

# Anhydrous Hydrogen Fluoride and Hydrofluoric Acid

Physical Properties



Solvay  
Special Chemicals



## Introduction

### Hydrogen Fluoride

Hydrogen fluoride (HF) is manufactured by Solvay in Bad Wimpfen (Germany), Ciudad Juárez (Mexico), Quzhou (Lansol JV in China) and Porto Marghera (Italy). Besides calcium fluoride ( $\text{CaF}_2$ ), also known as fluorspar, which Solvay sources in part from its own mines in places such as Okorusu (Namibia) and Chiprovtsi (Bulgaria), sulfuric acid and oleum are also used as raw materials. In a rotary kiln the mixture of calcium fluoride and sulfuric acid/oleum is heated, forming hydrogen fluoride and calcium sulfate ( $\text{CaSO}_4$ ). The gaseous hydrogen fluoride then has to undergo several purification steps to obtain technical grade HF (approx. 99.9%). The  $\text{CaSO}_4$  (anhydrite) thus produced is used in the building materials industry and has further applications in screed mixtures. The stored technical-grade HF is used for the production of fluorine-containing materials, or is dissolved in water to obtain hydrofluoric acid. Hydrofluoric acid can also be further purified for use in the semiconductor industry.

Most of the anhydrous hydrogen fluoride (AHF) is used in the production of fluorinated carbon compounds, the so-called HCFCs and HFCs. These materials are essential coolants, foam blowing agents, fire-extinguishing agents, solvents and raw materials for the production of fluorinated monomers for the plastics industry. Some additional major uses of AHF in organic chemistry are in Balz-Schiemann reactions, alkylation reactions in the petrochemical industry, reactions with  $\text{SF}_4$  in AHF to produce  $\text{CF}_3$  or  $\text{CF}_2\text{H}$  functional groups, and electrofluorination reactions.

Anhydrous hydrogen fluoride is highly soluble in water. The resulting hydrofluoric acid is transported in drums, tank trucks and rubber-lined railway tank cars. Hydrofluoric acid is used to clean cast metal, copper and brass. It removes efflorescence from bricks, stones and sand particles from metal castings. Frosted products, such as electric light bulbs, and other etched glass, e.g. polished crystal glass, and enamels are well-known. Purified e-grade hydrofluoric acid is required particularly for etching silicon in the photovoltaic and semiconductor industries. The manufacture of metal fluorides by fluoride precipitation reactions between HF and metal oxides, hydroxides or carbonates is of major importance for Solvay Fluor.

Cover photo:

Solvay Special Chemicals Mexico S.A. de C.V. Plant in Ciudad Juárez, Mexico

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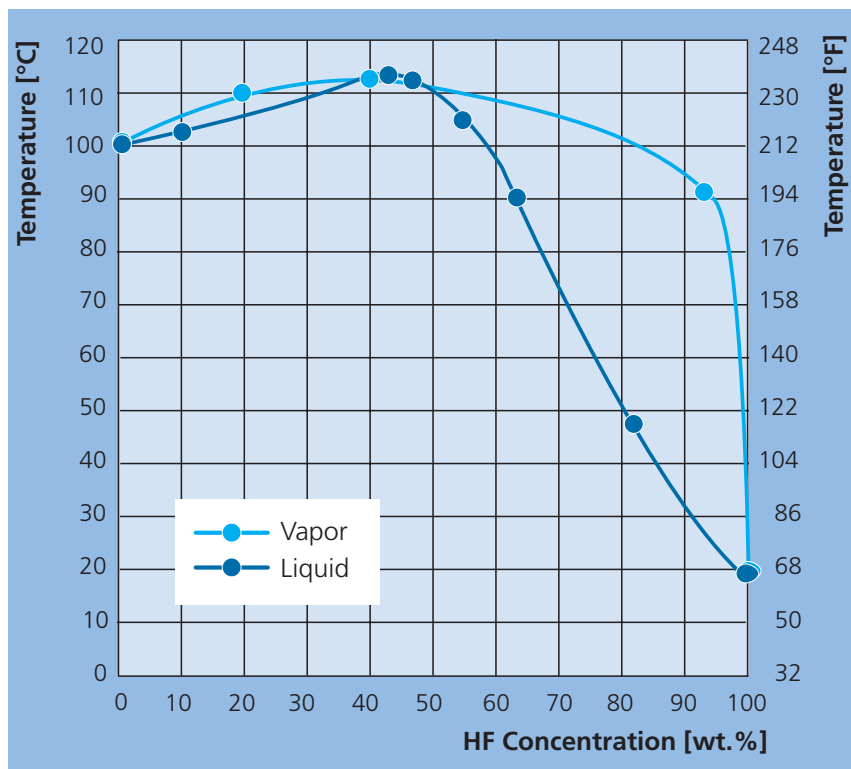
## Physical Properties of anhydrous hydrogen fluoride

