# Biochemistry of Selected Elements

# Distribution of main elements (mass %)

| Nature | |
|---|---|
| Oxygen | 50.0 |
| Silicium | 26.0 |
| Aluminium | 7.5 |
| Iron | 4.7 |
| Calcium | 3.4 |

| Human body | |
|---|---|
| Oxygen | 63.0 |
| Carbon | 20.0 |
| Hydrogen | 10.0 |
| Nitrogen | 3.3 |
| Calcium | 1.5 |

# Hydrogen in the human body

- **Elemental gaseous hydrogen ($H_2$)**

  formed in the large intestine by the action of microflora

  (not important in biochemistry)

- **Proton ($H^+$)**

  in body fluids determines the pH, constant pH values are kept

  by the three systems of buffers – see the table, the next slide

# Buffer systems in blood (pH = 7.40)

| **Buffer system** | **Buffer base** | **Buffer acid** | **Abundance** | **p$K_A$** | **Ratio [base] : [acid]** |
|---|---|---|---|---|---|
| Ideal buffer | Ideal base | Ideal acid | 100 % | 7.4 | 1 : 1 |
| Hydrogen carbonate | $HCO_3^-$ | $H_2CO_3 + CO_2$ | 50 % | 6.1 | 20 : 1 |
| Protein* | Protein-His | Protein-His-$H^+$ | 45 % | 6.0 – 8.0 | NA |
| Hydrogen phosphate | $HPO_4^{2-}$ | $H_2PO_4^-$ | 5 % | 6.8 | 4 : 1 |

* In plasma mainly albumin, in erytrocytes hemoglobin

## Covalently bound H in the molecules of nutrients

- in metabolic dehydrogenations are 2H transferred to cofactors $NAD^+$, FAD. Oxidation of NADH and $FADH_2$ in respiratory chain releases energy which is used to synthesize ATP (see lecture Bioenergetics)

## Hydride anion ($H^-$)

- formed transiently during dehydrogenation reactions by the action of $NAD^+$ ($2\ H \rightarrow H^- + H^+$)
- for more detailed explanation see the lecture Heterocycles

# Distinguish between proton and hydrogen

A donor of $H^+$ = acid

A donor of H = reductant

An acceptor of $H^+$ = base

An acceptor of H = oxidant

# Oxygen in nature

- the most abundant element (water, $CO_2$, minerals)
- dioxygen ($O_2$) in atmosphere, ozone ($O_3$) in ozonosphere
- air composition (vol. %):

| | |
|---|---|
| $N_2$ | 78 |
| $O_2$ | 21 |
| Noble gases | 0.9 |
| $CO_2$ | 0.03 |

## Reserves of $O_2$ in the adult body are very limited

- free $O_2$ in lungs (max. 1 litre)
- bound to Hb (blood), Mb (muscles) (1.5 litre)
- physically dissolved in blood (0.2 litre)

# Biochemical role of dioxygen

- transported from lungs as oxy-Hb to cells, where it diffuses to mitochondria
- **terminal acceptor of electrons in respiratory chain**
- four-electron reduction of dioxygen gives water:

$O_2 + 4\ e^- + 4\ H^+ \rightarrow 2\ H_2O$

# Dioxygen is also a hydroxylation agent

- phenylalanine $\rightarrow$ tyrosine
- tyrosine $\rightarrow\rightarrow$ adrenaline
- cholesterol $\rightarrow\rightarrow$ calcitriol
- cholesterol $\rightarrow\rightarrow$ bile acids
- hydroxylation of xenobiotics

$$R\text{-}H + O_2 + NADPH + H^+ \rightarrow R\text{-}OH + H_2O + NADP^+$$

# Reactive oxygen species (ROS) formed in the human body

- Superoxide anion-radical
- Hydroxyl radical
- Singlet oxygen
- Hydrogen peroxide

**Positive effects** - bactericidal (respiratory burst)

**Negative effects** – damage of biomolecules (membranes, enzymes, receptors, DNA)

# Superoxide anion-radical $\bullet O_2^-$

One-electrone reduction of dioxygen

$$O_2 + e^- \rightarrow \bullet O_2^-$$

[redox pair]

# Superoxide formation

- **Respiratory burst** (in neutrophils)

$$2\ O_2 + NADPH \longrightarrow 2\ {\bullet}O_2^- + NADP^+ + H^+$$

- **Spontaneous oxidation of hemoproteins**

$$\text{heme-}Fe^{2+} + O_2 \longrightarrow \text{heme-}Fe^{3+} + {\bullet}O_2^-$$

# Elimination of superoxide

- Superoxide dismutase
- Catalyzes the dismutation of superoxide

$$2 \bullet O_2^- + 2 H^+ \longrightarrow O_2 + H_2O_2$$

- Oxidation numbers of oxygen

$$-\tfrac{1}{2} \qquad \longrightarrow \qquad 0 \qquad -I$$

Dismutation is a special type of redox reaction in which an element is simultaneously reduced and oxidized so as to form two different products.

