



Do yourself a solid.

3.091 Introduction to Solid State Chemistry

Fall Term 2018

Exam 3

11/30/2018 (11:05 am – 11:55 am)

Name: _____

Recitation Section: _____ Recitation Instructor: _____

A complete exam consists of five (5) questions on a total of thirteen (13) pages.

Write your answers on these pages (you can use the back).

State your assumptions and show calculations that support your conclusions.

RESOURCES PERMITTED:

PERIODIC TABLE OF THE ELEMENTS

TABLE OF CONSTANTS

ONE AID SHEET (ONE PAGE 8.5" × 11", DOUBLE-SIDED O.K.)

A STAND-ALONE CALCULATOR – GRAPHING O.K.

NO BOOKS OR OTHER NOTES ALLOWED.

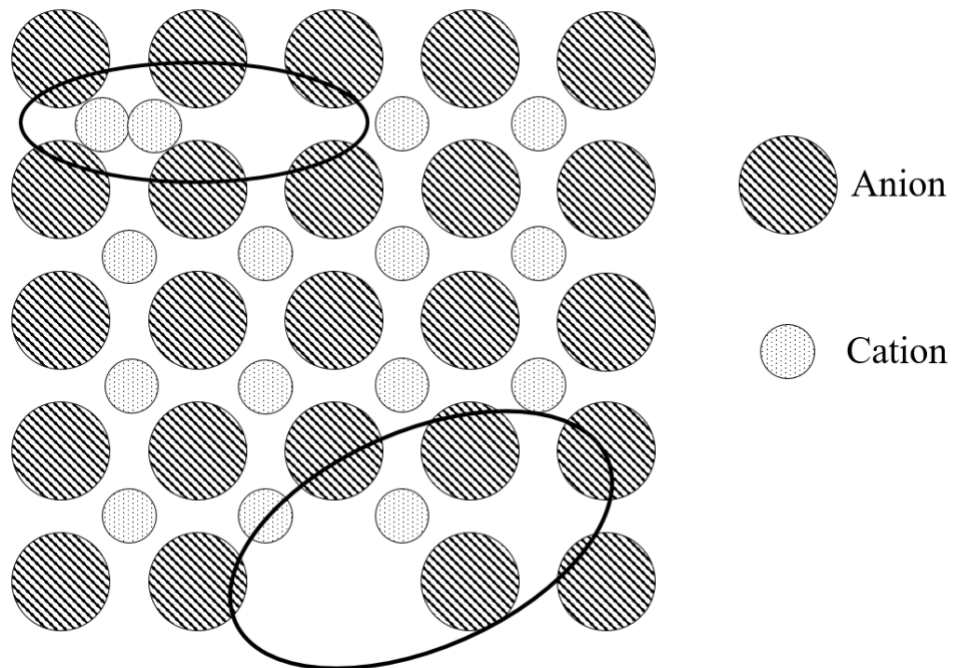
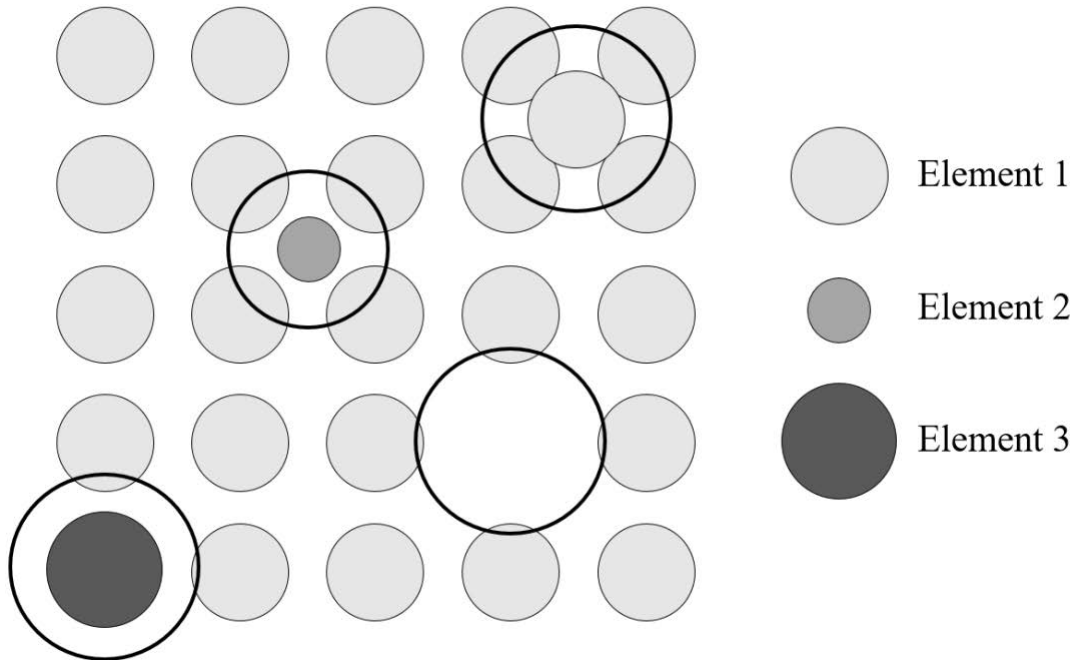
***USE OF WIRELESS COMMUNICATIONS DEVICES
STRICTLY FORBIDDEN.***

