

Finite Temperature EOS driver & Tabulated EOSs

C. D. Ott and E. O'Connor

July 23, 2013

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 `le`.

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 appropriate HDF5 dataset name will add this EOS variable to the main EOS array stored in memory. The index of this variable is returned 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 interpolates 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 arguments `rho`, `temp`, `ye`, `interpolated_value`, and `index_of_variable`, respectively. The last argument 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 tabulated 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 $\log_{10}(T)$
pointsy_e	dimensionless	number of table points in Y_e
logrho	$\log_{10}(\rho \text{ [g=cm}^3\text{)])}$	index variable
logrho	$\log_{10}(T \text{ [MeV]})$	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	particle mass fraction
Xh	mass fraction	average heavy nucleus mass fraction
Xn	mass fraction	neutron mass fraction
Xp	mass fraction	proton mass fraction
cs2	$\text{cm}^2=\text{s}^2$	speed of sound squared
dedt	erg=g=MeV	C_v
dpderho	$\text{dynes g=cm}^2=\text{erg}$	$dP/d\rho$ at constant
dpdrhoe	$\text{dynes cm}^3=\text{cm}^2=\text{g}$	$dP/d\rho$ at constant
energy_shift	erg=g	energy shift for table storage ^a
entropy	k_B/baryon	specific entropy
gamma	dimensionless	$d\log[P]/d\log[\rho]$
logenergy	$\log_{10}(\rho \text{ [erg=g]})$	specific internal energy
logpress	$\log_{10}(P \text{ [dynes=cm}^2\text{)])}$	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	$\mu_e - \mu_{\text{hat}}$

^asee below

^bincludes rest mass

^cincludes rest mass, see specific EOS for details

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Table 1: EOS driver HDF5 variables

Density	$10^{5.1} - 10^{15.4} \text{ g=cm}^3$
Temperature	$0.1 - 100 \text{ MeV}$
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 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 μ_n and μ_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 g=cm^3), ideal gas of Ni^{56} + electrons/positrons + photons.

Density	$10^3 - 10^{15.36} \text{ g/cm}^3$
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 $M = 938 \text{ MeV}$, i.e. $\mu_n = \tilde{\mu}_n - M$. Therefore $\mu^* = \mu_n - \mu_p$ 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 $\mu^* = \mu_n - \mu_p$ 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.