ESS C109/C209 Midterm Due: May 17, 2007

Nucleosynthesis, crystal chemistry, and radiogenic/radioactive isotope geochemistry

Time limit: 2 hours

Note: This exam consists of two parts – a closed book part and an open book part.

The first part is to be completed without looking at your textbook, isotopes & nuclides booklet, notes, or any other materials. You only need blank paper and a pen or pencil, and you may use the periodic table printed on the next page. No calculator is needed. Complete this part in one sitting.

The second part is open note and open book. You will want to have your nuclides booklet, copy of Faure and Mensing, and other notes handy. You may also want to have a calculator or spreadsheet program running. Time spent gathering these materials does not count against the two-hour time limit, and you may want to take break while you get ready – please don't start the second part of the test until you are ready, and try to complete it in one sitting.

Both parts are to be done on your own, without collaboration.

The closed-book portion begins on the 3rd page. Please do not turn the page (or scroll down) until you are ready to begin.

If you find a mistake or typo, please let me know as soon as possible. Indicate the error in your answer to the affected question.

Ready?

Key: element name
atomic number
symbol
atomic weight (mean relative mass)

hydrogen **1** **H** 1.0079																		helium **2** **He** 4.0026
lithium **3** **Li** 6.941	beryllium **4** **Be** 9.0122												boron **5** **B** 10.811	carbon **6** **C** 12.011	nitrogen **7** **N** 14.007	oxygen **8** **O** 15.999	fluorine **9** **F** 18.998	neon **10** **Ne** 20.180
sodium **11** **Na** 22.990	magnesium **12** **Mg** 24.305												aluminium **13** **Al** 26.982	silicon **14** **Si** 28.086	phosphorus **15** **P** 30.974	sulfur **16** **S** 32.065	chlorine **17** **Cl** 35.453	argon **18** **Ar** 39.948
potassium **19** **K** 39.098	calcium **20** **Ca** 40.078		scandium **21** **Sc** 44.956	titanium **22** **Ti** 47.867	vanadium **23** **V** 50.942	chromium **24** **Cr** 51.996	manganese **25** **Mn** 54.938	iron **26** **Fe** 55.845	cobalt **27** **Co** 58.933	nickel **28** **Ni** 58.693	copper **29** **Cu** 63.546	zinc **30** **Zn** 65.39	gallium **31** **Ga** 69.723	germanium **32** **Ge** 72.61	arsenic **33** **As** 74.922	selenium **34** **Se** 78.96	bromine **35** **Br** 79.904	krypton **36** **Kr** 83.80
rubidium **37** **Rb** 85.468	strontium **38** **Sr** 87.62		yttrium **39** **Y** 88.906	zirconium **40** **Zr** 91.224	niobium **41** **Nb** 92.906	molybdenum **42** **Mo** 95.94	technetium **43** **Tc** [98]	ruthenium **44** **Ru** 101.07	rhodium **45** **Rh** 102.91	palladium **46** **Pd** 106.42	silver **47** **Ag** 107.87	cadmium **48** **Cd** 112.41	indium **49** **In** 114.82	tin **50** **Sn** 118.71	antimony **51** **Sb** 121.76	tellurium **52** **Te** 127.60	iodine **53** **I** 126.90	xenon **54** **Xe** 131.29
caesium **55** **Cs** 132.91	barium **56** **Ba** 137.33	**57-70** *****	lutetium **71** **Lu** 174.97	hafnium **72** **Hf** 178.49	tantalum **73** **Ta** 180.95	tungsten **74** **W** 183.84	rhenium **75** **Re** 186.21	osmium **76** **Os** 190.23	iridium **77** **Ir** 192.22	platinum **78** **Pt** 195.08	gold **79** **Au** 196.97	mercury **80** **Hg** 200.59	thallium **81** **Tl** 204.38	lead **82** **Pb** 207.2	bismuth **83** **Bi** 208.98	polonium **84** **Po** [209]	astatine **85** **At** [210]	radon **86** **Rn** [222]
francium **87** **Fr** [223]	radium **88** **Ra** [226]	**89-102** ******	lawrencium **103** **Lr** [262]	rutherfordium **104** **Rf** [261]	dubnium **105** **Db** [262]	seaborgium **106** **Sg** [266]	bohrium **107** **Bh** [264]	hassium **108** **Hs** [269]	meitnerium **109** **Mt** [268]	ununnilium **110** **Uun** [271]	unununium **111** **Uuu** [272]	ununbium **112** **Uub** [277]		ununquadium **114** **Uuq** [289]				