Problem 1	23 pts	
Problem 2	20 pts	
Problem 3	20 pts	
Problem 4	21 pts	
Problem 5	16 pts	
TOTAL	100 pts	

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Problem 1 (23 POINTS)

- a) In the 2 crystalline solids shown below, there are circled SIX different point defects TOTAL. **Label** each defect with its name. (6 points)



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You decide to buy a ring from a jewelry store down on Mass Ave. Drawing on your deep knowledge of materials science from 3.091, you decide that a platinum ring is definitely the way to go. Unfortunately, the jeweler graduated from That School Down the Street; you are upset by their claim that the ring is “defect-free crystalline platinum.” Let’s prove them wrong!

b) First, you weigh the ring: it’s exactly 2 grams. How many platinum atoms are in the ring? (2 points)

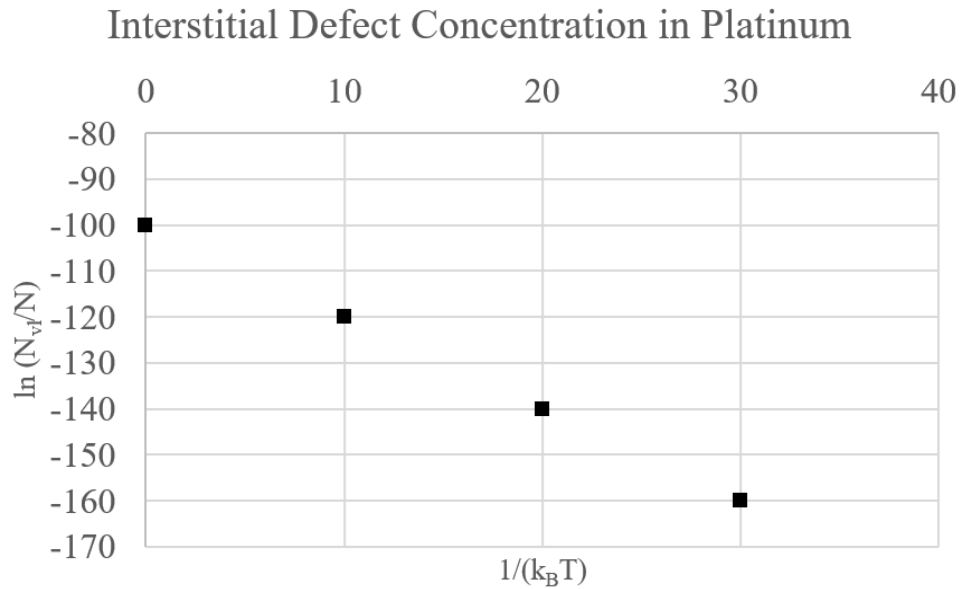
c) How many atomic sites are in the ring, N_{Pt} ? (2 points)

d) It’s a little chilly in the shop: 11°C (284 K). Assuming the ring is in thermal equilibrium, calculate the total number of vacancies, N_{v} , that you would expect at the current temperature. The constant, A , has a value of 1.11. Assume the vacancy formation energy for Pt is 0.96 eV. (4 points)

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- e) The jeweler is stressed out by your frantic calculations and eager to prove they're not cheating you; they hastily point out that the atoms that came from those vacancies are probably sitting in interstitial sites in the lattice. You quickly pull up a paper that has measured interstitial concentration in Pt.

Note: the units of interstitial defect concentration are mol/L.



