<u>Quantum Physics and Atomic Models Chapter Questions</u>

1. How was it determined that cathode rays possessed a negative charge?
2. J. J. Thomson found that cathode rays were really particles, which were subsequently named electrons. What property of electrons did he measure and with what piece of laboratory equipment?
3. Who determined the charge on an electron, and what was the name of the experiment?
4. How are X-rays produced? What is the charge on an X-ray? Who made the discovery?
5. Who discovered spontaneous radiation, and how was it observed?
6. What are the three types of radiation? Summarize their properties.
7. What is the major characteristic of a Blackbody?
8. When a blackbody is heated, what does it emit?
9. What was wrong with the classical physics prediction of Blackbody radiation as the temperature of the object got hotter? What was the nickname of this problem?
10. What assumption did Max Planck make to solve the Blackbody radiation problem?
11. When light is shown on certain metals, what is emitted by the metal? What is this called?
12. What properties of the Photoelectric effect could not be explained by the wave theory of light?
13. How did Albert Einstein explain the Photoelectric effect? Who first postulated that light was made up of particles?
14. Who was the first physicist who used an experimental method to propose what elements were made up of? What properties did he attribute to the atom?
15. Describe the Thomson Plum Pudding model of the atom.
16. What experiment was performed by Ernest Rutherford? How did it change the Thomson model?
17. What comprises most of an atom?
18. What properties of atoms were not explained by the Rutherford model?
19. How did Neils Bohr resolve the problems with the Rutherford model?

20. How were the equations for the Hydrogen spectra first created?

21. What are the limitations of the Bohr model?

22. Did the Compton shift support the wave or the particle model of light? What particles were involved in the collision that generated the wavelength shift?

23. Who demonstrated the existence of the neutron? What role does the neutron play in the nucleus?

24. Which physicists described light as a particle? Which physicists described light as a wave?

25. Who was the first to propose that particles (such as electrons) could act as waves? Why do we not see large objects (like other people) as waves?

26. Can the momentum and position of an electron be measured precisely at the same time? What is the principle called?

27. The wave function was developed by Erwin Schrodinger to explain the quantum world – if the wave function is known, various quantities, such as mass and momentum can be found. What is the classical physics analogue of the wave function?

28. Is it possible to know exactly where an electron is? What does the Schrodinger wave equation predict?

29. What theory integrated the explanation of electromagnetic force and quantum physics?

30. What theory integrated the explanation of the electromagnetic force and the weak nuclear force?

31. What theory explains the strong nuclear force?

32. What model explains the integration of the electromagnetic, weak nuclear and strong nuclear forces?

33. What theories are trying to explain everything in the universe?

34. How much of the universe can physicists actually observe?

Chapter Problems

Electrons, X-rays and Radioactivity
Class Work

1. In an Oil-drop experiment, a drop of oil with mass 4.1×10^{-15} kg is held motionless between two parallel plates, 2.0 cm apart, with a Voltage difference of 500.0 V. What is the net charge on the oil drop?

2. By using a Mass Spectrometer, the charge to mass ratio for an electron is found to be approximately 1.8×10^{11} C/kg. Given that the charge on an electron is 1.6×10^{-19} C, what is the mass of the electron found in this experiment?

Homework

3. In an Oil-drop experiment, a drop of oil with mass 8.2×10^{-15} kg is held motionless between two parallel plates, 4.0 cm apart, with a Voltage difference of 500.0 V. What is the net charge on the oil drop?

4. By using a Mass Spectrometer, the charge to mass ratio for an electron is found to be approximately 1.7×10^{11} C/kg. Given that the charge on an electron is 1.6×10^{-19} C, what is the mass of the electron found in this experiment?

Blackbody Radiation and the Photoelectric Effect
Class Work

5. What is the energy of a photon with a frequency of 5.0×10^{5} Hz?

6. What is the energy of a photon with a wavelength of 6.0×10^{-3} m?

7. What is the frequency of a photon carrying energy of 3.5×10^{-18} J?

8. What is the wavelength of a photon with energy of 7.3×10^{-17} J?

9. What wavelength is the maximum contributor to an object's color at a temperature of 3800 K?

10. A photoelectric surface has a work function of 3.7×10^{-19} J. What is the minimum frequency of photons that will eject electrons from the surface?

