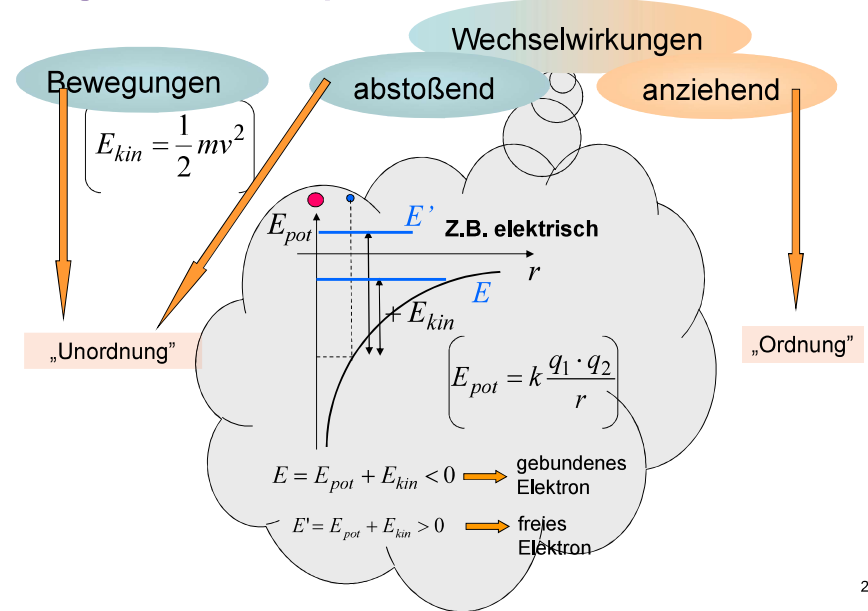


Biophysik für Pharmazeuten I.

2019/20
Vorlesung 5

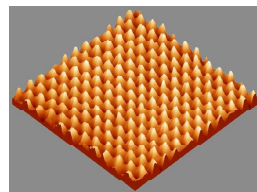
Struktur der Materie

Allgemeine Prinzipien

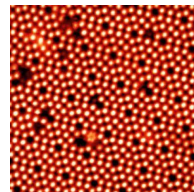


Atomarer Aufbau der Materie

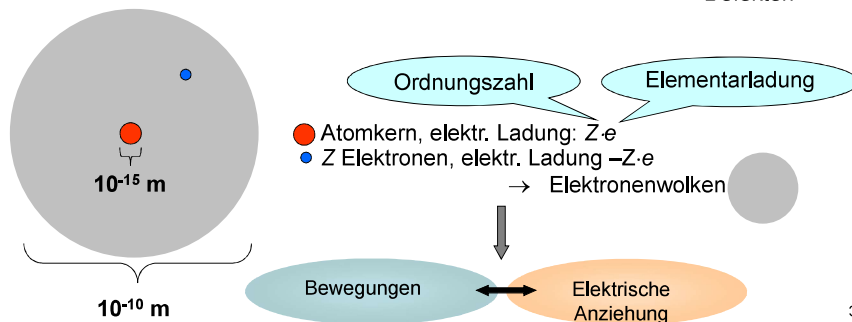
- Demokritos 5. Jht v. Chr.
- Daltonsches Gesetz 1803
- Moderne Mikroskope:



Graphit

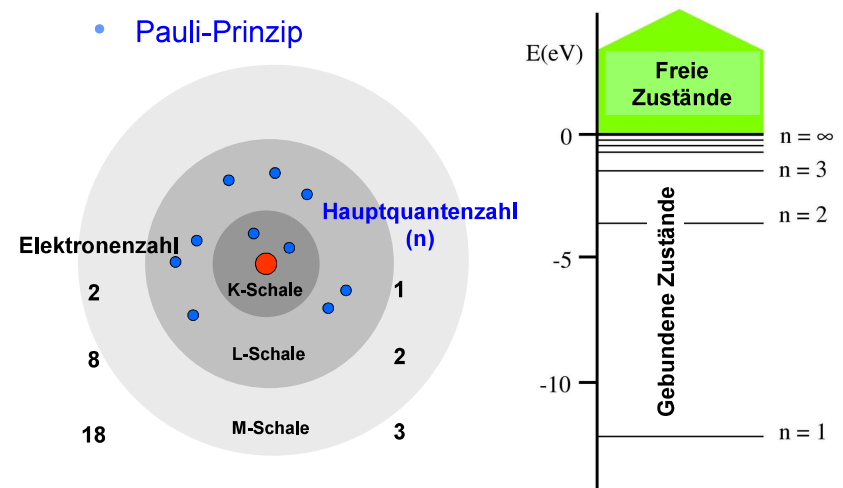


Si Kristall mit Defekten

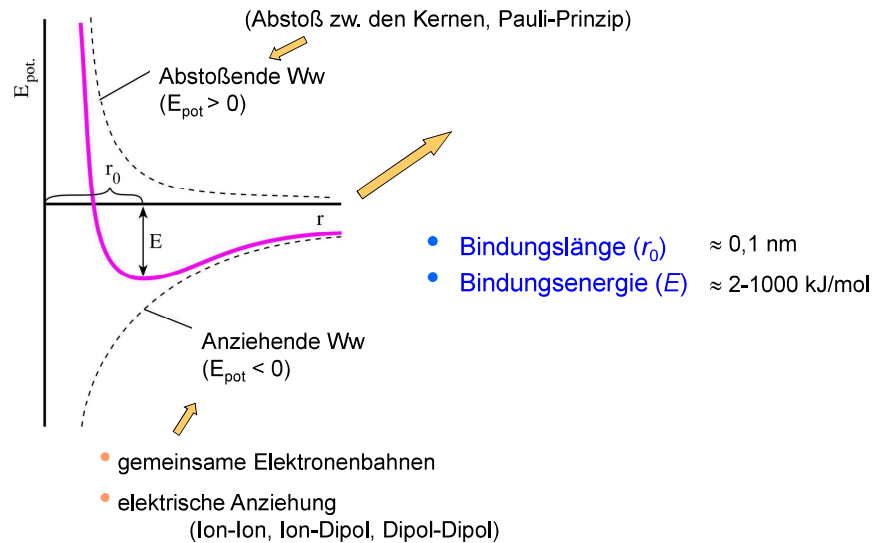


- Energieminimum
- Diskrete Energiezustände
- Pauli-Prinzip

Eine „neue“ Maßeinheit:
Elektronenvolt (eV), es gilt
 $1 \text{ eV} = 1,6 \cdot 10^{-19} \text{ J}$

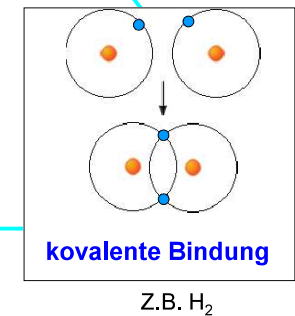
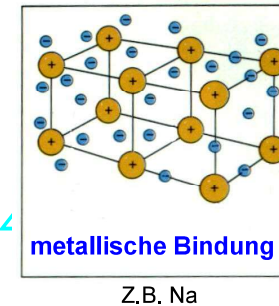
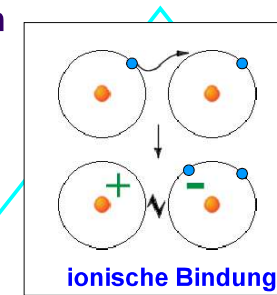


Atomare Wechselwirkungen

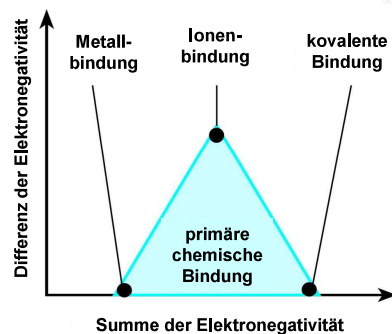
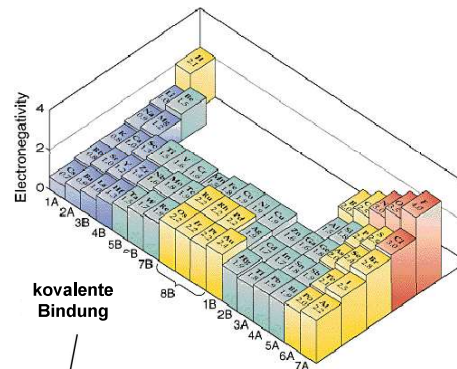


