Atomic Energy Levels

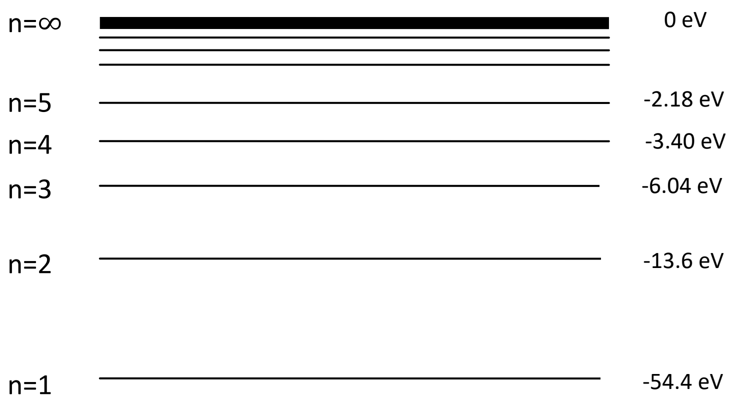
Problems Worksheet

1. A source of white light is shone through a dilute, cold sodium vapour sample. A spectrometer observes the light after it has passed through the gas.

   a. Describe what type of spectrum the spectrometer produces.

   b. Explain why this spectrum shows characteristic frequencies unique to sodium.

2. The energy level diagram of a helium atom with a single electron is shown below.

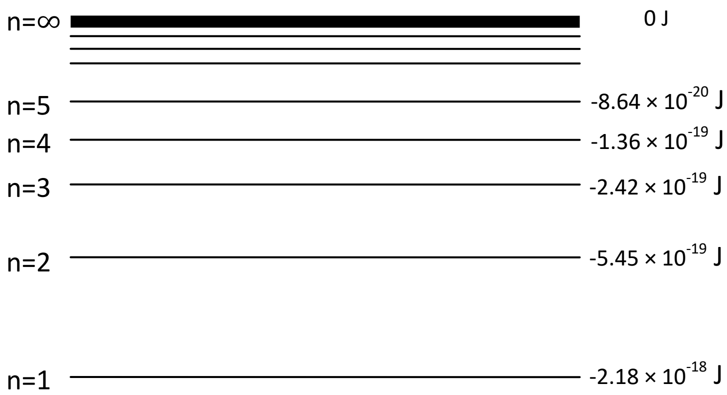


   a. How much energy is required to transition the electron from the ground state to the first excited state?

b. What is the ionisation energy of the single electron?

c. What frequency photon is emitted when an electron falls from the n=4 state to the n=3 state?

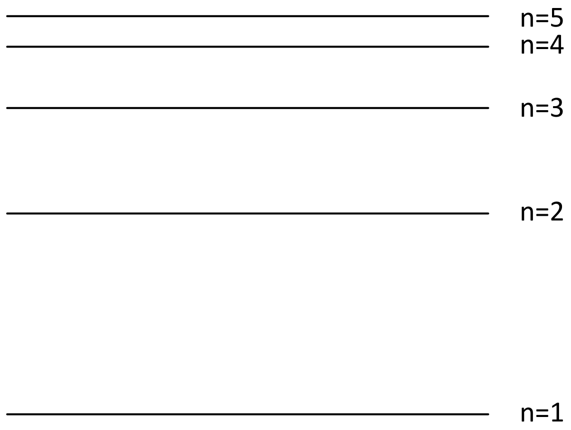
3. An excited hydrogen atom has its electron in the n=3 energy level. When the electron de-excites it emits a photon in the visible portion of the spectrum. The energy level diagram for hydrogen is given below.



a. Justify which transition during the de-excitation could have produced the visible photon.