11. A photoelectric surface has a work function of 3.7×10^{-19} J. What is the maximum wavelength of photons that will eject electrons from the surface?

12. A metal has a work function of 3.7×10^{-19} J. What is the maximum kinetic energy of photoelectrons if the incident light has a frequency of 9.4×10^{14} Hz?

13. In a photoelectric experiment the threshold frequency is 5.3×10^{14} Hz.
    a. What is the work function?

    The surface is exposed to light with a frequency of 6.6×10^{14} Hz.

    b. What is the maximum kinetic energy of photoelectrons?

Homework

14. What is the energy of a photon with a frequency of 4.0×10^{18} Hz?

15. What is the energy of a photon with a wavelength of 9.0×10^{-9} m?

16. What is the frequency of a photon carrying energy of 8.6×10^{-20} J?

17. What wavelength is the maximum contributor to an object's color at a temperature of 4200 K?

18. A photoelectric surface has a work function of 3.4×10^{-19} J. What is the minimum frequency of photons that will eject electrons from the surface?

19. A photoelectric surface has a work function of 7.5×10^{-19} J. What is the maximum wavelength of photons that will eject electrons from the surface?

20. A metal has a work function of 8.3×10^{-19} J. What is the maximum kinetic energy of photoelectrons if the incident light has a frequency of 3.4×10^{15} Hz?

21. In a photoelectric experiment the threshold frequency is 6.2×10^{14} Hz.
    a. What is the work function?

    The surface is exposed to a frequency of 7.5×10^{14} Hz.

    b. What is the maximum kinetic energy of photoelectrons?

22. What is the wavelength of a photon with energy of 5.1×10^{-16} J?

Atomic Models

Class Work

23. In the hydrogen atom an electron is excited to an energy level n = 4 then it falls down to the level n = 2.
    a. What is the wavelength of the emitted photon?
    b. What type of electromagnetic radiation is this photon associated with?
    c. What is the next possible transition?
    d. What is the wavelength associated with this transition?
24. The electron in a hydrogen atom has an energy of -13.6 eV on the ground level.
    a. Calculate the first five energy levels (n=1 to n=5).
    b. Draw the energy diagram including the ground level.
    c. The electron is on the n=4 level; draw all possible transitions.

Homework

25. In the hydrogen atom an electron is excited to an energy level n = 5 then it falls down to the level n = 3.
    a. What is the wavelength of the emitted photon?
    b. What type of electromagnetic radiation is this photon associated with?
    c. What are the next possible transitions?
    d. What are the wavelengths associated with these transitions?
26. The electron in a helium atom has an energy of -54.4 eV on the ground level.
    a. Calculate the first five energy levels (n=1 to n=5).
    b. Draw the energy diagram including ground level.
    c. The electron is on the n=3 level; draw all possible transitions.

Waves and Particles

Class Work

27. A bowling ball of mass 6.0 kg is moving with a speed of 10.0 m/s. What is the wavelength of the matter associated with the ball?
28. An electron travels at speed of 6.0×10^7 m/s. What is the de Broglie wavelength?

Homework

29. An asteroid of mass 5.4×10^3 kg is moving with a speed of 7.0 km/s. What is the wavelength of the matter associated with the asteroid?
30. A proton travels at speed of 4.8×10^7 m/s. What is the de Broglie wavelength?

Quantum Mechanics

Class Work

31. An electron's momentum is measured with an uncertainty of 3.0×10^{-32} kg m/s. How precisely can its position be determined at the same time?

32. A car is traveling down the road with a momentum of $2.8x10^4$ kg m/s (equivalent to a compact car moving at 50 mph). How precisely can its position be determined at the same time?