Formula weight (calculated) <sup>a)</sup>	20.006
Molecular Weight	
Saturated vapor, at boiling point <sup>a)</sup>	78.24
Saturated vapor, at 100 °C <sup>a)</sup>	49.08
Boiling point at 1,013 mbar [°C] <sup>a)</sup>	19.51
Melting point [°C] <sup>a)</sup>	-83.37
Density	
Liquid, at 25 °C [kg/m <sup>3</sup> ] <sup>a)</sup>	957.6
Vapor, saturated, at 25 °C [kg/m <sup>3</sup> ] <sup>a)</sup>	3.553
Gas density, at 1 bar and 25 °C [kg/m <sup>3</sup> ] <sup>b)</sup>	0.83
Specific volume at 1,013 bar and 21 °C [m <sup>3</sup> /kg] <sup>b)</sup>	1.205
Vapor pressure, at 25°C [bar] <sup>a)</sup>	1.23
Heat of vaporization	
Boiling point, at 1,013 mbar [kJ/kg] <sup>a)</sup>	374.5
Heat of fusion, melting point [kJ/kg] <sup>a)</sup>	196.9
Heat capacity, constant pressure	
Liquid, boiling point [kJ/kg] <sup>a)</sup>	2.32
Vapor, at 25 °C, 1,013 mbar [kJ/kg. K] <sup>a)</sup>	1.46
Heat of formation, Ideal gas, at 25 °C [kJ/mol] <sup>a)</sup>	-272
Free energy of formation, Ideal gas, at 25 °C [kJ/mol] <sup>a)</sup>	-272
Heat capacity at constant pressure (cP)	
1,013 bar and 25 °C [kJ/(mol·K)] <sup>b)</sup>	0.029
Entropy, ideal gas, at 25 °C [J/mol K] <sup>a)</sup>	174
Critical temperature [°C] <sup>a)</sup>	188
Critical pressure [bar] <sup>a)</sup>	64.9
Critical density [kg/m <sup>3</sup> ] <sup>a)</sup>	290
Viscosity of liquid, at 0 °C [cP] <sup>a)</sup>	0.26
Surface tension, at boiling point, dyn/cm <sup>a)</sup>	8.6
Refractive index, 5,893 Å at 25 °C <sup>a)</sup>	1.1574
Molar refractivity, 5,893 Å, formula wt. [cm <sup>3</sup> ] <sup>a)</sup>	2.13
Conductivity at 0 °C [μS/cm] <sup>a)</sup>	<1.6
Dielectric constant, at 0 °C <sup>a)</sup>	83.6
Dipole moment [D] <sup>a)</sup>	1.83
Compressibility Factor at 1,013 bar and 15 °C <sup>b)</sup> [Z]	0.9835
Thermal conductivity at 1,013 bar and 0 °C [mW/(m·K)] <sup>b)</sup>	23.53