Bindungstypen

- primäre
 $\approx 100 \text{ kJ/mol}$
 - kovalente
 - metallische
 - ionische

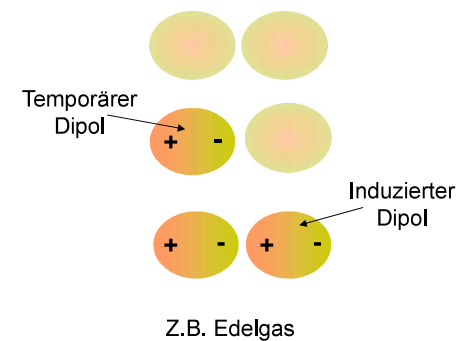


6

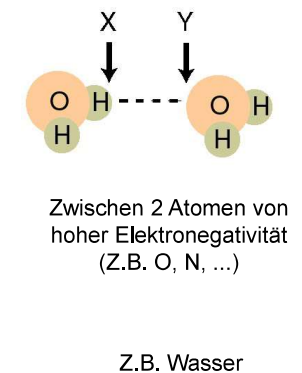


- sekundäre $\approx 10 \text{ kJ/mol}$
 - van der Waals (Orientierung, Induktion, Dispersion)
 - H-Brückenbindung

van der Waals Bindung (Dispersionskräfte)



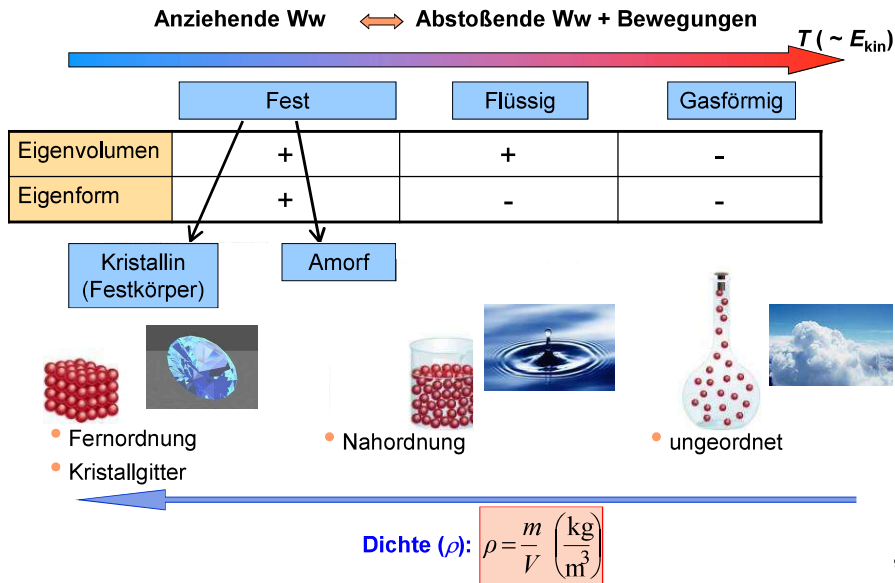
H-Brückenbindung



7

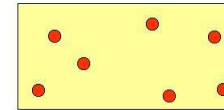
8

Aggregatzustände



9

Gase



Makroskopische Beschreibung:

- Kein Eigenvolumen und keine Eigenform
- Isotrop
- Messbare Größen:

Druck p , Volumen V , Stoffmenge ν , Temperatur T

$$pV = \nu RT$$

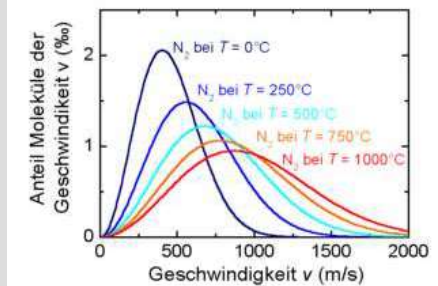
(Für ideale Gase: punktförmige Atome ohne Wechselwirkungen)

Mikroskopische Beschreibung:

- Ungeordnet
- Starke und fast freie Bewegung

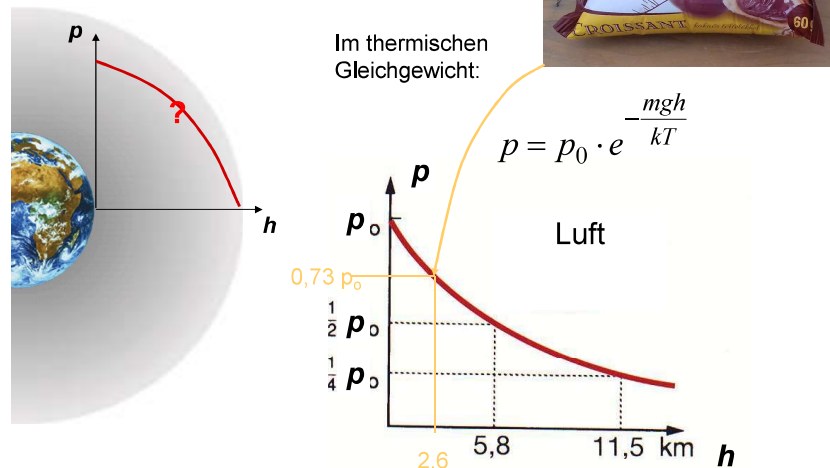
$$\frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$$

Maxwell-Boltzmann- Verteilung



10

Gas im Gravitationsfeld – barometrische Höhenformel:



11

Boltzmann-Verteilung im Allgemeinen

Die Verteilung der Teilchen auf die Energiezustände im thermischen Gleichgewicht ($T = \text{konstant}$):

$$\frac{n_i}{n_0} = \frac{e^{-\frac{\epsilon_i - \epsilon_0}{kT}}}{e^{-\frac{\epsilon_0 - \epsilon_0}{kT}}} \quad \Delta \epsilon \quad n_i = n_0 \cdot e^{-\frac{\epsilon_i - \epsilon_0}{kT}}$$

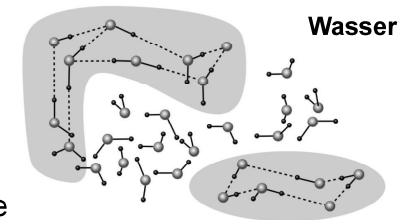
$$n_i = n_0 \cdot e^{-\frac{\epsilon_i - \epsilon_0}{kT}} = n_0 \cdot e^{-\frac{\Delta \epsilon}{kT}} = n_0 \cdot e^{-\frac{\Delta E}{RT}} \quad \left(\begin{array}{l} \Delta E = \Delta \epsilon \cdot N_A \\ R = k \cdot N_A \end{array} \right)$$

12

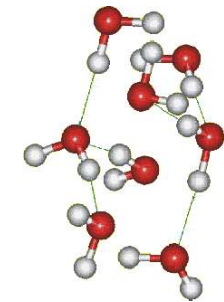
Anwendungen:

- Barometrische Höhenformel
- Thermische Elektronenemission von Metallen
- Konzentrationselemente, Nernst-Gleichung
- Chemische Reaktionen (Geschwindigkeits- und Gleichgewichtskonstante)
- Konzentration von thermischen Punktdefekten (in Kristallen und Makromolekülen)
- Elektrische Leitfähigkeit von Halbleitern
- ...

Flüssigkeiten

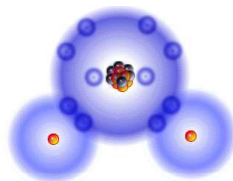


- Eigenvolumen
- Keine Eigenform/flüssig – keine innere Scherkräfte
- Nahordnung
einige nm große geordnete dynamische Bereiche
- Viele Strukturdefekte
- mittelstarke Bewegungen
- Isotrop

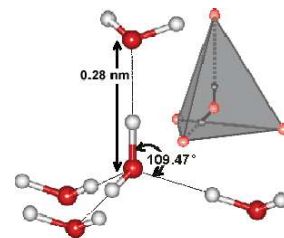


14

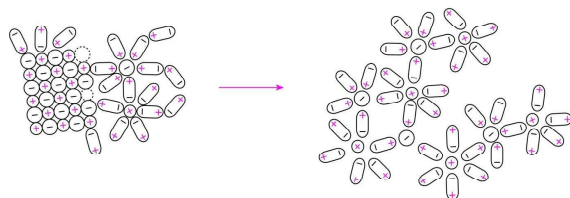
Wasser



Dipol



- hohe spezifische Wärmekapazität, Schmelzwärme und Verdampfungswärme
- hohe Oberflächenspannung
- gutes Lösungsmittel