Homework

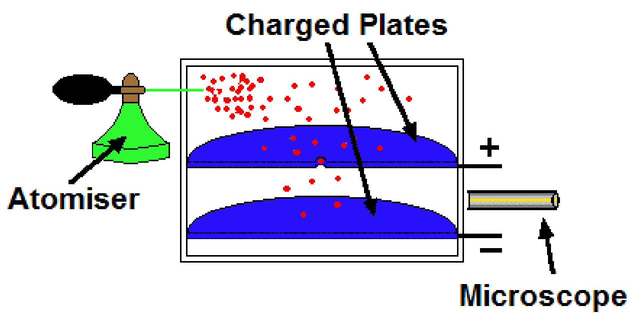
33. An electron's momentum is measured with an uncertainty of $2.5x10^{-32}$ kg m/s. How precisely can its position be determined at the same time?

34. A pickup truck is traveling down the road with a momentum of $5.1x10^4$ kg m/s (the pickup truck is moving at 50 mph). How precisely can its position be determined at the same time?

General Problems

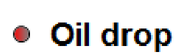
1. A mass spectrometer was used in the discovery of the electron. In the velocity selector, the electric and magnetic fields are set to only allow electrons with a specific velocity to exit the fields. The electrons then enter an area with only a magnetic field, where the electron beam is deflected in a circular shape with a radius of 8.0 mm. In the velocity selector, E = 400.0 V/m and B = 4.7×10^{-4} T. The same value of B exists in the area where the electron beam is deflected.

    a. What is the speed of the electrons as they exit the velocity selector?
    b. What is the value of e/m of the electron?
    c. What is the accelerating voltage in the tube?
    d. How does the electron radius change if the accelerating voltage is doubled?



2. In an oil-drop experiment a negatively charged oil drop has a mass of 3.0×10^{-15} kg and is held at rest between two parallel plates separated by a distance of 2.0 cm. The potential difference between the plates is 460 V.

    a. On the diagram below, show all the applied forces on the drop. Do not include the buoyant force of the air on the oil drop.



    b. What is the strength of the electric field between the plates?
    c. What is the net electric charge on the drop?
    d. How many excess electrons are on the drop?
    e. The potential difference between the plates is increased to 470 V; what happens to the oil drop?

3. A group of physics students perform a Photoelectric effect experiment. They use a light source with varying frequency. In the experiment they found the photocell is sensitive to light with a frequency greater than 6.0×10^{14} Hz.

    a. What is the threshold frequency for this photocell?
    b. What is the work function of the metal?

    The frequency of the incident light is changed to 7.5×10^{14} Hz.

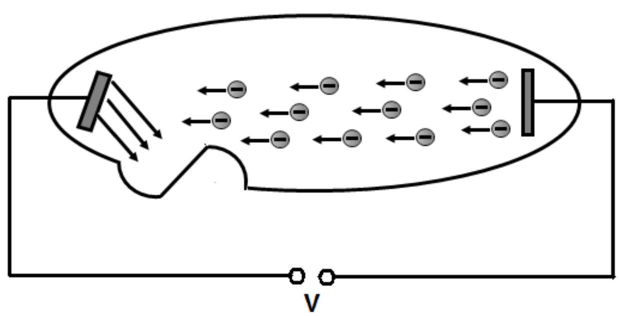
    c. What is the maximum kinetic energy of the photoelectrons emitted by the cell?

4. An experiment is conducted to investigate the photoelectric effect with a Barium plate. When the wavelength of the incident light is less than 500.0 nm the plate starts emitting electrons.

    a. What is the threshold frequency of the Barium plate?
    b. What is the work function of Barium?

    The wavelength of the incident light is changed to 300.0 nm.

    c. What is the kinetic energy of the photoelectrons?



5. In an X-ray tube, above, an accelerating voltage of 7.0×10^4 V is applied to accelerate electrons to high energies. ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg).
    a. What is the maximum kinetic energy of the accelerated electrons?
    b. What is the maximum speed of the accelerated electrons?
    c. What is the maximum energy of the emitted X-ray photons?
    d. What is the frequency of the emitted X-ray photons?
    e. What is the wavelength of the emitted X-ray photons?

6. The atomic energy levels can be determined by the following formula $E_n = Z^2E_1/n^2$ where Z = atomic number; E1 = -13.6eV (ground state of the hydrogen atom, n=1).

    a. What are the energy levels, for n=1, 2, 3 and 4 of the hydrogen atom?
    b. What is the frequency of the emitted photon if an electron makes a transition from the n = 3 level to the n = 2 level?
    c. What is the wavelength of the photon for the same transition?
    d. Would the emitted photon be visible?

