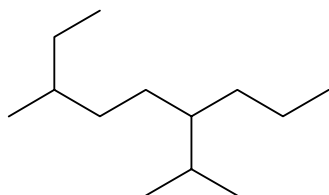


Solutions to Chemistry 123 (UBC) Practice Exam

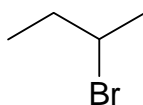
Part I: Organic Chemistry

1) Name the following compounds. Assign designation for stereochemistry if necessary.

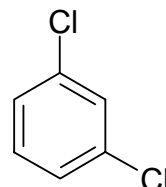
A)



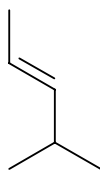
B)



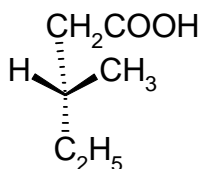
C)



D)



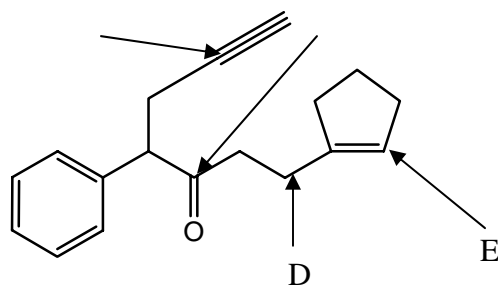
E)



Answer:

- A) 3-ethyl-6-isopropyl-nonane
- B) 2-bromo-butane
- C) m-dichlorobenzene or 1,3-dichlorobenzene
- D) (E)-4-methyl-2-pentene
- E) (R)-3-methyl-1-pentanoic acid

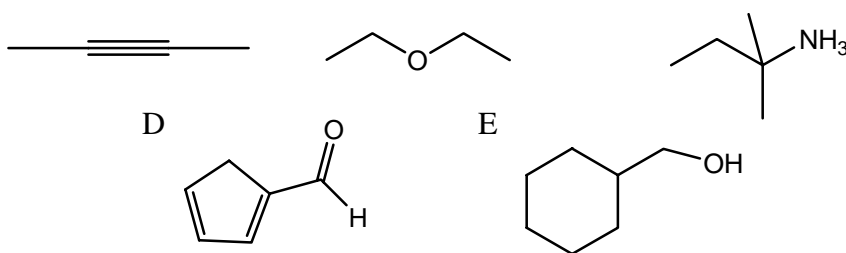
2) What is the hybridization at the sites indicated?



Answer:

- A) sp^2
 B) sp
 C) sp^2
 D) sp^3
 E) sp^2

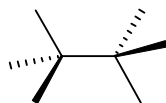
3) What functional groups are present in the following molecules?



- A) Alkyne
 B) Ether
 C) Amine
 D) Aldehyde
 E) Alcohol

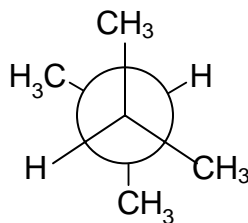
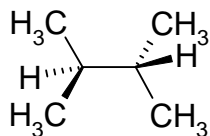
4) Draw three dimensional representations for the following:

- A) The most stable conformation of 2,3-dimethyl-butane. Use a Newman projection viewing along the C2-C3 bond.
 B) The least stable conformation of 2,3-dimethyl-butane. Use a Newman projection viewing along the C2-C3 bond.
 C) Complete the template below to clearly show the structure of (2S,3S)-2-bromo-3-chloro-butane. Show all atoms, including hydrogen and carbon, required to complete the structure.



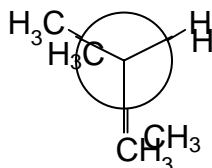
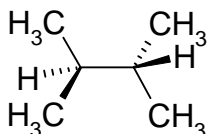
Answer:

A) Most stable 2,3-dimethyl-butane:



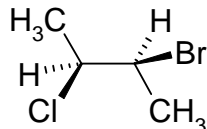
The most stable conformation is when the methyl groups are as far away from each other as possible.

