

**TABLE 19.7**

Properties of the Group 6A Elements

| Property                                                                                                            | Oxygen      | Sulfur           | Selenium         | Tellurium   | Polonium    |
|---------------------------------------------------------------------------------------------------------------------|-------------|------------------|------------------|-------------|-------------|
| Valence electron configuration                                                                                      | $2s^2 2p^4$ | $3s^2 3p^4$      | $4s^2 4p^4$      | $5s^2 5p^4$ | $6s^2 6p^4$ |
| Melting point (°C)                                                                                                  | −219        | 113 <sup>*</sup> | 221 <sup>†</sup> | 450         | 254         |
| Boiling point (°C)                                                                                                  | −183        | 445              | 685              | 988         | 962         |
| Atomic radius (pm)                                                                                                  | 66          | 104              | 116              | 143         | 167         |
| X <sup>2−</sup> ionic radius (pm)                                                                                   | 132         | 184              | 191              | 211         |             |
| First ionization energy (kJ/mol)                                                                                    | 1314        | 1000             | 941              | 869         | 812         |
| Electron affinity (kJ/mol)                                                                                          | −141        | −200             | −195             | −190        | −183        |
| Electronegativity                                                                                                   | 3.5         | 2.5              | 2.4              | 2.1         | 2.0         |
| Redox potential, $E^\circ(\text{V})$ for<br>$\text{X} + 2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2\text{X}$ | 1.23        | 0.14             | −0.40            | −0.79       | —           |

<sup>\*</sup>Rhombic S<sup>†</sup>Gray Se

## Die 10 wichtigsten Industriechemikalien

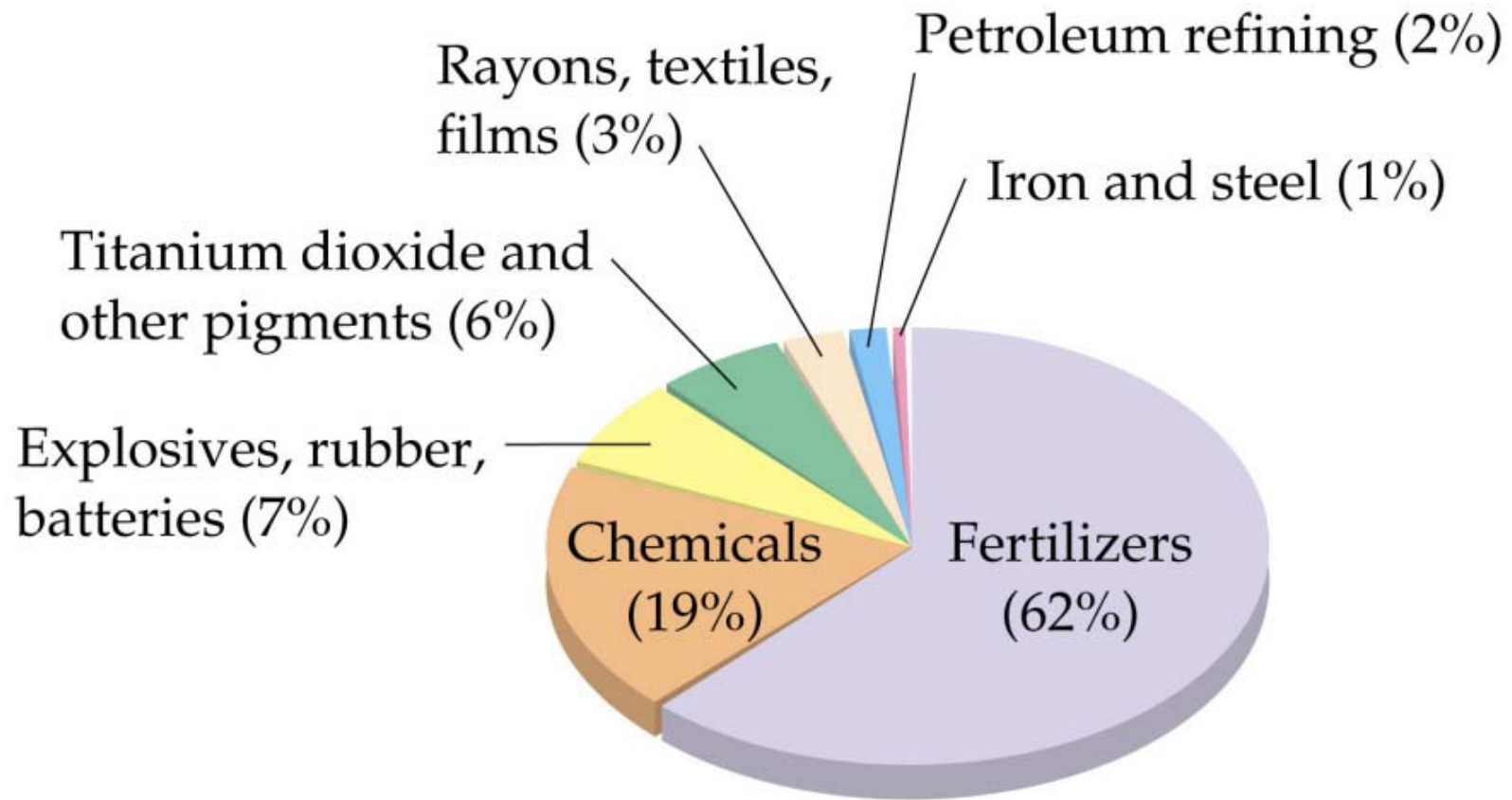
beachte: Schwefelsäure ist die wichtigste!

