
بسم الله الرحمن الرحيم
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Bismillah al rahman al rahim

دانشگاه علوم کشاورزی و منابع طبیعی گرگان
دانشکده صنایع غذایی

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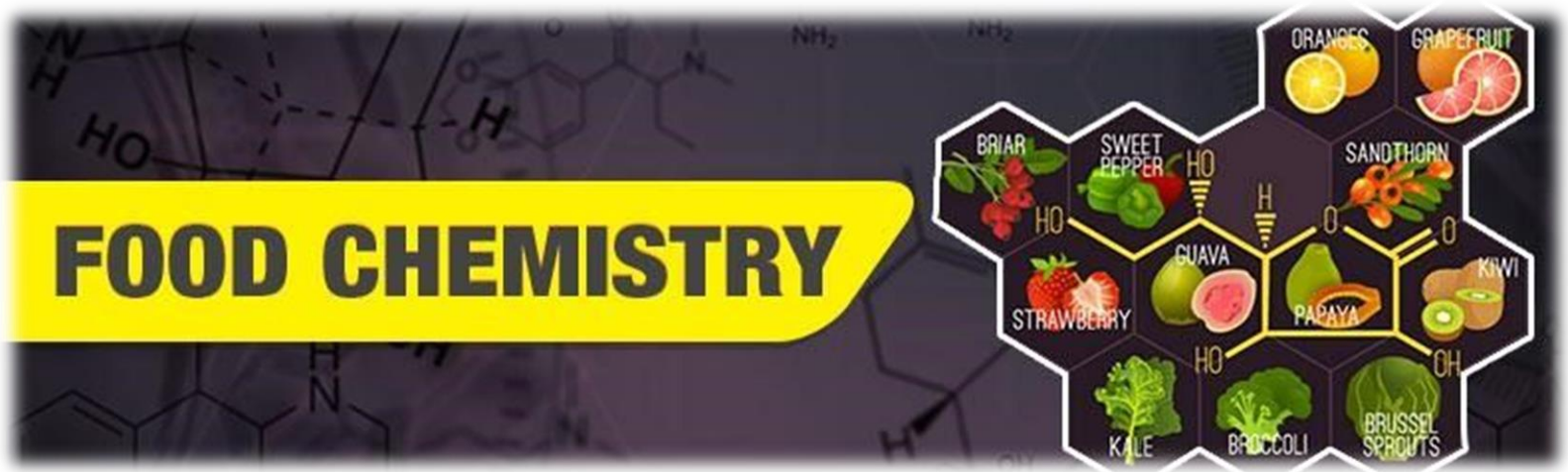