7. The atomic energy levels can be determined by the following formula $E_n = Z^2E_1/n^2$ where Z = atomic number; E1 = -13.6eV (ground state of the hydrogen atom, n=1).

    a. What are the energy levels, for n=1, 2, 3 and 4 of the singly ionized (only one electron present) helium atom (Z=2)?
    b. What is the frequency of the emitted photon if an electron makes a transition from the n = 4 level to the n = 2 level?
    c. What is the wavelength of the photon for the same transition?
    d. Would the emitted photon be visible?

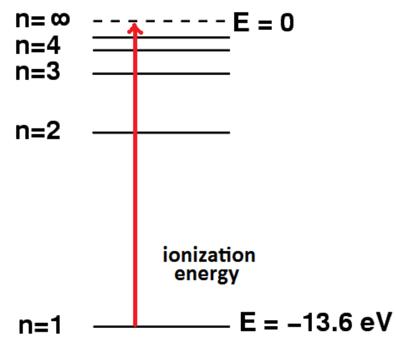
Chapter Questions

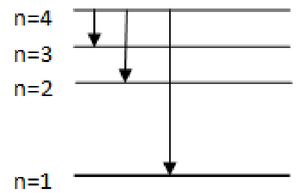
1. They were deflected by a magnetic field in the direction that a moving negative charge would move.
2. Charge/Mass ratio. Mass Spectrometer.
3. Robert Millikan and Harvey Fletcher. Oil-drop experiment.
4. Electrons striking a metal target. Neutral. Roentgen.
5. H. Becquerel, M. Curie, P. Curie. Uranium salts exposed photographic paper.
6. Alpha particles (Helium nucleus, +2e), Gamma Rays (EM radiation, neutral), Beta Particles (electrons from the nucleus, -e).
7. They absorb all incident radiation – so the radiated energy is just from the body's temperature.
8. Electromagnetic radiation in the form of a temperature dependent spectrum.
9. As the object got hotter, the intensity of the emitted radiation approached infinity according to classical physics calculations. Ultraviolet Explosion.
10. Energy emitted by the blackbody radiators could only be emitted in discrete packets of energy- quanta.
11. Electrons. The Photoelectric effect.
12. No electrons emitted below a certain cutoff frequency of the light. Number of electrons proportional to light intensity, but electron energy was independent of intensity. Electrons appeared instantly when illuminated with the proper light frequency.
13. A single photon struck and transferred all its energy to the electron which was then emitted if the light had sufficient energy (frequency). Sir Isaac Newton.
14. John Dalton. All elements were made up of specific indivisible atoms.
15. Electrons were spread out within a mass of positive charge.
16. Gold Foil Experiment. A small percentage of Alpha particles that struck the gold foil were deflected – showing the existence of a small, positively charged nucleus.
17. Empty space. A void.
18. Why the electrons didn't spiral into the nucleus and optical spectra.
19. Electrons were only allowed in specific orbits, and did not emit EM radiation in those orbits. Spectra resulted from electrons moving between the quantized orbits.
20. By creating equations to fit the measured spectra – no theory, just fitting the equations to the data.
21. Only applicable to Hydrogen like atoms (single electron), based on accelerating electrons not emitting EM radiation and did not predict intensities of emitted photons during electron energy level transitions.
22. Particle. X-ray photons struck electrons, giving up energy, and increasing the wavelengths of the X-rays.
23. James Chadwick. It provides the additional strong nuclear force to balance the electromagnetic repulsive force between the protons.
24. Newton, Planck, Einstein and Compton. Young, Maxwell.
25. de Broglie. Because the wavelengths of large objects are vanishingly small.
26. No. Heisenberg Uncertainty Principle.

27. The net force on an object.
28. No. Only the probability of an electron at a certain position can be determined.
29. Quantum Electrodynamics.
30. Electroweak Theory.
31. Quantum Chromodynamics.
32. The Standard Model.
33. Grand Unified Theory; String Theory.
34. 5%.

