

1. VODIK

1																		18
2																		
3																		
4																		
5																		
6			*															
7			**															

vodik
1
H
1.0078

VODIK

~ 1500. Paracelsus

1671. R. Boyle – plin koji gori

1766. H. Cavendish – zapaljivi zrak iz metalâ

1783. A. Lavoisier, ime: $\upsilon\delta\omicron\rho$ (voda) + $\gamma\epsilon\nu\eta\varsigma$ (tvoritelj, začetnik)

Bezbojni plin, bez mirisa, u zraku gori narančastim plamenom



Nevažni podatak 1:

Kao plin najmanje gustoće, vodik se rabio za punjenje balona od samog početka – prvi uspješni let balonom (doduše bez posade) izveo je Jacques Charles ($V_1/T_1 = V_2/T_2$) u kolovozu 1783. upravo s balonom punjenim vodikom (prvi let s posadom izveo je 1. prosinca – 10 dana nakon braće Montgolfier).

Mnogi rani zrakoplovci preferirali su balone punjene vodikom pred onima s vrućim zrakom. Jedan od njih je bio u prvi profesionalni avijatičar, Jean-Pierre Blanchard, kao i njegova supruga Sophie Blanchard koja je preuzela posao nakon njegove pogibije (od kombinacije srčanog udara i pada iz balona) 1809. Ona sama je poginula u padu balona 1819., nakon što se vodik zapalio od bengalske vatre koju je palila u gondoli. Time je ušla u povijest kao prva žena koja je poginula u zrakoplovnoj nesreći.



DEATH OF MADAME BLANCHARD.

VODIK – 1. ili 17. skupina?

	H ₂	Cl ₂	Na
KOVALENTNI RADIJUS / Å	0,37	0,99	1,86 (metalni)
IONSKI RADIJUS / Å	1,53 (H ⁻)	1,67	1,13 (K.B. = 4)
VRELIŠTE / K	20,28	238,25	1156,15
TALIŠTE / K	14,1	172,15	370,95
ENERGIJA IONIZACIJE / kJmol ⁻¹	1311	1255	495,8(I)
KOEFICIJENT ELEKTRONEGATIVNOSTI	2,2	3,2	0,9
ENERGIJA VEZE kJmol ⁻¹	436	242	
DULJINA VEZE / Å	0,74	1,99	
ELEKTRONSKI AFINITET / (-E _A) kJmol ⁻¹	72,77	348,8	52,7

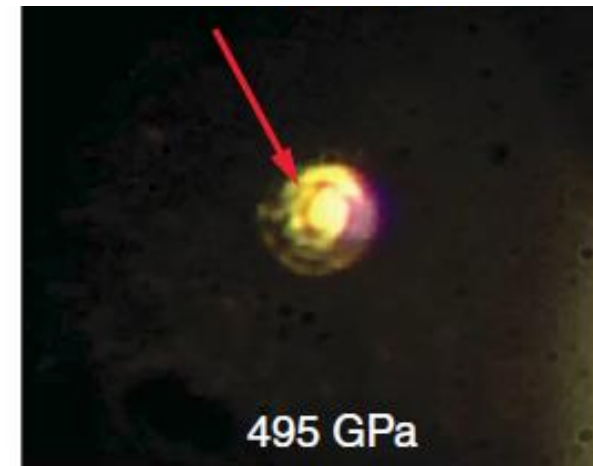
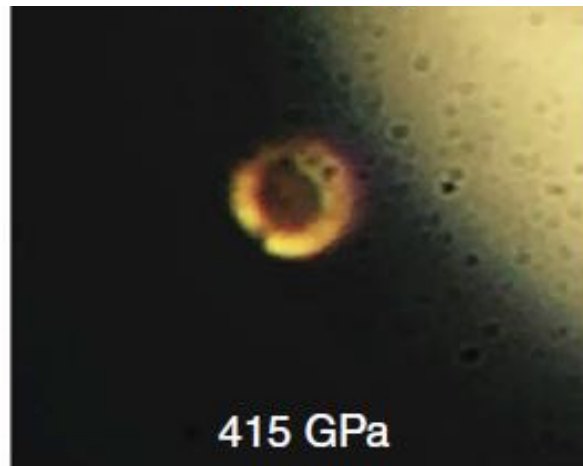
metalni vodik

1935. E. P. Wigner & H. B. Huntington
pretpostavili da vodik pri visokim tlakovima (preko
25 GPa) postoji kao vodljiva tekućina/krutina

Vjerojatno prisutan u plinovitim divovima (vanjska
jezgra)



2017. – 5,5 K, 450-500 GPa – eksperimentalno pripravljen



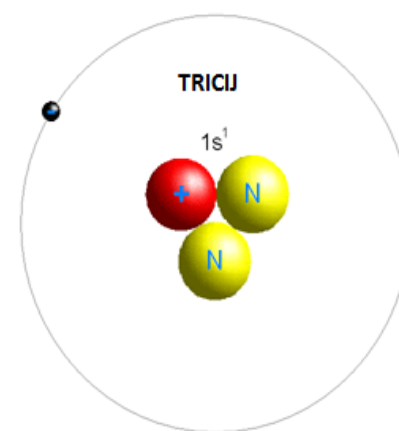
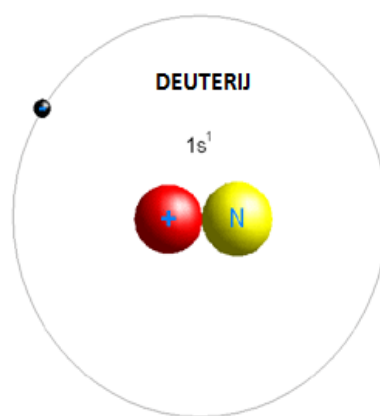
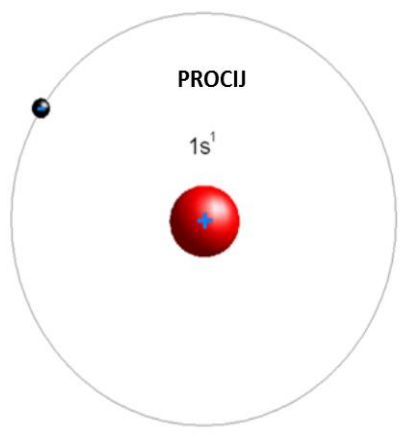
R. P. Dias, I. F. Silvera, *Science*, **355** (2017) 715–718.

8-10 μm ; debljina 1-1,8 μm

izotopi

1931.
H. Urey

1934. E. Rutherford
 $t_{1/2} = 12,56$ godina.



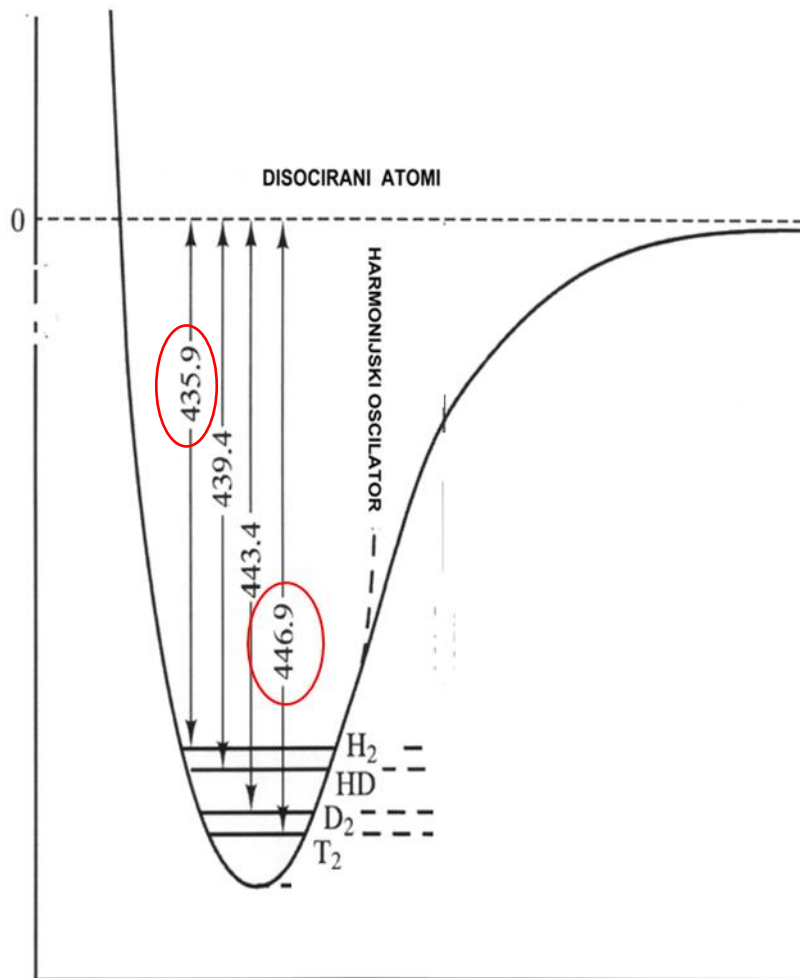
0,014%

Na (10^{18}) ^1H dolazi jedan ^3H

	H_2	D_2	T_2
T_v / K	20,28	23,45	25,04
T_T / K	14,10	18,73	20,62
ENERGIJA VEZE / kJmol^{-1}	435,9	443,4	446,9

VODIK

$E_p / \text{kJ mol}^{-1}$



MEĐUATOMSKE UDALJENOSTI

IZOTOPNI EFEKT

$$E_0 = \frac{1}{2} h \nu \quad \nu = \frac{1}{2\pi} \sqrt{\frac{k}{\mu}}$$

E_0 = energija nulte točke

h = Planckova konstanta

μ = reducirana masa

k = konstanta sile

Spinska izomerija

1912. Anomalni toplinski kapacitet vodika

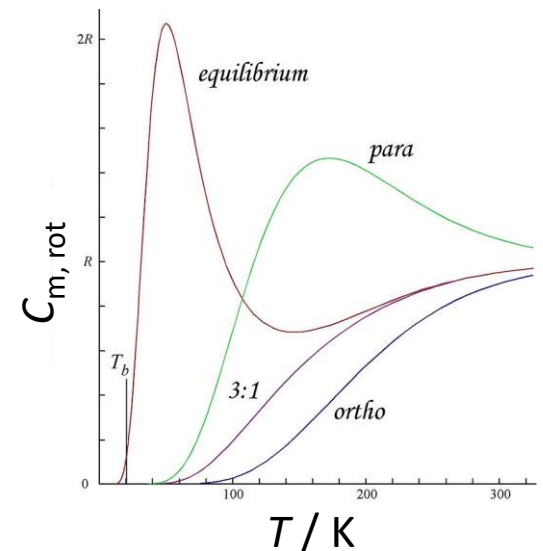
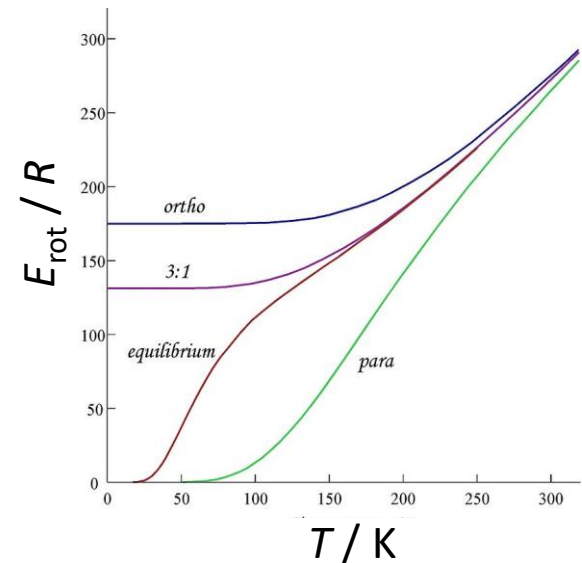
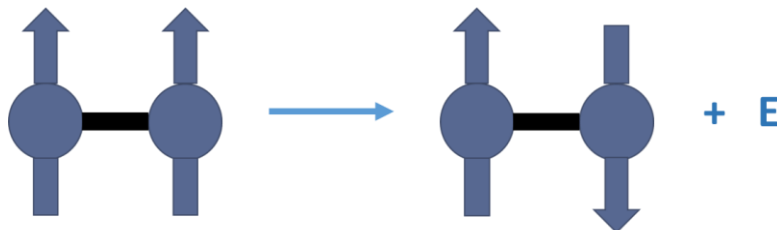
1927. Heisenberg i Hund – mogu postojati dva različita energijska stanja obzirom na spinove jezgara

ortho-H₂ (triplet) i *para*-H₂ (singlet)