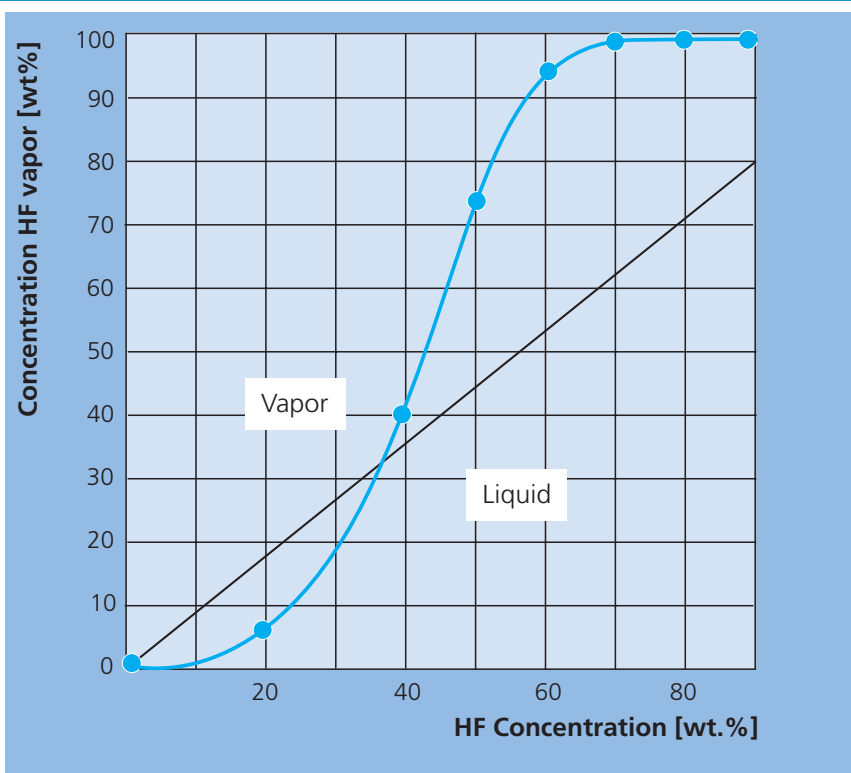
**Physical properties of aqueous 50% and 70% hydrogen fluoride at 20°C**

	<b>50 wt % HF</b>	<b>70 wt % HF</b>
Density liquid [kg/l] <sup>a)</sup>	1.17	1.23
Partial pressure HF [mbar] over HF-H <sub>2</sub> O solution <sup>a)</sup>	16.53	157.33
Partial pressure H <sub>2</sub> O [mbar] over HF-H <sub>2</sub> O solution <sup>a)</sup>	3.97	0.13
1g HF diluted with H <sub>2</sub> O Heat of dilution to < 1 wt % HF [J] <sup>a)</sup>	234	456
Freezing point [°C] <sup>d)</sup>	- 35	- 86
Boiling point [°C] <sup>a)</sup>	105	66

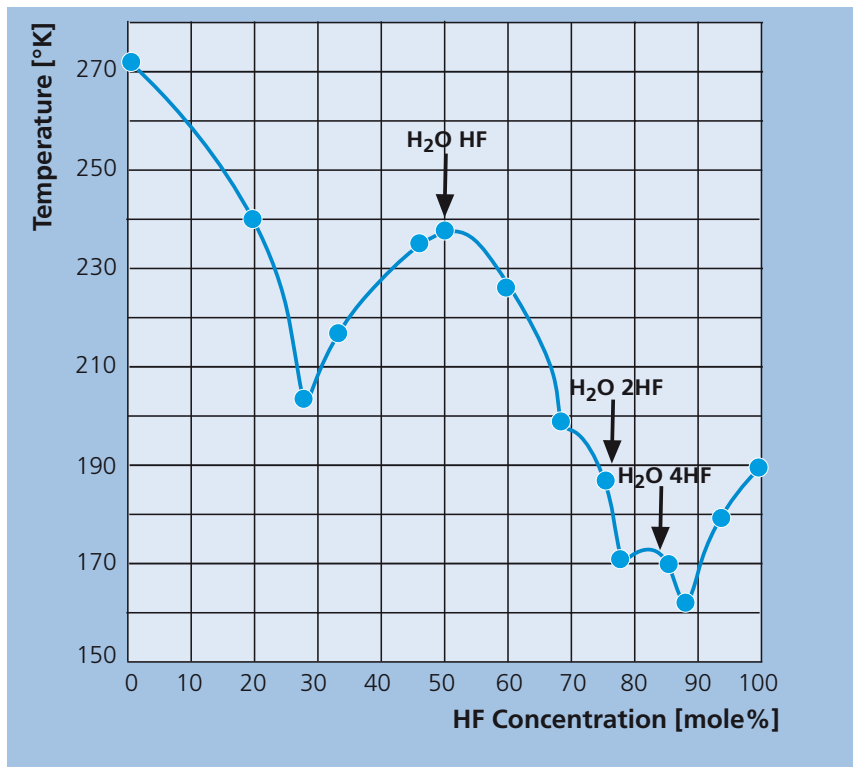
### The boiling point and liquid–vapor composition of the system HF–H<sub>2</sub>O <sup>c)</sup>