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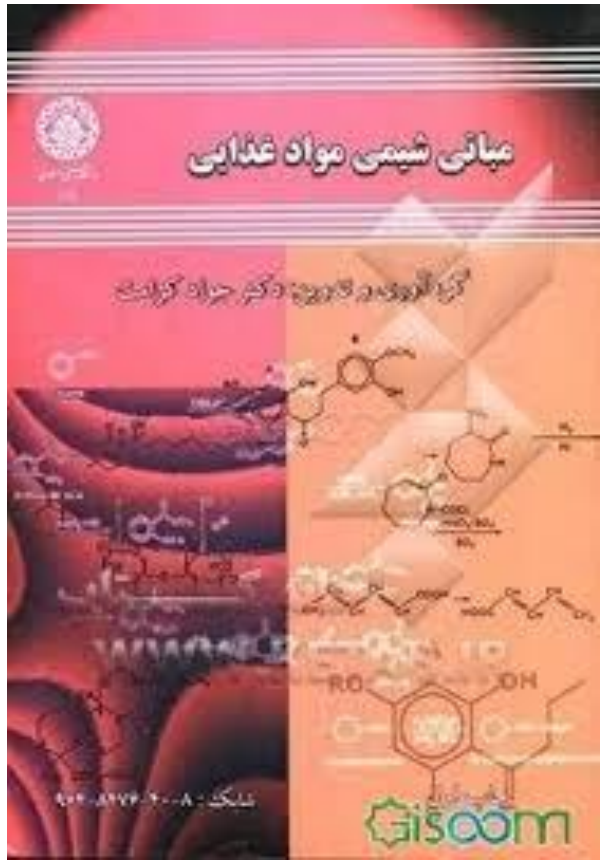
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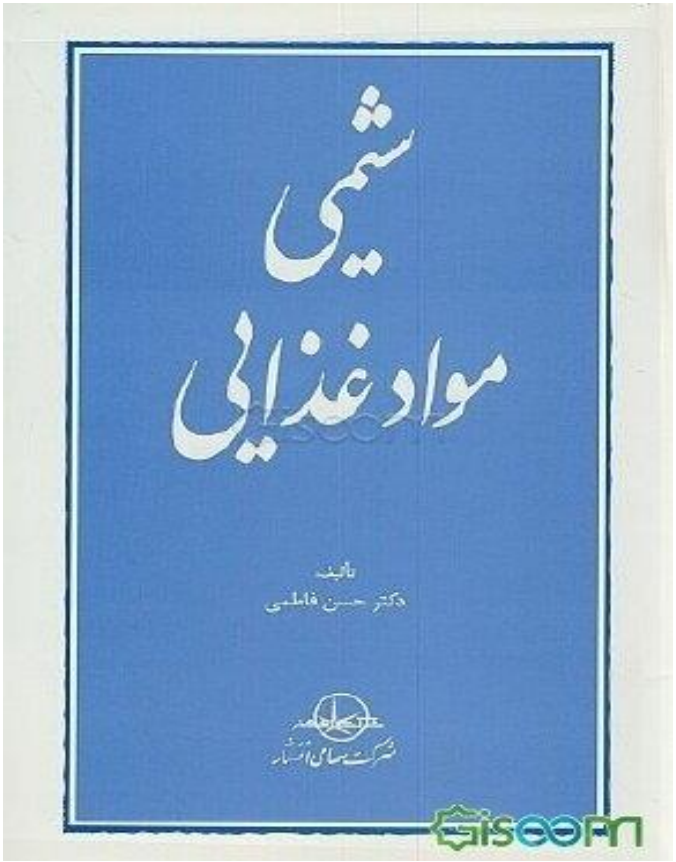
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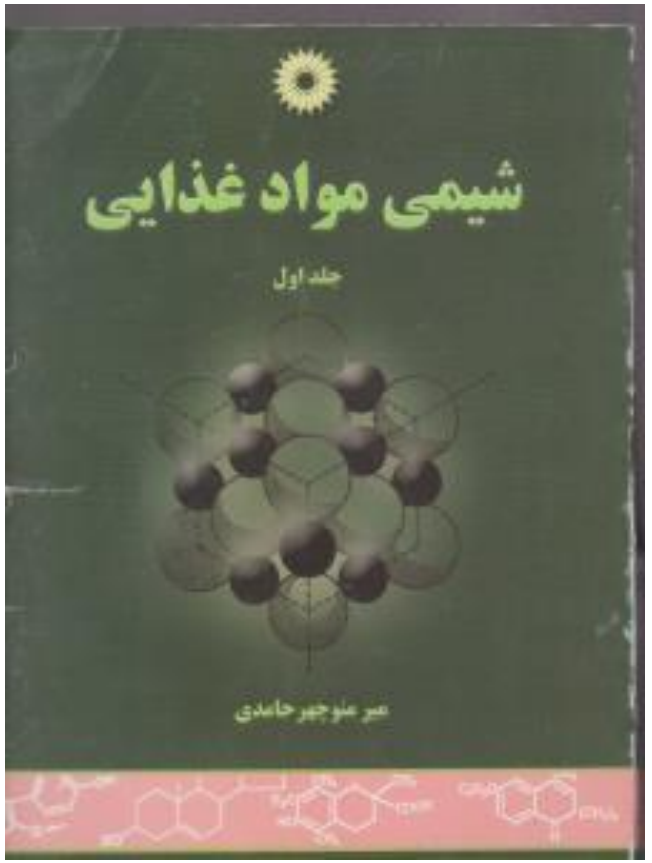
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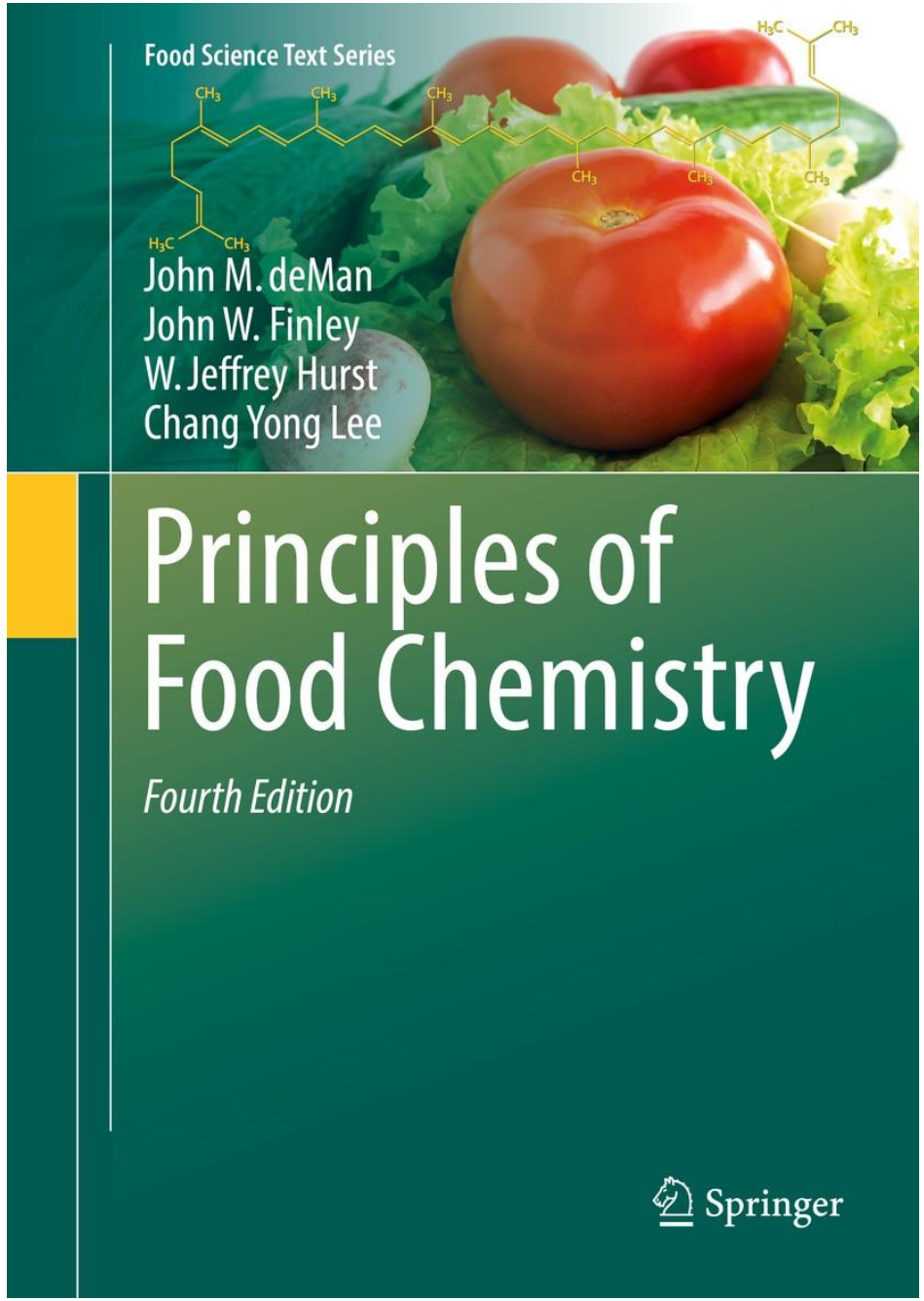
