RAOULT MEMORIAL LECTURE.

(Delivered on March 26th, 1902.)

By J. H. van't Hoff, Member of the Prussian Academy of Science, and Professor in the University of Berlin.

The foreign honorary member whom the Chemical Society lost a year ago, although of an amiable, social character, seems to have been a man of retiring disposition. He rarely left France, and for the larger part of his life lived in that somewhat out of the way town, Grenoble.

Raoult's life thus offers little of attractiveness; it is not romantic; yet, after many years of work, the romance of his life was that almost sudden rise to fame, spreading from this nearly unknown corner, first over the frontier of his country, and then back to France, which made him one of the most prominent men of science of his age.

François-Marie Raoult, born on the 10th of May, 1830, in Fournes, in the département du Nord, in France, was of modest origin, his father having been an employé des Contributions. It was intended that he should enter the Bureaux de l'Enregistrement, but this career did not satisfy his aspirations, so he left the Enregistrement and obtained permission to go to Paris, there to pursue his studies. Without fortune or patronage, young Raoult was a student struggling for a livelihood, unable to finish his studies without himself providing the means.

So he gave up studying at Paris, some years later, in 1853, after presenting to the Académie des Sciences a short communication, probably his first, containing observations on the transport of electrolytes by the action of the galvanic current as well as on electrical endosmosis (Compt. rend., 1853, 36, 826). Characteristic of the circumstances in which he pursued these investigations are his concluding words: "Je laisse à d'autres plus fortunés que moi le soin de mener la science plus avant dans la voie nouvelle que je viens de lui ouvrir."

It was in the same year, 1853, that Raoult accepted the appointment of Aspirant répétiteur in the Rheims Lycée, becoming in 1855 Régent de physique in the College of St. Dié; in 1856, Professeur adjoint, and subsequently Chargé de cours de physique in Rheims again; in 1860 in Bar-le-Duc; his leisure having been employed in obtaining his degree as Licencié des sciences physiques and Agrégé de l'Enseignement secondaire spécial. In 1862, he left Bar-le-Duc for a corresponding position in Sens, and in this small country town, with no intellectual resources, left to his own initiative amid adverse material surroundings, forced...
by want of means to construct his own apparatus, he prepared the Thèse on electromotive force for which, in 1863, he obtained his degree in Paris of Docteur ès-sciences physiques.

With this publication, Raoult began his scientific career, which may be divided into three distinct periods, physical, chemical, and physico-chemical.

**Raoult as a Physicist.**

The above-mentioned thesis at once characterises Raoult as an accurate and independent investigator, already in advance of his age in conclusions founded on careful examination of fact.

Firstly, employing different galvanic cells of the Daniell type, Raoult measured the heat due to the chemical action (chaleur chimique) and that due to the electric work produced (chaleur voltaïque). Contrary to the opinion then adopted, he found that these two values were by no means identical; in some cases, as in the ordinary Daniell cell, Cu | CuSO₄, ZnSO₄ | Zn, both practically correspond, for each is about 23.6 cal. for a gram-equivalent (the most exact recent measurement gave 24.8); in an analogous cell, Cu | Cu(NO₃)₂, AgNO₃ | Ag, however, the "chaleur chimique" amounted to 16.4, whereas the "chaleur voltaïque" was only 7.8. Keeping as closely as possible to the direct results of experiment—a characteristic of Raoult's way of working—he closes this communication with a mere question: "Pourquoi cette différence? Voilà une difficulté sérieuse digne de l'attention des physiciens."

A second part of this research was devoted to decompositions produced by a galvanic current in the so-called voltameter. Raoult studied especially the heat development accompanying decompositions, explaining it by the excess of heat corresponding to the electric work done in the voltameter over the heat absorbed by the chemical change produced, in this way applying to the voltameter the principle underlying his discovery of the difference between the two values found for the cell. Thirdly, this conception enabled him to determine indirectly the heat absorbed by the chemical change which occurs in the voltameter. It was thus, for example, that he found the heat absorbed in decomposing 9 grams of water to be 33.8 cal., whereas Favre and Silbermann found the heat developed in the formation of the same amount of water to be 34.5 cal.

