2. The heat of formation of ammonium chloride is -314 kJ/mol. Which equation below best represents this process?

X_ A. \( \frac{1}{2} \text{N}_2(g) + 2 \text{H}_2(g) + \frac{1}{2} \text{Cl}_2(l) \rightarrow \text{NH}_4\text{Cl}(s) \)

_ B. \( \text{N}_2(g) + 4 \text{H}_2(g) + \text{Cl}_2(l) \rightarrow 2 \text{NH}_4\text{Cl}(s) \)

_ C. \( \text{N}_2(g) + 4 \text{H}(g) + \text{Cl}(g) \rightarrow \text{NH}_4\text{Cl}(s) \)

_ D. \( \text{NH}_4\text{Cl}(s) \rightarrow \frac{1}{2} \text{N}_2(g) + 2 \text{H}_2(g) + \frac{1}{2} \text{Cl}_2(l) \)

_ E. \( 2 \text{NH}_4\text{Cl}(s) \rightarrow \text{N}_2(g) + 4 \text{H}_2(g) + \text{Cl}_2(l) \)

11. The addition of 4.35 kJ of heat to a 16.0 g sample of solid methanol (CH₄O) at -97.5 °C completely melts the sample and raises its temperature to -28.0 °C. The enthalpy of fusion of methanol is 3.215 kJ/mol (as shown in equation form below). What is the specific heat capacity of liquid methanol? *The freezing point of methanol is -97.5 °C, and you can assume that there is no volume change throughout the process. The molar mass of methanol = 32.042 g/mol*

\[
\text{CH}_4\text{O}(s) \rightarrow \text{CH}_4\text{O}(l) \quad \Delta H_{\text{fus}} = 3.215 \text{ kJ/mol (at } -97.5 \text{ °C)}
\]

\[
\text{heat added} = \text{heat required} = 0
\]

\[
-4350 \text{ J} + \left( \frac{16}{32} \right) (3215 \text{ J/mol}) + (16)(C_{\text{methanol}}) \left(-28 - (-97.5) \right) = 0
\]

\[
-4350 \text{ J} + 1607.5 \text{ J} + 1112 C_{\text{methanol}} = 0
\]

\[
C_{\text{methanol}} = 2.47 \frac{\text{ J}}{\text{g} \cdot \text{°C}}
\]
11. A common way that people try to cool their beverages is by blowing on the surface of the liquid. You are holding a cup of 200 g of water at 90 °C. You blow on the top of the cup and during that time 1.0 g of water evaporates as steam. In addition, 6.6 kJ of heat are lost to the surroundings. What is the final temperature of the water? The heat of vaporization of water is 44 kJ/mol.

\[ Q_{\text{surr}} + Q_{\text{vap}} + Q_{\Delta T} = 0 \]

\[ + \left( \frac{1.0}{18} \right) (44000 \text{ J/mol}) + (1993) (4.184) (T_f - 90 ^\circ C) \]

These require heat from the water.

Water will drop in temp.

6600 + 2444 + 832T_f - 74935 = 0

\[ T_f = 79.2 ^\circ C \]

\[ 2 \text{ sig fig} = 79 ^\circ C \]
6. (8 points) The decomposition of carbon monoxide into graphite and oxygen is an endothermic process:

\[ 2 \text{CO}(g) \rightarrow 2 \text{C}(s) + \text{O}_2(g) \quad \Delta H^\circ = +221.1 \text{ kJ} \]

Given the above data, what is the standard enthalpy of formation of carbon monoxide?

\[ \frac{1}{2} \text{C} + \frac{1}{2} \text{O}_2 \rightarrow \text{CO} \quad \Delta H^\circ = -221.1 \text{ kJ/mol} \]
13. The Haber process, one of the most important industrial chemical processes in the world, is used commercially for the manufacture of ammonia:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

56 kg of $N_2$ and 40 kg of $H_2$ are placed in a reaction vessel and the temperature is increased to 500 °C. Before the reaction begins, the pressure is measured at 200 atm. Assuming the temperature and volume remain constant, what is the pressure in the vessel upon completion of the reaction?

\[
\begin{array}{ccc}
\text{start} & \text{end} \\
N_2 & 2000 \text{ mol} & 0 \\
H_2 & 20000 \text{ mol} & 14000 \text{ mol} \\
NH_3 & 0 & 4000 \text{ mol}
\end{array}
\]

\[
\begin{align*}
2000 \text{ mol } N_2 & \rightarrow \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = 4000 \text{ mol } NH_3 \\
2000 \text{ mol } N_2 & \rightarrow \frac{3 \text{ mol } H_2}{1 \text{ mol } N_2} = 6000 \text{ mol } H_2
\end{align*}
\]

At const V, T:

\[
\frac{P_1}{N_1} = \frac{RT}{V} = \frac{P_2}{N_2} \quad \frac{200 \text{ atm}}{22000 \text{ mol}} = \frac{P_2}{18000 \text{ mol}}
\]

\[P_2 = 160 \text{ atm}\]
6. Equal amounts (same number of moles) of Ar and CH₄ gasses are combined in a container and allowed to effuse through a small hole. After a period of time, 1.33 mmol of Ar has effused. Do you expect a larger, smaller, or equal amount of CH₄ to have effused over the same time period? In one or two sentences, explain your choice. *You do not have to calculate the amount of CH₄ that has effused.*

\[ \text{CH}_4 \text{ will effuse faster due to the lower molar mass} \]
A 0.550 mol sample of sodium azide is placed in a container with a volume of 4.50 L. The container is evacuated (contains no gas before the reaction) and then the sodium azide is decomposed according to the reaction shown below. Assuming that no gas escapes and the solid sodium produced takes up negligible volume in the container, what is the pressure (in atm) inside the container if the final temperature is 25 °C?

\[
2 \text{NaN}_3(s) \rightarrow 2 \text{Na}(s) + 3 \text{N}_2(g)
\]

\[
\frac{1.550 \text{ mol NaN}_3}{2 \text{ mol NaN}_3} \times \frac{3 \text{ mol N}_2}{3 \text{ mol N}_2} = 0.825 \text{ mol N}_2
\]

\[
P_{\text{final}} = \frac{nRT}{V} = \frac{(0.825)(0.08206)(298)}{4.50} = 4.5 \text{ atm}
\]