Scientific Reflection on The Big Bang Theory

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Abstract

This write-up describes structured, iterative manner in the examination of the thought processes, methodologies and outcomes in the establishment of principles and empirical evidence in the analysis of the Big Bang theory. The objectives, hypotheses and results are reviewed in the perspective of Chemistry, using the principles of thermodynamics. The discussion explains the spontaneous splitting that creates the emission of molecules and gives rise to equilibrium processes. This work reports the assessment of chemical equilibrium processes through thermodynamic parameters such as: pressure, P, temperature, T, volume, V, Gibb's free energy, G, reaction quotient, Q and equilibrium constant, K. The equilibrium constant, K, is predictive of the reaction advances or recesses. Thus: K > 0 = forward reaction, K < 0 = reverse reaction and K = 0 shows equilibrium condition. The magnitude of K determines the degree to which any reaction proceeds under the given conditions. Large values of K show that the product concentration is high, relative to the reactants. Thus, the reaction favours the product concentration and vice versa. The magnitude of K is a function of the product formation.

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Introduction
The Big-Bang Theory
The Big Bang cosmological model explains the observable universe from the earliest known periods through subsequent evolutions. The theory defines the origin of the universe from the initial formations to modern-day evolutions. The universe started from the state of high density and high temperature and began to cool down

in order to allow the formation of particles that would become atoms after the first phase of expansion. Elements such as: Hydrogen, Helium, Lithium, etc., condensed through gravity and formed the early stars and galaxies. The theory defines only the size of the observable universe. The universe began as infinitely small, hot, dense point, which rapidly expanded and stretched over about 13.8 billion years. This initial rapid inflation set the stage for the vast and still-growing cosmos that exists today. Through the process of expansion and explosion, Hydrogen gas was created and then the formation and death (supernova) of stars and the creation of life. The laws of Physics explain the singularity of the big bang. The Big Bang models predict a uniform background radiation caused by high temperatures and densities in the distant past. Empirical evidences support the Big Bang activities. After the initial expansion, the universe cooled enough to allow the formation of subatomic particles and atoms. [What does reflection mean in science? - California Learning Resource Network] [What is the Big Bang Theory? | Space] [The Big Bang Theory: Definition, Explanation and Misconception (byjus.com)] [Big Bang - Wikipedia]

The Big Bang Theory is produced from advanced mathematical models and simulations. Everything in the entire universe was condensed in an infinitesimally small singularity, a point of infinite denseness and heat. A sudden explosive expansion began, blowing the universe outwards and faster than the speed of light. When the cosmic inflation stopped, a flood of matter and radiation, described as reheating started filling the universe with particles, atoms, which became the stars and galaxies. Now the cosmos contains fundamental particles such as: neutrons, electrons and protons which are the raw materials that form the building blocks for everything that exists today. The scattering of light by free electrons (Thomson scattering) would have caused light (photons) to scatter the way sunlight scatters from the water droplets in clouds, making the big bang activities visible. Furthermore, these free electrons collide with nuclei and formed neutral atoms, molecules, etc. The Big Bang Theory involves the splitting of matters producing great amount of energy and formation particulates. [was found only by accident almost 20 years later] [What is the Big Bang Theory? | Space]

Established observations such as:
- The Hubble Law
- The properties of the cosmic microwave background radiation (CMB)
- The relative abundances of light elements such as Helium-4 nucleus, Helium-3 nucleus, Lithium 7 nucleus, Deuterium, etc., are evidences for the Big Bang Theory

The Big Bang was an expansion of space itself, as described in the relativity theory. This means that all the distances in the universe stretched out at the same rate. The speed at which the universe is expanding is called the Hubble constant. It describes how the universe changes over time. The big-bang theory describes the origin of the universe. It states that the universe began from an initial point and expanded over billions of years to form the universe as it is today. As the universe expanded, it cooled. Particles such as: protons, neutrons, electrons, etc., began to form. The expansion was followed by nuclear fusion. Elements such as Hydrogen, Helium, Lithium, etc., combine in the process of the big bang nucleosynthesis.[The Big Bang Theory: The Epic Story of the Universe's Birth and Beyond]

However, it is recorded that most of the cosmos is made up of matter and energy that cannot be observed with the conventional instruments. This leads to such concepts as dark matter and dark energy. Also, different values of the Hubble constant are calculated depending on how the expansion of the universe is measured. The difference between the two ways of measuring the expansion of the universe is described as the Hubble tension. These puzzling phenomena of the dark matter and dark energy and the Hubble tension have created the room for further studies on the universe. Furthermore, the steady-state theory predicted that new matter is formed in such a manner that the density and temperature of the universe are constant, even when the universe is expanding. The Big Bang Theory is the scientific definition of the origin of the universe.

