Write the first letter of your last name in this box. →

THE UNIVERSITY OF BRITISH COLUMBIA
Department of Chemistry
Chemistry 123 Final Examination

SAMPLE FINAL Time Limit: 2.5 hrs

SURNAME/
LAST NAME:_____ GIVEN NAME(S):_____
(PRINTED CAPITALS IN INK) (PRINTED CAPITALS IN INK)

STUDENT NUMBER:_____ SIGNATURE:_____
(PRINTED IN INK) (SIGNED IN INK)

INSTRUCTIONS

1. Answer all questions.
2. Answers for **PART I** must be recorded on the "Chemistry 123 Final Examination Answer Bubble Sheet" provided. Answers for **PART 1** written directly on the examination paper ***will not be graded***. **DO NOT FOLD** the "Chemistry 123 Final Examination Answer Bubble Sheet".
3. Answers for **PART II** must be recorded directly on the examination paper.
4. Check that your examination paper contains pages numbered 1 through 22.
5. A sheet of "useful information" and the Periodic Table have been provided separately on blue paper.
6. The only calculators permitted are the Sharp EL−510 series. All other calculators will be confiscated by the examiners.
7. Model kits are allowed and may be pre−assembled.
8. No electronic communication devices are permitted on writing desks.
9. When handing in your exam, please place all loose pages inside the examination paper. **DO NOT FOLD** the "Chemistry 123 Final Examination Answer Bubble Sheet".

Check √ your lecture section:
___201 (MWF 1:00pm) Kayli Johnson
___202 (MWF 2:00pm) Laurel Schafer
___203 (MWF 3:00pm) Keng Chou/Jason Hein
___210 (MWF 10:00am) Keng Chou/Jason Hein
___211 (MWF 11:00am) Glenn Sammis
___222 (T, Th 2:00pm) Hongbin Li/Angela Crane
___266 (T, Th 11:00am) Anka Lekhi
___299 (T, Th 9:30am) Hongbin Li/Angela Crane

RULES GOVERNING FORMAL EXAMINATIONS

1. Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, his or her UBCcard for identification.
2. Examination candidates are not permitted to ask questions of the examiners or invigilators, except in cases of supposed errors or ambiguities in examination questions, illegible or missing material, or the like.
3. No examination candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination. Should the examination run forty-five (45) minutes or less, no examination candidate shall be permitted to enter the examination room once the examination has begun.
4. Examination candidates must conduct themselves honestly and in accordance with established rules for a given examination, which will be articulated by the examiner or invigilator prior to the examination commencing. Should dishonest behaviour be observed by the examiner(s) or invigilator(s), pleas of accident or forgetfulness shall not be received.
5. Examination candidates suspected of any of the following, or any other similar practices, may be immediately dismissed from the examination by the examiner/invigilator, and may be subject to disciplinary action:
   i. speaking or communicating with other examination candidates, unless otherwise authorized;
   ii.purposely exposing written papers to the view of other examination candidates or imaging devices;
   iii. purposely viewing the written papers of other examination candidates;
   iv. using or having visible at the place of writing any books, papers or other memory aid devices other than those authorized by the examiner(s); and,
   v. using or operating electronic devices including but not limited to telephones, calculators, computers, or similar devices other than those authorized by the examiner(s)—(electronic devices other than those authorized by the examiner(s) must be completely powered down if present at the place of writing).
6. Examination candidates must not destroy or damage any examination material, must hand in all examination papers, and must not take any examination material from the examination room without permission of the examiner or invigilator.
7. Notwithstanding the above, for any mode of examination that does not fall into the traditional, paper-based method, examination candidates shall adhere to any special rules for conduct as established and articulated by the examiner.
8. Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

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For pages 3-16 (Part I) to follow, please record all of your answers on the *separate Remark™ bubble sheet* provided.

PART I – Short Answer

1. **[2 marks]** The solution made by dissolving the salt $(CH_3)_3HNCl$ in water is
   A. acidic.
   B. basic.
   C. neutral.
   D. either acidic or basic depending on the amount of $(CH_3)_2H_2NCl$.
   E. either acidic or basic depending on the temperature of the solution.

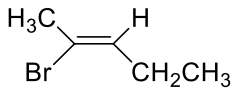
2. **[2 marks]** What is the final pH of an aqueous solution that is produced by adding 0.15 moles of ammonia (NH_3) and 0.45 moles ammonium chloride (NH_4Cl) to 1 L of water? Note: $K_a(NH_4Cl) = 5.6 \times 10^{-10}$

   A. 9.72
   B. 8.77
   C. 3.00
   D. 0.33

3. **[2 marks]** In a single step, an oxygen atom (O) collides with an ozone molecule (O_3), a chemical reaction occurs and the products separate as two O_2 molecules. According to the Law of Mass Action, the rate law for this chemical reaction is:

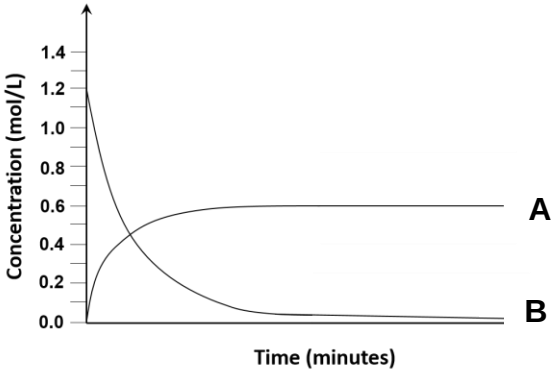
   A. $-\frac{d[O]}{dt} = k[O_2][O_2]$
   B. $-\frac{d[O]}{dt} = k[O_3]$
   C. $-\frac{d[O]}{dt} = k[O][O_3]$
   D. We cannot apply The Law of Mass Action in this case because the statement above does not describe an elementary reaction.

4. **[2 marks]** What is the name of the following compound?



   A. (*E*)–2–bromo–2–pentene
   B. (*E*)–4–bromo–3–pentene
   C. (*E*)–2–pentene bromide
   D. (*Z*)–2–bromo–2–pentene
   E. (*Z*)–3–bromo–2–pentene
   F. (*Z*)–2–pentene bromide

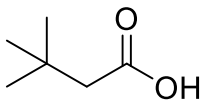
5. **[2 marks]** The concentrations of reactants and products in a chemical reaction were monitored and graphed below. Which reaction does this graph represent?



A. A → B
B. B → A
C. 2B → A
D. A → 2B
E. 2A → B
F. B → 2A

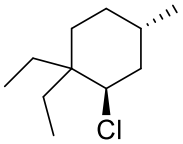
6. **[2 marks]** Under standard conditions, the Gibbs Free Energy difference between the two chair conformations of aminocyclohexane is 3.8 kJ mol^{-1} at 298 K.
Which of the following statement is **<u>correct</u>** about *trans*-1,2-diaminocyclohexane:
   A. The conformation with the amine groups in the axial position constitutes 78.4 % of the two forms.
   B. The conformation with the amine groups in the equatorial position constitutes 78.4 % of the two forms.
   C. The conformation with the amine groups in the axial position constitutes 82.3 % of the two forms.
   D. The conformation with the amine groups in the equatorial position constitutes 82.3 % of the two forms.
   E. The two conformations are present in equal amounts.
   F. It is not possible to tell the relative proportion based on the given information.

7. **[2 marks]** What is the name of the following compound?



   A. 2–*tert*–butylethanoic acid
   B. 3,3–dimethylbutanoic acid
   C. 1–hydroxy–2–*tert*–butylethanone
   D. 1–hydroxy–3,3–dimethylbutanone
   E. 3,3–dimethylbutanoate

8. **[2 marks]** What is the name of the following compound?