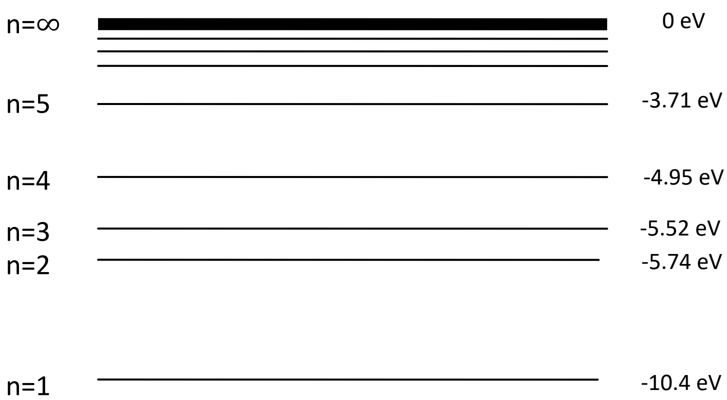
b. The hydrogen's excited state was caused by an incident electron. Calculate the minimum velocity of the incident electron required to excite the hydrogen's electron into the n=3 energy level.

4. An excited atom has an electron that is promoted to the n=4 energy level.
    a. Show on the energy level diagram below all possible energy level transitions as the electron returns to the ground state.



    b. Assuming that the spacing between the energy levels is to scale with the energy differences between the levels, indicate which transition of the electron (as it de-excites) would cause the longest wavelength photon to be emitted. Indicate which transition would cause the shortest wavelength photon to be emitted. Clearly label each of your choices on the diagram.

5. A sample of atomic mercury was exposed to a 12.5 eV electron beam. Incident electrons bombard the mercury atoms and a variety of electromagnetic radiation is detected by a spectrometer. The energy levels of atomic mercury is shown below.



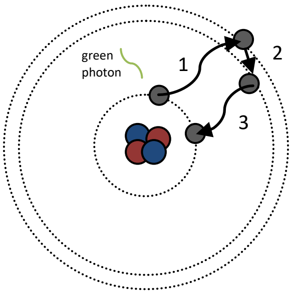
    a. Explain the origin of the electromagnetic radiation.

b. A bombarding electron causes a mercury electron to excite up to the n=2 level. Calculate the energy of the scattered electron.

c. A bombarding electron gives up all of its energy to a mercury electron in the ground state. Calculate the speed of the mercury atom's electron after the transfer of energy.

6. Molecular spectra (also called band spectra) are produced by the de-excitation of electrons in atoms bound within a molecule. Atomic spectra (also called line spectra) are produced by the de-excitation of electrons in single, isolated atoms. Explain what causes molecular spectra to have characteristic bands instead of lines. Use an energy level diagram to assist with your explanation.

7. A beam of monochromatic green light is incident upon a sample of atoms. Through spectral analysis and an understanding of Bohr's model of the atom, it is predicted that an electron in the atom makes three transitions between orbits of the atom after absorbing a photon.

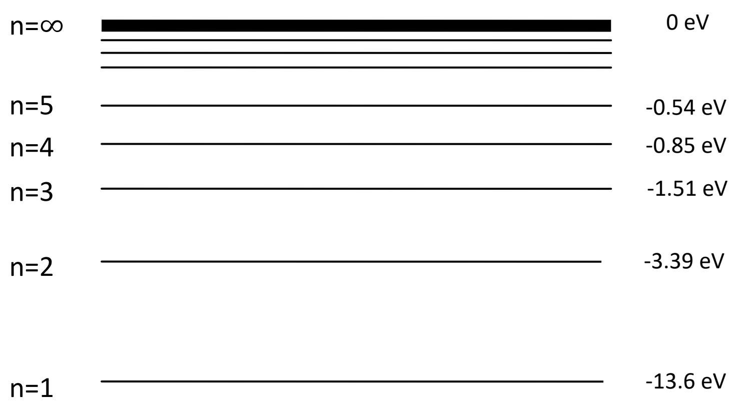


a. Which of the electron transitions (1,2 or 3) shown in the diagram is most likely to emit a photon of visible light. Justify your answer.

b. Predict the colour of the visible photon that is emitted by the transition you chose in part (a). Justify your answer.

c. The green light has a 527 nm wavelength and the energy difference between n=2 and n=3 levels is 0.520 eV. Calculate the wavelength of the emitted visible photon.