What is the Big Bang Theory? How did our universe begin? - Astronomy Explained] The universe has been expanding since the initial activity of the big bang. The expansion created everything the universe has. All matter; energy and the fabric of space were compressed into an infinitely small and dense point before the rapid and big expansion (big bang). The big bang is the story of how time, space, energy, matter and life started. [The Big Bang Theory: The Epic Story of the Universe's Birth and Beyond]

Elements

Thinkers and philosophers have considered the structure of matter since ancient times. Ancient Greeks described the elements as basic substances from which all forms of matter were created. The four types of matter assumed were: earth, air, fire and water. It was believed that these four types of matter could produce all other substances when combined in the right proportions. This concept of element as the building block of other substances is in agreement with science today. However, there are more than one hundred chemical elements which combine in many ways to form matter. The point of consideration was: "what would happen if matter was continuously subdivided into smaller pieces"? Would there be a stage at which it would become indivisible and still be the microscopic matter that contains the same units (atoms) as the whole, or would the subdivision continue forever? It is established that there is a stage at which the subdivision ends. That is, matter cannot undergo continuous sub-division because matter consists of basic tiny particles. The smallest particle of an element that exists is called an atom. Each element has a name and a unique chemical symbol. Another point of consideration was: "where did the elements come from"? All the elements in the universe except Hydrogen and Helium were made in the stars. Seconds after the universe came into being with the Big Bang activity, the only elements present were the simplest ones. After millions of years, as the universe cooled, the atoms of Hydrogen and Helium combine in large clouds under the influence of gravity, to form other bigger atoms. Also, these clouds gradually became hotter as they contracted and in due course burst into incandescence as stars. Within the stars, intense heat causes the atoms of Hydrogen to smash together, merge and become atoms of other elements. When two protons and one or two neutrons merge, the outcome is an atom of Helium with atomic number of 2 and mass number of 3 or 4. When a third proton and more neutrons join them, the outcome is an atom of Lithium with atomic number of 3 and a mass number of 6 or 7, etc. The fusion releases even more heat, which generates starlight [1].

Many years after a star was formed and it began to cool, its outer layer collapsed, like a falling roof, into its exhausted core. The mighty star quake produced great shock waves that the star struck off its outer layers and sent them into space in huge explosion called supernova. Six of the explosions have been detected in the galaxy in the past one thousand years; the most recent was in 1987. The shock of the explosion raised the temperature of the star, making it even brighter than before. The Crab nebula (produced by the supernova of 1054) was visible in broad daylight for three weeks. At high temperatures, the heavy atoms collided violently enough and merge. They become heavier atoms. The heavy elements that exit now, including Uranium and Gold, are formed in the same manner. The debris of exploding stars gradually aggregated under the influence of gravity and gave rise to a new generation of stars. However, all the debris are not collected in a single central body; some are collected into smaller bodies that went into orbit around the star. These bodies are the planets, one of them is the Earth. Matter was formed in this way from long-dead stars. Hydrogen and Helium were formed from the Big Bang. The heavier elements were made inside stars and then scattered throughout space as elements. The underlisted scientific evidence and parameters became manifest, such are: [1].

Compounds

Chemistry is the study of particles, atoms, elements or matter and its changes in many conditions. The smallest particle of an element that exists is called an atom. An element is a substance composed of only one kind of atom. Elements could be described as basic substances from which all forms of matter are built. Matter is any substance that has mass and takes up space. Generally, matter is composed of various combinations of the simplest form of elements. The substances around are combinations of elements rather than single element.