The conclusion to his two papers on this subject (*Ann. Chim. Phys.*, 1864, [iv], 2, 317; 1865, [iv], 4, 392) may be given in his own words:

"J'ai, le premier, mesuré et comparé la chaleur chimique et la chaleur voltaïque des piles."
"J'ai découvert les véritables lois qui président au dégagement de la chaleur dans les voltamètres."

"J'ai donné le premier moyen de mesurer la chaleur dégagée ou absorbée dans les actions chimiques accomplies sous l'influence des courants électriques."

In his further investigations on electro- and thermo-chemistry, Raoult liked to come back to that same question of difference between voltaic and chemical heat which he considered to be fundamental. A very striking proof of the non-identity of the two was given in the fact established by him (Compt. rend., 1869, 68, 643) that solid and liquid metals, at the temperature of fusion, produce in the cell the same electromotive force; he insisted on this especially in the case of bismuth, which metal, having a latent heat of fusion corresponding to 1.327 cal. for an equivalent of 105 grams, ought to produce in melting a difference in electromotive force of 0.055 Daniell.

A second indication in the same direction is not less valuable. Finding that the electromotive force in a Daniell cell increases on diluting the solution of zinc sulphate surrounding the zinc, but decreases on diluting that of the copper sulphate (ibid., 1869, 69, 823, 826), he insisted on the conclusion that in taking its saturated solution of zinc sulphate and so increasing the heat development of the reaction by that arising from the crystallising out of the solid sulphate, the electromotive force changes in the opposite sense and becomes smaller.

Raoult's attention being claimed by other pursuits, it was in 1870 that he summed up his views in a very interesting paper on the difference between voltaic and chemical heat (Bulletin de la Société de Statistique de l'Isère). He concluded that in the galvanic cell two different kinds of change take place, the one incapable, the other capable, of producing electromotive force. Those incapable are changes of state of aggregation, such as melting and dissolving; those capable are chiefly chemical change and change in concentration.* We now see how far Raoult had already gone in the right direction and how some further experiments on this influence of concentration, and especially how an application of theoretical considerations, might have led him to a definite solution of the problem.

* Dans les éléments voltaïques analogues à celui de Daniell, la désagrégation chimique des corps et leur diffusion dans l'eau, de même que les actions inverses ne participent en rien à la production du courant électrique, et ce sont les seules actions qui sont dans ce cas.
Raoult as a Chemist.

It was while he was carrying out this electro- and thermo-chemical research, in which many new facts and relations came to light, and on which, perhaps, it is not necessary to dwell on this occasion, that Raoult entered the Faculté des Sciences de Grenoble, in 1867, as Chargé du cours de chimie, being promoted, in 1870, to the Chair of Chemistry as successor to Leroy. This chair he occupied until his death on April 1st, 1901. From this time, a change is visible in the direction of Raoult's work, as he devoted himself more to purely chemical investigation, although he always had a tendency to look at the physical side of every problem.

This change in the field of Raoult's investigations explains how the hitherto continuous character of his work gave place to one of greater variety.

We now find Raoult occupied in examining the gas evolved by a "Fontaine ardente," at St. Barthélemy, near Grenoble, and proving it to be merely methane; next as a judicial expert we see him prove the presence of zinc and copper as normal constituents of the human liver, especially in advanced age (Compt. rend., 1877, 85, 40). The absorption of ammonia by ammonium nitrate he studied simultaneously with, but independently of, Divers (ibid., 1873, 76, 1261), and further, he recommended the use of retort-carbon as a means of preventing irregular boiling in the distillation of sulphuric acid. He also demonstrated the inverting action of light on sugar (ibid., 1871, 73, 1049). Then we find him studying the influence of carbon dioxide in air on respiration with the interesting result that it diminishes the production of the gas, this effect, however, being counteracted by the increased pulmonary action (ibid., 1876, 82, 1101). Lastly, aiming probably at a lecture experiment, Raoult investigated the formation of a basic carbonate of lime, CaO₂·CaCO₃, produced by heating calcium oxide in carbon dioxide (ibid., 1881, 92, 189, 1110, 1457) which compound has probably played a part in Debray's work on dissociation and has the property of setting like gypsum after addition of water. Medals made with this material, which has the properties of gypsum but is somewhat harder, were presented by Raoult to the French Academy.