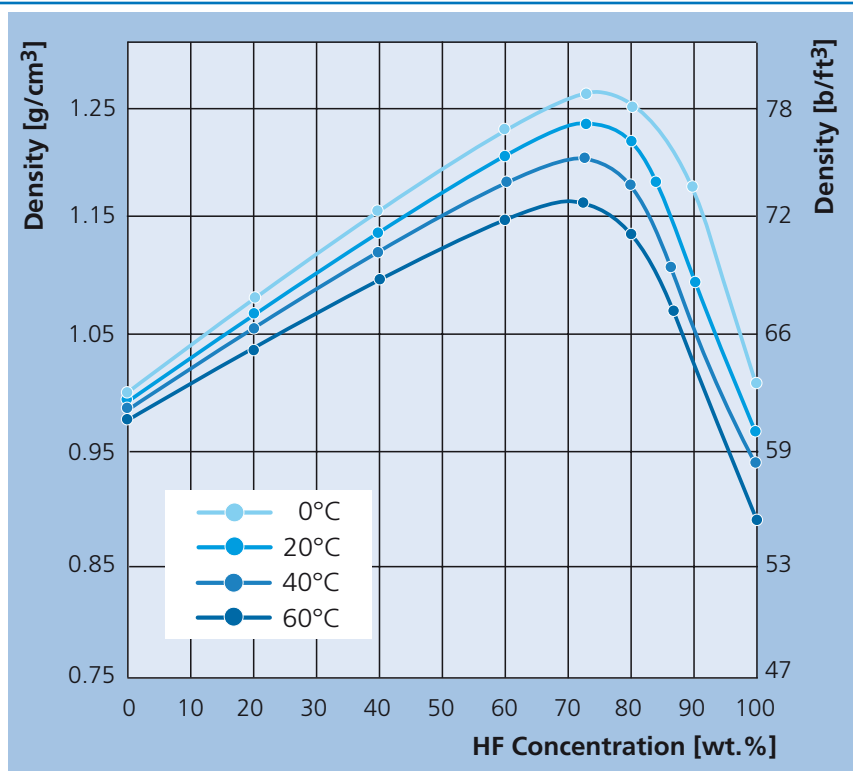
### Vapor–liquid equilibrium diagram at the normal boiling point <sup>c)</sup>



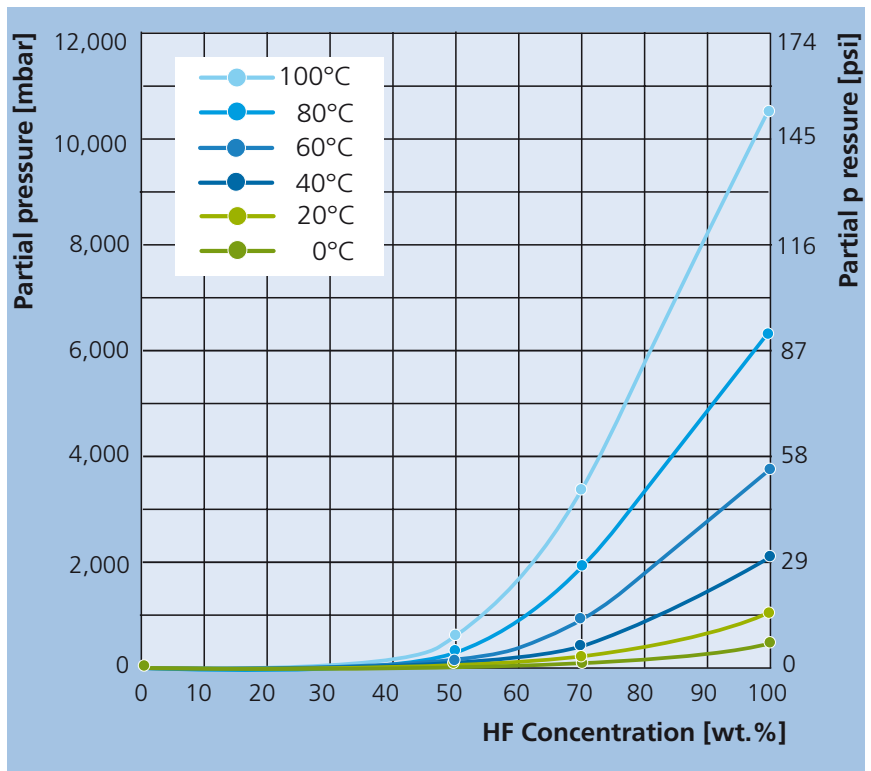
### Freezing point of aqueous solutions of hydrogen fluoride <sup>d)</sup>