0 K = 100 % *p*-H₂

20,1 K = 0,28 % *o*-H₂

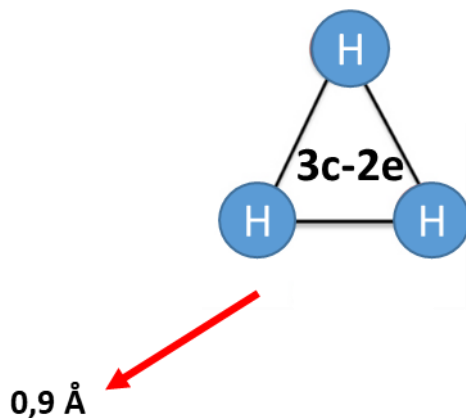
298,15 K = 75% *o*-H₂



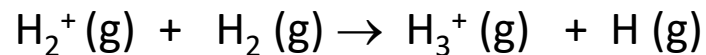
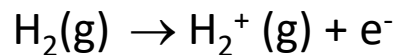
VODIK- H_n^+

1911. - J. J. Thomson

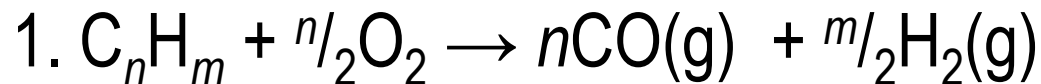
spektroskopska istraživanja: $H(g)$, $H^+(g)$, $H_2^+(g)$, $H_3^+(g)$



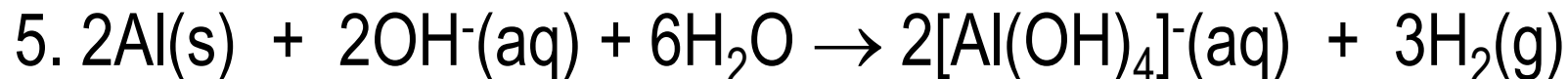
lančane reakcije u međuzvjezdanom prostoru $\rightarrow$ složenije molekule/ioni



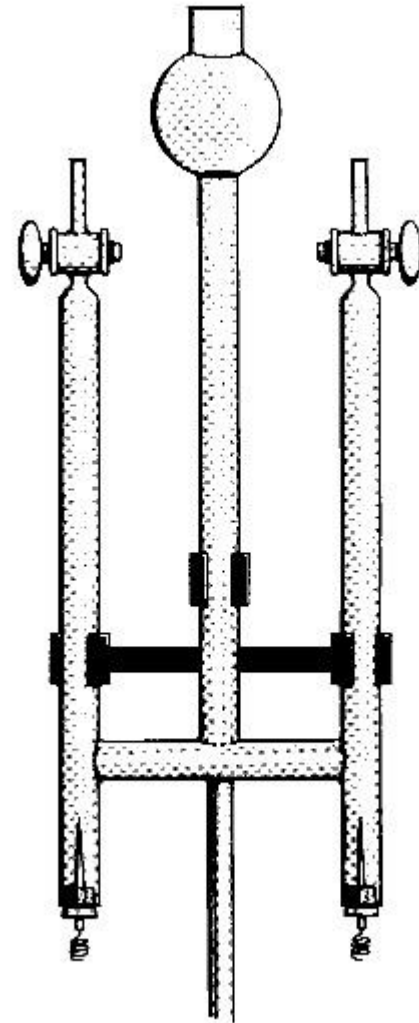
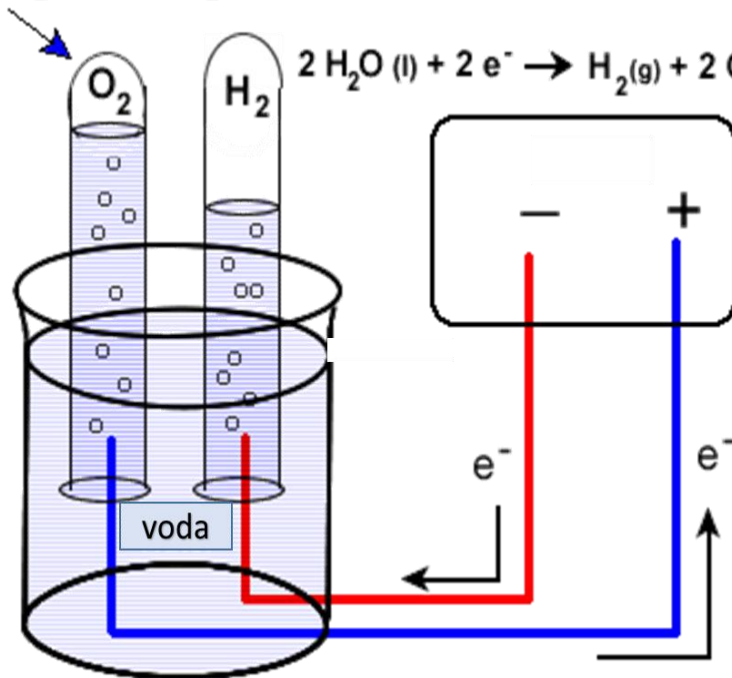
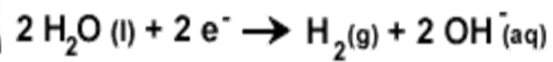
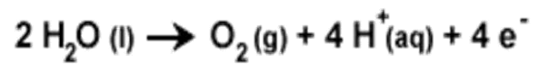
VODIK-DOBIVANJE



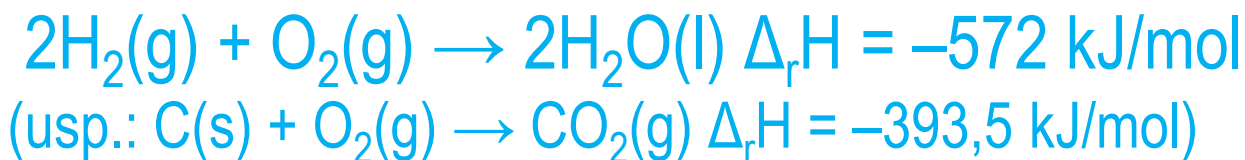
katalizator



Elektroliza vode



'GORIVO BUDUĆNOSTI'



Gorivo velike **specifične energije** čijim izgaranjem ne nastaju štetni produkti

Problemi za rješavati:

- jeftino dobivanje (pri nižim temperaturama)
- skladištenje (npr. kemijsko – hidridi ili porozne strukture)
- sigurno korištenje (npr. gorivne ćelije)

HIDRIDI

SMANJENJE JAKOSTI VEZE HIDRIDA ELEMENATA s i p BLOKA

1																		18
	1	2											13	14	15	16	17	
2	Li	Be											B	C	N	O	F	He
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi			
7																		
	IONSKI		METALNI								PRIJELAZNI		KOVALENTNI					

POLIMERNI

Entalpije nastajanja/kJ mol⁻¹

LiH -91	BeH ₂ ?	B ₂ H ₆ +32	CH ₄ -75	NH ₃ -46	H ₂ O -286	HF -269	 Stabilan (na zraku)
NaH -56	MgH ₂ -76	AlH ₃ -11	SiH ₄ +31	PH ₃ +5	H ₂ S -20	HCl -92	 Oksidira ga voda
KH -58	CaH ₂ -174		GeH ₄ +90	AsH ₃ +67	H ₂ Se +86	HBr -26	 Zapali se na zraku
RbH -54	SrH ₂ -177		SnH ₄ +163	SbH ₃ +145	H ₂ Te +154	HI +26	 Spontano se razlaže na elemente
CsH -56	BaH ₂ -171		PbH ₄ +250	BiH ₃ +278			

IONSKI HIDRIDI

Dobivanje: $M(l) + nH_2(g) \rightarrow MH_{2n}(s) \quad \Delta_r H < 0$

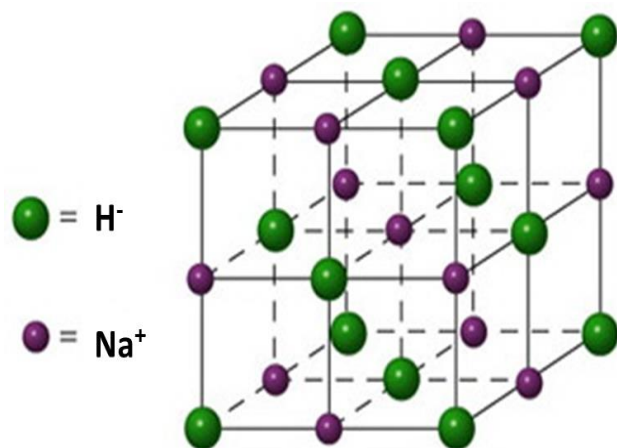
Dokaz postojanja **iona H^-** : elektroliza taline $\rightarrow$ **na anodi H_2**

Reducensi $\rightarrow$ s vodom $\rightarrow H_2$

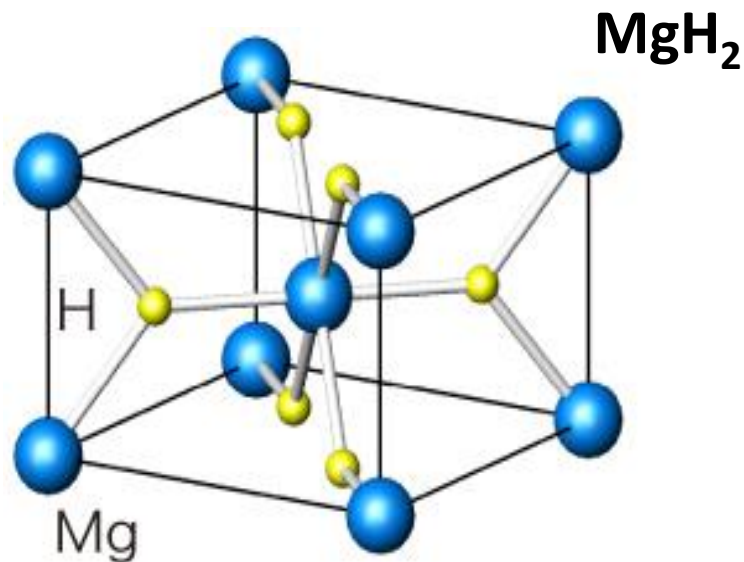


IONSKI HIDRID

Strukture hidrida alkalijskih metala:
→ struktura tipa NaCl → NaH



Strukture hidrida zemnoalkalijskih metala → struktura tipa rutila (TiO_2)

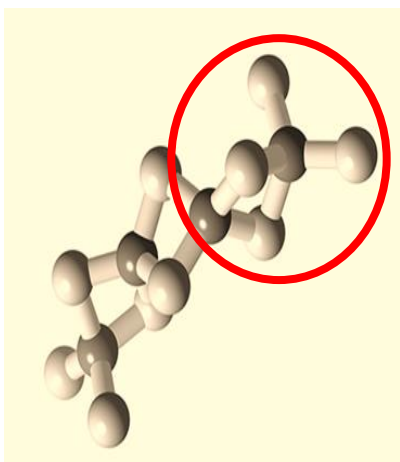


POLIMERNI IONSKI HIDRID

POLIMERNI HIDRID: BeH_2
- BEZBOJNE KRUTINE

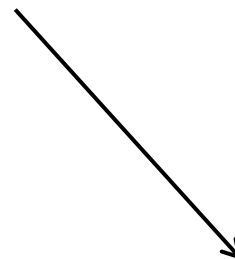
- $(\text{BeH}_2)_n \rightarrow \text{POLIMER}$

K. B. = 4

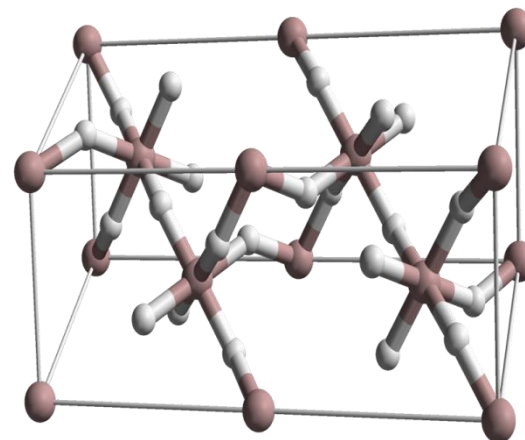


ili

$(\text{AlH}_3)_n$



K. B. = 6



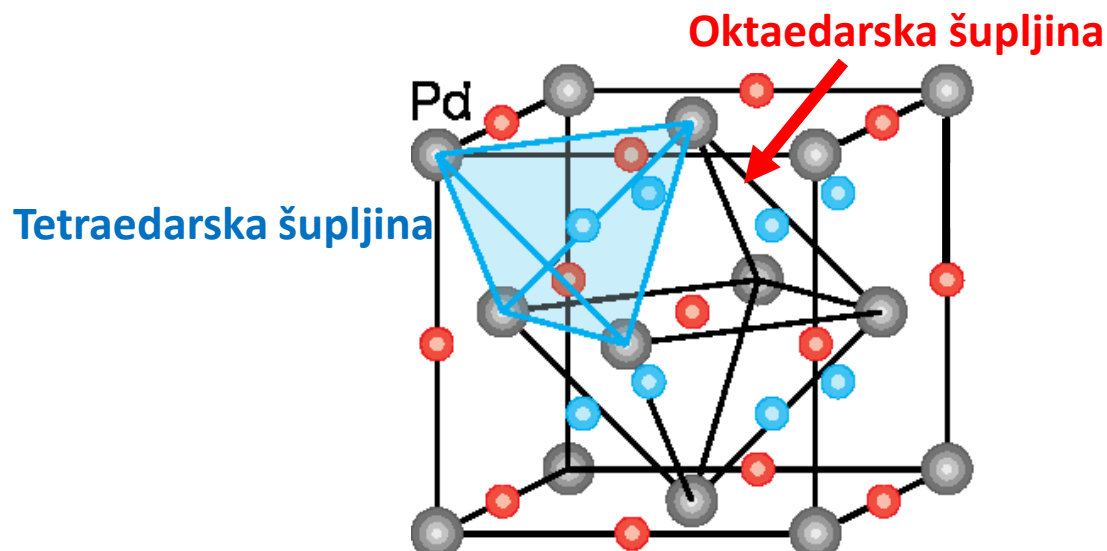
METALNI HIDRIDI

Stehiometrijski (npr lantanoidni LnH_2 i LnH_3) i nestehiometrijski (npr PdH_x , $x \approx 0,7$ pri normalnim okolnostima (p , T))

