List of molecules discovered in the ISM

# Interstellar Molecules

Shading indicates an identification made by IR, Vis, or UV spectra.
Unshaded entries were detected by radio or microwave methods.
"?" indicates an uncertain or controversial detection.
Molecules in blue have been identified in the ice phase as well as the gas phase.

| Molecules with Two Atoms | | | |
|---|---|---|---|
| $H_2$ hydrogen | CO carbon monoxide | CSi carbon monosilicide | CP carbon monophosphide |
| CS carbon monosulfide | NO nitric oxide | NS nitric sulfide | SO sulfur monoxide |
| HCl hydrogen chloride | NaCl sodium chloride | KCl potassium chloride | AlCl aluminum monochloride |
| AlF aluminum monofluoride | PN phosphorus mononitride | SiN silicon mononitride | SiO silicon monoxide |
| SiS silicon monosulfide | NH imidyl radical | OH hydroxyl radical | $C_2$ diatomic carbon |
| CN cyanide radical | HF hydrogen fluoride | FeO iron monoxide | LiH lithium hydride |
| CH methylidyne | $CH^+$ | $CO^+$ | $SO^+$ |
| SH mercapto radical | $O_2$ oxygen | $N_2$ nitrogen | |

| Molecules with Three Atoms | | | |
|---|---|---|---|
| $H_2O$ water | $H_2S$ hydrogen sulfide | HCN hydrogen cyanide | HNC hydrogen isocyanide |
| $CO_2$ carbon dioxide | $SO_2$ sulfur dioxide | MgCN magnesium cyanide | MgNC magnesium isocyanide |
| NaCN sodium cyanide | $N_2O$ nitrous oxide | $NH_2$ amidogen radical | OCS carbonyl sulfide |
| $CH_2$ methylene | HCO formyl radical | $C_3$ triatomic carbon | $C_2H$ ethynyl radical |
| $C_2O$ ketenylidene | $C_2S$ thioxoethenylidene | AlNC aluminum isocyanide | HNO nitrosyl hydride |
| SiCN silicon monocyanide | $N_2H^+$ | SiNC silicon isocyanide | *c*- $SiC_2$ silicon dicarbide |
| $HCO^+$ formyl cation | $HOC^+$ | $HCS^+$ | $H_3^+$ |
| $OCN^-$ solid-phase only | HCP | | |

| Molecules with Four Atoms | | | |
|---|---|---|---|
| $NH_3$ ammonia | $H_2CO$ (?) formaldehyde | $H_2CS$ thioformaldehyde | $C_2H_2$ acetylene |
| HNCO isocyanic acid | HNCS thioisocyanic acid | $H_3O^+$ hydronium ion | $SiC_3$ |
| $C_3S$ | $H_2CN$ | *c*- $C_3H$ | *l*- $C_3H$ |
| HCCN | $CH_3$ methyl radical | $C_2CN$ cyanoethynyl radical | $C_3O$ |
| $HCNH^+$ | $HOCO^+$ protonated $CO_2$ | | |

| Molecules with Five Atoms | | | |
|---|---|---|---|
| $CH_4$ methane | $SiH_4$ silane | $CH_2NH$ methyleneimine | $NH_2CN$ cyanamide |
| $CH_2CO$ ketene | HCOOH (?) formic acid | HCC-CN cyanoacetylene | HCC-NC isocyanoacetylene |
| *c*- $C_3H_2$ | *l*- $C_3H_2$ | $CH_2CN$ cyanomethyl | $H_2COH^+$ protonated formaldehyde |
| $C_4Si$ | $C_5$ | HNCCC | $C_4H$ |
| $C_4H^-$ | | | |

| Molecules with Six Atoms | | | |
|---|---|---|---|
| $CH_3OH$ methanol | $CH_3SH$ methanethiol | $C_2H_4$ ethylene | $H(CC)_2H$ diacetylene |
| $CH_3CN$ methylcyanide | $CH_3NC$ methylisocyanide | $HC(O)NH_2$ formamide | HCC-C(O)H propynal |
| $HC_3NH^+$ protonated cyanoacetylene | $HC_4N$ cyanopropenylidene | $C_5N$ | $C_5H$ |
| $H_2CCCC$ butatrienylidene | | | |

| Molecules with Seven Atoms | | | |
|---|---|---|---|
| $CH_2CH(OH)$ vinyl alcohol | *c*- $C_2H_4O$ ethylene oxide | $HC(O)CH_3$ acetaldehyde | $H_3C$-CC-H methylacetylene |
| $CH_3NH_2$ methylamine | $CH_2CH(CN)$ acrylonitrile | HCC-CC-CN cyanobutadiyne | $C_6H$ hexatriynyl radical |

