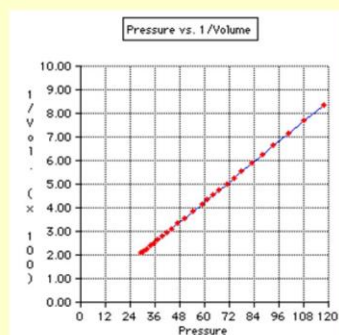
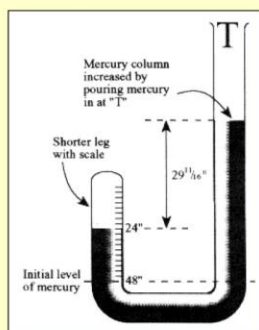




## Gassen

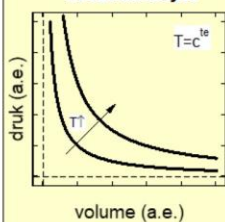
### het experiment van Boyle



## Gassen

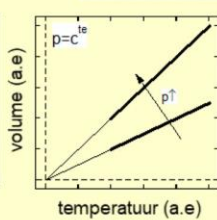
### Fenomenologische gaswetten

#### Wet van Boyle

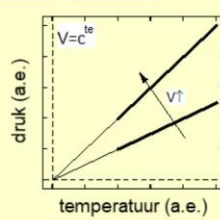


$$p \propto \frac{1}{V}$$

#### Wetten van Charles en Guy-Lussac

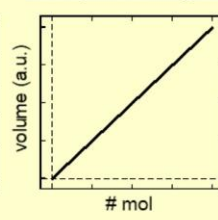


$$V \propto T$$



$$p \propto T$$

#### Principe van Avogadro



$$V \propto n$$

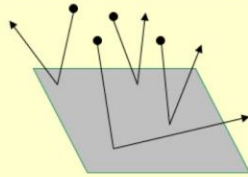
Ideale Gaswet

$$pV \propto nRT$$

R: gasconstante, 8.314 J K<sup>-1</sup> mol

## Gassen

### kinetische gastheorie



- ✓ druk ~ botsingen op wand
- ✓ kracht = uitgewisseld impuls per seconde

$$p = \frac{1}{3} \frac{N}{V} m u^2$$

#### Experimentele toets

$$N_A \frac{dE_{kin,mol}}{dT} = \frac{3}{2} R = 12.5 \text{ J K}^{-1} \text{ mol}^{-1}$$

warmtecapaciteit edelgasen

$$E_{kin,mol} = \frac{3}{2} k_B T$$



#### Fysische betekenis

ideaal gas

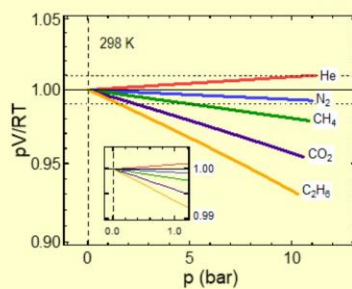
geen moleculaire interacties

$$k = 1.38 \cdot 10^{-23} \text{ J K}^{-1} \text{ (constante van Boltzmann} = R/N_A)$$

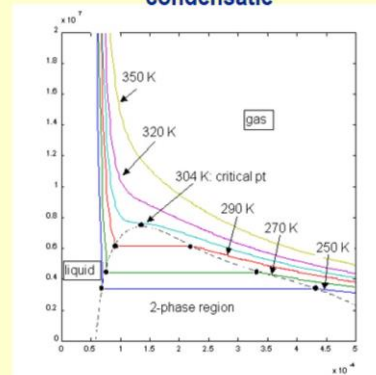
## Gassen

### reële gassen

Compressibiliteit  $Z = \frac{pV}{RT}$

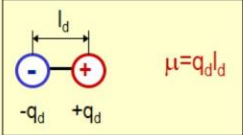


#### condensatie



## Gassen

### dipool-dipool interacties



$\mu = q_d l_d$

**Dipoolmoment**  
**Waterstofhalogeniden (Debye)**

HF	1.91
HCl	1.03
HBr	0.80
HI	0.44

$V_{\text{aaf}} \propto \mu_1 \mu_2 r^{-3}$   
 $V_{\text{tot}} \propto \mu_1^2 \mu_2^2 r^{-6}$

