BMB/Bi/Ch 173 – Winter 2018
Homework Set 5 – Assigned 2-7-18, due 2-13-18 by 10:30 a.m
TA – Taylor Stevens tstevens@caltech.edu
Office hours – SFL 220, Friday Feb 9 12:00pm - 1:30pm and Monday Feb 12 1:00pm - 3:00pm, or by appointment

1) Crystallization of biological macromolecules (40 points)

a) i) Describe the chemical interactions that occur at the surface of a protein in solution. How does addition of a precipitant affect these interactions and lead to crystallization? (10 points)

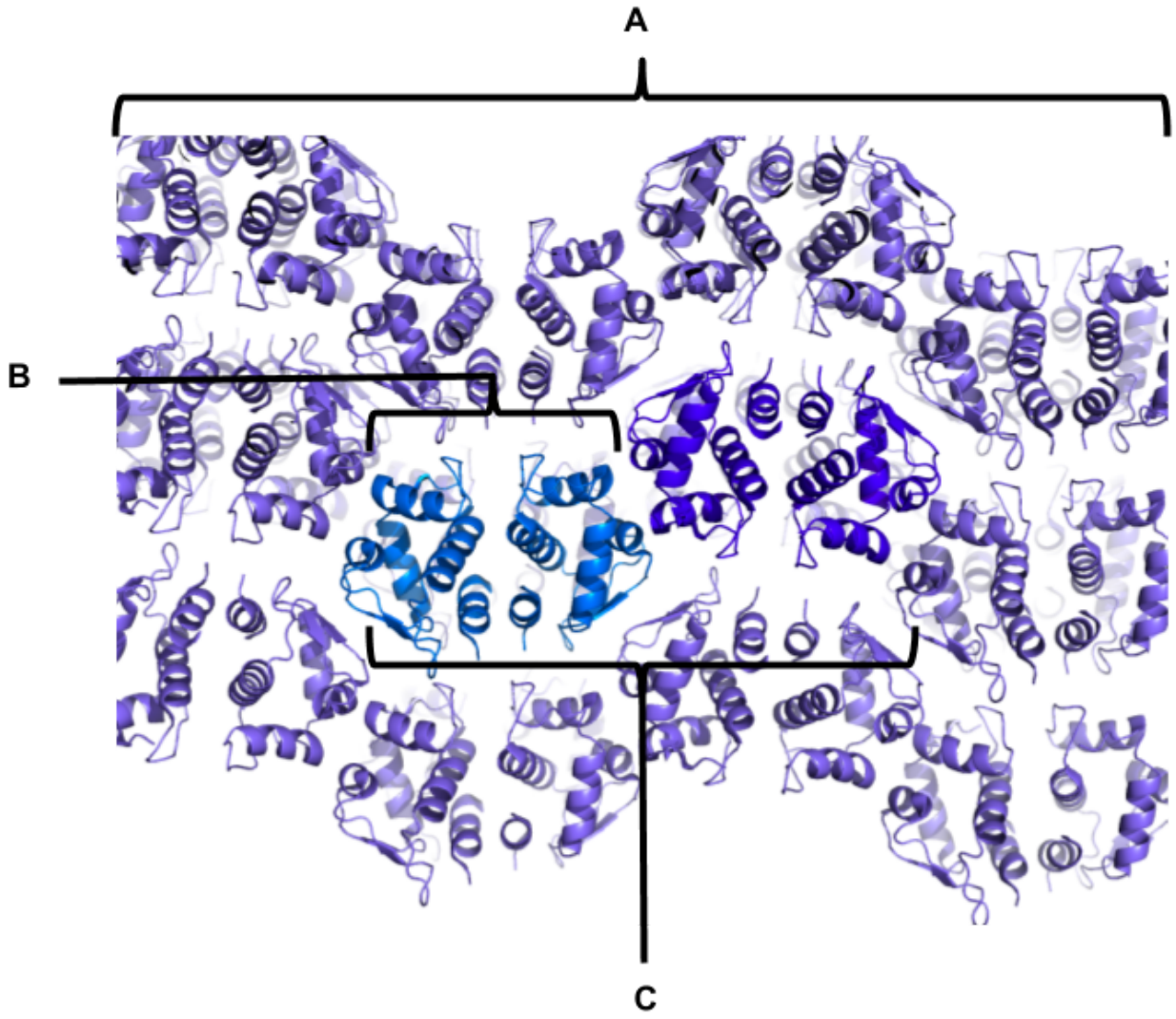
ii) Briefly describe two physical details of the crystallization process that involve changes in entropy (ΔS) and enthalpy (ΔH). Also describe the overall changes in free energy (ΔG) resulting from both details. (12 points)