This was Raoult's last purely chemical publication, for he had now found the right direction in which he was to go until death put an end to his labours.
Raoult as a Physico-chemist.

It was in 1878 that Raoult's first publication on freezing points appeared (Compt. rend., 87, 167). This was merely of an empirical character, and pointed to the proportionality (already indicated by Guldberg) between lowering of freezing point, lowering of vapour pressure, and rise of boiling point. Raoult thus entered at once into an investigation of the two subjects which were to form the cornerstones of his fame. As he himself afterwards relates, the lowering of vapour-pressure formed the primary subject of study, and I suppose that, finding the difficulty of determining the strength of alcoholic solutions by measuring their boiling points or vapour-pressures because of the volatility of alcohol, he applied himself to the indirect method of determining the freezing points. At all events, his next paper (ibid., 1880, 90, 865) is devoted to the freezing points of mixtures of alcohol with water. He determines the proportionality between the lowering of the freezing point and the percentage of alcohol present in the solvent, thus stating for this mixture the law which Blagden had found for solutions of inorganic substances. That this stood in close connection with practical application is obvious from the list of alcoholic liquids added to the paper, beginning with cider and ending with Marsala, indicating that their freezing points (-2° and -10.1°) were fairly proportional to their alcoholic strength. Moreover, he pointed out that a wine may be strengthened by freezing out part of the water.

Having by a happy stroke of luck passed from the investigation of ethyl alcohol to other alcohols and from these to other organic substances, which had not been examined by Blagden, by Rüdorff, or by de Coppet, and having introduced de Coppet's conception of molecular depression, Raoult as early as 1882 attained a wider view of the subject, and published his now historical table of 29 organic compounds (Compt. rend., 1882, 94, 1517) (see next page).

Following Raoult's conclusion, it is obvious from this table that the product obtained by multiplying the depression for a solution containing 1 gram of substance in 100 grams of water by the molecular weight of the dissolved substance, is a constant:

\[
\frac{C}{P} M = K,
\]

where \( C \) stands for the depression caused by \( P \) grams in 100 grams of water, and \( K \) the molecular constant.

It is astonishing how easily Raoult abandons the narrower view of
practical application for the wider scientific horizon, and instead of a list of ciders and Marsalas, an expression like this occurs:

"Cela tend à montrer que, dans la plupart des cas, les molécules des composés organiques sont simplement séparées par l'acte de la dissolution et amenées à un même état, sous lequel elles exercent la même influence sur les propriétés physiques de l'eau."

Of course Raoult does not omit to indicate that a new mode of determining molecular weights may be founded on freezing point experiments.

Two more papers appearing in the same year (Compt. rend., 95, 187, 1030) show that Raoult's general formulation of the freezing point law for solutions holds not only for water but also for other solvents.

Each solvent has its molecular constant which, in some cases, prob-
ably owing to the formation of double molecules by the dissolved substance, may be reduced to half the normal value. These constants are proportional to the molecular weight of the solvent \( M_1 \), being on an average:

\[
\frac{K}{M_1} = 0.62.
\]

Raoult's data are as follows:

<table>
<thead>
<tr>
<th>Substance</th>
<th>( K )</th>
<th>( M_1 )</th>
<th>( K/M_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>39</td>
<td>60</td>
<td>0.65</td>
</tr>
<tr>
<td>Formic acid</td>
<td>28</td>
<td>46</td>
<td>0.61</td>
</tr>
<tr>
<td>Benzene</td>
<td>49</td>
<td>78</td>
<td>0.63</td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>68</td>
<td>123</td>
<td>0.55</td>
</tr>
<tr>
<td>Ethylene dibromide</td>
<td>117</td>
<td>188</td>
<td>0.62</td>
</tr>
<tr>
<td>Water</td>
<td>37</td>
<td>3 \times 18</td>
<td>0.69</td>
</tr>
</tbody>
</table>

We observe the assertion by Raoult that the constant 18.5 for organic compounds in water is abnormal and is due to the formation of double molecules, whereas the molecular weight of water as a solvent is taken as 54, and is due to a polymerisation in the liquid state corresponding to \((\text{H}_2\text{O})_n\).

