

Stability in Liquid Phases of Molecular Compounds Composed of Saturated Atoms: Application with the Even-Odd Rule and a Specific Periodic Table for Liquids

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Abstract

Building on the idea that molecules in liquid phase associate into multi-molecular complexes through covalent bonds, the present article focuses on the possible structures of these complexes. Saturation at atomic level is a key concept to understand where connections occur and how far molecules aggregate. A periodic table for liquids with saturation levels is proposed, in agreement with the even-odd rule, for both organic and inorganic elements. With the aim at reaching the most stable complexes, meaning no other chemical reactions can occur in the liquid phase, the structure of complexes resulting from liquefaction of about 30 molecules is devised. The article concludes that complexes in liquids generally assume rounded shapes of an intermediate size between gas and solid structures. It shows that saturation and covalent bonds alone can explain the specific properties of liquids. While it is generally acknowledged that molecular energy in gases and solids are respectively linear kinetic and vibratory, we suggest that rotatory energy dominates in liquids.

Keywords

Liquid Phase, Even-Odd Rule, Molecular Stability, Specific Periodic Table, Saturation, Unsaturated, Rotational Energy, Angular Kinetic Energy

1. Introduction

In classical chemistry, liquids are defined as molecules kept together by intermolecular forces, such as Van Der Waals forces. In a previous article, G. Auvert has postulated that the forces keeping molecules together in liquids could in-

stead result from covalent bonds [1]. The present article forges ahead with the concept that liquids are composed of several gaseous molecules connected to each other by covalent bonds and explores the consequences for structures of molecules in liquids.

For this study, the notion of saturation is essential, because saturation is directly linked to the atoms tendency to establish covalent bonds. Saturation has been defined in various ways in the history of chemistry. At the atomic level, the octet rule, devised by Abegg, Lewis and Langmuir, defines saturation in organic compounds when an atom is surrounded by 8 electrons [2] [3] [4]. By extension, big organic molecules are said to be saturated when no multiple bonds and no ring are present [5]. In 2001, M. Badertscher *et al.* have included charges of atoms in their method to calculate unsaturation numbers [6]. The common agreement is that saturation involves the number of electrons in the outer shells of atoms in compounds. Saturation is linked to the concept of stability: A saturated molecule doesn't react with other molecules and a liquid made of saturated molecules is stable. On a more global scale, a liquid is deemed stable, when no chemical reactions occur within the liquid [7].

In the present paper, a somewhat alternative definition of saturation is given, rendering it applicable to inorganic molecules. The even-odd rule, presented in detail in previous articles [8], is applied to evaluate saturation levels at atomic scales. Saturation levels are summarized in a specific periodic table for atoms, which considers electrical charges of the atoms, the allowed number of bonds, and the organic or inorganic state of the atoms. This periodic table is valid for both gaseous molecules and in liquid phase [9]. This specific table becomes the tool used to systematically evaluate saturation at a molecular level, in liquid phase. About 30 molecules in liquid phase are derived, starting from molecules in gas phase and seeking stable compounds in liquid state.

In the discussion, the shape of the multi-molecular structures is discussed as well as the different cases of overall saturations. The findings shows that the multi-molecular structure of liquids can effectively explain why liquids have specific properties making them distinct from gas and solid phases.

2. Theoretical Bases

First, the present article capitalizes on propositions previously published by the author and recalled hereunder. These are also detailed further in the **Annexes A**:

- Molecular condensation corresponds to the formation of a new covalent bonds between two atoms of two molecules, and reversely the same bond is removed during vaporization [1],
- In gas phases, molecules are electrically neutral at molecular scale [8], and this is extended to liquid compounds [1], therefore ions are not included in this paper,
- When charged, atoms bear a single charge -positive or negative- [10],

- Multiple bonds between atoms are not allowed. Neighboring atoms can therefore only be linked through single covalent bonds [11], represented by one line in the usual manner [12],
- Compounds are noted in capitals as in our previous articles: H₂O is for neutral water [8], H₃O(+) for hydronium [13] also named oxonium, and OH(−) for hydroxide ions [14] and [15] p. 628.
- Atoms are also classified in three groups: inorganic, organic and semi-organic [9].

Note that compounds used in this paper must be stable, therefore, compounds like B₂H₆ which is a rocket propellant, are excluded from this paper.

3. Periodic Table for Atoms of Compounds in Liquid Phase

Table 1. First two rows of a specific “periodic table for saturated and unsaturated liquids compounds”. The left-side column shows saturation level of the atoms. The more saturated an atom of the compound is, the higher it is placed. Hence, the more stable the resulting compound is. The classification in columns of the atoms reflects the numbers of electrons starting from 1 for hydrogen up to 7 for fluorine. The classification of neutral atoms, in columns comes from the classical periodic table. In addition, charged atoms are positioned in the two nearest columns of the neutral atoms. Three groups are high lightened: white cells are inorganic atoms, green cells organic atoms, and yellow cells contain atoms classified as semi-organic atoms. The number of bonds appearing in column 2, indicates how many bonds atoms have when at that saturation level.