| Molecules with Eight Atoms | | |
|---|---|---|
| $CH_3COOH$ acetic acid | $HC(O)OCH_3$ methyl formate | $HOCH_2C(O)H$ glycolaldehyde |
| $H_3C$-CC-CN cyanomethylacetylene | $H_2C_6$ hexapentaenylidene | $H(CC)_3H$ triacetylene |
| $H_2C$=CH-C(O)H propenal | | $C_7H$ |

| Molecules with Nine Atoms | | |
|---|---|---|
| $(CH_3)_2O$ dimethyl ether | $CH_3CH_2CN$ ethylcyanide | $CH_3CH_2OH$ ethanol |
| $CH_3C_4H$ methylbutadiyne | HCC-CC-CC-CN cyanohexatriyne | $C_8H$ |

| Molecules with Ten Atoms | |
|---|---|
| $(CH_3)_2CO$ acetone | $HOCH_2CH_2OH$ ethylene glycol |
| $H_3C$-$CH_2$-C(O)H propanal | $CH_3(CC)_2CN$ methylcyanoacetylene |

| Molecules with Eleven Atoms |
|---|
| HCC-CC-CC-CC-CN cyanooctatetrayne |

| Molecules with Twelve Atoms | |
|---|---|
| $C_6H_6$ benzene | $(CH_2OH)_2C(O)$ dihydroxyacetone |

| Molecules with Thirteen Atoms |
|---|
| HCC-CC-CC-CC-CC-CN cyanodecapentayne |

See http://www-691.gsfc.nasa.gov/cosmic.ice.lab for the latest list.

# Chemistry

Reaction rates:

## neutral-neutral

| reaction | $\alpha$ | $\beta$ | $\gamma$ |
|---|---|---|---|
| $H_2 + O \rightarrow OH + H$ | 9.0(−12) | 1.0 | 4.5(3) |
| $H + OH \rightarrow O + H_2$ | 4.2(−12) | 1.0 | 3.5(3) |
| $H_2 + OH \rightarrow H_2O + H$ | 3.6(−11) | | 2.1(3) |
| $H + H_2O \rightarrow OH + H_2$ | 1.5(−10) | | 1.0(4) |
| $H + O_2 \rightarrow OH + O$ | 3.7(−10) | | 8.5(3) |
| $OH + O \rightarrow O_2 + H$ | 4.0(−10) | | 6.0(2) |
| $H_2 + C \rightarrow CH + H$ | 1.2( −9) | 0.5 | 1.4(4) |
| $H + CH \rightarrow C + H_2$ | 1.2( −9) | 0.5 | 2.2(3) |
| $C^+ + H_2 \rightarrow CH^+ + H$ | 9.4(−12) | 1.25 | 4.7(3) |

[a] Reaction rates of the form $k = \alpha\,(T/300)^{\beta}\,\exp[-\gamma/kT]$.

## ion-molecule

| reaction | $\alpha$ |
|---|---|
| $H_2^+ + H_2 \rightarrow H_3^+ + H$ | 2.1 (–9) |
| $H_3^+ + O \rightarrow OH^+ + H_2$ | 8.0 (–10) |
| $H_3^+ + CO \rightarrow HCO^+ + H_2$ | 1.7 (–9) |
| $H_3^+ + H_2O \rightarrow H_3O^+ + H_2$ | 5.9 (–9) |
| $OH^+ + H_2 \rightarrow H_2O^+ + H$ | 1.1 (–9) |
| $H_2O^+ + H_2 \rightarrow H_3O^+ + H$ | 6.1 (–10) |
| $C^+ + OH \rightarrow CO^+ + H$ | 7.7 (–10) |
| $C^+ + H_2O \rightarrow HCO^+ + H$ | 2.7 (–9) |
| $CO^+ + H_2 \rightarrow HCO^+ + H$ | 2.0 (–9) |
| $He^+ + CO \rightarrow C^+ + O + He$ | 1.6 (–9) |
| $He^+ + O_2 \rightarrow O^+ + O + He$ | 1.0 (–9) |
| $He^+ + H_2O \rightarrow OH^+ + H + He$ | 3.7 (–10) |
| $He^+ + H_2O \rightarrow H_2O^+ + He$ | 7.0 (–11) |
| $He^+ + OH \rightarrow O^+ + H + He$ | 1.1 (–9) |

[a] Reaction rates are of the form $k = \alpha$.

