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Brief communication

Fishing with Scissors: A Mnemonic for Thermodynamic Formula

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ABSTRACT

Most of the branches of engineering and basic science require, to a different extent, the use of basic thermodynamic formulas relating state variables (temperature, T; pressure, P; volume, V; entropy, S) and thermodynamic potentials (internal energy, U; Helmholtz free energy, A; enthalpy, H; Gibbs free energy, G). The different interrelations among variables, their constrains and dependencies make them particularly difficult to remember and understand. For students learning and for chemists and engineers needing to rapidly recall these thermodynamic relationships for problem solving and practical applications, a quick method to easily remember them would be most welcome. Herein, Fishing with scissors mnemonic is presented. The mnemonic is seen as Sun with rays. Thermodynamic potential terms (A, G, H, U) as alphabetic doubles are aligned in sun rays regions whereas state variables (T, P, S, V) are at sun body. Following a simple set of rules in this mnemonic, a large range of thermodynamic equations can be easily recalled without direction or sign difficulties present in previously reported methods.

Keywords: Fishing, Scissors, Thermodynamic mnemonic, State variable, Potential variables.

INTRODUCTION

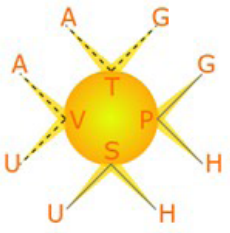
Thermodynamics is one of the branch of physics that cross-cut most engineering professions as it deals with systems reaching equilibrium and their exchange of energy, heat, work, or matter, which can be used to describe most chemical and engineering systems. A mathematical description of such system usually involves the use of basic thermodynamic formulas and their relationships. The relationship among the four state variables, Temperature, Pressure, Volume and Entropy, and four thermodynamic potentials, Internal energy, Helmholtz free energy, Enthalpy and Gibbs free energy, is the core of classical thermodynamics. These various differential and partial differential equations describing these relationships are difficult to remember and many mnemonic methods have been proposed to help students and practicing chemists and engineers to remember them. Several mnemonic schemes including Max Born square were given to help the recalling the relationships over the years (Born, 1929; Callen, 1960; Christle, 1957; Fox, 1976; Koening, 1972, Mitchell, 1991; Pate, 1999; Rao,

1994; Isihara, 1986, Zemansky, 1968; Zhao, 2009) but most of them were bulky and confusing with directions and sign. Herein, Fishing with scissors mnemonic is presented. It is easier, flowing and free from the direction or sign difficulties. It can be used to recall fundamental thermodynamic equations, Maxwell relations of thermodynamic potentials with state variable and Maxwell relations of state variable.

2.0. Mnemonic scheme

State variables Pressure "P"& volume "V" are placed horizontally and Temperature "T" & entropy "S" are placed vertically. Connecting all four state variables, a circle of state variable is sketched as shown in core region of graphic (named as sun region)

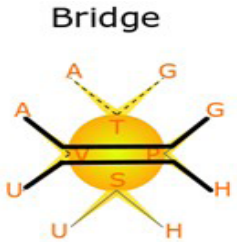
Figure 1. Potentials terms; Helmholtz free energy "A", Gibbs free energy "G", Enthalpy "H" and Internal energy "U" are placed as alphabetic doubles (as AAGGHHUU) as dashed and solid rays of the sun. The full sun graphic is the base of proposed thermodynamic mnemonic.



The terms of graphics can be picked in bridging, scissoring, fishing and swirling manner to write fundamental thermodynamic equations, fundamental integrated thermodynamic equations, Maxwell relations of thermodynamic potential with state value and Maxwell relations of state variable respectively.

Fundamental thermodynamic equations by bridging way

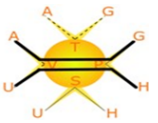
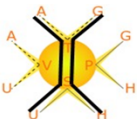
Let us start with bridging way. Pick up the term in bridging way (as guided by dark bridge line of Fig. 2) from solid rays through sun to dashed rays.



Arrange the terms in the following manner to get the equation. Solid ray term = product of sun terms + dash ray term

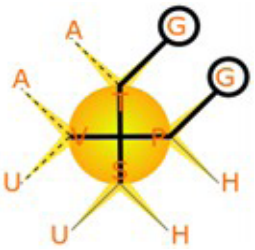
U= ST +A

Other example

Equation	Equation
 H = PV + U G = PV+ A	 U = ST + A H = ST + G

Fundamental integrated thermodynamic equations by Scissoring way

Let us start with Scissoring wayFig. 3. Pick up the term in scissoring way handle to tip (as guided by dark scissor line from handle to arm).

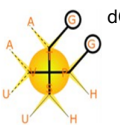
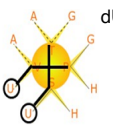
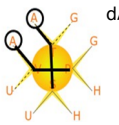
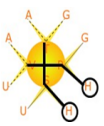


Arrange the terms in the following manner to get the equation.

d (Handle terms) = d (Arm term x Tip term) + d (Arm term x Tip term); if arm terms starts near the dash ray, the sign should be negative.