Saturation Levels	Numbers of bonds	Electron Numbers	1	2	3	4	5	6	7
0	4 bonds					B(−) C(n) N(+)			
	3 bonds				Be(−)		O(+)		
	2bonds			H(−) Li(−)				F(+)	
-1	3 bonds				B(n)C(+)		C(−) N(n)		
	2 bonds			Be(n)				O(n)	
	1 bond	H(n) Li(n)							F(n)
-2	2 bonds			B(+)		B(−) C(n) N(+)			N(−)
	1 bond	Be(+)			Be(−)		O(+)		O(−)
-3	1 bond				B(n) C(+)		C(−) N(n)		

The disclosed version of the specific “*periodic table for saturated and unsaturated liquid compounds*” specifically focuses on the saturation state of atoms. Apart from this, it is very similar to the periodic table exposed in a previous article by the same author(s) [9]. In the first column, level zero indicates saturated atoms. Levels -1, -2 or -3 indicate unsaturated atoms. In other words, level zero indicates bonding conditions for saturated atoms. For instance, H(−), with two bonds, is saturated. At a lower level, N(n), at level −3, with one bond, is unsaturated.

As an example, in **Table 1**, the oxygen atom is placed in column 5, 6 and 7. The positively charged O(+) has 3 bonds (as in H₃O(+)), neutral O(n) has 2 bonds (as in H₂O), and the negatively charged O(−) has 1 bond (as in OH(−)). Only O(+), with 3 bonds, is saturated, the others are not.

In **Table 1**, atoms without bonds are not mentioned since they do not form compounds. Such atoms, like for instance mono-atomic oxygen, can exist only after dissociation in the gas phase [17], at high temperatures.

The specific “*periodic table for saturated and unsaturated liquid compounds*” shows all possibilities an atom can have to form stable compounds in liquids. This is used to derive possible structures of several stable molecules in the following chapter.

4. Application

Note on three-dimensional representations

For a better understanding of molecular structures, the authors have chosen to use the frontal perspective as illustrated in **Figure 1**, as opposed to the angular perspective representation.

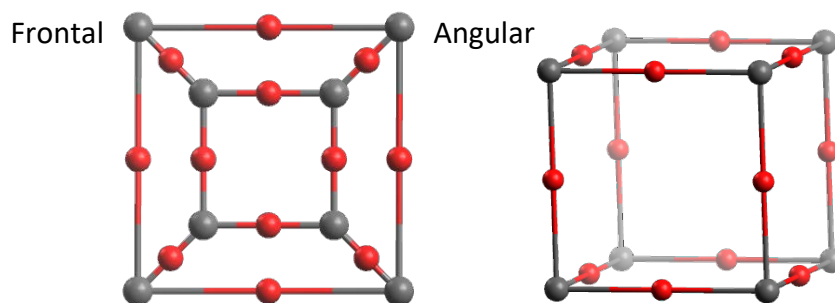


Figure 1. Molecules are represented using the frontal perspective (one vanishing point—left) as opposed to the angular perspective (right). Small spheres are atoms. In between atoms, lines are single-covalent bonds. Red atoms have 2 bonds and grey atoms have 3 bonds. Al_2O_3 can have this representation: O in red with two bonds and Al in grey with 3 bonds.

4.1. Saturated Atoms, or Saturated Compounds

In organic chemistry, an atom is said to be unsaturated only when it does not have multiple bonds. Inversely, compounds containing double or triple bonds are said to be unsaturated [16].

Beyond saturation or unsaturation at the atomic scale, the present paper offers alternative definitions of saturation in liquid compounds. We take the stance that a liquid is saturated when no chemical reactions occur within the liquid. In other words, the liquid is stable. There are two possible ways for a liquid to be stable. First, a compound is obviously saturated when all the atoms composing it are saturated; they have reached level (0) in the “periodic table for saturated and unsaturated liquid compounds” of **Table 1**. Second is when liquid compounds cannot react—*i.e.*, build bonds—with other atoms in the same liquid. This occurs sometimes when compounds have only one type of unsaturated atom at level (−1). Some examples are described in and after **Table 2**.

This concept of saturated compounds in liquids is applied below to more than 30 molecules, to devise the possible structures they have as liquids.

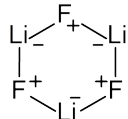
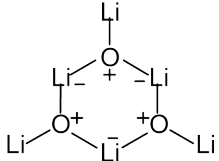
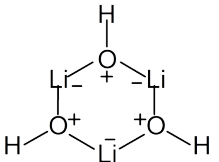
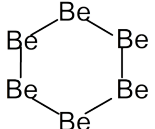
4.2. Molecular Compounds in Liquids

Compounds included in our study were chosen according to few principles, to reduce its magnitude. First, chosen compounds are composed of atoms of the two first rows of the classical periodic table. Second, of liquid compounds containing a maximum of one type of unsaturated atoms. Last, only condensation of gaseous molecules making electrically neutral compounds are considered.