# Hydroxyl radical •OH

- The most reactive species, very harmful
- The reactions of •OH with various biomolecules produce secondary radicals

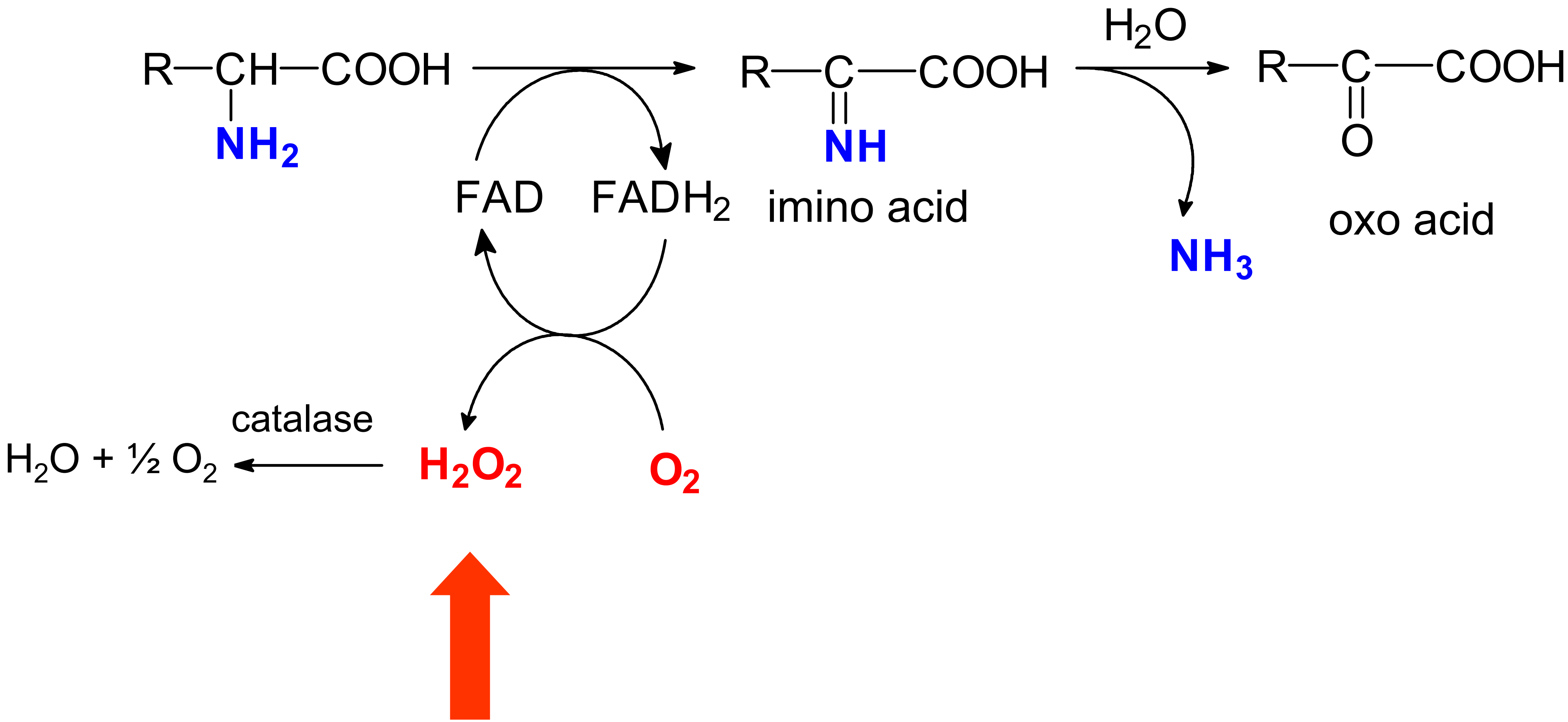
$$\bullet O_2^- + H_2O_2 \rightarrow O_2 + OH^- + \bullet OH$$

hydroxide hydroxyl

Catalyzed by reduced metal ions ($Fe^{2+}$, $Cu^{+}$)

(Fenton reaction)

# Hydrogen peroxide $H_2O_2$ is formed as a side product in the deamination of some amino acids



# Elimination of $H_2O_2$

- **Catalase**: $H_2O_2 \longrightarrow \frac{1}{2} O_2 + H_2O$
- **Glutathione peroxidase** (selenocysteine)

$$2\ G\text{-}SH + H\text{-}O\text{-}O\text{-}H \longrightarrow G\text{-}S\text{-}S\text{-}G + 2\ H_2O$$

# Compare: reduction of dioxygen

| **Type of reduction** | **Partial scheme (= redox pair)** |
|---|---|
| Four-electron | $O_2 + 4\,e^- + 4\,H^+ \rightarrow 2\,H_2O$ |
| One-electron | $O_2 + e^- \rightarrow \cdot O_2^-$ |
| Two-electron | $O_2 + 2\,e^- + 2\,H^+ \rightarrow H_2O_2$ |

!

# Antioxidant systems in the body

- **Enzymes**

  superoxide dismutase, catalase, glutathione peroxidase

- **Low molecular antioxidants**

  reducing substances with:

  phenolic / enolic -OH group, -SH group

  containing extended system of conjugated double bonds

# Lipophilic and hydrophilic antioxidants

| Antioxidant | Sources |
|---|---|
| Tocopherol | Plant oils, nuts, seeds, germs |
| Carotenoids | Fruits, vegetables (most effective is lycopene) |
| Ubiquinol | Formed in the body from tyrosine |
| L-ascorbate | Fruits, vegetables, potatoes |
| Flavonoids | Fruits, vegetables, tea, wine, cocoa |
| Dihydrolipoate | Made in the body from cysteine |
| Uric acid | Catabolite of purine bases |
| Glutathione | Made in the body from cysteine |

