Comité Technique Européen du Fluor (CTEF)

Working Group on Storage, Transport and Safety (STS)

Group 5

GENERAL PROPERTIES OF ANHYDROUS HYDROGEN FLUORIDE (AHF) AND HYDROFLUORIC ACID SOLUTIONS (HF)

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PREFACE

Anhydrous hydrogen fluoride/ hydrofluoric acid (AHF/HF) is essential in the chemical industry and there is a need for HF to be produced, transported, stored and used.

The AHF/HF industry has a very good safety record; nevertheless, the European AHF/HF producers, acting within Eurofluor (previously CTEF) have drawn up this document to promote continuous improvement in the standards of safety associated with AHF/HF handling.

This Recommendation is based on the various measures taken by member companies of Eurofluor.

Each company, based on its individual decision-making process, may decide to apply the present recommendation partly or in full.

It is in no way intended to be a substitute for various national or international regulations, which must be respected in an integral manner.

It results from the understanding and many years of experience of AHF/HF producers in their respective countries at the date of issue of this particular document.

Established in good faith, this recommendation should not be used as a standard or a comprehensive specification, but rather as a guide, which should, in each particular case, be adapted and utilised in consultation with an AHF/HF manufacturer, supplier or user, or other expert in the field.

It has been assumed in the preparation of this publication that the user will ensure that the contents are relevant to the application selected and are correctly applied by appropriately qualified and experienced people for whose guidance it has been prepared.

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The contents of this recommendation are based on the most authoritative information available at the time of writing and on good engineering practice, but it is essential to take account of appropriate subsequent technical developments or legislative changes. It is the intent of Eurofluor that this guideline be periodically reviewed and updated to reflect developments in industry practices and evolution of technology. Users of this guideline are urged to use the most recent edition of it, and to consult with an AHF/HF manufacturer before implementing it in detail.

This edition of the document has been drawn up by the Working Group on "Storage, Transport and Safety" to whom all suggestions concerning possible revision should be addressed via the offices of Eurofluor. It must not be reproduced in whole or in part without the authorisation of Eurofluor or member companies.

AHF is an acronym for anhydrous hydrogen fluoride.

HF is an acronym for hydrofluoric acid solutions of any concentration below 100%.

Content

1. Introduction - general remarks

This guideline has been developed by the Storage, Transport and Safety Group of Eurofluor (CTEF). It is intended to offer recommendations on General Properties of Anhydrous Hydrogen Fluoride (from here referred to as 'AHF' within this document) or Hydrofluoric acid solutions (from here referred to as 'HF') at ambient temperature (from -20°C to +50°C) unless stated otherwise.

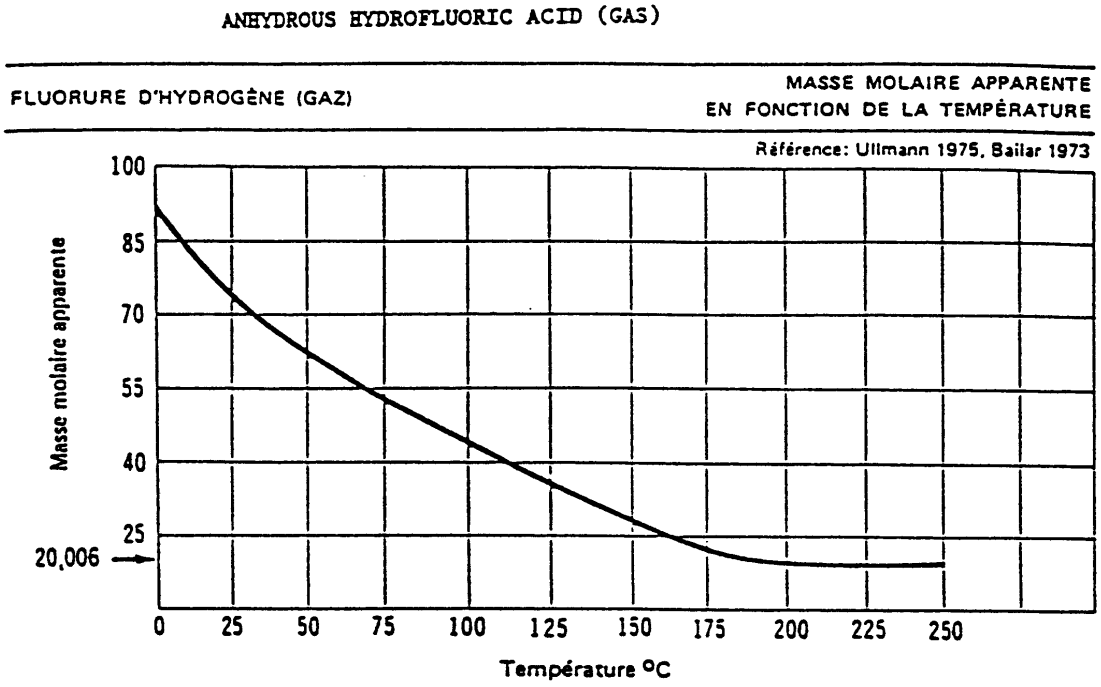
This Recommendation summarizes some physical properties of AHF/HF. However, main source of information on physical properties of HF as well as toxicological data can be found in the registration dossier of HF (12/2010) under the European Regulation EC/1907/2006 (REACH) or in Safety Data Sheets.

2. Physical properties of AHF

Table of physical properties of AHF

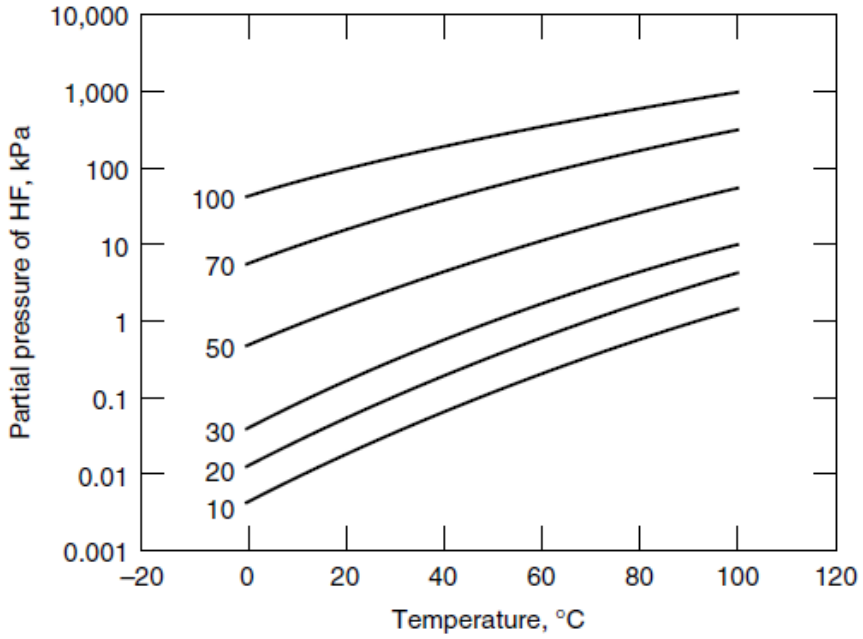
Appearance	Colorless liquid, fumes in air
Physical State	Liquid
Molecular Weight	20.01 g/mol (monomeric)
Chemical Formula	HF
Odour	Sharp Pungent Odour
Odour threshold	<1 ppm
Specific Gravity (Water=1.0)	0.97 at 21°C
Solubility in Water	100% by weight
pH	Not Applicable
Boiling Point	19.54°C at atmospheric pressure
Melting Point	-84°C
Vapour Pressure	1.03 bar at 21°C // 122 kPa at 25ºC
Vapour Density (Air=1.0)	2.21 at 21°C, 1.76 at 27°C
Evaporation Rate	Not Applicable
% Volatiles	100%
Ionization Potential	15.98 eV
Flash Point	Not Flammable
Explosive range	Non Explosive
Critical Temperature	187.9 °C
Critical Pressure	64.9 bar
Critical Density	290.0 kg/m³
Heat of Vaporization at boiling point	374.5 kJ/kg
Heat of fusion at freezing point	196.9 kJ/kg
Specific heat at constant pressure Liquid at boiling point Vapour at 25 °C, atmospheric pressure	 2.32 kJ/kg °C 1.46 kJ/kg °C
Viscosity of liquid at 0°C	0.25 cP
Surface tension at 0°C	10.27 mN/m

