1. The Bohr radius of the hydrogen atom is 0.529 Å, or 0.0529 nm. Assuming that we know the position of an electron in this orbit to an accuracy of 1% of the radius, calculate the uncertainty in the velocity of the electron. Be sure to include units in all calculations. (Note: Use the equation \( \Delta x \Delta p = h \), where \( h \) is equal to Planck’s constant, approximately \( 6.626 \times 10^{-34} \) J s. The mass of an electron is approximately \( 9.11 \times 10^{-31} \) kg.)

**Answer:** \( \Delta x = 0.01 \times 0.0529 \text{ nm} = 5.29 \times 10^{-4} \text{ nm} = 5.29 \times 10^{-13} \text{ m} \).
\[ \Delta p = \frac{h}{\Delta x} = \frac{6.626 \times 10^{-34} \text{ J s}}{5.29 \times 10^{-13} \text{ m}} = 1.25 \times 10^{-21} \text{ kg m/s} \]
Thus, \( \Delta v = 1.25 \times 10^{-21} \text{ kg m s}^{-1}/9.11 \times 10^{-31} \text{ kg} = 1.37 \times 10^9 \text{ m/s} \)

2. \( \text{C}_2\text{H}_6(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \)
If I have 50.0g of ethane and 75.0g of oxygen, which reactant is limiting? Which reactant is in excess? How much is it in excess? How much carbon dioxide is produced?

   a) Balance the equation
   b) Limiting Reactant?
   c) Reactant in Excess?
   d) How much in Excess? (in grams)
   e) How much Carbon Dioxide is produced? (in grams)

Answers
   a) \( 2\text{C}_2\text{H}_6(\text{s}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \)

\[
\begin{align*}
50.0 \text{ g C}_2\text{H}_6 \times & \frac{1 \text{ mol C}_2\text{H}_6}{30.0 \text{ g C}_2\text{H}_6} \times \frac{4 \text{ mol CO}_2}{2 \text{ mol C}_2\text{H}_6} \times \frac{44.0 \text{ g CO}_2}{1 \text{ mol CO}_2} = 147 \text{ g CO}_2 \\
75.0 \text{ g O}_2 \times & \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \times \frac{4 \text{ mol CO}_2}{7 \text{ mol O}_2} \times \frac{44.0 \text{ g CO}_2}{1 \text{ mol CO}_2} = 58.9 \text{ g CO}_2
\end{align*}
\]

   b) \( \text{O}_2 \)
   c) \( \text{C}_2\text{H}_6 \)

\[
\begin{align*}
75.0 \text{ g O}_2 \times & \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \times \frac{2 \text{ mol C}_2\text{H}_6}{7 \text{ mol O}_2} \times \frac{30.0 \text{ g C}_2\text{H}_6}{1 \text{ mol C}_2\text{H}_6} = 20.1 \text{ g C}_2\text{H}_6 \\
50.0 \text{ g C}_2\text{H}_6 - & 20.1 \text{ g C}_2\text{H}_6 = 29.9 \text{ g C}_2\text{H}_6
\end{align*}
\]
   d) \( 29.9 \text{ g C}_2\text{H}_6 \) in excess
   e) \( 58.9 \text{ g CO}_2 \) produced
3. Draw to quantum particles on an x-p plot. Show what is ‘allowed’ and what is ‘not-allowed’ for two quantum particles in a space.
1. 1) Hydrogen cyanide is produced industrially from the reaction of gaseous ammonia, oxygen, and methane, shown below:

\[ \text{\underline{\underline{\text{Answer: } _2\text{NH}_3(g) + _3\text{O}_2(g) + _2\text{CH}_4(g) \rightarrow _2\text{HCN} (g) + _6\text{H}_2\text{O} (g)}}} \]

After converting grams to moles for each of the reactants, students should determine that oxygen is the limiting reagent.

\[ 7.00 \times 10^3 \text{ kg of NH}_3, \text{ O}_2, \text{ and CH}_4 \text{ are reacted, what mass of HCN and } \text{H}_2\text{O will be produced, assuming 100% yield?} \]

2) Imagine Professor Gruebele’s one-dimensional “pinball machine” from the first day of class. The ball starts at position \( x=0 \) when he pulls the pin. When he lets go of the pin, the ball travels towards the other side of the box at a constant velocity until it hits the wall at \( x=L \). When it hits the wall, it changes direction, but on the way back its velocity decreases at a constant rate, until the ball comes to rest at \( x=0 \). Illustrate this scenario on an X-P Plot.