**TABLE 19.1**

The Top 10 Chemicals (2001 U.S. Production)

| Chemical                                         | Millions of Tons | Principal Uses                          |
|--------------------------------------------------|------------------|-----------------------------------------|
| Sulfuric acid ( $\text{H}_2\text{SO}_4$ )        | 40.1             | Fertilizers, chemicals, oil refining    |
| Nitrogen ( $\text{N}_2$ )                        | 35.5             | Inert atmospheres, low temperatures     |
| Oxygen ( $\text{O}_2$ )                          | 26.0             | Steelmaking, welding, medical uses      |
| Ethylene ( $\text{CH}_2=\text{CH}_2$ )           | 24.8             | Plastics, antifreeze                    |
| Lime ( $\text{CaO}$ )                            | 20.6             | Steelmaking, chemicals, water treatment |
| Propylene ( $\text{CH}_3\text{CH}=\text{CH}_2$ ) | 14.5             | Plastics, fibers, solvents              |
| Ammonia ( $\text{NH}_3$ )                        | 13.0             | Fertilizers, nitric acid                |
| Chlorine ( $\text{Cl}_2$ )                       | 12.0             | Chemicals, plastics, water treatment    |
| Phosphoric acid ( $\text{H}_3\text{PO}_4$ )      | 11.6             | Fertilizers, detergents                 |
| Sodium hydroxide ( $\text{NaOH}$ )               | 10.7             | Chemicals, textiles, soaps              |