Molar mass vs. temperature



Reference: Hodgman C.D. Handbook of Chemistry and Physics - Chemical Rubber Publishing Company 1951 - Allied Chemical

Vapour pressure



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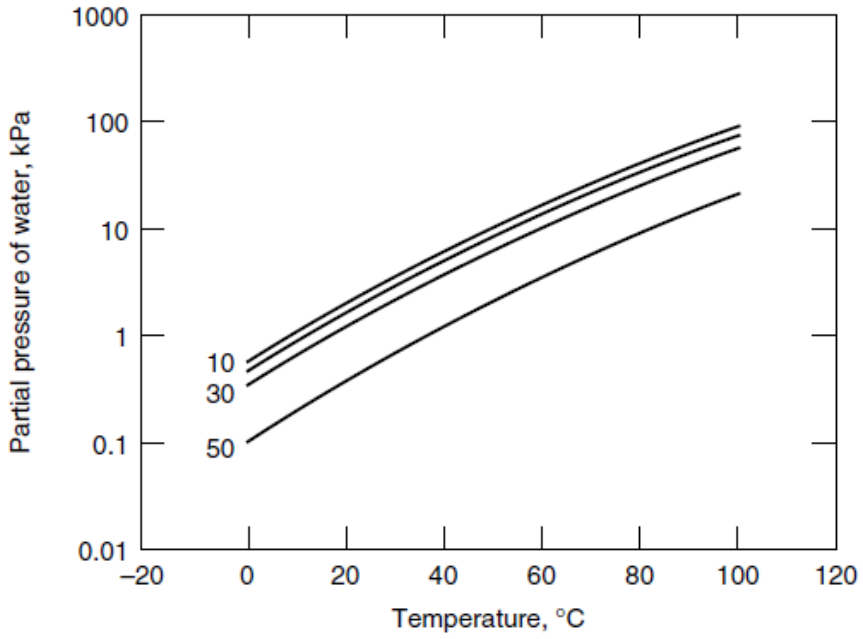


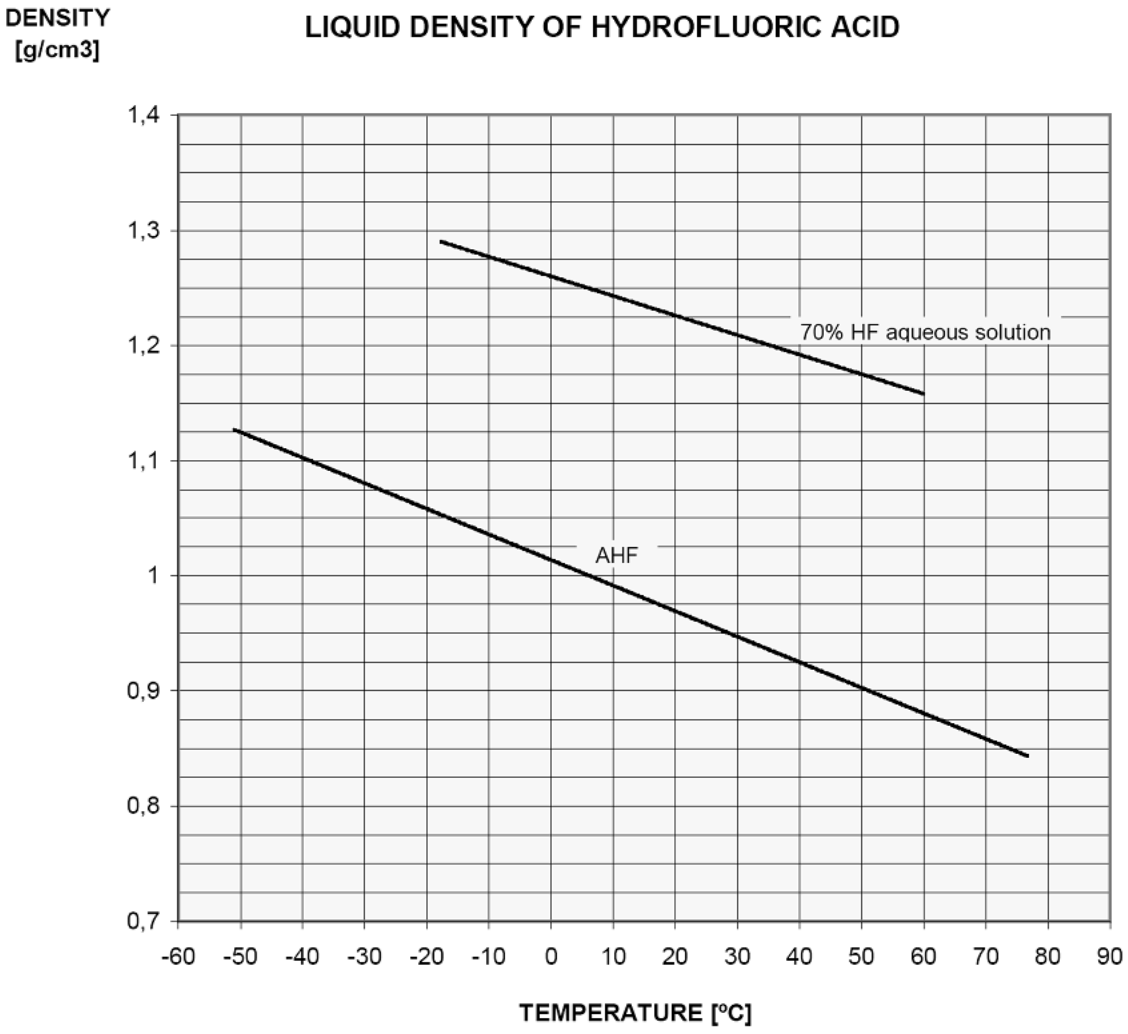
(b)

Partial pressures over HF-water solutions where the numbers represent the quantity of HF in solution expressed as wt % (a) of HF and (b) of H2O.