A compound is a substance that contains more than one element in a definite ratio. Water is a compound that contains an elemental Hydrogen and Oxygen; with two Hydrogen atoms for each Oxygen atom. Common salt (Sodium Chloride) is a compound too. It contains one Sodium atom for each Chlorine atom. Every compound shows specific ratio of combination of atoms. Compounds are classified as either organic or inorganic. The elements in a compound are not just mixed together but are bonded to one another in a specific ratio. The atoms of a compound are bonded to form molecules. An ion is a positively or negatively charged atom or molecule. Compounds consist of molecules which are either neutral or charged [1,2].

Chemical Systems

The Universe is the World because it is limitless, it is beyond the scope of thermodynamic consideration. Some thermodynamic limits are defined as follows: A thermodynamic system is the part of the universe set out for the purpose of experimental study. The immediate vicinity which can interact in one way or the other with the system is the surrounding. A thermodynamic process is any continued set of transformations of matter which involves the exchange of energy of a system. A chemical process shows the influence of both the extensive and intensive variables which make the accomplishment of a change possible. A change in a property of a system confirms that the process is achieved. A chemical system is the portion of matter which consists of components which interact within specified boundaries and is being studied for changes in its chemical reactions and properties. The components of the system could be elements, compounds, mixtures, etc. The interactions within the components of the system drive the system towards equilibrium or dynamic states. Chemical systems give the framework for analyzing and understanding the behaviour of matter at the molecular level. [chemical system - Search] [3].

Assessment of the Energy of Chemical Systems

Work and heat are thermodynamic functions which describe the transfer of energy from one system to another. Heat (q) is defined as the quantity of energy that flows across the boundary of a system during a change in its state, by virtue of the difference in temperature between the system and its surroundings. Energy flows from the point of higher to lower temperature. Work (W) is the form in which energy is transferred across the boundary by the displacement of some parts of the system by the action of an external force. A system is described by energy change which comes from either work done or heat acquired. The energy of a chemical system is determined by the principles of thermodynamics which describe how energy is stored, transformed and transferred during chemical reactions. [energy of chemical systems - Search] [1-7].

Internal Energy (E)

Each body (matter) has an amount of energy by virtue of its position in the universe. This intrinsic energy is the potential energy defined as the energy by virtue of the body's position at rest. Increase in temperature of anybody at rest increases the potential energy by the amount of heat gained. The heat energy gained increases the internal energy, E_i at rest to a higher energy, E_f. This change of energy, $\Delta E = E_f - E_i$, at constant volume is called the internal energy change, ΔE of the body. The total energy of a system is the internal energy. It is the sum of the potential energy plus the kinetic energies of all the particle due to the interactions within the system. [1-7].

First Law of Thermodynamics

The first law of thermodynamics defines the law of conservation of energy which states: Energy is neither created nor destroyed in any process but is transformed from one form to another. Energy is the capacity of a system to do work. When a system is heated to gain a quantity of heat, q, the heat acquired will raise the internal energy of the system and also do external work. The increase in the internal energy is given as dE and the work done is dW. The first law of thermodynamics states: The heat change in a system is equal to the change in internal energy and the work obtained from the system. The first law of thermodynamics is expressed as:

$$dq = dE + dW \qquad\qquad 1.1$$

Enthalpy (H)

Enthalpy of a system is defined as the sum of its internal energy and the product of its pressure and volume. [enthalpy of the system - Search] The only work obtainable from a chemical system is the pressure-volume (P-V) work which comes from expansion or contraction of the volume of the system. Work done under constant volume is 0 (zero). Thus,

$$dW = PdV = 0 \text{ since } dV = 0 \qquad\qquad 1.2$$

$$\text{Eq. 1.1 becomes:} \qquad dE = (dq)_v \qquad \text{at constant volume} \qquad 1.3$$

$$\Delta E = (q)_v \qquad\qquad 1.3A$$

Equation 1.3 and 1.3A show that the change in the internal energy is equal to the heat gained at constant volume. Internal energy change is not a measurable quantity. It is calculated through any change in the system. Heat change at constant pressure is described as enthalpy (H).

$$dH = dE + PdV \qquad\qquad 1.4$$

(Where E is the internal energy, P and V are the pressure and volume of the system respectively.) [1-7].