B) Least stable 2,3-dimethyl-butane:



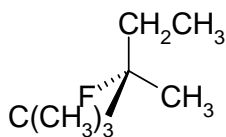
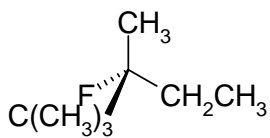
The least stable conformation is when the methyl groups are in the same plane, i.e. are in eclipsed conformation, because of steric strain.

C) (2S,3S)-2-bromo-3-chloro-butane

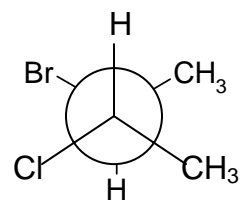
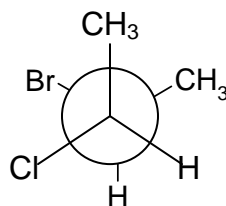


5) For each pair of structures, state whether they are constitutional isomers (C), diastereomers (D), identical (I) or enantiomers (E). More than one term may apply to each structure.

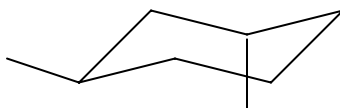
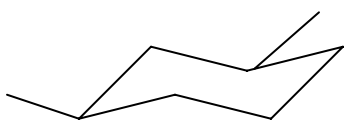
A)



B)



C)



Answer: A) Enantiomers

B) Diastereomers

C) Diastereomers

The definitions are as follows:

Constitutional isomers are compounds that have the same molecular formula but these compounds differ in the way the atoms are connected in three dimensional space. E.g. $\text{CH}_3\text{-O-CH}_3$ and $\text{CH}_3\text{CH}_2\text{-OH}$

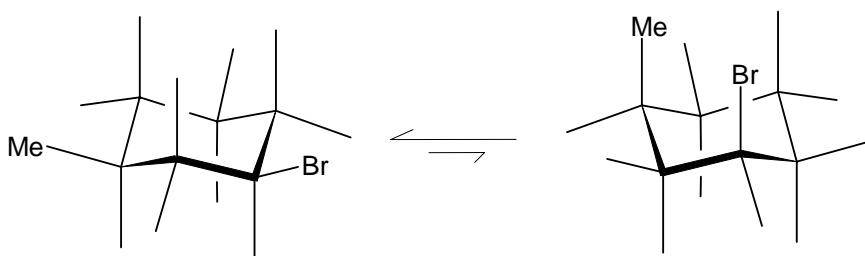
Enantiomers are stereoisomers that are mirror images of each other.

Diastereomers are stereoisomers that are not enantiomers, or mirror images of each other. Two stereoisomers are said to be diastereoisomers of each other if only one chiral centre differs between the two stereoisomers

- 6) A) Draw both chair forms of cis-1-bromo-3-methylcyclohexane
B) Which is more stable?

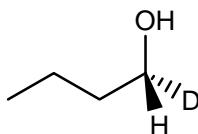
Answer:

A)

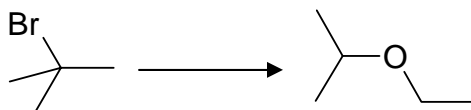


B) The conformation with both substituents in the equatorial position is more stable as this alleviates 1,3-diaxial interactions.

- 7) A) The structure below, (R)-1-deuterio-1-butanol, is heated with sodium bromide in sulfuric acid. If the reaction undergoes $\text{S}_{\text{N}}2$ kinetics, draw and name the major product(s) formed.



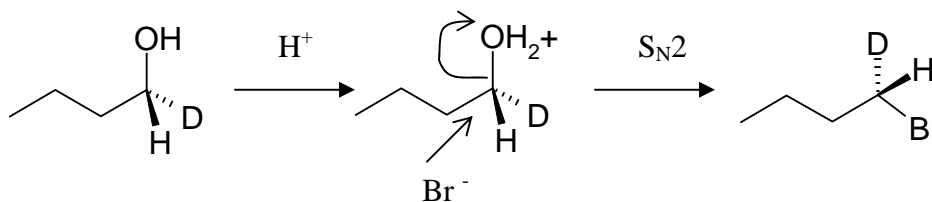
B) Propose & draw the mechanism for the following reaction:



C) How would you confirm the mechanism proposed for part B using a kinetic study?