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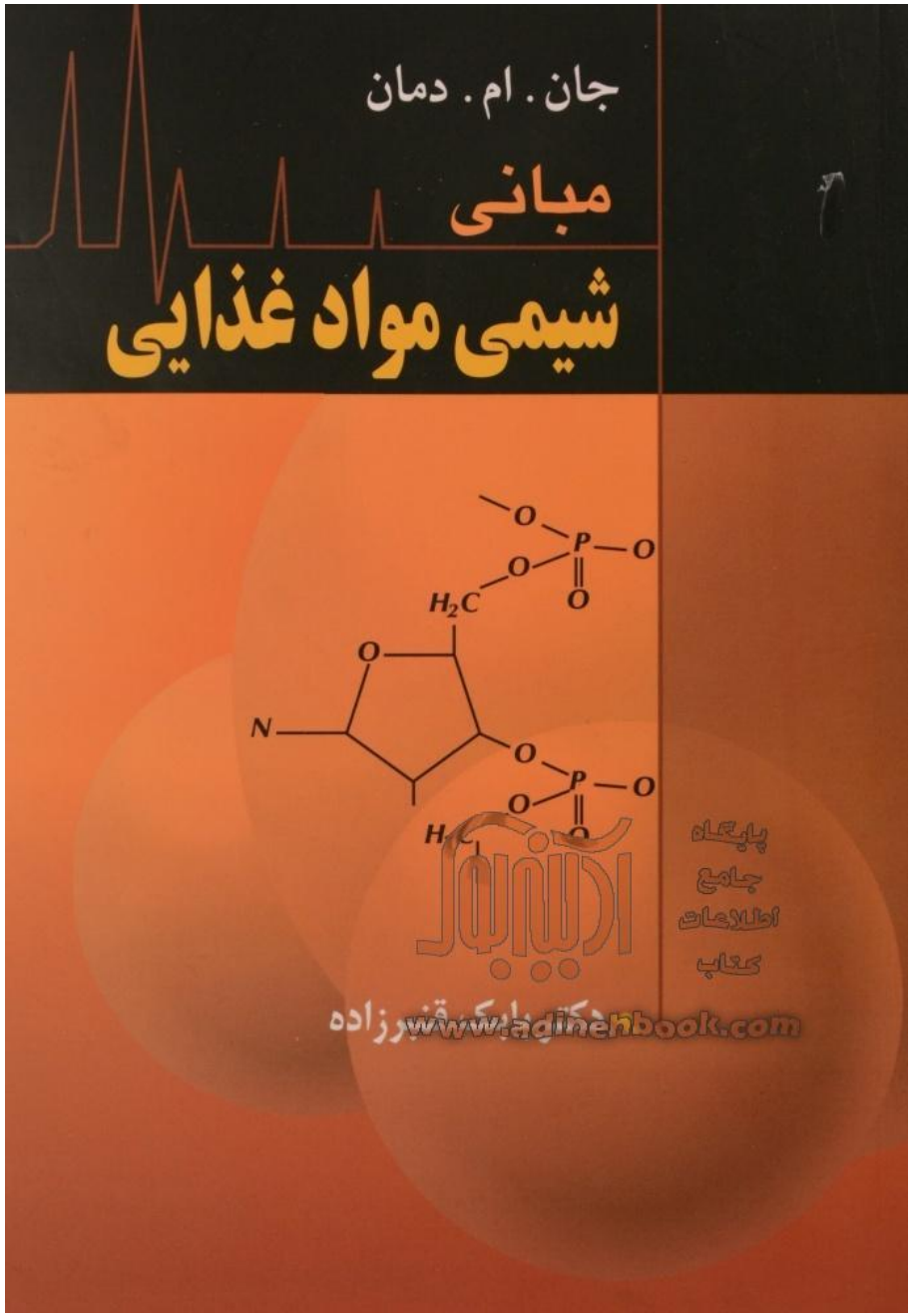
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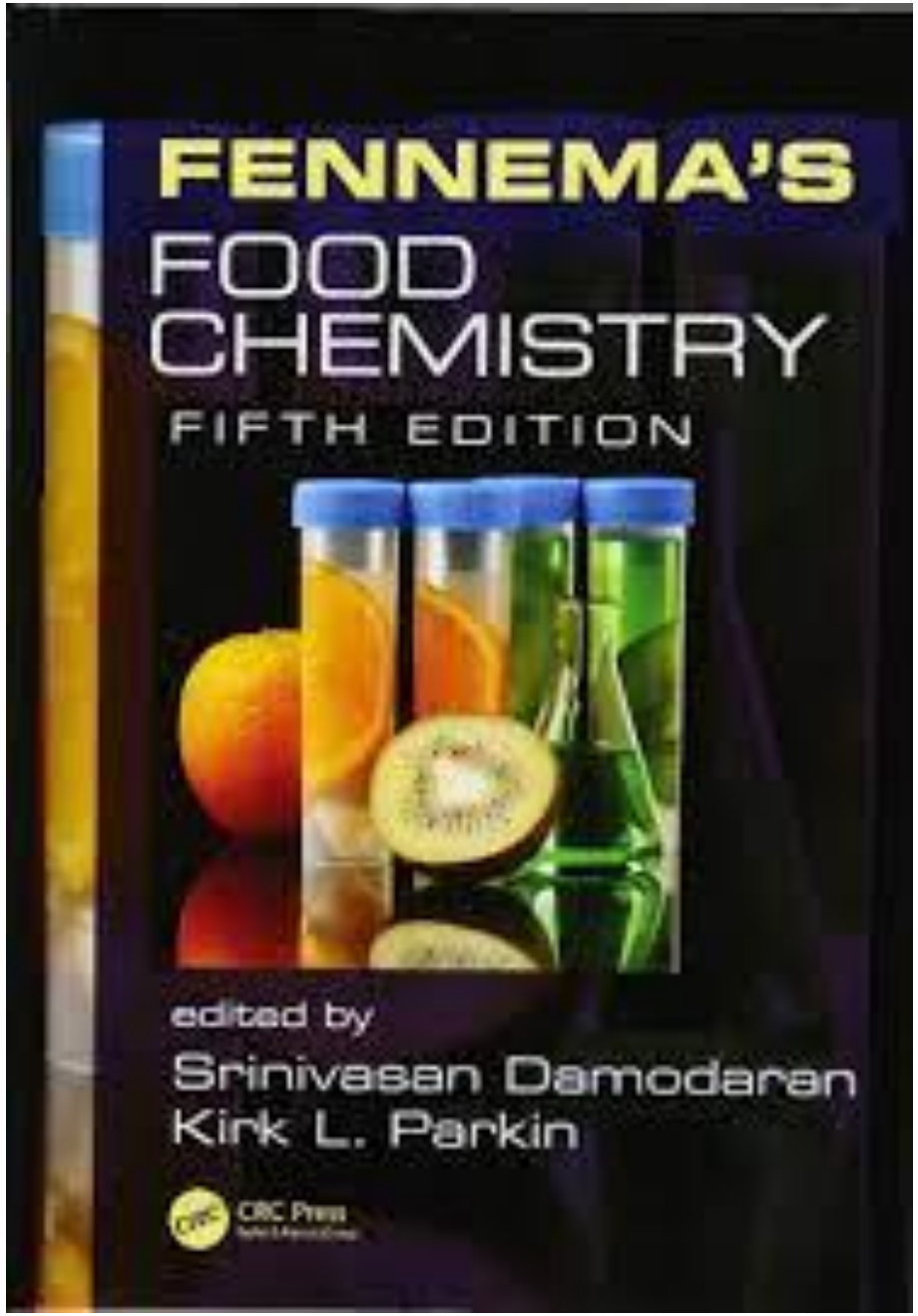
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Food Chemistry