## Verwendung von Schwefelsäure



**TABLE 6.7**

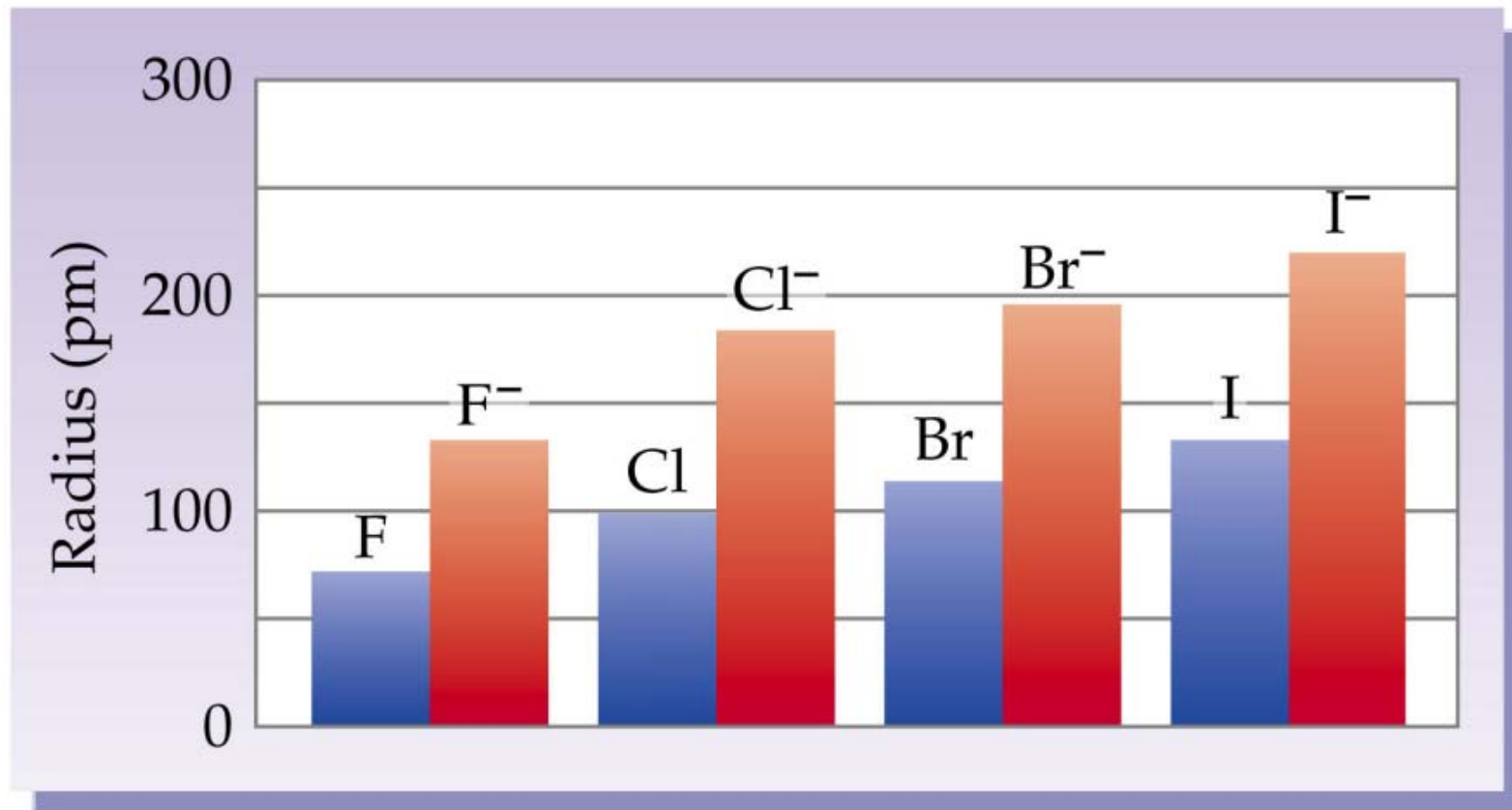
Properties of Halogens

| <b>Name</b> | <b>Melting Point (°C)</b> | <b>Boiling Point (°C)</b> | <b>Density (g/cm<sup>3</sup>)</b> | <b>Electron Affinity (kJ/mol)</b> | <b>Abundance on Earth (%)</b> | <b>Atomic Radius (pm)</b> | <b>Ionic (X<sup>-</sup>) Radius (pm)</b> |
|-------------|---------------------------|---------------------------|-----------------------------------|-----------------------------------|-------------------------------|---------------------------|------------------------------------------|
| Fluorine    | -220                      | -188                      | 1.50 ( <i>l</i> )                 | -328                              | 0.062                         | 72                        | 133                                      |
| Chlorine    | -101                      | -34                       | 2.03 ( <i>l</i> )                 | -349                              | 0.013                         | 99                        | 181                                      |
| Bromine     | -7                        | 59                        | 3.12 ( <i>l</i> )                 | -325                              | 0.0003                        | 114                       | 196                                      |
| Iodine      | 114                       | 184                       | 4.930( <i>s</i> )                 | -295                              | 0.000 05                      | 133                       | 220                                      |
| Astatine    | —                         | —                         | —                                 | -270                              | Trace                         | —                         | —                                        |