P. A. Munter, O. T. Aepli, and R. A. Kossatz, Ind. Eng. Chem. 41, 1504 (1949).

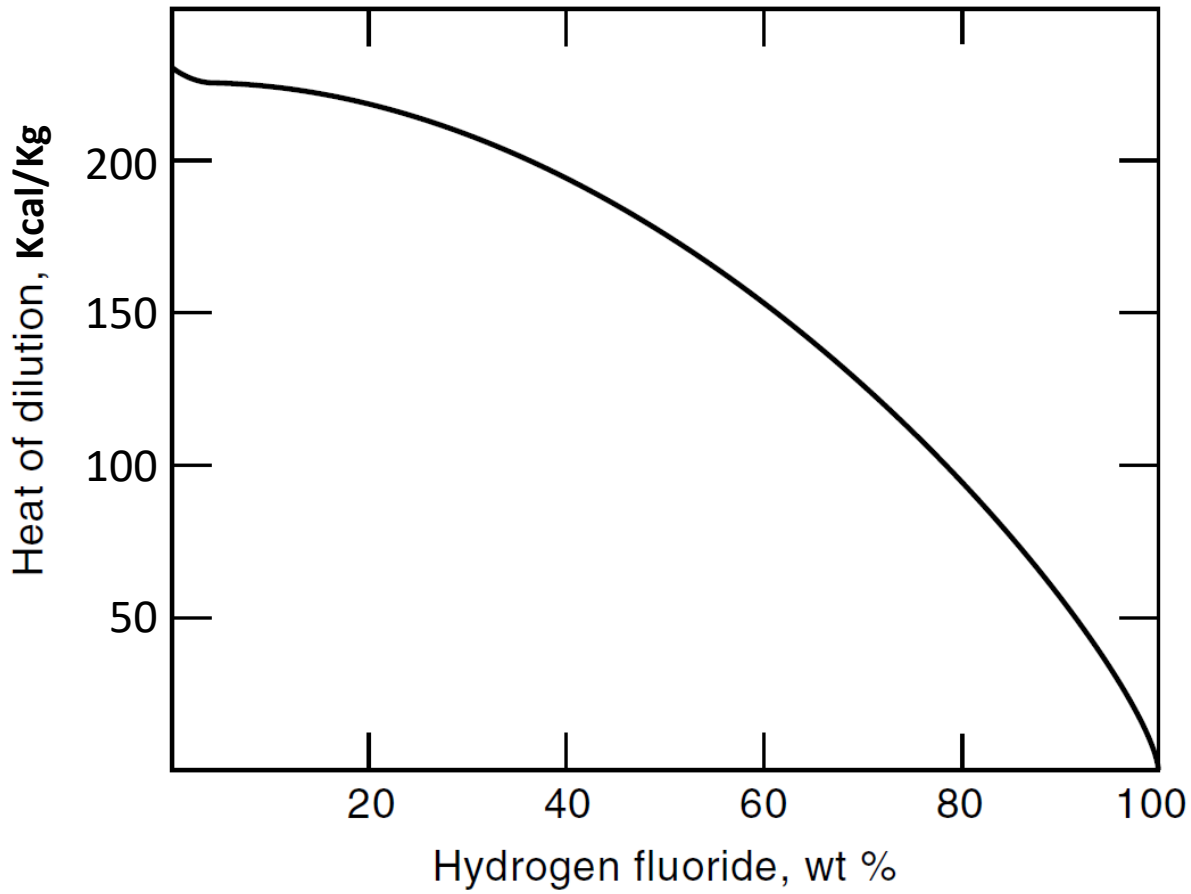
Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Liquid density



Reference Du Pont

Heat of dilution



Heat of solution per gram of AHF in water when mixed to the final concentration shown in wt% of HF

- Hydrofluoric Acid, Anhydrous—Technical, Properties, Uses, Storage, and Handling, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., 1984.
- Hydrofluoric Acid, Allied-Signal Corp., Morristown, N.J., 1978.
- G. K. Johnson, P. N. Smith, and W. N. Hubbard, J. Chem. Thermodyn. 5, 793 (1973).

Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Table 1: Heat of dilution of hydrogen fluoride

Concentration of HF % w/w	Heat of Dilution* KJ/Kg
100	0
90	217
80	380
70	502
60	623
50	736
40	820
30	874
20	912
10	937
0	970

(*) Heat evolved when 1 kg of anhydrous liquid HF at 25 °C is diluted to the given concentration

Table 2: Variation of vapour pressure, vapour density and liquid density with temperature

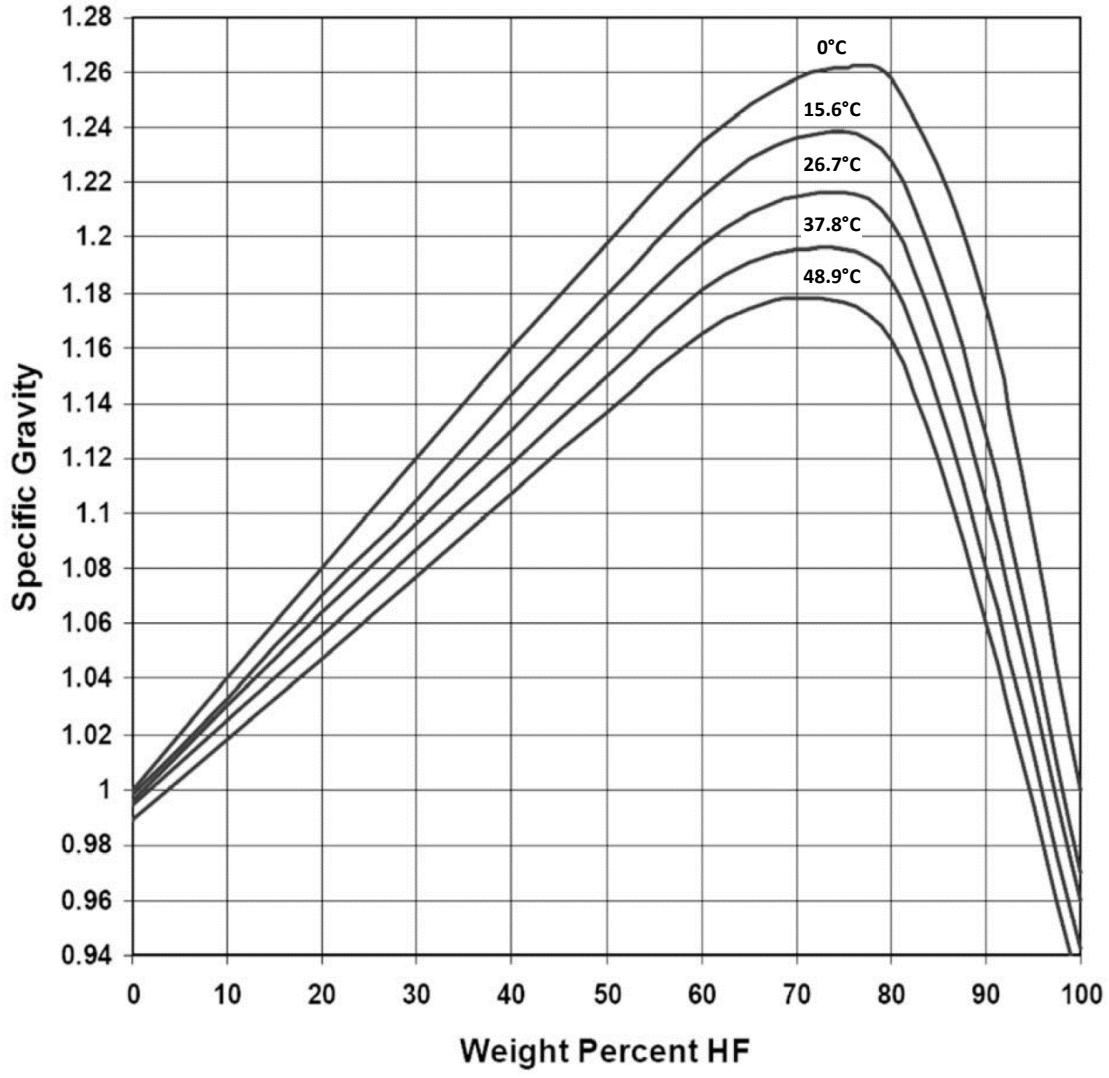
Temperature °C	Vapour pressure Bar Abs	Density Saturated Vapour Kg/m^3	Density Liquid Kg/m^3
-10	0.31	-	1,025
0	0.49	2.15	1,002
10	0.71	2.52	980
20	1.03	3.17	968
30	1.46	3.98	945
40	2.02	4.98	928
50	2.76	6.19	908
60	3.7	7.65	888
70	4.9	9.39	867
80	6.4	11.44	844
90	8.25	13.85	820
100	10.52	16.64	796

Table 3: Variation of density of superheated vapour at 1013 mbar with temperature

Temperature °C	Vapour Density Kg/m^3
19.5	2.93
30	1.79
40	1.13
50	0.85
60	0.77
70	0.74
80	0.71
90	0.68