4th revised and
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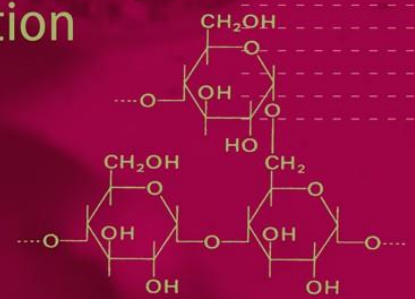

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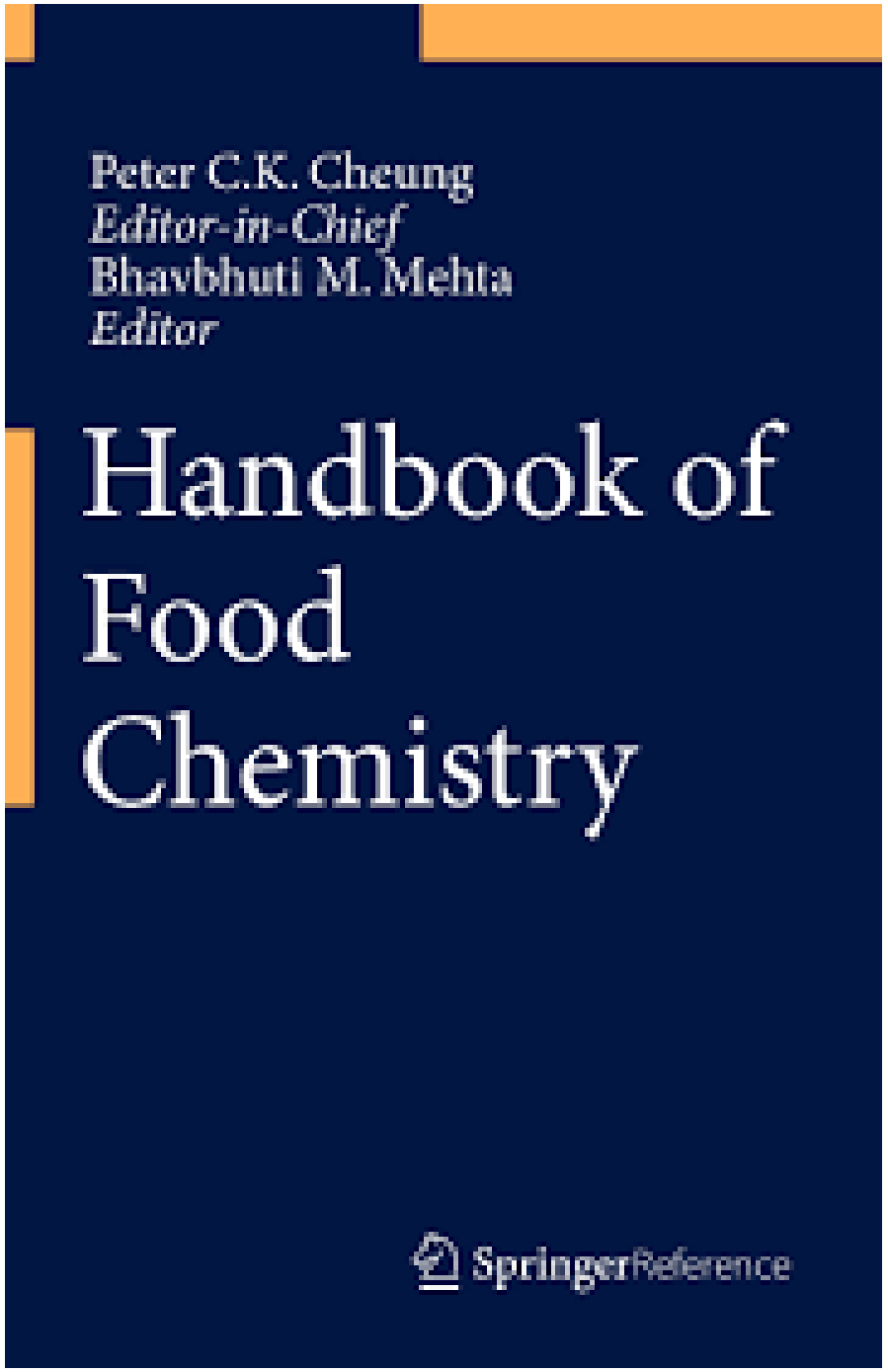
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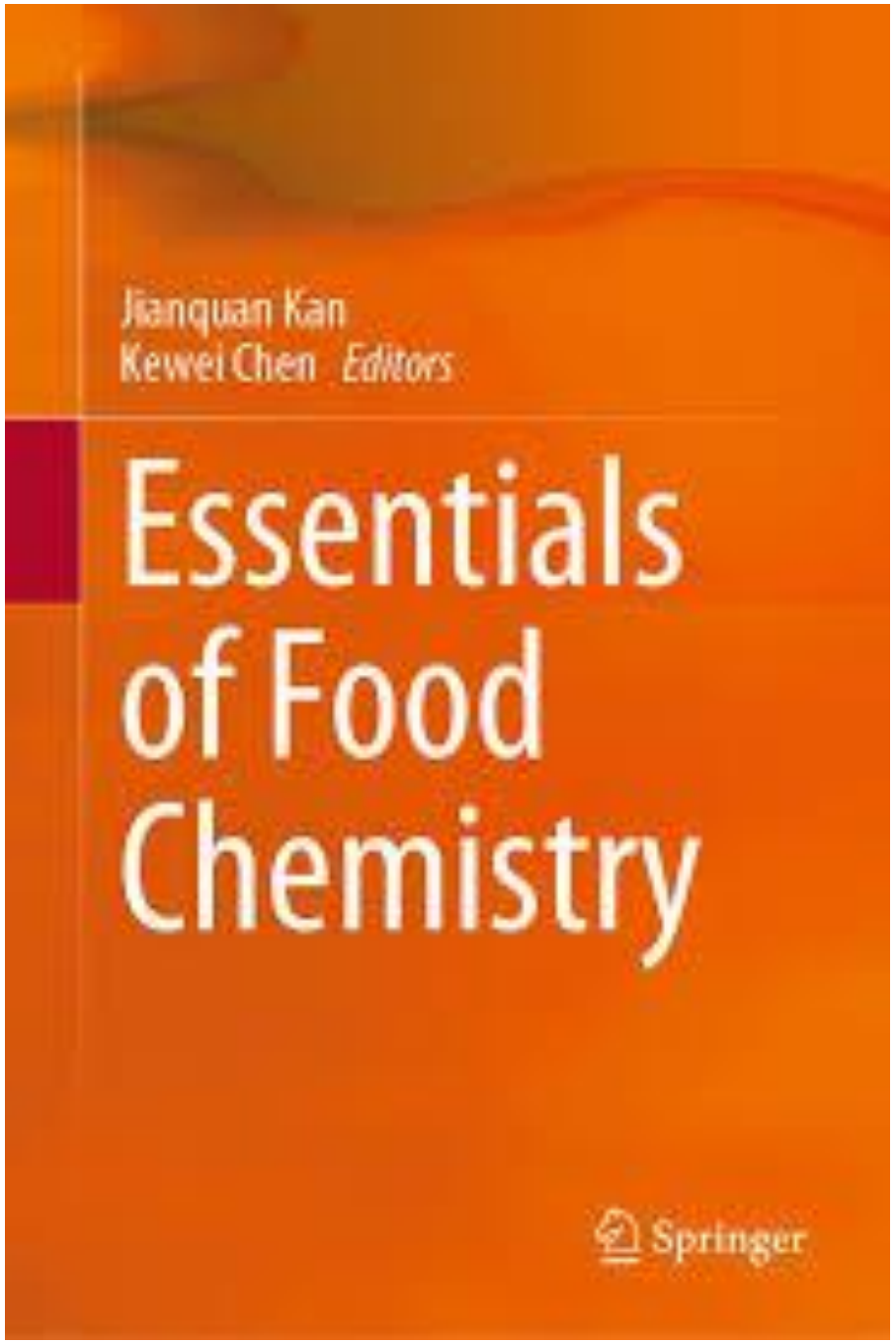
Jianquan Kan
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Essentials of Food Chemistry
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ارزیابی

STRUCTURE OF WATER

Introduction

- Water is relatively small inorganic molecule, but organic life is highly dependent on this tiny molecule. It is the only substance on the earth that occurs abundantly in all three physical states (gas, liquid and solid).

- Water is essential for life as:

(1) regulator of body temperature
(2) solvent
(3) carrier of nutrients and waste products
(4) reactant and reaction medium
(5) lubricant and plasticizer
(6) stabilizer of biopolymer conformation
(7) facilitator of the dynamic behavior of macromolecules (e.g. catalytic activity)

Introduction

- Most of the fresh foods contain large amounts of water.
- It is one of the major component in composition of many foods.
- Each food has its own characteristic amount of this component.