Nalik inermetalnim spojevima ili legurama – metalna svojstva, obično dosta stabilni

Vodik može biti sadržan kao molekule H_2 ili kao pojedinačni atomi (potonje omogućava katalitičko hidrogeniranje)

Nestehiometrijski hidridi – intersticijski (?) (atomi vodika u (oktaedarskim šuplinama) kristalne strukture metala



KOVALENTNI HIDRID

Ovisno o elektronskoj konfiguraciji centralnog atoma:

‘Elektronski egzaktni’ – hidridi 14. skupine: svi elektronski parovi središnjeg atoma rade veze s vodikom, središnji atom ima zadovoljen oktet. Najniža vrelišta i tališta (samo van der Waalove sile među molekulama)

Elektronima bogati – hidridi 15. – 17. skupine: središnji atom ima barem jedan nevezni elektronski par; Lewisove baze. Stvaraju vodikove veze među molekulama, mogu se protonirati

Elektronima deficitarni – hidridi 13. skupine: središnji atom nema zadovoljen oktet → Lewisova kiselina. Stvaraju premoštene vrste (oligo- i polimere-) i kompleksne hidride

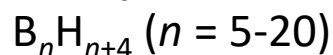
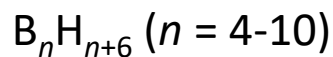
KOVALENTNI HIDRIDI

Ovisno o mogućnosti povezivanja 'središnjih atoma:

lančani hidridi

B

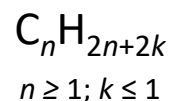
>1000



...

C

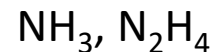
∞



$n \geq 1; k \leq 1$

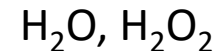
N

2



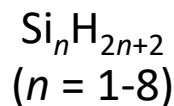
O

2



Si

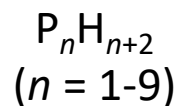
8



$(n = 1-8)$

P

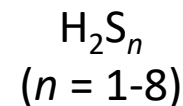
(85)



$(n = 1-9)$

S

8

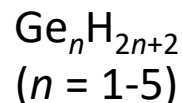


$(n = 1-8)$

...

Ge

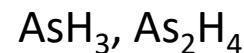
5



$(n = 1-5)$

As

2



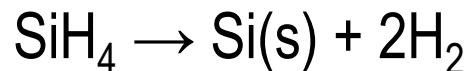
1 H 2.20			
5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44
13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58
31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55

HIDRIDI 14 SKUPINE

Ugljikovodici: C_nH_{2n+2} , C_nH_{2n} , ... (OK)

Silani: SiH_4 , Si_2H_6

- termodinamički manje stabilni od ugljikovodika;
- zapale se na zraku;
- eksplozivno reagiraju s fluorom, klorom i bromom;
- reducensi u vodenoj otopini;



Hidrosiliranje - adicija Si-H

HIDRIDI 14 SKUPINE



Germani, stanani i plumbani – stabilnost se smanjuje u skupini prema dolje



E = Ge, Sn

BOROVI HIDRIDI

Formula	Ime	temp. tališta / °C	temp. vrelišta / °C	Reakcije na zraku pri 25 °C	Reakcije s vodom	Termička stabilnost
B_2H_6	Diboran	- 164 °C	-92 °C	spontano zapaljenje	trenutna hidroliza	stabilan do 25 °C
B_5H_9	Pentaboran(9)	-47 °C	48 °C	spontano zapaljenje	hidroliza uz zagrijavanje	raspad 150 °C
B_5H_{11}	Pentaboran(11)	-123 °C	63 °C	spontano zapaljenje	trenutna hidroliza	raspad 25 °C
B_6H_{10}	Heksaboran(10)	-62 °C	108 °C	spontano zapaljenje	hidroliza uz zagrijavanje	raspad 25 °C
B_6H_{12}	Heksaboran(12)	-82 °C	80-90 °C		B_4H_{10} , $B(OH)_3$, H_2	tekućina stabilna nekoliko sati na 25 °C
B_9H_{15}	Enaboran(15)	3 °C		stabilan		
$B_{10}H_{14}$	Dekaboran(14)	99 °C		vrlo stabilan	spora hidroliza	stabilan do 150 °C

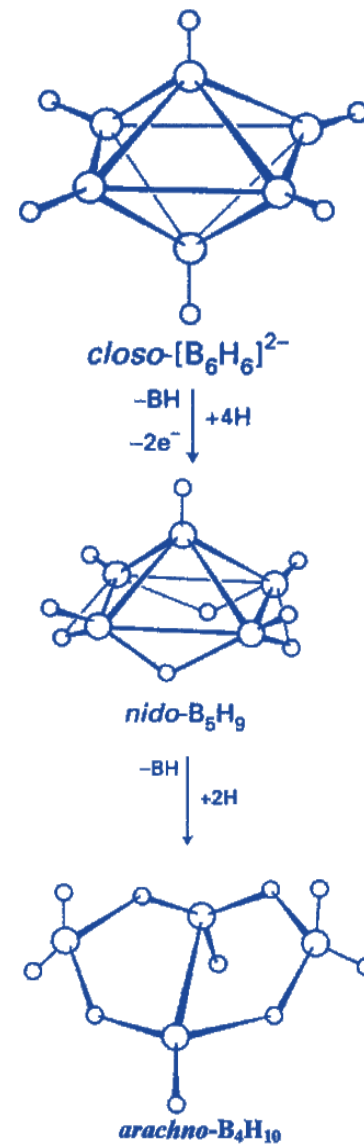
BOROVI HIDRID

Borani → tri osnovna strukturna tipa:

a) “*closo*” (kavez) $[B_nH_n]^{2-}$

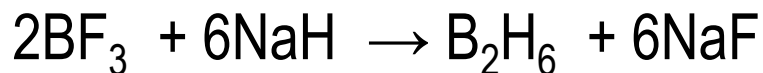
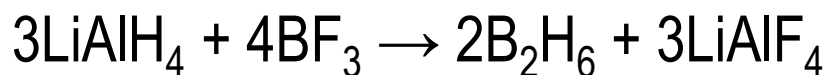
b) “*nido*” (lat. *nidus* - gnijezdo) $[B_nH_{n+4}]$

c) “*arachno*” (gr. *αράχνη* - pauk) $[B_nH_{n+6}]$

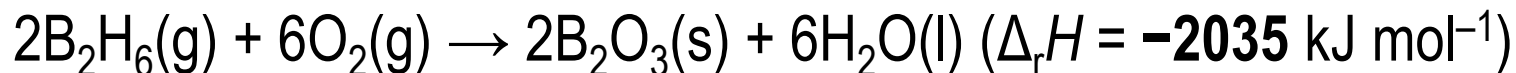


BOROVI HIDRIDI

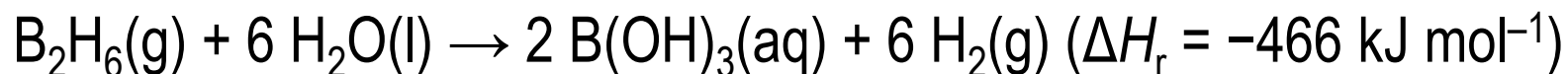
Najjednostavniji stabilni hidrid bora – DIBORAN



na zraku se spontano zapali

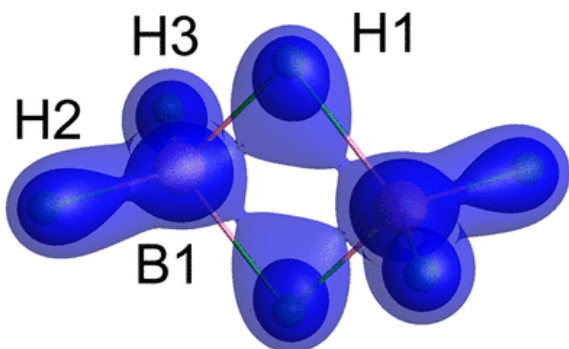
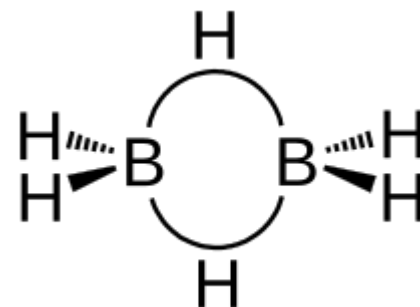
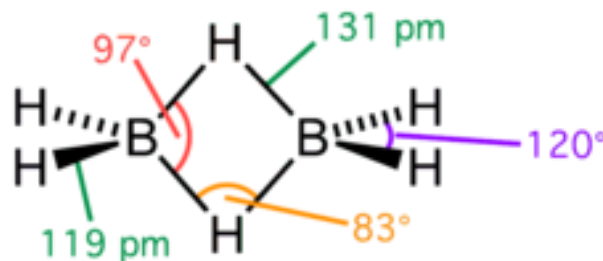
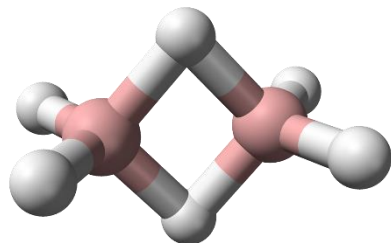


s vodom reagira burno

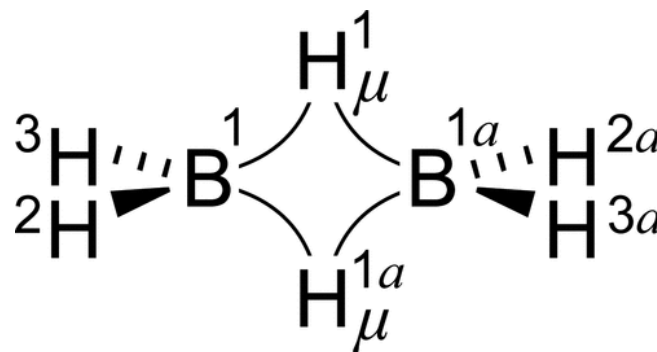


BOROVI HIDRIDI

Veza u diboranu – trocentrična dvoelektronska



plohe elektronske gustoće $\rho(r) = 0,126$ a.u. i $\rho(r) = 0,182$ a.u.