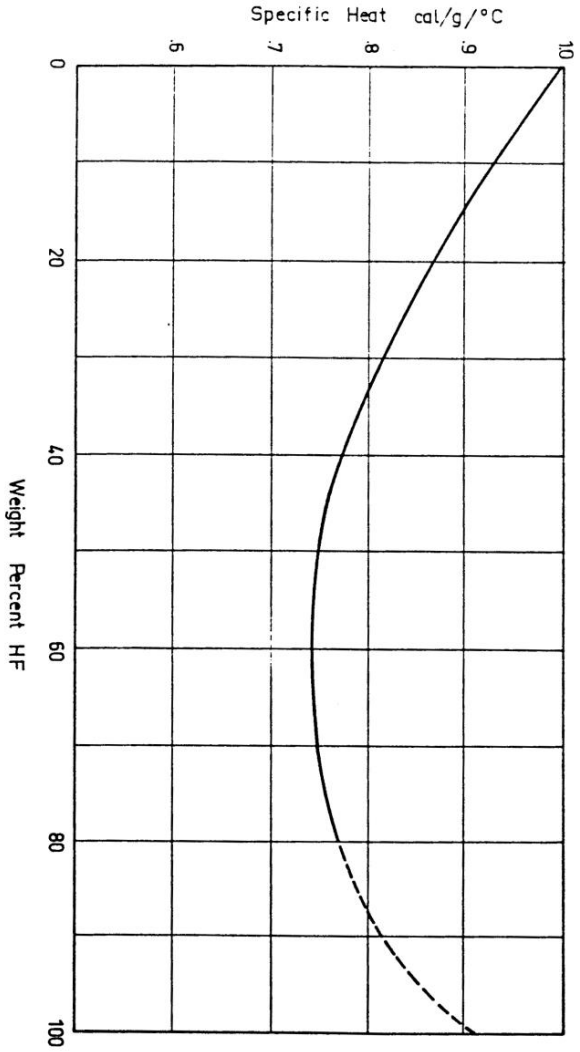
3. Physical properties of aqueous HF

Specific gravity of HF - H2O system



Reference Honeywell

Specific heat of aqueous hydrofluoric acid at 27° C

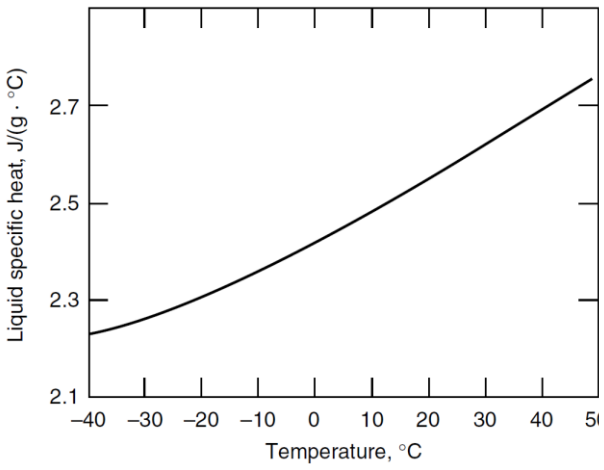


Reference:

Research Laboratories iof General Chemical Company

Roth at al Zelectrochem 43 350-55 (1937)

Dahmos and Jung Z Physik Chem B 21 317-22 (1933)

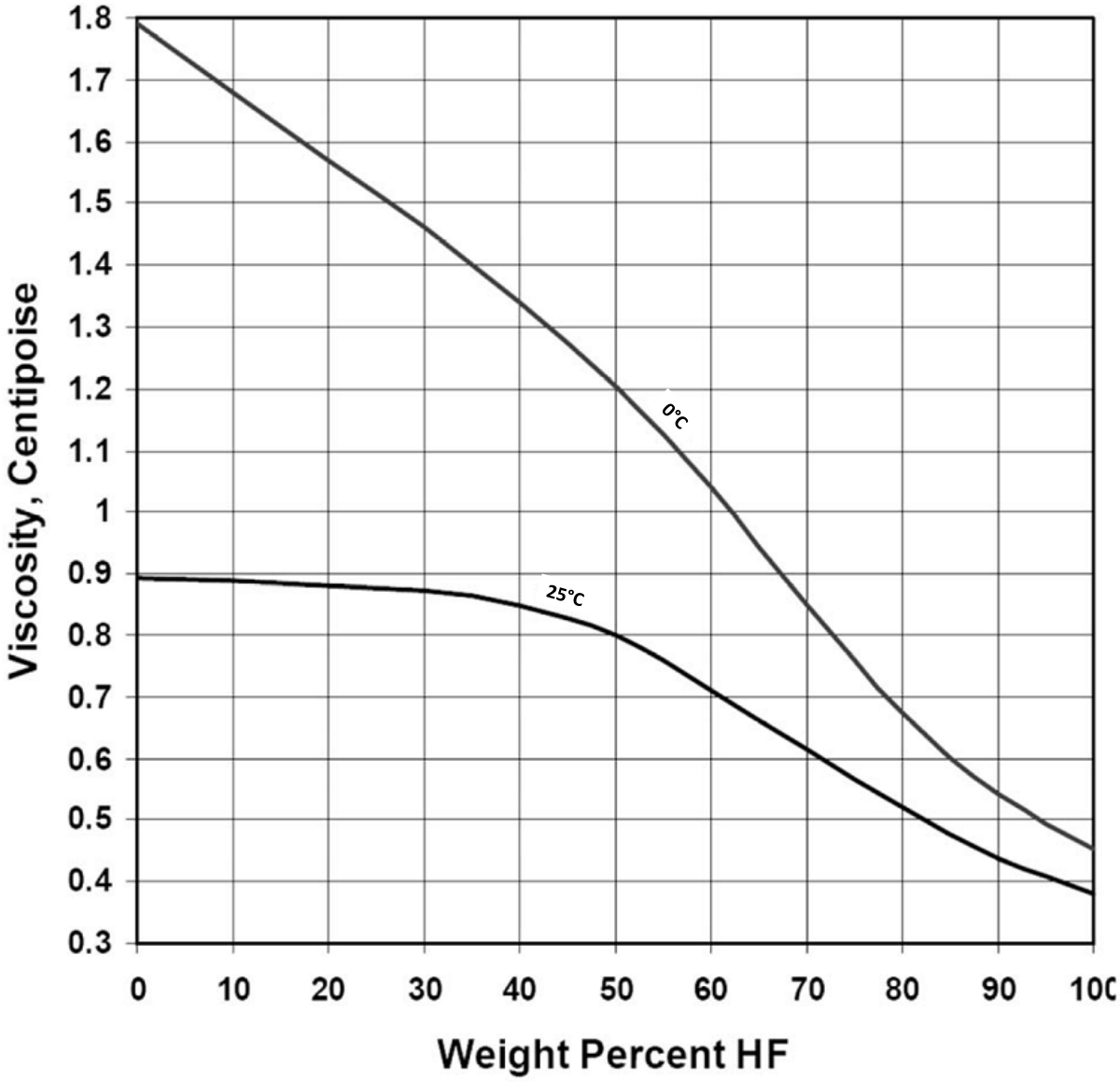


- J. H. Hu, D. White, and H. L. Johnston, J. Am. Chem. Soc. 75, 1232 (1953).
- Hydrofluoric Acid, Anhydrous—Technical, Properties, Uses, Storage, and Handling, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., 1984.

Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk. Copyright © 2015 Eurofluor. Reproduced with permission of John Wiley & Sons, Inc.