# Distribution of magnesium

| Human body | | Blood plasma (ECF) | |
|---|---|---|---|
| Bones | 60 % | Ionized | 60 % |
| Tissues (ICF) | 39 % | Associated with proteins | 33 % |
| ECF | 1 % | Chelated | 7 % |

# Biological role of magnesium

- typical intracellular cation
- associated with negative charges of proteins and nucleotides
- activator of many enzymes (kinases, ATPases)
- antagonist of calcium ions - $Mg^{2+}$ ions slow down neuromuscular transmission
- mineral component of bones

**Food sources**

most animal and plant foods, higher content in:

- green leafy vegetables (chlorophyl)
- wholemeal cereals, legumes, nuts, sesame seeds, halvah
- mineral waters (Magnesia)

# Distinguish: Two types of mineral waters

| **Feature** | **Magnesia** (CZ) | **Šaratica** (CZ) |
|---|---|---|
| Main cation | $Mg^{2+}$ | $Mg^{2+}$ |
| Main anion | $HCO_3^-$ | $SO_4^{2-}$ |
| Usage | source of Mg | osmotic laxative |

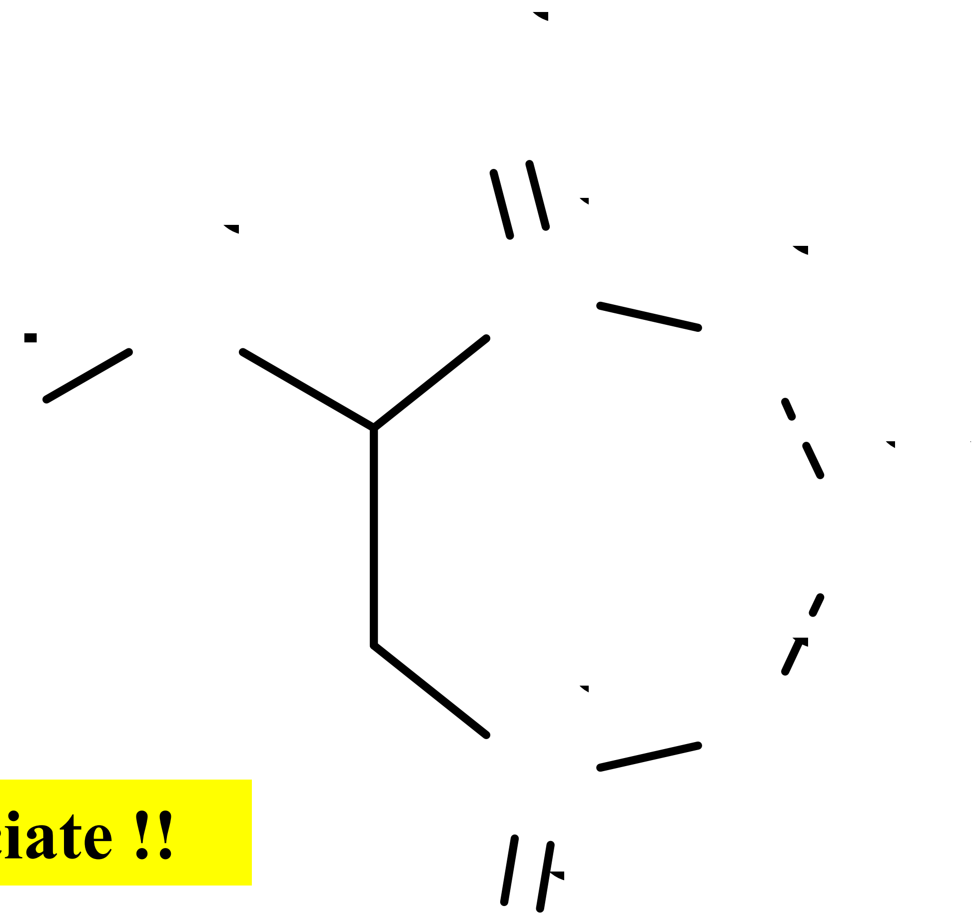
# Calcium in nature is abundant

- Minerals, sediments
- **$CaCO_3$ (limestone, marble, chalk, karst ....)**
- UK: White Cliffs of Dover (chalk)
- CZ: Moravian Karst (Macocha abyss)

# Distribution of calcium

| In body | | In blood plasma (ECF) | |
|---|---|---|---|
| Bones | 99 % | Ionized | 48 % |
| Tissues (ICF) | traces | Associated with proteins | 46 % |
| ECF | 1 % | Chelated | 6 % |

# Calcium malate is an example of chelate



**does not dissociate !!**

# $Ca^{2+}$ ions in body fluids

Extracellular fluid

- 2.4-2.7 mmol/l
- three forms
- blood clotting

Intracellular fluid

- cytosol ($10^{-7}$ mol/l)
- Mitochondria, ER - high deposits
- Regulation functions
- The second messenger
- Muscle contraction

# Calcium ion concentrations

| ECF | ICF |
|---|---|
| $10^{-3}$ M | $10^{-7}$ M |

**Difference by four orders !**

# Hormones regulating calcium level

| **Feature** | **Parathyrin** | **Calcitriol** | **Calcitonin** |
|---|---|---|---|
| Produced in | parathyroid glands | skin – liver – kidneys | thyroid gland |
| Chemical type | peptide | secosteroid | peptide |
| Main effect | release of Ca from bones | resorption of Ca from intestine | deposition of Ca into bones |