   A. (2*R*, 4*S*)-2-chloro-1,1-diethyl-4-methylcyclohexane
   B. (2*R*, 4*R*)-2-chloro-1,1-diethyl-4-methylcyclohexane
   C. (2*S*, 4*S*)-2-chloro-1,1-diethyl-4-methylcyclohexane
   D. (2*S*, 4*R*)-2-chloro-1,1-diethyl-4-methylcyclohexane

9. **[2 marks]** A reaction is carried out at 298 K and 1.0 bar and it is found that $\Delta H^{\circ} = 0.695\ kJ$ and $\Delta S^{\circ} = 1.26\ JK^{-1}$. Which of the following statements is **TRUE**?

   A. At equilibrium, there will only be products in the reaction flask.
   B. At equilibrium, there will only be reactants in the reaction flask.
   C. At equilibrium, there will be both products and reactants present in the reaction flask, but there will be more products than reactants.
   D. At equilibrium, there will be both products and reactants present in the reaction flask, but there will be more reactants than products.
   E. At equilibrium, there will be equal amounts of products and reactants in the reaction flask.

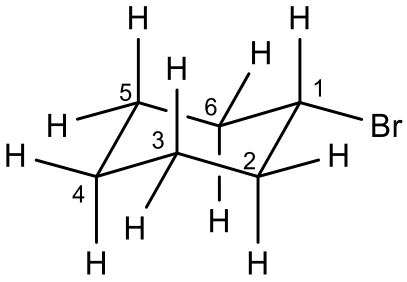
10. **[2 marks]** Given that the following reaction has a $\Delta G^{\ddagger}_{325} = 42$ kJ mol^{-1}:

$$\text{A} \rightarrow \text{B} \qquad \Delta G^{\circ}_{325} = -31 \text{ kJ mol}^{-1}$$

What is the Gibbs Free Energy of Activation at 325 K and standard state for the **reverse reaction**?

A. 73 kJ mol^{-1}
B. 11 kJ mol^{-1}
C. –42 kJ mol^{-1}
D. 31 kJ mol^{-1}
E. 42 kJ mol^{-1}
F. –31 kJ mol^{-1}

11. **[2 marks]** Which of the following sets of atoms are *cis* to the bromine atom in the structure below.



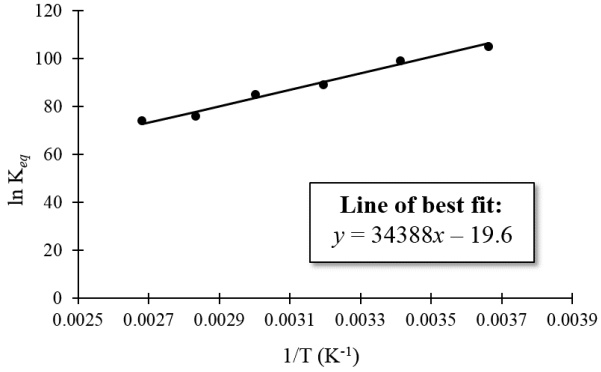
A. the equatorial H's at C–2 and C–6
B. the axial H's at C–2 and C–6
C. the equatorial H at C–4 and the axial H at C–5
D. the equatorial H at C–4 and the axial H at C–6
E. the axial H's at C–3 and C–4

12. **[2 marks]** The formation of water is given by the following equilibrium:

$$H_2\,(g) + \frac{1}{2}\,O_2\,(g) \rightleftharpoons H_2O\,(l)$$

Using the following van't Hoff Plot for data collected from studying the equilibrium above at various temperatures, determine the value for the entropy change of the reaction.

van't Hoff Plot for the formation of H_2O (l)



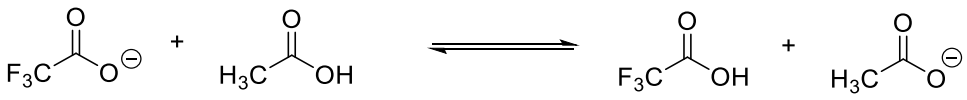
A. –285.9 kJ mol^{-1} K^{-1}
B. –19.6 J mol^{-1} K^{-1}
C. 163.0 J mol^{-1} K^{-1}
D. 34.4 kJ mol^{-1} K^{-1}
E. –163.0 J mol^{-1} K^{-1}
F. 285.9 kJ mol^{-1} K^{-1}

13. **[2 marks]** For a given chemical reaction, which of the following terms can be **correctly** associated with Gibbs Free Energy?

I. ΔG can be used to predict spontaneity only at constant temperature and pressure.
II. ΔG can be used to predict spontaneity when the temperature and pressure are not constant.
III. $\Delta G = -RT\,lnQ$
IV. The forward reaction is spontaneous only if $\Delta G^{\circ} < 0$.

A. I only
B. II only
C. I and III
D. II and IV
E. I, III and IV
F. II, III and IV

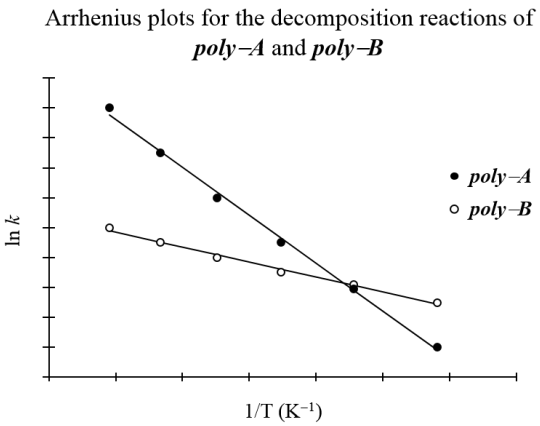
14. **[2 marks]** Consider the following organic acid-base equilibrium.



Which of the following is **TRUE** when the reactants are **FIRST** added together at 298 K?

A. $\Delta G < 0; \Delta G^{\circ} > 0$
B. $\Delta G < 0; \Delta G^{\circ} < 0$
C. $\Delta G > 0; \Delta G^{\circ} > 0$
D. $\Delta G > 0; \Delta G^{\circ} < 0$

15. **[2 marks]** A researcher is studying the rate of decomposition of two different biodegradable plastics (***poly–A*** and ***poly–B***). The decomposition pathway is found to follow first–order kinetics, and the reactions have been studied at various temperatures. Using the Arrhenius plot constructed from the researcher's data (to the right), what is **TRUE** about the activation energy of each decomposition reaction?



A. The activation energy for the decomposition of ***poly–A*** is higher than the activation energy for the decomposition of ***poly–B***.
B. The activation energy for the decomposition of ***poly–A*** is lower than the activation energy for the decomposition of ***poly–B***.
C. The activation energy for the decomposition of ***poly–A*** is equal to the activation energy for the decomposition of ***poly–B***.
D. The relative activation energies of the decomposition reactions cannot be determined from an Arrhenius plot.

For questions 16-19, consider a closed system of an ideal gas that undergoes an isothermal, reversible compression from state 1 ($P_1 = 1$ atm, $V_1 = 8$ L, $T = 0$ °C) to state 2 ($P_2 = 2$ atm, $V_2 = 4$ L, $T = 0$ °C). During this process, the system releases 298 J of heat to the surroundings.

16. **[1 mark]** Which of the following values corresponds to the work of the system?

A. $w = 298$ J
B. $w = -298$ J
C. $w = 0$ J
D. $w = 405$ J
E. $w = -405$ J

17. **[1 mark]** Which of the following values corresponds to the change in enthalpy of the system?

A. $\Delta H_{sys} = -298$ J
B. $\Delta H_{sys} = 298$ J
C. $\Delta H_{sys} = 0$ J
D. $\Delta H_{sys} = 405$ J
E. $\Delta H_{sys} = -405$ J

18. **[1 mark]** Which of the following values corresponds to the change in entropy of the system?

