QUESTION 1: **[36 MARKS]**

1.1. Consider two hypothetical pure substances, AB(*s*) and XY(*s*). When equal molar amounts of these substances are placed in separate 500-mL samples of water, they undergo the following reactions:

$$AB(s) \rightarrow A^{+}(aq) + B^{-}(aq)$$

$$XY(s) \rightarrow XY(aq)$$

1.1.1. Which solution would you expect to have the lower boiling point? Explain. (2)

1.1.2. Would you expect the vapor pressures of the two solutions to be equal? If not, which one would you expect to have the higher vapor pressure? Explain. (2)

1.1.3. Briefly describe a procedure that would make the two solutions have the same boiling point. (2)

1.2. When 0.10 mol of the ionic solid NaX, where X is an unknown anion, is dissolved in enough water to make 1.0 L of solution, the pH of the solution is 9.12. When 0.10 mol of the ionic solid ACl, where A is an unknown cation, is dissolved in enough water to make 1.0 L of solution, the pH of the solution is 7.00.

1.2.1. What would be the pH of 1.0 L of solution that contained 0.10 mol of AX? Be sure to document how you arrived at your answer. (4)

1.2.2. In the AX solution prepared above, is there any H_3O^+ present? If so, what is the source? Compare the $[OH^-]$ in the solution to the $[H_3O^+]$. (3)

1.3. The heat (enthalpy) of reaction for a given reaction is endothermic. Which (reactants or products) requires less energy to overcome the activation barrier? Explain. (2)

1.4. At 330 °C, the rate constant for the decomposition of NO_2 is 0.775 L/(mol.s). If the reaction is second order,

1.4.1. What is the concentration of NO_2 after 2.5×10^2 seconds if the starting concentration was 0.050 M? (4)

1.4.2. What is the half-life of this reaction under these conditions? (2)

1.5. Consider the reaction

$$2CO_2(g) \leftrightarrows 2CO(g) + O_2(g) \qquad \Delta H^\circ = 566 \text{ kJ}$$

Discuss the temperature and pressure conditions that would give the best yield of carbon monoxide. (4)

1.6. Lead(II) arsenate, $Pb_3(AsO_4)_2$, has been used as an insecticide. It is only slightly soluble in water. If the solubility is 3.0×10^{-5} g/L, what is the solubility product constant? Assume that the solubility equilibrium is the only important one. (Mm ($Pb_3(AsO_4)_2$) = 899 g/mol) (5)

1.7. Explain why water spontaneously freezes to form ice below 0 °C even though the entropy of the water decreases during the state change. (4)

1.7.1. Why is the freezing of water not spontaneous above 0 °C? (2)

<u>QUESTION 2:</u> (START ON A NEW PAGE) **<u>[23 MARKS]</u>**

2.1. A voltaic cell utilizes the following reaction:

$Al(s) + 3Ag^{+}(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$

What is the effect on the cell emf of each of the following changes? Explain your answers.

2.1.1. Water is added to the anode half-cell, diluting the solution. (2)

2.1.2. The size of the aluminum electrode is increased. (2)

2.1.3. A solution of $AgNO_3$ is added to the cathode half-cell, increasing the quantity of Ag^{+} but not changing its concentration. (2)

2.1.4. HCl is added to the $AgNO_3$ solution, precipitating some of the Ag^{+} as AgCl. (2)

2.2. Given the following standard reduction potentials,

$Ag^{+}(aq) + e^{-} \leftrightarrows Ag(s)$ $E° = 0.80$ V

$AgCN(s) + e^{-} \leftrightarrows Ag(s) + CN^{-}(aq)$ $E° = -0.01$ V

calculate the solubility product (K_{sp}) of AgCN at 25 °C. (5)

2.3. An iron object is plated with a coating of cobalt to protect against corrosion. Does the cobalt protect iron by cathodic protection? Explain. (2)

2.4. Consider a molten mixture of $BaCl_2$ and CuI_2

2.4.1. Why must the mixture be in the molten state before it is electrolyzed? (2)

2.4.2. Write the anode reaction, cathode reaction, and overall cell reactions for the electrolysis of the molten mixture. (3)

2.4.3. How many grams of product would be produced at the anode in the electrolysis of this molten mixture by a current of 4.25 A for 35.0 min? (3)

QUESTION 3: (START ON A NEW PAGE) [22 MARKS]

3.1. Explain why the bond angles in the hydronium ion (H_3O^+) are less than the bond angles in methane but greater than the bond angles in water (H_2O). Indicate the bond angles in methane and water in your explanation. (4)

3.2. You encounter some hydrocarbons with the following IUPAC names. Determine if these IUPAC names are **correct or incorrect**. For each **incorrect name**, explain why it is incorrect and give the correct IUPAC name.