- i) Estimate the formation energy (in J) of an interstitial defect from the plot. How does this compare to the vacancy formation energy in Pt, which was given above as 0.96 eV? *Hint*: assume that interstitial defect concentration follows an Arrhenius relationship. (5 points)

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ii) Could the jeweler be right, based on the activation energies for interstitial formation and vacancy formation? In other words, could the atoms from the vacant sites have become interstitial defects? Explain your reasoning in one sentence. (4 points)

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Problem 2 (20 POINTS)

a) Sketch the following on the axes provided:

i) A cooling curve (molar volume vs. temperature) for amorphous SiO_2 (3 points)

ii) A cooling curve (molar volume vs. temperature) for crystalline SiO_2 (3 points)

Please label curves i and ii.



b) On your plot above, label:

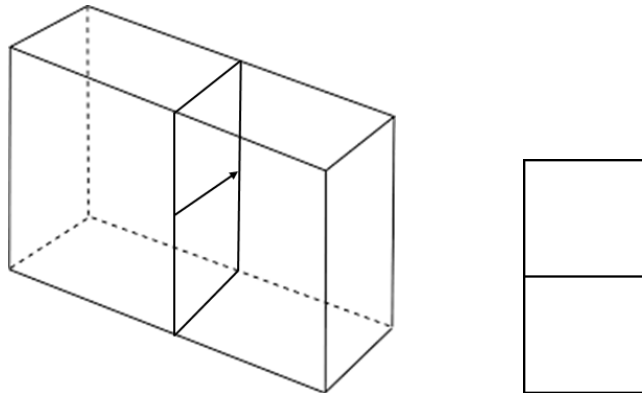
i) the melting point(s) (2 points)

ii) the glass transition temperature(s) (2 points)

c) List **TWO** ways you could change the glass transition temperature. (4 points)

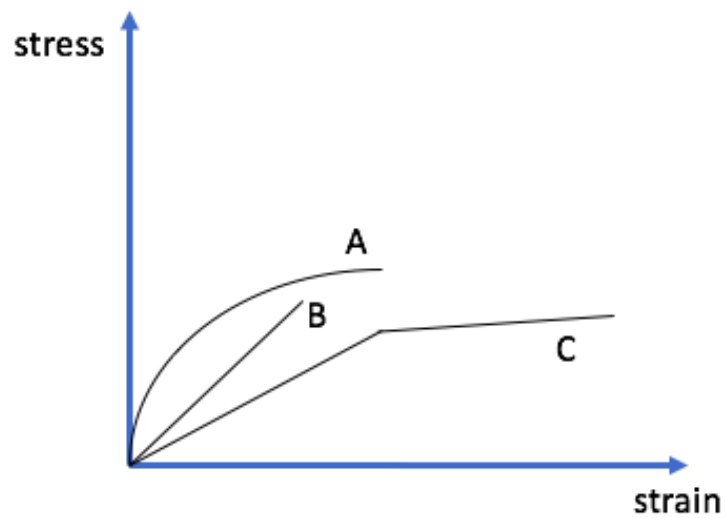
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- d) Tempered glass exhibits increased strength compared to regular glass. Consider a slice taken across a sheet of tempered glass:



With reference to your plot in a), explain how the molar volume changes across the slice. (4 points)

- e) Which of the following stress-strain curves could correspond to the tempered glass above? Circle the letter corresponding to your chosen curve. (2 points)



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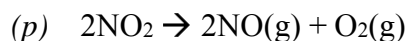
e) If we had given you hydrofluoric acid ($K_a=7.2 \times 10^{-4}$) rather than citric acid ($K_a=1.8 \times 10^{-5}$) in the goodie bag, would you expect the shells to have dissolved faster or slower? Briefly explain why. (4 points)

f) Explain **what** would happen to the pH of the hydrofluoric acid solution if it were to sit in a CO_2 environment for a few hours, and **why**. (4 points)

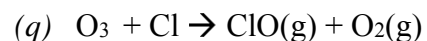
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Problem 4 (21 POINTS)

To compensate for some of the oxygen consumed by burning the candle on one of your many Friday night dates, you decide to run a reaction that produces O₂ gas **as fast as possible**. You recall two options:



OR



You are able to find some information about the reaction (*p*): its **rate law** is

$$\text{rate} = k[\text{NO}_2]$$

(Note: reactions *p* and *q* have the same numerical value for their reaction constants)