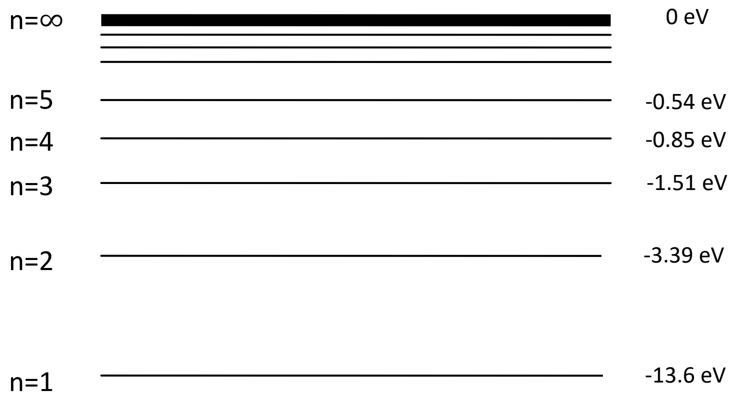
8. Hydrogen gas is bombarded with ultraviolet light with wavelengths that range between 9.60×10^{-8} m to 10.5×10^{-8} m. The energy levels of a hydrogen atom are given below.



a. Determine the wavelengths of this ultraviolet light that are capable of exciting a ground state electron in a hydrogen atom.

b. Explain why not all of the photons of this ultraviolet light are capable of exciting the hydrogen atom electron.

9. A 3610 THz photon is absorbed by the ground state electron of a hydrogen atom which ionises the atom.



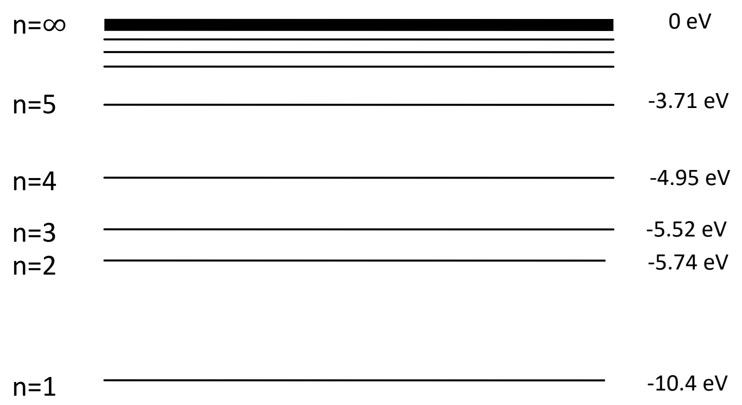
a. How much energy is required to ionise a hydrogen atom?

b. How does this amount of energy compare to the energy of the incident photon?

c. Account for why the difference in energy between the absorbed photon and the ionisation energy does not contradict the conservation of energy principle.

d. Calculate the frequency of the photon emitted when another electron is captured by the hydrogen atom and falls to the ground state.

10. A dilute mercury vapour was a vital part of the Franck-Hertz experiment in 1914 which supported the development of quantum physics. An modern alternative to this experiment was conducted by university students who shone a singular frequency electromagnetic radiation beam through a mercury cloud. The students increased the energy of the photons in this beam in discrete 2.00 eV steps (I.e.: 0.00 eV, 2.00 eV, 4.00 eV, 6.00 eV and so on). Use the mercury energy level diagram to assist with the following questions.