Cryoscopy. Inorganic Compounds.

Having thus obtained an insight into the laws governing organic compounds, Raoult enters the more difficult field of salt solutions, in which a good deal had already been done by Rüdorff and de Coppet, who nevertheless had not reached any general conclusions.

Raoult took acids and bases as intermediate links and found that strong monobasic acids, like hydrochloric acid, and strong mono-acid bases, like potassium hydroxide, have a molecular depression (37) double that of the weaker ones and of organic compounds (18.5). On this observation he founded a neat method of determining the amount of substitution which takes place when a strong acid or base acts on the solution of the salt of a weak one (Compt. rend., 1883, 96, 560; 97, 941).

The next year (1884) witnessed the publication of his systematic researches on the behaviour of salts, and it is curious to observe, by the way, that at this stage of his inquiry Raoult first adopted the new atomic weights and thereby the system of Avogadro, which, it might almost be said, he had unconsciously adhered to for more than two years. His first paper on salts (Compt. rend., 1884, 98, 509) still contains the formula KNO₅ for saltpetre, but in the next (ibid., 1047; 99, 324), he adopts the values H = 1, O = 16. The amount of systematic work done in this short space of time is astonishing, the different groups of salts being taken one by one in the order of the valency of
their metals and the basicity of their acids, and, grouping them in this happy way, Raoult reaches at once the general and unexpected result that the molecular depression of salts, strong acids, and bases can be calculated by a summation of numbers, relating to their radicles:

Univalent negative radicles....................... (Cl,Br,OH,NO₃) ... 20
Bivalent " " ................................... (SO₄,CrO₄,CO₃) ... 11
Univalent positive " ................................ (H,K,Na,NH₄) ... 15
Bi- and poly-valent positive radicles .......... (Ba,Mg,Al₂) ...... 8 *

Applying the method of calculation, for example:

for KOH we get 15 + 20 = 35, instead of 35.3 found.
for Al₂Cl₆ " 8 + 6 x 20 = 128, " 129 "

Let me state this in Raoult's own words in order to show in what an impartial and objective way his own conviction is subordinated to fact:

"Ces faits prouvent que, contrairement à ce que j'avais cru jusqu'ici, la loi générale de congélation ne s'applique pas aux sels dissous dans l'eau . . . ; par contre, ils tendent à montrer qu'elle s'applique aux radicaux constitutifs des sels, à peu près comme si ces radicaux étaient simplement mélangés dans les dissolutions."

As mentioned by Raoult, this additive character had been found by Favre and Valson to apply to the density, and by Hugo de Vries to the osmotic pressure of salt solutions.

An application of these results is made in deciding whether a double salt exists in solution as such, or is split up into its components, the former being the case, for example, in such a compound as sodium platinichloride, and the latter for the alums (Compt. rend., 1884, 99, 914). Most important, however, is the fact that from this time dates the great international co-operation in the field which Raoult had opened.

Whereas Raoult's early work on electromotive force and heat-development lay fallow, because the theoretical conceptions to which they could be attached were only developed about fifteen years later, it was an extraordinarily happy coincidence that his freezing point investigations met with corroborative theoretical views, which could only enhance the high value already attached to Raoult's achievements.

His first work on electromotive force, although important in character, left Raoult's name almost unknown, because it appeared at least ten years too soon, and was therefore overlooked when the stream of general development reached that field. Raoult at this period was

* In Raoult's Cryoscopie (1901), these numbers are 19, 9, 16, 5, respectively, the last number for bivalent radicles only.
Officier d'académie (1865), and Officier de l'Instruction publique (1872), and had received the Médaille des sociétés savantes in 1872.