A. $\Delta S_{sys} = -298\ \text{J K}^{-1}$
B. $\Delta S_{sys} = 298\ \text{J K}^{-1}$
C. $\Delta S_{sys} = 0\ \text{J K}^{-1}$
D. $\Delta S_{sys} = 1.09\ \text{J K}^{-1}$
E. $\Delta S_{sys} = -1.09\ \text{J K}^{-1}$
F. $\Delta S_{sys} = \infty\ \text{J K}^{-1}$

19. **[1 mark]** Which of the following values corresponds to the change in Gibbs free energy of the system?

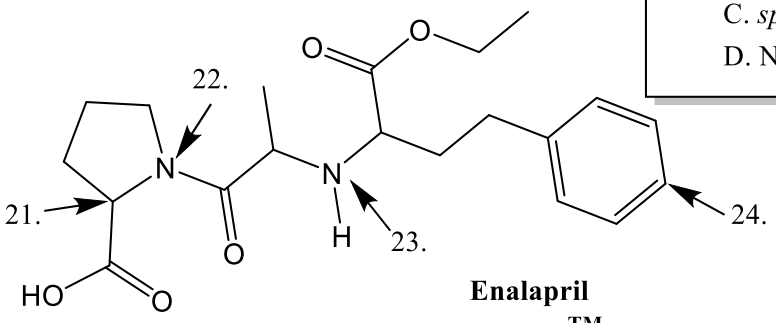
A. $\Delta G_{sys} = 0$ J
B. $\Delta G_{sys} = 298$ J
C. $\Delta G_{sys} = -298$ J
D. $\Delta G_{sys} = 405$ J
E. $\Delta G_{sys} = -405$ J

20. **[2 marks]** A system contains 1 kg of ice (initially at 0 °C) melted. During the melting process, the temperature of the surroundings was 0 °C and the pressure was 1 atm. Which of the following statements is **TRUE**?

A. $\Delta H_{sys} = 0$ J
B. $\Delta E_{sys} = 0$ J
C. $\Delta S_{sys} = 0$ J
D. $\Delta G_{sys} = 0$ J
E. None of the above.

Use the molecule shown below, Enalapril (Vasotec™), to answer questions 21-25.

[4 marks] Identify the hybridization of the indicated atoms.



Enalapril
Vasotec™

For each question (21-24), choose one of the following:

A. *sp*
B. sp^2
C. sp^3
D. None of the above.

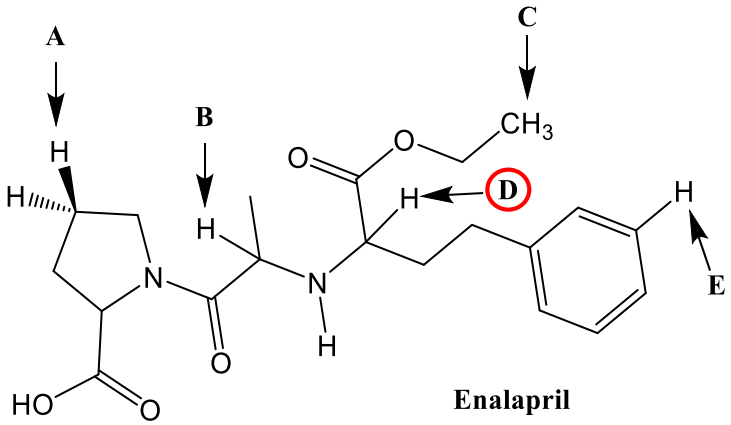
Answers:

21. C (sp^3)
22. B (sp^2)
23. C (sp^3)
24. B (sp^2)

25. **[1 mark]** Choose the letter that describes three of the functional groups present in Enalapril.

A. alcohol, ketone, amine
B. carboxylic acid, ether, amide
C. amine, ester, carboxylic acid
D. amide, ketone, carboxylic acid
E. aldehyde, amine, alcohol
F. ether, amine, ester

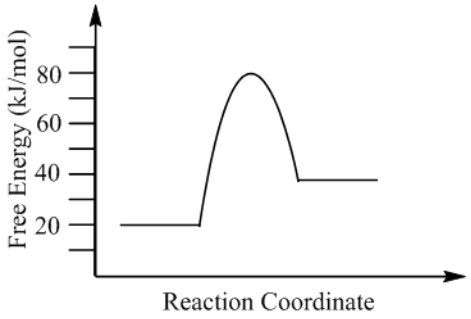
26. **[1 mark]** Which of the labelled protons **A-E,** is most acidic in the Enalapril molecule as drawn below:



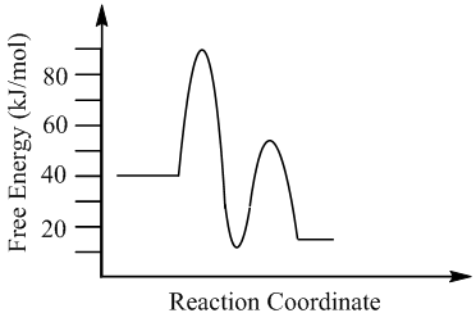
Enalapril
Vasotec™

For questions 27-30, consider the following reaction coordinate diagrams for processes at standard state.

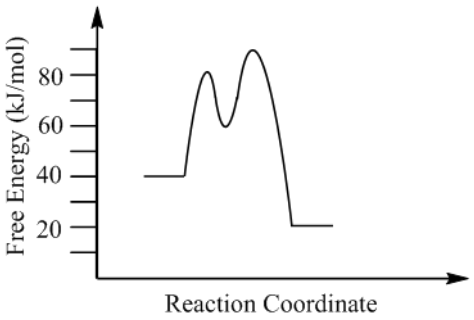
A



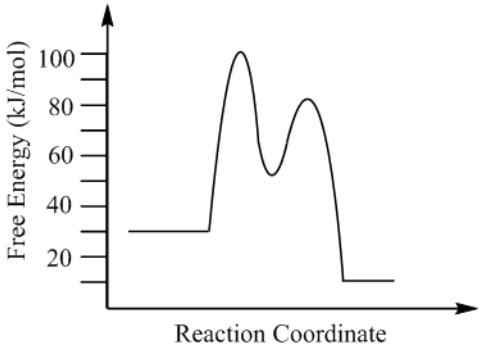
B



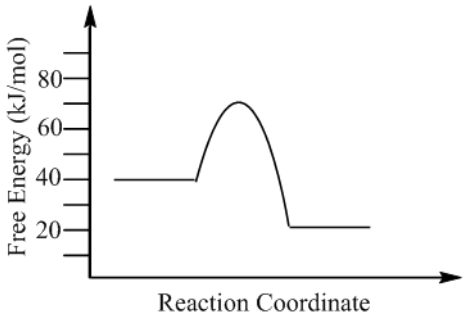
C



D



E



27. **[1 mark]** Identify the reaction coordinate diagram, **A-E**, that best represents a spontaneous S_N2 reaction at standard state.

E

28. **[1 mark]** Use the reaction coordinate diagram that you have chosen in part (a) to determine the numeric value for $\Delta G^{\ddagger}$ in kJ mol^{-1} of the rate determining step of an S_N2 reaction.

A. $\Delta G^{\ddagger}$ = 20 kJ mol^{-1} B. $\Delta G^{\ddagger}$ = 30 kJ mol^{-1} C. $\Delta G^{\ddagger}$ = 40 kJ mol^{-1}
D. $\Delta G^{\ddagger}$ = 50 kJ mol^{-1} E. $\Delta G^{\ddagger}$ = 60 kJ mol^{-1} F. $\Delta G^{\ddagger}$ = 70 kJ mol^{-1}

29. **[1 mark]** Identify the reaction coordinate diagram, **A-E**, that best represents a spontaneous S_N1 reaction at standard state.