15

Feste Körper

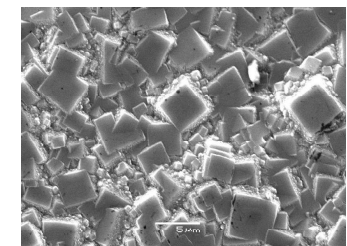
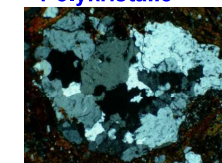
(Kristall = Festkörper)

Kristalline
Stoffe

Amorphe
Stoffe

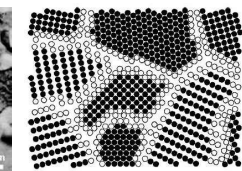
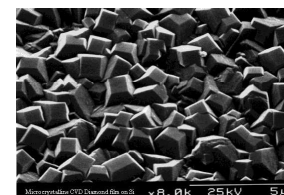
Einkristalle

Polykristalle



Mikrokristalline
Stoffe

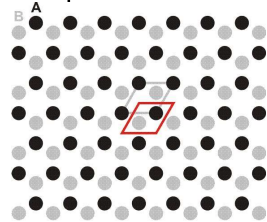
Nanokristalline
Stoffe



16

Festkörper (Kristalle)

- Eigenvolumen/Eigenform
- Fernordnung
geordnete Struktur in makroskopischen Bereichen
- Periodizität, Elementarzelle, Kristallgitter
- Wenig Defekte
- Schwache Bewegungen
- Oft anisotrop



Kristallgitter
(Raumgitter)

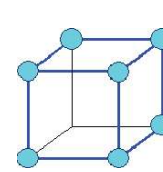
Elementarzelle



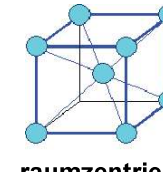
17

Raumgitter (Kristallklassen)

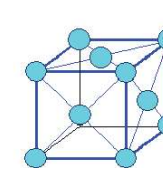
kubisch



einfach

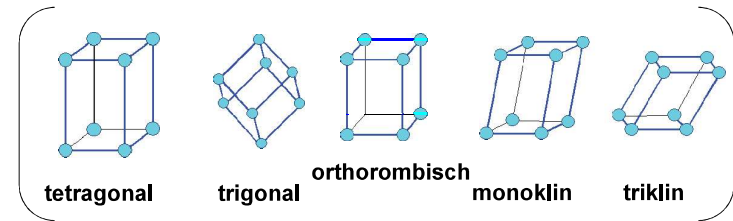
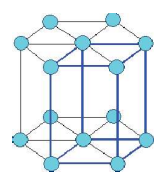


raumzentriert



flächenzentriert

hexagonal



18



19

Kristalltypen

- Atomkristall



Diamant



Si

- Ionenkristall



Salz



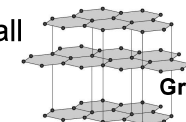
Apatit

- Metallkristall



Gold

- Molekülkristall

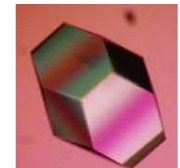


Graphit



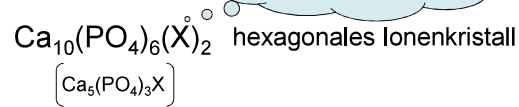
Eis

Eiweiß (Lysozym)

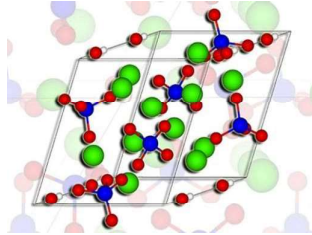
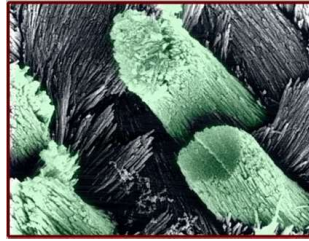