# Calcium phosphate $Ca_3(PO_4)_2$

- calcii phosphas
- Insoluble in water
- In body – apatites – binary phosphates (= two different anions)
- Bones - **hydroxylapatite** $Ca_5OH(PO_4)_3$
- Teeth - **fluoroapatite** $Ca_5F(PO_4)_3$

# Biological apatites are presented by different formulas

| **Name** | **Stoichiometric formula**<br>(the least ratio of elements) | **Crystal unit**<br>(multiple) |
|---|---|---|
| Hydroxylapatite | $Ca_5(PO_4)_3OH$ | $Ca_{10}(PO_4)_6(OH)_2$ |
| Fluoroapatite | $Ca_5(PO_4)_3F$ | $Ca_{10}(PO_4)_6F_2$ |
| Octacalcium phosphate | $Ca_4H(PO_4)_3$ | $Ca_8H_2(PO_4)_6$ |
| Tricalcium phosphate | $Ca_3(PO_4)_2$ | $Ca_9(PO_4)_6$ |

# Solubility of calcium phosphates

**(see also Medical chemistry – Practicals, p. 30-31)**

$Ca_3(PO_4)_2$ insoluble

$CaHPO_4$ insoluble

$Ca(H_2PO_4)_2$ **soluble**

# Solubility of calcium phosphates
## (see also Medical chemistry – Practicals, p. 30-31)

$$Ca_3(PO_4)_2 \underset{OH^-}{\overset{H^+}{\rightleftharpoons}} CaHPO_4 \underset{OH^-}{\overset{H^+}{\rightleftharpoons}} Ca(H_2PO_4)_2$$

| pH > 12 | pH 8-11 | pH 4-6 |
|---|---|---|
| | (kidney stones) | (urine) |

# Calcium sulfate $CaSO_4$

- calcii sulfas
- Insoluble **Caution!** $MgSO_4$ is soluble (laxative mineral waters)
- hemihydrate (½ $H_2O$) **plaster**

$$CaSO_4 \,.\, \frac{1}{2} H_2O \xrightarrow{\text{a} \quad \text{e}} CaSO_4 \,.\, 2\, H_2O$$

# Calcium carbonate $CaCO_3$ (calcii carbonas)

External aplication

- insolube
- **powders**
- **tooth paste**

Peroral aplication

- basic properties
- neutralizes gastric HCl

  **antacid**

  Tums (GB), Rennie (F)
- **Ca supplementation**

$$CaCO_3 + 2\ R\text{-}COOH \rightarrow \mathbf{CO_2}\uparrow + (R\text{-}COO)_2Ca + H_2O$$

# Calcium hydrogen carbonate $Ca(HCO_3)_2$

- calcii hydrogenocarbonas
- **Exists only in aqueous solution**
- Hardness of water
- By boiling $CO_2$ is removed to make hard scale

$$Ca(HCO_3)_2 \rightarrow CO_2\uparrow + CaCO_3\downarrow + H_2O$$

- Very common in mineral waters

# Hard water makes problems

Hard scale formation

$Ca(HCO_3)_2 \rightarrow CO_2\uparrow + \mathbf{CaCO_3}\downarrow + H_2O$

Soap does not work:

$Ca^{2+}(aq) + 2\ R\text{-}COONa \rightarrow \mathbf{(R\text{-}COO)_2Ca}\downarrow + 2\ Na^{+}(aq)$

R-COOH is a long-chain fatty acid (palmitic, stearic)

# Calcium in food

| Recommended intake: | |
|---|---|
| Infants | 1200 mg |
| Adults | 1000 mg |
| Older people | 1500 mg |

## Animal food

- milk
- dairy products
- **bioavailability ~ 50 %**

## Plant food

- poppy seed
- nuts, almonds
- dates, legumes
- **bioavailability ~ 10 %**

# Calcium content in some dairy products (mg/100 g)

| | |
|---|---|
| • Dried milk | 1300 |
| • Parmesan (I) | 1200 |
| • Emmental (CH) | 1000 |
| • Bryndza (SK) | 600 |
| • Processed cheese | 400 - 500 |
| • Yoghurts | 100 - 160 |
| • Milk | 110 - 130 |
| • Cottage cheese | 100 - 140 |
| • Butter | 20 |

# Intestinal absorption of calcium

**Increased by**

- vitamin D
- proteins
- milk fermented products (kefir)

**Decreased by**

- phosphates (*Coca-Cola*, processed cheese)
- oxalates
- fibre excess

# Sodium + Potassium

## Distribution in the body

| Sodium | | Potassium | |
|---|---|---|---|
| ECF | 50 % | ECF | 2 % |
| ICF | 10 % | ICF | 98 % |
| Bones | 40 % | | |

# Mean concentrations of ions in blood plasma

| Cation | mmol/l | |
|---|---|---|
| | Cation | Charge |
| $Na^{+}$ | 142 | 142 |
| $K^{+}$ | 4 | 4 |
| $Ca^{2+}$ | 2.5 | 5 |
| $Mg^{2+}$ | 1.5 | 3 |
| | | Total: 154 |

| Anion | mmol/l | |
|---|---|---|
| | Anion | Charge |
| $Cl^{-}$ | 103 | 103 |
| $HCO_3^{-}$ | 25 | 25 |
| $Protein^{-}$ | 2 | 18 |
| $HPO_4^{2-}$ | 1 | 2 |
| $SO_4^{2-}$ | 0.5 | 1 |
| Org. A. | 4 | 5 |