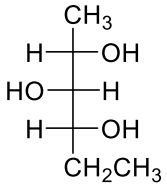
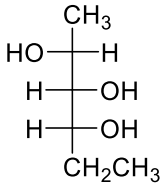
D

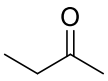
30. **[1 mark]** Use the reaction coordinate diagram that you have chosen in part (c) to determine the numeric value for $\Delta G^{\ddagger}$ in kJ mol^{-1} of the rate determining step of an S_N1 reaction.

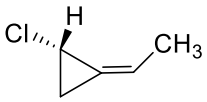
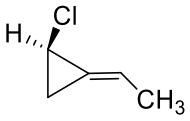
A. $\Delta G^{\ddagger}$ = 20 kJ mol^{-1} B. $\Delta G^{\ddagger}$ = 30 kJ mol^{-1} C. $\Delta G^{\ddagger}$ = 40 kJ mol^{-1}
D. $\Delta G^{\ddagger}$ = 50 kJ mol^{-1} E. $\Delta G^{\ddagger}$ = 60 kJ mol^{-1} F. $\Delta G^{\ddagger}$ = 70 kJ mol^{-1}

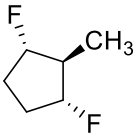
[12 marks] For questions 31-36, consider each pair of structural formulas. Identify the letter that corresponds to the term that **best** describes the relationship between the two structures. ***NOTE: Each term may be used more than once and not all terms need to be used.***

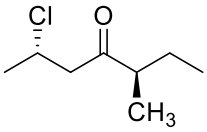
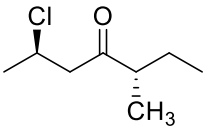
A. Identical
B. Constitutional Isomers
C. Enantiomers
D. Diastereomers
E. None of the above

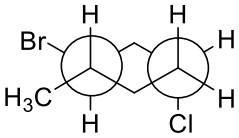
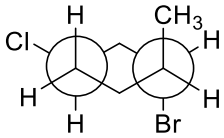
31.   **D**

32.   **B**

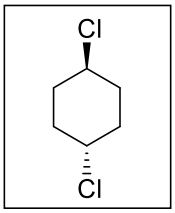
33.   **D**

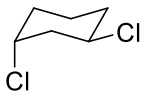
34.   **A**

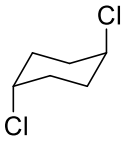
35.   **C**

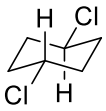
36.   **A**

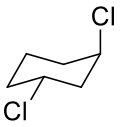
37. **[2 marks]** Are the molecules, a–d below, the same as the compound in the box?
Bubble yes Ⓨ or no Ⓝ for each part a–d on the bubble sheet.



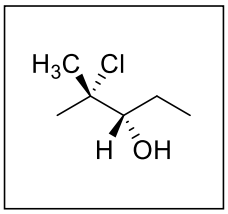
a)  **No**

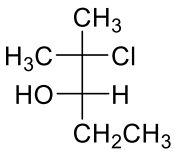
b)  **Yes**

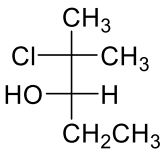
c)  **Yes**

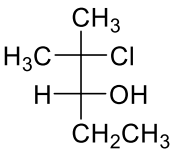
d)  **No**

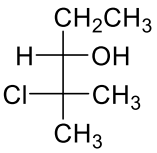
38. **[2 marks]** Are the molecules, a–d below, the same as the compound in the box?
Bubble yes Ⓨ or no Ⓝ for each part a–d on the bubble sheet.



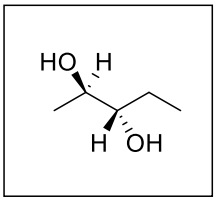
a)  **Yes**

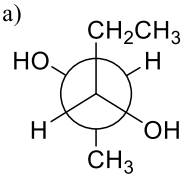
b)  **Yes**

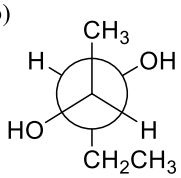
c)  **No**

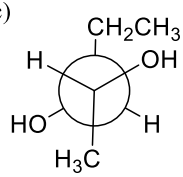
d)  **Yes**

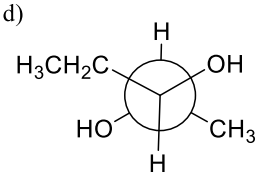
39. **[2 marks]** Are the molecules, a–d below, a Newman projection of the molecule in the box **in the same conformation?**
Bubble yes Ⓨ or no Ⓝ for each part a–d on the bubble sheet.



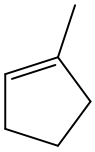
a)  **Yes**

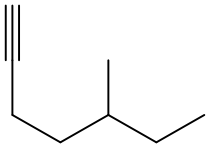
b)  **Yes**

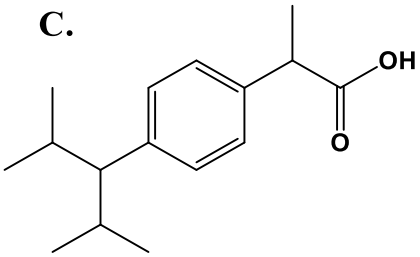
c)  **Yes**

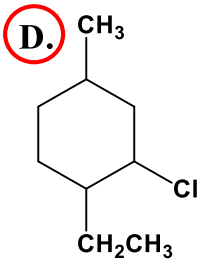
d)  **Yes**

40. **[2 marks]** Which molecule, A-D below, has the largest number of stereoisomers?

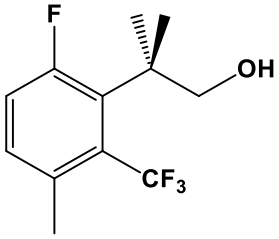
A. 

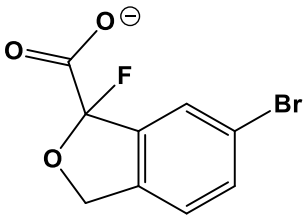
B. 

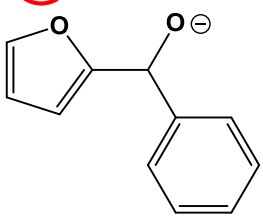
C. 

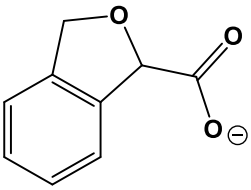
D. 

41. **[2 marks]** Which molecule below will be the strongest base?

A. 

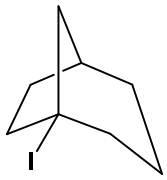
B. 

C. 

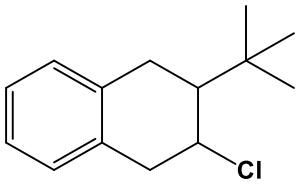
D. 

42. **[2 marks]** Which molecule below will react fastest in an S_N2 reaction as the electrophile?

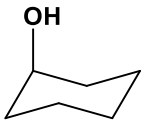
A.



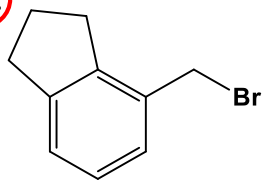
B.



C.

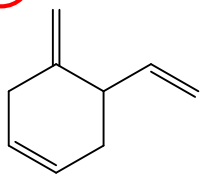


D.

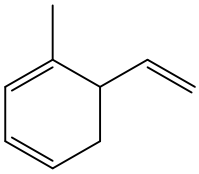


43. **[2 marks]** Which molecule below has the fewest valid resonance structures?

