Finite Temperature EOS driver & Tablulated EOSs

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1 EOS Driver

Here we describe the set of functions used to access the EOS. Please also review `driver.F90` for usage of the EOS routines.

1.1 `readtable('pathtoEOS.h5')`

This function must be called to initialize the EOS and read in the data from file.

1.2 `add_index('name of data set',ivariable)`

The main EOS table must be read in with `readtable`, however, this only reads in the default 19 variables that must be stored in the EOS table for compatibility with `EOSdriver`. There may be additional variables in the .h5 file that the user may wish to access. A call to `add_index` with the appropiate HDF5 dataset name will add this EOS variable to the main EOS array stored in memory. The index of this variable is return in `ivariable`. Use this with `nuc_eos_one` (described below) to interpolate this additional variable.

1.3 `nuc_eos_full`

1.4 `nuc_eos_short`

1.5 `nuc_eos_one`

This routine interpolated one and only one EOS variable. Interpolating one variable at a time is inefficient as there is a lot of overhead, however this may be acceptable in some situations. To use `nuc_eos_one`, provide as arguements `rho`, `temp`, `ye`, `interpolated_value`, and `index_of_variable`, respectively. The last arguement is either returned by `add_index` when the variable is added to the table, or can be found in `eosmodule.F90`. This routine does not accept the internal energy, entropy, or pressure as EOS inputs, any EOS inversion must be done separately.

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.

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

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`	$\mathrm{cm}^2/\mathrm{s}^2$	speed of sound squared
`dedt`	erg/g/MeV	C_v
`dpderho`	dynes $\mathrm{g/cm}^2$/erg	dP/dϵ at constant ρ
`dpdrhoe`	dynes $\mathrm{cm}^3/\mathrm{cm}^2$/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

Density	$10^{5.1}$ - $10^{15.4}$ g/cm^3
Temperature	0.1 - 100 MeV
Y_e	0.01 - 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 $10^7\mathrm{g/cm}^3$ – 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 $10^7\mathrm{g/cm}^3$), ideal gas of Ni^{56} + electrons/positrons + photons.

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

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.