Total: 154

# Biological roles of sodium and potassium

- $Na^+$ is main cation of ECF, contributes to plasma osmolality
- **$Na^+$ is the most hydrated ion** ⇒ sodium movement (retention, excretion) is followed by movement of water
- $K^+$ is main cation of ICF, associated with polyanions of proteins
- the uneven distribution of ions is maintained by $Na^+$,$K^+$-ATPase

| Ion | Ion diameter (nm) | |
|---|---|---|
| | Free | Hydrated |
| $Na^+$ | 0,19 | 0,52 |
| $K^+$ | 0,27 | 0,46 |

**Food sources**

**Sodium** – table salt, salty food, mineral waters

**Potassium** – most foods, higher content in plant foods: potatoes, legumes, fresh and dried fruits, nuts

# Hormones regulating sodium

| Feature | Aldosterone | Atrial natriuretic peptide (ANP) |
|---|---|---|
| Produced in | adrenal cortex | heart atrium |
| Chemical type | steroid | peptide |
| Main effects | resorption of $Na^+$ excretion of $K^+$ in kidneys | excretion of $Na^+$ and water in kidneys |

# **Elemental carbon occurs in various modifications**

- diamond, graphite, soot, coke, charcoal, fullerens
- graphene – Nobel Prize in Physics 2010
- **adsorption coal** (carbo adsorbens, carbo activatus) is non-polar intestinal adsorbent

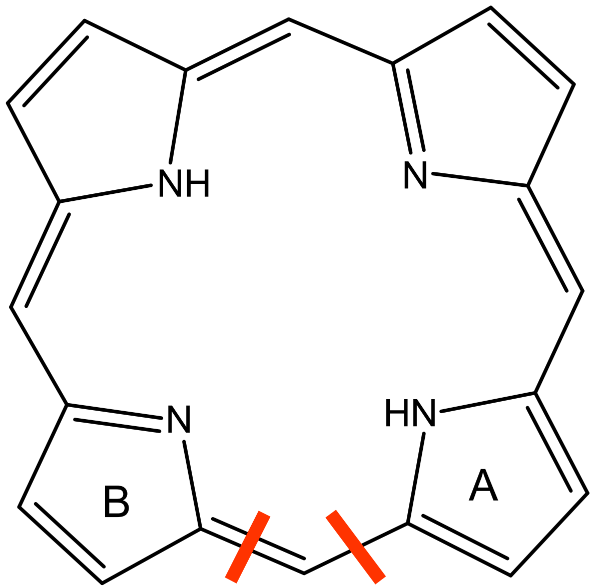
# Carbon monoxide CO

$^{-}\ \equiv O^{+}$

- Colourless, odourless gas, molecule makes a dipole
- **Exogenous sources**: incomplete combustion of carbon and organic compounds (cigarette smoke)
- **Toxicity**: strong affinity to $Fe^{2+}$ in hemoglobin to give **Carbonylhemoglobin (CO-Hb)** – does not transport $O_2$
- **Endogenous source**: heme catabolismus

heme $\rightarrow$ $Fe^{2+}$ + CO + biliverdin ($\rightarrow$ bilirubin)

# Hem degradation provides CO and bilirubin




$O_2$ + NADPH+$H^+$ at e s l tt

**CO + biliverdin + 3 $H_2O$**

**bilirubin**

# Carbonylhemoglobin (CO-Hb) in blood

| Subject / Situation | CO-Hb (%)* | |
|---|---|---|
| Newborns | 0.4 | Endogenous CO |
| Adults (rural areas) | 1-2 | Endogenous CO |
| Adults (big cities) | 4-5 | Exogenous CO |
| Smokers | 10-12 | Exogenous CO |
| Traffic policemen | 12-15 | Exogenous CO |
| Poisoning | 20-50 | Exogenous CO |
| Death | 55-60 | Exogenous CO |

* Percentage of total hemoglobin

# Carbon dioxide $CO_2$

O O

- carbonei dioxidum
- colourless gas, easily gets liquified
- linear molecule ⇒ zero dipol moment ⇒

  non-polar compound ⇒ poorly soluble in water
- **acidic oxide** = acid anhydride ($H_2O + CO_2 \rightarrow H_2CO_3$)

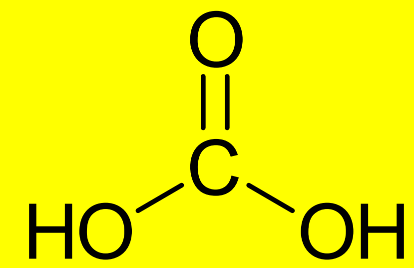
# Endogenous production of $CO_2$

- $CO_2$ is produced in **decarboxylation** metabolic reactions
- **oxidative decarboxylation of pyruvate** → acetyl-CoA
- **two decarboxylations in CAC** (isocitrate, 2-oxoglutarate)
- Other sources:

decarboxylation of amino acids → biogenous amines

non-enzymatic decarboxylation of acetoacetate → acetone

# Carbonic acid *in vitro*




$$H_2O + CO_2 \leftrightarrows H_2CO_3 \leftrightarrows HCO_3^- + H^+$$

$$800 \quad : \quad 1 \quad : \quad 0.03$$

- weak diprotic acid (p$K_{A1}$ = 6.37; p$K_{A2}$ = 10.33)
- does exist only in aq. solution, easily decomposes to $CO_2$ and water
- $CO_2$ predominates 800 × in sol. ⇒ therefore $CO_2$ included into $K_A$

