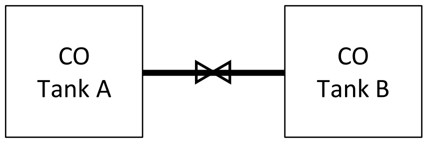
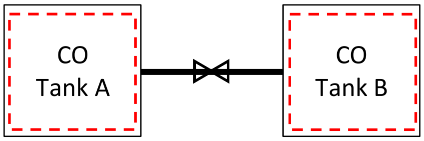
Two well-insulated, rigid tanks filled with carbon monoxide (CO) gas are connected by a valve. In tank A, 1 kg of gas is stored at 100 kPa (abs) and 300 K. In tank B, 5 kg of gas are stored at 500 kPa (abs) and 870 K. The valve is opened, and the contents of the two tanks are allowed to mix until equilibrium is attained.

Assuming ideal gas behavior for the carbon monoxide, determine:

a. the volume of each tank, in m^3,
b. the final temperature, in K, and
c. the final pressure, in kPa (abs).



SOLUTION:



The tank volumes may be found using the Ideal Gas Law,

$$pV = mRT \Rightarrow V = \frac{mRT}{p}. \quad (1)$$

Using the given data along with,

$$M_{CO} = 12.011\,\frac{kg}{kmol} + 16.00\,\frac{kg}{kmol} = 28.011\,\frac{kg}{kmol}, \quad (2)$$

$$R_{CO} = \frac{\bar{R}_U}{M_{CO}} = \frac{8.314\,\frac{kJ}{kmol.K}}{28.011\,\frac{kg}{kmol}} = 0.2968\,\frac{kJ}{kg.K}, \quad (3)$$

$m_A = 1$ kg, $T_{A1} = 300$ K, $p_{A1} = 100$ kPa (abs) => $\boxed{V_A = 0.890\ m^3}$,

$m_B = 5$ kg, $T_{B1} = 870$ K, $p_{B1} = 500$ kPa (abs) => $\boxed{V_B = 2.582\ m^3}$

Apply the First Law to the two tanks before (state 1) and after (state 2) the valve is opened,

$$\Delta E_{sys,12} = Q_{into\ sys,12} - W_{by\ sys,12}, \quad (2)$$

where,

$$\Delta E_{sys,12} = \Delta U_{sys,12} + \Delta KE_{sys,12} + \Delta PE_{sys,12} = \Delta U_{sys,12} = U_2 - U_1 \text{ (no changes in } KE \text{ or } PE\text{)}, \quad (3)$$

$$Q_{into\ sys,12} = 0 \text{ (the tanks are well-insulated)}, \quad (4)$$

$$W_{by\ sys,12} = 0 \text{ (the tanks are rigid)}. \quad (5)$$

Thus,

$$U_2 = U_1, \quad (6)$$

where,

$$U_1 = m_A u_{A1} + m_B u_{B1}, \quad (7)$$

$$U_2 = (m_A + m_B)u_2 \text{ (the tanks are mixed and in equilibrium at the end of the process)}. \quad (8)$$

Using the given data and the Ideal Gas Table for carbon monoxide (Table A-23 in Moran et al., 8^{th} ed., Wiley; refer to the end of this document),

$u_{A1} = u_{CO}(T_{A1} = 300\text{ K}) = 6229$ kJ/kmol,

$u_{B1} = u_{CO}(T_{B1} = 870\text{ K}) = 18858$ kJ/kmol,

=> $u_2 = 16753$ kJ/kmol => $\boxed{T_2 = 781\text{ K}}$ (interpolating from the Ideal Gas Table).

Use the Ideal Gas Law to determine the final pressure in the tanks,

$$pV = mRT \Rightarrow p_2 = \frac{(m_A + m_B)RT_2}{V_A + V_B}. \quad (9)$$

From the given and calculated data, $\boxed{p_2 = 401\text{ kPa (abs)}}$.