3.2.1. 3-ethyl-3-octen-5-ol (2)

3.2.2. (E)-1-isopropyl-1-butene (2)

3.2.3. 3-tert-butyl-2-methylcyclopentanone (2)

3.2.4. 1,5-dimethylcyclohexane (2)

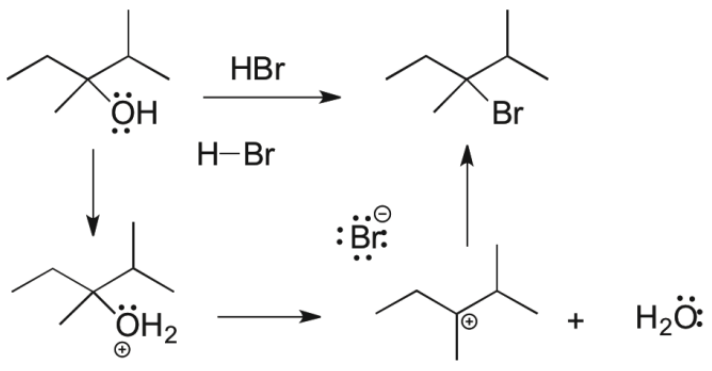
3.2.5. 3-butyl-2,2-dimethylhexane (2)

3.3. Explain why the cis-isomer of 2-butene has a higher boiling point (4 °C) than the trans-isomer (1 °C). (4)

3.4. Explain why the boiling point of carboxylic acids are higher than the boiling point of alcohols. (4)

QUESTION 4: (START ON A NEW PAGE) [25 MARKS]

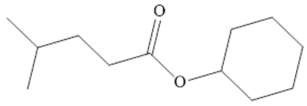
4.1. The following reaction has three mechanistic steps. Redraw the reaction mechanism and draw all curved arrows necessary to complete the mechanism. (4)



4.2. Draw a stepwise mechanism for the acid-catalyzed hydration of 3,3-dimethylbut-1-ene. (4)

4.3. Write down one difference between addition polymerization and condensation polymerization. (2)

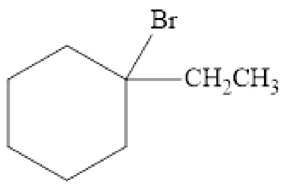
4.4. Give the required **IUPAC name** of either **reactant(s) or product(s)** in the following table depicting the outcome of different organic reactions: (5)

Question	**Reactant 1**	**Reactant 2**	**Reaction conditions**	**Products**
4.4.1	**2,2,4-trimethylpentane**	Br_2	UV light	
4.4.2			H^+	 + H_2O
4.4.3		Not applicable	H_2SO_4, Δ	**2-methylprop-1-ene + H_2O**
4.4.4	**3-methylhex-2-ene**	Not applicable	Br_2 and CCl_4 as solvent	

4.5. What is the name of the reaction taking place in part 4.4.3? (1)

4.5.1. What is the role of the acid in the reaction taking place in part 4.4.3? (2)

4.6. Predict the product(s) and identify the mechanism (S_N1/S_N2/E1/E2) when 1-bromo-1-ethylcyclohexane is treated with the following reagents. Give a brief explanation for your choice: (7)



1-bromo-1-ethylcyclohexane

Question number	**Reagent**	**Product(s)**	**Mechanism (S_N1/S_N2/E1/E2) with brief explanation**
4.6.1	CH_3OH		
4.6.2	NaOEt		

END OF PAPER

PSFT0B3 DATA

N_A (Avogadro's number) = 6.022×10^{23}

1 atm = 760 mmHg = 760 torr = 1.01×10^5 Pa = 1.013 bar

R (gas constant) = 0.0821 L·atm/K·mol

R (gas constant) = 8.314 J mol^{-1} K^{-1}

F (Faraday's constant) = 96 500 C mol^{-1}

SOLUBILITY TABLE:

Anion	**Solubility rule**
Mostly soluble	
Acetates, nitrates and perchlorates	All cations form *soluble* compounds. ($KClO_4$ and $AgC_2H_3O_2$ slightly soluble)
Chlorides, bromides, iodides	All cations form *soluble* compounds except Hg_2^{2+}, Ag^+ and Pb^{2+} ($PbCl_2$ and $PbBr_2$ slightly soluble)
Sulfates	All cations form *soluble* compounds except Pb^{2+}, Ba^{2+} and Sr^{2+} (Ca^{2+} and Ag^+ form slightly soluble compounds)
Mostly insoluble	
Carbonates and phosphates	All cations form *insoluble* compounds except Group IA metals and NH_4^+
Sulfides	All cations form *insoluble* compounds except Group IA and IIA metals and NH_4^+
Hydroxides	All cations form *insoluble* compounds except Group IA metals, Ba^{2+} and Sr^{2+} and NH_4^+ [$Ca(OH)_2$ is slightly soluble]

IUPAC Periodic Table of the Elements

Key:

atomic number
Symbol
name
conventional atomic weight
standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008 [1.0078, 1.0082]																	2 He 4.0026
3 Li 6.94 [6.938, 6.997]	4 Be 9.0122											5 B 10.81 [10.806, 10.821]	6 C 12.011 [12.009, 12.012]	7 N 14.007 [14.006, 14.008]	8 O 15.999 [15.999, 16.000]	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305 [24.304, 24.307]											13 Al 26.982	14 Si 28.085 [28.084, 28.086]	15 P 30.974	16 S 32.06 [32.059, 32.076]	17 Cl 35.45 [35.446, 35.457]	18 Ar 39.95 [39.792, 39.963]
19 K 39.098	20 Ca 40.078(4)	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845(2)	27 Co 58.933	28 Ni 58.693	29 Cu 63.546(3)	30 Zn 65.38(2)	31 Ga 69.723	32 Ge 72.630(8)	33 As 74.922	34 Se 78.971(8)	35 Br 79.904 [79.901, 79.907]	36 Kr 83.798(2)
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224(2)	41 Nb 92.906	42 Mo 95.95	43 Tc	44 Ru 101.07(2)	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60(3)	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71 lanthanoids	72 Hf 178.49(2)	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23(3)	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38 [204.38, 204.39]	82 Pb 207.2	83 Bi 208.98	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 actinoids	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm	62 Sm 150.36(2)	63 Eu 151.96	64 Gd 157.25(3)	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

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