is, in general, extraordinarily limited compared to, say, that available for surface tension: there are, in general, no measurements above the boiling point at atmospheric pressure, and for low boiling liquids scarcely any at all below 0°C. , which is in many cases, for example, pentane, the most important part of the range. I am planning a series of investigations to be carried out in this laboratory, in the hope of adding to the reliable data for viscosity, more especially the temperature variation required to give b .

Turning to the letters which have been sent to NATURE since my first letter was printed, the letter from my old friend Dr. S. E. Sheppard, published on Mar. 29, gives what is practically my formula and states one of my first results, namely, that for a large number of liquids the formula represents the observed data, within experimental error, over a wide range of temperature. The complete independence of our work—our letters were written within a few days of one another, his in America, mine in England—may serve to emphasise the point that I wish to stress, namely, that this formula has a fundamental significance, and the constant b —Sheppard's k —has an intimate relation to the various properties connected with the internal energy of liquids. The other points of interest which Sheppard raises are not the same as mine. Sheppard has not made it quite clear how he obtains his a for associating liquids, for $\eta = Ae^{b/T}$ will not fit, for example, water. Presumably, he has found the value of b by fitting one or two of the low temperature values. I note that he has found that the formula has been already given by Senor J. de Guzman in the *Anales de la Sociedad Española de Física y Química*, 1913. Prof. Kendall has pointed out to me that he mentions it, in the form $\log \eta^{1/3} = a/T + b$, in a footnote to a paper in the *Journal of the American Chemical Society*, 39, 1799; 1917. I have also, since deriving it, found that J. S. Dunn has given it in a short paper in the *Transactions of the Faraday Society*, 22, 401; 1926, as quoted in Mr. E. W. Madge's letter. Mr. Dunn's paper had escaped my attention just as it has that of Dr. Sheppard and his collaborators. No particular attention ever seems to have been paid to the formula before, and it is not quoted in the standard books, for example, Hatschek's "Viscosity of Liquids". It is

always distressing to find that one has been anticipated, in whatever degree, but it certainly does not seem to have been previously realised that the formula $\eta = Ae^{b/T}$ is fundamentally characteristic of normal liquids.

As regards Mr. E. W. Madge's formula, $\eta = \frac{A}{T-b}e^{\beta T}$,

it does not seem to fit octane sensibly better than my formula with two constants, and it does not fit water so well as the formula $\eta = Ae^{b/T-\theta}$, with the same number of constants, which I quote earlier in this letter, variations as large as 1.5 per cent occurring in Mr. Madge's table, as against 0.9 per cent over the same range with my simpler three-constant formula. If Mr. Madge had computed the value for supercooled water at -9.3°C. , he would have found a discrepancy of nearly 5 per cent, as against 1.3 per cent given by $\eta = Ae^{b/T-\theta}$!

Dr. Frenkel's formula is scarcely, as he claims, "practically equivalent" to mine, for it is $ATe^{b/T}$, instead of $Ae^{b/T}$, and the multiplication by T renders it unable to fit the variation of viscosity with temperature, interesting as is its derivation.

I am afraid I can attach but little importance to the fact, cited by Dr. Black, that the formula does not fit commercial mineral oils, of no definite composition, in view of my success, confirmed by Dr. Sheppard, in fitting a great variety of pure chemical substances. I have investigated the type of variation from the formula shown by Dr. Black's oils, and it is of a nature quite different from that shown by pure substances which do not fit, namely, such as associate strongly. So far as I can learn, oils of this type often change their viscosity permanently on heating.

Sir Ambrose Fleming's very interesting letter deals with the points which lie somewhat off the main current of my argument.

I feel that some apology for the length of this letter is needed, but, even in this space, I have only been able to refer in the briefest possible manner to points connected with the subject which I have under immediate investigation.

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Catalytic Reactions at High Pressures.

