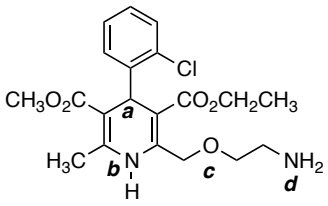
Section 1: Multiple choice. Questions 1-25 must be answered on the MC Answer Form by shading the appropriate circle with **pencil**. Remark responses will be used to calculate your grade. Please indicate your answers on this examination paper in the event your MC Answer Form is lost.

Note that ***more than one letter*** could be entered as an answer to a multiple choice question. Questions are not equally weighted in marks; it is ***not 1 mark per answer***.

questions 1 to 4:
Consider the molecule (*Norvasc, a heart medication)* the right. Take note of the fact that specific atoms in this structure have been labelled ***a*** through ***d***.



1) Indicate the hybridization of the carbon atom labeled ***a***:

(**A**) s (**B**) p (**C**) sp (**D**) sp^2 (**E**) sp^3 (**F**) σ (sigma) (**G**) π (pi)

2) Indicate the hybridization of the nitrogen atom labeled ***b***:

(**A**) s (**B**) p (**C**) sp (**D**) sp^2 (**E**) sp^3 (**F**) σ (sigma) (**G**) π (pi)

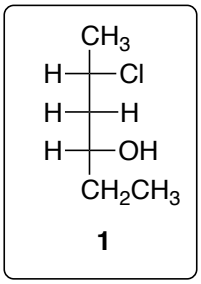
3) The non-bonded electron pairs on the oxygen atom labeled ***c*** reside in a _____ orbital.

(**A**) s (**B**) p (**C**) sp (**D**) sp^2 (**E**) sp^3 (**F**) σ (sigma) (**G**) π (pi)

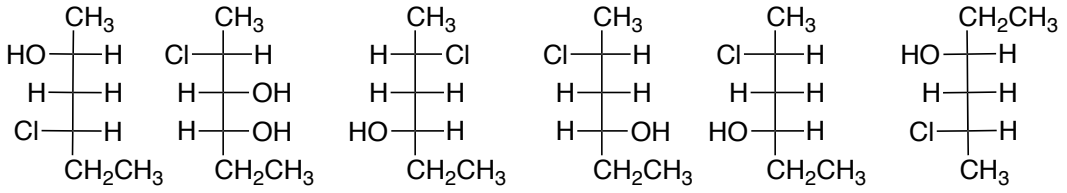
4) The non-bonded electron pair on the nitrogen atom labeled ***d*** resides in a _____ orbital.

(**A**) s (**B**) p (**C**) sp (**D**) sp^2 (**E**) sp^3 (**F**) σ (sigma) (**G**) π (pi)

Questions 5-7. Consider the compounds **1**, and ***A***-***F*** (below) when answering. More than one letter may be indicated in your answers. Take note that incorrect responses will be subtracted from correct responses.



1



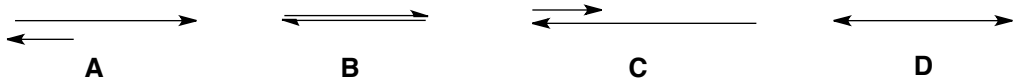
A ***B*** ***C*** ***D*** ***E*** ***F***

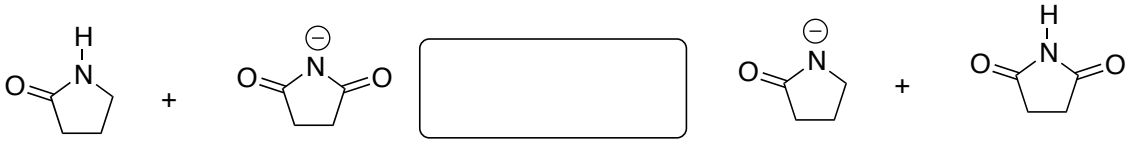
5) What compound(s) ***A***-***F*** is/are *constitutional isomer(s)* of compound **1**?