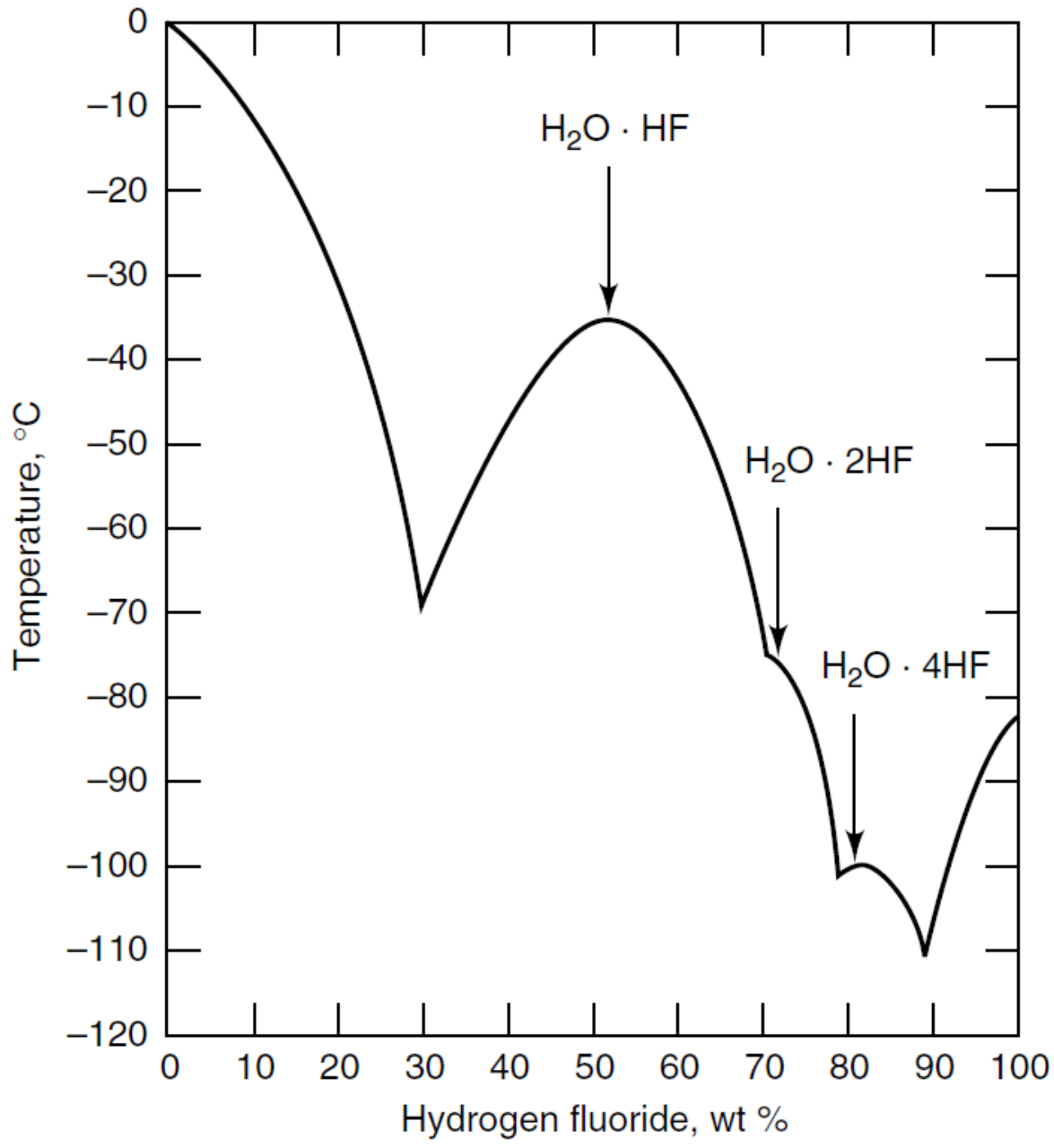
Specific heat of liquid AHF

Viscosity of HF - H_2O system



Reference Honeywell

Freezing points of aqueous hydrofluoric acid

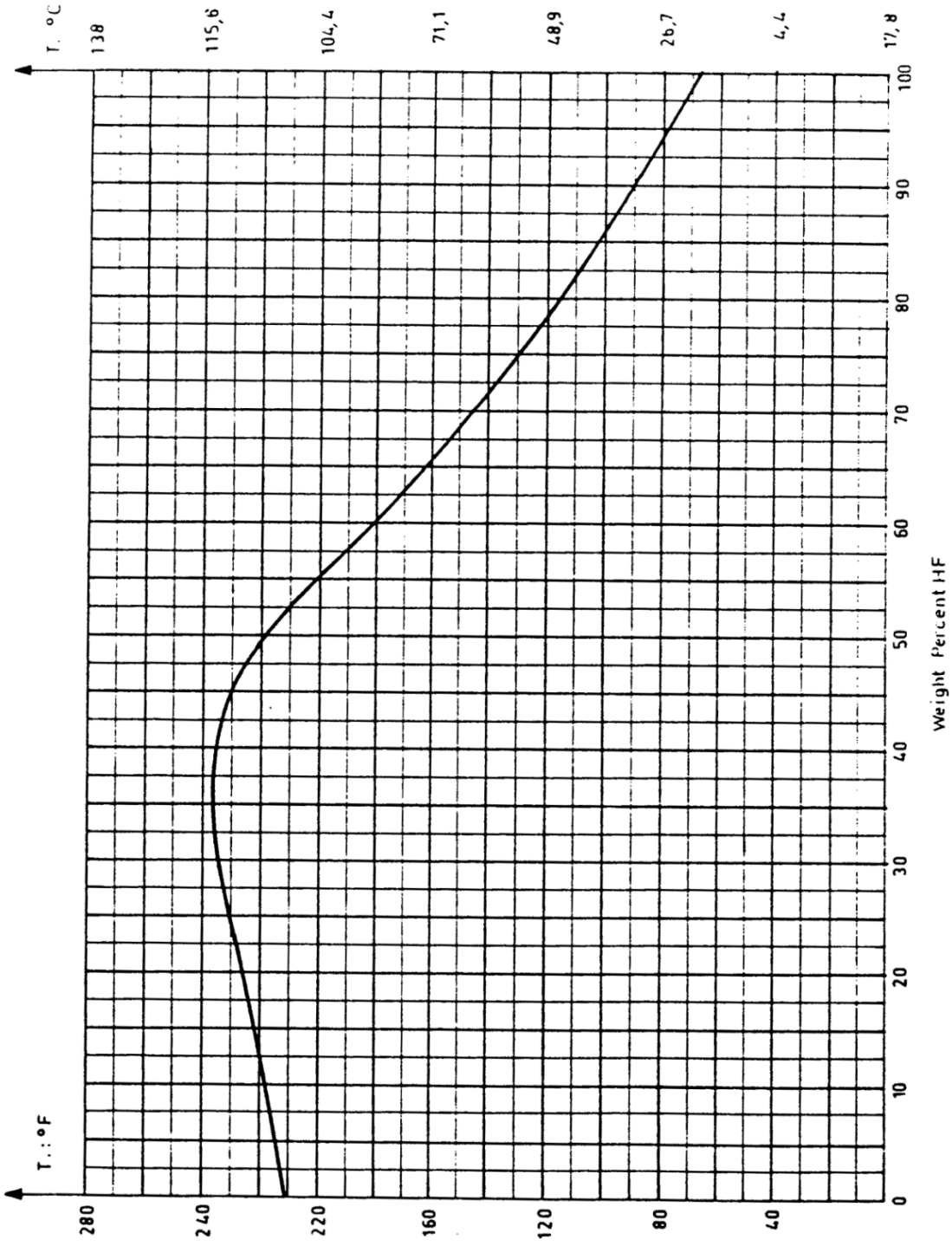


Freezing point, HF–water system

