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Varmafræði - Dæmablað 3

*Q.1

$m = 1{,}3\ kg$, $V_1 = 7{,}5 m^3$, $V_2 = 2{,}5 m^3$, $P = 180\ kPa$

$R_{helium} = 2{,}077 \frac{kJ}{kg \cdot K}$

The initial temperature:

$$PV_1 = mR_{helium} T_1 \Rightarrow T_1 = \frac{P_1 V_1}{mR_{helium}}$$

$$\Rightarrow T_1 = \frac{180\ kPa \cdot 7{,}5 m^3}{1{,}3\ kg \cdot 2{,}077 \frac{kJ}{kg \cdot K}} \approx \underline{\underline{500\ K}}$$

Final temperature:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow T_2 = \frac{T_1 \cancel{P_2} V_2}{\cancel{P_1} V_1} = \frac{T_1 V_2}{V_1}$$

$$\Rightarrow T_2 = \frac{500 K \cdot 2{,}5 m^3}{7{,}5 m^3} = \underline{\underline{166{,}7\ K}}$$

Total work:

$$W_b = P \cdot (V_2 - V_1) = 180 kPa \cdot (2{,}5 m^3 - 7{,}5 m^3)$$

$$= \underline{-900\ kJ}$$

Which means that the work required for the compression is $\underline{900\ kJ}$

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Q2) $T = 320°C$, $V_1 = 2{,}1 m^3$, $x = 0{,}8$

Table A4 gives:

$$P_{@\,320°C} = 11284 \text{ kPa}$$

and

$$v_1 = v_{f\,@\,320°C} = 0{,}001499 \frac{m^3}{kg}$$

$$v_{g\,@\,320°C} = 0{,}015470 \frac{m^3}{kg}$$

Now we can find v_2

$$v_2 = v_f + x v_{fg} = v_f + x(v_g - v_f)$$

$$= 0{,}001499 \frac{m^3}{kg} + 0{,}8 \cdot (0{,}015470 - 0{,}001499) \frac{m^3}{kg}$$

$$= 0{,}0127 \frac{m^3}{kg}$$

Then we can find the volume in the end:

$$\frac{V_2}{v_2} = \frac{V_1}{v_1} \Rightarrow V_2 = \frac{V_1}{v_1} \cdot v_2 = \frac{2{,}1 m^3 \cdot 0{,}0127 \frac{m^3}{kg}}{0{,}001499 \frac{m^3}{kg}}$$

$$\Rightarrow V_2 = 17{,}79 m^3$$

We can assume constant pressure so:

$$W_b = P(V_2 - V_1) = 11284 \text{ kPa} (17{,}79 - 2{,}1) m^3$$

$$\approx 177046 \text{ kJ}$$

$$\approx 1{,}77 \cdot 10^5 \text{ kJ}$$

*Q5 $V_1 = 0{,}75\,m^3$, $P_1 = 1400\,kPa$, $P_2 = 550\,kPa$, $x_1 = 1$

In the begining we have (from table A12)

$$v_1 = v_{g@1400kPa} = 0{,}014107\,\frac{m^3}{kg}$$

At 550 kPa we have

$$v_{f@550kPa} = 0{,}0008130\,\frac{m^3}{kg}$$
$$v_{g@550kPa} = 0{,}037408\,\frac{m^3}{kg}$$

And since $v_1 = v_2$ because it's a rigid tank:

$$x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0{,}014107\,\frac{m^3}{kg} - 0{,}0008130\,\frac{m^3}{kg}}{0{,}037408\,\frac{m^3}{kg} - 0{,}0008130\,\frac{m^3}{kg}}$$

$= 0{,}363$ which is a saturated mixture

Final temp is then:

$$T_{sat@550kPa} = 18{,}73\,°C$$

Now we have

$$m_{total} = \frac{V_1}{v_1} = \frac{0{,}75\,m^3}{0{,}014107\,\frac{m^3}{kg}} = 53{,}17\,kg$$

and we know that $x_2 = 0{,}363$
so amount condensed is:

$$m_f = (1 - x_2)\, m_{total}$$
$$= (1 - 0{,}363) \cdot 53{,}17\,kg$$
$$= 33{,}87\,kg$$

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*Q7)

$V_1 = 0,065 m^3$, $P_1 = 230 kPa$, $T_1 = 55°C = 328 K$,

$W = 8,3 kJ$

In table A2 we get

$$R_{nitro} = 0,2968 \frac{kJ}{kg\,K}$$

$$c_v = 0,743 \frac{kJ}{kg\,K}$$

Using ideal gas equation we get:

$$P_1 V_1 = mRT_1 \Rightarrow m = \frac{P_1 V_1}{RT_1}$$

$$\Rightarrow m = \frac{230 kPa \cdot 0,065 m^3}{0,2968 \frac{kJ}{kgK} \cdot 328 K} = 0,1536 kg$$

The equation for the work is:

$$W = m \cdot c_v \cdot (T_2 - T_1)$$

$$\Rightarrow T_2 = \frac{W}{m \cdot c_v} + T_1 = \frac{8,3 kJ}{0,1536 kg \cdot 0,743 \frac{kJ}{kgK}} + 328 K$$

$$\Rightarrow \underline{\underline{T_2 \approx 400 K}}$$

$\boxed{Q8}$ $m = 5,4\ kg$, $p = 215\ kPa$, $T = 37^\circ C = 310\ K$

$W_{out} = 14,7\ kJ$, $W_{in} = 3,56\ kJ$

Since this is a closed system we have

$$E_{in} - E_{out} = \Delta E_{system}$$

$$\Rightarrow Q_{in} + W_{in} - W_{out} = m\,C_v(T_2 - T_1)$$

Now we know since this is a isothermal process that $T_1 = T_2$ so

$$Q_{in} + W_{in} - W_{out} = 0$$

$$\Rightarrow Q_{in} = W_{out} - W_{in} = 14,7\ kJ - 3,56\ kJ$$
$$= 11,14\ kJ$$