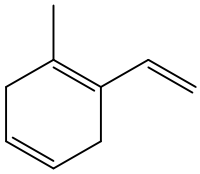
A.



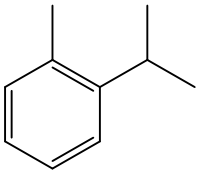
B.



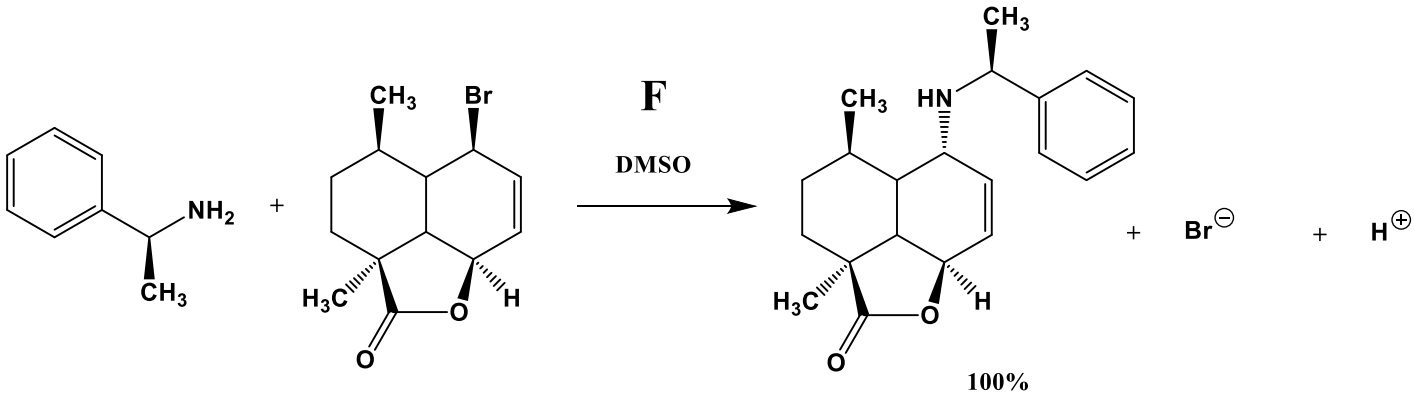
C.



D.



Consider the following reaction to answer questions 44-48:



44. **[1 mark]** Identify the label (**A–F**) for the electrophile in the reaction above. **B**

45. **[1 mark]** Identify the label (**A–F**) for the nucleophile in the reaction above. **A**

46. **[1 mark]** Identify the label (**A–F**) for the leaving group in the reaction above. **D**

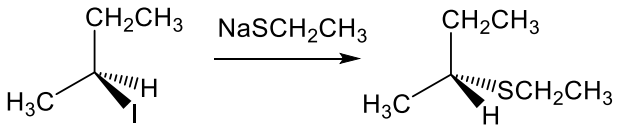
47. **[1 mark]** Identify the label (**A–F**) for the solvent in the reaction above. **F**

48. **[1 mark]** Did this reaction undergo an S_N1, S_N2 or acid-base mechanism?

A. S_N1
B. S_N2
C. Acid-Base

Use the following information to answer questions 49-52.

In **REACTION 1**, optically pure (*S*)–2–iodobutane (**A**) is reacted with $NaSCH_2CH_3$, and a single, optically pure product, *sec*–butyl ethyl sulfide (**B**) is obtained with a specific optical rotation of –25°.



A
(*S*)-2-iodobutane
Boiling point: 120 °C

B
sec-butyl ethyl sulfide
Boiling point: 134 °C
Optical rotation: -25°

49. **[1 mark]** What is the specific optical rotation of (*S*)–2–iodobutane?

A. +25°
B. +20°
C. 0° (there is no optical rotation)
D. –20°
E. –25°
F. Not enough information

50. **[1.5 marks]** Consider the following statements about **REACTION 1**. Determine if they are **TRUE or FALSE. Bubble true Ⓣ or false Ⓕ for each part a–c on the bubble sheet.**

(a) Reaction 1 is an S_N1 reaction. **F**

(b) The asymmetric center in the product has *R* configuration. **T**

(c) The initial step in this reaction is an acid-base step. **F**

In **REACTION 2**, optically pure (*S*)–2–iodobutane is reacted with $HSCH_2CH_3$, and *sec*–butyl ethyl sulfide is produced, but the optical rotation was found to be –20°.

51. **[2 marks]** Consider the following statements about **REACTION 2**. Determine if they are **TRUE or FALSE. Bubble true Ⓣ or false Ⓕ for each part a–d on the bubble sheet.**

(a) The product(s) is a racemic mixture. **F**

(b) The product(s) is optically pure. **F**

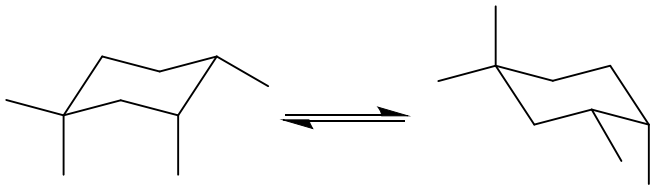
(c) The product(s) will boil at 120 °C. **F**

(d) The product(s) will boil at 134 °C. **T**

52. **[2 marks]** What is the ratio of (*S*)–*sec*–butyl ethyl sulfide (*R*)–*sec*–butyl ethyl sulfide produced by **REACTION 2**?

Answer Code	**% of (*S*)–*sec*–butyl ethyl sulfide**	**% of (*R*)–*sec*–butyl ethyl sulfide**
A.	100	0
B.	90	10
C.	75	25
D.	50	50
E.	25	75
F.	10	90
G.	0	100

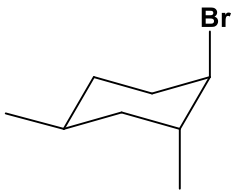
53. **[2 marks]** Consider the following chair flip equilibrium of the substituted cyclohexane, 1,1,3,4-tetramethylcyclohexane.



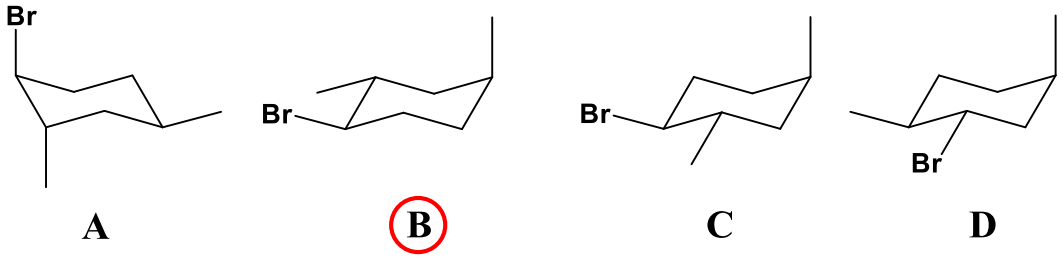
Which of the following is **TRUE** of the equilibrium as shown?