Trial #	[O ₃] M	[Cl] M	rate M/s
1	0.07	0.25	10
2	0.14	0.25	20
3	0.07	0.5	20

a) Use the experimental data in the table above about reaction (*q*) to determine its:

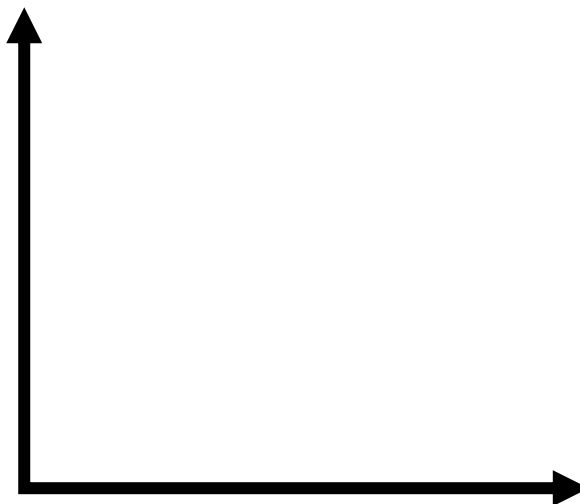
i. Rate law (5 points)

ii. Overall order (2 points)

iii. Value of *k*, the reaction constant (5 points)

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- b) Plot the linear version of the integrated rate law that describes $2\text{NO}_2 \rightarrow 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$. Label the axes, y-intercept, and slope. (5 points)



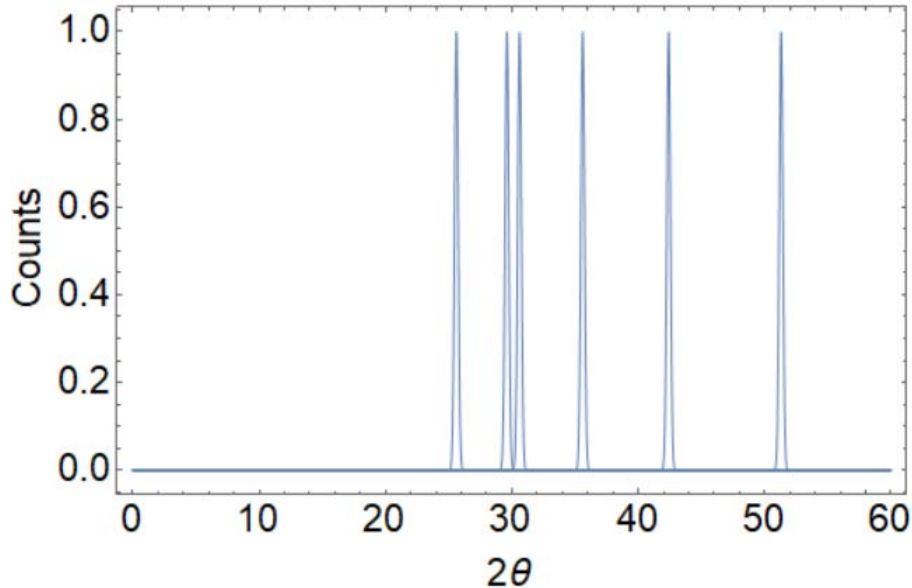
- c) If you have 2 mols of NO_2 , 1 mol of Cl , and 1 mol of O_3 available (but you can only run one reaction), which reaction would you choose to produce oxygen the fastest? Justify your answer with ONE sentence. (4 points)

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Problem 5 (16 POINTS)

Your research supervisor wants you to characterize two pure elemental powders she found in the back of the lab. Unfortunately, time on the XRD machine is very limited; to save time, you mix **BOTH POWDERS** together and perform XRD on the mixture.

You get the following plot of intensity (counts) vs. 2θ (degrees):



From the plot, you have the following data to help identify the samples. You may find it helpful to add columns to assist your thinking (ungraded).

2θ (degrees)	(sin θ)²
25.6	0.049
29.6	0.065
30.7	0.070
35.6	0.093
42.4	0.131
51.3	0.187

- a) Use selection rules to determine the crystal structures of the samples (8 points)
Note: Assume sample 1 corresponds to the element with the lowest 2-theta peak.

Sample 1: _____

Sample 2: _____

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- b) What are the lattice constants of the samples? Copper k-alpha radiation (wavelength=1.54 Angstroms) was used. Show your thinking! (8 points)

Sample 1: _____

Sample 2: _____

END OF 3.091 EXAM 3

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