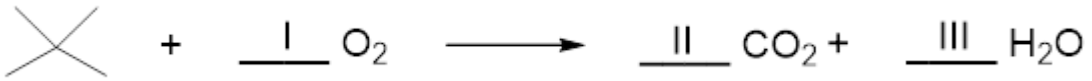
SECTION A **[TOTAL = 20 MARKS]**

Circle the correct answer on **this** question paper: Each question has only ONE correct option.

1. Identify the correct coefficients required to balance the following combustion reaction?



A. I = 4; II = 5; III = 12
B. I = 16; II = 10; III = 11
C. I = 8; II = 5; III = 6
D. I = 2; II = 4; III = 6
E. I = 9; II = 15; III = 5 (1 mark)

2. What is the relationship between the following compounds?

A. constitutional isomers
B. stereoisomers
C. identical
D. not isomers; different compounds entirely
E. location isomers (1 mark)

3. Using these metal ion/metal standard reduction potentials

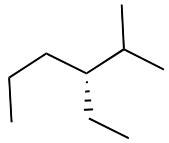
$Fe^{2+}(aq)\|Fe(s)$	$Zn^{2+}(aq)\|Zn(s)$	$Cr^{3+}(aq)\|Cr(s)$	$Cu^{2+}(aq)/Cu(s)$
-0.44 V	-0.76 V	-0.74 V	+0.34 V

Calculate the standard cell potential for the cell whose reaction is

$Fe^{2+}(aq) + Cr(s) \rightarrow Fe(s) + Cr^{3+}(aq)$

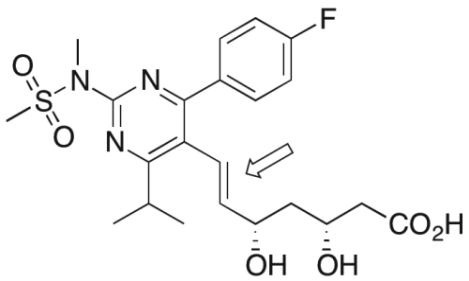
A. -0.30 V
B. -1.18 V
C. +0.30 V
D. +0.16 V
E. -0.16 V (2 marks)

4. Which of the following is the correct IUPAC name of the following structure?



A. (*S*)-3-ethyl-2-methylhexane
B. (*R*)-3-ethyl-2-methylhexane
C. (*S*)-3-ethyl-2-methylpentane
D. (*R*)-3-ethyl-2-methylpentane
E. (S)-3-ethyl-3-methylhexane (1 mark)

5. Shown below is the structure of Crestor® (rosuvastatin), a medication used to reduce cholesterol. Which term describes the double bond indicated by the arrow?

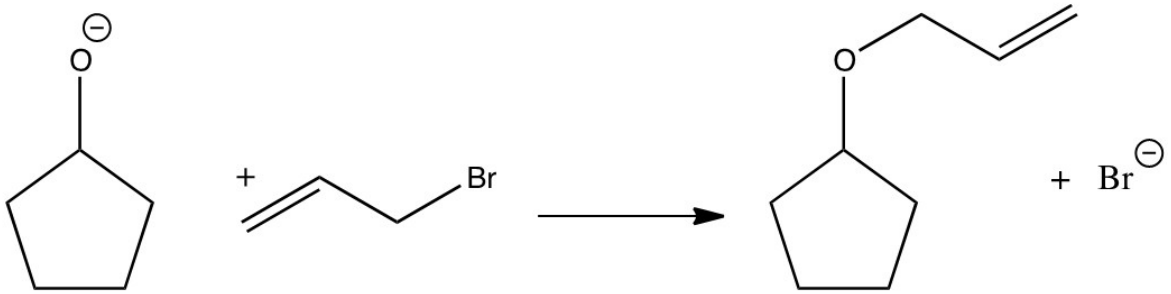


A. cis only
B. trans only
C. both terms may be used
D. neither cis nor trans
E. cannot be determined from the structure (1 mark)