A. Products are favoured.
B. Reactants are favoured.
C. Neither side is favoured.

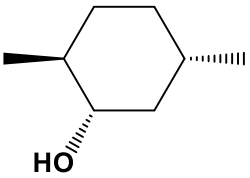
54. **[2 marks]** Consider the substituted cyclohexane molecule shown below:



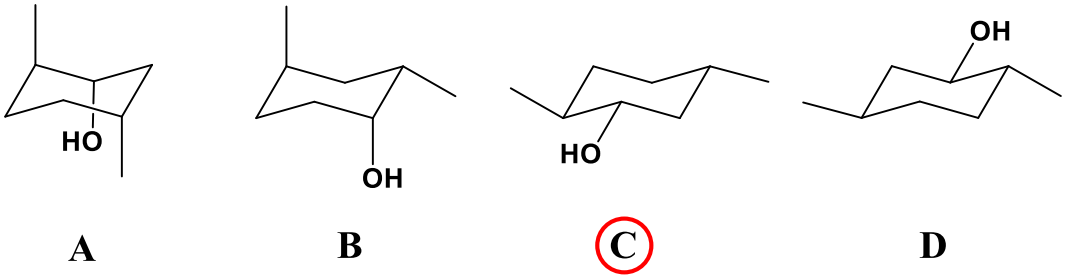
Which of the following corresponds to the other chair conformer of this cyclohexane molecule, after a chair flip has occurred?



55. **[2 marks]** Consider the substituted cyclohexane molecule shown below:

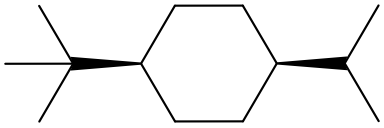


Which of the following corresponds to a chair conformer of this cyclohexane molecule?



Use the following information to answer questions 56-57.

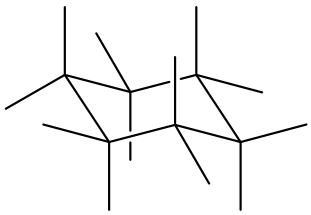
Consider *cis*-1-*tert*-butyl-4-isopropylcyclohexane.



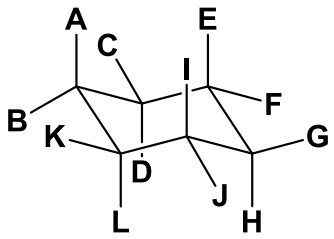
***cis*-1-*tert*-butyl-4-isopropylcyclohexane**

56. **[2 marks]** Convert the 2D line-bond structure of ***cis*-1-*tert*-butyl-4-isopropylcyclohexane** into the **LOWEST ENERGY CHAIR CONFORMATION** by bubbling in the position of the substituents based on the answer input template provided. ***An empty chair template is provided for rough work below.*** **More than one solution is possible; All correct solutions will be accepted.**

Template for rough work

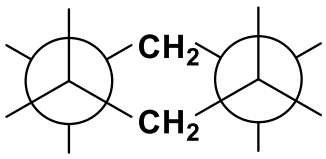


Template for answer input

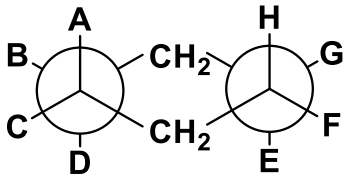


Possible Combinations						
tBu	F	G	J	K	B	C
iPr	L	A	D	E	H	I

57. **[2 marks]** Convert the 2D line-bond structure of ***cis*-1-*tert*-butyl-4-isopropylcyclohexane** into the **LOWEST ENERGY NEWMAN PROJECTION** by bubbling in the position of the substituents based on the answer input template provided. ***An empty Newman Projection template is provided for rough work below.*** **More than one solution is possible; All correct solutions will be accepted.**



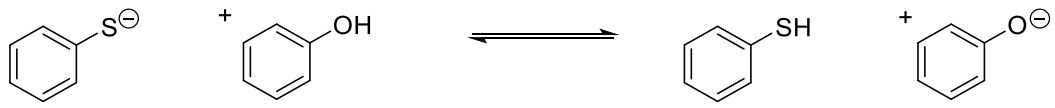
Template for rough work



Template for answer input

Possible Combinations				
tBu	B	C	G	F
iPr	H	E	A	D

Consider the following equilibrium to answer questions 58-59:



58. **[1 mark]** What is **TRUE** about the magnitude of the equilibrium constant, K?

A. K > 1
B. K = 1
C. K < 1
D. Not enough information.

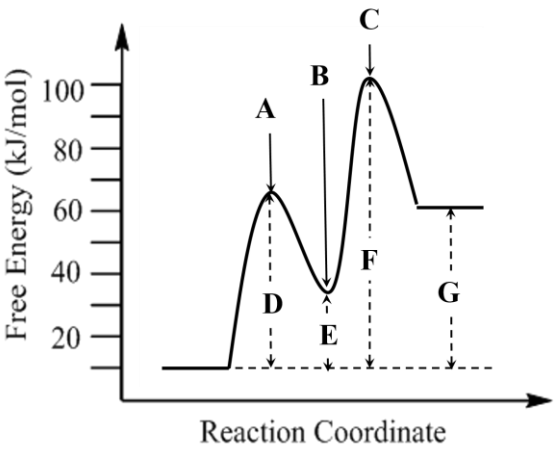
59. **[1 mark]** Which of the following is the **SINGLE** determining factor for the correct answer in question 58 above?

A. Polarizability
B. Electronegativity
C. Hybridization
D. Induction
E. Resonance

Use the following information to answer questions 60-63.

Consider the following reaction coordinate diagram for a reaction occurring at constant temperature and pressure:

For each statement below choose **ONE** of the labels A-G to answer the question. ***There may be more than one correct answer. Please only choose ONE as your answer.***



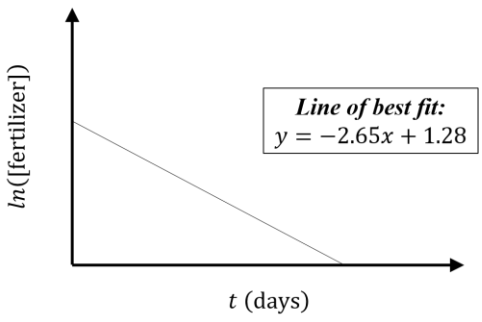
60. **[1 mark]** Identify one label (**A-G)** that is a transition state. **A or C**

61. **[1 mark]** Identify one label (**A-G)** that is an intermediate. **B**

62. **[1 mark]** Identify one label (**A-G)** that is a change in Gibbs Free Energy of Activation for one of the steps in the forward reaction. **D or F**

63. **[1 mark]** Identify one label (**A-G)** that is a change in Standard Molar Gibbs Free Energy of Reaction for the **OVERALL** forward reaction. **G**

64. **[1 marks]** Consider the data collected from experiments involving the decomposition of a fertilizer seen below. What is the half-life of the fertilizer?



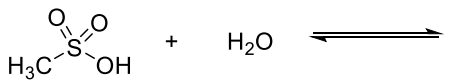
A. 2.65 days
B. 1.28 days
C. 3.82 days
D. 1.84 days
E. 0.26 days
F. 0.54 days

For pages 17-22 (Part II) to follow, please write all of your work and answers *directly on the examination.*

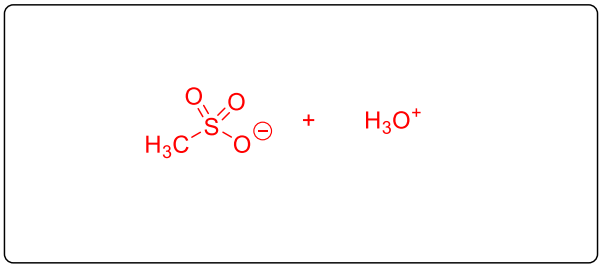
PART II – Long Answer

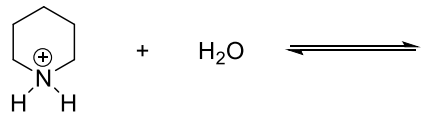
1. Consider the following acids and their provided pK_a values:

(a) **[4 marks]** Complete the Brønsted–Lowry acid–base dissociation reaction of each acid in H_2O. **Place your final answer in the box provided.**

