Write your answers on these pages.

State your assumptions and show calculations that support your conclusions.

RESOURCES PERMITTED: PERIODIC TABLE OF THE ELEMENTS, TABLE OF CONSTANTS, AN AID SHEET (ONE PAGE 8½" × 11"), AND A CALCULATOR.

NO BOOKS OR OTHER NOTES ALLOWED.
2009 Test #1, Problem #1

Uranium metal can be produced by the reaction of uranium tetrafluoride (UF₄) with magnesium (Mg) in a sealed reactor heated to 700ºC. The by-product is magnesium fluoride (MgF₂). To ensure that all the magnesium is consumed in the reaction, the reactor is charged with excess UF₄, specifically 10% more than the stoichiometric requirement of the reaction. To produce 222 kg of U, how much UF₄ and Mg must be introduced into the reactor? Express your answers in kg.

2009 Test #1, Problem #2

(a) In box notation, give the complete ground-state electron configuration of each of the following gas-phase species:
   (i) Ca²⁻ 
   (ii) Mg⁴⁺

(b) Give the chemical identities of the species with these ground-state electron configurations:
   (i) a neutral atom with [Xe]⁴d¹⁵⁵d¹⁰⁶s²⁶p¹ 
   (ii) an atom with net charge 4⁺ and [Ar]³d³

(c) Write the quantum numbers (n, l, m, s) of one of the 3d and one of the 4s electrons in iron (Fe).
For a given cation, C, and anion, A, show the following four energy states on the same energy-level diagram: (1) ions at infinite separation; (2) ion pair CA; (3) ion line CACACA…; (4) crystalline solid of CA. Assume that the comparison is based upon identical numbers of ions in all four states. The diagram need not be drawn to scale; however, you must convey relative values of the different energy states.
2009 Test #1, Problem #6

Atoms of ionized helium gas (He\(^{+}\)) are struck by electrons in a gas discharge tube operating with the potential difference between the electrodes set at 8.88 V. The emission spectrum includes the line associated with the transition from \(n = 3\) to \(n = 2\). Calculate the minimum value of the de Broglie wavelength of scattered electrons that have collided with He\(^{+}\) and generated this line in the emission spectrum.
2009 Test #2, Problem #2

(a) You discover that someone has been using your x-ray generator and has changed the target/anode. To determine the chemical identity of the new target, you go ahead and operate the x-ray generator and find the wavelength, $\lambda$, of the $K_\alpha$ peak to be 0.250 Å. What element is the target made of?

(b) Hilary Sheldon conducts an experiment with her x-ray diffractometer. A specimen of tantalum (Ta) is exposed to a beam of monochromatic x-rays of wavelength set by the $K_\alpha$ line of titanium (Ti). Calculate the value of the smallest Bragg angle, $\theta_{hkl}$, at which Hilary can expect to observe reflections from the Ta specimen.

DATA: \( \lambda_{K_\alpha} \) of Ti = 2.75 Å; lattice constant of Ta, $a = 3.31$ Å

(c) Sketch the emission spectrum (intensity versus wavelength) of an x-ray target that has been bombarded with photons instead of with electrons. Assume that the incident photons have more than enough energy to dislodge $K$-shell electrons in the target. On your spectrum label the features associated with $K_\alpha$ radiation, $K_\beta$ radiation, and $L_\alpha$ radiation.