from an acid by the REMOVAL of ONE

PROTON (H^+) from the acid. Example: NO_3^- is the conjugate base of HNO_3

- A conjugate acid is obtained from a base by the ADDITION OF ONE PROTON (H^+). Example: HNO_3 is the conjugate acid of NO_3^-

6.1.3 Calculate the pH of a 0,3 mol·dm^{-3} nitric acid solution. (3)

Answer: pH = -log[H_3O^+] = -log(0,3) = -(-0,52) = 0,52
Study Tips:

- You must be able to use a scientific calculator.
- You must know all the log laws from mathematics and apply them to chemistry.

6.2 A laboratory technician wants to determine the percentage purity of magnesium oxide. He dissolves a 4,5 g sample of the magnesium oxide in 100 cm^3 hydrochloric acid of concentration 2 mol·dm^{-3}.

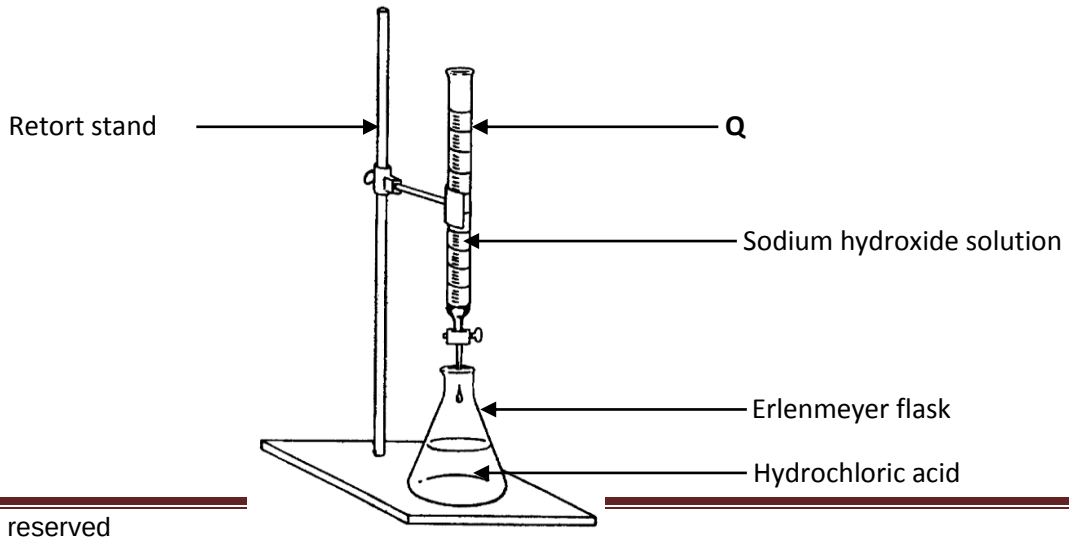
6.2.1 Calculate the number of moles of hydrochloric acid added to the magnesium oxide. (3)

Answer: n = cV = (2)(0,1) = 0,2 mol
Study Tips: Method to find n(HCℓ):
STEP 1: Write down the given: V(HCℓ) = 100 cm^3 [HCℓ] = 0,2 mol.dm^{-3}
STEP 2: Write down what you have to calculate viz: n(HCℓ)
STEP 3: Write down an equation that contains the variables in STEP 1 and 2 viz.

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

STEP 4: Convert 100 cm^3 to dm^3: Divide 100 cm^3 by 1000 to obtain 0,1 dm^3
NOTES: Procedure: If 10 cm = 1 dm, then (10 cm)^3 = (1 dm)^3 i.e.
1000 cm^3 = 1 dm^3
STEP 5: Now calculate n(HCℓ): n(HCℓ) = cV, etc.

He then uses the apparatus below to titrate the EXCESS hydrochloric acid in the above solution against a sodium hydroxide solution.



6.2.2 Write down the name of apparatus **Q** in the above diagram. (1)

Answer: Burette
Study Tips: PRACTICAL WORK IS EXAMINABLE. You must know the experiments done for your SBA mark and those that are demonstrated by your teacher. Know safety precautions too. Note that practical work is examinable. Refer to section 2.6 of the EG for more information.

6.2.3 The following indicators are available for the titration:

INDICATOR	pH RANGE
A	3,1 – 4,4
B	6,0 – 7,6
C	8,3 – 10,0

Which ONE of the above indicators (**A**, **B** or **C**) is most suitable to indicate the exact endpoint in this titration? Give a reason for the answer. (3)

Answer: B
Study Tips: What is hydrolysis? It is the reaction of a salt with water to form a solution that is acidic or basic. We use our knowledge of hydrolysis and pH to choose an indicator for a titration.