# Chemistry

Chemical reaction schemes involving

oxygen and carbon

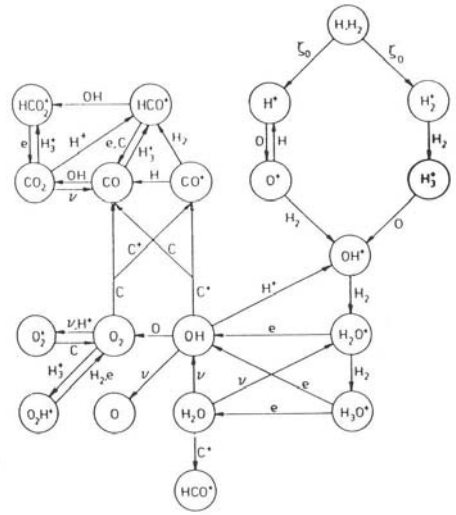


**Fig. 9.3.** A somewhat simplified version of the gas-phase chemistry of oxygen in dense molecular clouds, and of its coupling with carbon chemistry. Exothermic reactions are symbolized by arrows joining one of the parent products to the resulting one, the other parent partner being indicated near the arrow. From Prasad et al. [415], with the kind permission of Kluwer Academic Publishers.

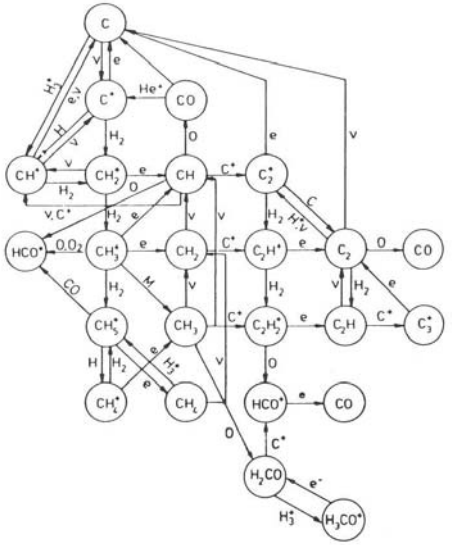
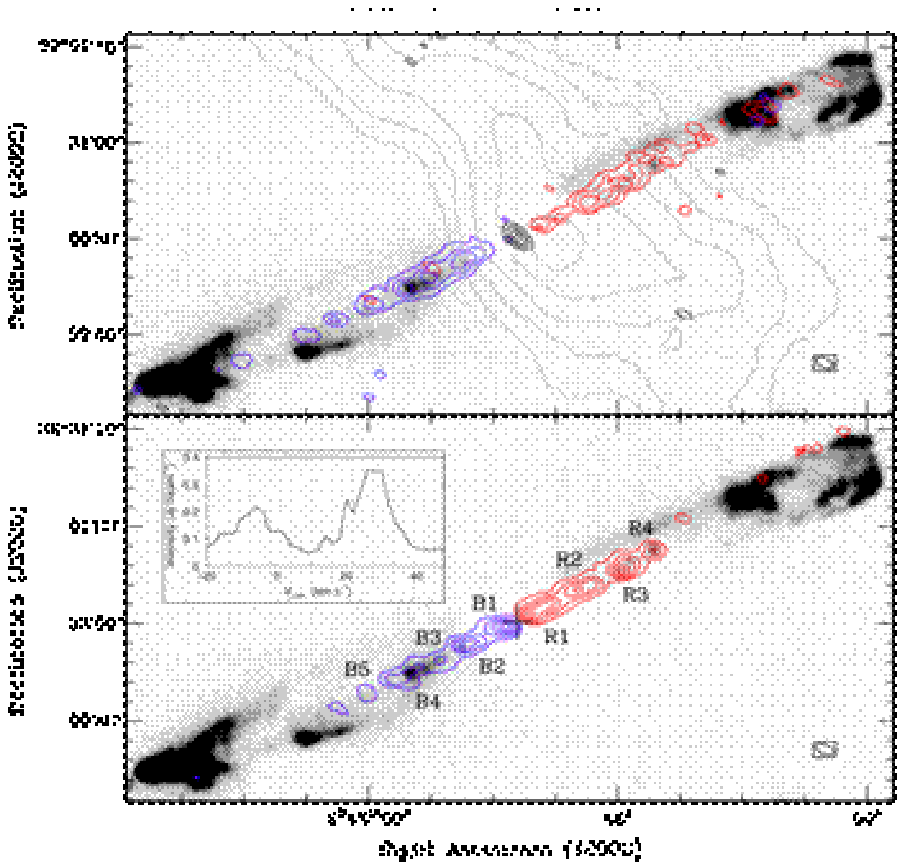