KOMPLEKSNI HIDRIDNI

Elektronima deficitantni hidridi – Lewisove kiseline
– vežu dodatni hidridni anion

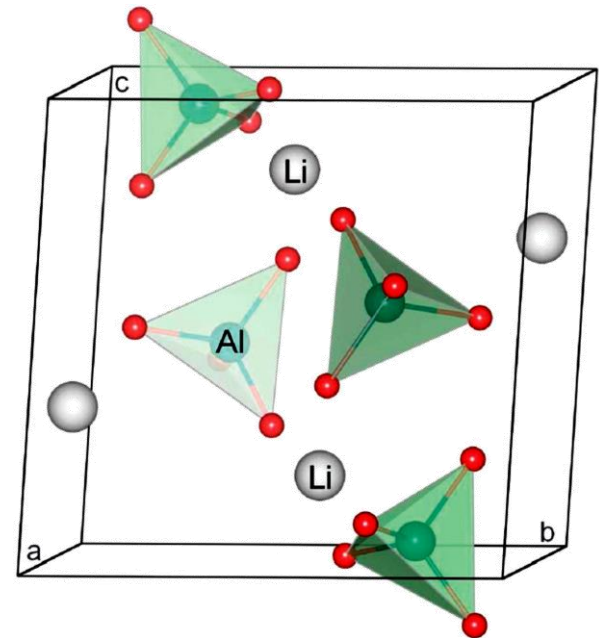
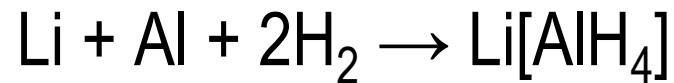
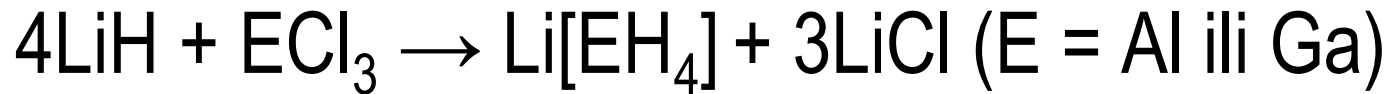
BH_4^- , AlH_4^- i $\text{GaH}_4^- \rightarrow$ kompleksni hidridni anioni



BH_4^- prekursor u sintezi većine B-H spojeva

Reducens u vodenoj otopini (Ni^{2+} ili Cu^{2+})

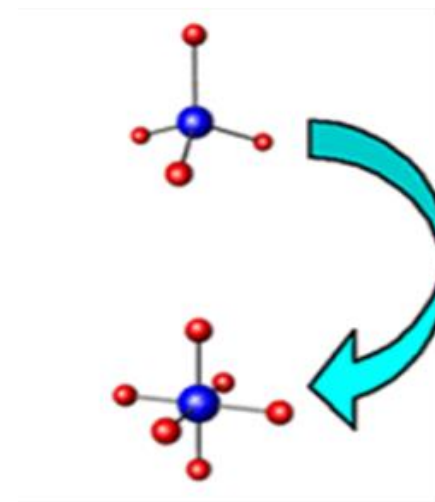
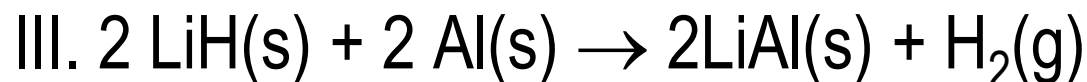
KOMPLEKSNI HIDRIDI



KOMPLEKSNI HIDRIDI

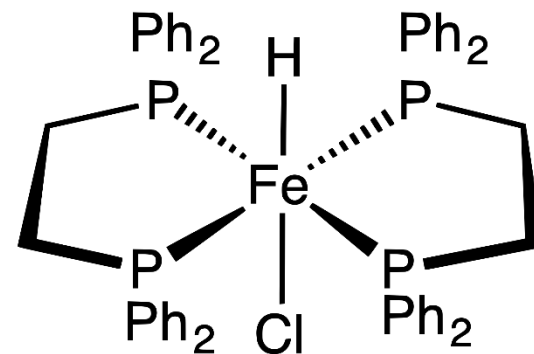
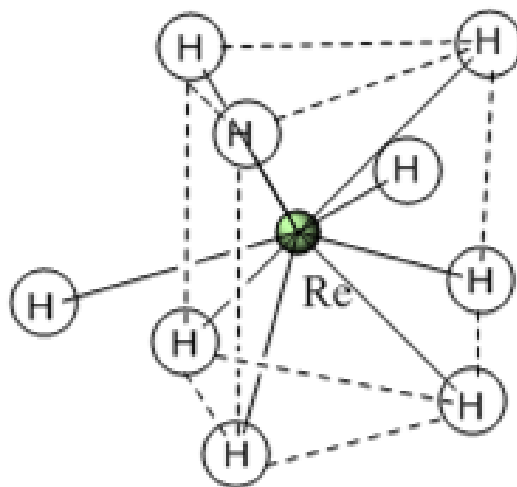
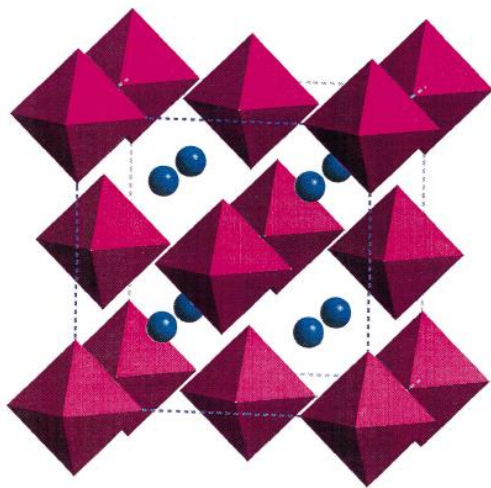
Dugotrajnim stajanjem $\text{Li}[\text{AlH}_4]$ prelazi u $\text{Li}_3[\text{AlH}_6]$

Zagrijavanjem se raspada u 3 koraka:



KOMPLEKSNI HIDRIDI

Mnogi prijelazni metali taokder tvore i hidridne komplekse (varijabilne stabilnosti i svojstava)

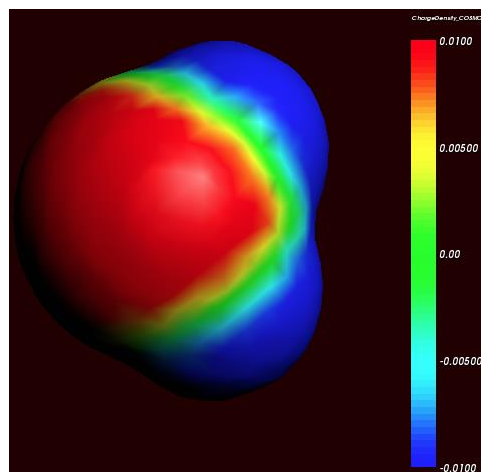
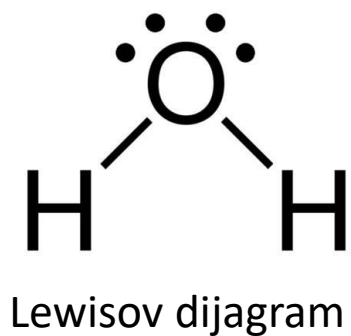


bis((difenilfosfino)etan)hidridokloridoželjezo(II)

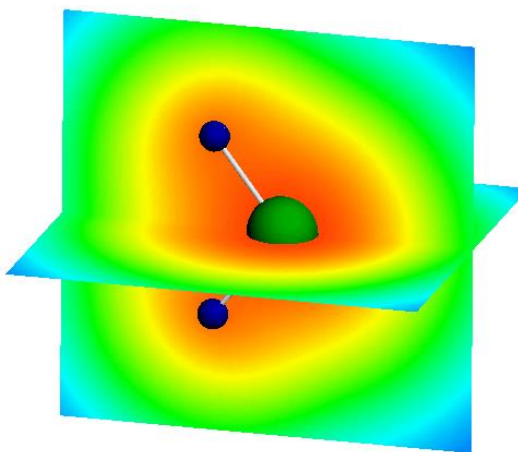
ELEKTRONIMA BOGATI HIDRIDI

VEZNI KUTEVI (°) KOD MOLEKULA HIDRIDA 15. I 16. SKUPINE

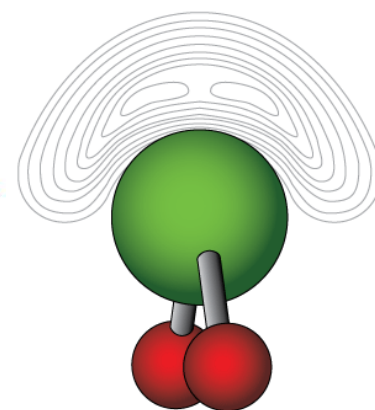
NH ₃	106,6	H ₂ O	104,5
PH ₃	93,8	H ₂ S	92,1
AsH ₃	91,8	H ₂ Se	91
SbH ₃	91,3	H ₂ Te	89



ESP



elektronska
gustoća



deformacijska
elektronska
gustoća



Vodikov kation (proton + deutron + triton + ...) – **hidron**

Ion H⁺ može postojati samo u plinovitoj fazi

Simbol H⁺(aq) predstavlja bilo koji od oblika koji se u vodenoj otopini može pojaviti:

H₃O⁺ - oksonijev ion ('hidronijev ion')

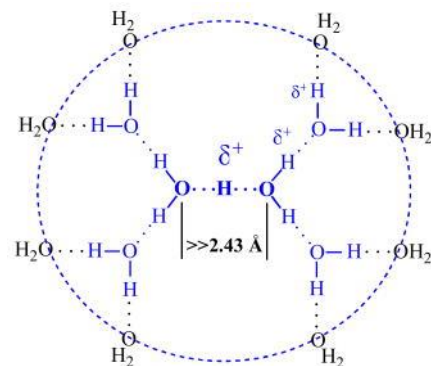
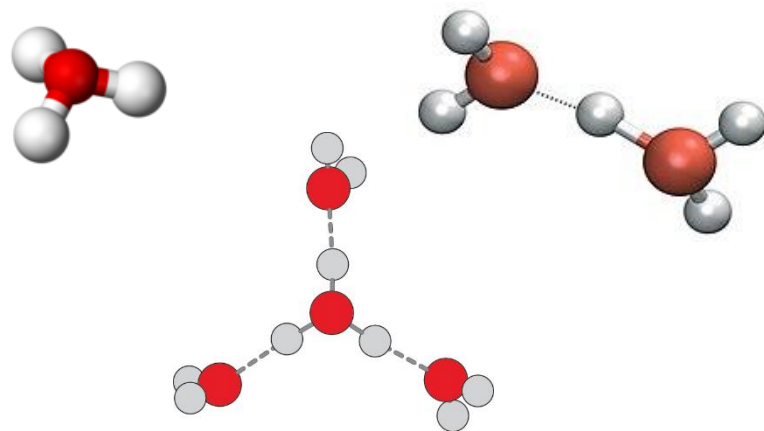
H₅O₂⁺ - Zundelov ion (pretpostavljen 1963.)

H₉O₄⁺ - Eigenov ion (pretpostavljen 1954.)

...

Računski se pokazalo da je (u plinovitoj fazi) najstabilniji H₄₃O₂₁⁺ (tj. [H₃O⁺(H₂O)₂₀])

U otopini dominantan H₉O₄⁺ ili H₁₃O₆⁺ (ili...?)



Zašto ne VuK?

Kad se u jedan utezni dio vode dodaju četiri utezna dijela koncentrirane sumporne kiseline temperatura smjese povisi se na 120 °C.

$$w(\text{H}_2\text{SO}_4) = ?$$

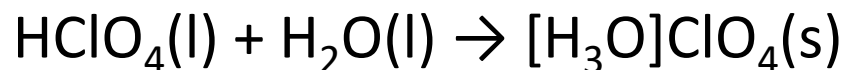
Ako je $w(\text{H}_2\text{SO}_4) \leq (\text{cca}) 60 \%$, daljnji dodatak vode ne dovodi do porasta temperature.

$$N(\text{H}_2\text{SO}_4) : N(\text{H}_2\text{O}) = ?$$

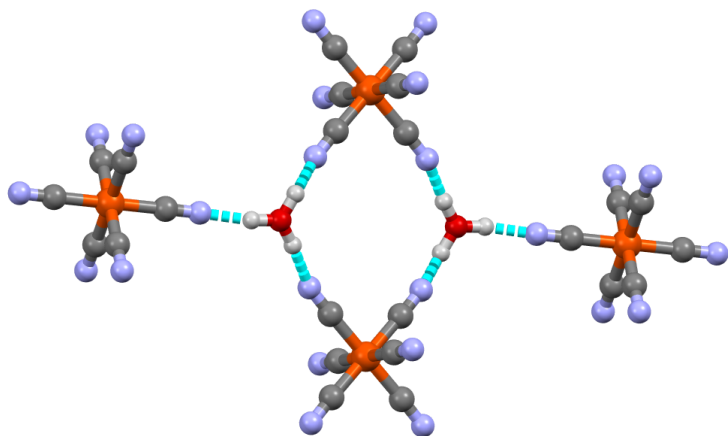
H⁺

Neki od tih kationa su pronađeni i u čvrstoj fazi (kristalizirane su njihove soli)

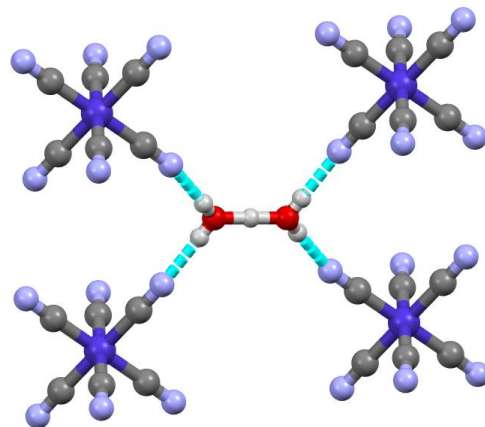
- Većina jakih kiselina ($pK_a < -9$) kristaliziraju kao oksonijeve soli



