Uganda Advanced Certificate of Education (UACE) – Chemistry Paper 1 (Theory)
Time: 2 hours 45 minutes
"Prepared by Teacher Joel PCM – Designer of Physics, Chemistry & Mathematics Item Banks.
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Instructions:
Answer all questions in Section A.
In Section B, attempt 1 item from Part I and 1 item from Part II.
Write your answers as reports, analyses, or recommendations, using data provided where applicable.

SECTION A – Compulsory Items

Item 1 – AO3 (Quantitative Chemistry / Thermochemistry / Kinetics)
A fertilizer company produces ammonia (NH_3) by reacting nitrogen with hydrogen under controlled conditions. In a trial experiment, 10.0 g of nitrogen is combined with 3.0 g of hydrogen. After 1 hour, only 2.5 g of hydrogen has reacted. The company observes that the reaction rate doubles when the temperature is raised from 298 K to 318 K. The enthalpy change of the reaction is measured as -92 kJ/mol.

Task:
Write a detailed scientific report analyzing:
Which reactant is limiting.
The expected quantity of ammonia formed.
The efficiency of the reaction compared to the theoretical maximum (percentage yield).
How temperature affects the reaction rate, referencing kinetic principles.

Item 2 – AO4 (Equilibrium & Electrochemistry)
A laboratory investigates a solution containing 0.50 M Fe^{2+} and 0.10 M Fe^{3+} in acidic medium. A platinum electrode is immersed and connected to a standard hydrogen electrode. The reduction potential for Fe^{3+}/Fe^{2+} is +0.77 V.

Task:
Prepare a scientific report that:
Determines the electrode potential using the Nernst equation.
Explains the effect of changing ion concentrations on the potential.
Predicts how equilibrium shifts when additional Fe^{2+} is added.
Suggests one real-life application of this redox system in industry.

SECTION B – Optional Items

Part I – AO1 (Atomic Structure, Bonding, Periodicity)

Students choose 1 out of 2 items.

Item 3
A chemical plant produces metal oxides used in ceramics. They observe varying melting points, solubilities, and reactivities for BeO, MgO, CaO, and Al_2O_3. They request an analysis of periodic trends to optimize product quality.

Task:
Write a report analyzing:
Trends in atomic radius and ionization energy.
Differences in melting points of oxides.
The nature of bonding in BeO, MgO, and Al_2O_3.
Recommendations for production improvement based on periodic properties.

Item 4
A laboratory studies group 17 elements (halogens) for potential use in disinfectants. Observations include differences in reactivity, solubility, and bond strengths across fluorine to iodine.

Task:
Write a report that:
Explains the trend in reactivity down the group.
Compares bond strengths and their effect on chemical behaviour.
Suggests which halogen is most suitable for industrial applications and why.

Part II – AO2 (Organic Chemistry / Mechanisms / Synthesis)

Students choose 1 out of 2 items.
Item 5
A chemist synthesizes butan-2-ol by reducing butan-2-one with sodium borohydride. The alcohol is then dehydrated using concentrated H_2SO_4 to produce but-2-ene.
Task:
Write a detailed report covering:
The mechanism of reduction of butan-2-one to butan-2-ol.
The formation of cis and trans but-2-ene during dehydration.
Suggested test to distinguish butan-2-ol from butan-1-ol.
Industrial relevance of the reaction.

Item 6
A pharmaceutical company investigates the synthesis of phenylmethanol from benzaldehyde. They plan to convert it into other derivatives for medicinal applications.

Task:
Prepare a scientific report that:
Shows the synthesis pathway from benzaldehyde to phenylmethanol.
Explains the reaction mechanism for each step.

Discusses possible functional group transformations.
Recommends safety and efficiency improvements in the process.

Paper Summary:

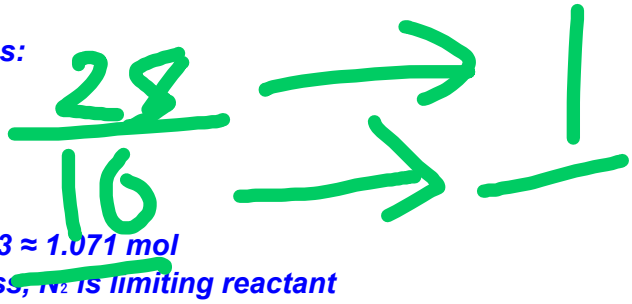
Section A: 2 compulsory items
Section B, Part I: 2 items (choose 1)
Section B, Part II: 2 items (choose 1)
Total items in paper: 6

UACE Chemistry – Paper 1 (Theory) Solution Guide
Prepared by Tr Joel PCM
Designer of Physics, Chemistry, and Mathematics Item Banks

SECTION A – Compulsory Items

Item 1 – AO3 (Quantitative Chemistry / Thermochemistry / Kinetics)

Scenario Summary: Ammonia production with $N_2 + H_2 \rightarrow NH_3$. 10 g N_2, 3 g H_2, 2.5 g H_2 reacted, ΔH = -92 kJ/mol, reaction rate doubles with 20 K rise.



