Quantum Mechanics Questions

1.
    a. The first step in the formation of ozone in the upper atmosphere occurs when oxygen molecules absorb UV radiation of wavelengths ≤ 242 nm. Calculate the frequency and energy of the least energetic of these photons.
    b. Ozone absorbs light having wavelengths of 2200 to 2900 Å, thus protechting organisms on the Earth's surface from this high-energy UV radiation. What are the frequency and energy of the most energetic of these photons?
2.
    a. What is the frequency of light having a wavelength of 456nm?
    b. What is the wavelength (in nanometers) of readiation having a frequency of 2.45×10^9 Hz
3. What is the wavelentgh, in nm, of radiation that has an energy content of 1.0×10^3 kJ/mol? In which region of the electromagnetic spectrum is this radiation found?
4. A ruby laser produces radiation of wavelength 633 nm in pulses whose duration is 1.00×10^{-9} s.
    a. If the laser prodcues 0.376 J of energy per pulse, how many photos are produced in each pulse?
    b. Calculate the power (in watts) delivered by the laser per pulse.
5. Only a fraction of the electrical energy supplied to a tungsten lightbulb is converted to visible light. The rest of the energy shows up as infrared radiation, (that is, heat). A 75 W bulb converts 15 % of the energy supplied to it into visible light (Assume the wavelength to be 550nm). How many photons are emitted by the lightbulb per second?
6. A photoelectric experiment was performed by separately shining a laser at 450 nm (blue light) and a laser at 560 nm (yellow light) on a clean metal surface and measuring the number and kinetic energy of the ejected electrons. Which light would generate more electrons? Which light would eject electrons with greater kinetic energy? Assume that the same amount o fenergy is delivered to the metal surface by each laser and that the frequencies of the laser lights exceed the threshold frequency.
7. Which of these electron transitions correspond to absorption of energy and which to emission?
    a. n = 2 to n = 4
    b. n = 3 to n = 1
    c. n = 5 to n = 2
    d. n = 3 to n = 4
8. The H atom and the Be^{3+} ion each have one electron. Does the Bohr model predict their spectra accurately? Would you expect their line spectra to be identical? Explain.
9. Use the Rydberg equation to calculate the wavelength (in nm) of the photon emitted when a hydrogen atom undergoes a transition from n = 5 to n = 2?
10. What is the wavelength (in nm) of the least energetic spectral line in the infrared series of the H atom?

11. Calculate the energy difference for the transition in problem 4 for 1 mol of H atoms.
12. Arrange the following H atom electron transitions in order of *increasing* frequency of the photon absorbed or emitted:
    a. n = 2 to n = 4
    b. n = 2 to n = 1
    c. n = 2 to n = 5
    d. n = 4 to n = 3
13. The oxidising agents used in most fireworks consist of potassium salts, such as $KClO_4$ or $KClO_3$, rather than the corresponding sodium salts. One of the problems with using sodium salts is their extremely intenst yellow-orange emission at 589 nm, which obscures other colours in the display. What is the energy (in J) of one photon of this lighit? What is the energy (in kJ) of 1 'mol' of photons of this light?
14. If particles have wavelike motion, why don't we observe that motion in the macroscopic world?
15. How fast must a 56.6g tennis ball travel in order to have a de Broglie wavelength that is equal to that of a photon of green light (5400 Å)?
16. How many orbitals in an atom can have each of the following designations:
    a. 1s
    b. 4d
    c. 3p
    d. n=3
17. For each of the following, give the sublevel designation for allowable m_l values, and the number of orbitals:
    a. n = 4, l = 2
    b. n = 5, l = 1
    c. n = 6, l = 3
18. Are the following quantum number combinations are allowed? If not, show two ways to correct them:
    a. n = 2, l = 0, m_l = -1
    b. n = 4, l = 3, m_l = -1
    c. n = 3, l = 1 , m_l = 0
    d. n = 5, l = 2, m_l = 3
19. The quantum-mechanical treatment of the hydrogen atom gives the energy, E, of the electron as a function of the principal quantum number, *n*:

$$E = \frac{h^2}{8\pi^2 m_e a_0^2 n^2}$$

Where h is Planck's constant, m_e is the electron mass, and $a_0 = 52.92 \times 10^{-12}$m

    a. Write the expression in the form E = -(constant)$\frac{1}{n^2}$, evaluate the constant (in J), and compare it with the corresponding exxpression from Bohr's theory.
    b. Use the expression to find the energy change between n = 2 and n = 3.
    c. Calculate the wavelength of the photon that corresponds to this energy change.
20. Five lines in the H atom spectrum have the following wavelengths (in Å):
    a. 1212.7

b. 4340.5
c. 4861.3
d. 6562.8
e. 10938

Three lines result from transitions to $n_{final}=2$ (visible series). The other two results from transitions in different series, one with $n_{final} = 1$ and the other with $n_{final} = 3$. Identify n_{final} for each line.

21. The following quantum number combinations are not allowed. Assuming the n and m_l values are correct, change the l value to create an allowable combination:
    a. $n = 3, l = 0, m_l = -1$
    b. $n = 3, l = 3, m_l = 1$
    c. $n = 7, l = 2, m_l = 3$
    d. $n = 4, l = 1, m_l = -2$
22. Which of the quantum numbers relate(s) to the electron only? Which relate(s) only to the orbital?
23. Define *shielding* and *effective nuclear charge*. What is the connection between the two?
24. How many electrons in an atom can have each of the following quantum number or sublevel designations?
    a. 4p
    b. $n = 3, l = 1, m_l = 1$
    c. $n = 5, l = 3.$
25. Write a full set of quantum numbers for the following:
    a. The outermost electron in an Rb atom
    b. The electron gained when an S^- ion becomes an S^{2-} ion
    c. The electron lost when an Ag atom ionises
    d. The electron gained when an F^- ion forms from an F atom
26. Draw the partial (valence-level) orbital diagram, and write the symbol, group number, and period number of the element:
    a. $[He]2s^22p^4$
    b. $[Ne]3s^23p^3$
27. Explain the relationship between the trends in atomic size and in ionisation energy within the main groups.