G. H. Cady and J. H. Hildebrand, J. Am. Chem. Soc. 52, 3843 (1930).

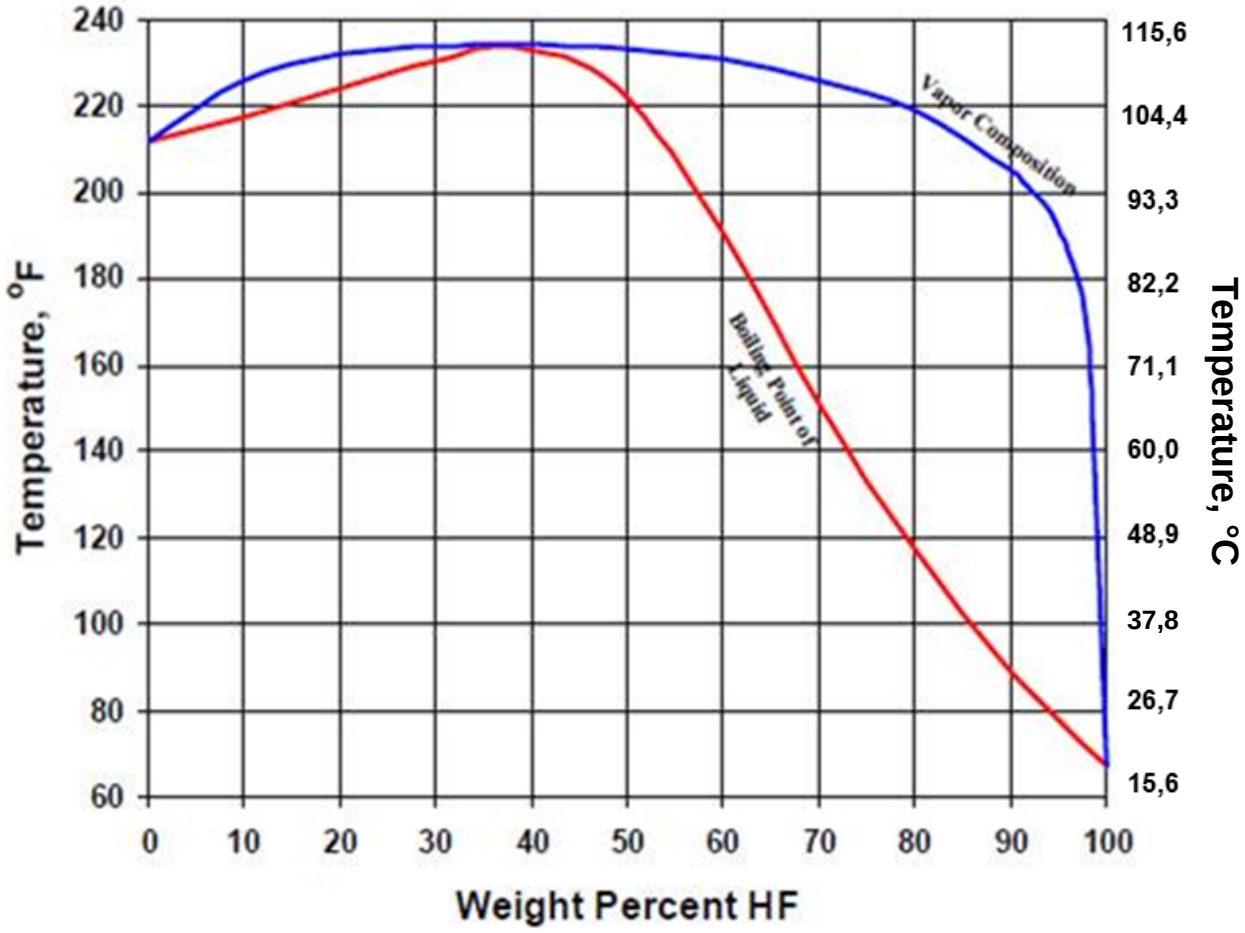
Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Boiling point of aqueous hydrofluoric acid



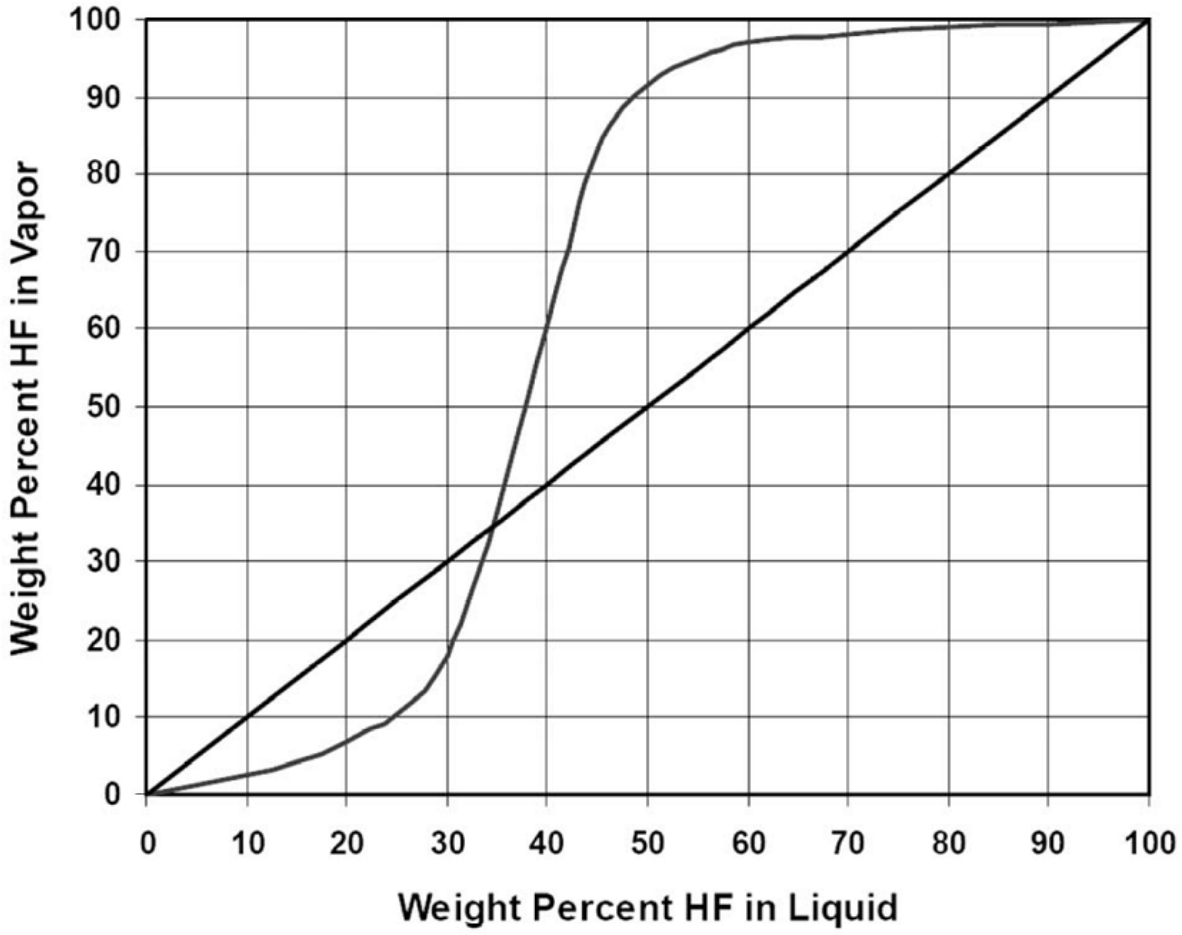
Reference: Research Laboratories of General Chemical Company