6. What is the molarity of OH^- ions if the H^+ ion concentration in an aqueous solution at 25.0 $^{\circ}C$ is 0.100 M?

A. 0.100 M
B. 1.00×10^{-7} M
C. 10×10^{-12} M
D. 1.00×10^{-13} M
E. 0 M (2 marks)

7. What are the nucleophile, electrophile, and leaving group in the reaction shown below?



A. Nucleophile bromo-2-propene; electrophile cyclohexoxide; leaving group Br
B. Nucleophile cyclohexoxide; electrophile bromo-2-propene; leaving group Br
C. Nucleophile Br; electrophile bromo-2-propene, leaving group cyclohexoxide
D. Nucleophile cyclohexoxide; electrophile Br; leaving group bromo-2-propene
E. Nucleophile Br; electrophile cyclohexoxide; leaving group bromo-2-propene

(2 marks)

8. What is the oxidation number of the arsenic atom in the AsO_4^{3-} ion?

A. +1
B. +3
C. +4
D. +5
E. +6

(1 mark)

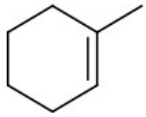
9. Which of the following is the rate equation for the reaction shown?

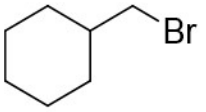
$$CH_3CH_2CH_2CHBrCH_3 + NaN_3 \longrightarrow CH_3CH_2CH_2CHN_3CH_3 + NaBr$$

A. Rate = $k[CH_3CH_2CH_2CHBrCH_3]$
B. Rate = $k[NaN_3]$
C. Rate = $k[CH_3CH_2CH_2CHBrCH_3]\,[NaBr]$
D. Rate = $k[CH_3CH_2CH_2CHBrCH_3]\,[NaN_3]$
E. Rate = $k[CH_3CH_2CH_2CHBrCH_3]^2\,[NaN_3]$

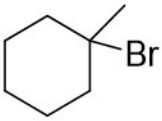
(1 mark)

10. Which of the molecules below arises when the given alkene undergoes *anti*-Markovnikov hydrohalogenation with HBr?

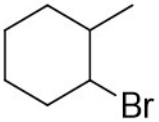




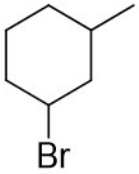
I



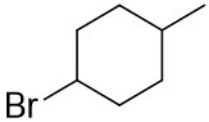
II



III



IV



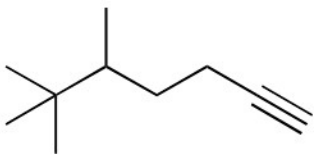
V

A. I
B. II
C. III
D. IV
E. V (2 marks)

11. The pK_a of acetic acid, $HC_2H_3O_2$, is 4.76. A buffer solution was made using an unspecified amount of $NaC_2H_3O_2$ and 0.30 moles of acetic acid in enough water to make 1.50 liters of solution. Its pH was measured as 4.55. How many moles of $NaC_2H_3O_2$ were used?

A. 0.10 mol
B. 0.18 mol
C. 0.30 mol
D. 0.37 mol
E. 0.49 mol (2 marks)

12. What is the IUPAC name for the molecule shown?

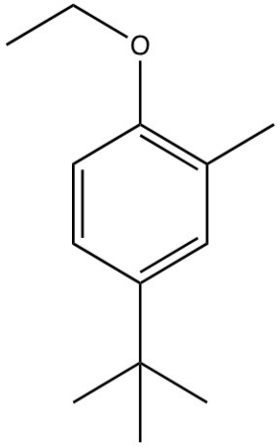


A) 5,6,6-trimethyl-1-heptyne
B) 5-*tert*-butyl-1-hexyne
C) 2,2,3-trimethyl-6-heptyne
D) 2,2,3-(3-butynyl)butane
E) *sec*-butyl-*tert*-butylacetylene (1 mark)