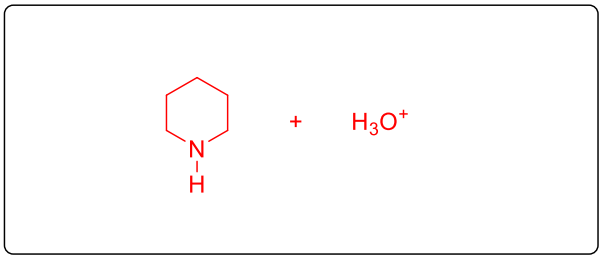


pKa = − 2.5

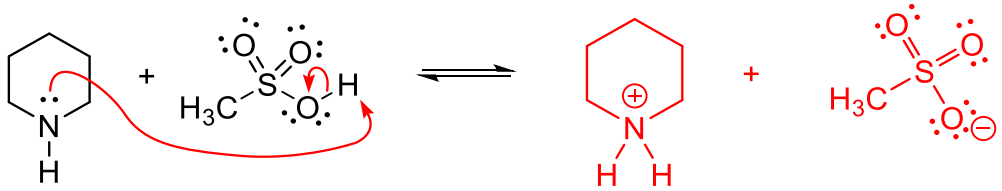




pKa = 11.1



(b) **[3 marks]** Draw the correct products of the following acid–base reaction. Draw a curved arrow mechanism for the formation of the products.



(c) **[1 mark]** What is **TRUE** about the magnitude of the equilibrium constant, K, in part (b)? **Place your final answer in the box provided.**

A. K > 1
B. K = 1
C. K < 1
D. Not enough information.

Answer:

A

2. Tom and Jerry are studying an overall reaction:

$$A + B \longrightarrow P + C$$

Their supervisor suggests that the reaction may occur in two elementary steps:

Step 1: $A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} X$ **Step 2:** $X + B \xrightarrow{k_2} P + C$

(a) **[3 marks]** Tom assumes that **X** is an intermediate which follows the Steady State Approximation. What is the rate law Tom will obtain for product formation in terms of [A], [B], k_1, k_{-1}, and k_2. **Show all work. Place your final answer in the box provided.**

Rate law of the final step: $\frac{d[P]}{dt} = +k_2 \underbrace{[X]}_{\text{intermediate}} [B]$

Make SSA for d[X]/dt $\frac{d[X]}{dt} = +k_1[A] - k_{-1}[X] - k_2[X][B] \underbrace{=0}_{SSA}$

Solve for [X] $[X] = \frac{k_1[A]}{k_{-1} + k_2[B]}$

Sub expression for [X] into the rate law of the final step:

$$\frac{d[P]}{dt} = +k_2\left(\frac{k_1[A]}{k_{-1} + k_2[B]}\right)[B]$$

$$r = \frac{\text{d[P]}}{\text{dt}} = \frac{k_1 k_2[A][B]}{k_{-1} + k_2[B]}$$

(b) **[2 marks]** Jerry assumes that $k_1 >> k_2$ and $k_{-1} >> k_2$. What is the rate law Jerry will obtain for product formation in terms of [A], [B], k_1, k_{-1}, and k_2. **Show all work. Place your final answer in the box provided.**

Rate law of the final step: $\frac{d[P]}{dt} = +k_2 \underbrace{[X]}_{\text{intermediate}} [B]$

Step 1 is a fast equilibrium ($k_1 >> k_2$ and $k_{-1} >> k_2$), so

$$[X] = \frac{k_1[A]}{k_{-1}}$$

$$r = \frac{\text{d[P]}}{\text{dt}} = \frac{k_1 k_2[A][B]}{k_{-1}}$$

(c) **[1 mark]** Tom and Jerry carried out reaction rate measurements and obtain the following data.

	Run 1	**Run 2**	**Run 3**	**Run 4**
[A] (M)	1	1	1	1
[B] (M)	1	2	3	4
Initial rate (M/s)	0.050	0.067	0.075	0.080

Whose model is more likely to be correct? **Place your final answer in the box provided.**

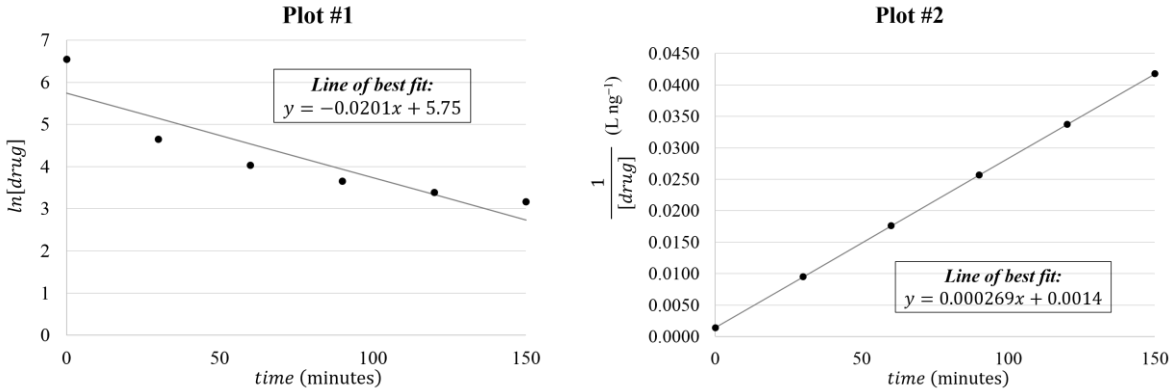
A. Tom
B. Jerry

Answer:

A

3. After intravenous injection of a drug to treat hypertension (high blood pressure), the blood plasma of a patient was analyzed for the remaining drug at various times after injection by measuring the concentration (ng L^{-1}) of the drug in the blood plasma. The following data was collected at 310 K and used to generate the plots below.

Note that for this process, $rate = -\frac{d[drug]}{dt}$



(a) **[2 marks]** Based on the information above, is the drug removal process a first or second order process. **Place your final answer in the box provided.**

A. First-Order B. Second-Order

Answer: **B**

(b) **[2 marks]** Determine the rate constant, *k*, in L ng^{-1} min^{-1} for the drug removal process at 310 K. **Show all work. Place your final answer in the box provided.**

From the line of best fit of the second graph
the slope = *k* = 0.000269 L ng^{-1} min^{-1}

$k =$ 0.000269 L ng^{-1} min^{-1}

(c) **[3 marks]** Calculate the value of the initial concentration of drug in the blood stream, in ng L^{-1}, of the patient of this particular drug trial at 310 K. **Show all work. Place your final answer in the box provided.**

From the line of best fit of the second graph
the intercept, b, = $1/[drug]_0$
$[drug]_0 = 1/0.0014 = 714$ ng/L.

$[drug] =$ **714 ng/L**

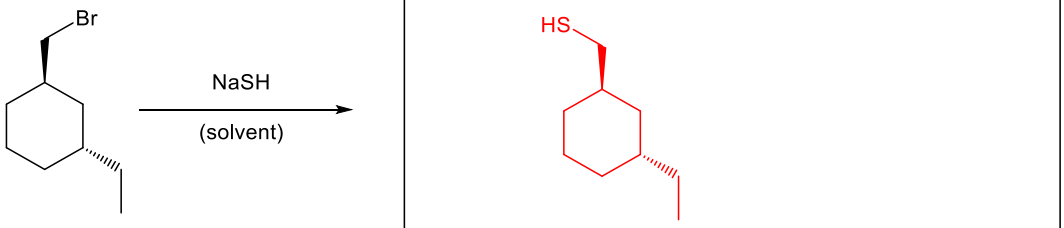
4. **[12 marks]** Draw the compounds named in the boxes provided.

