Practice FRQs

Answer the following questions about the element selenium, Se (atomic number 34). 2000 7

a) Samples of natural selenium contain six stable isotopes. In terms of atomic structure, explain what these isotopes have in common, and how they differ. *(2pts)*

common - all have 34 protons

differ - each has a different # of neutrons = different mass number

b) Write the complete electron configuration (e.g., $1s^2\ 2s^2$. . . etc.) for a selenium atom in the ground state. Indicate the number of unpaired electrons in the ground-state atom, and explain your reasoning. *(2pts)*

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$

2 unpaired e^-

c) In terms of atomic structure, explain why the first ionization energy of selenium is

i) less than that of bromine (atomic number 35), and *(1pt)*

Se has a larger radius than Br. There is less coulombic attraction between the p^+ and e^-, so it requires less E to remove an e^-

ii) greater than that of tellurium (atomic number 52). *(1pt)*

Se has a smaller radius than Te. There is more coulombic attraction between the p^+ and e^-, so it requires more E to remove an e^-

Answer the following questions regarding light and its interactions with molecules, atoms, and ions. 1999 2

a) The longest wavelength of light with enough energy to break the Cl–Cl bond in $Cl_2(g)$ is 495 nm.

i) Calculate the frequency, in s^{-1}, of the light. *(1pt)*

$c = \lambda\nu$

$2.998 \times 10^8 \frac{m}{s} = (4.95 \times 10^{-7} m)\nu$

$495\ nm \left| \frac{1\ m}{1 \times 10^9\ nm} \right.$

$= 6.06 \times 10^{14}\ s^{-1}$

ii) Calculate the energy, in J, of a photon of the light. *(1pt)*

$E = h\nu$

$E = (6.626 \times 10^{-34}\ J \cdot s)(6.06 \times 10^{14}\ s^{-1}) = 4.01 \times 10^{-19}\ \frac{J}{photon}$

iii) Calculate the minimum energy, in kJ mol^{-1}, of the Cl–Cl bond. *(1pt)*

$\frac{4.01 \times 10^{-19}\ J}{1\ photon} \left| \frac{6.022 \times 10^{23}\ photons}{1\ mol} \right| \frac{1\ kJ}{1000\ J} = 242\ \frac{kJ}{mol}$

b) A certain line in the spectrum of atomic hydrogen is associated with the electronic transition in the H atom from the sixth energy level ($n = 6$) to the second energy level ($n = 2$).

i) Indicate whether the H atom emits energy or whether it absorbs energy during the transition. Justify your answer. *(2pt)*

E is emitted since $n=2$ is lower than $n=6$.

ii) ~~Calculate the wavelength, in nm, of the radiation associated with the spectral line. *(3pts)*~~

Answer the following questions related to sulfur and one of its compounds. 2009 6

a) Consider the two chemical species S and S^{2-}.

i) Write the complete electron configuration of each species. *(2pts)*

$S: 1s^2 2s^2 2p^6 3s^2 3p^4$

$S^{-2}: 1s^2 2s^2 2p^6 3s^2 3p^6$

ii) Explain why the radius of the S^{2-} ion is larger than the radius of the S atom. *(1pt)*

S^{-2}: 16 protons < 18 e^- = less coulombic attraction

S : 16 protons = 16 e^- = more coulombic attraction

iii) Which of the two species would be attracted into a magnetic field? Explain. *(1pt)*

S - unpaired e^- 

b) The S^{2-} ion is isoelectronic with the Ar atom. From which species, S^{2-} or Ar, is it easier to remove an electron? Explain. *(1pt)*

S^{-2}: 16 protons < 18 e^- = less coulombic attraction

Ar : 18 protons = 18 e^- = more coulombic attraction

Using principles of atomic and molecular structure and the information in the table, answer the following questions about atomic fluorine, oxygen, and xenon, as well as some of their compounds. 2008 5

Atom	First Ionization Energy ($kJ\ mol^{-1}$)
F	1,681.0
O	1,313.9
Xe	?

a) Write the equation for the ionization of atomic fluorine that requires 1,681.0 kJ mol^{-1}. *(1pt)*

$F(g) \rightarrow F^+(g) + e^-$

b) Account for the fact that the first ionization energy of atomic fluorine is greater than that of atomic oxygen. (You must discuss <u>both</u> atoms in your response.) *(1pt)*

F has a greater effective nuclear charge in the 2p orbital. O has 1 less proton and 1 less electron so it has less coulombic attraction. Less energy is required to remove an electron.

c) Predict whether the first ionization energy of atomic xenon is greater than, less than, or equal to the first ionization energy of atomic fluorine. Justify your prediction. *(1pt)*

Less than.

The e^- of Xe would be removed from the 5p orbital vs the 2p orbital for F. 5p is further from the nucleus so those e^- have less coulombic attraction.