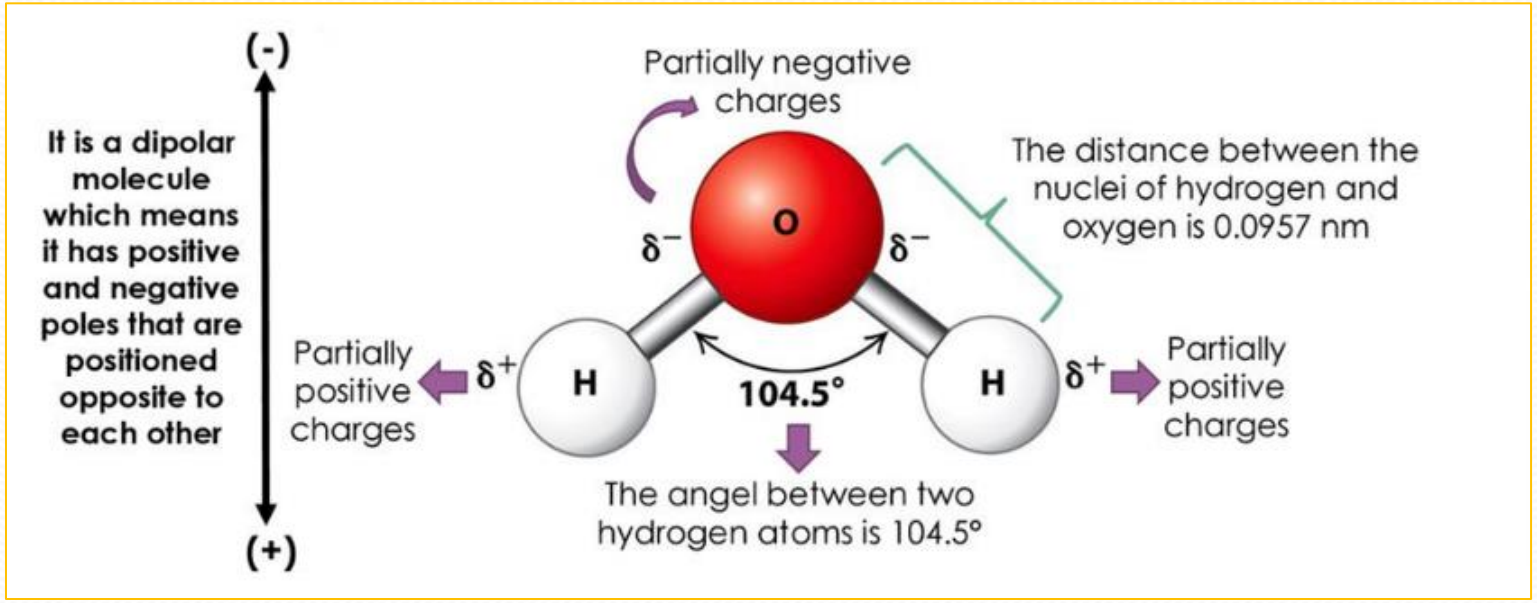
Food	Percentage water
Dairy products	
Butter	15
Cheeses (wide range of moisture content depending on type)	
Cheddar cheese	40
Cottage cheese	75
Cream	60–70
Dry milk powders	4
Fluid dairy products (whole milk, nonfat milk, butter milk	87–91
Ice cream and sherbet	65
High lipid foods	
Margarine	15
Mayonnaise	15
Pure oils and fats	0
Salad dressings	40
Fruits and vegetables	
Avocado	65
Beans (green, lima)	67
Berries	81–90
Citrus fruits	86–89
Cucumbers	96
Dried fruits	up to 25
Fresh fruits (edible portion)	90
Fresh fruits, juices, and nectars	85–93
Guavas	81
Legumes (dry)	10–12
Melons	92–94
Ripe olives	72–75
Potatoes	
White potatoes	78
Sweet potatoes	69
Tap roots	
Radishes (highest)	93
Parsnips (lowest)	79
Cereals and cereal products	
Breakfast cereals	<4
Macaroni	9
Milled grain products: flour, grits, semolina germ	10–13
Whole grained cereals	10–12
Baked cereal products	
Bread	35–45
Crackers and pretzels	5–8
Pies	43–59
Rolls	28
Nut meats	
Ripe raw nuts	3–5
Fresh chestnuts	53
Meat, seafood, and poultry products	
Animal flesh and seafoods (wide range depending on fat content and age of specimen)	50–85
Eggs	
Fresh eggs	74
Dried eggs	5
Poultry meats	
Geese	50
Chicken	75
Sugar and sugar-based products	
Honey and other syrups	20–40
Fruit jellies, jams, and marmalades	≤35
White sugar (cane or beet), hard candy, plain chocolate	≤1

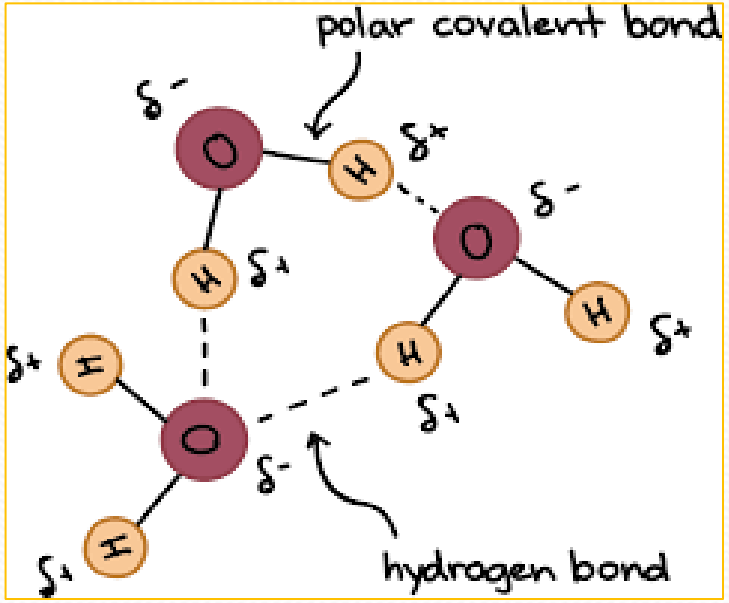
Introduction

- Shelf-life or long-term storage
- Unit operations:
  - Dehydration or drying
  - Concentration
  - Freezing
  - Gelation
  - Salt or sugar addition
- Texture, taste, appearance, production economics

Effect of water on structure, appearance and taste of foods as well as their susceptibility to spoilage depends on its amount, location, and orientation. Therefore, it is essential to know its **physical properties**.

