

# 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  $8\frac{1}{2}'' \times 11''$ ), AND A CALCULATOR.

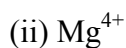
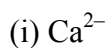
**NO BOOKS OR OTHER NOTES ALLOWED.**

## 2009 Test #1, Problem #1

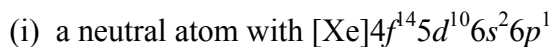
Uranium metal can be produced by the reaction of uranium tetrafluoride ( $\text{UF}_4$ ) with magnesium ( $\text{Mg}$ ) in a sealed reactor heated to  $700^\circ\text{C}$ . The by-product is magnesium fluoride ( $\text{MgF}_2$ ). To ensure that all the magnesium is consumed in the reaction, the reactor is charged with excess  $\text{UF}_4$ , specifically 10% more than the stoichiometric requirement of the reaction. To produce 222 kg of U, how much  $\text{UF}_4$  and  $\text{Mg}$  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:



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



(c) Write the quantum numbers ( $n$ ,  $l$ ,  $m$ ,  $s$ ) of **one** of the  $3d$  and **one** of the  $4s$  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 ( $\text{He}^+$ ) 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  $\text{He}^+$  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.

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