iii) For crystals to spontaneously form, crystallization must result in a negative free energy change. Describe a protein modification that can increase the probability of crystallization and explain which parameter (entropy or enthalpy) it will affect. (10 points)

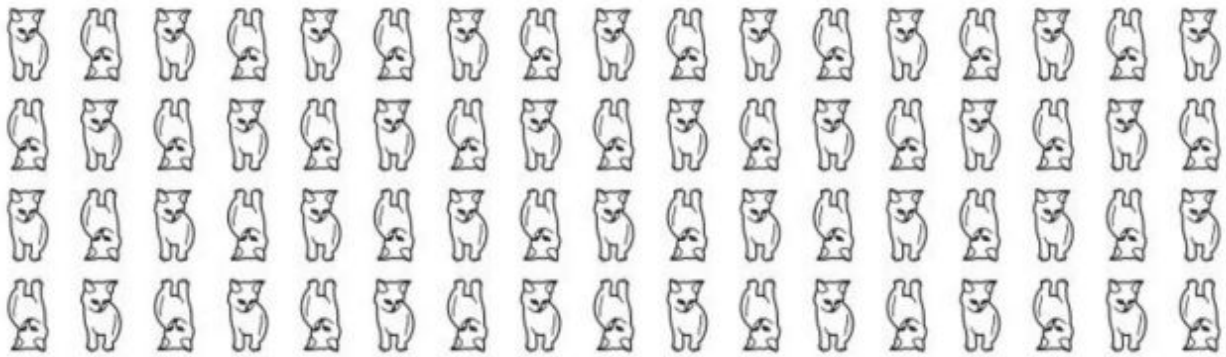
b) Give two reasons for why crystal-derived structures are likely to be biologically relevant, as well as two reasons for why crystal-derived structures may not be biologically relevant. (8 points)

2) Lessons about lattices (40 points)

a) In the following figure, three features are highlighted. Determine which feature is the crystal lattice, the unit cell, and the asymmetric unit. How is the unit cell related to the crystal lattice? How is the asymmetric unit related to the unit cell? (15 points)



b) Outline three possible unit cells on the lattice shown below. (15 points)



c) What are space groups? How many space groups exist? Why are there not more? How many are available to biological macromolecules and why does this differ from the total number? (10 points)

3) Properties of X-rays (40 points)

a) Why is X-ray radiation specifically used for structure determination as opposed to radiation with larger wavelengths (UV) or smaller wavelengths (gamma)? (12 points)

b) You, as a potential Caltech crystallographer, have an advantage over many of your peers in the field in that you have convenient access to SSRL. List one advantage of using X-rays at this facility rather than from a home source? (10 points)

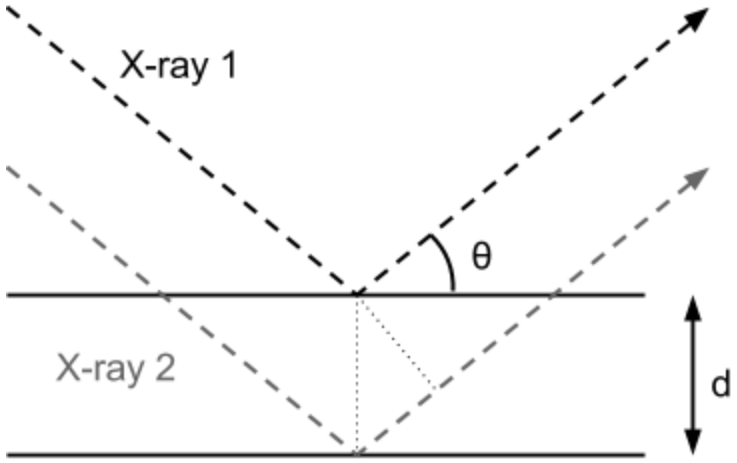
c) Why do proteins need to form crystals in order to produce diffraction data? (12 points)