Water Molecule

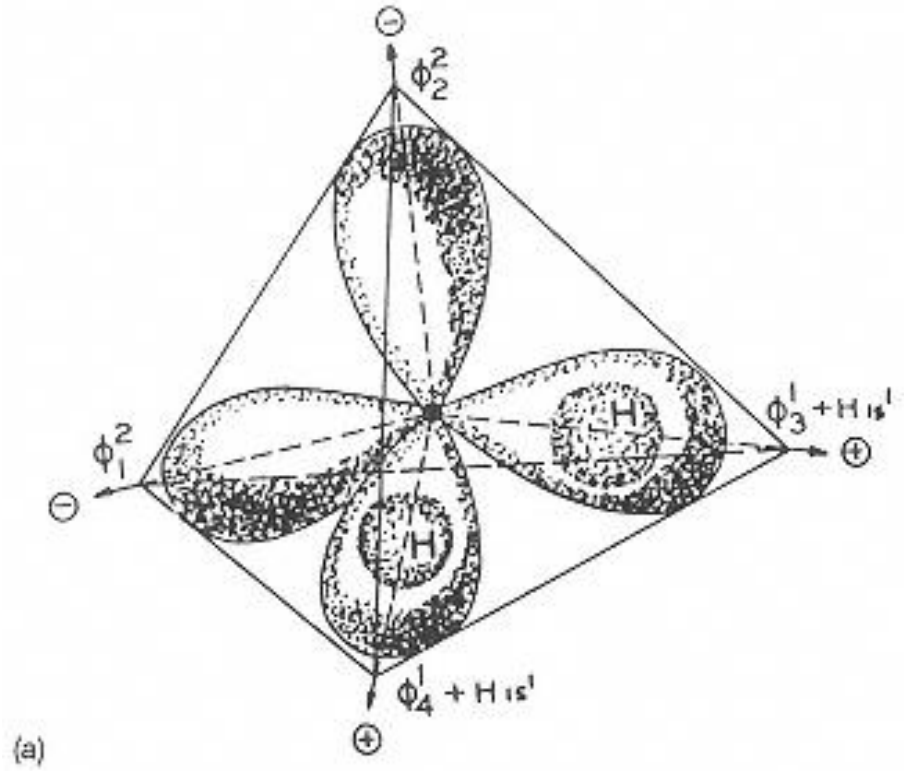


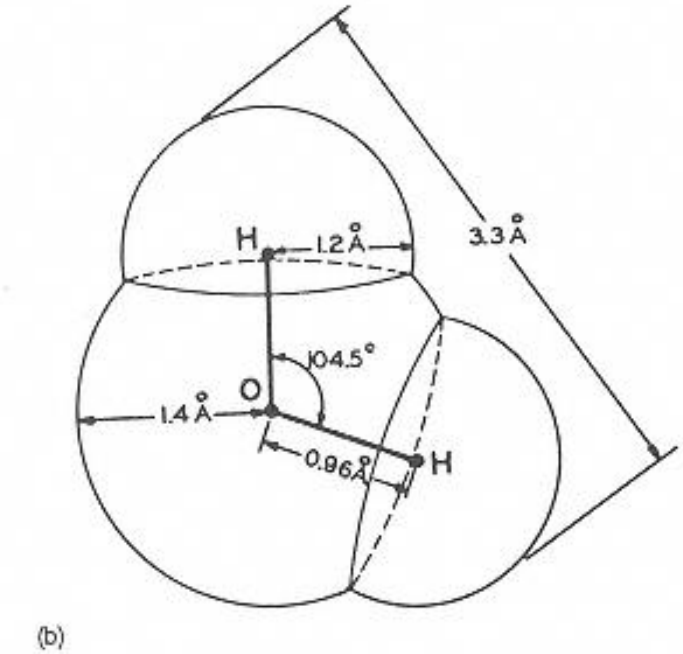


Some the unusual properties of water are due strong intermolecular attractive forces among molecules of water

Water Molecule

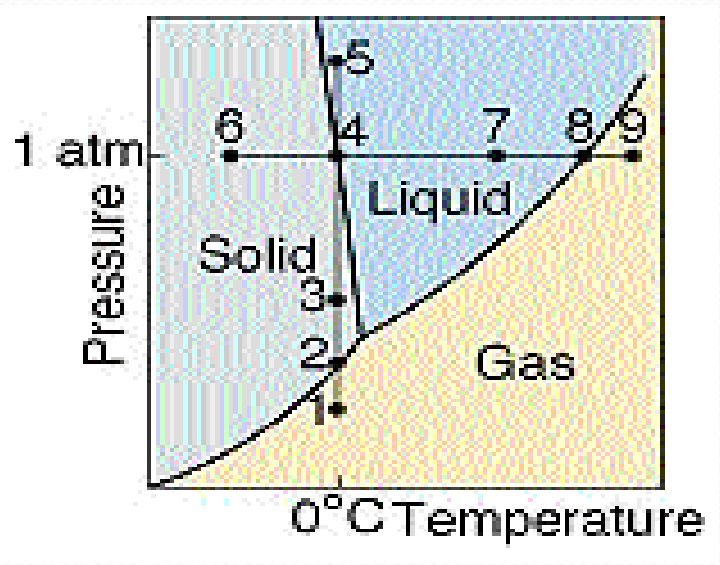
- O: 1S2 2S2 2Px2 2Py1 2Pz1
- H – O – H : 90 º
- 104.5 º
- SP3 Hybrid
- Tetrahedron
- 109 º 28´
- Quadropole
  - O : 2δ- = 1.08 × 10^{-19} C
  - H : δ+ = 0.54 × 10^{-19} C





PHYSICAL PROPERTIES OF WATER AND ICE

- Molecular weight : 18.0153 g/mole
- Phase transition properties :
  - Melting point at 101.3 kPa (1 atm) : 0.000 ºC
  - Boiling point at 101.3 kPa (1 atm): 100.000 ºC
  - Critical temperature : 373.99 ºC
  - Critical pressure : 22.064 MPa (218.6 atm)
  - Triple point : 0.01 ºC and 611.73Pa (4.589 mm Hg)
  - Enthalpy of fusion at 0 ºC : 6.012 kJ (1.436 kcal)/mole
  - Enthalpy of vaporization at 100 ºC : 40.657 kJ (9.711 kcal)/mole
  - Enthalpy of sublimation at 0 ºC : 50.91 kJ (12.16 kcal)/mole



PHYSICAL PROPERTIES OF WATER AND ICE

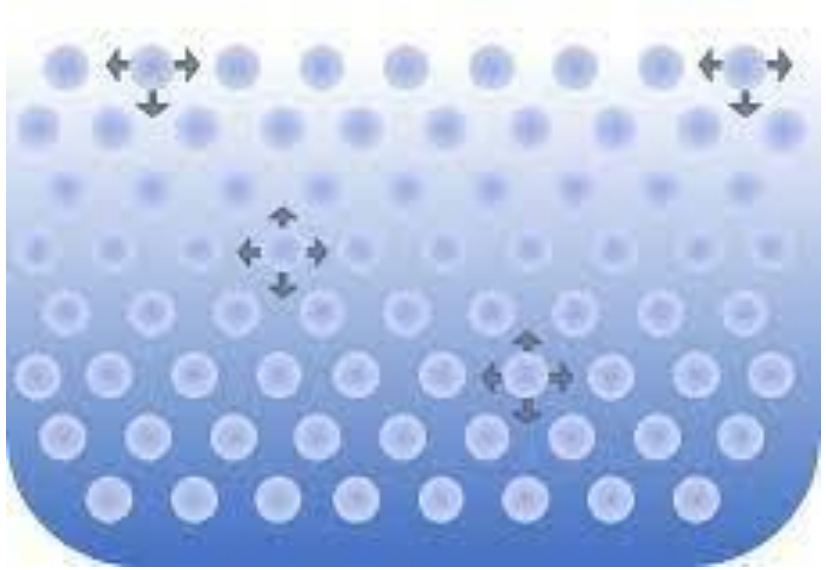
Important Physical Properties for Water and Other Substances