$$K_{A\,eff} = \frac{[H^+][HCO_3^-]}{[CO_2 + H_2CO_3]}$$

$K_{A\,eff}$ = effective dissociation constant

# Carbonic acid in blood plasma

$$H_2O + CO_2 \leftrightarrows H_2CO_3 \leftrightarrows HCO_3^- + H^+$$

1 : traces : 20

- formation catalyzed by carbonic anhydrase
- under physiological conditions: $pK_{A1} = 6.10$
- $CO_2$ is continually eliminated from body by lungs
- the overall concentration of carbonic acid:

$$\mathbf{[CO_2 + H_2CO_3] = pCO_2 \times \mathit{s} = 0.23\ pCO_2\ (kPa)}$$

directly measurable quantity

# Compare: $CO_2$ in water and blood

| Liquid | pH | $[CO_2] : [HCO_3^-]$ |
|---|---|---|
| Carbonated water[a] | 3.50 – 5.00 | 800 : 0.03 |
| Blood[b] | 7.36 – 7.44 | 1 : 20 |

[a] **Closed system** (PET bottle), 25 °C, $pK_{A1} = 6.37$
pH ~ $pCO_2$ ~ the pressure of $CO_2$ applied in carbonating process

[b] **Open system**, 37 °C, $pK_{A1} = 6.10$
$CO_2$ continually eliminated, $pCO_2$ in lung alveoli ~ 5.3 kPa,
acid component of hydrogen carbonate buffer

Nitrogen

# Metabolic pathway of nitrogen

| | |
|---|---|
| **Intake** | Food proteins (meat, eggs, dairy products) |
| **Metabolism** | digestion (stomach, intestine): protein → AA<br>anabolic reactions: AA → tissue proteins / other products<br>catabolism (transamination + deamination):<br>AA → $NH_3$ → urea |
| **Urine excretion** | urea (300 - 600 mmol/day)<br>$NH_4^+$ (30 - 50 mmol/day) |

**see lectures:**
**Biochemical reactions**
**Amino acids**

# Compare

| Feature | Nitrates | Nitrites |
|---|---|---|
| Formula | $NO_3^-$ | $NO_2^-$ |
| Food sources | water, vegetables | sausages |
| Limits for drinking water | 50 mg/l | 0.5 mg/l |
| Endogenous source | arginine $\rightarrow$ NO $\rightarrow$ $NO_3^-$ | - |
| Acute toxicity | no | yes |
| Toxic mechanism | - | Hb-Fe(II) $\rightarrow$ Hb-Fe (III)<br>$R^1R^2NH \rightarrow R^1R^2N\text{-}N\text{=}O$ |

# Biochemical features of phosphorus

| | |
|---|---|
| **Intake** | Most foods, phospholipids (meat, eggs),<br>phytates (cereals), phosphoproteins (milk - casein) |
| **Distribution in body** | **ICF:** mostly phosphoesters (metab. of glucose), macroergic compounds<br>**Nucleus:** DNA<br>**Cell membranes:** phospholipid bilayer<br>**ECF:** hydrogen phosphate buffer, phospholipid monolayer of lipoproteins<br>**Bones, teeth:** biological apatites |
| **Urine excretion** | $H_2PO_4^-$ (30 - 50 mmol/day) |

# Compare

!

| **Liquid** | **pH** | **Prevailing species** |
|---|---|---|
| Blood | 7.4 | $HPO_4^{2-}$ |
| Urine | 5.5 | $H_2PO_4^-$ |
| *Coca-Cola* | 2.5 | $H_3PO_4$ |

Sulfur

# Metabolic pathway of sulfur

**see also lecture Amino acids**

| | |
|---|---|
| **Intake** | food proteins (AA cysteine and methionine) |
| **Metabolism** | **Anabolic:**<br>Cys, Met → tissue proteins<br>methionine → SAM → methylation reactions<br>cysteine → taurine → conjugation reactions<br>cysteine → glutathione (GSH) → antioxidant, conjugation reactions<br>cysteine → $SO_4^{2-}$ → PAPS → sulfation reactions<br>**Catabolic:**<br>Cys, Met → $HSO_3^-$ → $SO_4^{2-}$ (excretion)<br>bacterial decomposition (large intestine) → thiols (R-SH) + sulfane ($H_2S$) |
| **Urine excretion** | $SO_4^{2-}$ (8 - 35 mmol/day) |

# Distinguish

| | |
|---|---|
| **Sulfite** | anion $SO_3^{2-}$ (alkyl sulfite R-O-$SO_2$H ester) |
| **Sulfide** inorganic | anion $S^{2-}$, ZnS zinc sulfide |
| **Sulfide** organic | R-S-R dialkylsulfide<br>R-S-S-R dialkyldisulfide |
| **Sulfate** | anion $SO_4^{2-}$ (alkyl sulfate R-O-$SO_3$H ester) |

# Iron in human body

- Essential microelement
- In body: about 4-5 g Fe
- Most in blood hemoglobin (60-85 %)

  myoglobin (10 %; muscles), and ferritin (10 %; liver)
- **Iron in body is always associated with proteins (heme and non-heme)**

Free $Fe^{2+}$ ions are toxic

# Hemoproteins

| Protein | Redox state | Function |
|---|---|---|
| Hemoglobin | $Fe^{2+}$ | transport of $O_2$ in blood |
| Myoglobin | $Fe^{2+}$ | $O_2$ deposit in muscles |
| Catalase | $Fe^{3+}$ | $H_2O_2$ decomposition |
| Peroxidase | $Fe^{3+}$ | peroxide decomposition |
| Cytochromes | $Fe^{2+} \leftrightarrows Fe^{3+}$ | components of resp. chain |

