

SPECIFIC HEAT CAPACITIES AND THEIR RATIO AS FUNCTIONS OF TEMPERATURE FOR SEVERAL COMMON GASES

1. NOTATION AND UNITS

		<i>SI</i>	<i>British</i>
c_p	specific heat capacity of gas at constant pressure	J/kg K	ft lbf/slug K
c_v	specific heat capacity of gas at constant volume	J/kg K	ft lbf/slug K
m	molecular mass	kg/kmol	slug/slug-mol
p	static pressure	N/m ²	lbf/ft ²
p_0	datum pressure taken as one atmosphere (1.01325×10^5 N/m ² , 2.11622×10^3 lbf/ft ²)	N/m ²	lbf/ft ²
$\mathcal{R}$	universal gas constant (8.31432×10^3 N m/kmol K, 8.94946×10^4 ft lbf/slug-mol K)	N m/kmol K	ft lbf/slug-mol K
R	gas constant, $\mathcal{R}/m$	N m/kg K	ft lbf/slug K
T	static temperature	K	K
γ	ratio of specific heat capacities, c_p/c_v		
ρ	density	kg/m ³	slug/ft ³

2. NOTES

The ratio of the specific heat capacities at constant pressure and constant volume is defined by the equation:

$$\gamma(p, T) = c_p(p, T)/c_v(p, T). \quad (2.1)$$

A gas is defined as calorically perfect when c_p and c_v , and hence γ , are independent of temperature and pressure. It is often sufficiently accurate to assume that real gases have a constant ratio of the specific heat capacities. However, with increasing temperature large errors may result if account is not taken of caloric imperfections.

In Figures 1a to 1d the variation of γ with temperature for several common gases is plotted at a pressure of one atmosphere. The curves give information over the temperature range bounded at low temperatures by the onset of liquefaction and at high temperatures by the approach of dissociation. In addition, the curves for air take into account the significant effects due to the formation of nitric oxide (NO) at higher temperatures. Except for steam and helium (Derivation 2) the curves are based on Derivation 1.

Over a wide temperature range the influence of pressure on γ is small. Sketch 2.1 shows the lower and upper temperature boundaries between which the curves in Figures 1a to 1d give $(\gamma - 1)$ to within one per cent at pressures other than one atmosphere. With one exception, where upper boundaries are not indicated

the influence of dissociation is only appreciable at temperatures greater than those considered in this Item. In the case of steam, however, no reliable estimate of the influence of dissociation is available and hence no upper boundary is shown. For information outside the range covered in this Item reference should be made to Derivation 1 for all the gases except steam and helium, which it does not treat.

For a gas that is calorically imperfect (*i.e.* c_p and c_v vary with temperature and pressure) but that is, however, thermally perfect (*i.e.* has an equation of state $p = \rho RT$) the following relation holds,

$$c_p(T) = c_v(T) + R, \quad (2.2)$$

where $R = \mathcal{R}/m. \quad (2.3)$

Combining Equations (2.1) and (2.2)

