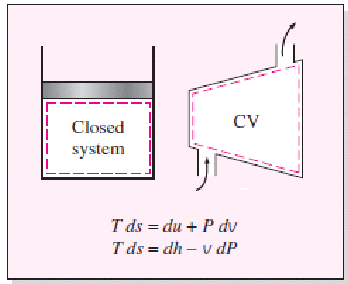
Termodynamic

Tuesday, April 20, 2021 8:22 AM

▪ THE *T ds* RELATIONS

$$T\,ds = du + P\,dv \qquad (\text{kJ/kg})$$

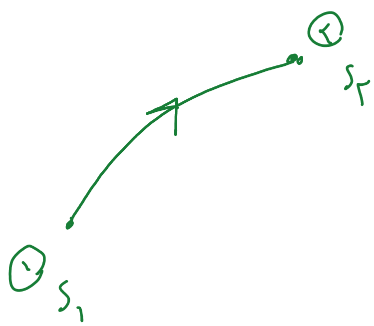
$$T\,ds = dh - v\,dP$$



* این روابط هم برای فرایندهای برگشت پذیر کاربرد دارد هم برای فرآیندهای برگشت ناپذیر

$$T\,ds = du + p\,dv \longrightarrow ds = \frac{du}{T} + \frac{p\,dv}{T} \qquad (1)$$

$$T\,ds = dh - v\,dp \longrightarrow ds = \frac{dh}{T} - \frac{v\,dP}{T} \qquad (2)$$



$$s_2 - s_1 = \int \frac{\delta Q}{T} + S_{gen}$$

7–8 ▪ ENTROPY CHANGE OF LIQUIDS AND SOLIDS

$P \longrightarrow$ فشار مطلق

$T \longrightarrow$ دمای مطلق (K)

$$ds = \frac{du}{T} + \frac{p\,dv}{T} \qquad (1)$$

$$ds = \frac{dh}{T} - v\frac{dP}{T} \quad (2)$$

جامد و مایع → تراکم ناپذیر → $dv = 0$ $\quad v \simeq 0$

مثلاً $\rho = 2500\ kg/m^3 \rightarrow v = \frac{1}{2500} = 0.0004$

$$\begin{cases} ds = \frac{du}{T} \\ ds = \frac{dh}{T} \end{cases}$$

$C_v = C_p = C$

$du = C_{av}\, dT = dh$

$h \rightarrow P$

$$ds = \frac{du}{T} = \frac{C_{av}\, dT}{T} \rightarrow \int_1^2 ds = \int_1^2 \frac{C_{av}\, dT}{T}$$

$$S_2 - S_1 = C_{av} \int_1^2 \frac{dT}{T} = C_{av} \ln T_2/T_1$$

$$S_2 - S_1 = C_{av} \ln \frac{T_2}{T_1}$$

جامدات و مایعات.

$$\begin{cases} T_{av} = \frac{T_2 + T_1}{2} \\ T_{av} \xrightarrow{\text{جدول}} C_v, C_p, C \end{cases}$$

TABLE A–3

Properties of common liquids, solids, and foods (*Concluded*)

(*b*) Solids (values are for room temperature unless indicated otherwise)

Substance	Density, ρ kg/m^3	Specific heat, c_p kJ/kg·K
Metals		
Aluminum		
200 K		0.797
250 K		0.859
300 K	2,700	0.902
350 K		0.929
400 K		0.949
450 K		0.973
500 K		0.997
Bronze (76% Cu, 2% Zn, 2% Al)	8,280	0.400
Brass, yellow (65% Cu, 35% Zn)	8,310	0.400
Copper		
−173°C		0.254
−100°C		0.342
−50°C		0.367
0°C		0.381
27°C	8,900	0.386
100°C		0.393
200°C		0.403
Iron	7,840	0.45
Lead	11,310	0.128
Magnesium	1,730	1.000
Nickel	8,890	0.440
Silver	10,470	0.235
Steel, mild	7,830	0.500
Tungsten	19,400	0.130

Substance	Density, ρ kg/m^3	Specific heat, c_p kJ/kg·K
Nonmetals		
Asphalt	2110	0.920
Brick, common	1922	0.79
Brick, fireclay (500°C)	2300	0.960
Concrete	2300	0.653
Clay	1000	0.920
Diamond	2420	0.616
Glass, window	2700	0.800
Glass, pyrex	2230	0.840
Graphite	2500	0.711
Granite	2700	1.017
Gypsum or plaster board	800	1.09
Ice		
200 K		1.56
220 K		1.71
240 K		1.86
260 K		2.01
273 K	921	2.11
Limestone	1650	0.909
Marble	2600	0.880
Plywood (Douglas Fir)	545	1.21
Rubber (soft)	1100	1.840
Rubber (hard)	1150	2.009
Sand	1520	0.800
Stone	1500	0.800
Woods, hard (maple, oak, etc.)	721	1.26
Woods, soft (fir, pine, etc.)	513	1.38