# Other iron-proteins

| Protein | Redox state | Function |
|---|---|---|
| Transferrin | $Fe^{3+}$ | transport of Fe in plasma |
| Ferritin | $Fe^{3+}$ | cell storage of Fe |
| Hemosiderin | $Fe^{3+}$ | cell storage of Fe |
| Fe-S proteins | $Fe^{2+} \leftrightarrows Fe^{3+}$ | components of resp. chain |

# Food sources of iron

**Animal**

- pork blood
- blood sausage
- liver, liver pate
- red meat
- bioavailability ~ 20 %

**Plant**

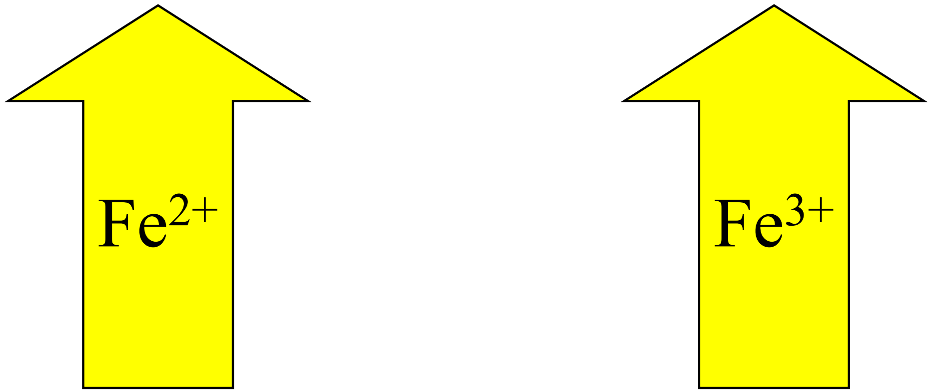
- broccoli
- green leafy vegetables
- bioavailability ~ 10 %

# Intestinal resorption of iron

- **Only as $Fe^{2+}$**
- Needed ascorbic acid (vitamin C), $Fe^{3+}$ is reduced to $Fe^{2+}$
- Daily intake 10-30 mg
- Daily need 1 mg (males), 2 mg (females)
- **Resorption hindered by:** tanins, polyphenols (tea), phytates, oxalic acid (spinach), excess of dietary fibre (vegetarians)

# The Latin names of iron salts

ferrosi × ferri



# Distinguish

| | |
|---|---|
| ferrosi sulfas<br>$FeSO_4$ | ferri sulfas<br>$Fe_2(SO_4)_3$ |
| ferrosi sulfis<br>$FeSO_3$ | ferri sulfis<br>$Fe_2(SO_3)_3$ |

# Iron salts for peroral supplementation

- Iron(II) sulfate (ferrosi sulfas)
- Iron(II) fumarate (ferrosi fumaras)
- Iron(II) gluconate (ferrosi gluconas)

# Halogens in nature

| | |
|---|---|
| **Fluorine** | minerals: fluorite $CaF_2$, fluoroapatite $Ca_5(PO_4)_3F$ |
| **Chlorine** | NaCl (rock salt), seawater (~ 3 %),<br>salt lakes (up to 25 %): Dead Sea, Great Salt Lake |
| **Bromine** | seawater |
| **Iodine** | seawater, seaweed |

# Halogens in human body

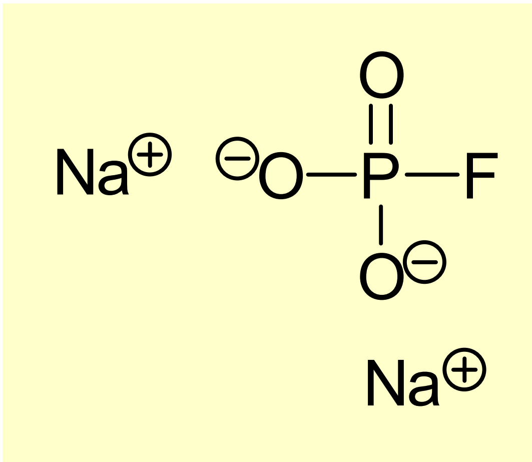
| | |
|---|---|
| **Fluorine** | bones, teeth (fluoroapatite) |
| **Chlorine** | $Cl^-$ is the main anion of blood plasma<br>HCl in stomach ($H^+$ from $H_2CO_3$, $Cl^-$ from plasma) |
| **Bromine** | traces in tissues and body fluids |
| **Iodine** | thyroid gland (thyroxine) |

# Halogens in food

| | |
|---|---|
| **Fluorine** | tap water, mineral waters, sea food,<br>black tea (*Camellia sinensis*) |
| **Chlorine** | table salt NaCl |
| **Bromine** | sea food |
| **Iodine** | sea food, iodinated salt,<br>Czech mineral water Vincentka |

# Fluorine compounds

- **Sodium fluoride** NaF (natrii fluoridum)
  in tablets – caries prevention in infants,
  tooth paste, oral rinse, dental floss
- **Sodium monofluorophosphate** $Na_2PO_3F$
  (dinatrii fluorophosphas)
  tooth paste etc.



|  | **Osmolarity** | **Osmolality** |
| --- | --- | --- |
| Definition | i $c$ | i $c_m$ |
| Unit | mmol/l | mmol/kg $H_2O$ |
| Temperature dependent | yes | no |