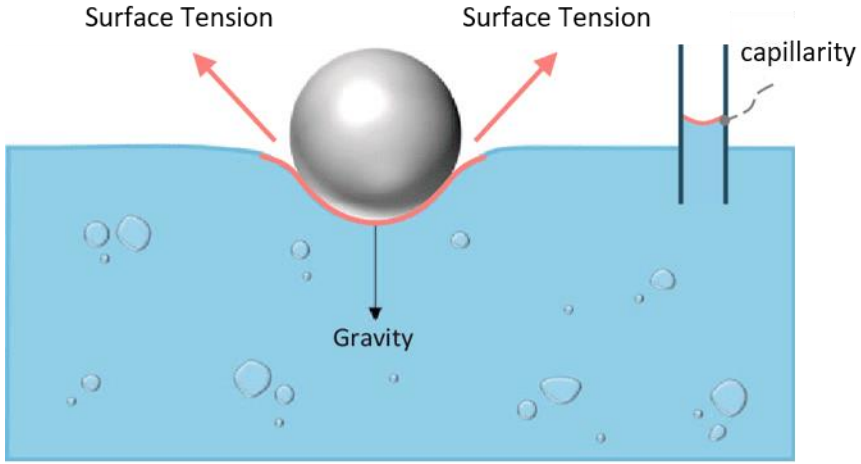
Chemical substance	Melting point (°C)	Boiling point (°C)	Heat of vaporization (cal g^{-1})	Heat of fusion (cal g^{-1})	Dielectric constant at 25°C
Water	0.0	100.0	540	80.0	78.5
Ethanol	−114.0	78.0	204	24.9	24.3
Methanol	−98.0	65.0	263	22.0	32.6
Acetone	−95.0	56.0	125	23.0	20.7
Ethyl acetate	−84.0	77.0	102	—	6.0
Chloroform	−63.0	61.0	59	—	—
Ammonia	−78.0	−33.0	327	84.0	16.9
Hydrogen sulfide	−83.0	−60.0	132	16.7	—
Hydrogen fluoride	−92.0	19.0	360	54.7	—

PHYSICAL PROPERTIES OF WATER AND ICE

Other properties	Temperature			
	20°C	0°C	0°C (ice)	−20°C (ice)
Density (g/cm^3)	0.99821	0.99984	0.9168	0.9193
Viscosity (pa · sec)	1.002×10^{-3}	1.793×10^{-3}	—	—
Surface tension against air (N/m)	72.75×10^{-3}	75.64×10^{-3}	—	—
Vapor pressure (kPa)	2.3388	0.6113	0.6113	0.103
Heat capacity (J/g · K)	4.1818	4.2176	2.1009	1.9544
Thermal conductivity (liquid) (W/m · K)	0.5984	0.5610	2.240	2.433
Thermal diffusitity (m^2/s)	1.4×10^{-7}	1.3×10^{-7}	11.7×10^{-7}	11.8×10^{-7}
Permittivity (dielectric constant)	80.20	87.90	~90	~98

Intermolecular attractive forces
in the plane of the surface resulting
downward net force and minimized surface area





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$K_{ice,\ o\ ^oC} \approx 4\ K_{water,\ o\ ^oC}$

$\alpha_{ice,\ o\ ^oC} \approx 9\ \alpha_{water,\ o\ ^oC}$

Which one is faster?

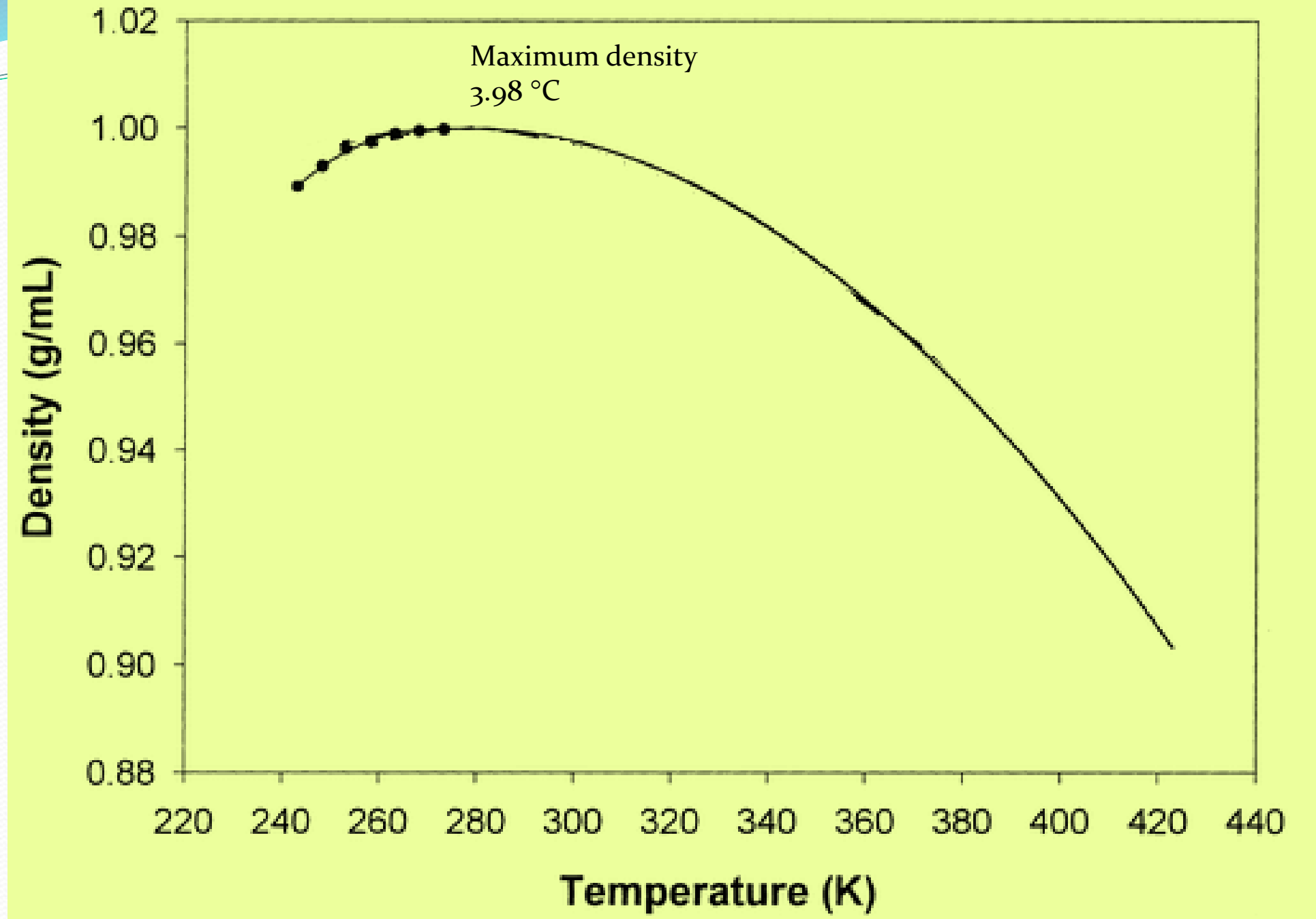
Freezing

Thawing (defrosting)