THE technical synthesis of ammonia by high pressure catalysis has given a great impetus to the development of high pressure reactions. At the present time reaction pressures are confined to a few hundred atmospheres, at which pressures the technical problems in so far as material and construction are concerned may be fairly claimed to be solved. Work in the high pressure laboratory at Amsterdam envisages operating pressures above ten thousand atmospheres and a few determinations of physical constants have already been made at pressures as high as 35,000 atmospheres. At these pressures, again, especially at high temperatures, new problems of material, construction, and design will confront the engineer hoping to industrialise a process operating under these conditions. Technical interest in catalysis at high pressures is at present focused on the numerous reactions involving the use of water gas as raw material and on hydrogenation of coal, including products derived from coal. Many others involving processes of amination and oxidation are doubtless capable of development.

Whilst the difficulties involved in the hydrogenation of coal are partly economic in character and lie partly in the variability of the raw material, these factors are not so important in many of the reactions involving

water gas, and in that field it is clear that a whole series of careful physical chemical investigations are necessary before the state of affairs may be considered to be at all satisfactory.

In developing the synthesis of ammonia, preliminary work involved the determination of the data necessary to establish the conditions of equilibrium of the system

over a wide range of pressure and of temperature. This phase of the problem was in part simplified by the absence of other reactions in the combination of the two gases and by a knowledge, with fairly accurate data available, of the specific heats of hydrogen and nitrogen and approximate values for the heat of formation of ammonia, its specific heat and compressibility. More accurate data have only recently been obtained, but the approximate data available before development of the industrial processes were sufficiently accurate.

In the case of reactions involving water gas, the state of affairs is much more complex because there is a whole series of reactions which are possible with the gases carbon monoxide and hydrogen. The initial

reactions which are important may be formulated as follows :

- (1) $\text{CO} + \text{H}_2 \rightleftharpoons \text{HCHO}$
- (2) $\text{CO} + 2\text{H}_2 \rightleftharpoons \text{CH}_3\text{OH}$
- (3) $\text{CO} + 3\text{H}_2 \rightleftharpoons \text{CH}_4 + \text{H}_2\text{O}$

By aldol condensation together with stages of hydrogenation a whole sequence of higher aldehydes and alcohols may be obtained from (1), with the possible exception of ethyl alcohol.

Accurate data on the heats of these reactions, on the specific heats and on the compressibilities of most of the products, are at present not available and in consequence the equilibrium under high pressures and over a range of temperatures for any one of these reactions cannot as yet be said to be determined with any degree of accuracy. The work at the Imperial College on the experimental determination of the methanol equilibrium, reaction (2), appears to be the most complete at the present time. Having obtained preliminary if not exact information on the conditions of equilibrium, the next stage involves the choice of a suitable catalyst, and here we note that apart from chemical reactivity the catalyst employed must possess the additional property of being highly selective in its action. Whilst it is known from investigations that a copper catalyst favours reaction (1), a zinc oxide catalyst containing certain promoters, for example, chromium oxide, favours (2), and an active nickel catalyst is most suitable for the formation of methane, and that the rate of aldol condensation resulting in the formation of higher alcohols can readily be augmented by the addition of small quantities of alkali, the mechanism of the catalytic processes themselves which must contain the secret of the selectivity of these catalysts is unknown.

Although the use of iron as a catalyst in the synthesis of ammonia has been known for nearly thirty years, it is only recently that any definite ideas as to what constitutes an active catalyst for this reaction have been developed. These may be said to have originated in an examination of the activity of catalysts prepared by two different ways ; as minute agglomerates and crystals formed as a result of condensation from the vapour phase, and by the breaking up of large crystals by processes of 'activation' and prevention of the regrowth of the grain size by the addition of suitable materials.

Developments along similar lines involving measurements both on the heats of adsorption as well as reaction rates in both forward and reverse directions may assist in the building up of a satisfactory interpretation of catalytic action. From the discussion which was held at the Royal Society on Mar. 20 on catalytic chemical reactions under high pressures, it was clearly evident that work both scientific and industrial in this important field is advancing rapidly in England, and in addition that the organic chemistry of the simpler aliphatic compounds was a field which requires immediate exploration by both physicists and physical chemists.