Be sure to clearly show the stereochemistry of the structures that you draw.

a) **(*E*)–3–bromo–2–hexene** *Line structure with wedges/dashes as needed.*	b) **(*S*)–2–chloropentane** *Line structure with wedges/dashes as needed.*	c) **Propanal** *Line structure with wedges/dashes as needed.*
d) **Cyclohexane** *Line structure in chair conformation*	e) **Methylcyclohexane** *Line structure in chair conformation with methyl group in an axial position*	f) **Ethylcyclohexane** *Line structure in chair conformation with ethyl group in an equatorial position*

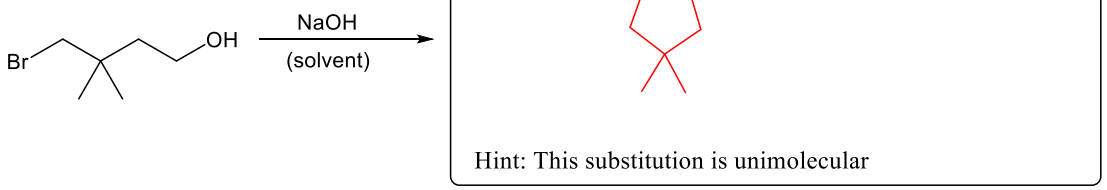
5. **[6 marks]** Predict the product(s) for each of the following reactions:

a)



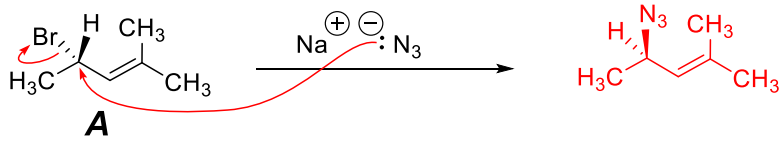
b)

c)



Hint: This substitution is unimolecular

6. (a) **[3 marks]** Mickey mixes bromide ***A*** with a high concentration of sodium azide, ***a strong nucleophile***, to produce one (or more) compounds. Draw the expected product(s) and the curved arrow mechanism which is consistent with your proposed reaction product(s). ***Be sure to clearly show the stereochemistry of the structure(s) that you draw.***
Show all work.



(b) **[2 marks]** Mickey's lab partner, Minnie, decides to store bromide ***A*** in ethanol (CH_3CH_2OH) over the weekend. When Minnie gets back to the lab, she cannot find bromide ***A*** in the ethanol solution.

Mickey and Minnie hypothesize that bromide ***A*** underwent a substitution reaction. In order to determine the mechanism of this reaction, a kinetic study was performed and the following data collected:

Experiment	**[bromide *A*] (M)**	**[CH_3CH_2OH] (M)**	**Reaction Rate ($M\ hr^{-1}$)**
I	1.0	1.0	0.044
II	2.0	1.0	0.088
III	1.0	3.0	0.044

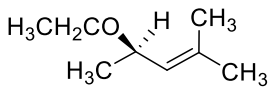
Did this reaction undergo an S_N1 or an S_N2 mechanism?
Place your final answer in the box provided.

A. S_N1
B. S_N2

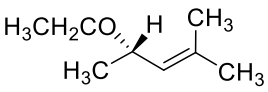
Answer:

A

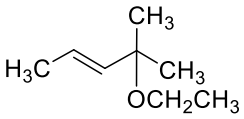
(c) Mickey and Minnie analyze the product mixture using spectroscopy and find that the following compounds have formed:



B

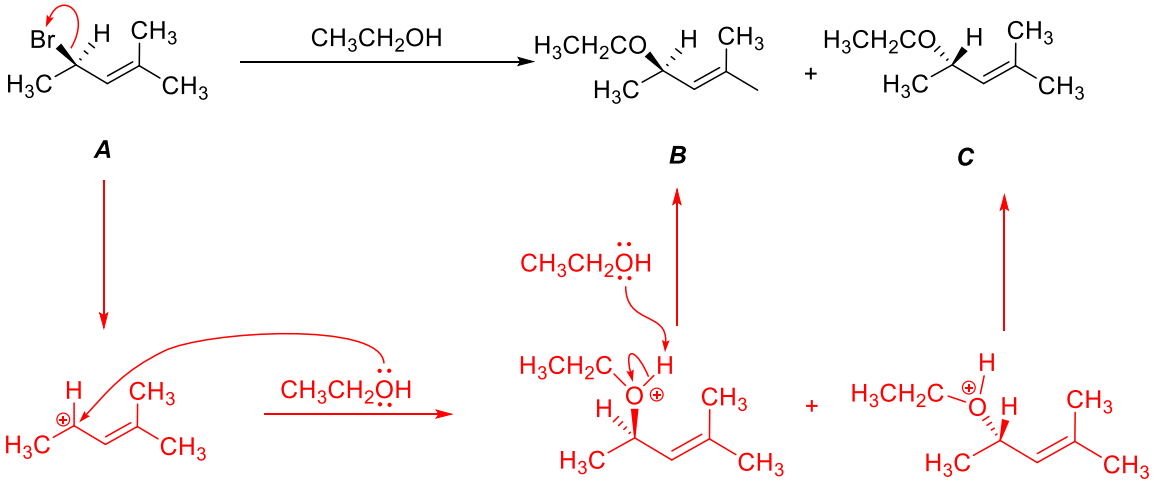


C



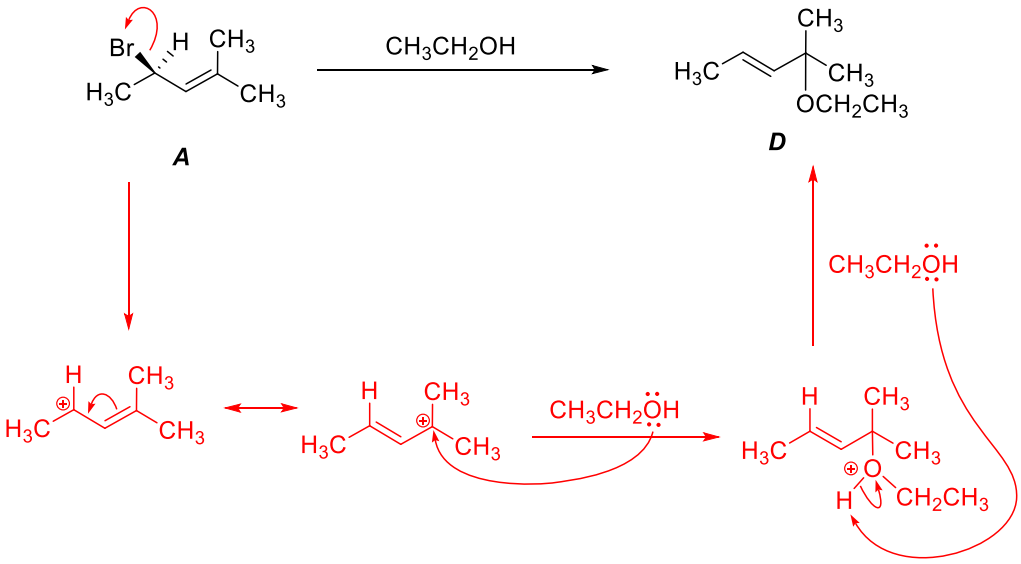
D

i. **[4 marks]** Based on the mechanism determined in part b), draw a curved arrow mechanism for the formation of ***B*** and ***C***. ***Be sure to clearly show the stereochemistry of the structure(s) that you draw.*** **Show all work.**



Nu attacks from either front (top) or back (bottom) to form two different products.

ii. **[3 marks]** Based on the mechanism determined in part b), draw a curved arrow mechanism for the formation of ***D***. ***Be sure to clearly show the stereochemistry of the structure(s) that you draw.*** **Show all work.**



END OF EXAMINATION