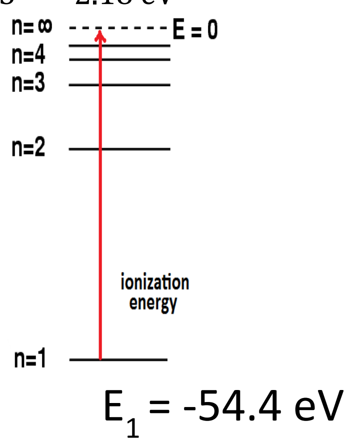
Chapter Problems

1. 1.6×10^{-18} C
2. 8.9×10^{-31} kg
3. 6.4×10^{-18} C
4. 9.4×10^{-31} kg
5. 3.3×10^{-28} J
6. 3.3×10^{-23} J
7. 5.3×10^{15} Hz
8. 2.7×10^{-9} m
9. 760 nm
10. 5.6×10^{14} Hz
11. 540 nm
12. 2.5×10^{-19} J
13. 3.5×10^{-19} J, 8.8×10^{-20} J
14. 2.7×10^{-15} J
15. 2.2×10^{-15} J
16. 1.3×10^{14} Hz
17. 690 nm
18. 5.1×10^{14} Hz
19. 270 nm
20. 1.4×10^{-18} J
21. 4.1×10^{-19} J, 8.8×10^{-20} J
22. 3.9×10^{-10} m
23. a) 488 nm
    b) Visible light-green
    c) 2→1
    d) 122 nm
24. a) 1^{st} -13.6 eV
    2^{nd} -3.4 eV
    3^{rd} -1.51 eV
    4^{th} -0.85 eV
    5^{th} -0.54 eV

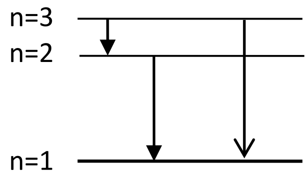
b) 

c) 

25. a) 1.29×10^{-6} m
    b) Infrared radiation
    c) 3→2, 3→1, 2→1
    d) 3→2: 661 nm
    3→1: 103 nm
    2→1: 122 nm
26. a) 1^{st} -54.4 eV
    2^{nd} -13.6 eV
    3^{rd} -6.04 eV
    4^{th} -3.40 eV
    5^{th} -2.18 eV



b)



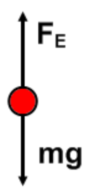
c)

27. 1.1×10^{-35} m
28. 1.2×10^{-11} m
29. 1.8×10^{-41} m
30. 8.3×10^{-15} m
31. 2.2×10^{-2} m
32. 5.5×10^{-34} m
33. 2.7×10^{-2} m
34. 2.6×10^{-34} m

General Problems

1. a) $8.5 \times 10^{5} \mathrm{m/s}$
   b) $2.3 \times 10^{11} \mathrm{C/kg}$
   c) 1.6 V
   d) doubles

2. a)



   b) 2.3×10^4 V/m
   c) $1.3 \times 10^{-18} C$
   d) 8 electrons
   e) It will accelerate upwards.

3. a) $6.0 \times 10^{14} \mathrm{Hz}$
   b) $4.0 \times 10^{-19} \mathrm{J}$
   c) $9.7 \times 10^{-20} \mathrm{J}$

4. a) $6 \times 10^{14} \mathrm{Hz}$
   b) $4.0 \times 10^{-19} \mathrm{J}$
   c) $2.6 \times 10^{-19} \mathrm{J}$

5. a) $1.1 \times 10^{-14} \mathrm{J}$
   b) $1.6 \times 10^{8} \mathrm{m/s}$
   c) $1.1 \times 10^{-14} \mathrm{J}$
   d) $1.7 \times 10^{19} \mathrm{Hz}$
   e) $1.8 \times 10^{-11} \mathrm{m}$

6. a) −13.6eV, −3.40eV, −1.51eV, −0.85eV
   b) $4.56 \times 10^{14} \mathrm{Hz}$
   c) 658nm
   d) Yes – red light

7. a) −54.4eV, −13.6eV, −6.04eV, −3.40eV
   b) $2.46 \times 10^{15} \mathrm{Hz}$
   c) $1.22 \times 10^{-7} \mathrm{m}$
   d) No – Ultraviolet