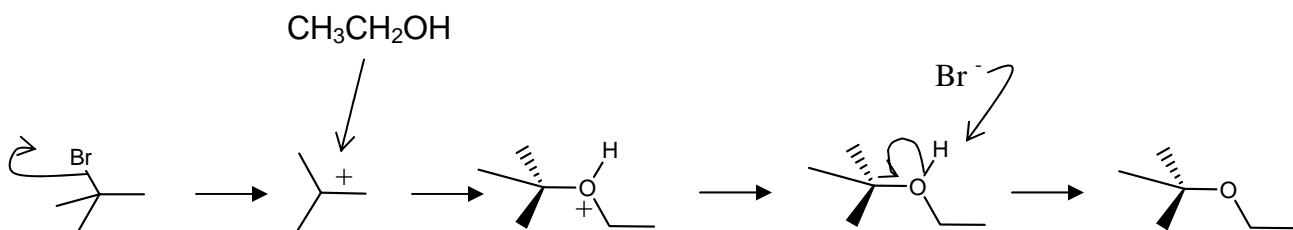
Answer:

A)



The major product is (S)-1-deuterio-1-butanol

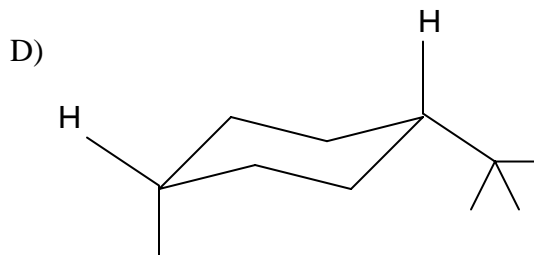
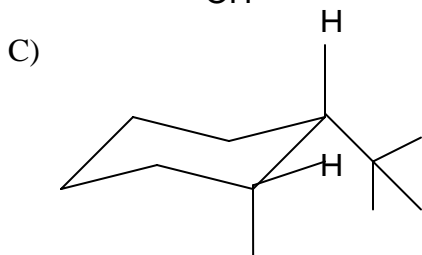
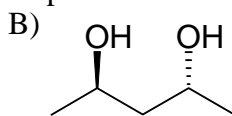
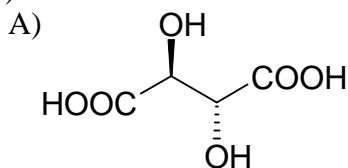
B) The product can be formed by a S_N1 reaction, with Br^- as a leaving group, resulting in a carbocation intermediate. Addition of ethanol as the nucleophile results in the final product.



C) S_N1 reactions undergo first-order kinetics. The rate of the reaction should be:

$$\text{Rate} = k[\text{substrate}] = k[\text{tert-butyl-bromide}]$$

8) State whether the following compounds are chiral or achiral.



Answer:

A) Achiral B) Chiral C) Chiral D) Achiral

Chiral molecules have a “handedness” to them, whereas achiral molecules have a plane of symmetry to them.

9) State the laws of thermodynamic and include relevant equations.

Answer:

- 1) Energy cannot be created nor destroyed. Any energy transferred from a system must be transferred to its surroundings. $\Delta E = q + W$
- 2) The total entropy of a system and its surroundings always increase for a spontaneous process. $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} \geq 0$
- 3) The entropy of a perfect crystal at 0K is zero. $\lim_{T \rightarrow 0} S^\circ_T = 0$

Part II: Review

10) A) A system cools while expanding against a constant external pressure. Give the signs of q , w , and ΔU for this process. Make sure you explain the sign of each quantity to get the full marks.