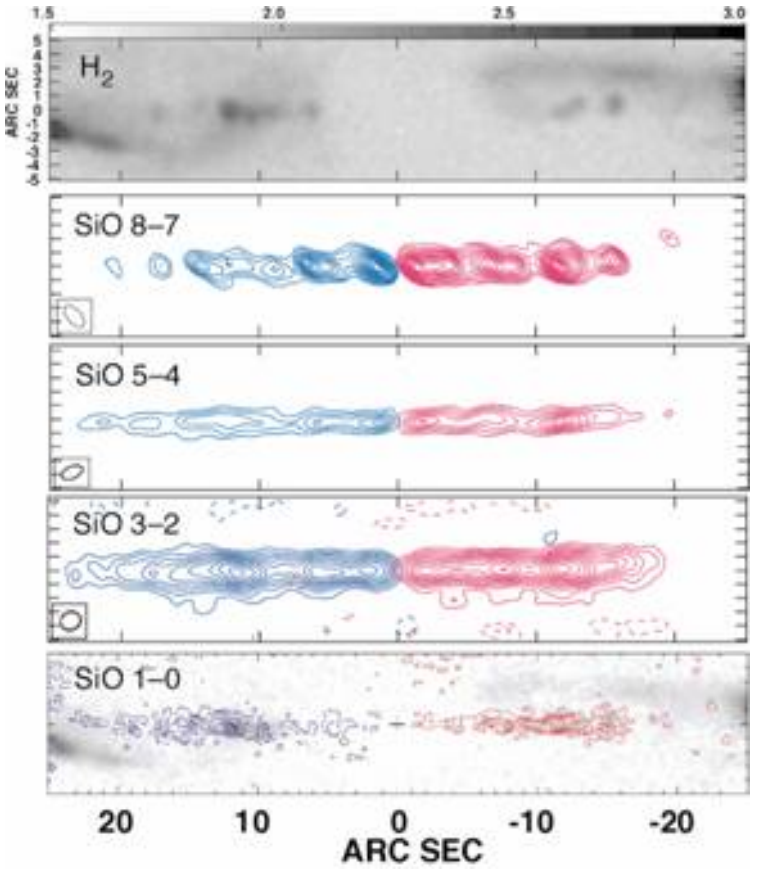
**Fig. 9.2.** A somewhat simplified version of the gas-phase chemistry of carbon in dense molecular clouds, and of its coupling with oxygen chemistry. Exothermic reactions are symbolized by arrows joining one of the parent products to the resulting one, the other parent partner being indicated near the arrow. From Prasad et al. [415], with the kind permission of Kluwer Academic Publishers.

# Chemistry

Bipolar stellar outflow from the massive young star HH 211

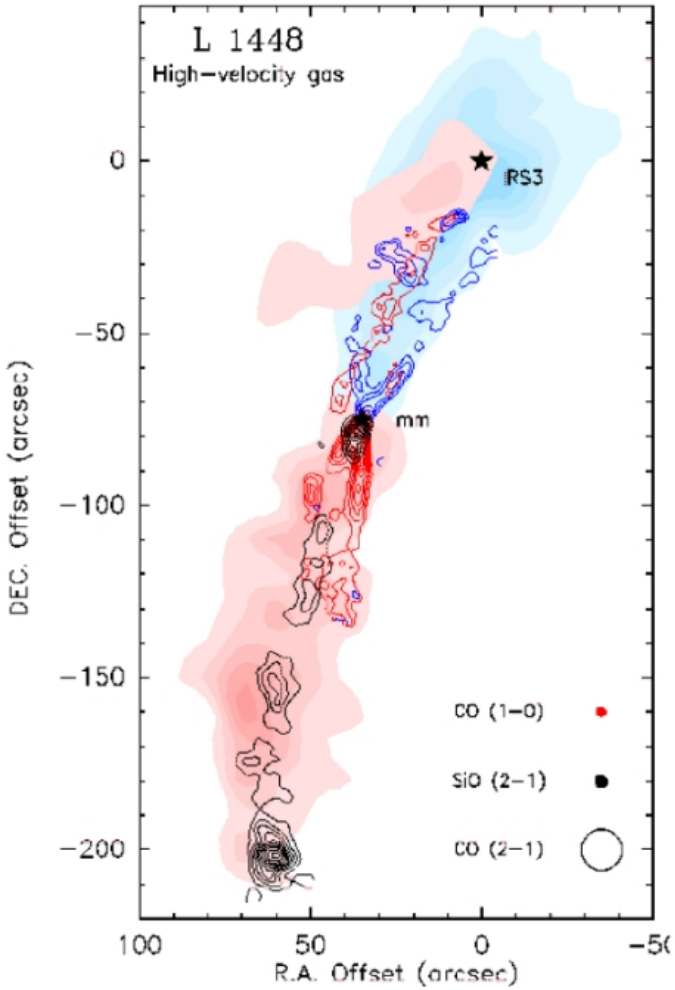
CO and SiO



# Chemistry

Bipolar stellar outflow from the massive young star L1448




Circumstellar chemistry around the evolved star IRC+10216