The work on cryoscopy came just at a time when an ardent activity was developing in different countries and from different points of view. Victor Meyer in Germany and Paternò in Italy applied Raoult's method of determining molecular weights as early as 1886; de Vries has already been quoted; then came the theory of solutions, developed by Arrhenius in Sweden and by myself in Holland, and then the great support lent by Ostwald in his Zeitschrift für physikalische Chemie, in which Raoult at once took part with enthusiasm, as the facsimile of his letter published with this lecture proves. Rarely has science seen such international interest centred on one problem, and Raoult stood at once foremost, in the position of great advantage belonging to the man who relies on fact in the first instance, and is eager for generalisation, absolutely independent in his opinions, and open to every achievement on his way.

An unbroken series of distinctions now showered down on Raoult, beginning in 1888 with the Prix international de chimie La Caze, followed by the Davy Medal in 1892, Correspondent de l'Institut in 1890, and honorary or foreign Fellow of the Society of Rotterdam in the same year, of the Literary and Philosophical Society of Manchester in 1892, of the Chemical Society of London in 1898, and of the Academy of St. Petersburg in 1899. In 1900, he was crowned with the Commandership of the Légion d'honneur, a distinction which gave him the highest gratification.

Cryoscopy. Theory of Solutions.

In the meantime, in 1892, Raoult recommenced his freezing point investigations, which had been interrupted in 1884, but now received a new direction with special relation to the theory of solutions. As is well known, this theory treats of the laws governing extreme dilution, and assumes that it is possible to calculate Raoult's freezing point constants under these conditions. We therefore see him occupied in accumulating experimental data for these conditions with the accuracy and impartiality so characteristic of his work.

Let us notice that at first Raoult deemed the molecular constant 18.5 found for organic compounds in aqueous solution to be abnormal, and assumed 37 as the normal value, thus considering organic compounds to be present in the form of double molecules (ibid., 1882, 95, 1030). It was natural to try, from this point of view, whether extreme dilution would not break down those double molecules and consequently double the molecular constant. A first series of experiments made with cane sugar (Compt. rend., 1892, 114, 268,
 seemed favourable to this view, and extreme dilution appeared to show an increase in the molecular constant up to 20·9. As, however, ethyl alcohol did not show an analogous increase (ibid., 1897, 124, 851, 885), the experiments with cane sugar were again taken up with increased precautions (ibid., 1897, 125, 751) and, by a small extrapolation, gave 18·7 as the limit for extreme dilution, alcohol giving 18·3. At the same time, Raoult examined sodium and potassium chlorides with the utmost care, and finding, as the limiting values, 37·4 and 36·4 respectively, he openly declared himself in favour of the new theory of solutions:

"En définitive, il est maintenant démontré, pour moi, que les abaissements moléculaires du chlorure de potassium et du sucre, comme ceux du chlorure de sodium et de l'alcool, ont des valeurs limites conformes aux prévisions de M. Arrhénius."

In the summary of his work in this direction (Cryoscopie, Scientia, No. 13, 1901), written in the last year of his life, Raoult grants all the conclusions of the theory of solutions, but as a thoroughly experimental investigator he objects to build it up on that large but hypothetical principle called the extended law of Avogadro. He consequently prefers generalisation, and in such a sense expresses his views on solutions as follows in concluding a lecture at the Paris International Congress of Chemistry in 1900. "À une même température l'acte de la dissolution et celui de la vaporisation réduisent chaque corps en particules, qui ont la même masse et la même force vive de translation à l'état dissous et à l'état gazeux."

Vapour-pressure.

We now come to the parallel series of experiments on vapour-pressure which Raoult executed. As has been observed, it was the proportionality between the rise of boiling point, the lowering of vapour-pressure, and the depression of freezing point, which first led Raoult to his freezing point investigations. It was the fertility of this field which brought him back to a study of vapour-pressure once more.

As had already been proved in some cases by Wullner, Raoult found proportionality to exist between the lowering of the vapour-pressure \((f-f')\) and the pressure \((f)\), at least for dilute solutions, and hence the relative lowering of pressure

\[
\frac{f-f'}{f}
\]

is independent of temperature.