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TABLE A-23

Ideal Gas Properties of Selected Gases

Enthalpy $\bar{h}(T)$ and internal energy $\bar{u}(T)$, in kJ/kmol. Absolu

	Carbon Dioxide, CO_2 ($\bar{h}_f^\circ$ = −393,520 kJ/kmol)			Carbon Monoxide, CO ($\bar{h}_f^\circ$ = −110,530 kJ/kmol)			Water Vapor, H_2O ($\bar{h}_f^\circ$ = −241,820 kJ/km		
T(K)	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	
0	0	0	0	0	0	0	0	0	
220	6,601	4,772	202.966	6,391	4,562	188.683	7,295	5,466	178
230	6,938	5,026	204.464	6,683	4,771	189.980	7,628	5,715	180
240	7,280	5,285	205.920	6,975	4,979	191.221	7,961	5,965	181
250	7,627	5,548	207.337	7,266	5,188	192.411	8,294	6,215	182.
260	7,979	5,817	208.717	7,558	5,396	193.554	8,627	6,466	184.
270	8,335	6,091	210.062	7,849	5,604	194.654	8,961	6,716	185.
280	8,697	6,369	211.376	8,140	5,812	195.173	9,296	6,968	186.6
290	9,063	6,651	212.660	8,432	6,020	196.735	9,631	7,219	187.7
298	9,364	6,885	213.685	8,669	6,190	197.543	9,904	7,425	188.7
300	9,431	6,939	213.915	8,723	6,229	197.723	9,966	7,472	188.92
310	9,807	7,230	215.146	9,014	6,437	198.678	10,302	7,725	190.03
320	10,186	7,526	216.351	9,306	6,645	199.603	10,639	7,978	191.09
330	10,570	7,826	217.534	9,597	6,854	200.500	10,976	8,232	192.136
340	10,959	8,131	218.694	9,889	7,062	201.371	11,314	8,487	193.144
350	11,351	8,439	219.831	10,181	7,271	202.217	11,652	8,742	194.125
360	11,748	8,752	220.948	10,473	7,480	203.040	11,992	8,998	195.081
370	12,148	9,068	222.044	10,765	7,689	203.842	12,331	9,255	196.012
380	12,552	9,392	223.122	11,058	7,899	204.622	12,672	9,513	196.920
390	12,960	9,718	224.182	11,351	8,108	205.383	13,014	9,771	197.807
400	13,372	10,046	225.225	11,644	8,319	206.125	13,356	10,030	198.673
410	13,787	10,378	226.250	11,938	8,529	206.850	13,699	10,290	199.521
420	14,206	10,714	227.258	12,232	8,740	207.549	14,043	10,551	200.350
430	14,628	11,053	228.252	12,526	8,951	208.252	14,388	10,813	201.160
440	15,054	11,393	229.230	12,821	9,163	208.929	14,734	11,075	201.955
450	15,483	11,742	230.194	13,116	9,375	209.593	15,080	11,339	202.734
460	15,916	12,091	231.144	13,412	9,587	210.243	15,428	11,603	203.497
470	16,351	12,444	232.080	13,708	9,800	210.880	15,777	11,869	204.247
480	16,791	12,800	233.004	14,005	10,014	211.504	16,126	12,135	204.982
490	17,232	13,158	233.916	14,302	10,228	212.117	16,477	12,403	205.705
500	17,678	13,521	234.814	14,600	10,443	212.719	16,828	12,671	206.413
510	18,126	13,885	235.700	14,898	10,658	213.310	17,181	12,940	207.112
520	18,576	14,253	236.575	15,197	10,874	213.890	17,534	13,211	207.799
530	19,029	14,622	237.439	15,497	11,090	214.460	17,889	13,482	208.475
540	19,485	14,996	238.292	15,797	11,307	215.020	18,245	13,755	209.139
550	19,945	15,372	239.135	16,097	11,524	215.572	18,601	14,028	209.795
560	20,407	15,751	239.962	16,399	11,743	216.115	18,959	14,303	210.440
570	20,870	16,131	240.789	16,701	11,961	216.649	19,318	14,579	211.075
580	21,337	16,515	241.602	17,003	12,181	217.175	19,678	14,856	211.702
590	21,807	16,902	242.405	17,307	12,401	217.693	20,039	15,134	212.320

