3.091 OCW Scholar

Self-Assessment
Structure of the Atom

Supplemental Exam Problems for Study

Solution Key

Problem #1

Tantalum metal is produced by the reaction of potassium heptafluorotantalate (K_2TaF_7) with elemental sodium (Na) in a reactor heated to 850ºC. The by-products are potassium fluoride (KF) and sodium fluoride (NaF).

(a) Write a balanced equation for the reaction.

$K_2TaF_7 + 5Na \rightarrow Ta + 2KF + 5NaF$

(b) A reactor is charged with 222 kg of K_2TaF_7 and 6.66 kg of Na, and the reaction is allowed to go to completion. Calculate how much tantalum is produced. Express your answer in kg.

K 39.1 K_2TaF_7 392.1

Na 23.0 ∴ 222 Kg K_2TaF_7 = $\frac{222 \times 10^3}{392.1}$ = 566.2 moles

Ta 180.9

F 19.0 ∴ 6.66 kg Na = $\frac{6.66 \times 10^3}{23.0}$ = 289.6 moles

Clearly the amount of Na < 5x mol amount of Ta

∴ Na is limiting reagent

∴ Ta yield = $\frac{1}{5}$ moles Na = $\frac{289.6}{5}$ = 57.9

$\Rightarrow 57.9 \times 180.9 \frac{g}{mol}$ = 10.5 kg Ta

Problem #2

(a) Name the element with these ground-state electron configurations:

(i) a ***neutral atom*** with [Kr]$4d^{10}5s^{2}5p^{1}$ In

(ii) an atom with ***net charge 2–*** and [Ne]$3s^{2}3p^{6}$ S^{2-}

(b) Write the quantum numbers (*n*, *l*, *m*, *s*) of each of the 5d and 6s electrons in rhenium (Re).

(6, 0, 0, 1/2) (5, 2, −2, 1/2) (5, 2, 1, 1/2)

(6, 0, 0, −1/2) (5, 2, −1, 1/2) (5, 2, 2, 1/2)

(5, 2, 0, 1/2)

(c) For each of the following pairs, (1) identify the larger atom or ion and (2) state one reason for your choice.

(i) Rb and Rb^+ Rb. Rb^+ has lost 1 e^- & is isoelectronic w/ Kr which is n=4

(ii) Rb^+ and Kr Kr. Rb^+ is isoelectronic w/ Kr but Rb^+ has more protons ∴ same no e^-s are more tightly bound in Rb^+ ⇒ Rb^+ is smaller

(d) Making reference to the underlying physical principle, describe how a beam of mercury atoms (Hg) would behave in the Stern-Gerlach experiment (passage of a beam of atoms through a divergent magnetic field).

Hg is $4f^{14}5d^{10}6s^{2}$ ⇒ no unpaired e^-s ∴ in divergent mag. field, no net force is exerted on Hg

∴ no deflection of Hg atom beam

Problem #3

Determine whether a beam of α-particles with a de Broglie wavelength of 3.091×10^{-12} m is capable of ionizing argon (Ar) gas. α-particles are doubly ionized helium atoms (He^{2+}).

Compare E_α with I.E. of Ar

$$E_\alpha = \frac{1}{2} m v^2 = \frac{1}{2} \frac{p^2}{m} = \frac{h^2}{2m_\alpha \lambda^2}$$

I.E. of Ar from P.T. = 15.8 eV

$$m_\alpha = 4.00 \times 1.66 \times 10^{-27}\ kg$$

$$\therefore E_\alpha = \frac{(6.6 \times 10^{-34})^2}{2 \times 4 \times 1.66 \times 10^{-27} (3.091 \times 10^{-12})^2} = \frac{3.43 \times 10^{-18}\ J}{1.6 \times 10^{-19}}$$

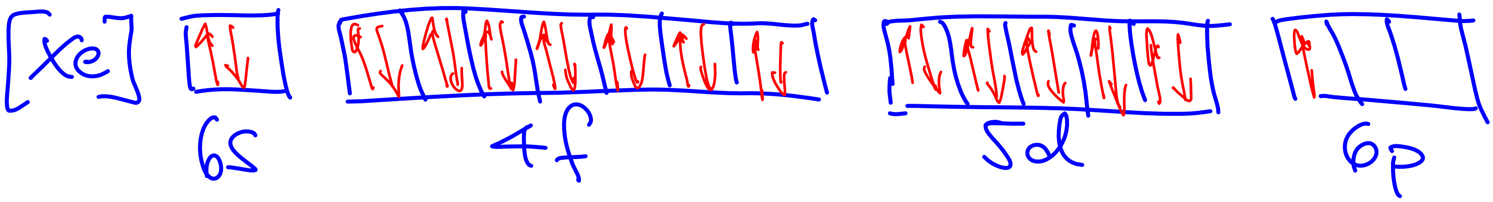
$$= 21.5\ eV > I.E.(Ar)$$

∴ α beam will ionize Ar

Problem #4

(a) In box notation (arrows for electrons and boxes for orbitals), give the ground-state electron configuration of thallium (Tl).

$[Xe]\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^1$



(b) Specify the values of the 4 quantum numbers for the outermost electron in thallium.

(n, l, m, s)

$(6, 1, -1, \frac{1}{2})$

(c) Are thallium atoms paramagnetic? If so, why? If not, why not?

yes. unpaired electron

(d) The ionic forms of thallium are Tl^+ and Tl^{3+}. Explain with reference to the relevant electron configurations.

Tl^+ has filled subshells 6s, 4f, 5d

Tl^{3+} has filled subshells 4f & 5d