The second step was to prove the consequence of proportionality between the lowering of vapour-pressure and of freezing point and to
test the constancy of the so-called molecular lowering which was found (Compt. rend., 1886, 103, 1127; 1887, 104, 967) and could be expressed by

\[ \frac{f - f'}{f'} M = K, \]

where, as before, \( P \) is the number of grams of substance dissolved in 100 grams of the solvent, and \( M \) its molecular weight.

The third step was fundamental and may be considered as the happiest generalisation which Raoult reached (Compt. rend., 1887, 104, 1430). It was indicated by the results of freezing point determinations in which Raoult had hoped to detect proportionality between molecular lowering and the molecular weight of the solvent (a relation, however, which did not prove to be general). The molecular lowering of vapour-pressure was therefore compared with the molecular weight of the solvent, with results which are shown in the following table:

<table>
<thead>
<tr>
<th>Dissolvant</th>
<th>Poids moléculaire du dissolvant ( M' )</th>
<th>Diminution moléculaire normale de tension ( K )</th>
<th>Diminution de tension produite par 1 mol. dans 100 mols. ( \frac{K}{M'} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eau</td>
<td>18</td>
<td>0·185</td>
<td>0·0102</td>
</tr>
<tr>
<td>Chlorure phosphoreux</td>
<td>137·5</td>
<td>1·49</td>
<td>0·0108</td>
</tr>
<tr>
<td>Sulfure de carbone</td>
<td>76</td>
<td>0·80</td>
<td>0·0105</td>
</tr>
<tr>
<td>Bichlorure (CCl4)</td>
<td>154</td>
<td>1·62</td>
<td>0·0105</td>
</tr>
<tr>
<td>Chloroforme</td>
<td>119·5</td>
<td>1·30</td>
<td>0·0109</td>
</tr>
<tr>
<td>Amylène</td>
<td>70</td>
<td>0·74</td>
<td>0·0106</td>
</tr>
<tr>
<td>Benzine</td>
<td>78</td>
<td>0·83</td>
<td>0·0106</td>
</tr>
<tr>
<td>Iodure de méthyle</td>
<td>142</td>
<td>1·49</td>
<td>0·0105</td>
</tr>
<tr>
<td>Bromure d'éthyle</td>
<td>109</td>
<td>1·18</td>
<td>0·0109</td>
</tr>
<tr>
<td>Éther</td>
<td>74</td>
<td>0·71</td>
<td>0·0096</td>
</tr>
<tr>
<td>Acétoné</td>
<td>58</td>
<td>0·59</td>
<td>0·0101</td>
</tr>
<tr>
<td>Alcool méthylique</td>
<td>32</td>
<td>0·33</td>
<td>0·0103</td>
</tr>
</tbody>
</table>

Raoult formulates the relation thus found as follows: "1 Mol. de substance fixe, non saline, en se dissolvant dans 100 mol. d'un liquide volatil quelconque, diminue la tension de vapeur de ce liquide d'une fraction à peu près constante de sa valeur et voisine de 0·0105," that is,

\[ \frac{K}{M_1} = 0·0105. \]

It was this conclusion that at once brought Raoult into relation with my theory of solutions (Bihang K. Svenska Vet.-Akad. Handl., 1886, 21, No. 17), with which it is in agreement, as Raoult himself states (Compt. rend., 1887, 105, 859):
“L'accord entre l'expérience et la théorie est donc, sur tous les points, aussi complet qu'on peut le désirer en pareille matière.”

It was the investigation of this law which Raoult pursued in detail in the latter part of his life; he found it to apply also to salts such as sodium chlorate, potassium acetate, sodium acetate, lithium chloride, lithium bromide, potassium thiocyanate, calcium nitrate, calcium chloride, and mercuric chloride, at least in alcoholic solution, in which they behave as non-electrolytes (Compt. rend., 1888, 107, 442), whereas in aqueous solution they behave, to use his own words, “comme s'ils étaient décomposés en leurs ions.”

