TUTORIAL 2 (FIRST LAW OF THERMODYNAMICS)  

Question 1

If $P_1 = 3.00 \text{ atm}$, $V_1 = 500 \text{ cm}^3$, $P_2 = 1.00 \text{ atm}$, and $V_2 = 2000 \text{ cm}^3$. Calculate the work, $W_{rev}$ for processes shown in Figure (a) and (b).

Given:
$P_1 = 3.00 \text{ atm}$,
$P_2 = 1.00 \text{ atm}$,
$V_1 = 500 \text{ cm}^3$,
$V_2 = 2000 \text{ cm}^3$

Fine $W_{rev} =$ **area under the curve**, for processes shown in Figure (a) and (b).

For (a):

Use P-V work equation:

$W = -P\Delta V$

$= - (P_2)(V_2-V_1)$

$= - (1 \text{ atm}) (2000 \text{ cm}^3 - 500 \text{ cm}^3)$

$= - 1500 \text{ cm}^3\text{.atm}$

Then convert to Joule unit:

$W = -1500 \text{ cm}^3\text{.atm} \left( \frac{101.325 \text{ J}}{1 \text{ L.atm}} \right) \left( \frac{1 \text{ L}}{1000 \text{ cm}^3} \right)$

$= - 151.995 \text{ J} \sim -152 \text{ J}$
For (b):

Use P-V work equation:

\[ W = -P\Delta V \quad \text{Since } P \text{ is constant, } P_1 = P_2 \]

\[ = -(P_1)(V_2 - V_1) \]

\[ = -(3 \text{ atm})(2000\text{cm}^3 - 500\text{cm}^3) \]

\[ = -4500 \text{ cm}^3.\text{atm} \]

Then convert to Joule unit:

\[ W = -4500 \text{ cm}^3.\text{atm} \times \frac{101.325 \text{ J}}{1 \text{ L.atm}} \times \frac{1 \text{ L}}{1000\text{cm}^3} \]

\[ = -455.9625 \text{ J} \sim -456 \text{ J} \]
Question 2
The initial temperature of 150g of ethanol was 22°C. What will be the final temperature of the ethanol if 3240 J was needed to raise the temperature of the ethanol?
(Specific heat capacity of ethanol is 2.44 J°C⁻¹g⁻¹).

Given:
q = 3240 J
m = 150 g
Cₚ = 2.44 J/g°C
T₁ = 22°C

Find T₂

Use the Specific Heat Capacity equation:

\[ q = mC_p\Delta T \]
\[ = mC_p(T_2 - T_1) \]

From the equation,

\[ T_2 = \left( \frac{q}{mC_p} \right) + T_1 \]
\[ = \left( \frac{3240 J}{150 g \times 2.44 J/g°C} \right) + 22°C \]
\[ = 30.85 °C \sim 30.9 °C \]
Question 3
Calculate the internal energy, \( U \) when 1.00 mol of \( \text{H}_2\text{O} \) goes from 25.0°C and 1.00 atm to 30.0°C and 1.00 atm. Densities of water are 0.9970 g/cm\(^3\) at 0°C and 0.9956 g/cm\(^3\) at 100°C.

**Given:**
- \( n = 1.00 \) mol
- \( P = 1.00 \) atm
- \( T_1 = 25 \) °C
- \( T_2 = 30 \) °C
- \( \rho_{\text{H}_2\text{O}} \) at 0 °C = 0.9970 g/cm\(^3\)
- \( \rho_{\text{H}_2\text{O}} \) at 100 °C = 0.9956 g/cm\(^3\)

**Find \( U \).**
From the periodic table, \( M_w \) of \( \text{H}_2\text{O} \) = 18 g/mol
The standard specific heat capacity of water is, \( C_p \) of \( \text{H}_2\text{O} \) = 1.0 cal/g °C

So, according to the 1\(^{\text{st}}\) Law, \( U = q + W \)
You need to find the \( q \) and \( W \) first!

To find \( q \), you need to use the Specific Heat Capacity equation: \( q = mC_p\Delta T \)
However, the mass is not given, so you need to find it first.

To find MASS, use the moles equation:
\[
n = \frac{m}{M_w}
\]
\[
m = nM_w
= (1.00 \text{ mol}) (18 \text{ g/mol})
= 18 \text{ g}
\]

Then, use this value to find \( q \):
\[
q = mC_p\Delta T
= (18 \text{ g}) (1.0 \text{ cal/g °C}) (30 \text{ °C} - 25 \text{ °C})
= 90 \text{ cal.}
\]

Then, find the \( W \) by using the P-V work equation: \( W = -P\Delta V \)
However, the value for V is not given, so you need to find V first.

To find VOLUME, use the density equation: \( \rho = \frac{m}{V} \)
From the equation, \( V = \frac{m}{\rho} \)
Use this $V = \frac{m}{\rho}$ equation into the P-V work equation to find $W$:

$$W = -P \Delta V$$

$$= -P \frac{m}{\rho_2} - \frac{m}{\rho_1}$$

$$= -1.00 \text{ atm} \frac{18 \text{ g}}{0.9956 \text{ g/cm}^3} - \frac{18 \text{ g}}{0.9970 \text{ g/cm}^3}$$

$$= -0.025 \text{ cm}^3 \cdot \text{ atm}$$

Convert to calorie unit:

$$W = -0.025 \text{ cm}^3 \cdot \text{ atm} \left| \frac{101.325 \text{ J}}{1 \text{ L.atm}} \right| \left| \frac{1 \text{ L}}{1000 \text{ cm}^3} \right| \left| \frac{1 \text{ cal}}{4.184 \text{ J}} \right|$$

$$1 \text{ L.atm} = 101.325 \text{ J}$$

$$1 \text{ L} = 1000 \text{ cm}^3$$

$$W = -0.0006 \text{ cal}$$

Therefore:

$$U = q + W$$

$$= 90 \text{ cal} + (-0.0006 \text{ cal})$$

$$= 89.9994 \text{ cal} \sim \textbf{90 cal}$$
Question 4
A cylinder fitted with a frictionless piston contains 3.00 mol of He gas at $P=1.00 \text{ atm}$ and is in a large constant-temperature bath at 400 K. The pressure is reversibly increased to 5.00 atm. Find $w$, $q$, and $U$ for this process.

Given:

$$n = 3.00 \text{ mol}$$
$$P_1 = 1.00 \text{ atm}$$
$$P_2 = 5 \text{ atm}$$
$$T = 400 \text{ K} \rightarrow \text{ constant}$$

Find $W$, $q$ and $U$.

To find $W$, use the work equation for isothermal process:

$$W = -q = nRT \ln \frac{V_1}{V_2} = nRT \ln \frac{P_2}{P_1}$$

$$W = nRT \ln \frac{P_2}{P_1}$$

$$= 3.00 \text{ mol} \times 8.314 \frac{J}{\text{mol.k}} \times 400 \text{ K} \ln \frac{5.00 \text{ atm}}{1.00 \text{ atm}}$$

$$= 1.61 \times 10^4 \text{ Joule.}$$

To find $q$:

Since $W = -q$;

So, $q = -W = -1.61 \times 10^4 \text{ Joule.}$

To find $U$:

For isothermal process, $\Delta U = 0$ at constant temperature.

Therefore, $U = 0$. 