B) You know that a certain reaction, in which 3 moles of gaseous reactants were converted to 5 moles of liquid products, is endothermic. You measured the values of the equilibrium constant K at various temperatures and plan on obtaining ΔH and ΔS graphically. Sketch the appropriate graph for this task. Make sure you label your axes clearly including units and the zero point on each axis if necessary.

Answer:

$$A) q = C\Delta T$$

C , molar heat capacity, it is always > 0

ΔT is negative since the system is cooling

Thus, $q < 0$, and energy is flowing out of the system via heat.

$$w = -P_{\text{ext}}\Delta V$$

P_{ext} is positive

ΔV is positive (expanding system)

Thus, $w < 0$, and system is doing work on its surroundings.

$$\Delta U = q + w$$

Since both q and w is < 0 , $\Delta U < 0$.

$$B) \Delta G^\circ = -RT\ln(k) = \Delta H^\circ - T\Delta S^\circ$$

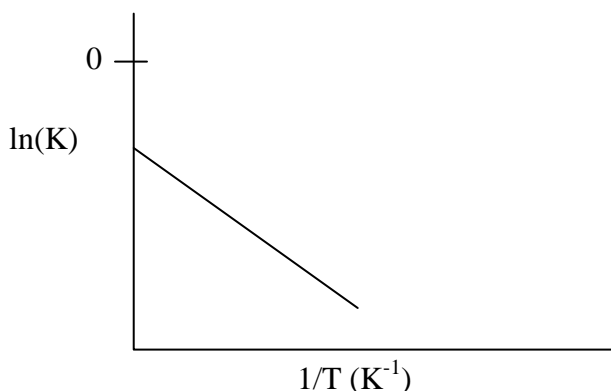
$$\ln(K) = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R}$$

3 moles of *gaseous* reactants \rightarrow 5 moles of *liquid* products = decrease in disorder; $\Delta S^\circ < 0$

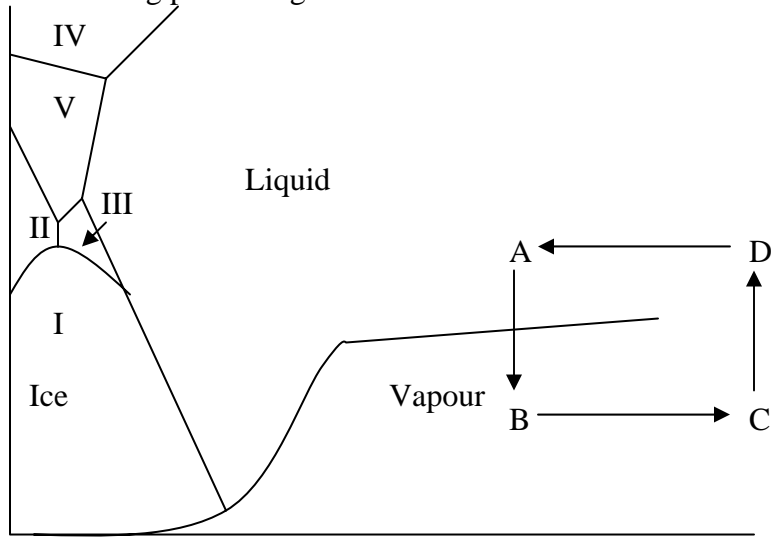
To obtain ΔS° , find the y-int. y-int = $\frac{\Delta S^\circ}{R} < 0$ since $\Delta S^\circ < 0$.

To obtain ΔH° , find the slope. Slope = $\frac{-\Delta H^\circ}{R}$.

Since the reaction is endothermic, $\Delta H^\circ > 0$ and the slope of the line is negative.

