Chapter 14 Review Questions

1. A particular quantum system has allowed quantum states with energies $E = n^2 \times (1 \text{ eV})$. Which of the following energy photons will never be absorbed by the system?

   1 eV
   3 eV
   5 eV
   24 eV

2. A particular quantum system has the energy levels shown below. How many different frequency photons could this system emit?

   n=4
   n=3
   n=2
   n=1

   2
3. The energy levels of a hydrogen atom are given by $E=-13.6/n^2$ eV. Calculate the wavelength of the photon emitted as a result of the $n=2$ to $n=1$ transition.

120 nm
90 nm
365 nm
200 nm

4. When a high voltage is applied to a low-pressure gas causing it to glow, it will emit which type of spectrum?

line absorption
line emission
continuous
monochromatic
5. Which of the following transitions produce the longest wavelength photon?

A

B

C

n=3

n=2

D

n=1

6. For a quantum particle in a box, the lowest energy quantum state has 1/2 of the particle deBroglie wave fitting in the box. The next highest state corresponds to

1/4 deBroglie wavelength

1/2 deBroglie wavelength

1 deBroglie wavelength

2 deBroglie wavelengths
7. In the Bohr model of the atom, when the orbital radius increases, the wavelength of the orbiting electron increases.

decreases.

stays the same.

is not completely determined by the radius.

8. The Heisenberg uncertainty principle says that

The momentum of a particle is always uncertain.

The position of a particle is always uncertain.

A more precise measurement of the position means the momentum is less precisely known.

A measurement cannot be made.
9. For a particle in a box, there are some quantum states in which there is zero probability for finding the particle at particular spatial locations. This is because

   The particle is moving too quickly

   The probability can never be greater than one

   The ground state has the lowest energy

   The particle interferes destructively with itself

10. A particle in a box is in its ground state. The momentum of the particle is

   known exactly

   uncertain

   negative

   positive
11. A quantum particle in a box is in its ground states. As the width of the box is decreased, the energy of the particle

is unchanged

becomes larger

becomes smaller

is too uncertain to measure

Answers
1. The only photons that can be absorbed are the ones that will move an electron from one quantum state to another. So the photon energy must equal an energy difference between two states. For the system, the quantum states have energies 1 eV, 4 eV, 9 eV, 16 eV, 25 eV...
3 eV = 4 eV - 1 eV
5 eV = 16 eV - 9 eV
24 eV = 25 eV - 1 eV
Only 1 eV does not work.
2. **Photons are emitted when the system makes a transition to a state with lower energy. The possible transitions are:**

3. The energy of the photon is \(-13.6/4\)-\((-13.6/1)\)=10.2 eV. The wavelength is given by \(E=hf=hc/wavelength\), so wavelength=\(hc/E\)
\[=1240 \text{ eV-nm}/10.2 \text{ eV}\]
\[=122 \text{ nm}.

4. A discrete number of photons can be emitted, corresponding to energy differences between the quantum states. This makes the spectrum be a series of lines.

5. The smallest energy difference corresponds to the lowest energy photon. The lower the energy, the longer the wavelength.

6. The standing wave condition is that an integer number of half wavelengths must fit inside the box. The sequence is then 1/2 wavelength, 1 wavelength, 3/2 wavelengths, etc.
In the Bohr model, the quantization appears as an integer number of wavelengths around the circumference. But the classical orbital conditions also apply: the acceleration due to the coulomb force is weaker, and the corresponding orbital velocity is smaller. Smaller kinetic energy -> longer wavelength.

The position or momentum can be known exactly, but they cannot be known exactly at the same time. The Heisenberg uncertainty principle relates the uncertainty in the position to the uncertainty in the momentum.

Quantum mechanics applies to all objects. Macroscopic objects appear to behave classically because the differences between quantized states (for instance the energy difference) are much smaller than the properties of the states (for instance their energy).

Classically, the particle is bouncing back and forth. It has positive velocity (momentum) for part of the time and negative velocity (momentum) for part of the time. Quantum mechanically, the particle is in a superposition of two quantum states, one with positive momentum and one with negative momentum. It's momentum then does not have a definite value. It is uncertain.
Since the potential energy is zero, the energy is all kinetic energy, and directly related to the wavelength through the momentum. $E = \frac{p^2}{2m}$, $p = \frac{h}{\text{wavelength \ (deBroglie)}}$. The wavelength is set by the size of the box. As the box is shrunk, the wavelength becomes shorter, and the energy goes up.