20

Apatit



OH : Hydroxiapatit
F : Fluorapatit



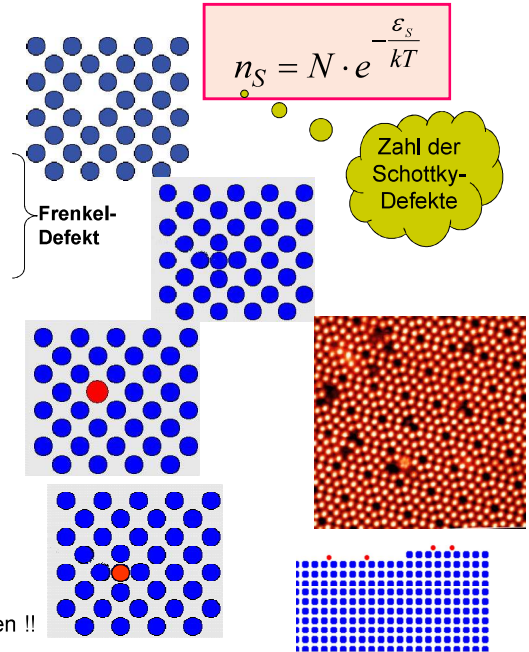
Dentin, Knochen: 20-60 nm x 6 nm große Kristalle
Zahnschmelz: 500-1000 nm x 30 nm große Kristalle

21

Gitterdefekte

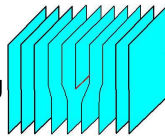
• Punktdefekte

- thermisch
 - Vakanz/Leerstelle (Schottky-Defekt)
 - Interstitielles Atom (Zwischengitteratom)
- Fremdatom
 - An einer Gitterstelle (Substitutionsatom)
 - An einer Zwischengitterstelle (interstitielles Atom)

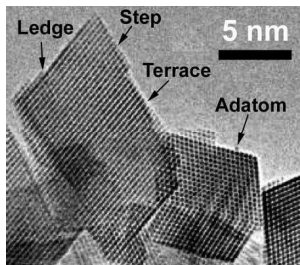
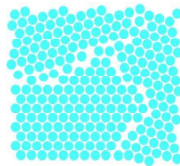
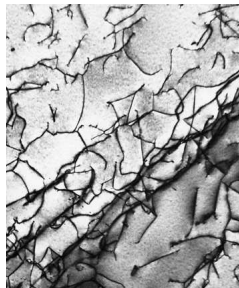


22

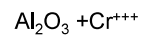
- Versetzungen
 - Stufenversetzung
 - Schraubenversetzung
- Korngrenzen



Versetzungen in einer Ti-Legierung



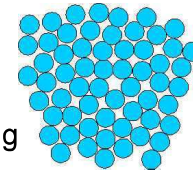
Gitterdefekte \Rightarrow Eigenschaften!!



23

Amorphe (feste) Körper

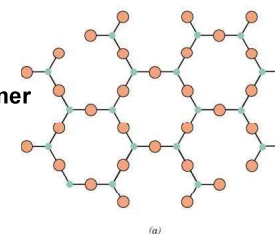
- Eigenvolumen
- Mechanisch hart
- Keine Eigenform/flüssig
sehr hohe Viskosität;
„gefrorene Flüssigkeit“
- Nahordnung
- Viele Defekte
- Isotrop



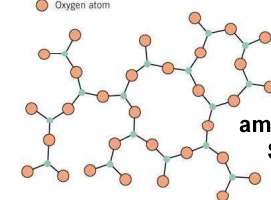
Z.B. Glas, Harz, Wachs, Bitumen,



kristalliner SiO_2



(a)



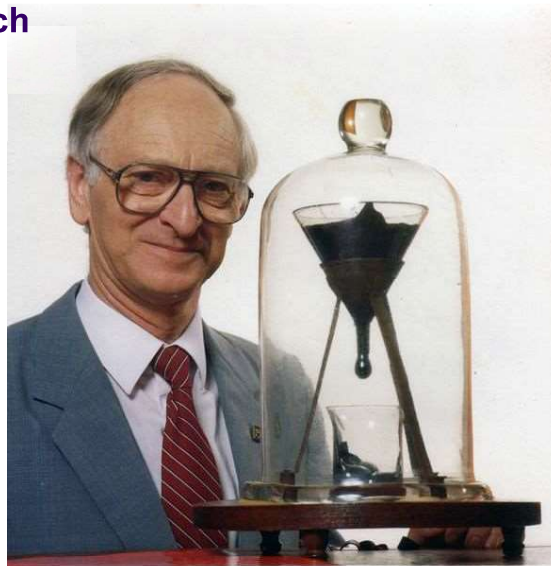
amorpher SiO_2

(b)