## Übersicht: Halogene

|                        | Sdp. °C | Smp. °C | Farbe         | Darstellung                                                               | Verwendung                                                                                                                                         |
|------------------------|---------|---------|---------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| F <sub>2</sub><br>(g)  | -188    | -220    | blass<br>gelb | Elektrolyse                                                               | Fluorchlorkohlenwasserstoffe,<br>Blutersatz, Ionenaustauscher<br>für Brennstoffzellen,<br>Herstellung von Kernbrenn-<br>stoffen [UF <sub>6</sub> ] |
| Cl <sub>2</sub><br>(g) | -35     | -101    | gelb-<br>grün | Elektrolyse                                                               | organ. Chlorverbindungen<br>(70%), Desinfektionsmittel<br>(20%), Bleichmittel<br>(Baumwolle, Papier)                                               |
| Br <sub>2</sub><br>(l) | 59      | -7      | braun         | Cl <sub>2</sub> +2Br <sup>-</sup> -><br>2Cl <sup>-</sup> +Br <sub>2</sub> | Bromchemikalien                                                                                                                                    |
| I <sub>2</sub><br>(s)  | 184     | 114     | violett       | Cl <sub>2</sub> +2I <sup>-</sup> -><br>2Cl <sup>-</sup> +I <sub>2</sub>   | org. Iodverbindungen,<br>I <sub>2</sub> +CH <sub>3</sub> CH <sub>2</sub> OH als<br>Desinfektionsmittel,<br>wichtiges Spurenelement                 |

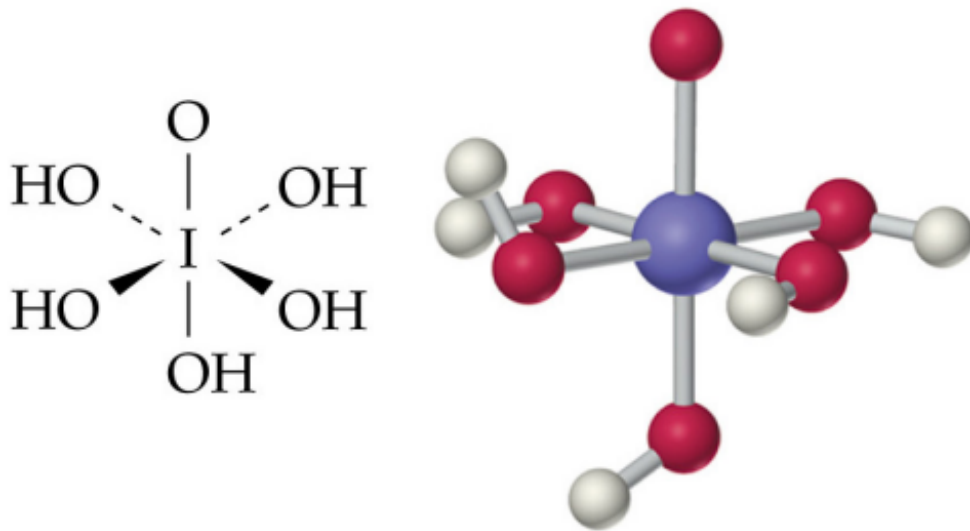
Ionenradien der Halogenide im Vergleich zu den  
Atomradien der Halogen-Atome



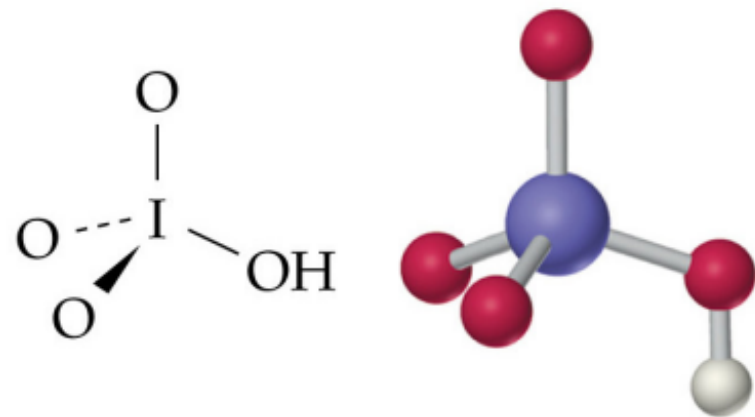
**TABLE 19.8****Oxoacids of the Halogens**