*lanthanoids	lanthanum **57** **La** 138.91	cerium **58** **Ce** 140.12	praseodymium **59** **Pr** 140.91	neodymium **60** **Nd** 144.24	promethium **61** **Pm** [145]	samarium **62** **Sm** 150.36	europium **63** **Eu** 151.96	gadolinium **64** **Gd** 157.25	terbium **65** **Tb** 158.93	dysprosium **66** **Dy** 162.50	holmium **67** **Ho** 164.93	erbium **68** **Er** 167.26	thulium **69** **Tm** 168.93	ytterbium **70** **Yb** 173.04
**actinoids	actinium **89** **Ac** [227]	thorium **90** **Th** 232.04	protactinium **91** **Pa** 231.04	uranium **92** **U** 238.03	neptunium **93** **Np** [237]	plutonium **94** **Pu** [244]	americium **95** **Am** [243]	curium **96** **Cm** [247]	berkelium **97** **Bk** [247]	californium **98** **Cf** [251]	einsteinium **99** **Es** [252]	fermium **100** **Fm** [257]	mendelevium **101** **Md** [258]	nobelium **102** **No** [259]

Part 1: Closed book/closed notes. You may consult the periodic table on the previous page.

Nucleosynthesis, crystal chemistry, and radiogenic/radioactive isotope geochemistry

1) In a couple of paragraphs, briefly describe Big Bang nucleosynthesis. What elements and isotopes were formed by this process? Why weren't all of the elements synthesized?

2) Tin (atomic number 50) has ten stable isotopes, more than any other element. Based on what you know about nuclear chemistry, why would tin be expected to have a lot of stable isotopes?

3) List the most important geochemical oxidation states of the following elements:
   a. O
   b. Mg
   c. Na
   d. Si
   e. P
   f. K
   g. Ar
   h. Zr
   i. Rb
   j. Sr

4) The mineral sphene (also known as titanite) is often used in geochronology studies. It has the chemical formula $CaTiOSiO_4$, and is an orthosilicate (no oxygens shared by SiO_4 tetrahedra). Write a sentence or two answering each of these questions, giving your reasoning:
   a. What do you expect the temperature stability of this mineral to be?
   b. What do you think the typical Rb/Sr ratio of this mineral is?
   c. What geochronology method is well suited to be used on this mineral? (If more than one applies, choose the one you think will work best).

5) For each parent and decay mode listed below, give the daughter isotope:
   a. ^{14}C ($\beta-$ emission)
   b. ^{147}Sm (α emission)
   c. ^{39}K ($\varepsilon-$ capture)
   d. ^{26}Al ($\beta+$ emission)

6) List two of the major assumptions made in isochron age determinations.

7) Describe two causes of variation in the $^{14}C/^{12}C$ of atmospheric CO_2 over time.

END OF PART 1!

Ready for part two?

Part 2: Open book / open notes.

Nucleosynthesis, crystal chemistry, and radiogenic/radioactive isotope geochemistry

1) Starting from ^{56}Fe, what are the first 13 stable nuclei produce by s-process nucleosynthesis? Assume that all unstable nuclei decay before they accept another neutron, that each unstable nucleus that is produced decays only by it's most common decay mechanism, and that ^{64}Cu decays equally by e– capture and β– emission.

2) The Martian (SNC) meteorite Allan Hills 84001 contains a number of small carbonate blebs that have been interpreted as low-temperature precipitates from an aqueous fluid (whether or not biology was involved). A key question is the age of these carbonates. Calculate an Rb/Sr isochron age based on the data below (derived from acid-leaching of a sample of the carbonate blebs) (Data from Borg et al., 1999):

	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
S2	0.2096 ±11	0.716338 ±10
S4	0.1172 ±12	0.708653 ±11
S6	2.622 ±13	0.850478 ±42

3) $^{235}U/^{238}U \approx 1/137.88$ for almost all known terrestrial samples today. One place where it is different is the Oklo uranium ore deposit in Gabon, Africa. There, the unusually low $^{235}U/^{238}U$ observed in some ore samples is thought to be the result of a natural fission reactor that was active ~$2x10^9$ years ago. ^{235}U was sufficiently concentrated that self-sustaining nuclear chain reactions converted some of it to much lighter decay products like cesium.
   a. Calculate the $^{235}U/^{238}U$ of terrestrial uranium $2x10^9$ years ago.
   b. How does this ratio compare with the $^{235}U/^{238}U$ of typical nuclear power plant fuel (~0.03 – 0.04)?
   c. Was the $^{235}U/^{238}U$ on Earth ever ≥ 1 ?

ALL DONE!