Expected Report Structure & Solutions:
Limiting Reactant:
Moles of N_2 = 10 / 28 ≈ 0.357 mol
Moles of H_2 = 3 / 2 = 1.5 mol
Reaction: $N_2 + 3H_2 \rightarrow 2NH_3$
H_2 required for 0.357 mol N_2 = 0.357 × 3 ≈ 1.071 mol
Available H_2 = 1.5 mol → H_2 is in excess, N_2 is limiting reactant
Moles of NH_3 Formed:
From limiting N_2: 1 mol N_2 → 2 mol NH_3
0.357 mol N_2 → 0.357 × 2 ≈ 0.714 mol NH_3
Mass NH_3 = 0.714 × 17 ≈ 12.14 g
Percentage Yield:
Actual collected = 1.8 g
% yield = (1.8 / 12.14) × 100 ≈ 14.83%
Effect of Temperature on Reaction Rate:
Using Arrhenius principle: Rate ∝ e^(-Ea/RT)
Increasing temperature increases molecular kinetic energy → more molecules surpass activation energy → rate doubles
Report Tips:
Include all calculations neatly
Explain trends qualitatively (e.g., why the reaction is endothermic/exothermic)
Connect to industrial efficiency

Item 2 – AO4 (Equilibrium & Electrochemistry)

Scenario Summary: Fe^{2+}/Fe^{3+} redox system. E° = +0.77 V, $[Fe^{2+}]$ = 0.50 M, $[Fe^{3+}]$ = 0.10 M
Solution Steps:

Electrode Potential (Nernst Equation):
$E = 0.77 + 0.059 \log \frac{0.10}{0.50}$
$E = 0.77 + (0.059 \times -0.699) \approx 0.77 - 0.041 \approx 0.729$ V
Effect of Increasing Fe^{3+} Concentration:
Increases $[Fe^{3+}]/[Fe^{2+}]$ → log term more positive → potential E increases
Effect of Adding Fe^{2+}:
Increases $[Fe^{2+}]$ → log term decreases → potential E decreases
Le Chatelier: Equilibrium shifts to produce more Fe^{3+}
Industrial Application:
Redox titrations (e.g., determination of iron content)
Corrosion monitoring
Electroplating
Report Tips:
Include calculation table for clarity
Connect trends to equilibrium principles
Suggest real-world relevance

SECTION B – Optional Items
Part I – AO1 (Atomic Structure, Bonding, Periodicity)

Item 1 (Metal Oxides / Periodicity)
Key Points to Include in Report:
Atomic radius trend: Decreases across period, increases down group
Ionization energy trend: Increases across period, decreases down group
Melting points of oxides: Ionic oxides (MgO, Al_2O_3) have high mp, covalent oxides (BeO?) lower
Bonding nature: BeO (covalent), MgO/Al_2O_3 (ionic)
Recommendations: Control temperature during production, choose elements with proper oxide stability, improve purity

Item 2 (Halogens / Reactivity)
Key Points to Include in Report:
Reactivity trend: F > Cl > Br > I
Bond strength trend: F_2 weakest single bond (reactive), I_2 strongest → least reactive
Industrial choice: Cl_2 preferred for disinfection, I_2 in pharmaceuticals
Safety and handling notes

Part II – AO2 (Organic Chemistry / Mechanisms / Synthesis)

Item 1 (Butan-2-ol Synthesis / Dehydration)
Key Points to Include:
Reduction mechanism: $NaBH_4$ donates hydride to carbonyl carbon → alcohol
Dehydration: H_2SO_4 protonates OH → elimination forms but-2-ene
Cis/Trans formation: Double bond allows stereoisomers

Test: Lucas test, solubility, or oxidation
Industrial relevance: Alcohols as intermediates, solvents

Item 2 (Phenylmethanol Synthesis)
Key Points to Include:
Pathway: Benzaldehyde + $NaBH_4$ → Phenylmethanol → derivatives (ester, halide, etc.)
Mechanism: Hydride transfer, nucleophilic attack, workup
Functional group transformations: oxidation, substitution
Safety & efficiency: Proper temperature control, avoid excess reagents
General Tips for Students' Reports:
Begin with brief introduction summarizing the scenario
Present calculations neatly (if any)
Analyse trends and observations critically
Give recommendations or conclusions
Write coherently and use subheadings

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"Persistence Leads to Success"

<u>For more chemistry practice and video explanations, visit my YouTube channel:</u>
<u>https://youtu.be/ao_cFr7InKs?si=D4TYvWjdVhOiDsK8 (Click to browse)</u>