6) What compound(s) ***A***-***F*** is/are *enantiomer(s)* of compound **1**?

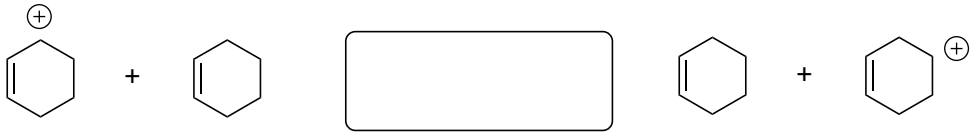
7) What compound(s) ***A***-***F*** is/are *diastereomer(s)* of compound **1**?

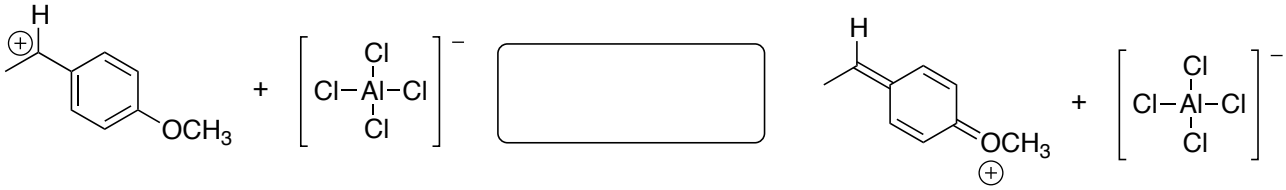
• For questions 8)-13), select the letter (**A**, **B**, **C**, **D**) that corresponds to the arrows that *best* describes the relationship between the 'reactants' and 'products'. Be sure to fill in your MC Answer Sheet!



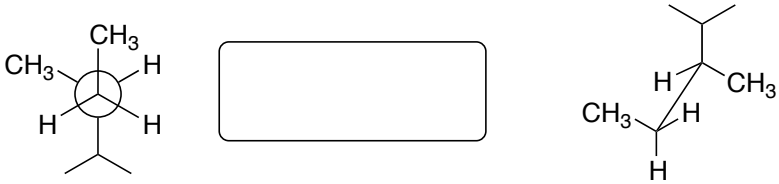
8) 

9) 

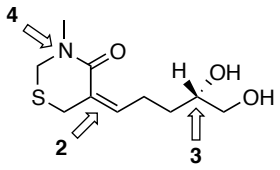
10) 

11) 

12) 

13) 

Questions 14-16. Consider the molecule below when answering these questions.



14) The configuration of the alkene indicated by **2** is:

A: *R* **B**: *S*
C: *cis* **D**: *trans*
E: *E* **F**: *Z*
G: (+)- **H**: (-)-

15) The configuration of chirality center **3** is:

A: *R* **B**: *S*
C: *cis* **D**: *trans*
E: *E* **F**: *Z*
G: (+)- **H**: (-)-

16) The functional group indicated by **4**:

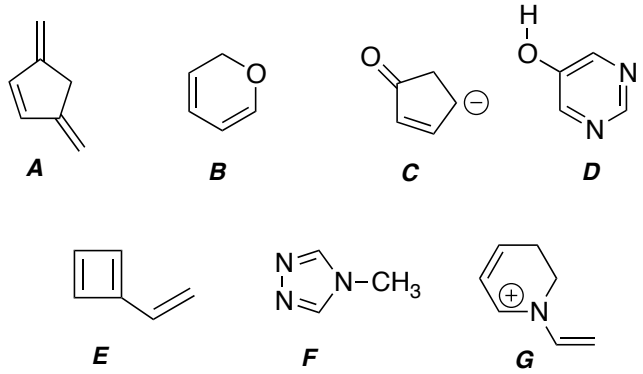
A: acetal **B**: 3° amine
C: 3° amide **D**: 2° amide
E: 2° imine **F**: 1° amine
G: 2° amine **H**: ketone

1°: primary; 2° secondary; 3° tertiary

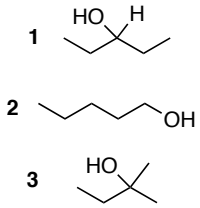
Question 17:

Consider the series ***A***-***G*** on the right.

