1. For the following molecules, name the idealized VSEPR geometry and assign the point group: (a) GeH$_2$D$_2$ (D = deuterium); (b) AsF$_5$; (c) C$_2$H$_2$; (d) SiH$_3$D; (e) SO$_2$Cl$_2$

2. List the symmetry elements of the following organic molecules: (a) cyclohexane in the boat conformation; (b) cyclohexane in the chair conformation; (c) biphenyl (C$_6$H$_5$-C$_6$H$_5$), where the rings are co-planar; (d) biphenyl, where the rings are perpendicular to each other; (e) biphenyl, where the rings define an angle of $45^\circ$.

3. Naphthalene is shown below. Give its point group, as well as that of all possible isomers of monochloronaphthalene (note: do not duplicate any of your answers! e.g.: 2-monochloronaphthalene is equivalent to 3-, 6- and 7-monochloronaphthalene).

4. Determine the point groups and vibrational mode symmetries ($\Gamma_{\text{vib}}$) for gaseous BF$_3$, NF$_3$ and ClF$_3$. Would IR and Raman spectroscopies be able to differentiate between these gases? (Hint: $N = 4$ for each, so they have the same number of vibrational degrees of freedom; also, a doubly degenerate set of vibrations will appear at the same energy in a spectrum.)

5. Describe the bonding in [Ni(NH$_3$)$_6$]$_{2+}$ with each of the following models: (a) valence bond theory; (b) crystal field theory.

6. Draw out all the isomers, geometric and optical, of the following: (a) [Co(en)$_2$Cl$_2$]; (b) [Co(en)$_2$(NH$_3$)Cl]$^{2+}$; (c) [Co(en)(NH$_3$)$_2$Cl$_2$]$^*$. 

7. Use crystal field theory to discuss the relative differences in the geometry, color, molar absorptivity and magnetism of the complexes NiCl$_4^{2-}$ and PtCl$_4^{2-}$.

Total: 100 marks