Physics 30 – Lesson 30
Light Spectra and Excitation States

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1. /1 When a solid, liquid or very dense gas is heated until it gives off light and the light is passed through a prism, a **continuous** spectrum is produced.

2. /1 When a rarefied gas is excited with electrical energy until it gives off light which is passed through a prism, an **emission** spectrum is produced.

3. /1 When white light is passed through a gas and then allowed to go through a prism, it will produce an **absorption** spectrum.

4. /2 Every element and molecule emits or absorbs only certain, discrete wavelengths of light. The pattern produced is characteristic of that element or molecule.

5. /2 The Franck-Hertz experiment demonstrated that atoms accept and emit energy in discrete, characteristic amounts. This demonstrated that atoms behave in a quantum manner which explains the emission and absorption spectra of the element.

6) /3

A. An atom's ground state is the normal energy state of an atom.
B. When an atom absorbs energy one of its electrons jumps to a higher or excited energy state.
C. An atom's ionization energy is the energy required to free the electron from the atom.

7) /3

$$E_{photon} = 4.7eV - 1.4eV = 3.3eV$$

$$f = \frac{E}{h}$$

$$f = \frac{3.3eV}{4.14\times10^{-15}eV\cdot s}$$

$$\boxed{f = 8.0\times10^{14}Hz}$$

8) /4

A) A 3.6 eV electron does not have sufficient energy to excite the mercury atom to the first excitation state. Therefore the incident electron is reflected with an energy of 3.6 eV.

B) $E_1 = 6.8eV - 4.9eV$

$$\boxed{E_1 = 1.9eV}$$

$$E_2 = 6.8eV - 6.7eV$$

$$\boxed{E_2 = 0.1eV}$$

9) The excitation states can be determined by examining the difference between the energy of the incident electrons and the out coming electrons. The results indicate that the atom

/3 has the following excitation energies : **6.8 eV**, **8.7 eV**, and **9.3 eV**.

10) The mercury atom will return to its ground state by emitting a 4.9 eV photon.

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11) White light contains all frequencies of visible light. As white light passes through the gaseous element, the element absorbs only certain wavelengths (energies) of light that

2/ correspond to the excitation states of that particular element. These absorbed wavelengths are removed from the while light creating dark lines in the spectra.

12) Gases absorb light energy and then re-emits light at frequencies beyond or below human

/2 vision.

13) Absorption involves absorption of energy from ground to excited states. Emission involves release of energy as electrons fall down toward the ground state. If an electron

/2 falls to the ground state it will produce an emission line corresponding to the absorption line. However, if the electron undergoes several intermediate jumps as it falls toward the ground state, it will emit a number of lower energy photons that will not correspond to the absorption spectrum.

14) For the electron, 4.9 eV of energy is absorbed by an atom and the electron scatters with the remaining 0.1 eV.

/4

For the photon, the atom can only absorb photon energy that corresponds with its excitation states. Since 5.0 eV is not an excitation energy for mercury, the 5.0 eV photon passes through the mercury vapour.

15)

A. The atom's electron eventually drops to the ground state and a photon is emitted.

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B. The light emitted can go off in any direction. It is very unlikely that it will be emitted in the same original direction.

16) (a) The excitation state energies correspond to the energies of the absorbed photons.

$$E_1 = \frac{hc}{\lambda_1}$$

$$E_1 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{172\times10^{-9}m}$$

/5 $$\boxed{E_1 = 7.23eV}$$

$$E_2 = \frac{hc}{\lambda_2}$$

$$E_2 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{194\times10^{-9}m}$$

$$\boxed{E_2 = 6.41eV}$$

$$E_3 = \frac{hc}{\lambda_3}$$

$$E_3 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{258\times10^{-9}m}$$

$$\boxed{E_3 = 4.82eV}$$

(b) The emission spectrum will have six wavelengths – three wavelengths corresponding to the atom falling directly back to the ground state (172 nm, 194 nm, and 258 nm) and three wavelengths corresponding to intermediate energy jumps as shown below.

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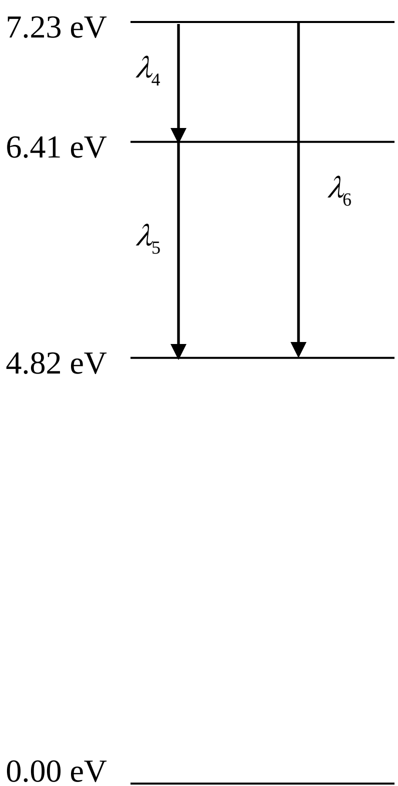

$$\lambda_4 = \frac{hc}{\Delta E}$$

$$\lambda_4 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{(7.23eV - 6.41eV)}$$

$$\boxed{\lambda_4 = 1517nm}$$

$$\lambda_5 = \frac{hc}{\Delta E}$$

$$\lambda_5 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{(6.41eV - 4.82eV)}$$

$$\boxed{\lambda_5 = 782nm}$$

$$\lambda_6 = \frac{hc}{\Delta E}$$

$$\lambda_6 = \frac{4.14\times10^{-15}eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{(7.23eV - 4.82eV)}$$

$$\boxed{\lambda_6 = 516nm}$$

17) /3

$$\Delta E = \frac{hc}{\lambda}$$

$$\Delta E = \frac{4.14\times10^{-15} eV\cdot s(3.0\times10^{8}\ m/s)}{589\times10^{-9} m}$$

$$\boxed{\Delta E = 2.1 eV}$$

18) /2

3.0 eV energy cannot be absorbed by mercury

$\therefore E_k = 3.0\, eV$

19) /2

The 7.0 eV electron can excite a mercury atom to the 2nd excitation state (6.7 eV). The atom can emit a **6.7 eV** photon if the atom falls directly to ground state. Or the atom may fall down to the 1st excitation state emitting a 6.7 eV – 4.9 eV = **1.8 eV** photon and then fall to the ground state and emit a **4.9 eV** photon.

20) /3

$$E = \frac{hc}{\lambda}$$

$$E = \frac{4.14\times10^{-15} eV\cdot s(3.0\times10^{8}\ m/s)}{684\times10^{-9} m}$$

$$\boxed{E = 1.82 eV}$$