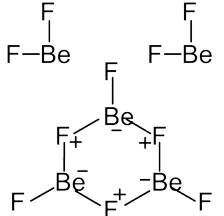
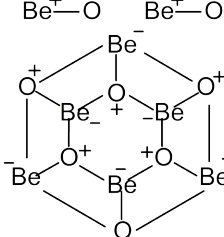
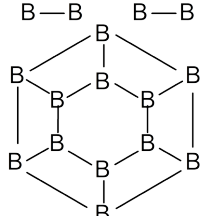
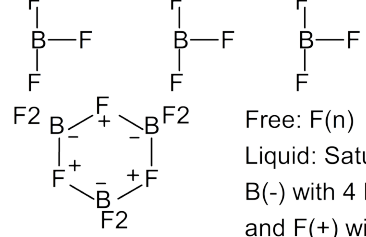
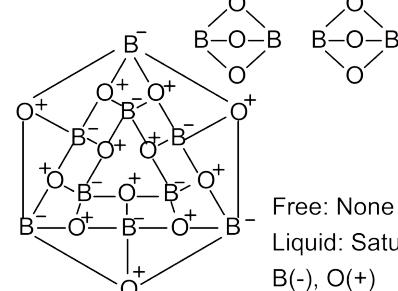
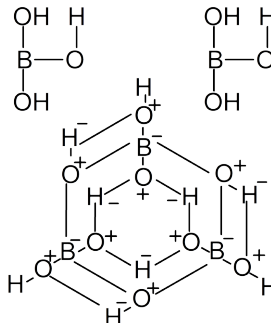
Note that gaseous molecules must be stable, therefore, compounds like H₂O₂, a liquid propellant, are excluded from this paper.

The method used to build **Table 2**, is detailed at the end of this section.

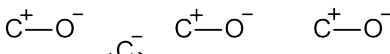
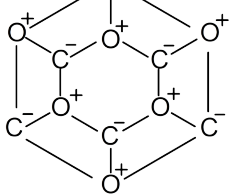
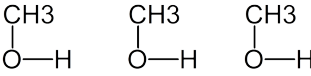
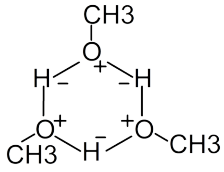
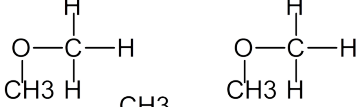
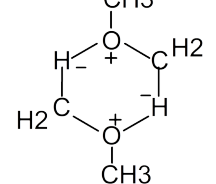
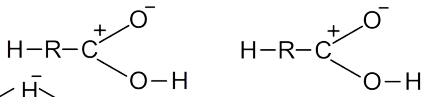
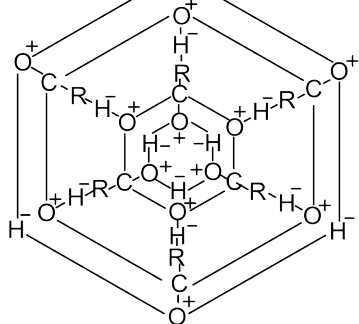
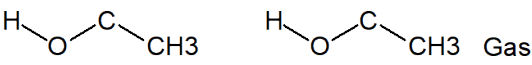
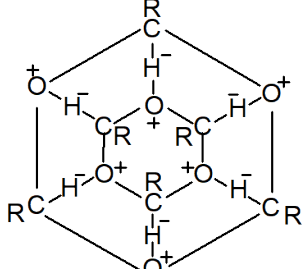
Table 2. Structural study of compounds in gaseous and liquid phases. Column 1 lists names of compounds in gaseous phase. Column 2 indicates the number of bonds and the saturation level of the atoms before and after condensation, and the temperature range of the liquid phase. Column 3 shows structures in the gas phases and saturated compounds in liquid phases using molecules of column 1. Molecules in liquids have more bonds than in the gas phase. Charges are deduced from the “*Periodic table for saturated and unsaturated liquid compounds*” of **Table 1**. In column 2, the saturation level of each atom is given for gas (top) and liquid (below). When the saturation level is zero, the atom is saturated.

Molecules	Liquid °C	Chemistry with covalent bonds
Lithium	Bond/Level	
LiF Lithium Fluoride	Li(n) 1b -1 F(n) 1b -1 845 to 1676 Li(-) 2b 0 F(+) 2b 0	$\text{Li}-\text{F}$ $\text{Li}-\text{F}$ $\text{Li}-\text{F}$ Gas  Free: None Liquid: Saturated Li(-) and F(+)
Li ₂ O Lithium Oxide	Li(n) 1b -1 O(n) 2b -1 1438 to 2600 Li(-) 2b 0 O(+) 3b 0	$\text{Li}-\text{O}-\text{Li}$ $\text{Li}-\text{O}-\text{Li}$ $\text{Li}-\text{O}-\text{Li}$ Gas  Free: Li(n) Liquid: Saturated Li(-) and O(+)
LiOH Lithium Hydroxide	Li(n) 1b -1 O(n) 2b -1 462 to 924 Li(-) 2b 0 O(+) 3b 0	$\text{H}-\text{O}-\text{Li}$ $\text{H}-\text{O}-\text{Li}$ $\text{H}-\text{O}-\text{Li}$ Gas  Free: H(n) Liquid: Saturated Li(-) and O(+)
Beryllium		
Be ₂ Beryllium	Be(+) 1b -2 Be(-) 1b -2 1287 to 2469 Be 2b -1 Be 2b -1	$\text{Be}^{-}-\text{Be}^{+}$ $\text{Be}^{-}-\text{Be}^{+}$ $\text{Be}^{-}-\text{Be}^{+}$ Gas  Free: none Liquid: Only Be(n) 2 bonds