| <b>Oxidation State</b> | <b>Generic Name (formula)</b>        | <b>Chlorine</b>   | <b>Bromine</b>    | <b>Iodine</b>                                     |
|------------------------|--------------------------------------|-------------------|-------------------|---------------------------------------------------|
| +1                     | Hypohalogenige Säure (HXO)           | HClO              | HBrO              | HIO                                               |
| +3                     | Halogenige Säure (HXO <sub>2</sub> ) | HClO <sub>2</sub> | —                 | —                                                 |
| +5                     | Halogensäure (HXO <sub>3</sub> )     | HClO <sub>3</sub> | HBrO <sub>3</sub> | HIO <sub>3</sub>                                  |
| +7                     | Perhalogensäure (HXO <sub>4</sub> )  | HClO <sub>4</sub> | HBrO <sub>4</sub> | HIO <sub>4</sub> , H <sub>5</sub> IO <sub>6</sub> |

## Strukturformeln von Para- und Metaperjodsäure



Paraperiodic acid,  $\text{H}_5\text{IO}_6$



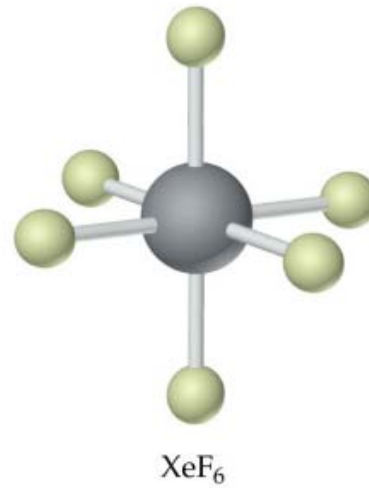
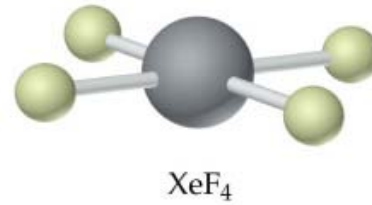
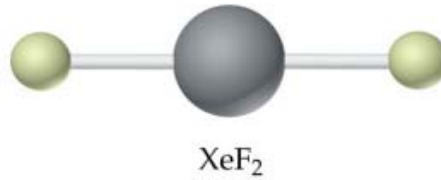
Metaperiodic acid,  $\text{HIO}_4$

**TABLE 6.8**

## Properties of Noble Gases

| <b>Name</b> | <b>Melting Point (°C)</b> | <b>Boiling Point (°C)</b> | <b>First Ionization Energy (kJ/mol)</b> | <b>Abundance in Dry Air (Vol %)</b> |
|-------------|---------------------------|---------------------------|-----------------------------------------|-------------------------------------|
| Helium      | −272.2                    | −268.9                    | 2372.3                                  | $5.2 \times 10^{-4}$                |
| Neon        | −248.6                    | −246.1                    | 2080.6                                  | $1.8 \times 10^{-3}$                |
| Argon       | −189.3                    | −185.9                    | 1520.4                                  | 0.93                                |
| Krypton     | −157.4                    | −153.2                    | 1350.7                                  | $1.1 \times 10^{-4}$                |
| Xenon       | −111.8                    | −108.0                    | 1170.4                                  | $9 \times 10^{-6}$                  |
| Radon       | −71                       | −61.7                     | 1037                                    | Trace                               |

# Struktur einiger Xenon-Fluor-Verbindungen



## Bindungskräfte in Festkörpern

| Typ              | Intermolekulare Kräfte                       | Eigenschaften                    | Beispiele                                                 |
|------------------|----------------------------------------------|----------------------------------|-----------------------------------------------------------|
| Ionenkristall    | Ion-Ion-Wechselwirkung                       | brüchig, hart, hoher Smp.        | NaCl, KBr, CaCO <sub>3</sub>                              |
| Molekulkristall  | Dipol-Dipol, H-Brücken, van der Waals-Kräfte | weich, tiefer Smp., nichtleitend | H <sub>2</sub> O, CO <sub>2</sub> , organische Substanzen |
| Atomkristall     | kovalente Bindungen                          | hart, hoher Smp.                 | Diamant                                                   |
| Metallkristall   | metallische Bindung                          | variable Härte und Smp., leitend | Na, Cu, Au, Ag                                            |
| Edelgas-kristall | van der Waals-Kräfte                         | sehr tiefer Smp.                 | He, Ne                                                    |