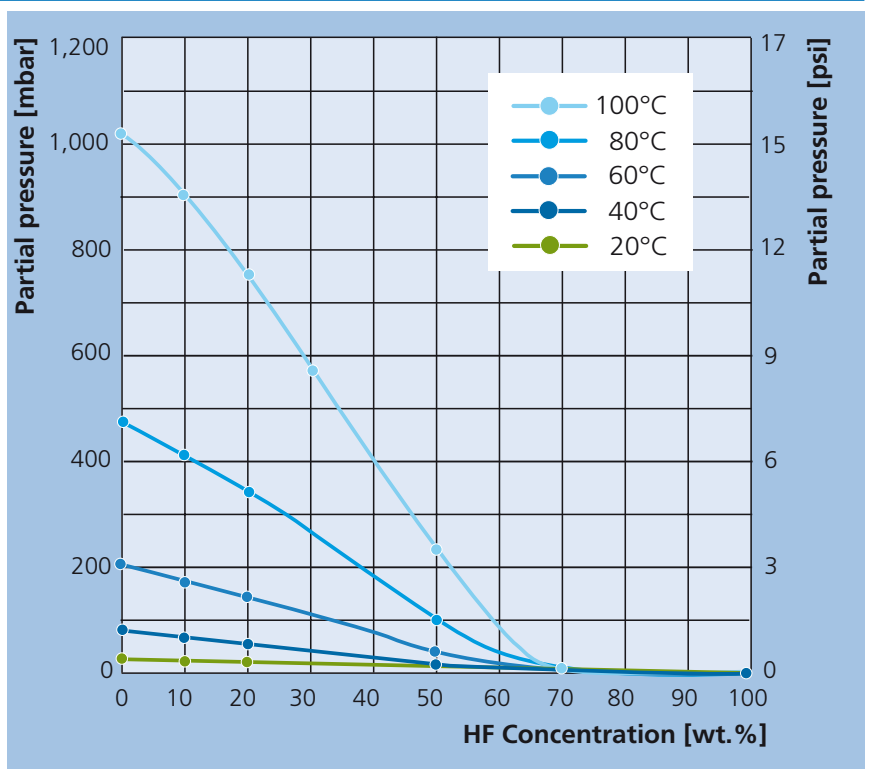
### Density of aqueous hydrogen fluoride <sup>a)</sup>