Indicate the species that have *aromatic character.* More than one compound may be selected. Note that incorrect selections will be subtracted from correct.



Question 18. Rank the compounds 1-3 (below) in order of *increasing* boiling point (lowest to highest):

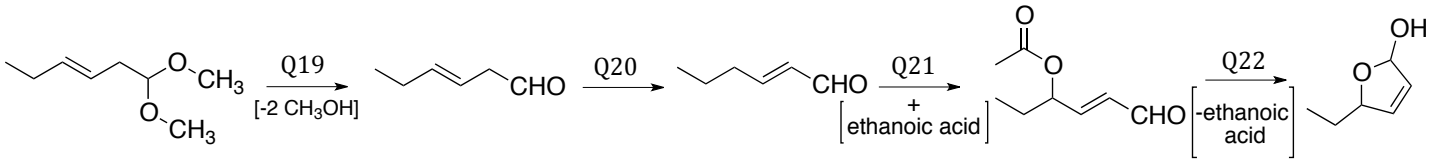


A) 1<2<3 **D**) 3<2<1

B) 1<3<2 **E**) 2<3<1

C) 3<1<2 **F**) 2<1<3

Question 19-22. Classify each of these transformations as either an **A**) oxidation; **B**) reduction or **C**) no change in oxidation level.



23. The C-C-C bond angles of 2-methylpropene are smaller than the H-C-H bond angle of methane.
(**A**) TRUE (**B**) FALSE

24. Compounds that have a least one carbon atom having four different substituents always exhibit optical activity. (**A**) TRUE (**B**) FALSE

25. In the reaction between boron trifluoride and diethyl ether, the boron compound acts as a Lewis acid.
(**A**) TRUE (**B**) FALSE

Section 2. Short answer questions. Please write your answers in the designated space. Please note that in some cases it is better for you to work out your answer on practice paper and copy a neat version to the examination paper.

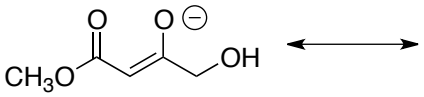
*****Messy and/or incoherent answers that are difficult to read or interpret may receive reduced or zero credit.*****

2-1) (6 marks) Two dominant resonance forms contribute to the structure of diazomethane (H_2CN_2), a molecule with a nitrogen-nitrogen multiple bond.

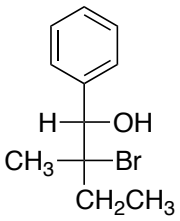
(a) Draw the Lewis structures of each of the important resonance contributors to diazomethane. Clearly show unbonded electron pairs and formal charges if necessary.

(b) Circle the most important resonance contributor and justify your selection using a *short phrase*.

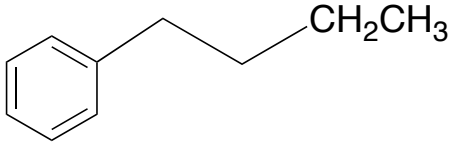
2-2) (4 marks) Draw the *contributing resonance structures* that stabilize the following anion. Be sure to indicate electron movement using curved arrows between each structure in your sequence:



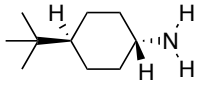
2-3) (3 marks) Using the supplied template, provide a *zig-zag projection* from the Fischer projection of compound **4**:



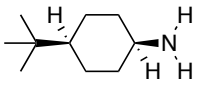
4



2-4) (5 marks) Two cyclohexylamine derivatives ***a*** and ***b*** are shown below.



a

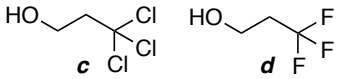


b

(a) What is the stereochemical relationship between ***a*** and ***b****?*

(b) Experiments clearly indicate that compound ***a*** is a stronger Brönsted base compared to compound ***b***. Use the conformational and configurational differences between ***a*** and ***b*** to justify this experimental result with pictures accompanied by brief comments.