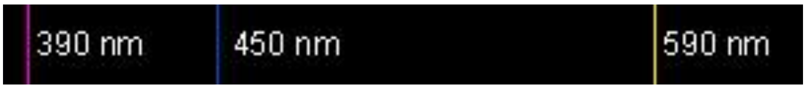


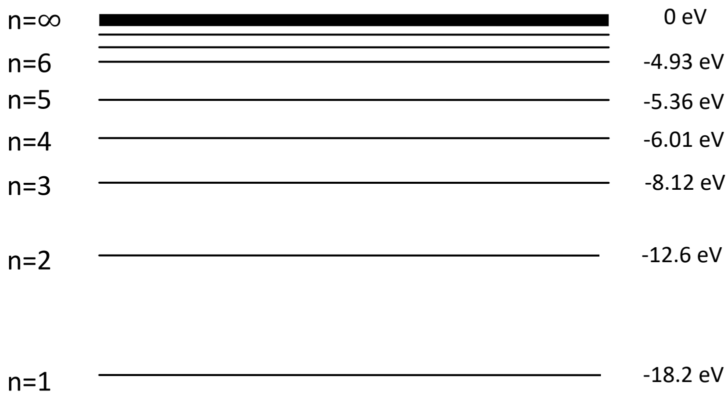
a. What minimum photon energy would the students find was able to cause electrons in the ground state of the mercury atoms to be excited? To which level would this electron jump?

b. Calculate the kinetic energy of the ground state electron, after it was excited by a photon with the minimum energy you chose for part (a).

c. The original experiment was conducted using a beam of electrons in place of the beam of electromagnetic radiation. If the electrons in the beam had the same discrete energy settings (0.00 eV, 2.00 eV, 4.00 eV etc), what minimum energy electron would be capable of exciting the mercury atoms? Justify your answer.

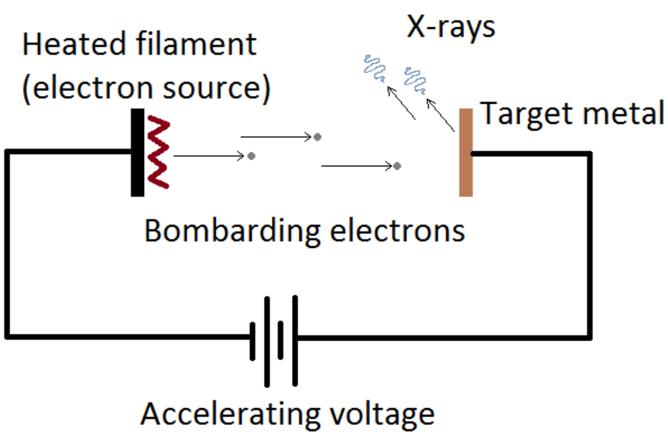
11. The line spectrum shown below is produced by an atom with the energy level profile given below the spectrum.



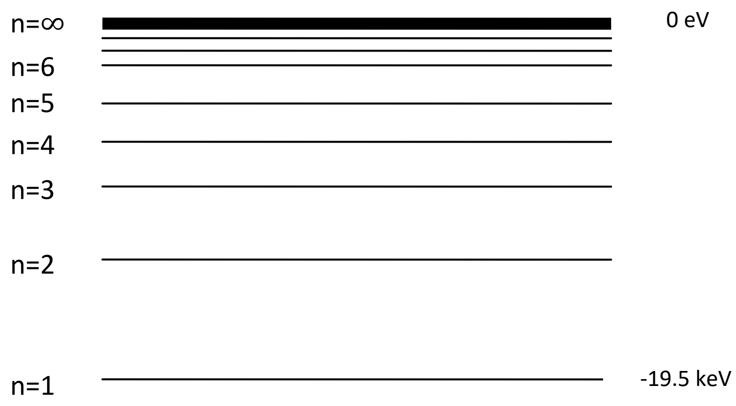


Justify that the line spectrum shown can be produced by this particular atom.

12. Characteristic X-rays are a form of electromagnetic radiation that is produced by bombarding a target metal with high energy electrons. The bombarding electrons are released from a heated filament and then accelerated by an electric field produced by an accelerating voltage applied between the filament and the target metal.



The bombarding electrons need sufficient energy to ionise an electron from the n=1 level of the atoms in the target metal. When another electron falls down to the n=1 level from a much higher level, a photon is released which is in the X-ray portion of the spectrum. The energy levels of a particular target metal used in an X-ray tube is given below.



a. What accelerating voltage is required to form characteristic X-rays of this target metal?

b. The characteristic X-ray frequency is unique to each element. Explain why changing the element of the target metal will produce a different frequency X-ray.