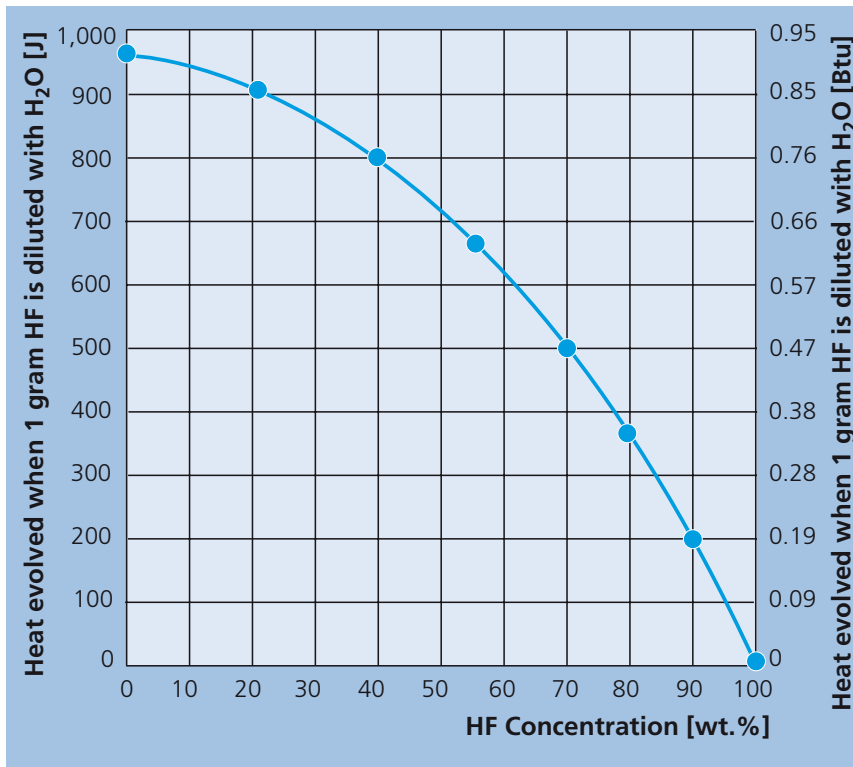
### Partial pressure of hydrogen fluoride over HF – H<sub>2</sub>O solution <sup>a)</sup>



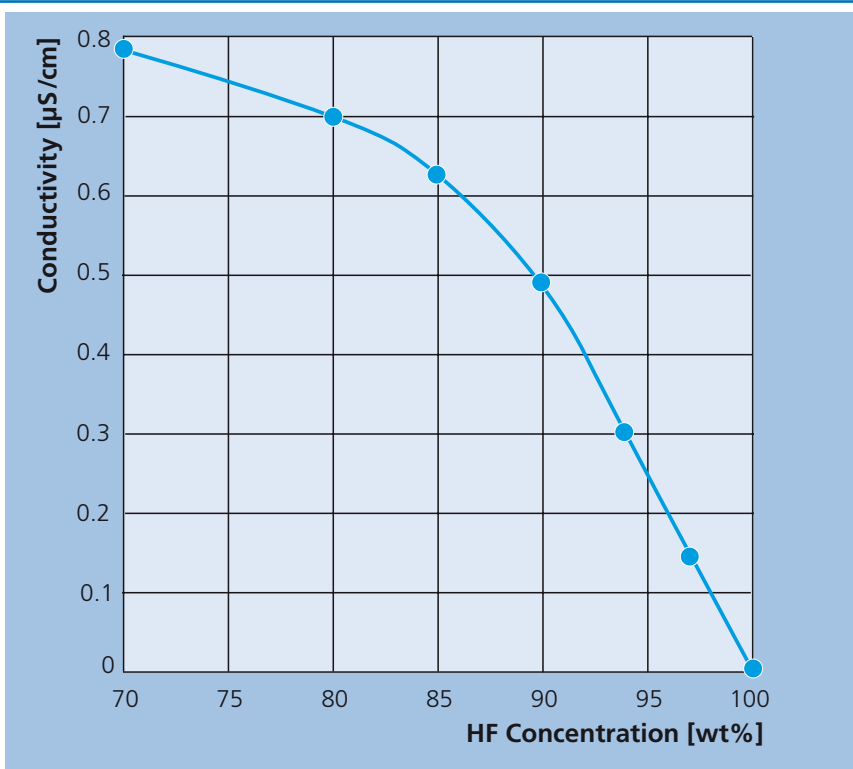
### Partial pressure of H<sub>2</sub>O over HF – H<sub>2</sub>O solution <sup>a)</sup>