So, dG = -d(TS) + d(PV)

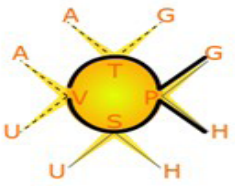
Other example

Equation	Equation
 dG= –d(TS) + d(PV)	 dU= –d(VP) + d(ST)
 dA= –d(TS) –d(PV)	 dH= d(ST) + d(PV)

Maxwell relation of thermodynamic potential and state variable

Let us start with Fishing way Fig. 4. Pick up the term in Fishing way from tail to mouth (as guided by dark line from tail to mouth).

Fish



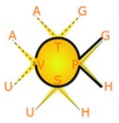
Arrange the terms in the following manner to get the equation.

[d(Tail ray term)/d(first Sun term)]$_{(abdomen\ term)}$ = Mouth term; if tail terms are at dash ray it should be written with – ve sign.

$(dG/dP)_T = V$ -----(1)

$(dH/dP)_s = V$ -----(2)

From (1) and (2), $V = (dG/dP)_T = (dH/dP)_s$

Equation	Equation
 $\left(\frac{dG}{dP}\right)_T = V$ $\left(\frac{dH}{dP}\right)_S = V$ $V = \left(\frac{dG}{dP}\right)_T = \left(\frac{dH}{dP}\right)_S$	 $-\left(\frac{dU}{dV}\right)_S = P$ $-\left(\frac{dA}{dV}\right)_T = P$ $P = -\left(\frac{dU}{dV}\right)_S = -\left(\frac{dA}{dV}\right)_T$
 $\left(\frac{dU}{dS}\right)_V = T$ $\left(\frac{dH}{dS}\right)_P = T$ $T = \left(\frac{dU}{dS}\right)_V = \left(\frac{dH}{dS}\right)_P$	 $-\left(\frac{dG}{dT}\right)_P = S$ $-\left(\frac{dA}{dT}\right)_V = S$ $S = -\left(\frac{dG}{dT}\right)_P = -\left(\frac{dA}{dT}\right)_V$

Maxwell relations of state variable

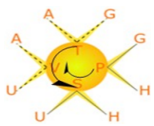
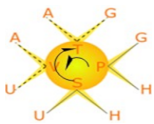
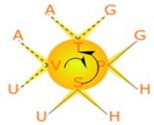
Let us start with swirl wayFig. 5. There is two type of swirl named (1) up directed swirl (2) down directed swirl. In every swirl, pick up the state term from sun region in two counter ways (as guided by dark line) such that first counter cover vertical half terms of Sun (called vertical swirl) whereas second counter way cover horizontal half terms of Sun (called horizontal swirl).

Swirl

Arrange the terms in the following manner to get the equation.

[d(First vertical swirl term)/d(Second vertical swirl term)]$_{(Third\ vertical\ swirl\ term)}$ = [d(First horizontal swirl term)/d(Second horizontal swirl term)]$_{(Third\ horizontal\ swirl\ term)}$.

If initial two continuous terms swirl near the dash rays then the derivative sign will be negative.

Down directed Swirl	Equation	Up directed Swirl	Equation
	$-\left(\frac{dT}{dV}\right)_S = \left(\frac{dP}{dS}\right)_V$		$\left(\frac{dS}{dV}\right)_T = \left(\frac{dP}{dT}\right)_V$
	$\left(\frac{dT}{dP}\right)_S = \left(\frac{dV}{dS}\right)_P$		$\left(\frac{dS}{dP}\right)_T = -\left(\frac{dV}{dT}\right)_P$

CONCLUSION

Fishing with scissors mnemonic is presented which is easier, flowing and free from the direction/sign related difficulties. This mnemonic covers wide range of formula as fundamental thermodynamic equations, Maxwell relations of thermodynamic potentials with state variable and Maxwell relations of state variable.

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REFERENCES

1. Born, Max. “Lecture on Maxwell’s Relations”, Gottingen Lectures on Thermodynamics., **1929**.
2. Callen, H.B. Thermodynamics, Wiley, New York., **1960**, 117-121.

3. Christle, D.E. Multipurpose Mnemonic for Thermodynamic Equations, *Am. J. Phys.,* **1957**, *25*, 486.
4. Fox, R. F. J. The thermodynamic cuboctahedron, *Chem. Educ.*, **1976**, *53*, 441-442 Koening, F. O. Families of Thermodynamic Equations. II. The Case of Eight., **1972**.
5. Characteristic Functions, *J. Chem. Phys.*, **1972**, *56*, 4556.
6. Mitchell, G. *Phys. Educ.*, **1991**, *26*, 145.
7. Pate, S. F. The thermodynamic cube: A mnemonic and learning device for students of classical thermodynamics, *Am. J. Phys.,* **1999**, *67*, 1111.
8. Rao, Y. V. C. Postulational Allied Publishers, Mumbai, India., **1994**, 107.
9. Isihara, M. Cubic Relation between Thermodynamic Functions and Natural Variables for Chemical Thermodynamic Systems, *Bull. Chem. Soc. Jpn.*, **1986**, *59*, 2932.
10. Zemansky, M.V. McGraw-Hill, New York. Zhao, J.C. **(2009)** MRS BULL., **1968**, *34*, 92-94.