13. Methanoic acid is commonly known as _____.

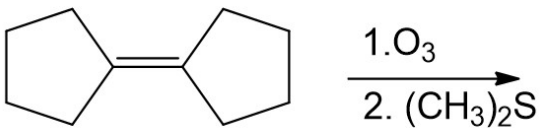
A) formic acid
B) acetic acid
C) malonic acid
D) glutaric acid
E) oxalic acid (1 mark)

14. Provide an IUPAC name for the following compound.



A) 4-butyl-1-ethoxy-2-methylbenzene
B) 1-*t*-butyl-4-ethoxy-3-methylbenzene
C) 1-butyl-4-ethoxy-3-methylbenzene
D) 4-*t*-butyl-1-ethoxy-2-methylbenzene
E) 4-*t*-butyl-1-ethoxy-2-methylcyclohexane (1 mark)

15. What is the predicted product of the reaction shown?



A) cyclopentene
B) cyclopentanol
C) cyclopentanal
D) cyclopentanone
E) none of these

SECTION B **[85 MARKS]**

QUESTION 1: **[20 MARKS]**

1.1 You have two samples of different metals, metal G and metal H, each having the same mass. You heat both metals to 105 ºC and then place each one into separate beakers containing the same quantity of water at 35 ºC.

1.1.1 You measure the temperatures of the water in the two beakers when each metal has cooled by 10 ºC and find that the temperature of the water with metal G is higher than the temperature of the water with metal H. Which metal has the greater specific heat? Explain. (3 marks)

1.1.2 After some time, the temperature of the water in each beaker rises to a maximum value. In which beaker does the water rise to the higher value, the one with metal G or the one with metal H? Explain. (2 marks)

1.1.3 Acetic acid, CH_3COOH, is contained in vinegar. Suppose acetic acid was formed from its elements, according to the following equation:
$2C(\text{graphite}) + 2H_2(g) + O_2(g) \rightarrow CH_3COOH(l)$

Find the enthalpy change, ΔH, for this reaction, using the following data:
$CH_3COOH(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$; $\Delta H = -800$ kJ
$C(\text{graphite}) + O_2(g) \rightarrow CO_2(g)$; $\Delta H = -320$ kJ
$H_2(g) + 12O_2(g) \rightarrow H_2O(l)$; $\Delta H = -212$ kJ (5 marks)

1.2 Consider the Haber process:
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$; $\Delta H° = -91.8$ kJ
The density of ammonia at 25ºC and 1.00 atm is 0.696 g/L. The density of nitrogen, N_2, is 1.145 g/L, and the molar heat capacity is 29.12 J/(mol. ºC).

1.2.1 How much heat is evolved in the production of 1.00 L of ammonia at 25 ºC and 1.00 atm? (5 marks)

1.2.2 What percentage of this heat is required to heat the nitrogen required for this reaction (0.500 L) from 25ºC to 400ºC, the temperature at which the Haber process is run? (5 marks)

QUESTION 2: **[15 MARKS]**

2.1. A chemist working for ArcelorMittal as a researcher in the electrochemistry lab was supposed to plate a given metal sample with gold to protect it from rusting. He was required to deposit 8.5000 troy ounces of gold (1 troy ounce = 31.103 gram) on a medallion using the electrolytic reaction,

$$Au(CN)_4^-(aq) + 3\,e^- \leftrightarrows Au(s) + 4\,CN^-$$

He mistakenly deposited 8.148 troy ounces of gold on the medallion instead of the correct amount. Using calculations based on your knowledge of Faraday's law of electrolysis specify how many hours and minutes he should run the cells in the forward direction, using a current of 1.350 amperes, to rectify the error and bring the amount of gold deposited to the correct weight. (6 marks)