- If the substances used in the titration are HCℓ, a <u>strong acid</u>, and NaOH, a <u>strong base</u>, the pH of the solution that forms is 7.
- If the titration is between a <u>weak acid</u> such as CH_3COOH and a <u>strong base</u> such as NaOH, the salt formed, CH_3COONa, undergoes <u>cationic hydrolysis</u>, as shown below:
  $CH_3COO^- + H^+ + OH^- \rightarrow CH_3COOH + OH^-$.
  The OH^- ion makes the solution basic. Indicator **C** should be used for this titration.
- If the titration is between a <u>strong acid</u> such as HCℓ and a <u>weak base</u> such as NH_3, the salt formed, $NH_4C\ell$, undergoes <u>anionic hydrolysis</u>, as shown below:
  $NH_4^+ + H^+ + OH^- \rightarrow NH_4OH + H^+$
  The H^+ ion formed makes the solution acidic. Indicator **A** should be used for this titration

6.2.4 During the titration, the technician uses distilled water to wash any sodium hydroxide spilled against the sides of the Erlenmeyer flask into the solution.

Give a reason why the addition of distilled water to the Erlenmeyer (1)

flask will not influence the results.

Answer: $n(OH^-)$ remains constant.
Study Tips: The endpoint is dependent only on the $n(H^+)$ and the $n(OH^-)$ present but not on the water added.

6.2.5 At the endpoint of the titration he finds that 21 cm^3 of a 0,2 mol dm^{-3} sodium hydroxide solution has neutralized the EXCESS hydrochloric acid.

Calculate the number of moles of hydrochloric acid in excess. (3)
Study Tips: Follow the STEPS in 6.2.1 to obtain the answer. The balanced chemical equation for the reaction between NaOH and HCℓ is:

$$NaOH + HC\ell \rightarrow NaC\ell + H_2O$$

Answer

$$n(NaOH) = cV = (0,2)(0,021) = 0,0042 = n(HC\ell)$$

6.2.6 The balanced equation for the reaction between hydrochloric acid and magnesium oxide is:

$$MgO(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$$

Calculate the percentage purity of the magnesium oxide. Assume that only the magnesium oxide in the 4,5 g sample reacted with the acid. (5)

Study Tips: The problem solving process to obtain the answer is shown below:
STEP 1: Calculate the $n(HC\ell)$ that reacted with the MgO.

$$n(HC\ell)_{reacted} = 0,2 - 0,0042 = 0,1958 \text{ mol}$$

STEP 2: From the balanced equation in 6.2.6, obtain n(MgO) that reacted with the $n(HC\ell)$.

$$n(MgO) : n(HC\ell) = 1:2$$
$$\therefore n(MgO) = ½\ (n(HC\ell) = ½\ (0,1958) = 0,0979 \text{ mol}$$

STEP 3: From the n(MgO) calculated in STEP 2, calculate the mass of MgO that reacted with the HCℓ.

$$Mass(MgO) = nM = (0,0979)(40) = 3,916 \text{ g}$$

STEP 4: Calculate the %age purity of the MgO.

$$\%age\ purity\ of\ the\ MgO = \frac{3,916}{4,5} \times 100\% = 87,02\%$$

Activity 6.1
3,6 g of commercial washing soda ($Na_2CO_3.\ 10H_2O$) are dissolved in a 250 cm^3 measuring flask, which is then filled to the mark. In a titration, 25 cm^3 of this commercial washing powder solution was neutralised by 23,5 cm^3 of a HCℓ solution

of concentration 0,11 mol.dm^{-3}. The balanced chemical equation for the reaction is:

$$Na_2CO_3 + 2HC\ell \rightarrow 2NaC\ell + CO_2 + H_2O$$

6.1.1 Choose a suitable indicator for this titration, using the table in question 6.2.3.
6.1.2 Give a reason why the water of hydration is omitted from the balanced equation.
6.1.3 Calculate the n($HC\ell$) that reacted with the Na_2CO_3 in the titration.
6.1.4 Calculate the n(Na_2CO_3) in the 250 cm^3 measuring flask.
6.1.5 Calculate the percent (%) of Na_2CO_3 in the commercial washing soda (Na_2CO_3. $10H_2O$)