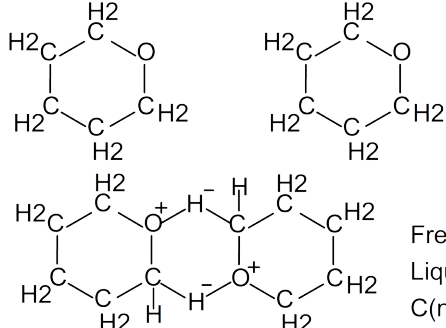
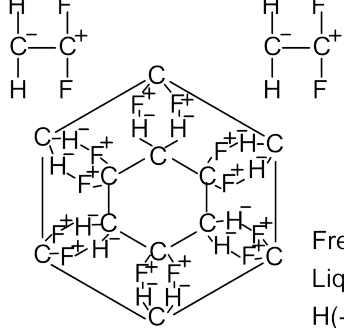
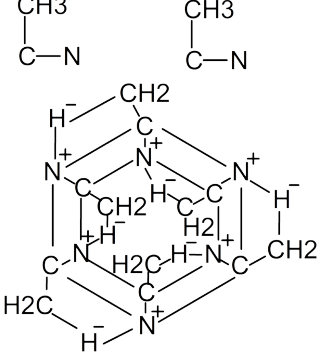
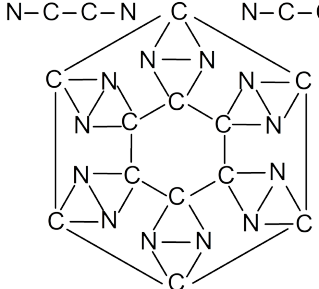
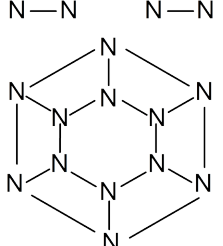
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<p>BeF₂ Beryllium Fluoride</p>	<p>Be(n) 2b -1 F(n) 1b -1 554 to 1169 Be(-) 3b 0 F(+) 2b 0</p>	 <p>Gas</p> <p>Free: F(n) Liquid: Saturated F(+) and Be(-)</p>
<p>BeO Beryllium Oxide</p>	<p>Be(+) 1b -2 O(-) 1b -2 2507 to 3900 Be(-) 3b 0 O(+) 3b 0</p>	 <p>Gas</p> <p>Free: None Liquid: Saturated Be(-) and O(+)</p>
Boron		
<p>B₂ Di-boron</p>	<p>B(n) 1b -3 B(n) 1b -3 2076 to 3927 B(n) 3b -1 B(n) 3b -1</p>	 <p>Gas</p> <p>Free: B(n) Liquid: Only B(n) 3 bonds</p>
<p>BF₃ Boron Trifluoride</p>	<p>B(n) 3b -1 F(n) 1b -1 -127 to -100 B(-) 4b 0 F(+) 2b 0</p>	 <p>Gas</p> <p>Free: F(n) Liquid: Saturated B(-) with 4 bonds and F(+) with 2 bonds</p>
<p>B₂O₃ Boron Oxide</p>	<p>B(n) 3b -1 O(n) 2b -1 450 to 1860 B(-) 4b 0 O(+) 3b 0</p>	 <p>Gas</p> <p>Free: None Liquid: Saturated B(-), O(+)</p>
<p>B(OH)₃ Trihydroxy Borane</p>	<p>O(n) 2b -1 H(n) 1b -1 B(n) 3b -1 171 to 300 O(+) 3b 0 H(-) 2b 0 B(-) 4b 0</p>	 <p>Gas</p> <p>Free: H(n) Liquid: Saturated B(-), O(+) and H(-)</p>

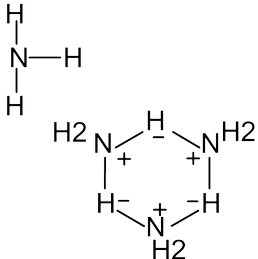
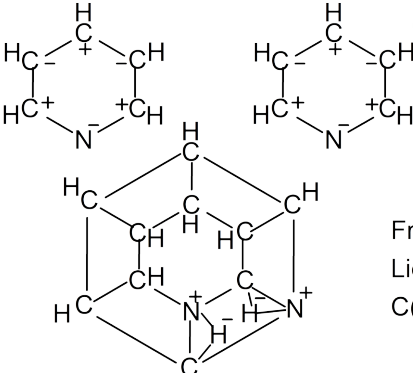
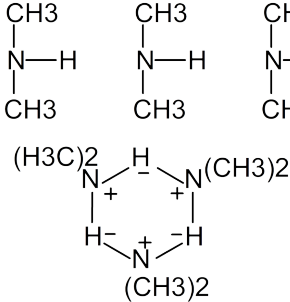
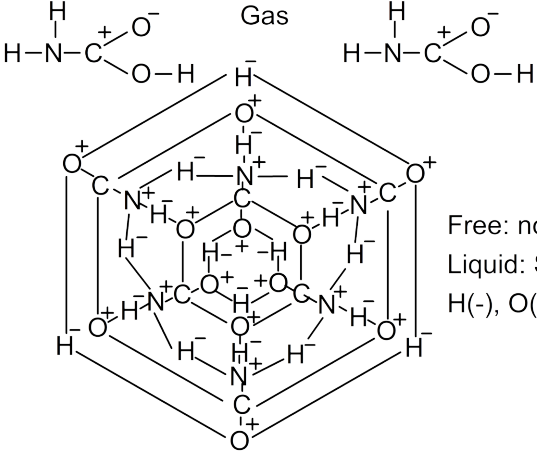
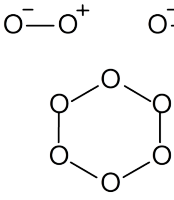
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<p>Carbon</p> <p>CO Carbon Monoxide</p>	<p>C(+) 1b -3 O(-) 1b -2 -205 to -191 C(n) 2b -1 O(n) 2b 0</p>	 <p>Gas</p>  <p>Free: C(-) 3 bonds Liquid: Saturated O(+) 3 bonds</p>
<p>(CH₃)OH Methanol</p>	<p>O(n) 2b -1 H(n) 1b -1 -97 to 65 O(+) 3b 0 H(-) 2b 0</p>	 <p>Gas</p>  <p>Free: H(n) Liquid: Saturated H(-), O(+), C(n)</p>
<p>(CH₃)₂O Dimethyl ether</p>	<p>O(n) 2b -1 H(n) 1b -1 -141 to -24 O(+) 3b 0 H(-) 2b 0</p>	 <p>Gas</p>  <p>Free: H(n) Liquid: Saturated H(-), O(+) and C(n)</p>
<p>CH₃(CH₂)_n COOH Saturated fatty acid</p>	<p>O(-) 1b -2 O(n) 2b -1 C(+) 3b -1 H(n) 1b -1 -20 to 141 O(+) 3b 0 O(+) 3b 0 C(n) 4b 0 H(-) 2b 0</p>	<p>R=(CH₂)_n</p>  <p>Gas</p>  <p>Free: H(n) in R Liquid: Saturated H(-), O(+) and C(n)</p>
<p>(OH)C₂H₃ Ethanal Acetaldehyde</p>	<p>C(n) 2b -2 O(n) 2b -1 H(n) 1b -1 -123 to 20 C(n) 4b 0 O(+) 3b 0 H(-) 2b 0</p>	 <p>Gas</p>  <p>R is -CH₃</p> <p>Free: H(n) Liquid: Saturated C(n), O(+) and H(-)</p>