The table above shows the first three ionization energies for atoms of four elements from the third period of the periodic table. The elements are numbered randomly. Use the information in the table to answer the following questions. 2007B 6

	1st Ionization Energy (kJ mol^{-1})	2nd Ionization Energy (kJ mol^{-1})	3rd Ionization Energy (kJ mol^{-1})
Element 1	1,251	2,300	3,820
Element 2	496	4,560	6,910
Element 3	738	1,450	7,730
Element 4	1,000	2,250	3,360

a) Which element is most metallic in character? Explain your reasoning. *(2pts)*

Element 2 - lowest IE's

metals have low IE

Na

Mg

b) Identify element 3. Explain your reasoning. *(2pts)*

Mg - relatively low 1st and 2nd IE's compared to the 3rd.

This indicates 2 valence e⁻.

c) Write the complete electron configuration for an atom of element 3. $1s^2 2s^2 2p^6 3s^2$ *(1pt)*

d) What is the expected oxidation state for the most common ion of element 2 ? $+1$ *(1pt)*

e) What is the chemical symbol for element 2 ? Na *(1pt)*

f) A neutral atom of which of the four elements has the smallest radius? Explain your answer. *(1pt)*

Element 1 - highest 1st IE so it's electrons are experiencing the largest coulombic attraction.

Account for each of the following observations in terms of atomic theory and/or quantum theory. *2006B 7*

a) Atomic size decreases from Na to Cl in the periodic table. *(2pts)*

All elements are in the 3rd E level, but there is an increasing # of protons and electrons across the row. This causes the effective nuclear charge to ↑, so the greater attracti... results in smaller atom...

b) Boron commonly forms molecules of the type BX_3. These molecules have a trigonal planar structure. *(2pts)*

B has 3 valence e⁻ which will form 3 bonds with X. The 3 bonds orient themselves 120° apart to minimize repulsions. This forms Trig Plane geometry.

c) The first ionization energy of K is less than that of Na. *(2pts)*

K's valence electron is 4s¹, Na's is 3s¹

The 4s¹ e⁻ is further away from the nucleus and easier to remove.

d) Each element displays a unique gas-phase emission spectrum. *(2pts)*

Each element has a different electron arrangement. The transition from excited state to ground state will be different for each atoms electrons.

Answer the following problems about gases. 2007B 2

a) The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated in the table.

Isotope	Mass (amu)
Ne-20	19.99
Ne-22	21.99

i) Using the information in the table, calculate the percent abundance of each isotope. *(1pt)*

$20.18 = (19.99 \cdot x) + (21.99 \cdot (1-x))$

$20.18 = 19.99x + 21.99 - 21.99x$

$-1.81 = 2.00x$

$x = 0.905$

Ne-20 = 90.5%

Ne-22 = 9.5%

ii) Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon. *(3pts)*

$$12.55\ g\ Ne \left| \frac{1\ mol\ Ne}{20.18\ g\ Ne} \right| \frac{0.095\ mol\ Ne\text{-}22}{1\ mol\ Ne} \left| \frac{6.022 \times 10^{23}\ atoms\ Ne\text{-}22}{1\ mol\ Ne\text{-}22} \right.$$

$$= 3.558 \times 10^{27}\ atoms\ Ne\text{-}22$$

b) A major line in the emission spectrum of neon corresponds to a frequency of $4.34 \times 10^{14}\ s^{-1}$. Calculate the wavelength, in nanometers, of light that corresponds to this line. *(2pts)*

$c = \lambda\nu$

$2.998 \times 10^{8}\ \frac{m}{s} = (\lambda)(4.34 \times 10^{14}\ s^{-1})$

$\lambda = 6.90 \times 10^{-7}\ m$

$= 690.\ nm$

c) In the upper atmosphere, ozone molecules decompose as they absorb ultraviolet (UV) radiation, as shown by the equation below. Ozone serves to block harmful ultraviolet radiation that comes from the Sun.

$$O_3(g) \xrightarrow{-UV} O_2(g) + O(g)$$

A molecule of $O_3(g)$ absorbs a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$.

i) How much energy, in joules, does the $O_3(g)$ molecule absorb per photon? *(1pt)*

$E = h\nu$

$= (6.626 \times 10^{-34}\ J \cdot s)(1.00 \times 10^{15}\ s^{-1}) = 6.63 \times 10^{-19}\ \frac{J}{photon}$

ii) The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol^{-1}. Does a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$ have enough energy to break this bond? Support your answer with a calculation. *(2pts)*

$$\frac{6.63 \times 10^{-19}\ J}{1\ photon} \left| \frac{6.022 \times 10^{23}\ photons}{1\ mol} \right| \frac{1\ kJ}{1000\ J} = 399\ \frac{kJ}{mol}$$

yes $399\ kJ > 387\ kJ$