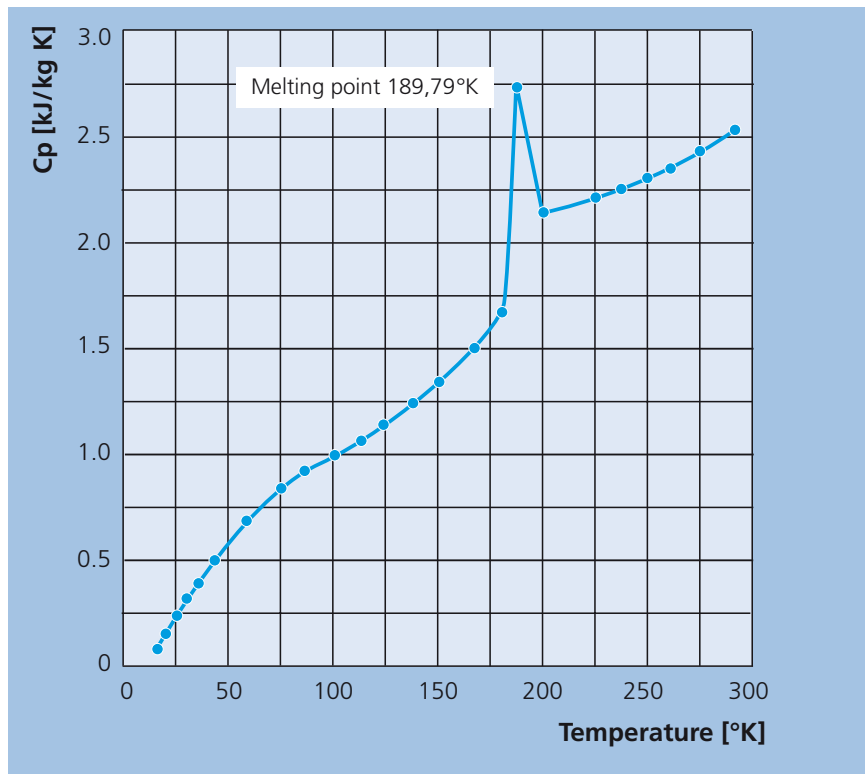
### Heat of dilution of aqueous HF solutions <sup>a)</sup>



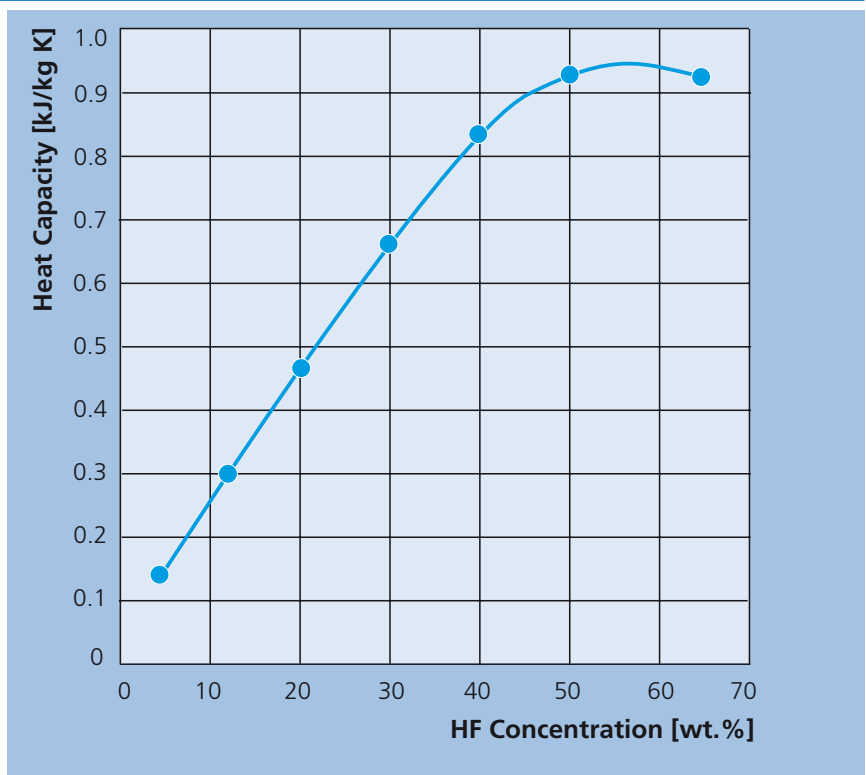
### Specific conductivity of HF-H<sub>2</sub>O solutions, at 0 °C <sup>a)</sup>