Boiling point of HF - H_2O system



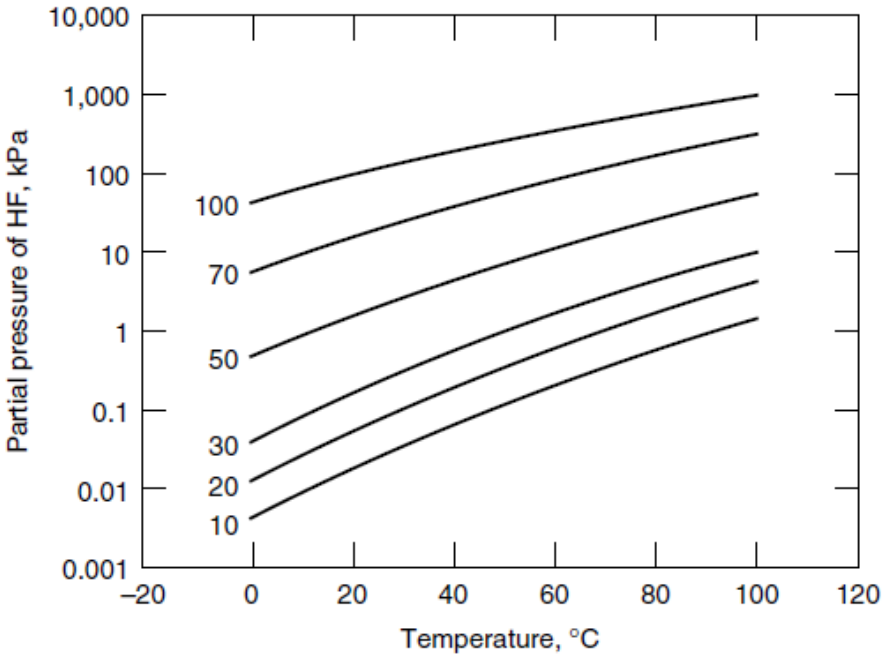
Reference Honeywell

Vapour liquid equilibrium diagram at the normal boiling point



Reference Honeywell

Partial vapour pressure of HF over aqueous solutions of HF



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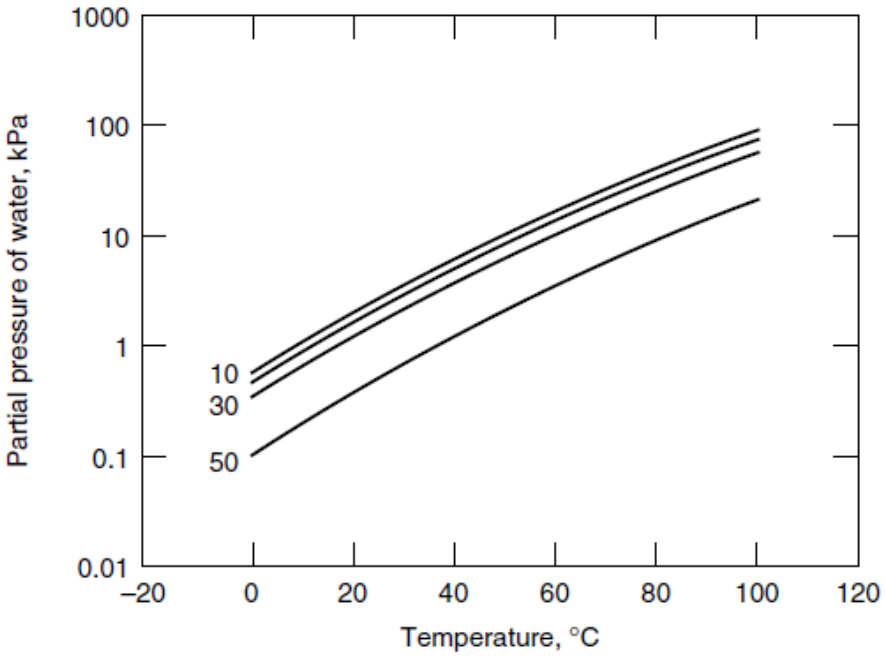

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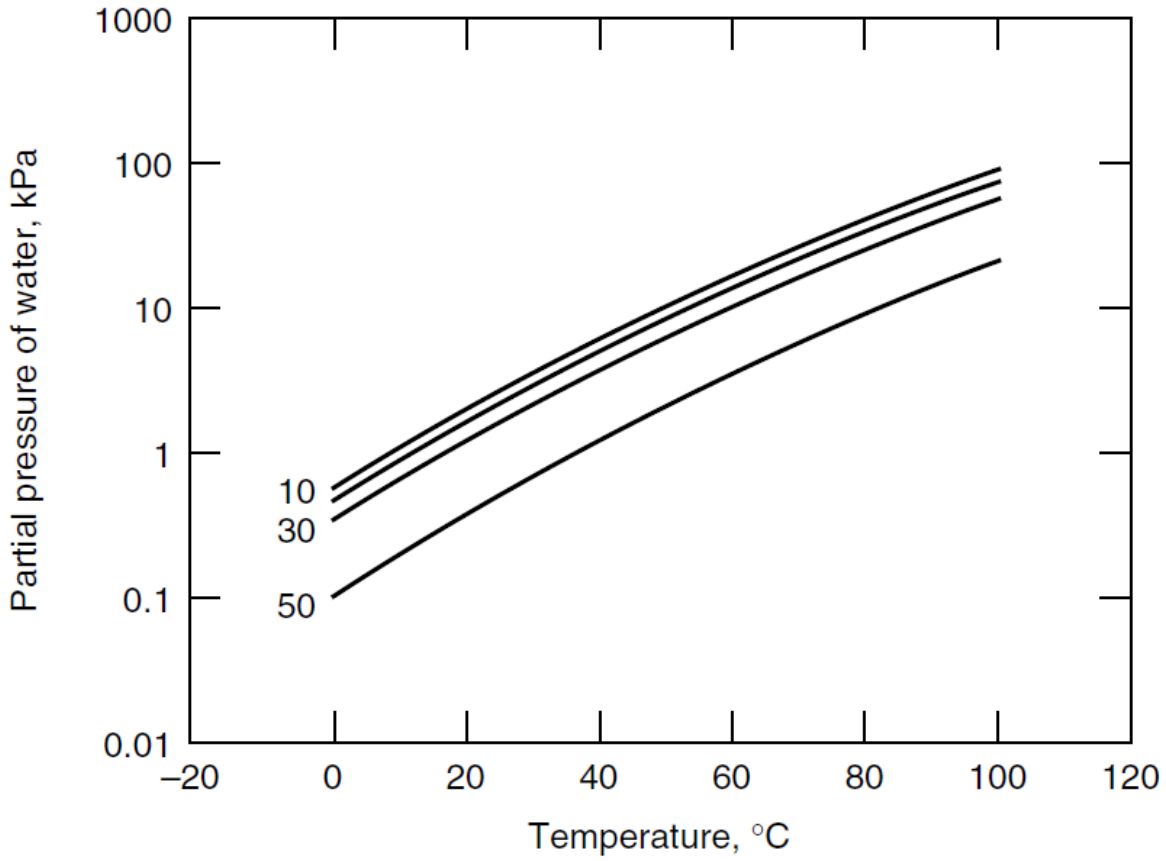
Partial pressures over HF-water solutions where the numbers represent the quantity of HF in solution expressed as wt % (a) of HF and (b) of H2O.