d) Why can we not do microscopy with X-rays. (6 points)

4) Diffraction theory (80 points)

a) Using the diagram below as a starting point, use simple geometry to derive Bragg's Law: $n\lambda = 2d\sin(\theta)$.

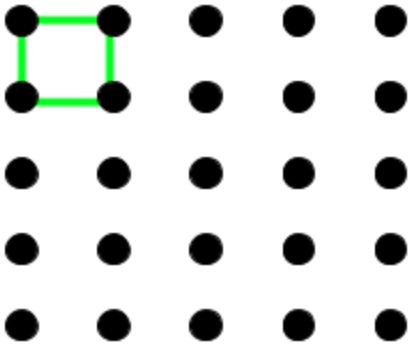
Hint: Use the right triangle that is drawn for you with a dashed line. (20 points).



b) In Bragg's law, what set of numbers is n restricted to? In terms of the physical properties of the x-ray, what is n? (10 points)

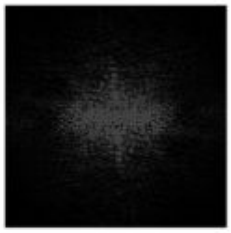
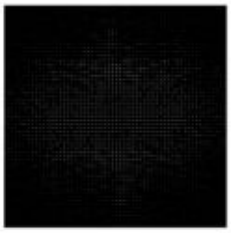
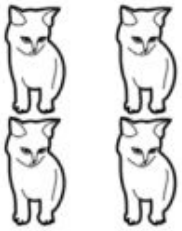
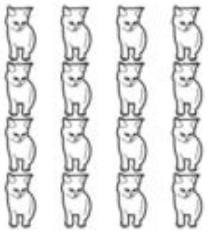
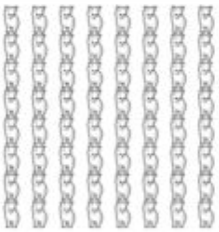
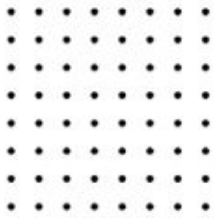
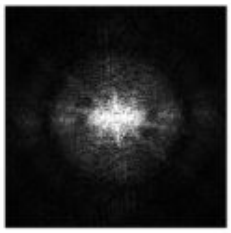
c) Below is an example 2D lattice with the unit cell drawn in green. Assume that each point in the lattice is separated by 200 Å. We can draw a set of imaginary lines through this lattice by

connecting each lattice point with a point that is *h* unit cells across and *k* unit cells above (these are referred to as bragg planes in 3D). Draw the bragg planes corresponding to (*h*,*k*) = (1,0), (1,1), and (1,2). For each of these cases, calculate the spacing between the bragg planes (d in bragg's law). Once you have calculated d for each set of lines, calculate the 3 smallest diffraction angles (in degrees) you will observe when using x-rays with a 1 Å wavelength. If the distance between each lattice point increases, how will this affect the diffraction angles (do not need to calculate)? (24 points)



d) If two different proteins happen to crystallize in identical unit cells (same dimensions and space group), what would be different about the resulting diffraction data? (6 points)

e) Match each image with its Fourier transformation. Briefly explain how you made each match, and discuss any trends that you see. (Note: These images may not print clearly and are best viewed on a computer screen. You may need to zoom in to distinguish important features) (20 points)

Images			Fourier Transformations			
A		E		I		M	
B		F		J		N	
C		G		K		O	
D		H		L		P