Continued

<p>(CH₂)₅O Tetrahydro pyrane</p>	<p>O(n) 2b -1 H(n) 1b -1 -49 to 48 O(+) 3b 0 H(-) 2b 0</p>	 <p>Gas</p> <p>Free: H(n) Liquid: Saturated C(n), O(+), H(-)</p>
<p>C₂H₂F₂ Ethylene</p>	<p>C(+) 3b -1 C(-) 3b -1 H(n) 1b -1 F(n) 1b -1 -169 to -104 C(n) 4b 0 C(n) 4b 0 H(-) 2b -0 F(+) 2b 0</p>	 <p>Gas</p> <p>Free: None Liquid: Saturated H(-), F(+) and C(n)</p>
<p>CH₃CN Acetonitrile</p>	<p>N(n) 1b -3 C(n) 2b -2 H(n) 1b -1 -45 to 82 N(+) 4b 0 C(n) 4b 0 H(-) 2b 0</p>	 <p>Gas</p> <p>Free: H(n) Liquid: Saturated C(n) with 4 bonds N(+) with 4 bonds H(-) with 2 bonds</p>
<p>C₂N₂ Cyanogen</p>	<p>N(n) 1b -3 C(n) 2b -2 -28 to -21 N(n) 3b -1 C(n) 4b 0</p>	 <p>Gas</p> <p>Free: N(n) with 3b Liquid: Saturated C(n) with 4 bonds</p>
Nitrogen		
<p>N₂ Dinitrogen</p>	<p>N(n) 1b -3 -210 to -196 N(n) 3b -1</p>	 <p>Gas</p> <p>Free: none Liquid: N(n) 3 bonds</p>

Continued

NH ₃ Ammonia	N(n) 3b -1 H(n) 1b -1 -78 to -33 N(+) 4b 0 H(-) 2b 0	 <p>Free: H(n) Liquid: Saturated N(+) and H(-)</p>
C ₅ H ₅ N Pyridine	C(+) 3b -1 C(-) 3b -1 N(-) 2b -2 H(n) 2b -1 -41 to 115 C(n) 4b 0 C(n) 4b 0 N(+) 4b 0 H(-) 2b 0	 <p>Free: H(n) with 1b Liquid: Saturated C(n), N(+), H(-)</p>
(CH ₃) ₂ NH Dimethyl-amine	N(n) 3b -1 H(n) 1b -1 -93 to 8 N(+) 4b 0 H(-) 2b 0	 <p>Free: H(n) Liquid: Saturated N(+) and H(-)</p>
CH ₃ NO ₂ H ₂ NCOOH Carbamic acid	H(n) 1b -1 C(+) 3b -1 O(n) 2b -1 O(-) 1b -2 -29 to 101 H(-) 2b 0 C(n) 4b 0 O(+) 3b 0 O(+) 3b 0	 <p>Free: none Liquid: Saturated H(-), O(+), C(n), N(+)</p>
Oxygen		
O ₂ Dioxygen	O(-) 1b -2 O(+) 1b -2 -219 to -183 O 2b -1 O 2b -1	 <p>Free: O(n) with 2 bonds Liquid: only O(n)</p>