- Slabije kiseline rjeđe, a ponekad i (mješovite) soli (ovisno o mogućnostima kristalnog pakiranja)

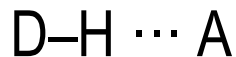


$(2\text{-Clpy})_2(\text{PyH})_2(\text{H}_3\text{O})_2[\text{Fe}(\text{CN})_6]$



$(\text{H}_5\text{O}_2)(2\text{-BrpyH})_2[\text{Co}(\text{CN})_6]$

VODIKOVA VEZA



1912. W. M. Latimer i W. H. Rodebush $\rightarrow$ HF + H₂O

1920. uvode pojam “vodikova veza” (1919. M. Huggins)

Intramolekulske i intermolekulske

Jedna od najjačih neveznih (nekovalentnih) interakcija među molekulama:

- a) slabe H-veze $\Delta H \approx 10-50 \text{ kJ mol}^{-1}$
- b) jake H-veze $\Delta H \approx 50-100 \text{ kJ mol}^{-1}$
- c) vrlo jake H-veze $\Delta H > 100 \text{ kJ mol}^{-1}$

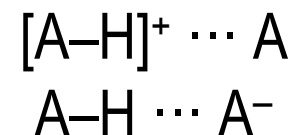
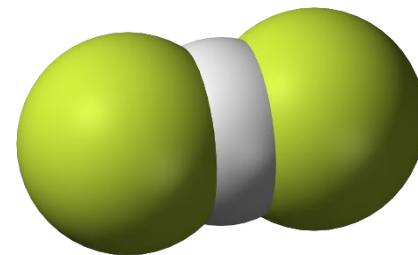
Duljina ($d(D \cdots A)$) jakih i vrlo jakih H-veza $< 3 \text{ \AA}$
Kutevi $D-H \cdots A$ bliski 180°

Podjela prema G. A. Jeffreyju (1997.)

	jaka	srednja	slaba
vrsta interakcije	kovalentna	elektrostatska	elektrostatska / disperzijska
duljina veze $H\cdots A$ (Å)	1,2 – 1,5	1,5 – 2,2	> 2,2
produljenje veze D–H (Å)	0,08 – 0,25	0,02 – 0,08	< 0,02
omjer $D-H/H\cdots A$	$D-H \approx H\cdots A$	$D-H < H\cdots A$	$D-H \ll H\cdots A$
$D\cdots A$ (Å)	2,2 – 2,5	2,5 – 3,2	> 3,2
usmjerenost	jaka	srednja	slaba
kut (°)	170 – 180	> 130	> 90
energija veze (kcal mol⁻¹)	15 – 40	4 – 15	< 4
rel. pomak u IR spektru (cm⁻¹)	25 %	10 – 25 %	< 10 %

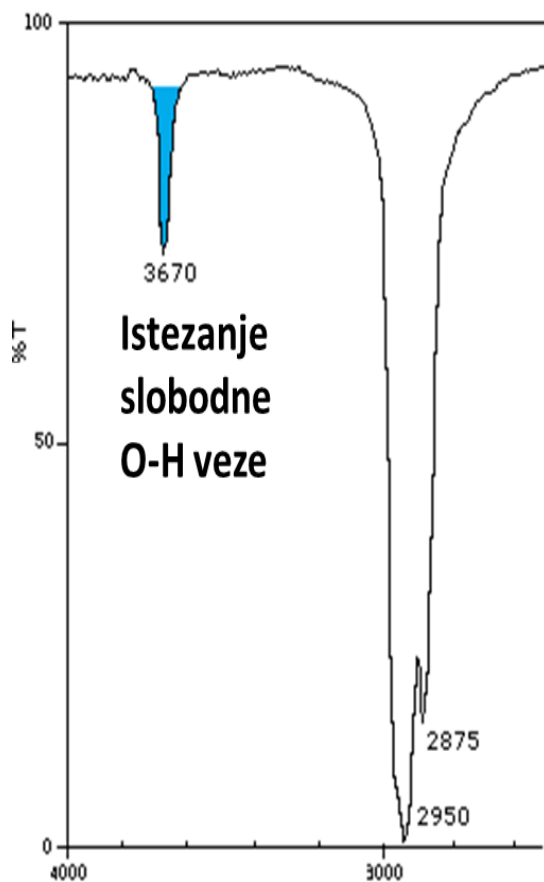
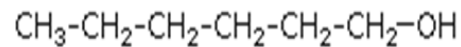
VODIKOVA VEZA

X-H...Y Veza	Spoj	E _{veze} kJ mol ⁻¹	X...Y (Å)	X-H (Å)
F...H...F	KHF ₂	~212	2,26	1,13
F-H...F	HF(g)	~28,6	2,55	
O-H...O	(HCO ₂ H) ₂	29,8	2,67	
O-H...O	H ₂ O(s)	~21	2,75	1,01
O-H...O	B(OH) ₃		2,74	1,03
N-H...N	Melamin	~25	3,00	
N-H...N	N ₂ H ₅ Cl		3,12	
C-H...N	(HCN) _n		3,20	

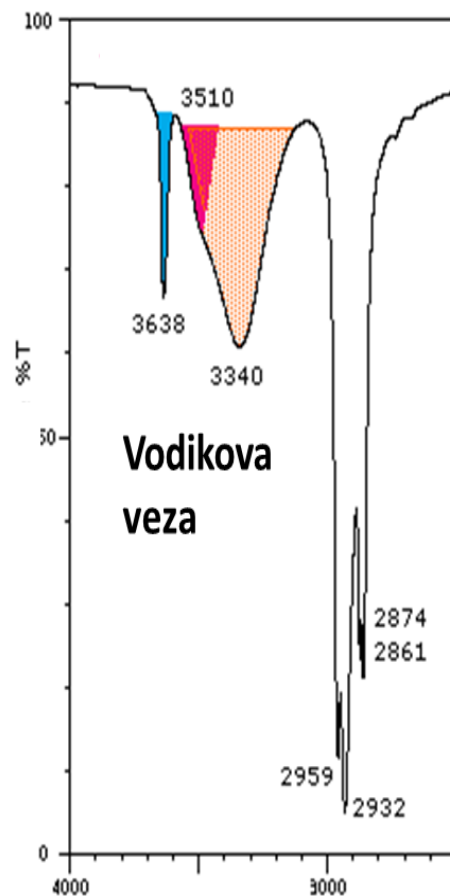


Nabojem potpomognuta
(simetrična) vodikova
veza
(donor i akceptor su
recipročna kiselina i
baza)

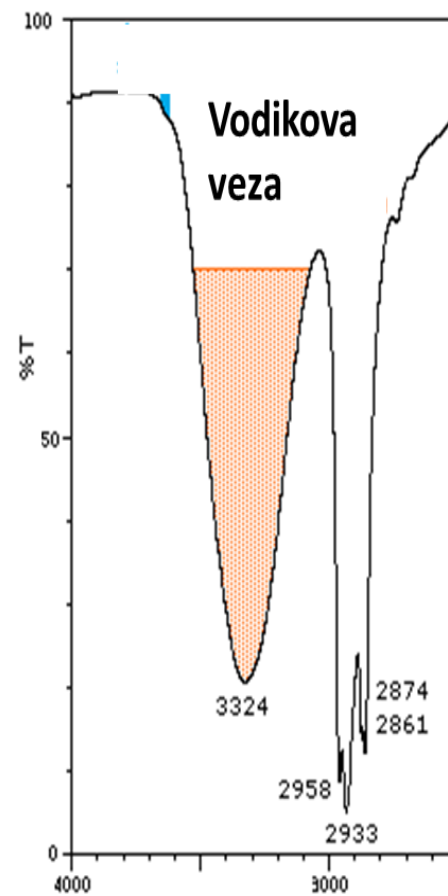
VODIKOVA VEZA – IR



Plinska faza

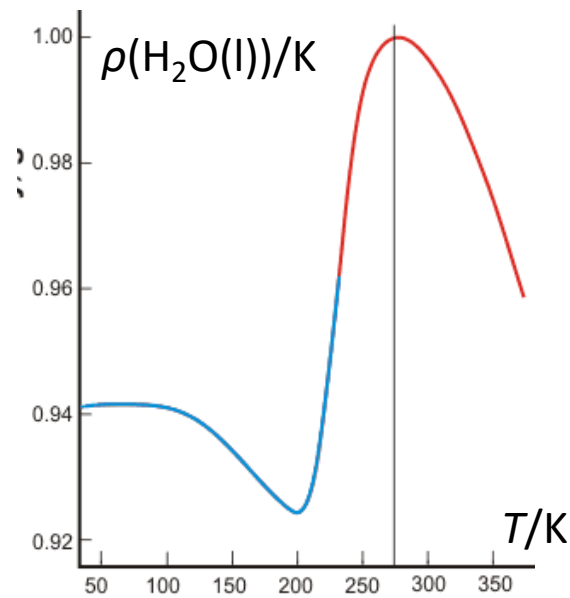
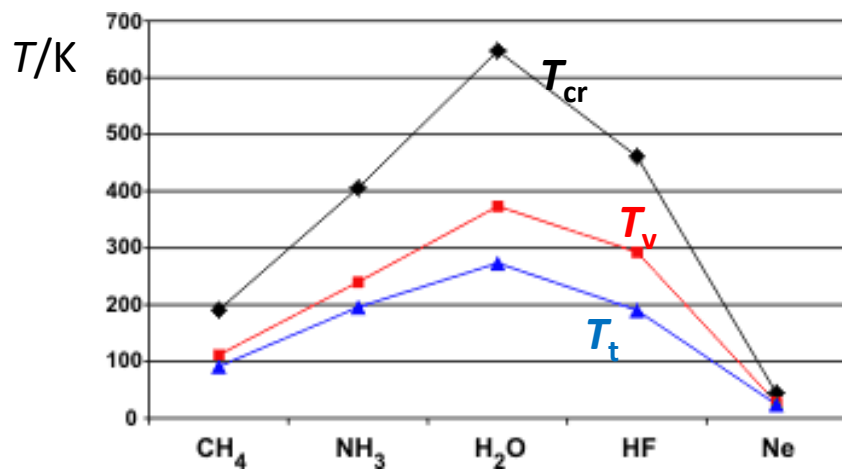
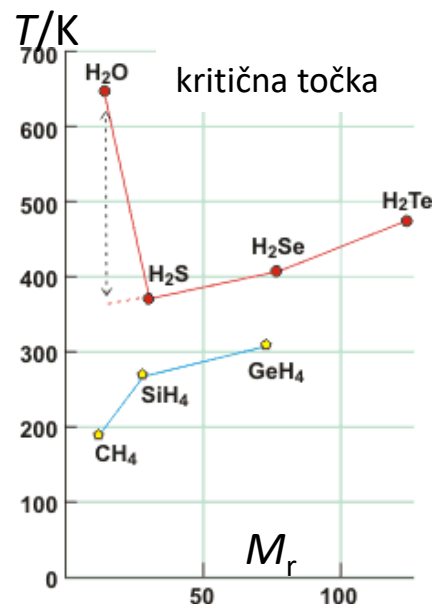
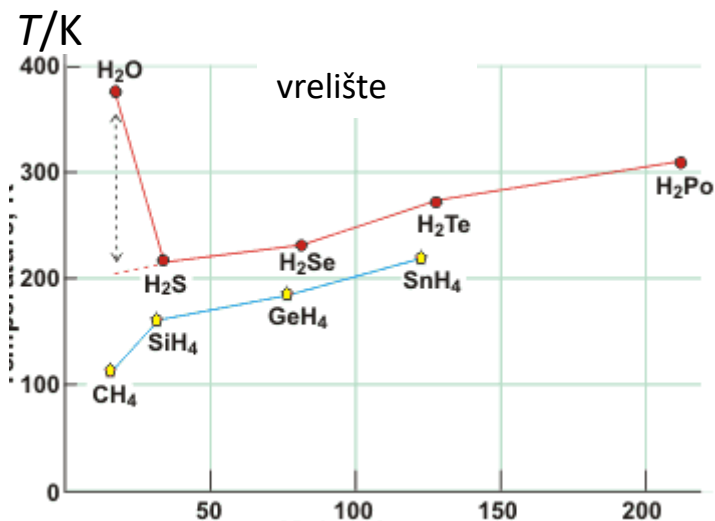
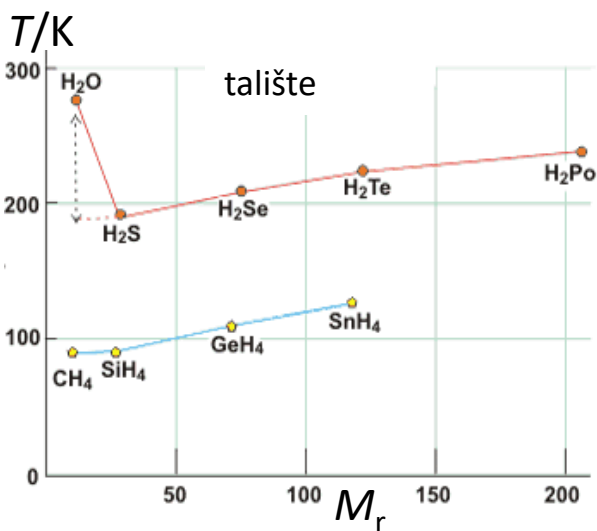


