GEO3-1304 - SPEM: "Aanvullende toets" 17th October 2008

Instructions:

Read all questions through, thoroughly, before answering.
Answer **25** out of the 30 questions and clearly label your answers with the question number.
Use S.I. units, unless stated otherwise.
Show any calculation steps clearly and use annotated diagrams where appropriate.
Write your name clearly on each separate answer sheet.
Duration of examination: 2 hours (14:00 t/m 16:00hr)

Use the following where needed:

Charge on electron, e = 1.60219×10^{-19} C, Rest mass of electron, $m_e = 9.10956 \times 10^{-31}$ kg
Avogadro's Constant, $N_A = 6.022 \times 10^{23}$ mol $^{-1}$, 1 electron volt (eV) = 1.602×10^{-19} J
Planck's constant, h = 6.626×10^{-34} J s, Universal Gas Constant, R = 8.314 J mol $^{-1}$ K $^{-1}$,
Boltzmann's constant, k = 1.381×10^{-23} J K $^{-1}$
$\log_a x = \log_b x / \log_b a$.

Questions:

1. What phase transitions does olivine undergo at (a) a depth of approximately 400-500 km in the mantle (upper mantle-transition zone boundary) and (b) at 670-700 km (transition zone-lower mantle boundary)?
2. Describe the forces that keep atoms in place within a crystal lattice. What is the source of theses forces and why are atoms so regularly spaced?
3. What is the co-ordination state of Si in perovskite ($MgSiO_3$)? How are the polyhedra (e.g. tetrahedra, octahedra etc.) in Perovskite linked?
4. Describe, with simple energy diagrams relating to the atomic lattice scale, the reason for thermal expansion of solid crystalline materials.
5. Where at the Earth's surface would you find the freshest samples of upper mantle rocks that had originated from just below the Moho? Which minerals would be indicative of depth in such a sample?
6. Where and how is the majority of heat stored in crystals and what do metals also contain that can increase their heat capacity at low temperatures? At room temperature, what is a typical value of the molar heat capacity for most common metals above atomic weight of 30 g mol^{-1}?
7. Which mineral is responsible for seismic anisotropy in the D" layer at the base of the mantle and why?
8. What is Bragg's law of diffraction, used in X-ray crystallography? Do higher energy X-rays produce wider or narrower diffraction patterns?
9. Why do minerals typically undergo transitions at higher or lower temperatures than predicted by the calculated boundary on a phase diagram? Would the degree to which you have to pass over this threshold be the same when heating up or cooling down?
10. Describe the classification basis for the three main families of meteorites and what is the main significance of iron meteorites for planetary evolution?
11. Which thermodynamic parameter can be calculated from a calorimetry experiment? What are the main limitations on the data quality obtained by calorimetry?

12. What are the advantages of neutron diffraction over electron and X-ray diffraction in understanding crystal structure?
13. What is interstitial solid solution? Give an example of a mineral that shows this type of solid solution. In your answer explain how charge balance is maintained in the structure.
14. How can pressure be measured in a diamond anvil cell?
15. Describe how to construct a solvus curve (plotted on a composition vs temperature diagram) for a regular solid solution in terms of Gibbs free energy, enthalpy and entropy.
16. Potassium chloride and sodium chloride are very similar alkali halides and both have f.c.c. crystal structure. Why does the X-ray powder diffraction pattern of potassium chloride show many fewer lines compared with sodium chloride and no "all odd" Miller indices (i.e. h, k, l = odd, odd, odd)?
17. Give an example of a mineral that undergoes exsolution. Which product minerals make up the exsolution texture? In what type of rocks and/or geological setting would these minerals be found?
18. What does solid state ionic electrical conduction have in common with high temperature deformation of the mantle?
19. Why do you need to use a high power density laser to convert diamond to graphite even if the phase diagram predicts graphite to be more stable?
20. What are the atomic-scale mechanisms for atomic or ionic diffusion to proceed in pure but defective crystals? Why does this proceed faster at higher temperature?
21. Why doesn't potassium substitute into the olivine structure? Which mineral groups contain significant amounts of alkali metals?
22. What may be obtained from a $\log_e$ (diffusion coefficient) versus reciprocal absolute temperature plot? What is this kind of plot called?
23. What is spinoidal decomposition?
24. How is pressure measured in a diamond anvil cell?
25. What are the two possible mechanisms of transformation of olivine to ringwoodite (spinel structure) and why is this important?
26. Write an equation relating flux to driving force for three different transport processes, to show their similarity of form, and give the name of each of the relations.
27. What structure does Fe adopt in the solid inner core and how many repeat layers are there in this structure?
28. What is the significance of the following equation for transport processes?

$$\frac{\partial \Phi}{\partial t} - C\frac{\partial^2 \Phi}{\partial x^2} = 0$$

Give a couple of names for it, in association with its application to two different transport processes. Briefly describe an application of it, to show its usefulness.
29. In kinetic experiments it is common to measure the formation of a product mineral against time. It is often possible to fit more than one curve to the data (since they are often not very precise) with more than one rate law. If this happens, how would you figure out which rate law is correct?
30. What is the significance of $\sqrt{Dt}$, where D = diffusion coefficient and t is time?