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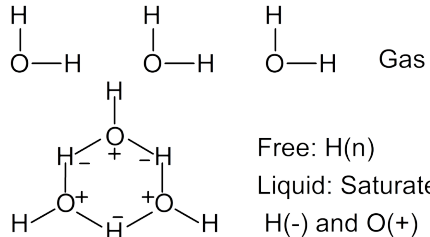
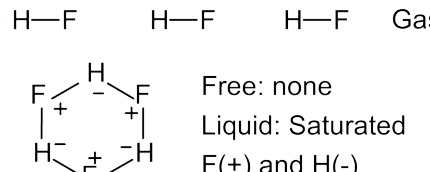
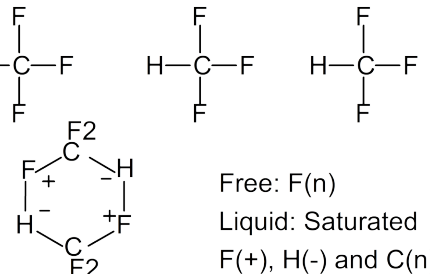
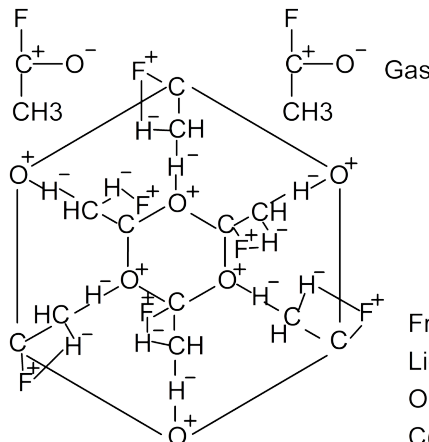
<p>H₂O Water</p>	<p>O(n) 2b H(n) 1b 0 to 100 O(+) 3b 0 H(-) 2b 0</p>	 <p>Gas</p> <p>Free: H(n) Liquid: Saturated H(-) and O(+)</p>
Fluorine		
<p>HF Hydrofluoric Acid</p>	<p>H(n) 1b -1 F(n) 1b -1 -83 to 19 H(-) 2b 0 F(+) 2b 0</p>	 <p>Gas</p> <p>Free: none Liquid: Saturated F(+) and H(-)</p>
<p>Carbonyl fluoride CHF₃ CH₂F₂ CH₃F C₂H₃F</p>	<p>F(n) 1b -1 H(n) 1b -1 -155 to -82 -136 to -52 -138 to -78 -160 to -72 F(+) 2b 0 H(-) 2b 0</p>	 <p>Gas</p> <p>Free: F(n) Liquid: Saturated F(+), H(-) and C(n)</p>
<p>F(CO)CH₃ Acetyl Fluoride</p>	<p>C(+) 3b -1 O(-) 1b -2 H(n) 1b -1 -84 to 21 C(n) 4b 0 O(+) 2b 0 H(-) 2b 0</p>	 <p>Gas</p> <p>Free: H(n) Liquid: Saturated O(+), H(-), F(+) C(n) with 4 bonds</p>

Table 2 shows stable well-known molecules and their structure when forming a liquid. It starts with molecules in the gaseous state. Then, using the “*specific periodic table for liquid compounds*”, of **Table 1**, multi-molecular structures are shown, resulting from aggregation of molecules in liquid phase. These structures achieve both saturation and overall electrical neutrality.

In **Table 2**, gaseous molecules (upper side in column 3) can be divided in two groups. In the first, molecules are composed of neutral atoms. In the second, some atoms are charged in an overall neutral group.

In the first group, the uncharged atoms are at saturation level (-1) in the molecular simplest form. To reach level (0), a covalent bond must be built. This will

lead to a positive charge on organic atoms and a negative charge on the inorganic atoms. For example, the HF molecule can interact with another by forming a new bond between two different atoms (one H with one F which made a H(-) to F(+)) covalent bond with a total neutral charge). Then another HF built a bond and the chain of three HF can form a new bond leaving a hexagonal saturated structure (HF)₃.

In the second group, two steps are needed to reach saturation level (0). Charges must be first neutralized and then saturation level (0) can be reached. For example, in BeO molecules, Be and O are connected and charged (Be(+)) and O(-)). They both erect a new bond to neutralize the charge first with two bonds. O(n) is bonded with Be(n) at saturated level (-1). Then, O(n) and Be(n) becomes Be(-) and O(+), both with 3 bonds at level (0). In this process, all new bonds connect organic atoms to inorganic atoms.

All liquids in **Table 2** are very stable. This is mainly due to the presence of only one sort of neutral atom in liquid compounds. These neutral atoms cannot build other bonds and remain at saturation level (-1). No opportunity to create new bonds means a very stable state.

5. Discussion

The discussion considers how a liquid can be stable without each of the atoms being saturated, what is the kinetic energy in the liquids, which types of gases can make fully saturated liquids and that fully saturated liquids seem to be made from an equal number of organic and inorganic atoms.

5.1. Hexagonal Form

In **Table 2**, the authors chose the hexagon as a shape that the studied compounds could possibly assume. This form is inspired from the hexagonal structure of cyclohexane, but it could be another cyclic structure of more than 6 atoms (cycles of 4 atoms are rarely observed in nature). The saturation level is not modified when the number of atoms increases in the cycle.

5.2. Kinetic Energy in Gas and in Liquid

In phase diagrams of compounds, a triple point is experimentally observed. At that point, gas, liquid and solid co-exist at the same temperature, *i.e.*, with the same energy density. The form of energy in each state is different. In gas, the energy is mostly available as linear kinetic energy. The linear speed is important and the distance between molecules is very high. In a solid, intermolecular distance is very small, and kinetic energy is absent. The energy is present as a harmonic oscillation process. In liquids, the distance is small as in a solid, and linear kinetic energy is reduced. The energy in liquid is rotational kinetic energy. This is understandable by the moment of inertia of the compounds described in **Table 2**, which is bigger in liquids compared to small gaseous molecules.

