3.091 OCW Scholar

Self-Assessment Exam
Structure of the Atom

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 (UF_4) with magnesium (Mg) in a sealed reactor heated to 700ºC. The by-product is magnesium fluoride (MgF_2). To ensure that all the magnesium is consumed in the reaction, the reactor is charged with excess UF_4, specifically 10% more than the stoichiometric requirement of the reaction. To produce 222 kg of U, how much UF_4 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) Ca^{2-} (ii) Mg^{4+}

(b) Give the chemical identities of the species with these ground-state electron configurations:

(i) a neutral atom with $[Xe]4f^{14}5d^{10}6s^{2}6p^{1}$ (ii) an atom with net charge 4+ and $[Ar]3d^{3}$

(c) Write the quantum numbers (n, l, m, s) of ***one*** of the 3*d* and ***one*** of the 4*s* electrons in iron (Fe).

2009 Test #1, Problem #4

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, λ, of the K_α 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_α line of titanium (Ti). Calculate the value of the smallest Bragg angle, θ_{hkl}, at which Hilary can expect to observe reflections from the Ta specimen.

DATA: λ_{K_α} 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_α radiation, K_β radiation, and L_α radiation.

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