CCl_4 otopina

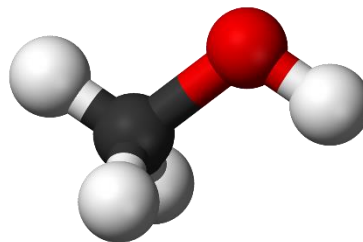
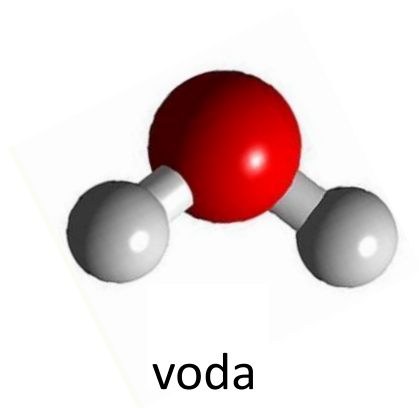


Tekućina

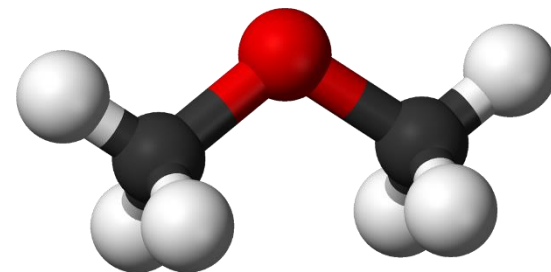
VODIKOVA VEZA I ANOMALIJE VODE



Polarnost molekule ili vodikova veza?



metanol



dimetil-eter

μ / D

1,85

1,62

1,43

Mogućih vodikovih
veza po molekuli

4

2

0

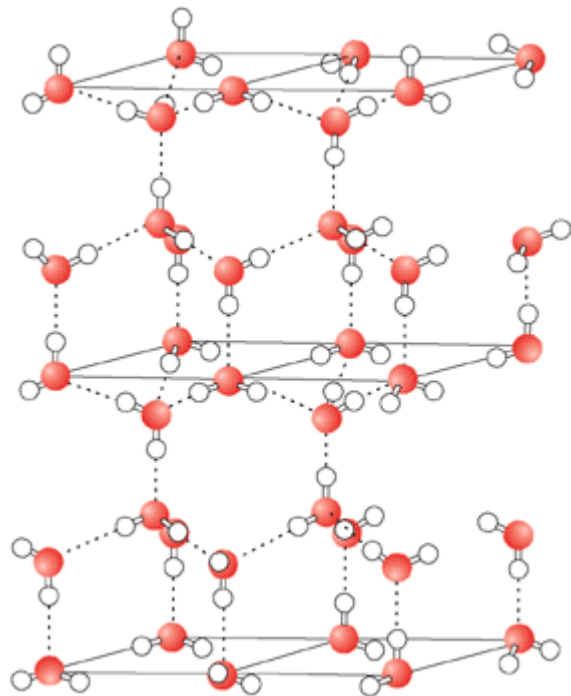
Vrelište / °C

100

64,7

-23,6

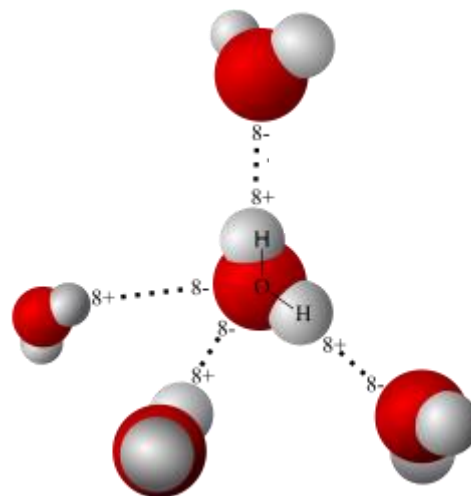
Vodikove veze u ledu (Ih)

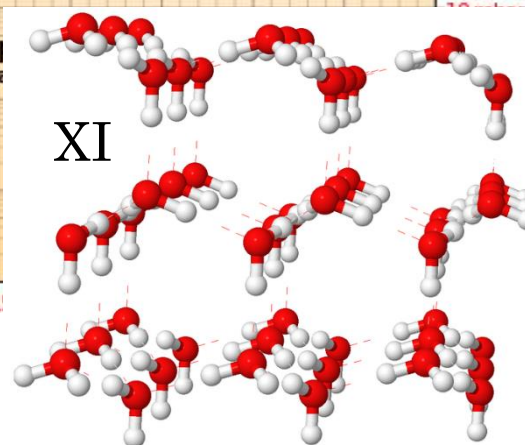
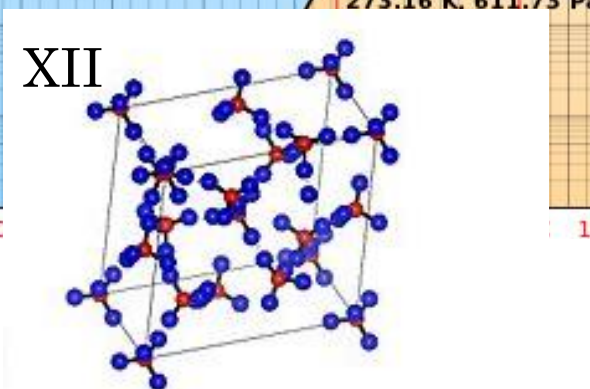
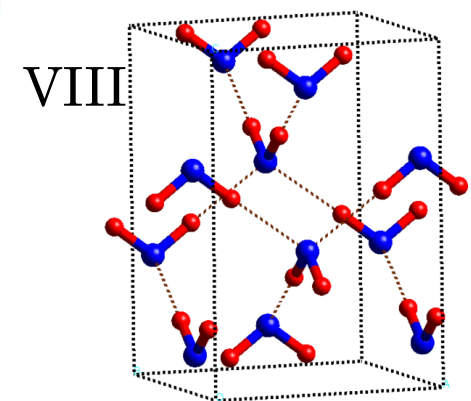
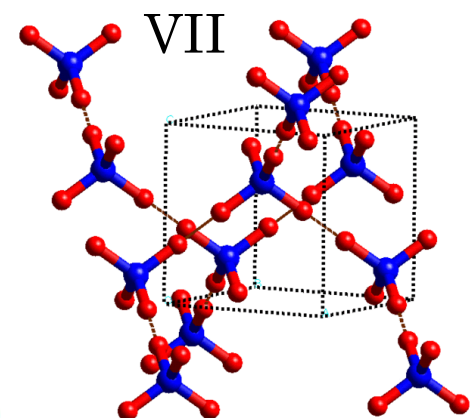
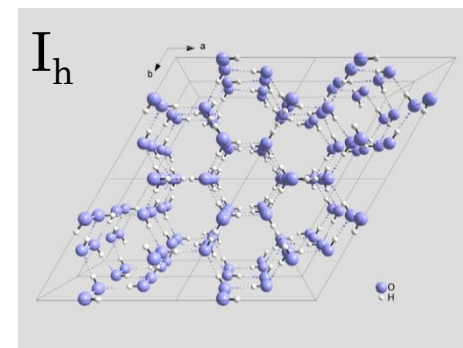
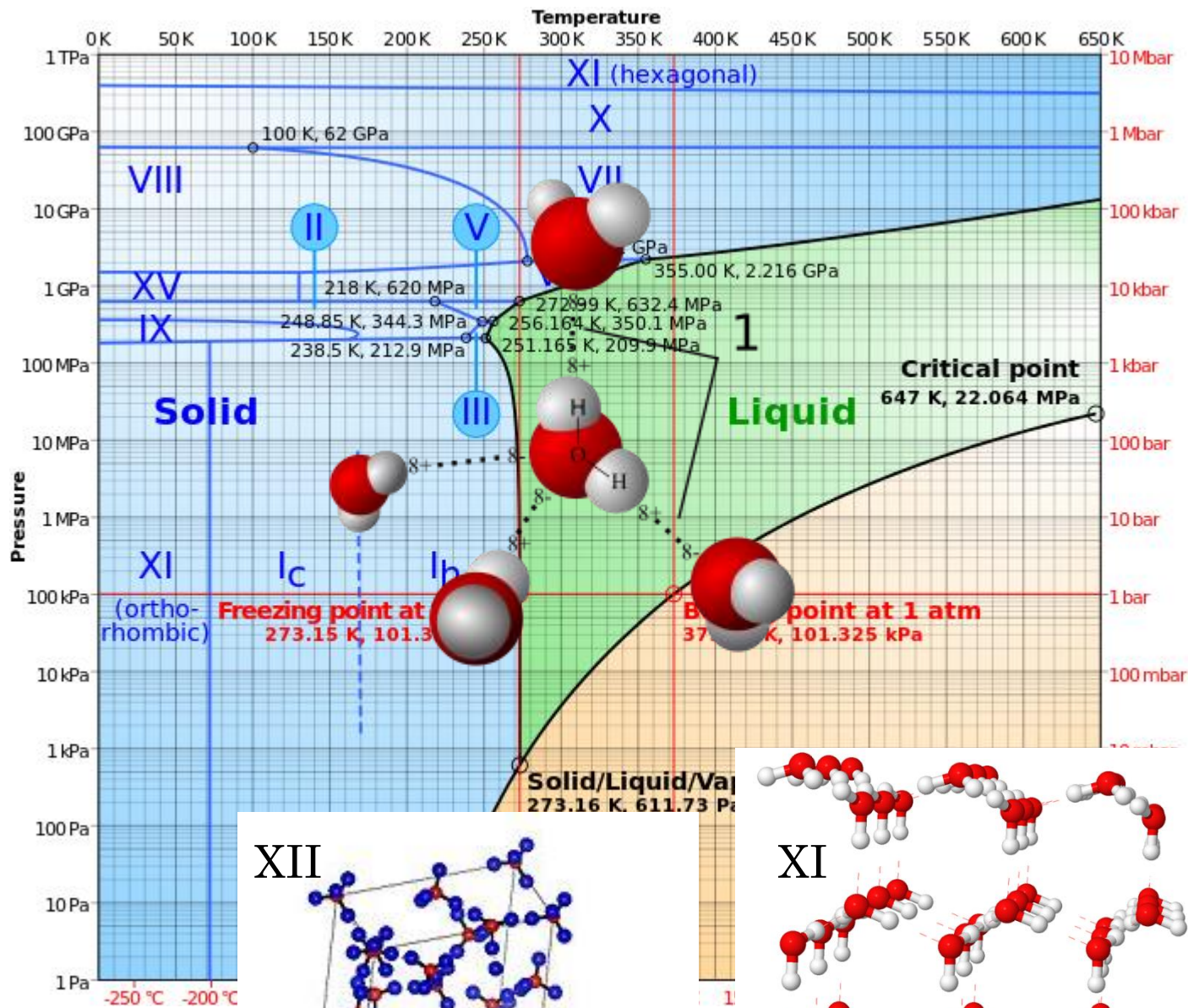