Consequently, and according to our model, a liquid is not compressible, but it

has a very useful viscosity.

5.3. Homonuclear Compounds in Liquid Phase

In the obtained results, some molecules in liquid phase still host unsaturated atoms, although they are stable on a global scale, such as di-beryllium. In gas phase, Be₂ involves two Beryllium atoms bearing opposite charges, linked through a single bond. This compound liquefies under 2469°C. From the “*periodic table for compounds in saturated and unsaturated liquids*”, both Beryllium atoms in Be₂ are at saturation level (-2). To tend toward saturation, both atoms erect an additional bond and reach saturation level (-1); charges are neutralized. Although Be atoms haven’t reached full saturation, the molecule remains in this state because conditions are not met to reach further saturation levels. To reach full saturation (level (0)), Be atom would have to build another bound but in the process become negatively charged (Be(-) with 3 bonds). Be(-) can however only bond with a positively charged atom, which would be at this point unavailable. Hence with Be atoms at levels (-1) and two bonds, (Be₂)₃ in liquid phase is stable, and forms a saturated liquid made of unsaturated atoms.

For the authors, the same reasoning process applies to Be, B, N and O diatomic molecules. These atoms would all liquefy with their atoms bonding with an additional atom, thus remaining at saturation level (-1). They probably form rings of 6 atoms or more and remain stable if they remain pure.

The same does not apply to lithium and fluorine which do not made bonds with Li(+) and F(-), and which are located at both ends of row 2 in **Table 1**.

5.4. Specific Case

The case of carbon differs slightly from the formers, although it hosts unsaturated atoms in its higher saturation level (-1). Since it is a semi-organic atom, as shown in **Figure 2**, atoms in C₂ start at saturation level (-3), then reaches saturation level (-2) by bonding with additional atoms and losing its charge (illustration as a hexagon, but it could be a wider polygon). The stable configuration is at the saturation level (-1), with three bonds and with charges.

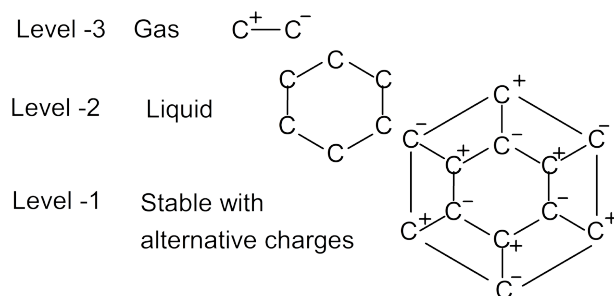


Figure 2. Carbon atoms are always unsaturated.

In some physical conditions, at high pressure above 0.1 GPa and high temperature above 4600°C a nearly liquid phase composed of chain with molecule of

level (-1). This compound is not forming a similar liquid as the other gas used in **Table 2**.

5.5. Heteronuclear Compounds

Consider LiF, a compound made with two neutral atoms at saturation level (-1) in the gas phase in **Table 2**. LiF exhibits one bond between two neutral atoms. This molecule can form a new bond with Li(-) and F(+) resulting in the compound (LiF)₃. There are 3 negative charges with the inorganic Li atoms, and 3 positive charges in the organic F atoms. As shown in **Table 2**, this compound is neutral and fully saturated.

5.6. Complex Compounds

NCCN is an example of a compound with only neutral atoms. N(n) has one bond (level (-3)), and C(n) has two bonds (level (-2)). After two bonding steps, both become neutral, C with four bonds and N with 3 bonds. C is saturated, but N remains at saturation level (-1). This compound is stable in liquid phase, having only one type of neutral atoms (nitrogen) which is unsaturated.

5.7. The Role of Organic and Inorganic Atoms

In **Table 1**, except with carbon atoms, fully saturated atoms are never neutral; they either bear a negative or a positive charge. As a compound must be neutral overall, a fully saturated molecule must be composed of organic and inorganic atoms. According to examples of **Table 2**, only less than one type of atoms is possible at level (-1) to have a liquid. Without counting these atoms, the number of other atoms must be equal in both groups (organic and inorganic). For example, in liquid BF₃, there are 3 negative Boron and 3 positive fluor atoms (same in NH₃). This compound is globally neutral with the charges on both group: organic and inorganic.

The authors propose that this constatation of alternating organic and inorganic atoms as shown in **Table 2**, can be generalized as a rule. For example, in (Be(OH)₃)₃.

Another property available in **Table 2**, is about the succession of organic and inorganic charged atoms. The smallest liquid is for HF, the first in **Table 2**. In it, The F(+) is only connected to H(-), and H(-) only to F(+). For bigger compounds in the gas phase, H(-) with two bonds are connected to organic N(+) or O(+). Reversely, N and O are connected to H. In the liquid phase, organic is never connected to another organic (except as previously described when having only one sort of atoms).

The authors also propose that this observation in **Table 2**, can be generalized as a rule.

6. Conclusions

Building on the idea that molecules in liquid phase associate into multi-molecular

complexes through covalent bonds, as published in previous works, the present article focuses on the possible structures of these complexes. During liquefaction, unsaturated atoms in gaseous molecules establish bonds with other molecules to form bigger rounded-shaped complexes. A “*specific periodic table for atoms*” indicating saturation levels in relation to the number of bonds and its local charge is presented, as a tool to systematically predict what atom is most likely to establish bonds. This table is valid for organic and inorganic elements. With the aim at reaching the most stable complexes, meaning no other chemical reactions can occur in the liquid phase, the structure of complexes resulting from liquefaction of about 30 molecules is presented.

