

University of Canterbury

End of Year Examinations 2009

Prescription Number(s):	CHEM 412 BCHM 412
Paper Title:	Structural Chemistry and Biology

Time Allowed: TWO HOURS

Number of pages: SIX

Answer **FOUR** questions out of
FIVE.

All questions are of equal value.

1. (a) Outline the general strategy for determination of the structure of a protein by NMR methods.
- (b) Examine the magnetogyric ratios and natural abundance data for the spin $\frac{1}{2}$ nuclei in the following table and then discuss, using these data and other chemical and biochemical considerations, whether fluorine-substituted amino acids could be usefully employed in protein structure determination by NMR methods.

Isotope	Natural Abundance /%	Magnetogyric Ratio $/10^7 \text{ radT}^{-1} \text{ s}^{-1}$	NMR Frequency ($B = 2.3\text{T}$) /MHz
^1H	99.985	26.75	100
^{13}C	1.11	6.73	25.1
^{15}N	0.37	-2.71	10.1
^{19}F	100.0	25.18	94.1

2. (a) Write short explanatory notes on the following terms (as they relate to NMR spectroscopy)
- (i) bulk magnetization
 - (ii) rotating frame
 - (iii) T_1 and T_2 relaxation times
 - (iv) free induction decay (FID)
 - (v) COSY
 - (vi) TOCSY
- (b) The inversion-recovery and spin-echo pulse sequences both consist of a π pulse and a $\pi/2$ pulse, separated by a variable delay time, t_D , but in different orders. The spin-echo sequence also has an additional t_D at the end of the sequence.

Use vector diagrams to explain

- (i) how each of these pulse sequences works
- (ii) the purpose of these pulse sequences.

3. LiGeTaO_5 crystallises in the space group $P2_1/c$ with four formula units in the unit cell. The Patterson function shows sixteen strong peaks, with co-ordinates and weights measured relative to an origin peak of unit weight given in the following table. Assign these peaks and hence determine the co-ordinates of the tantalum and germanium atoms.

x	y	z	approx. weight
0.501	0.500	0.483	0.40
0.000	0.984	0.500	0.40
0.499	0.515	0.016	0.20
0.499	0.484	0.016	0.20
0.000	0.630	0.235	0.17
0.499	0.869	0.752	0.17
0.000	0.353	0.735	0.17
0.499	0.146	0.252	0.17
0.499	0.130	0.752	0.17
0.000	0.369	0.235	0.17
0.499	0.853	0.252	0.17
0.000	0.646	0.735	0.17
0.500	0.500	0.012	0.08
0.000	0.722	0.500	0.08
0.499	0.777	0.487	0.04
0.499	-0.777	0.487	0.04

- (a) The oxygen positions can then be determined using the Heavy Atom method. For the (400) diffracted beam, calculate $F(400)$ from the tantalum and germanium atoms alone in terms of the atomic scattering factors of these atoms. Then show that the sign of the total diffracted beam, $S(400)$ must have the same sign, no matter what the magnitude and phase of the contribution from the oxygen atoms. You may assume that atomic scattering factors are directly proportional to atomic numbers at all scattering angles
- (b) How would you attempt to find the position of the lithium atoms?

4. Answer **either** (a) **or** (b).
- (a) (i) Describe how the method of isomorphous replacement is used to determine the structures of large biological molecules such as proteins.
- (ii) Indicate what parameters must be determined first, and why protein molecules are particularly suitable candidates for this type of structure determination.
- (iii) Show also how ambiguities arise in the phase determination process, and how these may be overcome.
- (iv) Under what circumstances can phase angles be determined unambiguously using this method ?
- (b) (i) Zinc n-butanoate, $\text{Zn}(\text{C}_4\text{H}_7\text{O}_2)_2$, is monoclinic with space group $P2_1/c$ and the unit cell contains four formula units. The calculated three-dimensional Patterson function shows the following centrosymmetric pairs of strong peaks, with the first two being roughly twice the weight of the others :

Peak	x	y	z
1	0.50	0.50	0.0
2	0.0	0.92	0.5
3	0.5	0.42	0.5
4	0.5	0.58	0.5

If the General Equivalent Positions (GEPs) are :

$$(x,y,z), (-x, \frac{1}{2}+y, \frac{1}{2}-z), (x, \frac{1}{2}-y, \frac{1}{2}+z), (-x, -y, -z),$$

calculate the co-ordinates of the Zn-Zn vectors and hence determine the numerical co-ordinates of the zinc atoms.

- (ii) The structure of zinc n-butanoate is determined using the method of isomorphous replacement, as the cadmium compound has an identical structure. If the measured intensity of the (202) diffracted beams is considerably reduced in the cadmium compound, calculate the phase of the (202) beam in zinc butanoate. Why can this method not be used for the (102) beam?

5. Answer **either** (a) **or** (b).

- (a) (i) What is meant by the term “Special Equivalent Position”? Using space group $P2_1/c$ as an example, show how the co-ordinates of these special positions may be derived from the four General Equivalent Positions (x,y,z) , $(-x,1/2+y,1/2-z)$, $(x,1/2-y,1/2+z)$ and $(-x,-y,-z)$.
- (ii) Using the same reasoning, derive the Special Equivalent Positions in the space group $P2_1/m$, where the General Equivalent Positions have the co-ordinates (x,y,z) , $(-x,1/2+y,-z)$, $(x,1/2-y,+z)$ and $(-x,-y,-z)$.
- (iii) Would it be possible to distinguish between $P2_1/m$ and $P2_1$ on the basis of X-ray diffracted intensities ?
- (b) (i) $(NH_4)WO_3$ is monoclinic, space group $P2_1$ with four formula units in the unit cell. A set of strong peaks of equal weight are observed in the Patterson function with the following co-ordinates :

x	y	z	x	y	z	x	y	z
0.964	0.500	0.052	0.019	0.468	0.542	0.531	0.986	0.042
0.945	0.032	0.510	0.945	0.968	0.510	0.543	0.486	0.990
0.019	0.532	0.542	0.488	0.482	0.500	0.543	0.514	0.990
0.476	0.018	0.552	0.476	0.982	0.552	0.531	0.014	0.042
0.488	0.518	0.500	0.074	0.500	0.032	0.012	0.500	0.948

If the general positions of space group $P2_1$ are (x,y,z) and $(-x,1/2+y,-z)$, determine the co-ordinates of the tungsten atoms.

- (ii) Using these co-ordinates, and assuming that the scattering factor of an atom is directly proportional to its atomic number, calculate the true phase of the (200) diffracted beam.

END OF PAPER