2-5) (4 marks) Circle the most acidic compound between compounds ***c*** and ***d*** below. Justify your selection with brief comments. Note that stating that one compound has a lower pK_A than the other will not receive credit!



c

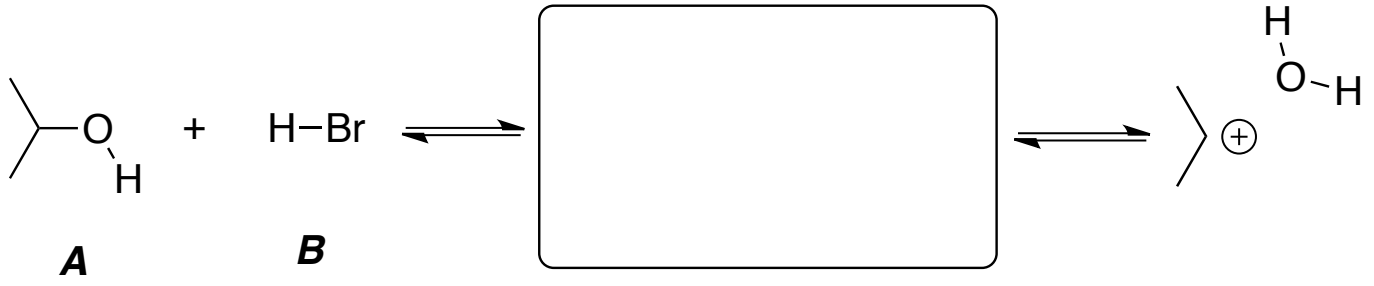
d

2-6) (9 marks) (a) The experimental record clearly indicates that alcohols react with strong acids to form carbocation intermediates:

i) Draw δ+ and δ- charges on structures ***A*** and ***B***.

ii) Using arrows to indicate electron movement, draw electron flow to generate the boxed intermediates.

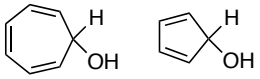
iii) Provide the required structures in the box, and draw electron flow to explain the formation of the carbocation intermediate.



A ***B***

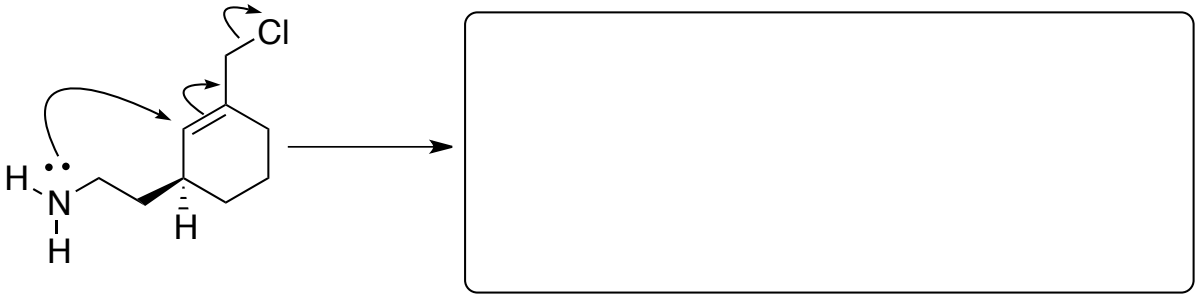
*conjugate acid of **A*** and
*conjugate base of **B***

(b) The reaction in part (a) is performed on the two alcohols ***1*** and ***2*** below. Clearly indicate which alcohol would be expected to react more quickly. Justify your answer with pictures accompanied by brief comments.



1 ***2***

2-7) (3 marks) You are given the curved arrow description of this literature reaction. Provide the *product* after this transformation. Be sure to include formal charges if they are required.



reaction intermediate after this transformation

end of exam questions