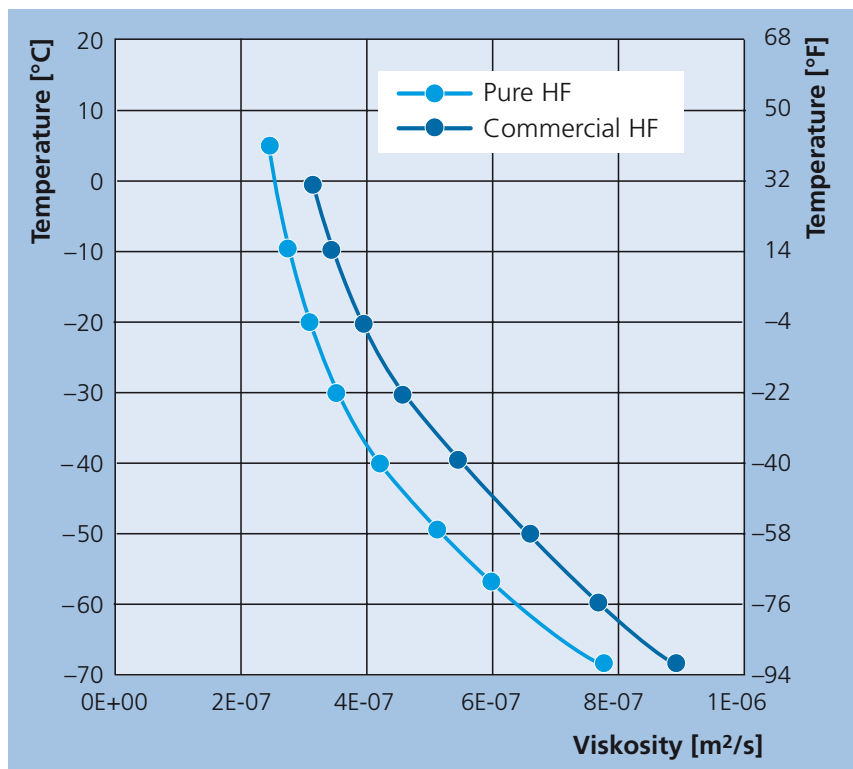
### Heat capacity of anhydrous hydrogen fluoride <sup>e)</sup>



### Heat capacity function for aqueous hydrogen fluoride at 25 °C <sup>f)</sup>



## Viscosity of hydrogen fluoride with differences in purity <sup>g)</sup>



## Bibliography

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- b) Air Liquide Gas Encyclopaedia "Hydrogen Fluoride" (1976)
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- f) Kelly L. Elmore, John D. Hatfield, Charles M. Mason, Arthur D. Jones, J. Am. Chem. Soc., 71 (8), pp 2710-2714 (1949)
- g) J. H. Simons, Richard D. Dresdner, J. Am. Chem. Soc., 66 (7), pp 1070-1072 (1944)

## Further Information

In addition to physical properties data, Solvay Fluorides, LLC is pleased to offer supporting documentation and reference literature including, but not limited to:

- First Aid and Medical Treatment for Hydrofluoric Acid Exposure tri-fold poster
- Summary of First Aid Procedures for Hydrofluoric Acid Exposure wallet cards
- Making it Safe for Hydrofluoric Acid safety training video
- Making it Safe for Hydrofluoric Acid Drum Handling safety training video
- Making it safe for Anhydrous Hydrofluoric Acid safety training video (available late 2011)
- Summary of First Aid Procedures for Hydrofluoric Acid Exposure wall poster (available late 2011)

For a full range of recommended practices specific to the Hydrogen Fluoride (HF) Industry including bulk storage guidelines, materials of construction, personal protective equipment and unloading guidelines, please visit the Hydrogen Fluoride Industry Practices Institute website at:

**[www.HFIPI.com](http://www.HFIPI.com)**

For all other information, please visit our website at:

**[www.solvay-fluor.com](http://www.solvay-fluor.com)**

For technical or sales information please refer to

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