The standard enthalpy change of formation is the standard enthalpy of reaction for the formation of the substance from the elements in their standard states. The change of standard enthalpy of any reaction is therefore the standard enthalpy of formation of the products minus the standard enthalpy of formation of the reactants [I-7].

$$\Delta H^o rxn = \sum Hi^o \text{ (Products)} - (\sum Hi^o \text{ (Reactants)}) \qquad\qquad 1.5$$

Bond Enthalpy (H_B)

Energy is given out when atoms combine to form molecules. Also, the equivalent amount of energy is consumed for the molecule to break into atoms. The bond dissociation energy is the amount of energy needed to break a diatomic molecule. Bond energy is characteristic of the particular bond. It is a measure of the bond strength. [1-7]

Entropy (S)

The first law of thermodynamics does not define the ease or extent of energy convertibility in a system. The total heat cannot be converted to work without leaving permanent changes either in the system or its surroundings. This suggests that some of the heat is retained by the system. Entropy defines the extra change other than the work done. Entropy is a measure of the disorderliness of a system. The spontaneity of a chemical reaction is determined by the entropy. Entropy is used to determine the spontaneity of reactions towards the formation of compounds. All naturally occurring processes tend to change spontaneously in a direction which will lead to increase in entropy. Second law of thermodynamics states that ''all processes in nature tend to occur only with an increase in entropy and the direction of change is always such as to lead to the entropy increase.'' The differential expression of the entropy is given by: [1-4]

$$dS \qquad = \qquad dq_{rev}/T \qquad\qquad 1.6$$

(where q = heat, T = temperature)

Thermodynamic Functions

These are variable parameters used to describe the state of the system. They are state functions.

Gibb's Free Energy (G)

Gibbs' free energy is the measure of the driving tendency that accompanies any processes.

$$G = H - TS \qquad\qquad 1.7$$

(where H is enthalpy)

G is used for the prediction of the commencement, of a reaction.

Treatment of Gibb's Free Energy

$$aA + bB \leftrightharpoons mM + nN \qquad\qquad 1.8$$

The Gibb's free energy of the reactants and products of the process in Eq. (1.8) is:

$$G_{(reactants)} = G^0_R + RT\ln a_A{}^a a_B{}^b \qquad\qquad 1.9$$

$$G_{(products)} = G^0_P + RT\ln a_M{}^m a_N{}^n \qquad\qquad 1.10$$

The change in Gibb's free energy at any temperature for Eq.1.8 is:

$$\Delta G = \Delta G^0 + RT\ln a_M{}^m a_N{}^n / a_A{}^a a_B{}^b \qquad\qquad 1.11$$

But

$$K = a_M{}^m a_N{}^n / a_A{}^a a_B{}^b \qquad\qquad 1.12$$

Therefore,

$$\Delta G = \Delta G^0 + RT\ln K_a \qquad\qquad 1.13$$

K_a is the activity equilibrium constant obtained from the ratio of activities of the products over the activities of the reactants.

Chemical Equilibrium

Chemical reaction equilibrium is the stage of a system when there is no tendency for the composition to change. All chemical equilibria are dynamic, with the forward and reverse reactions occurring at the same rate. Chemical equilibrium is considered as the state of a system in which the rate of disappearance of the reactants to form products is equal to the rate at which the products interact to reform the reactants. [1,3] [Introduction to Chemical Equilibrium - Chemistry LibreTexts, Chemical Equilibrium: Definition, Principles, and Examples, chemical equilibrium - Search]

Reaction Advances of a Chemical Process: the Law of Mass Action

The driving force for a chemical change is related to the masses of the active species involved in the chemical reaction through the law of mass action which states: The driving force of a chemical reaction is proportional to the active masses of the reacting species [3].

Thus: Rate of chemical change $\propto$ concentration of reacting species

$$\text{Rate} \propto C_A . C_B \text{ (in Eq. 1.15)} \qquad\qquad 1.14$$

Assuming that A and B are the reacting species of concentration C, for a generalized chemical reaction;

$$aA + bB \leftrightharpoons cC + dD \qquad\qquad 1.15$$

By the law of mass action, the forward reaction shows:

$$\text{Rate} \propto C_A{}^a . C_B{}^b \qquad\qquad 1.16A$$

or

$$\text{Rate} \propto [A]^a[B]^b \qquad\qquad 1.16B$$

Similarly, the reverse reaction becomes:

$$\text{Rate} \propto C_C{}^C . C_D{}^d \qquad\qquad 1.17A$$

or
$$\text{Rate} \propto [C]^c[D]^d \qquad\qquad 1.17B$$

Removing the proportionality constants from Eqs 1.16 & 1.17 gives the following:
$$R_f = K_f[A]^a[B]^b \qquad\qquad 1.18A$$

$$R_b = K_b[C]^c[D]^d \qquad\qquad 1.18B$$

R_f and R_b correspond to the rates of forward and reverse reactions respectively and (K_f and K_b) are the proportionality constants for the same.
At equilibrium, rate of forward reaction is equal to rate of reverse reaction.

i.e. $\qquad\qquad R_f = R_b \qquad$ (at equilibrium) $\qquad\qquad 1.19$

$$K_f[A]^a[B]^b = K_b [C]^c[D]^d \qquad\qquad 1.20$$
and
$$K_f/k_b = [C]^c[D]^d/[A]^a [B]^b = K \qquad\qquad 1.21$$

K is the equilibrium constant.
Equilibrium constant shows at a glance whether a reaction mixture contains a high concentration of product at equilibrium or a small concentration. It predicts the direction in which the reaction will go. The information also shows whether an industrial process will produce enough products to be worthwhile. Equilibrium constant shows nothing about the rate at which equilibrium is reached [1, 3].

Reaction Advances: Reaction Quotient (Q)

Reaction quotient is also another parameter that predicts whether an arbitrary reaction mixture forms more products or decomposes into reactants. Reaction quotient is defined in the same way as the equilibrium constant but with the molar concentrations to give Q_C or partial pressure to give Q_P, at any stage of the reaction. Reaction quotient is a pure (unitless) number, in the same manner as K. Reactions have the tendency to form products if Q < K; and to form reactants if Q > K. When Q = K, then the mixture has its equilibrium composition and has no tendency to change in either direction.

Equilibrium Constant (K) as a Parameter for Predicting Advances of Industrial Processes
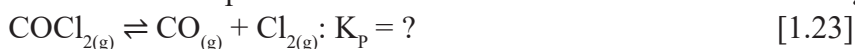Consider the Phosgene formation/dissociation as shown below.
The formation of Phosgene from Chlorine and Carbon monoxide has an equilibrium constant
$$K_P = 26.0 \text{ at } 393°C \text{ [1]}.$$

Thus: $\qquad\qquad CO_{(g)} + Cl_{2(g)} = COCl_{2(g)}: K_P = 26.0 \qquad\qquad [1.22]$
The degree of dissociation of Phosgene at the same temperature is calculated below. Dissociation of Phosgene:
$$COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}: K_P = ? \qquad\qquad [1.23]$$
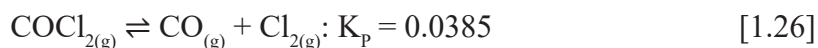
The formation equilibrium constant (K_P) = 26.0.[1]
$$K_{\text{forward reaction}} = 1/K_{\text{reverse reaction}} \text{ [3]} \qquad\qquad [1.24]$$

$$K_r = 1/K_f = 1/26.0 = 0.0385 \qquad\qquad [1.25]$$

Let $\propto$ = yield/degree of dissociation.
Assuming 1 mole of Phosgene:

$$COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}: K_P = 0.0385 \qquad\qquad [1.26]$$

Let $COCl_{2(g)} = n(1-\alpha)$, $CO_{(g)} = n\alpha$ and $Cl_{2(g)} = n\alpha$

Total number of moles, $n_t = n(1-\alpha) + 2n\alpha = n(1+\alpha)$ [1.27]