$$d(\text{O}—\text{O}) = 275 \text{ pm}$$

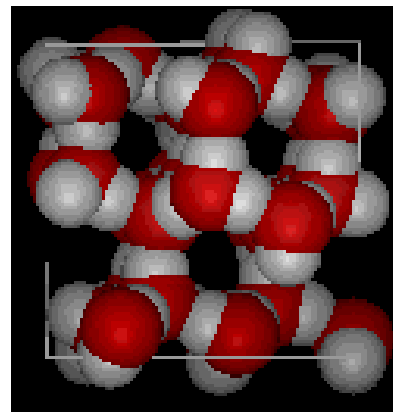
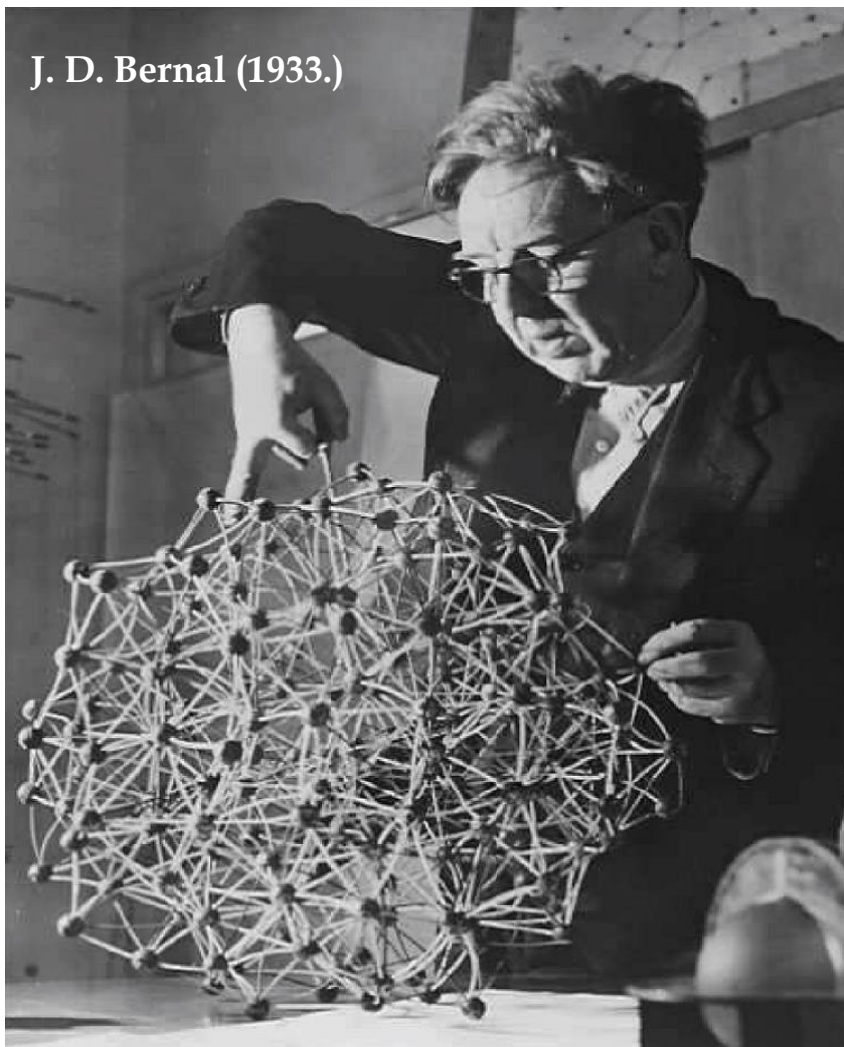
$$\alpha(\text{O}—\text{H} \cdots \text{O}) = 180^\circ$$

Položaji vodikovih jezgara su nasumični

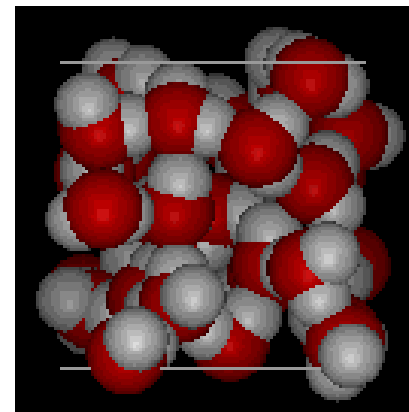




Struktura tekuće vode?



(s)

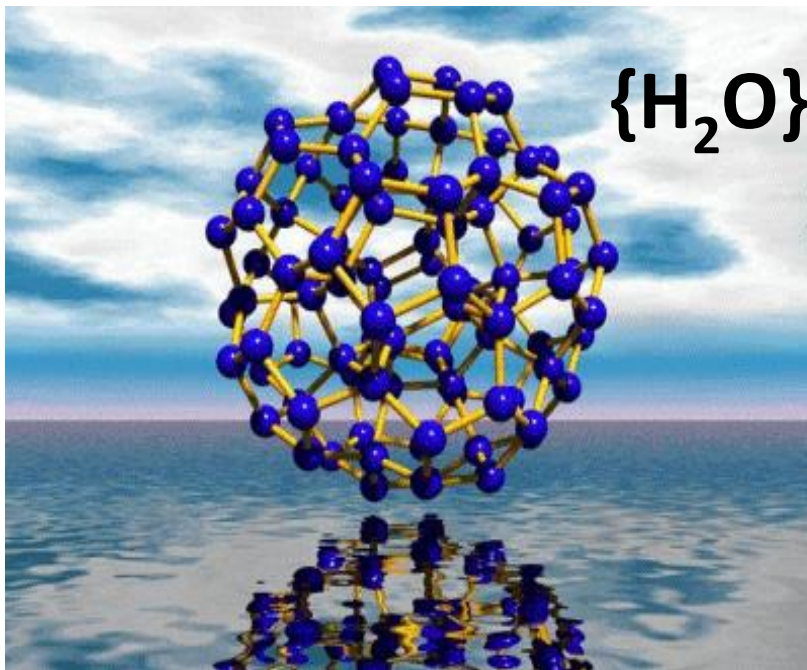


(l)

Struktura tekuće vode nalik nepravilnoj strukturi leda s dodatnim molekulama u šupljinama

Lanci i klusteri povezani vodikovom vezom (prosječno 3,2-4 vodikove veze po molekuli – 77-100% mogućih vodikovih veza)

KLUSTERI VODE



$$E_{\text{veze}} = 23,3 \text{ kJ mol}^{-1} - 29,7 \text{ kJ mol}^{-1}$$

- A. Müller, H. Bögge and E. Diemann, Structure of a cavity-encapsulated nanodrop of water, *Inorg. Chem. Commun.* **6** (2003) 52-53; Corrigendum: A. Müller, H. Bögge and E. Diemann, *Inorg. Chem. Commun.* **6** (2003) 329;
- B. M. Garcia-Ratés, P. Miró, J. M. Poblet, C. Bo and J. B. Avalo, Dynamics of encapsulated water inside Mo_{132} cavities, *Journal of Physical Chemistry B*, **115** (2011), 5980-5992.

VODIKOVA VEZA - KLATRATI

KLATRATI (lat. *clatri*: rešetka; *clatratus*: ograđen):

Tvari u kojima „*molekula domaćina*” ima kavezastu kristalnu strukturu sa šupljinama u kojima su smještene „*molekule ili atomi gosta*”

- odnos veličine šupljine u strukturi „*molekula domaćina*” i dimenzija „*molekule ili atomi gosta*”
- polarizabilnost
- npr. kristalni hidrati → atomi plemenitih plinova ili molekule klora ili metana uklopljeni u „*kavez*” nastao povezivanjem molekula vode pomoću vodikovih veza

KLATRATI

Klatrati – voda kao domaćin

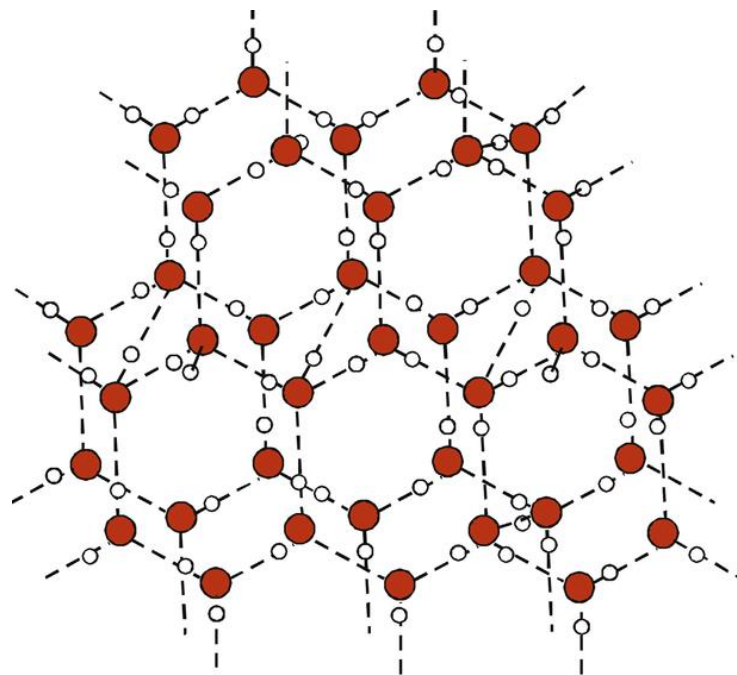
a) Jedinična ćelija – 46 molekula H_2O

gosti - Ar, Kr, Xe

- Cl_2 , SO_2 , CH_3Cl

b) Jedinična ćelija – 136 molekula H_2O

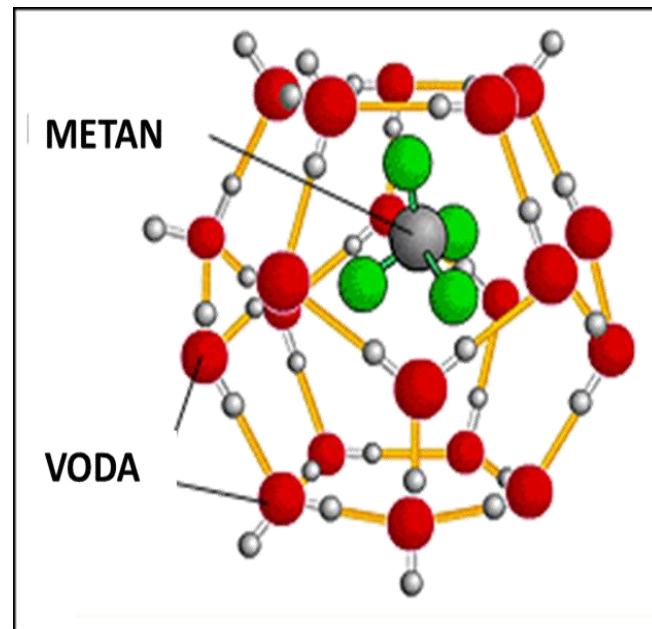
gosti - kloroform (CHCl_3)



KLATRATI

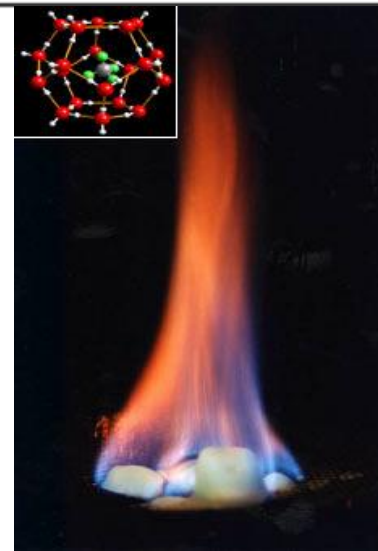
- niska temperatura
- visok tlak

U šuplinama kristalne rešetke leda (domaćin) nalaze se "zarobljene" velike količine metana



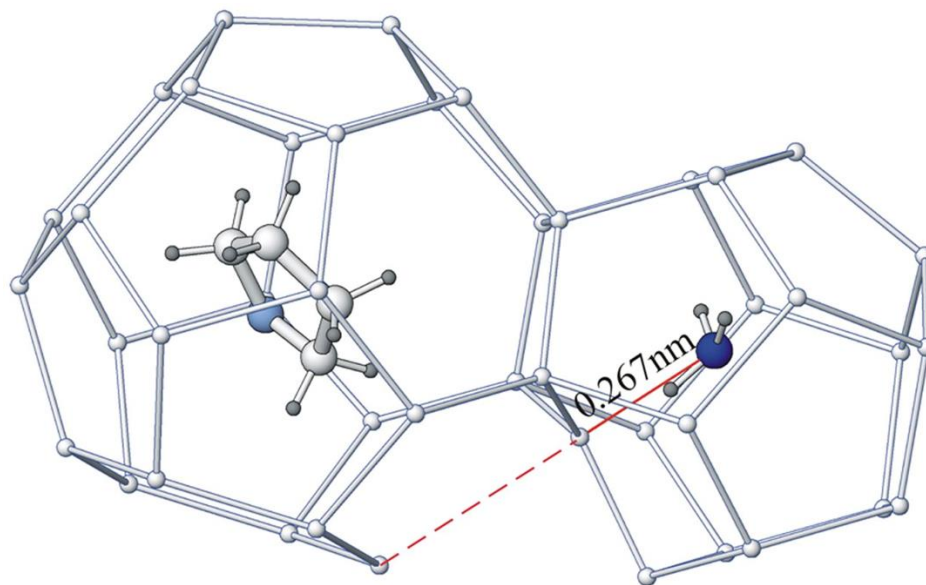
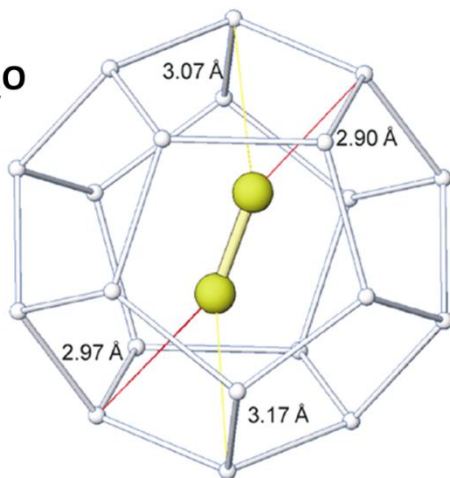
Metanski klatrat – stabilan do 18 °C

prosječni sastav – 1 mol CH_4 : 5,75 mol H_2O



KLATRATI

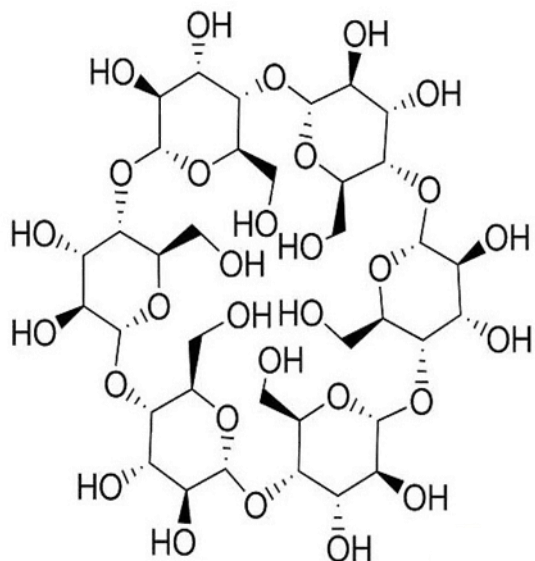
$\text{Cl}_2 \cdot 6,92 \text{ H}_2\text{O}$