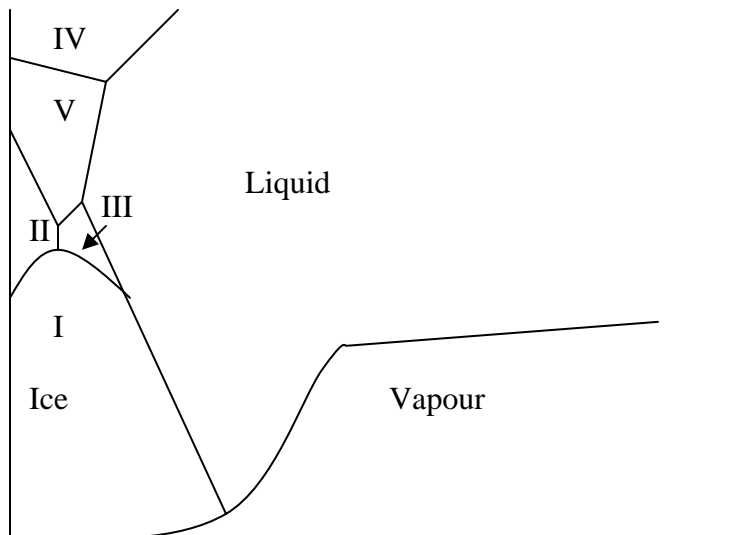


11) For the following phase diagram for water:



A) Which phase of ice has the greatest density?

B) Draw in the boiling point and melting point at normal conditions ($P = 1 \text{ atm}$). Label the axis and write in the proper temperatures.

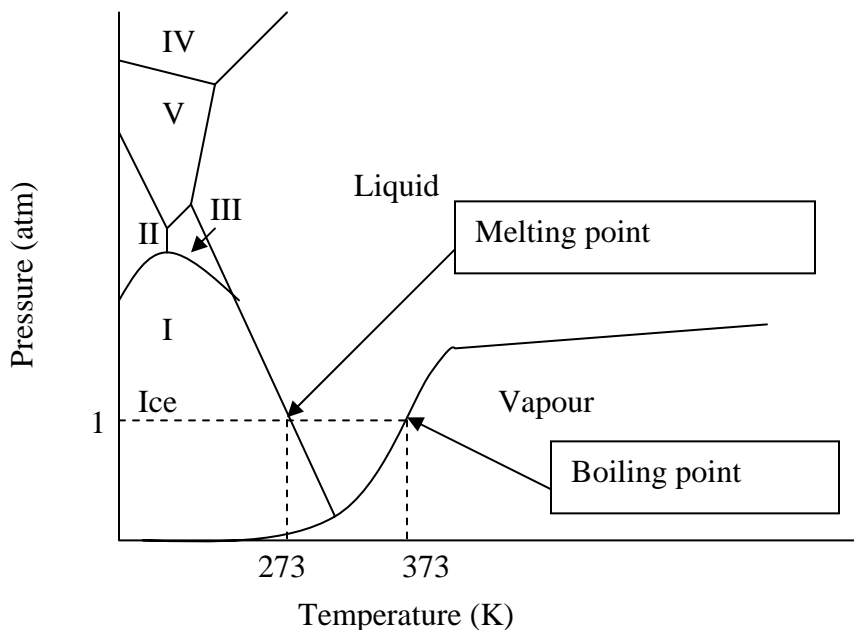


C) State the different phases of water as you move from point A, B, C to D.

Answer:

- A) Which phase of ice has the greatest density?
Ice IV; Density increases as you move up in a phase diagram.

B)



- C) Liquid → Vapour → Supercritical fluid → supercritical fluid (higher density)

- 12) a) What is the pH at the equivalent point when a solution of 100.0mL of 0.100M aniline is titrated with 0.500M HCl? (K_b of aniline = 4.2×10^{-10})
b) What is the pH when only half the necessary volume of HCl is added?

Answer:

At the equivalence point, sufficient amount of H^+ has been added to completely react with the base (aniline) present.