Assuming total pressure, P at equilibrium; the partial pressures are:

$$P_{COCl2(g)} = (n_{COCl2(g)}/n_t)P = [(1-\alpha)/(1+\alpha)]P \qquad [1.28]$$

$$P_{Cl2(g)} = (nCl_{2(g)}/n_t)P = [\alpha/(1+\alpha)]P \qquad [1.29]$$

$$PCO_{(g)} = (nCO_{(g)}/n_t)P = [\alpha/(1+\alpha)]P \qquad [1.30]$$

The definition of K_P for the dissociation reaction Eq. 1.26 is given as:

$$K_P = P_{CO(g)} \times P_{Cl2(g)}/P_{COCl2(g)} \qquad [1.31]$$

$$= [\alpha/(1+\alpha)]P \times [\alpha/(1+\alpha)]P / [(1-\alpha)/(1+\alpha)]P \qquad [1.32]$$
$$= (\alpha^2 P)/\frac{1-\alpha}{1+\alpha} \qquad [1.32]$$

$$K_P = (\alpha^2 P) / (1-\alpha^2) \qquad [1.32]$$

The State of Gases in Relation to the Pressure-Volume-Temperature Relationship

The empirical relation which describes the state of the gas to changes in pressure, volume and temperature as defined in the gas laws is given as:

$$PV = KT \qquad [1.33]$$

(where K is a mathematical constant with physical significance) [1] K is independent of the nature of the gas but depends on the pressure, volume and temperature, represented as:

$$K = PV/T \qquad [1.34]$$

K is proportional to the number of moles (n) of the gas.

Thus, $K = nR$ [1.35]

(where n is the number of substance of the gas occupying the volume (V) at pressure (P) and temperature (T). R is the universal gas constant for all gases.

Hence, $PV = (K)T = (nR)T$ [1.36A]

i.e. $PV = nRT$ [1.36]

Following the Phosgene formation/dissociation, Eq (1.26),

$$K_p = 0.0385$$
$$= 0.5 \text{ atm}$$

Assuming P

Then,

$$(\alpha^2 P)/(1-\alpha^2) = 0.0385$$
$$0.5\alpha^2 = 0.0385 - 0.0385\alpha^2$$
$$0.5\alpha^2 + 0.0385\alpha^2 = 0.0385$$
$$0.5385\alpha^2 = 0.0385$$
$$\alpha^2 = 0.0385/0.5385$$
$$\alpha^2 = 0.0715$$
$$\alpha = 0.2674$$

$$K_P = 0.0385$$

Assuming P $\quad$ = 1.0 atm

Then,

$$(\alpha^2 P)/(1 - \alpha^2) = 0.0385$$
$$\alpha = 0.1926$$

$$K_P = \quad 0.0385$$

Assuming P = 1.5 atm

Then,

$$(\alpha^2 P)/(1 - \alpha^2) = 0.0385$$
$$\alpha = 0.1581$$

$$K_P = 0.0385$$

Assuming P $\quad$ = 2.0 atm

Then,

$$(\alpha^2 P)/(1 - \alpha^2) = 0.0385;$$
$$\alpha = 0.1375$$

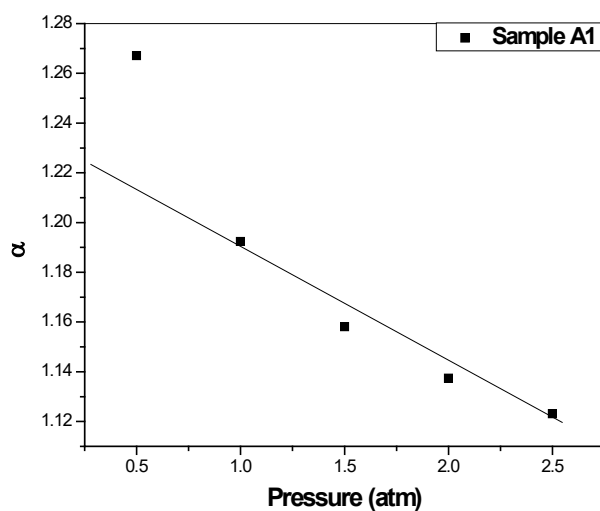$$K_P = 0.0385$$

Assuming P = 2.5 atm

Then,

$$(\alpha^2 P)/(1 - \alpha^2) = 0.0385$$
$$\alpha = 0.0152$$

Variation of pressure with the degree of yield/dissociation in Phosgene

Temperature Effects for the Advances of Reaction

Equilibrium constant (K) depends on temperature. The formation of products is favoured by lowering the temperature, in exothermic reactions. Conversely, products' formation is favoured by an increase in temperature in endothermic reactions. These observations are consistent with the Le Chatelier's principle. Also, K_a and K_p are constants at constant temperature. Consequently, their magnitudes vary as the temperature is changed. The standard Gibb's free energy is defined as:

$\Delta G^o = -RTlnK_a$ [1.37]

$lnK_a = -\Delta G^o/RT$ [1.38]

Differentiating Eq. (1.38) w.r.t. T gives:

$d(lnK_a)/dT = -1/R \times d(\Delta G^o/T)/dT$ [1.39]

By definition, $\Delta G^o = \Delta H^o + T\Delta S^o$ [1.40]

Dividing through Eq. (1.40) by T gives:

$(\Delta G^o)/T = \Delta H^o/T + \Delta S^o$ [1.41]

Differentiating Eq (1.41) w.r.t. T gives:

$d/dT(\Delta G^o)/T = -\Delta H^o/T_2$ [1.42])

Substitution of Eq. 1.39 into Eq. 1.42 gives:

$d(lnKa)/dT = \Delta H^o/RT_2$ [1.43]

Eq. (1.43) describes the temperature coefficients of lnK_a in terms of the heat of reaction and the enthalpy (H). Consider reactions in which gases are involved.
Let $K_a = K_p$ [1.44]
Therefore, $d(lnK_p)/dT = \Delta H^o/RT_2$ [1.45]

Temperature effect on K_p

Integration of Eq. (1.45) between pressure $K_p{}^1$ and $K_p{}^2$ as the temperature changed from T_1 to T_2 gives:

$$\int^{Kp1}_{Kp2} d(lnKp) = H^0/R \int^{T1}_{T2} dT/T_2 \qquad [1.46]$$

i.e.

$$lnK_{p1}/K_{P2} = \Delta H^o/RT \times (T_2-T_1)/T_1T_2 \qquad [1.47]$$

Also;

$$\int d(lnKp) = \Delta H^0/R \int dT/T \qquad [1.48]$$

$$ln(Kp) \qquad = -\Delta H^o/R(1/T) + C \qquad [1.49]$$

Equation (1.49) is used to determine graphically the various values of $ln(K_p)$ and $(1/T)K$, in which case, the slope of the plot is: $-\Delta H^o/R$
Hence, $\Delta H^o = 2.303 (-R) \times$ slope of the plot.

Enthalpy of a Chemical Process
From the First law of thermodynamics:
$\Delta H = \Delta E + P\Delta V$ [1.50]

Equation (1.50) gives the change in enthalpy of a system at constant pressure. ΔH is the heat acquired by the system in going from the initial to final state, for the pressure-volume work. Heat gained on the part of the system is positive (+ve) while the heat loss is negative (-ve). When the heat change in a system is $q > 0$, then $\Delta E > 0$ and $\Delta H > 0$. These conditions mean absorption of heat by the system. Again, when the heat change in a system is $q < 0$, then $\Delta E < 0$ and $\Delta H < 0$. This condition shows removal of heat from the system; there are decreases in E and H of the system. [1-8].

Conclusion

Chemical processes could be defined as the extension of the big bang activities happening in the laboratories, industries and in the unguarded everyday processes. The descriptive effects of entropy, internal energy, Gibb's free energy, etc., describe the spontaneous activities as seen in nature. These phenomena are harnessed for optimum effects in realities.

Equilibrium parameters give information on reaction advances. The following parameters are used in studying advancements in processes. They are: reaction quotient, equilibrium constant, entropy, Gibb's free energy, temperature effects, pressure/volume effects, etc. Entropy predicts spontaneity of chemical processes, $\Delta S > 0$ shows spontaneity and irreversible processes, $\Delta S < 0$ shows non-spontaneity and irreversible processes and $\Delta S = 0$ shows equilibrium and reversible processes. Gibb's free energy predicts commencement of a reaction but not advancement. When $\Delta G < 0$, the process is feasible, when $\Delta G > 0$, the process is not feasible, when $\Delta G = 0$ there is equilibrium. On the other hand, the equilibrium constant illustrates the advancement of a reaction. The magnitude of the equilibrium constant shows the extent to which any reaction proceeds under the applied conditions. Reaction quotient, Q, is a descriptive of the equilibrium constant. Reactions have the tendency to form products when $Q < K$ and to form reactants if $Q > K$. When $Q = K$, the reaction mixture has equilibrium composition.

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