Answer:

3) \( \alpha \)-Synuclein is a monomeric protein, which has a molecular weight of about 16 kDa. \( \alpha \)-Synuclein aggregates into fibers and is the main component of plaque in Alzheimer’s patients. The resolution of the protein can be measured to 1 Å. What is the \( \Delta v \) of 1 \( \alpha \)-Synuclein? (Hint a protein that has a MW of 1 kDa= 1000g/mol 1Å=0.1 nm)

Answer:
\[ \Delta x = 0.1 \times 10^{-9} \, m \]

\[ m = \frac{16000 \, g}{1 \, \text{mol}} \times \frac{1 \, \text{mol}}{6.022 \times 10^{23}} = 2.7 \times 10^{20} \, g = 2.7 \times 10^{-21} \, kg \]

\[ \Delta x \Delta \nu = h = 6.62 \times 10^{-34} \]

\[ \frac{h}{m \Delta x} = \Delta \nu = 0.245 \, \text{m/s} \]
1) 1) Today, you are a fugitive electron. You are being chased by 2 police electrons (who apparently weight exactly as much as you do) with 2 different velocities: Chuck \((5 \times 10^{-3} \text{ m/s})\) and Tim \((3.3 \times 10^5 \text{ m/s})\). You are all racing down the position coordinate on a Cartesian graph, and they travel as a group to catch you. While their group is centered on the origin, at least how many meters away in the positive x direction do you have to be away from them not to be captured? Use the following equation:

\[
\Delta x \cdot \Delta p \geq \frac{\hbar}{2}
\]

\[
\Delta x \cdot 2m_e \cdot \Delta v = \frac{\hbar}{2}
\]

\[
\Delta x = \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s}}{8\pi(9.11 \times 10^{-31} \text{ kg}) \cdot (3.3 \times 10^5 \text{ m/s} - 5.0 \times 10^{-3} \text{ m/s})}
\]

\[
\Delta x = 8.77 \times 10^{-11} \text{ m}
\]

\[
\Delta x/2 = 4.38 \times 10^{-11} \text{ m}
\]

The key to solving this problem is to recognize that since they travel as a group, they are being treated as a single particle. The fact that there are only two particles reflects the fact that this does not break the Pauli Principle, even if they are centered around the origin together. TA note: this is different than the other problem in which I tried to treat the five electrons as 1 (which breaks the Pauli Principle). With this correction, this affects their mass and also accounts for the spread in their velocities. Since they are centered on the origin, the spread in their position will be halved to determine the distance away you must be.
2) Draw and label the following particles on an x-p plot.
   a. A classical particle
   b. A quantum particle at rest
   c. A quantum particle not at rest.
   Make sure that particles “b” and “c” obey the Pauli principle.

   SOLUTION: 1 pt. per correctly labeled particle. Particle “a” should be a dot, particle “b” should be a circle about the origin, and particle “c” should be another closed shape that doesn’t touch particle “b”. 1 additional point for making sure that the two quantum particles follow the PP.

3) Two compounds, A and B, react by the following chemical equation: 4A + B \rightarrow 2C. Equal masses of A and B are added to a reaction flask, and the reaction is started. If A has a greater molar mass than B, then which is the limiting reagent? Why

   SOLUTION: 1 pt. for saying that A is limiting. 2 pts for the explanation, which must include “we have fewer moles of A being used up faster” or similar.