Tav

C

برای موادی که دمای Tav برای آنها درجدول ذکر نشده باشد برای هر Tav مقدار Cp داخل جدول را در نظر بگیریم

(*c*) Foods

Food	Water content, % (mass)	Freezing point, °C	Specific heat, kJ/kg·K Above freezing	Specific heat, kJ/kg·K Below freezing	Latent heat of fusion, kJ/kg
Apples	84	−1.1	3.65	1.90	281
Bananas	75	−0.8	3.35	1.78	251
Beef round	67	—	3.08	1.68	224
Broccoli	90	−0.6	3.86	1.97	301
Butter	16	—	—	1.04	53
Cheese, swiss	39	−10.0	2.15	1.33	130
Cherries	80	−1.8	3.52	1.85	267
Chicken	74	−2.8	3.32	1.77	247
Corn, sweet	74	−0.6	3.32	1.77	247
Eggs, whole	74	−0.6	3.32	1.77	247
Ice cream	63	−5.6	2.95	1.63	210
Lettuce	95	−0.2	4.02	2.04	317
Milk, whole	88	−0.6	3.79	1.95	294
Oranges	87	−0.8	3.75	1.94	291
Potatoes	78	−0.6	3.45	1.82	261
Salmon fish	64	−2.2	2.98	1.65	214
Shrimp	83	−2.2	3.62	1.89	277
Spinach	93	−0.3	3.96	2.01	311
Strawberries	90	−0.8	3.86	1.97	301
Tomatoes, ripe	94	−0.5	3.99	2.02	314
Turkey	64	—	2.98	1.65	214
Watermelon	93	−0.4	3.96	2.01	311

Source: Values are obtained from various handbooks and other sources or are calculated. Water content and freezing-point data of foods are from *ASHRAE, Handbook of Fundamentals*, SI version (Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1993), Chapter 30, Table 1. Freezing point is the temperature at which freezing starts for fruits and vegetables, and the average freezing temperature for other foods.

$$s_2 - s_1 = c_{av} \ln \frac{T_2}{T_1}$$ → تغییرات آنتروپی برای مواد جامد - مایع

$S_{gen} = \Delta S_{\text{سیستم}} + \Delta S_{\text{محیط}}$

* اگر جامد و مایع فرایند آیزونتروپیک طی کنند ← $s_1 = s_2$

$$s_2 - s_1 = c_{av} \ln T_2/T_1 \rightarrow c_{av} \ln \frac{T_2}{T_1} = 0$$

$$\rightarrow \ln \frac{T_2}{T_1} = 0 \rightarrow \frac{T_2}{T_1} = 1 \rightarrow \boxed{T_2 = T_1}$$

EXAMPLE 7–7 Effect of Density of a Liquid on Entropy

Liquid methane is commonly used in various cryogenic applications. The critical temperature of methane is 191 K (or −82°C), and thus methane must be maintained below 191 K to keep it in liquid phase. The properties of liquid methane at various temperatures and pressures are given in Table 7–1. Determine the entropy change of liquid methane as it undergoes a

EXAMPLE 7–7 Effect of Density of a Liquid on Entropy

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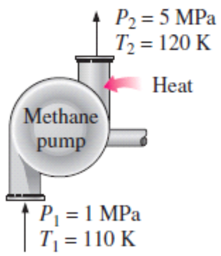

TABLE 7–1

Properties of liquid methane

Temp., T, K	Pressure, P, MPa	Density, ρ, kg/m³	Enthalpy, h, kJ/kg	Entropy, s, kJ/kg · K	Specific heat, c_p, kJ/kg · K
110	0.5	425.3	208.3	4.878	3.476
	1.0	425.8	209.0	4.875	3.471
	2.0	426.6	210.5	4.867	3.460
	5.0	429.1	215.0	4.844	3.432
120	0.5	410.4	243.4	5.185	3.551
	1.0	411.0	244.1	5.180	3.543
	2.0	412.0	245.4	5.171	3.528
	5.0	415.2	249.6	5.145	3.486

$S_٢ - S_١ = C_{av} \, Ln \frac{T_٢}{T_١}$

T₁ = ١١٠ K, P₁ = ١ Mpa → h₁ = ٢٠٩, S₁ = ٤,٨٧٥, Cp = ٣,٤٧١

T₂ = ١٢٠ K, P = ٥ MPa → h₂ = ٢٤٩,٦, S₂ = ٥,١٤٥, C = ٣,٤٨٦

ΔS = S₂ − S₁ = ٥,١٤٥ − ٤,٨٧٥ = ٠/٢٧ kJ/kg.K

C_av = (٣,٤٧١ + ٣,٤٨٦) / ٢ = ٣,٤٧٨٥

S₂ − S₁ = C_av Ln T₂/T₁ = ٣,٤٧٨٥ Ln ١٢٠/١١٠

$$\Delta s = c_{avg} \ln \frac{T_2}{T_1} = (3.4785 \text{ kJ/kg}\cdot\text{K}) \ln \frac{120 \text{ K}}{110 \text{ K}} = 0.303 \text{ kJ/kg}\cdot\text{K}$$