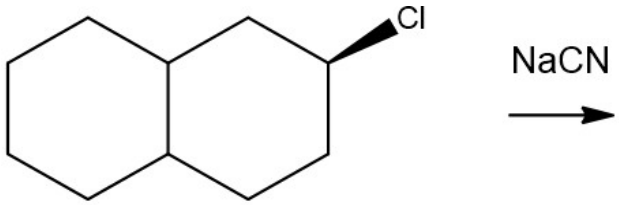
2.2. Sketch a galvanic cell with metallic zinc and metallic tin electrodes. Make sure to label the anode and cathode, and to suggest a good electrolyte. (4 marks)

2.3 If the measured voltage of the cell Zn(s) | Zn^{2+}(aq) || Ag^+(aq) | Ag(s) is 1.37 V when the concentration of Zn^{2+} ion is 0.030 M, what is the Ag^+ ion concentration in this cell?

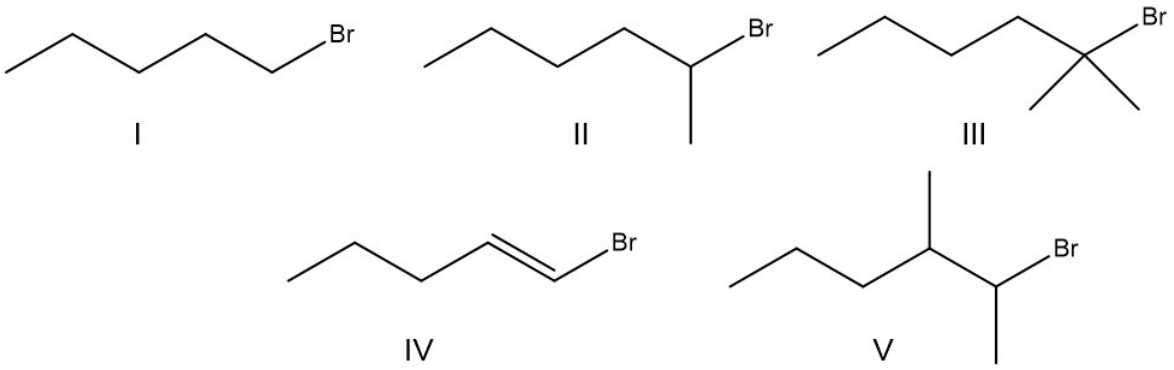
(5 marks)

QUESTION 3: **[15 MARKS]**

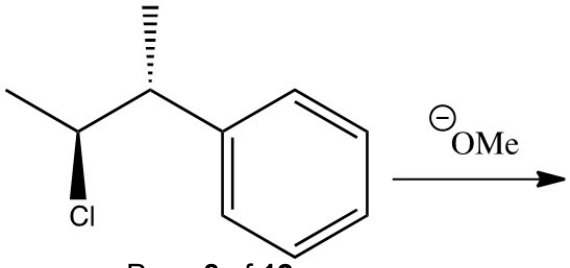
3.1. Write down the products for the S_N2 reaction shown below and illustrate the mechanism of the reaction with curved arrows. (4marks)



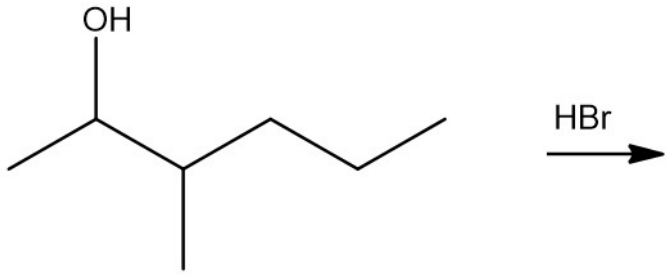
3.2. You have been given the option of using any of the five alkyl halides shown below for an S_N2 reaction? Which of them will you select to achieve the fastest S_N2 reaction? Support your answer with a brief explanation. (3 marks)



3.3. Show the mechanism of the following elimination reaction with curved arrows and draw the structure of the product formed. (5 marks)



3.4. Show the predicted curved arrow mechanism for the reaction below and determine the product formed. Note that three steps are required to obtain the product.



