

Geochemical Principles - Ge2303 - Final review topics.

The final will be Saturday May 17, 8:00 a.m. to 10:00 p.m. in 110 Pillsbury Hall. I will hold a review session from 10:00 to 11:00 p.m. on Friday May 16th in 440 Shepherd Laboratories. The test will be comprehensive but more strongly weighted toward material not covered on the midterm. There will be at least one question very similar to one of the midterm questions. The test will include lecture and recitation material, problem sets, and the following book chapters: 2, 3 (p.22-26 only), 4, 6, 7, 8, 11, 9 (p.110-114 only), 10 (p.130-137 and 142-149 only), and 17. The test will be closed book except for the list of thermodynamic equations, the list of recitation equations (mass spectrometer and error analysis equations), and the list of units related to thermodynamics. You may use a calculator. The test will be similar in format to the midterm, with the exception of one long essay question, further described below. As with the midterm, you will be given choices on certain sets of problems, but the choices will be organized so that you will need to answer some specific questions. In some cases there will be no choices. The one long essay question will be required and will have the following general format. I will give you an atom of a particular element or an atom of a particular isotope and tell you its location on earth (the phase in which it resides and its location). Your charge will be to describe the life history of this atom or the various bits of mass that ended up in this atom from the time of the Big Bang to present.

The following topics will be covered:

(topics prior to midterm)

sub-atomic particles and definitions of terms related to isotopes and elements

atomic mass, atomic weight, binding energy/mass deficit

factors affecting nuclear stability: Even-even, odd-odd, even-odd, odd-even; Z/N at low mass, high mass; the "valley of stability", mass/binding energy parabolas.

Basic reason for the formation of chemical bonds, main types of chemical bonds, basic layout of the Periodic Table into groups and periods and rationale for this grouping.

Valences of major elements found in the earth, ionic radii and coordination numbers of major cations found in rock-forming minerals.

Solid solution (limited and complete), simple substitution, coupled substitution, solid solution series, end members, Goldschmidt's Rules

Geochemical classification of the elements (lithophile, siderophile, chalcophile, etc.)

Electromagnetic energy/ light waves, color, and energy

The Doppler Effect and the basis for its use in determining velocities of stars (including Fraunhofer Lines and the concept of the Red Shift)

Cepheid Variables and the basis for their use in determining distances to stars.

The arguments for using the observed relationship (what is this relationship?) between distances and velocities of distant stars/galaxies to propose the Big Bang Theory.

Solar/cosmic abundances of the elements, how they are constructed, what are their characteristics and how can we explain their characteristics (this is a very big question).

Which elements formed during the Big Bang, and which afterwards.

How do stars form? What initially causes stars to be hot? What maintains this heat over millions and billions of years? Describe qualitatively the interplay of fusion and gravitational heat. What general nuclear reactions are responsible for most of the energy generated by stars? What is the main fusion reaction taking place in our sun today? H-fusion/the CNO cycle, H-R diagrams, Main sequence stars, Red Giants, and processes leading up to the transition from a Main sequence star to a Red Giant, the triple alpha process, carbon burning, oxygen burning, silicon burning, r-, p-, and s-processes, Super Novas and processes leading up to Super Novas, population II (first generation) and population I (second generation stars).

Terrestrial abundances of the elements, how do we estimate them and how do we explain differences with cosmic/solar abundances?

Core and mantle abundances, heterogeneous vs. homogeneous accretion.

Oceanic crust/continental crust mineralogy and abundances and explanations for differences as compared to the mantle.

Mineralogy of the mantle and differences in mineralogy above and below the 400 and 670 discontinuities, changes in coordination number of cations with depth/pressure.

(recitation topics prior to midterm)

Accuracy, precision, error calculations, propagation of error, counting statistics

mass spectrometer principles, motion of ions through a mass spectrometer

(topics subsequent to midterm)

System, surroundings, open vs. closed systems, extensive vs. intensive properties, changes in state, phases, components, equilibrium, stable and meta-stable phases.

The phase rule and use of the phase rule.

Heat, work, 1st law of thermodynamics, internal energy and calculation of changes in internal energy.

Enthalpy, relationship between enthalpy and q at constant P , change in enthalpy with temperature, exothermic and endothermic reactions.

Entropy, second and third laws of thermodynamics, calculation of entropies from heat capacities, change in entropy with temperature.

Gibbs Free Energy, relationship between tendency to reduce enthalpy and increase entropy, minimizing G , changing of G with T and P (including quantitative calculations), arguments for high temperature favoring high entropy phases and high pressure favoring high density (low volume) phases, Clausius-Clapeyron Equation.

Law of Mass Action (for ideal gases), Law of Mass Action for liquids and solids, equilibrium constants, and calculation of K as a function of P and T starting with ΔV_R , ΔS_R , and a value for free energy at a particular P and T . Relationship between dilution of a phase and stability, relationship between this concept and melting point depression (e.g. addition of water to a dry silicate system) or boiling point elevation.

Exchange reactions, basic concept as well as use for geothermometry including specific examples, general Clapeyron slopes for exchange reactions

Concept of solubility products, ion activity products, saturated solutions, undersaturated solutions, supersaturated solutions, and how all of this relates to equilibrium constants. Calculation of concentrations in solution at equilibrium using equilibrium constants.

Carbonate equilibria, including *the five reactions that control the aqueous carbonate species, knowledge of how the concentrations of the aqueous carbonate species can be calculated from the K 's of these reactions, how changing pH , T , P , and partial pressure of CO_2 shift these equilibria and the concentrations of the aqueous carbonate species, understanding of how these equilibria affect: atmospheric CO_2 in general and anthropogenic CO_2 in particular, cave formation, deposition of calcite in caves, precipitation of calcite associated with photosynthesis, the carbonate compensation depth, and fizzing when acid is added to calcite.*

Weathering reactions that draw down atmospheric CO_2 and the reverse reactions that release CO_2 during metamorphism, the general factors that affect these reactions (and therefore can potentially shift atmospheric CO_2), how these factors may have

changed in the past to affect climate change, ultimately how these reactions will affect anthropogenic CO₂ and on what timescales. (All of this requires some general knowledge of the "Greenhouse Effect" and CO₂'s role as a "Greenhouse Gas").

Equilibrium fractionation of stable isotopes as described by an isotopic exchange reaction. Which isotope (heavy or light) tends to fractionate into the phase with the stronger bond? Is fractionation between phases bigger or smaller at high temperature? How does this tendency relate to higher S at higher T? How does the presence of water affect the range of observed isotopic compositions of oxygen? Delta notation.

The general modern geographic pattern of the oxygen isotopic composition of meteoric precipitation and the explanation for this pattern (including the Raleigh fractionation model), the relationship between mean annual temperature and mean annual oxygen isotopic composition of meteoric precipitation, the interpretation of ice core oxygen isotopic composition back through time.

The marine oxygen isotope record from calcitic foram shells, the two factors that affect this record (temperature and ice volume), and how these factors affect the record (heavier or lighter with increased temperature or ice volume, plus the basic processes that cause the marine oxygen isotope record to depend on these factors.

Modes of radioactive decay; the integral and differential forms of the radioactive decay equation; the isochron equation.