7–9 ▪ THE ENTROPY CHANGE OF IDEAL GASES

$$ds = \frac{du}{T} + \frac{P\,dv}{T} \longrightarrow ds = \frac{C_{v,av}\,dT}{T} + \frac{R\,dv}{v}$$

$$ds = \frac{dh}{T} - \frac{v\,dP}{T}$$

$$\int_1^2 ds = C_{v,av}\int_1^2 \frac{dT}{T} + R\int_1^2 \frac{dv}{v}$$

$$du = C_{v,av}\,dT$$

$$dh = C_{P,av}\,dT$$

$$Pv = RT \longrightarrow \frac{P}{T} = \frac{R}{v}, \quad \frac{v}{T} = \frac{R}{P}$$

$$s_2 - s_1 = C_{v,av} \ln\frac{T_2}{T_1} + R \ln\frac{v_2}{v_1}$$

$$ds = \frac{dh}{T} - \frac{v\,dP}{T} \longrightarrow ds = \frac{C_{P,av}\,dT}{T} - \frac{R\,dP}{P}$$

$$\int ds = C_{P,av}\int\frac{dT}{T} - R\int dP/P$$

$$s_2 - s_1 = C_{P,av} \ln\frac{T_2}{T_1} - R \ln\frac{P_2}{P_1}$$

داجم تغییرات آنتروپی در طی فرایند برای گاز کامل به بقیه خواص ترمودینامیک

$$s_2 - s_1 = c_{v,\text{avg}} \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1} \qquad (\text{kJ/kg} \cdot \text{K}) \qquad \textbf{(7–33)}$$

$$s_2 - s_1 = c_{p,\text{avg}} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1} \qquad (\text{kJ/kg} \cdot \text{K}) \qquad \textbf{(7–34)}$$

TABLE A–2

Ideal-gas specific heats of various common gases (*Continued*)

(*b*) At various temperatures

Temperature, K	c_p kJ/kg·K	c_v kJ/kg·K	k	c_p kJ/kg·K	c_v kJ/kg·K	k	c_p kJ/kg·K	c_v kJ/kg·K	k
	Air			*Carbon dioxide, CO_2*			*Carbon monoxide, CO*		
250	1.003	0.716	1.401	0.791	0.602	1.314	1.039	0.743	1.400
300	1.005	0.718	1.400	0.846	0.657	1.288	1.040	0.744	1.399
350	1.008	0.721	1.398	0.895	0.706	1.268	1.043	0.746	1.398
400	1.013	0.726	1.395	0.939	0.750	1.252	1.047	0.751	1.395
450	1.020	0.733	1.391	0.978	0.790	1.239	1.054	0.757	1.392
500	1.029	0.742	1.387	1.014	0.825	1.229	1.063	0.767	1.387
550	1.040	0.753	1.381	1.046	0.857	1.220	1.075	0.778	1.382
600	1.051	0.764	1.376	1.075	0.886	1.213	1.087	0.790	1.376
650	1.063	0.776	1.370	1.102	0.913	1.207	1.100	0.803	1.370
700	1.075	0.788	1.364	1.126	0.937	1.202	1.113	0.816	1.364
750	1.087	0.800	1.359	1.148	0.959	1.197	1.126	0.829	1.358
800	1.099	0.812	1.354	1.169	0.980	1.193	1.139	0.842	1.353
900	1.121	0.834	1.344	1.204	1.015	1.186	1.163	0.866	1.343
1000	1.142	0.855	1.336	1.234	1.045	1.181	1.185	0.888	1.335

T_{av} → 500

EXAMPLE 7–9 Entropy Change of an Ideal Gas

Air is compressed from an initial state of 100 kPa and 17°C to a final state of 600 kPa and 57°C. Determine the entropy change of air during this compression process by using (*a*) property values from the air table and (*b*) average specific heats.

(1) $P_1 = 100$ kPa, $T_1 = 17°C + 273 = 290$ K

(2) $P_2 = 600$ kPa, $T_2 = 57 + 273 = 330$ K

$T_{av} = \frac{330 + 290}{2} = 310$

$s_2 - s_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

$$s_۲ - s_۱ = C_{p,av} \ln \frac{T_۲}{T_۱} - R \ln \frac{P_۲}{P_۱}$$

$$T_{av} = \frac{۴۲۰ + ۲۹۰}{۲} = 360$$

$$C_{p,av} = ۱٫۰۰۵$$

$$s_۲ - s_۱ = ۱٫۰۰۵ \ln \frac{۴۲۰}{۲۹۰} - ۰٫۲۸۷ \ln \frac{۹۰۰}{۲۹۰} =$$