(3 marks)

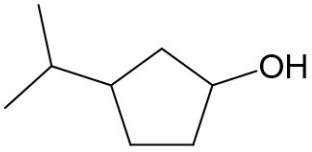
QUESTION 4: **[30 MARKS]**

4.1. Draw the structure of the following compounds:

4.1.1. (*S*)-3-hexyn-2-ol (2 marks)
4.1.2. 3-phenylpropanal (2 marks)
4.1.3. (*E*)-4-cyclopentyl-2-pentene (2 marks)

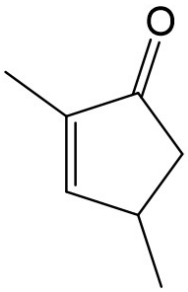
4.2. Write the IUPAC name for the following structures.

4.2.1.



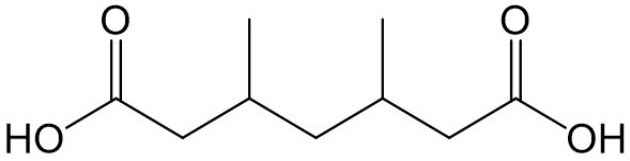
(3 marks)

4.2.2.



(3 marks)

4.2.3.



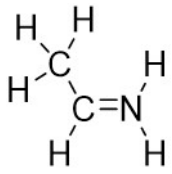
(3 marks)

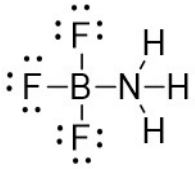
4.3. Draw the Lewis structures of the following compounds:

4.3.1. H_2SO_4 (2 marks)

4.3.2. SF_6 (2 marks)

4.4. Determine the formal charges of nitrogen in the following structures – I and II.

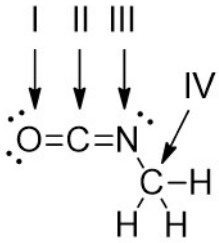




(4 marks)

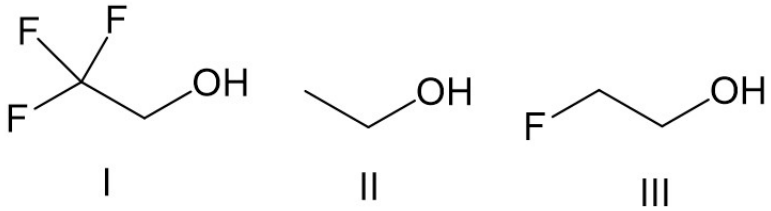
Structure I Structure II

4.5. Determine the hybridization of the indicated atoms (I, II, II and IV) in the following compound?



(4 marks)

4.6. Rank the alcohols shown in decreasing order of acidity. Justify your answer



I II III

(3 marks)