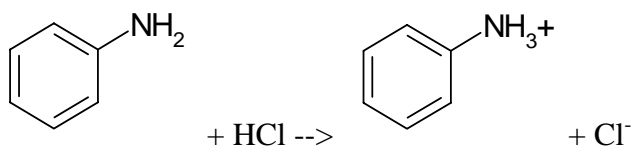
Thus, the # of moles of H^+ = # of moles of aniline.

$$(0.1L)(0.1M) = (0.5M)(V_{HCl})$$

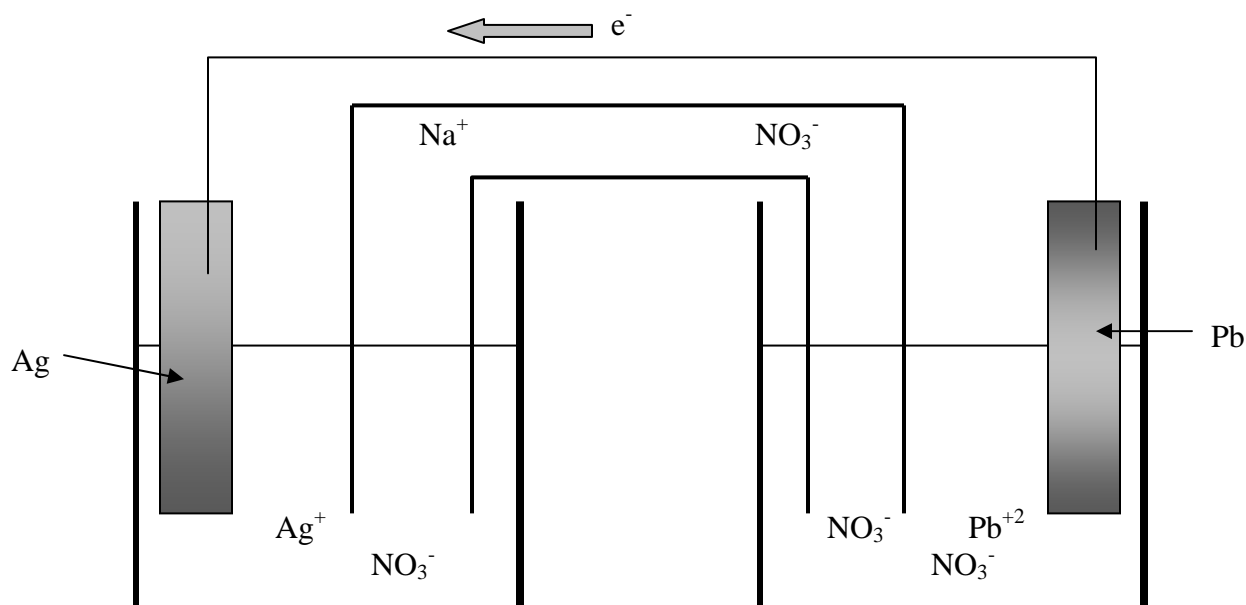
$$V_{HCl} = 0.02L = 20mL$$

$$\text{Total volume} = 120mL$$

$$\text{New } [] \text{ of aniline} = \frac{(0.100M)(0.1L)}{0.120L} = 0.0833M$$



14) Consider the following galvanic cell:



- A) Based on the direction of electron flow, write the anodic half reaction.
 B) Based on the direction of electron flow, write the cathodic half reaction.
 C) Write the net cell reaction.
 D) Calculate the cell potential at 25°C when $[Ag^+] = 1.0M$, $[Pb^{+2}] = 0.001M$.

Answer:

- A) From the direction of the electron flow, Pb is the anode (-) and is oxidized.

$$Pb(s) \rightarrow Pb^{+2}(aq) + 2e^-$$
- B) From the direction of the electron flow, Ag is the cathode (+) and is reduced.

$$Ag^+(aq) + e^- \rightarrow Ag(s)$$
- C) The net reaction is:

$$Pb(s) + 2Ag^+(aq) \rightarrow Pb^{+2}(aq) + 2Ag(s)$$
- D) Using the Nernst Equation: $E = E^\circ - \frac{0.0592V}{n} \log Q$

From a table of standard reduction table:

$$E^\circ = E^\circ_{\text{anode}} + E^\circ_{\text{cathode}} = 0.13 + 0.8 = 0.93$$

$$E = 0.93 - 0.0592 \log \frac{[Pb^{+2}]}{[Ag^+]^2}$$

$$E = 1.11V$$