But the best part of his work was still to be done, in cooperation with Recoura (Compt. rend., 1890, 110, 402; 1896, 122, 1175). In using acetic acid, and afterwards formic acid, as a solvent, Raoult found that \( K/M_1 \) had a value of about 0.0161, instead of 0.0105, and at once attributed the discrepancy to the abnormal vapour density of acetic acid (which again is involved in the theory of solutions, as \( M_1 \) means, on this basis, the molecular weight of the solvent as derived from the density of its saturated vapour), a number which also exceeds the normal value by about 60 per cent. It was on this account that, in a later publication (ibid., 1893, 117, 833), he gave this most general and exact expression for his vapour-pressure observations:

\[
\frac{d_1 - f'}{d - f} \times 100 \frac{M}{M_1} = \frac{d_1}{d} \text{ or } \frac{K}{M_1} = 0.01 \frac{d_1}{d},
\]

where \( d_1 \) is the observed density in the saturated vapour and \( d \) that calculated from \( M_1 \).

Although by this plan Raoult obtained absolute identity with the expression derived from the theory of solutions, he preferred to regard his formula, founded on fact, as an equation essential to the osmotic law, osmotic pressure still being a value unsuited for direct estimation. This Raoult had learned by a preliminary investigation (Compt. rend., 1895, 121, 187), abandoned when the manometer broke after the highest osmotic pressure ever observed, namely, 50 atmospheres, had been attained, a value far higher than is wanted in these experiments.

We are now coming to the end. Raoult's constitution seems to have been a vigorous one; the only indication to the contrary which I can discover is that in 1887 he resigned an additional professorship of Chemistry and Toxicology at the Grenoble Medical School, which he had held since 1873; this he resigned on account of his health, at first provisionally, and then, in 1892, for good. The 7th of April, 1900, was the date for his official superannuation, but by a special decision of the Board of Trustees, he remained in office, hors cadre, a
very high distinction and a proof of his unbroken vigour at that time. Yet, wise man as he was, he used well those days, no doubt fearing that they might not last, and in two exhaustive treatises, dated 1900 and 1901, he published his final views on Tonometry and Cryoscopy (Scientia, No. 8 and No. 13); it was just in time, for, without any warning symptoms, he died, almost suddenly, on April 1st, 1901.

As I had not the honour of being personally acquainted with Raoult and only occasionally corresponded with him, I must rely on the verdict of others if I venture to consider him as a man. Yet his character may be read in his papers: activity, patience, tenacity to an extreme degree in pursuing an aim, having an eye as much for detail as for vaster and vaster horizons, absolute independence of mind, power of criticising or of admitting without passion the views of others as well as his own, and of testing both with the same calm conviction that the last word must rest with experiment; this is what we read in every page and what the whole chemical world may know.

Looking at him still more closely, let us read what was said in the name of the University and of the Faculty at the grave in that Grenoble which Raoult had chosen for his residence during more than thirty years. Possessor of the highest local distinctions, if such may be counted; doyen; holder of the only medal of the French Government for services given by him as vice-president of the Conseil d'hygiène de l'Isère, the representative man of the University: words fail me to express how greatly he was regretted both on account of his character, and of the distinction which he had conferred on the city which mourned him.

To her who best must have known Raoult I am indebted for my last and best words*:

"Ce que fut l'homme privé, tous ceux qui l'ont connu ont apprécié cet esprit bienveillant, fin, spirituel, cette extrême bonté, cette modestie à toute épreuve.

Il ne m'appartient pas de vous dire ce qu'il fut pour les siens, se dévouant à eux entièrement, les entourant de son amour, de sa sollicitude.

Tendre père, il eut l'immense douleur de se voir enlever une enfant de 8 ans, et plus tard une fille de 26 ans, laissant un enfant à qui il prodigua toutes ses tendresses.

Puiss ce récit bien douloureux pour moi vous faire comprendre que comme homme et comme savant celui que je pleure mérite tous les regrets."

* Letter from Mme. Raoult, Grenoble, January 24th, 1902.