Finite Temperature EOS driver & Tablulated EOSs

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1 EOS Driver

2 Tabulated EOSs

2.1 Table format

Our EOS driver accepts tablulated EOS in `HDF5` format. Table 1 lists the required fields and a short description.

Variable	Units	Description
`pointsrho`	dimensionless	number of table points in $\log_{10}(\rho)$
`pointstemp`	dimensionless	number of table points in $\log_{10}$(T)
`pointsye`	dimensionless	number of table points in Y_e
`logrho`	$\log_{10}(\rho[\mathrm{g/cm^3}])$	index variable ρ
`logrho`	$\log_{10}(T[\mathrm{MeV}])$	index variable T
`logrho`	number fraction	index variable Y_e
`Abar`	A	average heavy nucleus mass number
`Zbar`	Z	average heavy nucleus atomic number
`Xa`	mass fraction	α particle mass fraction
`Xh`	mass fraction	average heavy nucleus mass fraction
`Xn`	mass fraction	neutron mass fraction
`Xp`	mass fraction	proton mass fraction
`cs2`	$\mathrm{cm^2/s^2}$	speed of sound squared
`dedt`	erg/g/MeV	C_v
`dpderho`	dynes $\mathrm{g/cm^2}$/erg	dP/dϵ at constant ρ
`dpdrhoe`	dynes $\mathrm{cm^3/cm^2/g}$	dP/dρ at constant ϵ
`energy_shift`	erg/g	energy shift for table storage [a]
`entropy`	k_B/baryon	specific entropy
`gamma`	dimensionless	dlog $[P]$/dlog $[\rho]$
`logenergy`	$\log_{10}(\epsilon[\mathrm{erg/g}])$	specific internal energy
`logpress`	$\log_{10}(P[\mathrm{dynes/cm^2}])$	pressure
`mu_e`	MeV/baryon	electron chemical potential[b]
`mu_p`	MeV/baryon	proton chemical potential[c]
`mu_n`	MeV/baryon	neutron chemical potential[d]
`muhat`	Mev/baryon	mu_n - mu_p
`munu`	Mev/baryon	mu_e - muhat

[a] see below
[b] includes rest mass
[c] includes rest mass, see specific EOS for detials
[d] includes rest mass, see specific EOS for detials

Table 1: EOS driver `HDF5` variables

2.2 Shen EOS

2.2.1 Table Construction

Our Shen EOS is constructed on the basis of the Shen et al. 1998 relativistic-mean field nuclear EOS table. Electrons (fully general, based on TimmesEOS) and Photons are added.

Original Shen EOS table extent:

Density	$10^{5.1}$ - $10^{15.4}$ g/cm^3
Temperature	0.1 - 100 MeV
Y_e	0.01 - 0.56

Table extent of current table [`myshen_test_220r_180t_50y_extT_20090312.h5`]:

Density	10^{3} - $10^{15.36}$ g/cm^3
Temperature	0.01 - 250 MeV
Y_e	0.015 - 0.56

This bigger table is realized by extending the original Shen table in multiple ways in multiple directions:

(a) density:
Match of pure ideal gas of Ni^{56} + electrons/positrons + photons at densities below 10^7g/cm^3 – at this density pressures, energies and entropies match okayish with the values in the Shen table. The compositions (`Abar`,`Zbar`,`Xh`,`Xa`,`Xp`,`Xn`) are kept constant in the low-density region and `mu_n` and `mu_p` are set to 0 – ideally, at low densities, a full NSE EOS with nuclear reaction network (at low T) should be stitched onto the Shen; working on that, but not yet ready.

(b) temperature (extrapolation):
At high density: linear extrapolation of everything in T to lower temperatures and higher temperatures. At low densities (below 10^7g/cm^3), ideal gas of Ni^{56} + electrons/positrons + photons.

2.2.2 Chemical Potentials

The nucleon chemical potentials are fully relativistic in the Shen EOS. They include the rest mass but are given with respect to a mass of $M = 938$ MeV, i.e. $\mu_n = \tilde{\mu}_n - M$. Therefore $\hat{\mu} = \mu_n - \mu_p$ includes the neutron-proton mass difference.

2.2.3 Energy Shift

In some regions the negative nuclear binding energy is larger in magnitude than the thermal/excitation energy. In this case the specific internal energy (ϵ) becomes negative. To allow for storage and interpolation of ϵ in logarithmic fashion, the energy is shifted up by an energy shift specified in the variable `energy_shift`. This energy shift is handled internally in the EOS routines.

2.3 LS EOSs

2.3.1 Chemical Potentials

The nucleon chemical potentials are fully relativistic in the LS EOSs in the sense that they include the rest mass of the particles. The chemical potentials are given with respect to the neutron rest mass. Therefore $\hat{\mu} = \mu_n - \mu_p$ includes the neutron-proton mass difference.

2.3.2 Energy Shift

In some regions the negative nuclear binding energy is larger in magnitude than the thermal/excitation energy. In this case the specific internal energy (ϵ) becomes negative. To allow for storage and interpolation of ϵ in logarithmic fashion, the energy is shifted up by an energy shift specified in the variable `energy_shift`. This energy shift is handled internally in the EOS routines.