$$c_p = \gamma R/(\gamma - 1) \quad (2.4)$$

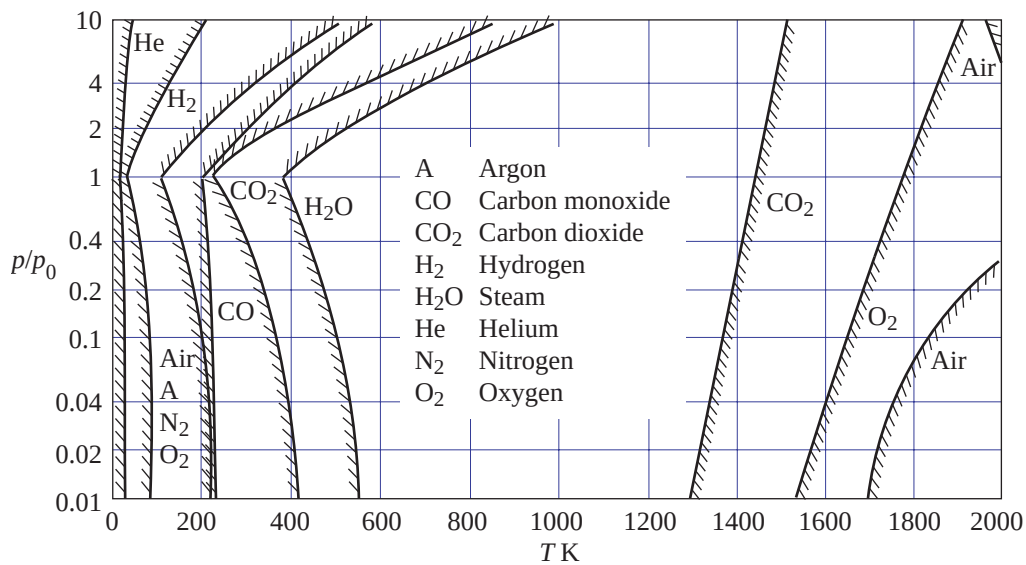
and $c_v = R/(\gamma - 1). \quad (2.5)$

Sketch 2.2 is a plot of temperature and pressure showing the regions where, using a value of γ given by Figures 1a to 1d, c_p and c_v can be calculated, using Equations (2.4) and (2.5), to within one per cent.

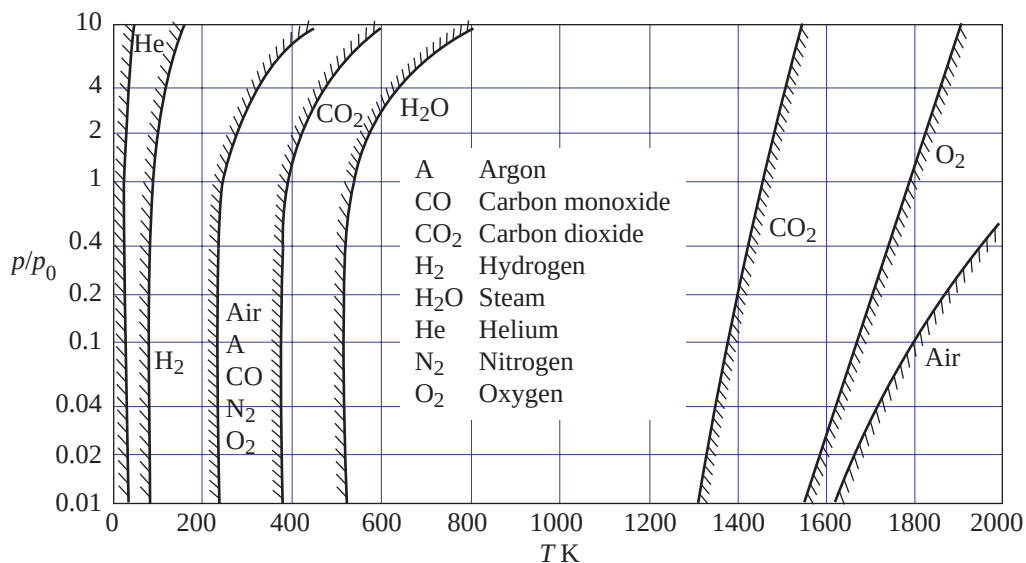
In order to determine the gas constant for a particular gas the molecular mass is required. Table 2.1 gives the value of the molecular mass for the common gases considered in this Item.

TABLE 2.1

Gas	Molecular Mass (kg/kmol, slug/slug-mol)
Air	28.97
Argon	39.95
Carbon Dioxide	44.01
Carbon Monoxide	28.01
Helium	4.003
Hydrogen	2.016
Nitrogen	28.02
Oxygen	32.00
Steam	18.02



Sketch 2.1 One per cent error boundaries for $(\gamma - 1)$



Sketch 2.2 One per cent error boundaries for c_p and c_v

3. DERIVATION

1. HILSENATH, J.
et al. *Tables of thermodynamic and transport properties.*
Pergamon Press, 1960. (Originally published as National Bureau of
Standards Circular 564, 1955.)
2. NATIONAL ENGINEERING COMMUNICATION FROM NATIONAL ENGINEERING LABORATORY, East
LABORATORY Kilbride, Glasgow.