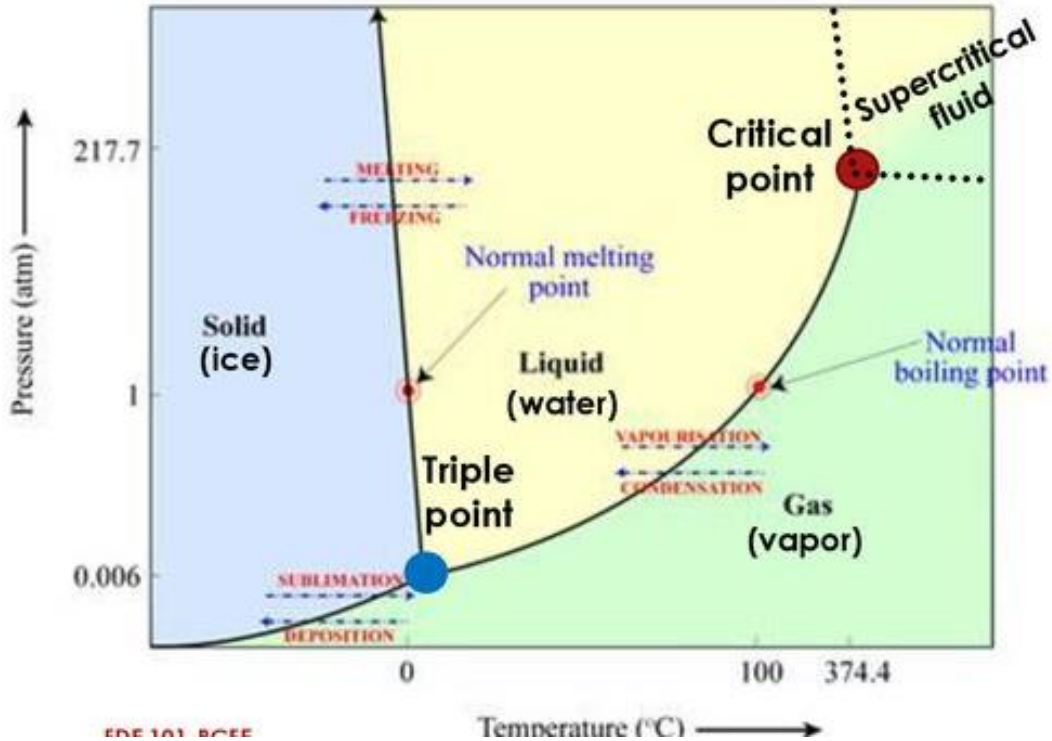
STRUCTURE OF WATER

- Fluidity
- Two reasons:
  - Open liquid, a density about 40% lower than non-structured liquids
  - Breaking about 15% of hydrogen bonds when melting
- The number of hydrogen bonds depends on temperature

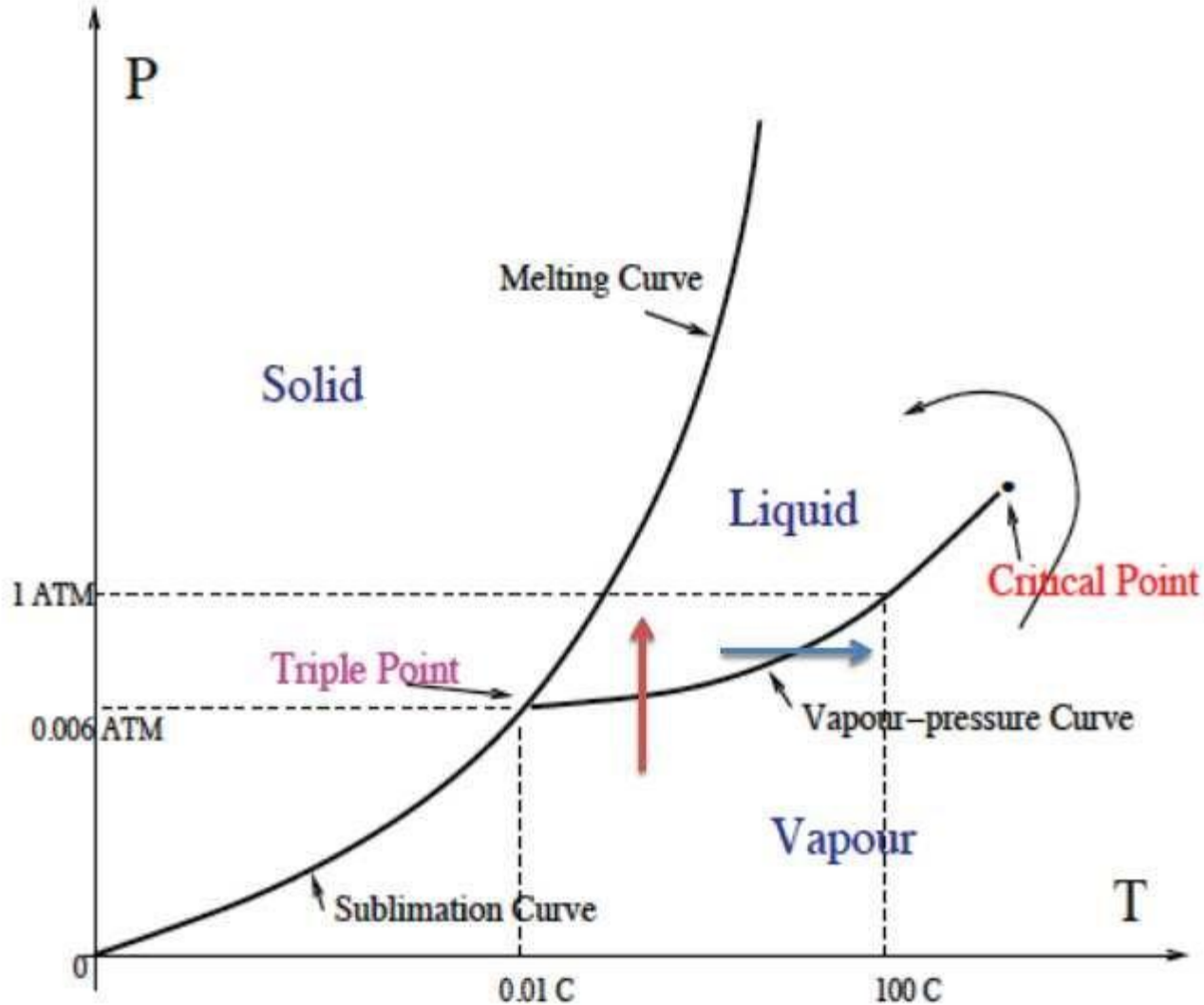
	Coordination number	O-H … O distance (Å)
Ice (0 ºC)	4.0	2.76
Water (1.5 ºC)	4.4	2.9
Water (83 ºC)	4.9	3.05


Maximum density
3.98 °C
Density (g/mL)
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
220
240
260
280
300
320
340
360
380
400
420
440
Temperature (K)

Three Phase Diagram of Water



- The blue area is a low temperature-high pressure zone in which the water is in solid phase (ice form)
- The green area is a high temperature-low pressure zone in which the water is in gas phase (vapor form)
- The yellow area is a high temperature-high pressure zone in which the water is in liquid phase (water form)
- Triple point is specific condition in which solid, liquid and gas phases are in equilibrium.
- Critical point is another specific condition. When the temperature and pressure increase, the density of the water decrease where the pressure of the water increase. At this point, its form is neither liquid nor gas. It gains the new phase, which is called supercritical fluid.


P
Melting Curve
Solid
Liquid
Critical Point
1 ATM
Triple Point
0.006 ATM
Vapour–pressure Curve
Vapour
Sublimation Curve
T
0
0.01 C
100 C