P. A. Munter, O. T. Aepli, and R. A. Kossatz, Ind. Eng. Chem. 41, 1504 (1949).

Partial pressure of water vapour over aqueous hydrofluoric acid versus temperature

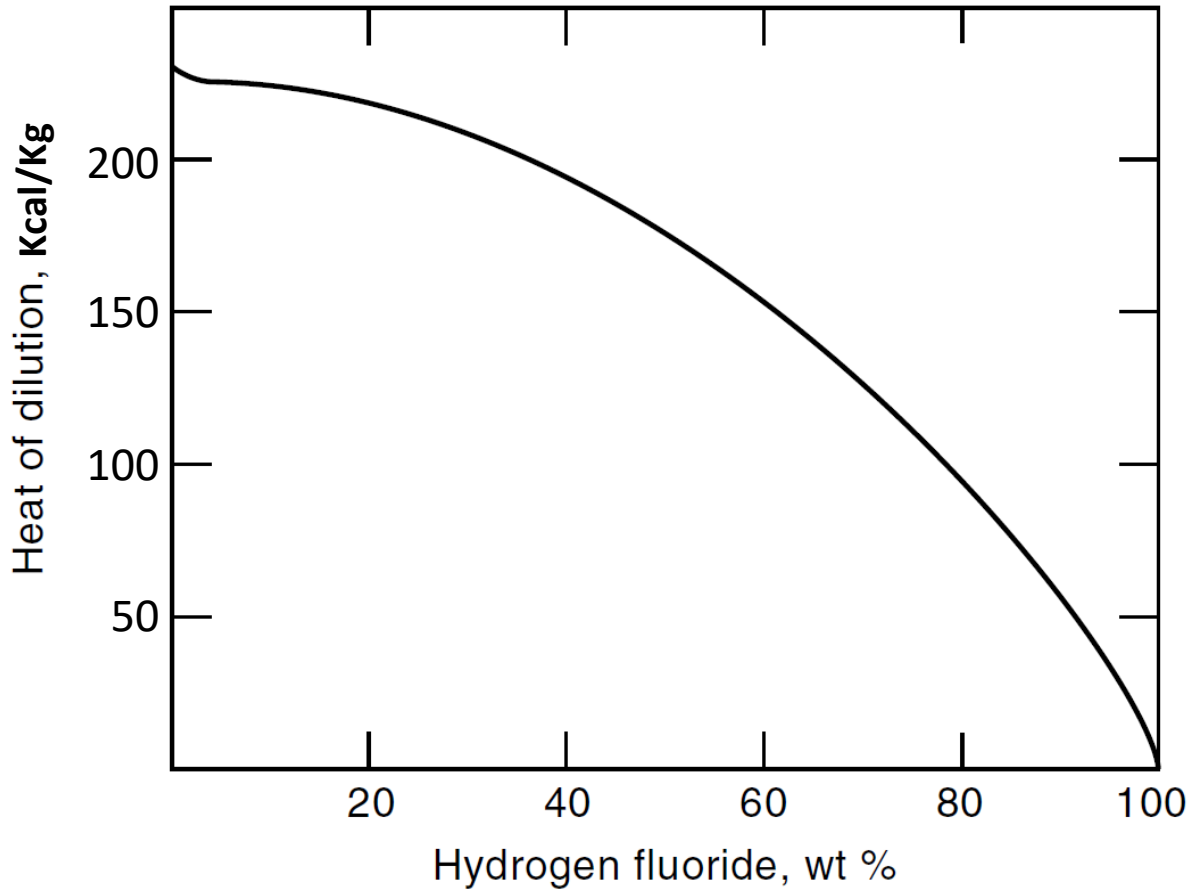


Partial pressures over HF-water solutions where the numbers represent the quantity of HF in solution expressed as wt % of H2O.

P. A. Munter, O. T. Aepli, and R. A. Kossatz, Ind. Eng. Chem. 41, 1504 (1949).

Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Heat of water solution of anhydrous hydrofluoric acid liquid versus final concentration at 25° C (Heat Evolved)

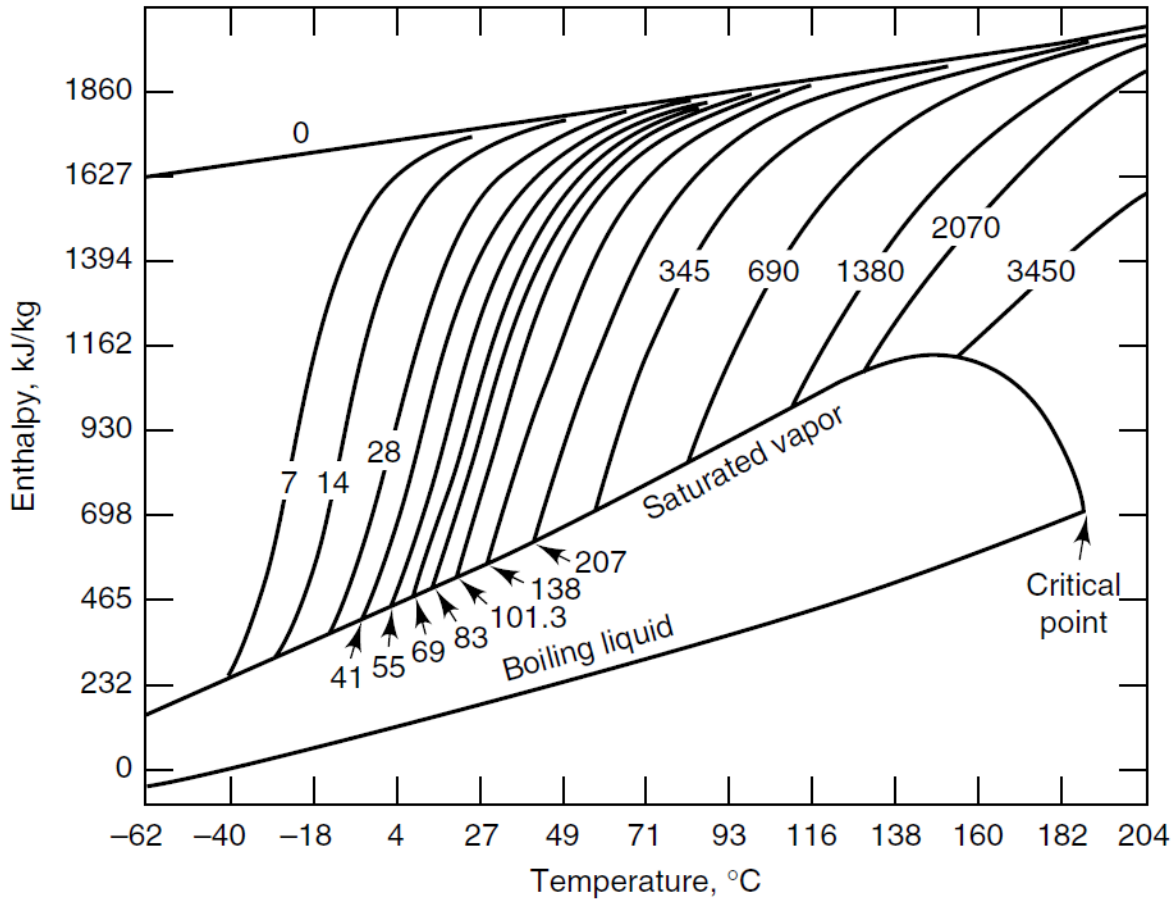


Heat of solution per gram of AHF in water when mixed to the final concentration shown in wt% of HF

- Hydrofluoric Acid, Anhydrous—Technical, Properties, Uses, Storage, and Handling, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., 1984.
- Hydrofluoric Acid, Allied-Signal Corp., Morristown, N.J., 1978.
- G. K. Johnson, P. N. Smith, and W. N. Hubbard, J. Chem. Thermodyn. 5, 793 (1973).

Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Enthalpy versus concentration at atmospheric pressure standard state: liquid water at 0° C and HF in infinitely diluted solutions at 0° C



Vapour-phase enthalpy of anhydrous HF where the numbers represent the partial pressure of HF in kPa. The critical point occurs at 1888C. To convert kPa to psi, multiply by 0.145. To convert kJ/kg to Btu/lb, multiply by 4.302×10^{-4}.

- C. E. Vanderzee and W. W. Rodenburg, J. Chem. Thermodyn. 2, 461 (1970).
- Hydrofluoric Acid, Allied-Signal Corp., Morristown, N.J., 1978.
- E. U. Franck and F. Meyer, Z. Electrochem. 63, 571 (1959).
- W. Spalthoff and E. U. Franck, Z. Electrochem 61(8), 993 (1957).
- R. M. Yabroff, J. C. Smith, and E. H. Lightcap J. Chem. Eng. Data 9(2), 178 (1964).

Reference: Kirk-Othmer Encyclopaedia of Chemical Technology, Volume 11, 5th edition, Donald Othmer, Raymond Kirk.

Enthalpy / Concentration diagram for the system HF/H_2O