Several findings emerge from this study. Firstly, some complexes reach full saturation, meaning that the resulting liquid is very stable, while others remain partially unsaturated, but unable to bond to other molecules in a pure form. The latter displays only one element with saturation level (−1). This would explain why some liquids are stable if they remain pure. Secondly, the concept of saturation is very useful for identifying finite multi-molecular structures. These structures, greater than in gases but smaller than in solids, are alone able to account for the properties of liquids: heavier than gases but fluidic. Lastly, complexes in liquids seem to generally assume rounded shapes. While it is generally acknowledged that molecular energy in gases and solids are respectively linear kinetic and vibratory, it suggests that rotatory energy dominates in liquids. This can explain why liquids are incompressible.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Annexes A. Tools and Rules to Build Liquid Compounds

Below, we will recall the rules used in this article, and which were previously introduced. These rules detailed below have been previously tested for bonding structures of molecules [8] and for crystals [18] [19].

For the sake of clarity, the authors have chosen to list the most important items of the rules.

A.1. Single Covalent Bonding between Atoms

Conventional concepts of bonding conditions use multi-bonded representations between atoms in compounds. In the present paper, the drawing of covalent bonded connections between charged or uncharged atoms in molecules is different [20]. This is used with the following modifications:

A single covalent bond between two first neighbors classically drawn with one line, is not modified.

A classical representation of a double-bond is replaced by a single bond, and by adding one positive charge on one connected atom and a negative charge to the other one.

A triple bond is replaced by a single covalent bond without any other impact.

A quadruple bond is transformed into a single bond using the same procedure as a double bond.

This can be summarized as: in a molecule, one atom is connected only to each of its first neighbors by only one covalent bond which is always a pair of electrons and represented by a single line.

A.2. Even-Odd Rule

Specific Basic Concepts of the even-odd rule about atoms in compounds are described in the next three sub-chapters.

A.2.1. Uncharged Atoms

The even-odd rule, proposed for chemical structural formula of liquid, is that uncharged atoms are as follow:

The number of single bonds around an atom is even when having an even number of electrons. The smallest number of bonds is equal to zero. (Two in liquids).

The number of single bonds around an atom is odd when having an odd number of electrons, but the smallest number of bonds is equal to one.

A.2.2. Charged Atoms in Compounds

In the even-odd rule, the structure of molecules containing charged atoms are also with single covalent bonds. But numbers of bonds are reversed compared to the neutral atoms. They are as follow:

For neutral even atoms, when it is charged, the number of single bonds around is odd. The smallest number of bonds is equal to one.

For neutral odd atoms, when it is charged, the number of single bonds around

is even, but the smallest number of bonds is equal to zero. (Two in liquids)

A.2.3. Higher Numbers of Bonds

The even-odd rule does not limit the number of bonds for an atom. The most evident limitation can be the number of electrons. Unfortunately, only hydrogen atoms follow such a limitation. For all the other atoms, only experimental data give the limitation of the number of bonds for any atoms. Again unfortunately, the limitation is not the same for neutral and for charged atoms.

In this paper, to work with this limiting numbers, only data available coming from scientific knowledge are used [12] [15] [21] [22]. **Table 2** includes these limiting numbers of bounds.

A.2.4. Covalent Bonds between Neutral and Charged Atoms

Two atoms having the same charge are electrically under a repulsive force. When having opposite charges, they are attracting each other. Due to the presence of a covalent bond between two atoms, the rule is different. It is proposed to be:

When one atom is neutral, the other can be neutral or charged (positively or negatively),

When one atom is charged, the other cannot have the same charge. It can be neutral or with the other charge.

Consequently, a neutral atom having one bond at a positive atom and another bond to a negative atom, cannot build another bond which will be in opposite of the just above condition: in $A(+)-B(n)-C(-)$, it means that $B(n)$ cannot built another bond which impose a change in its charge. This is blocked by at least one of the two other atoms.

The second consequence is that when only one type of atoms is used, the highest level will be (-1) , and the liquid will never be saturate, but it stays stable: di-hydrogen with two $H(n)$ and one bond at level (-1) , will never built liquid hydrogen at level 0. Also, dinitrogen with one bond between two $N(n)$ at level (-3) , will be liquid first at level (-2) and second at level (-1) , but it will never have 4 bonds at level (0).

A.3. Organic, Inorganic or Semi-organic Atoms

Conventionally in chemistry, organic compounds are composed of five atoms: H, C, N, O, F. From this starting point, any compounds with one or more other atoms are classified to be inorganic.

In the present paper, a different classification is used with the following conditions:

When a neutral atom has a lower number of bonds than the number of bonds it can have with a negative charge, this atom is inorganic, (see Li, Be, B).

In the opposite, when the number of bonds is higher when having a positive charge, this atom is organic, (see N, O, F).

When atoms are between these two groups, they are said to be semi-organic.

From these definitions, and as shown in **Table 2**, three groups are possible at

an atomic scale *i.e.*, for each atoms of a compound. In the two first row of **Table 2**, they are: inorganic in white color for H, Li, Be, B and C(+), organic in green color for C(-) N, O, F, and semi-organic with yellow color for B(-), C(n) and N(+).