Ellingham Diagram Interpretation

The Ellingham Diagram is a plot of the standard Gibbs energy of formation (see below) for a one mole of a particular anion (S in this explanation). Therefore, in this case every reaction is based on one mole of S_2 gas as a function of T for every sulfide.

For example:

$$M + S_2 = MS_2$$
$$2M + S_2 = 2MS$$
$$2M + S_2 = M_2S_2$$
$$3M + S_2 = M_3S_2$$

Using one mole of S_2 makes all reactions immediately comparable.
For example if one wishes to compare the relative stability of Al_2S_3 and FeS_2, one reaction issubtracted from the other as follows:

$$[3Al + S_2 = Al_3S_2 \quad \Delta G^\circ_{Al3S2}]$$
$$- [2Fe + S_2 = FeS_2 \quad \Delta G^\circ_{FeS2}]$$
$$3Al + FeS_2 = 2Fe + Al_3S_2 \qquad \Delta G^\circ_R = \Delta G^\circ_{Al3S2} - \Delta G^\circ_{FeS2}$$

If $\Delta G^\circ_R < 0 \rightarrow$
$\Delta G^\circ_R > 0 \leftarrow$
$\Delta G^\circ_R = 0$ Equilibrium

However, it is much easier from a practical perspective to just think as follows:

- S goes from high chemical potential to low just as current runs from high voltage to low voltage.
- The vertical scale is also S relative potential (relative to S_2 gas at 1 atm).
- The basis of the relative state is of no consequence if we simply want to know where the S ends up.
- Since S "flows" (like current) from high to low potential, it goes to the lower sulfides.
- That is to say, the sulfides at the bottom are more stable that those at the top.
- A corollary is that the METALS at the top are NOBLE and metals at the bottom are REACTIVE.

More Info on Chemical Potential
For the reactions

$$M + S_2 = MS_2$$
$$2M + S_2 = 2MS$$
$$2M + S_2 = M_2S_2$$
$$3M + S_2 = M_3S_2$$

The standard Gibbs energy of formation is

$\Delta G^\circ_R = -RT \ln 1/P_{S2} = RT \ln P_{S2}$ if the metal and the sulfide activities are both unity (or the same).
Generally, all reactions are thought of as involving the pure metal and sulfide and gases other than S_2 as being at 1 atm.
The term $RT \ln P_{S2}$ is also known as the relative chemical potential of S_2 gas from the expression $\mu_{S2} = \mu^o_{S2} + RT \ln P_{S2}/ P^o_{S2}$ since $P^o_{S2} = 1$ atm (more precisely fugacity =1).

Therefore, the relative chemical potential is
$\Delta\mu_{S2} = \mu_{S2} - \mu^o_{S2} = RT \ln P_{S2}$, which is an alternative name for the vertical coordinate of the Ellingham diagram.

So, the vertical scale of the Ellingham Diagram is

$$\Delta G^\circ_R = RT \ln P_{S2} = \Delta\mu_{S2}$$

If one thinks of the vertical scale as the relative chemical potential, it makes it akin to "S–voltage" and S goes to the compound having the lowest S-potential just as electrical current flows to the lowest available potential. Voltage can be relative to anything – usually a stake at your home sets the ground as 0. The relative sulfur potential is set at 0 when the pressure of S_2 is 1 atm.