---

2 kJ mol<sup>-1</sup>  
0.3 kJ mol<sup>-1</sup>

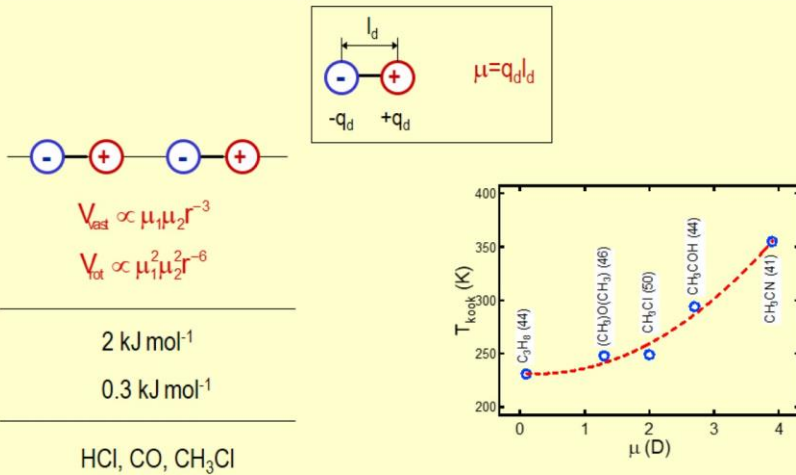
---

HCl, CO, CH<sub>3</sub>Cl

1D(ebye)=3.336 10<sup>-30</sup> Cm (≈0.1e gescheiden over 0.2 nm)

## Gassen

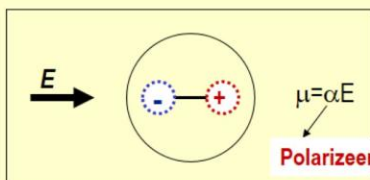
### dipool-dipool interacties



1D(ebye)=3.336 10<sup>-30</sup> Cm (≈0.1e gescheiden over 0.2 nm)

## Gassen

### geïnduceerde dipoolinteracties



Polarizeerbaarheid

Polarizeerbaarheids-  
Volume ( $\text{\AA}^3$ )

He	0.21
Ne	0.39
Ar	1.63
Kr	2.48
Xe	4.01
HF	0.51
HCl	2.63
HBr	3.61
HI	5.42

dipool-geïnduceerde dipool



$$V \propto \mu_1^2 \alpha_2 r^{-6}$$

$$< 1 \text{ kJ mol}^{-1}$$

London



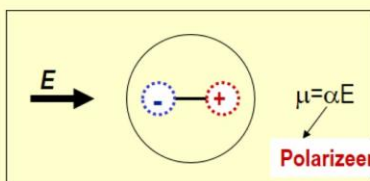
$$V \propto \alpha_1 \alpha_2 r^{-6}$$

$$2\text{-}20 \text{ kJ mol}^{-1}$$

He, CH<sub>4</sub>, O<sub>2</sub>

## Gassen

### geïnduceerde dipoolinteracties



Polarizeerbaarheid

dipool-geïnduceerde dipool



$$V \propto \mu_1^2 \alpha_2 r^{-6}$$

$$< 1 \text{ kJ mol}^{-1}$$

London

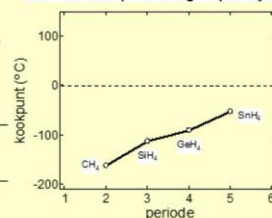


$$V \propto \alpha_1 \alpha_2 r^{-6}$$

$$2\text{-}20 \text{ kJ mol}^{-1}$$

He, CH<sub>4</sub>, O<sub>2</sub>

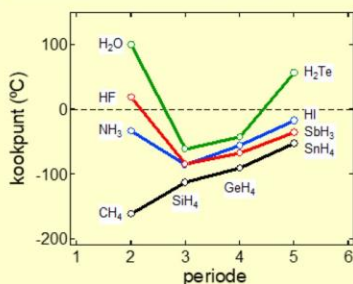
Normaal kookpunt van groep IV hydriden



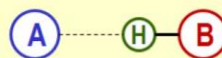
## Gassen

### de waterstofbinding

Normaal kookpunt van groep IV tot VII hydriden

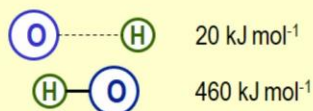
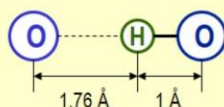


#### waterstofbrug



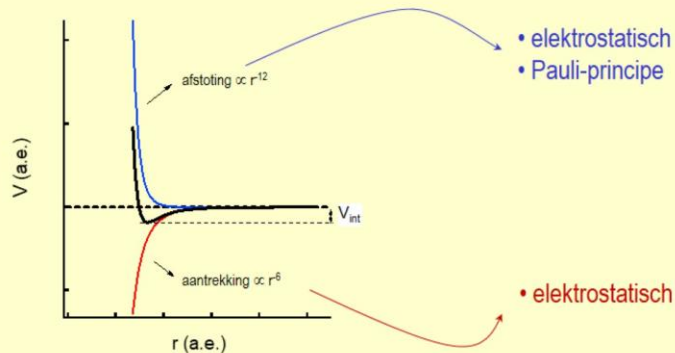
- ✓ gebaseerd op orbitaaloverlap
- ✓ A en B = N, O of F
- ✓ contactinteractie (kort bereik)
- ✓ 20 kJ mol<sup>-1</sup>

Voorbeeld: H<sub>2</sub>O



## Gassen

### moleculaire interacties



Lennard-Jones potentiaal 
$$V(r) = 4\varepsilon \left\{ \left( \frac{r_0}{r} \right)^{12} - \left( \frac{r_0}{r} \right)^6 \right\}$$