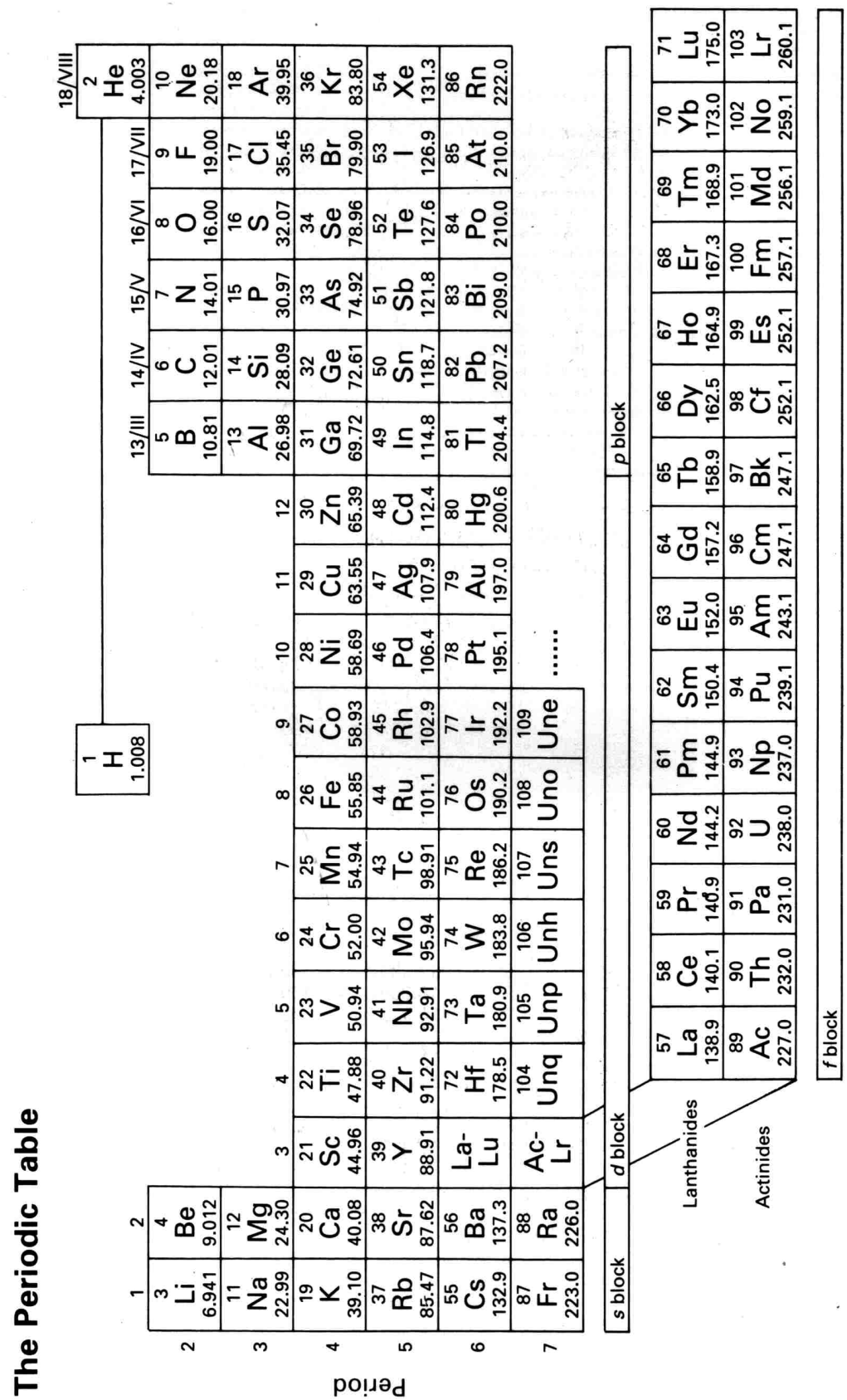
End of Paper

Data sheet

N_A (Avogadro's number) = 6.022×10^{23}
1 atm = 760 mmHg = 760 torr = 101.3 kPa = 1.013 bar
R (gas constant) = 0.0821 L·atm/K·mol
R (gas constant) = $8.314\ 4621(75) \times 10^{-2}$ L bar K^{-1} mol^{-1}
101.3 J = 1 L.atm

Table 1: Specific Heat Capacities

Compound	C_s (J/ºC.g)	Compound	C_s (J/ºC.g)
H_2O (l)	4.184	Pb	0.128
Al	0.903	Au	0.129
Cu	0.385	Ag	0.235
Fe	0.449	C (graphite)	0.711


The Periodic Table
Period
1
2
3
4
5
6
7
18/VIII
13/III
14/IV
15/V
16/VI
17/VII
s block
d block
p block
f block
Lanthanides
Actinides