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TABLE A-23

(Continued)

$\bar{h}$ and $\bar{u}$ in kJ/kmol. $\bar{s}^\circ$ in

	Carbon Dioxide, CO_2 ($\bar{h}_f^\circ$ = −393,520 kJ/kmol)			Carbon Monoxide, CO ($\bar{h}_f^\circ$ = −110,530 kJ/kmol)			Water Vapor, H_2O ($\bar{h}_f^\circ$ = −241,820 kJ/k	
T(K)	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$
600	22,280	17,291	243.199	17,611	12,622	218.204	20,402	15,413
610	22,754	17,683	243.983	17,915	12,843	218.708	20,765	15,693
620	23,231	18,076	244.758	18,221	13,066	219.205	21,130	15,975
630	23,709	18,471	245.524	18,527	13,289	219.695	21,495	16,257
640	24,190	18,869	246.282	18,833	13,512	220.179	21,862	16,541
650	24,674	19,270	247.032	19,141	13,736	220.656	22,230	16,826
660	25,160	19,672	247.773	19,449	13,962	221.127	22,600	17,112
670	25,648	20,078	248.507	19,758	14,187	221.592	22,970	17,399
680	26,138	20,484	249.233	20,068	14,414	222.052	23,342	17,688
690	26,631	20,894	249.952	20,378	14,641	222.505	23,714	17,978
700	27,125	21,305	250.663	20,690	14,870	222.953	24,088	18,268
710	27,622	21,719	251.368	21,002	15,099	223.396	24,464	18,561
720	28,121	22,134	252.065	21,315	15,328	223.833	24,840	18,854
730	28,622	22,552	252.755	21,628	15,558	224.265	25,218	19,148
740	29,124	22,972	253.439	21,943	15,789	224.692	25,597	19,444
750	29,629	23,393	254.117	22,258	16,022	225.115	25,977	19,741
760	30,135	23,817	254.787	22,573	16,255	225.533	26,358	20,039
770	30,644	24,242	255.452	22,890	16,488	225.947	26,741	20,339
780	31,154	24,669	256.110	23,208	16,723	226.357	27,125	20,639
790	31,665	25,097	256.762	23,526	16,957	226.762	27,510	20,941
800	32,179	25,527	257.408	23,844	17,193	227.162	27,896	21,245
810	32,694	25,959	258.048	24,164	17,429	227.559	28,284	21,549
820	33,212	26,394	258.682	24,483	17,665	227.952	28,672	21,855
830	33,730	26,829	259.311	24,803	17,902	228.339	29,062	22,162
840	34,251	27,267	259.934	25,124	18,140	228.724	29,454	22,470
850	34,773	27,706	260.551	25,446	18,379	229.106	29,846	22,779
860	35,296	28,125	261.164	25,768	18,617	229.482	30,240	23,090
870	35,821	28,588	261.770	26,091	18,858	229.856	30,635	23,402
880	36,347	29,031	262.371	26,415	19,099	230.227	31,032	23,715
890	36,876	29,476	262.968	26,740	19,341	230.593	31,429	24,029
900	37,405	29,922	263.559	27,066	19,583	230.957	31,828	24,345
910	37,935	30,369	264.146	27,392	19,826	231.317	32,228	24,662
920	38,467	30,818	264.728	27,719	20,070	231.674	32,629	24,980
930	39,000	31,268	265.304	28,046	20,314	232.028	33,032	25,300
940	39,535	31,719	265.877	28,375	20,559	232.379	33,436	25,621
950	40,070	32,171	266.444	28,703	20,805	232.727	33,841	25,943
960	40,607	32,625	267.007	29,033	21,051	233.072	34,247	26,265
970	41,145	33,081	267.566	29,362	21,298	233.413	34,653	26,588
980	41,685	33,537	268.119	29,693	21,545	233.752	35,061	26,913
990	42,226	33,995	268.670	30,024	21,793	234.088	35,472	27,240

Tables from Moran et al., 8th ed., Wiley.