ERIC K. RIDEAL.

Historic Natural Events.

April 14, 1912. S.S. *Titanic* sunk by Iceberg in Atlantic.—During the months of April and May 1912, there was an abnormally large amount of ice off the Newfoundland Banks. In April no fewer than 395 icebergs were counted south of lat. 48° N., compared with an average number of 83, and in May 345 compared with an average of 130. The icebergs spread far to the south of their usual limits, and on April 14, the White Star liner *Titanic* struck one in lat. 41° 46' N., long. 50° 14' W., and sank with great loss of life. As a result of this disaster, the first International Con-

ference for Safety of Life at Sea was held in London in 1913, at which it was decided to establish and maintain a regular patrol of the iceberg area.

April 15, 1077. End of 'Canossa' Winter.—The winter of 1076–77 was so rigorous in England, France, and central Europe that the oldest inhabitants did not remember a similar one. The "Harleian Miscellany" records that "in the tenth year of his [William the Conqueror's] reign, the cold of winter was exceeding memorable, both for sharpness and for continuance, for the earth remained hard from the beginning of November until the midst of April then ensuing". In Europe the snow lasted from Nov. 1 to Mar. 26, and the Rhine was crossed on the ice so late as April. In central France hard frosts continued for four and a half months and the vines perished. The passes across the Apennines were completely blocked by snow and ice. It was from Jan. 25 to 28, 1077, that the Emperor Henry IV. of Germany stood shivering, bare-headed and barefooted, and clad in a hair shirt, before Pope Gregory VII. in the courtyard of the Castle of Canossa in northern Italy, before the Pope removed the ban of excommunication imposed for his harsh treatment of the Saxon princes.

April 15, 1927. Mississippi Floods.—The floods in the Mississippi valley in February–July 1927, because of their magnitude, protracted duration, and economic destructiveness, formed one of the greatest calamities of modern times. Their beginnings may be traced back to the abnormal rains of September 1926 over the greater part of the Mississippi drainage area. There were further heavy rains in October and November, and in December there were general floods in the southern streams tributary to the Ohio River. The early months of 1927 also had a rainfall above the normal in most parts of the basin, but the most serious flooding did not begin until April 15, 1927, when a crevasse began to form in the levee guarding the river at Dorena, Mo., 30 miles below Cairo, Ill. From that date the floods spread with terrible rapidity, and crevasses were formed in the levees. The total area of lands overflowed was 28,573 square miles, and the damage was estimated as more than 284 million dollars. The loss of life was 214 ; this (as well as the material loss) would have been far higher but for the warnings issued by the U.S. Weather Bureau.

April 18, 1850. Tornado at Dublin.—A violent thunderstorm developed at 3.30 p.m., with hailstones as large as pigeon's eggs. At 4 p.m. a tornado passed over, with hurricane winds from south-east, which abruptly changed to north-west. A great deal of damage was done ; in some districts practically every pane of glass was blown in, chimneys were overthrown, and roofs carried off, while many trees were uprooted. These fell to north-west and south-east in about equal proportions, adjacent trees sometimes lying in opposite directions. The Cattle Show was in progress, and the cattle broke loose, leading to fearful confusion.

April 18, 1906. Earthquake in California.—The Californian earthquake on this day caused much damage in San Francisco, less by the shock than by the fires that followed it. The most remarkable feature of this earthquake was the great length (not less than 270 miles) of an old fault known as the San Andreas rift along which the displacement occurred, reaching from Cape Mendocino on the north to near Monterey on the south. Subsequent surveys of the district showed that the crust on both sides of the fault had moved, that on the south-west side to the north-west and on the other side to the south-east.

April 19, 1849. Snowstorm.—There was heavy snow in south-east England on April 16–20, and on April 19 the Westerham coach was buried and left all night in a snow drift on Titsey Hill.