24

Längster Versuch der Welt

- Pechtropfen-Experiment
- In 1927 gestartet
- 9 Tropfen
(in 1938, 1947, 1954, 1962, 1970, 1979, 1988, 2000 und 2014)

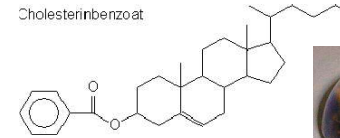


<https://de.wikipedia.org/wiki/Pechtropfenexperiment>

<http://www.nature.com/news/world-s-slowest-moving-drop-caught-on-camera-at-last-1.13418>

Flüssigkristalle

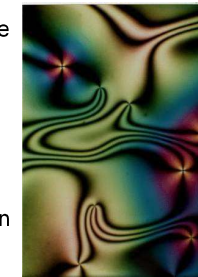
Cholesterinbenzoat



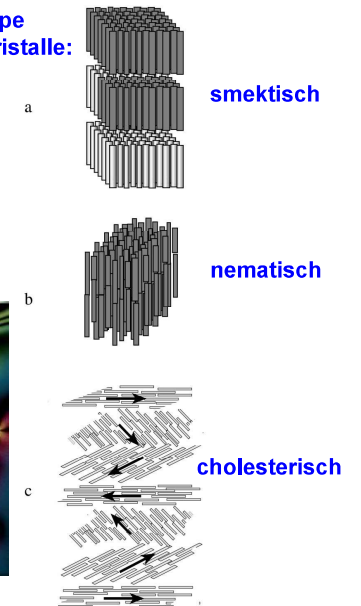
1883 Reinitzer



- Anisodimensionale Moleküle
- Mesophase
- Flüssig
- Teilweise geordnete Strukturen
- Optisch anisotrop
- Gegen äußere Einwirkungen empfindliche Struktur

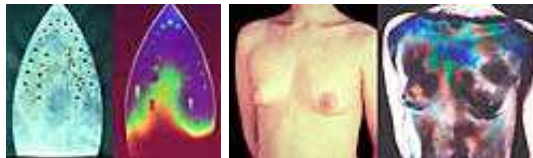


Termotrope Flüssigkristalle:

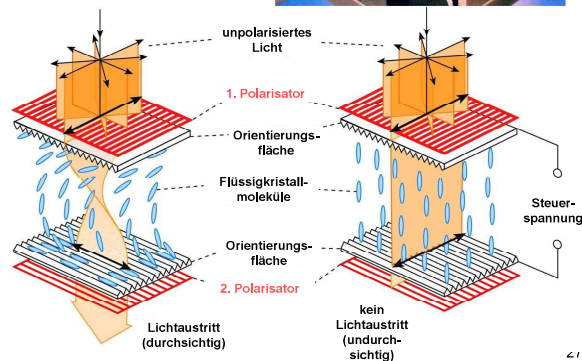
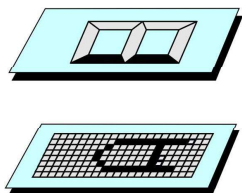


26

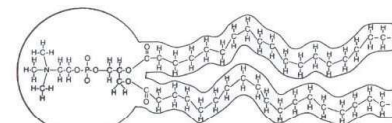
Kontaktthermographie/Plattenthermographie (thermo-optisches Phänomen)



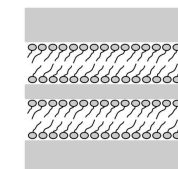
LCD (elektro-optisches Phänomen)



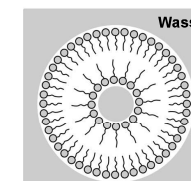
Lyotrope Flüssigkristalle:



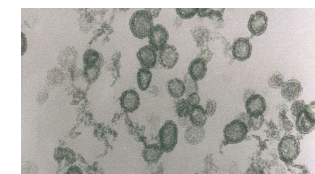
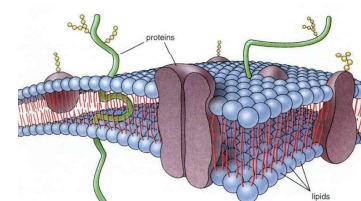
hydrophil hydrophob
Phospholipidmolekül



Lamellare Struktur



Liposom



28