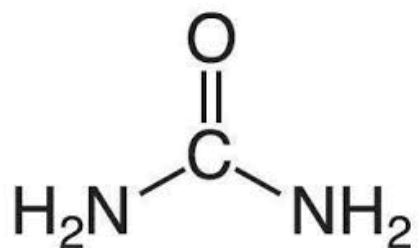
$\text{THF} + 5\% \text{ NH}_3(\text{aq})$ THF: H_2O 1:17 pri -10 °C

KLATRATI - DOMAĆINI

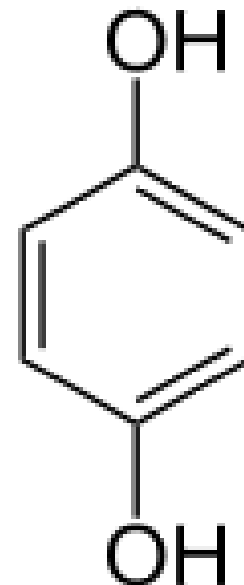
ciklodekstrin



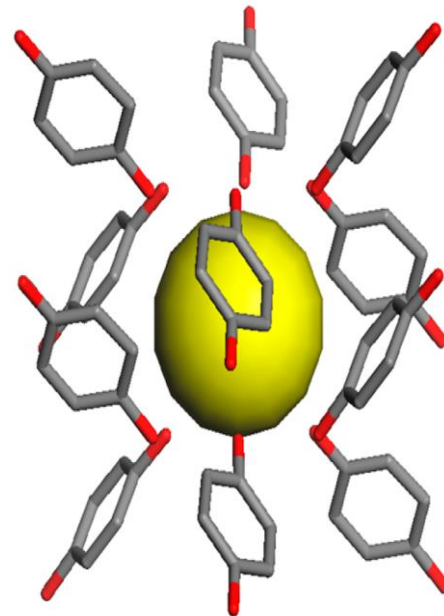
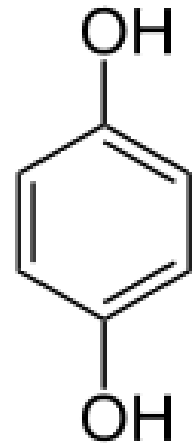
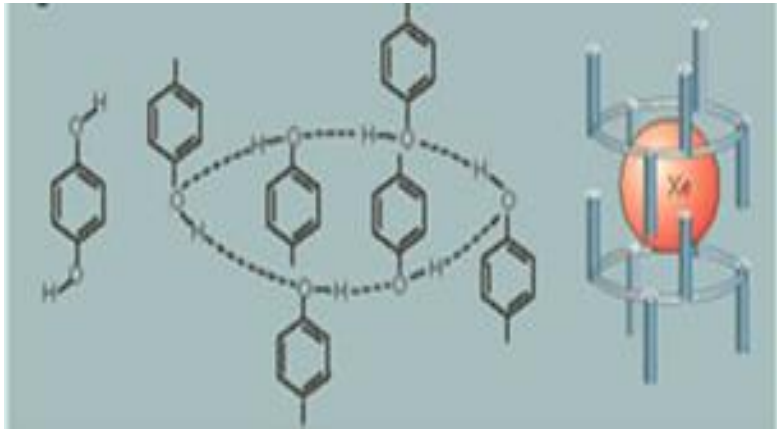
urea



hidrokinon



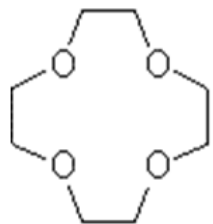
KLATRATI



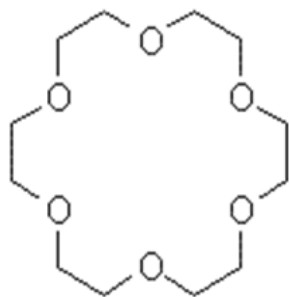
VODIKOVA VEZA

‘Kompleksi *Domaćin-gost*’: *npr.* metalni ion i krunasti eteri, ali i oksonijev ion i krunasti eteri

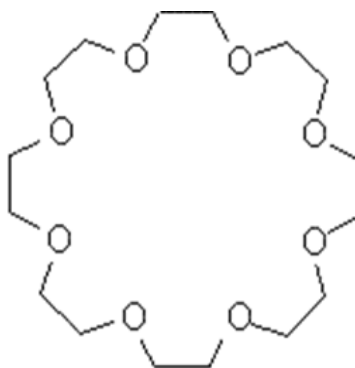
KRUNASTI ETERI



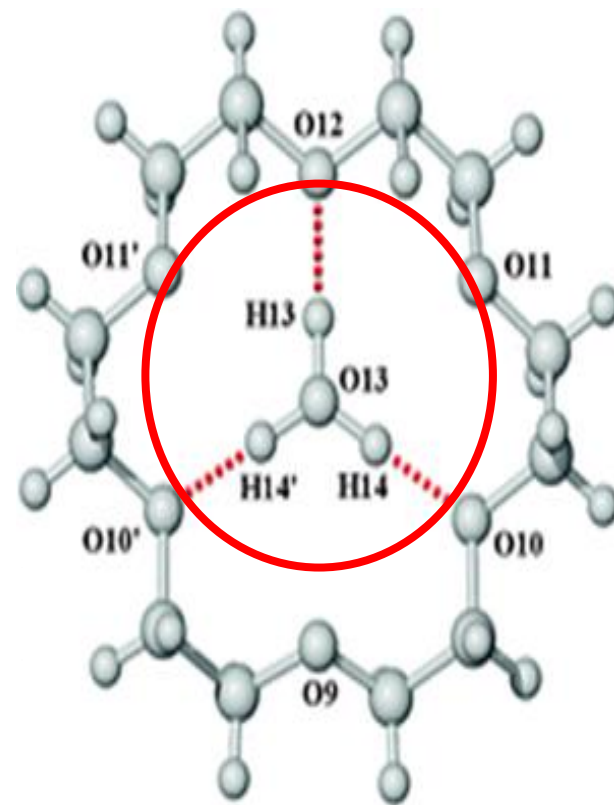
[12]-kruna-4



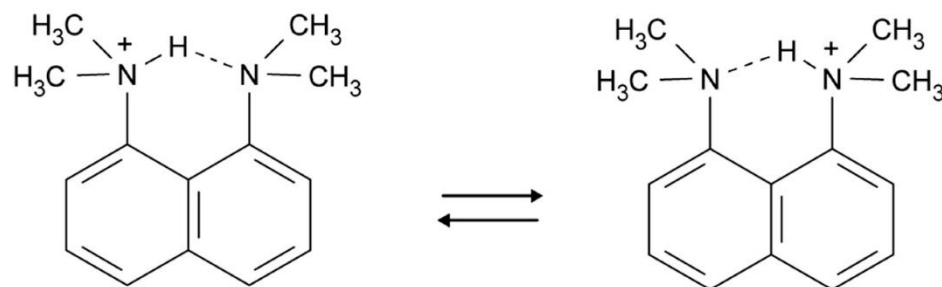
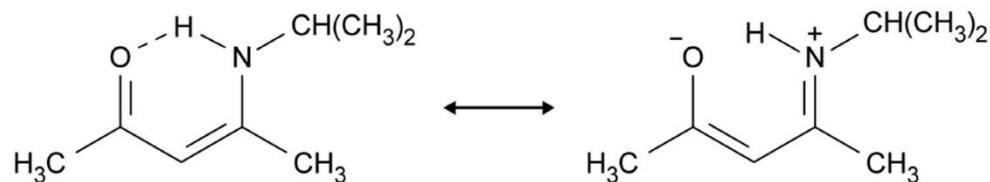
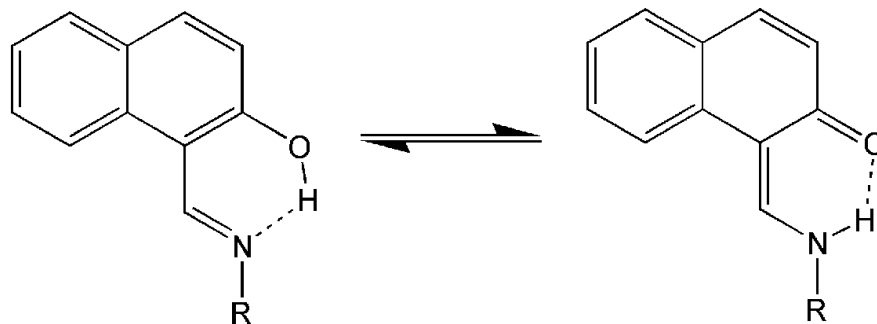
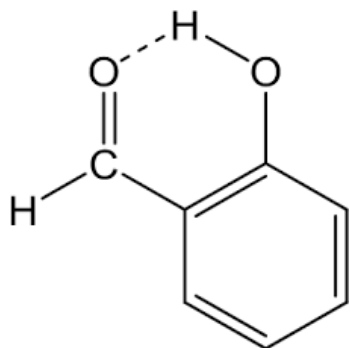
[18]-kruna-6



[24]-kruna-8



INTER- vs. INTRAmolekulska



'The Etter Rules'

Pravila vodikove veze u molekulskim (organskim) krutinama (M. Etter)

Opća pravila:

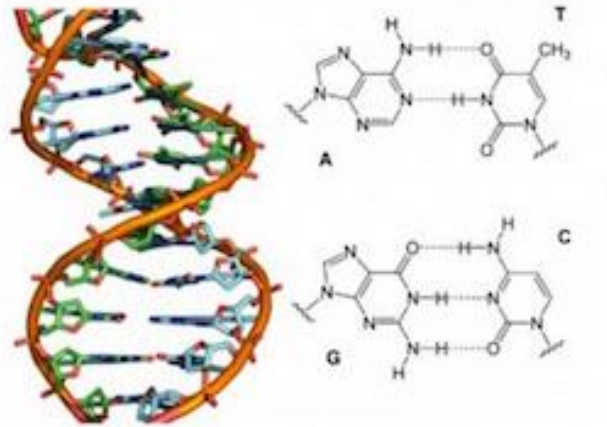
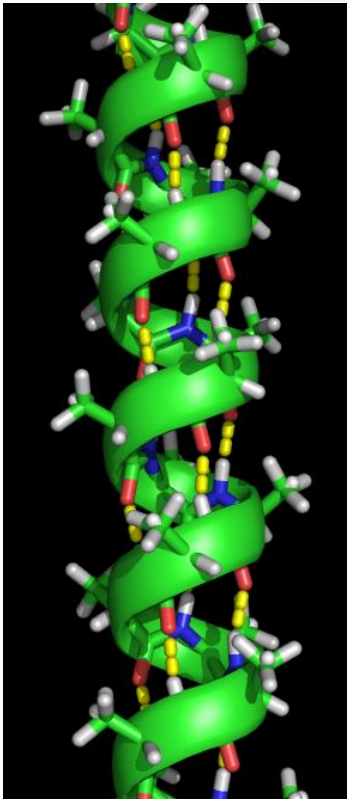
1. Svi dobri donori i akseptori vodikove veze sudjeluju u vodikovoj vezi
2. Unutarmolekulska veza kojom nastaju šesteročlani prstenovi povoljnija je od međumolekulske veze.
3. Najbolji donor vodikove veze tvori vezu s najboljim akseptorom (Drugi najbolji donor s drugim akseptorom i t.d.)



Margaret C. Etter,
(1943.–1992.)

+ **Specifična pravila** (za pojedine skupine spojeva)

U BIOLOŠKIM SUSTAVIMA



Proteini, DNA...

