1 Cognitive reasoning in the chemical sciences 3.7

1. **Set 1** Please answer the questions.

   (a) For an electron in a box. If n doubles and L halves, what happens to v, the velocity?

   (b) For an ideal gas. If V is constant, p doubles n stays constant and one doubles mass, what happens to v_{rms}?

   (c) For the Bohr model using shielded electrons if one compares an electron for an atom where Z_{eff} halves and n doubles, what happens to E_{tot}?

   (d) For the van der Waals equation, if $a > 0$ and $b = 0$, what happens to pV/nRT?

   (e) For the van der Waals equation, if $a = 0$ and $b > 0$, what happens to pV/nRT?

   (f) For a molecule. If E_{pot} becomes more negative, what happens to E_K?

   (g) For an atom. If one doubles E_{tot}, what happens to E_K?

   (h) For effusion. If one doubles n, halves V, keeps m constant and doubles T, what happens to the rate of effusion?

   (i) Which is lower in energy, an electron in the $n = 4$ state for the hydrogen atom or the $n = 2$ state for a electron in a box? How do you know this answer?

2. **Set 2:** In this set you need to state the equations and the pictures you would use to solve the problem. After stating these tools, please then state a procedure which allows the carrying out of the posed problem.

   (a) Given: the volume, the pressure, the temperature, and the number of grams of a flask of ideal gas. Find the molar mass.

   (b) Given: the volume, v_{rms}, number of moles, and pressure of a flask of ideal gas. Find: the molar mass of the gas.

   (c) Light is absorbed by a molecule and an electron is released. Given: the wavelength of the incoming light and the energy of the electron before the light is received. Find: the velocity of the released electron.

   (d) Given for a particle in a box: the mass of the particle, the length of the box, and the value of n. Find the momentum of the particle.

   (e) Light is absorbed by a molecule and an electron is released. Given: the wavelength of the incoming light and the average potential energy of the electron before the light is received. Find: the velocity of the released electron.

   (f) Given: the volume and pressure of a flask of diatomic ideal gas. Find: the kinetic energy.

   (g) Light is absorbed by a molecule and an electron is released. Given: the wavelength of the incoming light and the average potential energy of the electron before the light is received. Find: the wavelength of the released electron.

   (h) Given: the mass of the particle, the length of the box, and the value of n. Find the kinetic energy of the particle.

   (i) For an atom. Given: the average velocity of an electron. Find: the average potential energy of this electron.

   (j) Given: The wavelength of light of an incoming photon hitting an electron in a molecule (the electron is not ejected from the molecule). Also given: the percent change in wavelength which accepting this light causes to the electron. Find: the initial energy of the electron.

(k) The muon has a charge of minus one. Its mass is 200 times bigger than an electron's. A proton and a muon form an object much like a hydrogen atom. State procedure to find the ratio of the $n = 3$ to $n = 1$ transition energy for the muon-proton system and that for the hydrogen atom.

(l) Given the number of radial nodes and the number of angular nodes, how would you determine if the state is $1s$, $3p$ etc...?

(m) Given the radial distribution function for an electron , give a procedure which will allow you to estimate the value of λ.

(n) Given the radial distribution function for an electron , give a totally different procedure which will allow you to estimate the value of λ.

3. **Set 3:** State answers to the following questions:

(a) The volume of a gas increases by 1%, the number of moles increases by 2%, the pressure increases by 3% and the temperature remains unchanged. Is this gas an ideal gas?

(b) Incoming light is accepted by a hydrogen-like atom and an electron is released. The velocity of the exiting electron is recorded. Now a new frequency light is absorbed by a hydrogen-like atom which was in the same initial state as the first. This exiting electron velocity doubles. Can we calculate the difference between the frequencies of the first and second electrons.? If yes, how do we do so?

(c) Given: Two van der Waals gases. They have the same b value but different a values. At a given p and T, does one mole of the one with a bigger a value occupy more or less volume than a mole of the other gas?

(d) A particle in a box. The length doubles, what happens to the energy of the $n = 2$ state?

(e) Gas effuses from a flask into a vacuum. Given: The initial rate of gas effusion. The molar density of gas molecules increases by x%, find the decrease in temperature required so that no change in effusion rate occurs.

(f) The wavelength of an electron in an atom increases. Does the total energy increase or decrease. Please state reason.

(g) Given: Two van der Waals gases. They have different a values and b values from each other. In the limit of very high pressure and assuming constant temperature, how many of these four constants control which of these gases has gfreater molar density? Please state reason.

(h) An electron in a hydrogen-like atom transists from the $n = 3$ to $n = 2$ state. What is the percent change in potential energy?

(i) The volume of a gas increases by 1%, the number of moles increases by 2%, the pressure increases by 3% and the temperature remains unchanged. Can you deduce $a > 0$, $b > 0$ or that both a and b are > 0? State your reasoning.

(j) Can the energy of an electron in an electron in a box ever equal zero?

(k) Can the energy of an electron in a particle in a box ever be lower than the energy of an electron in an atom?

(l) What is the potential energy for a particle in the box?

(m) For a particle in the box, what is E_{pot}/E_K?

(n) For an electron in an atom, what is E_{pot}/E_K?

(o) On a drum, which "orbital" is higher in energy, the one with two radial nodes and two angular nodes, or the one with two radial nodes and one angular node?