Answer all questions in the booklets provided. A point-group flow chart, character tables and a periodic table are provided.

## Question 1-(15 marks, 5 marks each)

List all of the symmetry elements and determine the point group for the following:
a) $\mathrm{SF}_{5} \mathrm{Cl}$
b) 1,3,5-trichlorobenzene
c) $\mathrm{SiO}_{2}$

## Question 2-(10 marks)

a) Use VSEPR theory to draw and then predict the actually geometry of a) $\mathrm{SbF}_{4}^{-}$and b) $\mathrm{SeF}_{3}{ }^{+}$ (3 marks each)
b) Explain the trend in the following set of bond angles: $\mathrm{NCl}_{3}\left(\angle \mathrm{Cl}-\mathrm{N}-\mathrm{Cl}=107.1^{\circ}\right)$, $\mathrm{NF}_{3}\left(\angle \mathrm{~F}-\mathrm{N}-\mathrm{F}=102.3^{\circ}\right), \mathrm{PCl}_{3}\left(\angle \mathrm{Cl}-\mathrm{P}-\mathrm{Cl}=100.3^{\circ}\right)$, and $\mathrm{PF}_{3}\left(\angle \mathrm{~F}-\mathrm{P}-\mathrm{F}=97.7^{\circ}\right)$. $(4$ marks $)$

Question 3 - (10 marks)
a) Determine the symmetry label of the following three SALC's under $C_{6 v}$. (6 marks)
b) Which of the above SALC's will be able to mix with an atomic orbital on the central metal? (1 mark)
c) Which symmetry types (in general) in $C_{6 v}$ are IR active and which are Raman active? (3 marks)

## Question 4 - ( 15 marks)

Using the Table below, determine the reducible representation for the planar trans- $\mathrm{N}_{2} \mathrm{~F}_{2}$ molecule. Using the appropriate character table, factor the reducible representation into a set of irreducible representations and subsequently into a set of irreducible representations corresponding to the vibrational modes only. Give the labels of the IR and Raman active modes.

## Symmetry Operation

| E | 3 |
| :--- | ---: |
| i | -3 |
| $\sigma$ | 1 |
| $C_{2}$ | -1 |
| $C_{3}$ | 0 |
| $C_{4}$ | 1 |
| $\mathrm{C}_{6}$ | 2 |
| $\mathrm{~S}_{3}$ | -2 |
| $\mathrm{~S}_{4}$ | -1 |
| $\mathrm{~S}_{6}$ | 0 |

## Question 5 - ( 10 marks)

Consider the octahedral complex $\left[\mathrm{VBr}(\mathrm{SCN})(\mathrm{en})_{2}\right] \mathrm{Br}(\mathrm{en}=$ ethylenediamine $)$
Give one example (draw two structures) of each of the following forms of isomers: a) geometric b) optical c) linkage d) ionization e) name the two structures you drew in part d).