# NaCl in medicine

Saline solution NaCl (natrii chloridi solutio) is isotonic with blood plasma: **154 mmol/l** (0.9 %)

**Osmolarity** **i $c$ = 2 × 154 = 308 mmol/l**

Usage: infusions

**Osmolality of blood plasma:**

280-295 mmol/kg $H_2O$ ≈ 2 [$Na^+$] + [glucose] + [urea]

# Compare concentrations (mmol/l)

| Blood plasma | |
| --- | --- |
| $Na^+$ | $Cl^-$ |
| 133-150 | 97-108 |

~ 100

| Saline sol. NaCl | |
| --- | --- |
| $Na^+$ | $Cl^-$ |
| 154 | 154 |

Saline solution of NaCl has increased concentration of chloride ions compared to plasma!!

# Chloride balance

- Usual daily intake: 5-12 g NaCl
- **Chloride loss**: vomiting ⇒ increased $HCO_3^-$ in plasma ⇒ alkalosis
- **Chloride excess:** infusions of saline sol. ⇒ decreased $HCO_3^-$ in plasma ⇒ acidosis

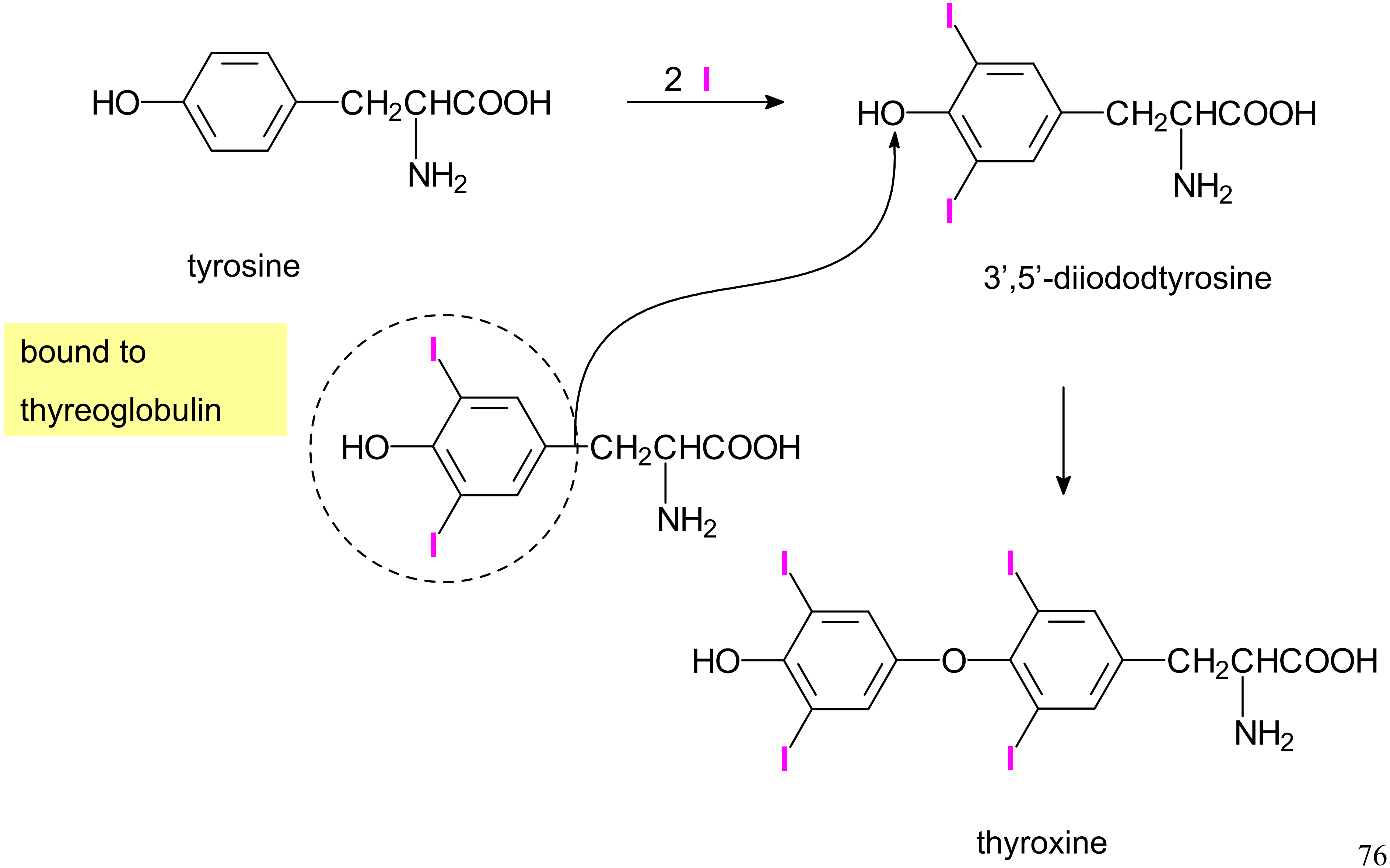
# HCl in stomach

- acidum hydrochloricum, strong acid
- $H^+$ comes from $H_2CO_3$ (parietal cells), $Cl^-$ from plasma
- Concentration ~ 0.1 mol/l, **pH 1-2**
- Bactericidal effect
- Protein denaturation – for better digestion
- Pepsin activation (pepsinogen → pepsin)

# Iodine in human body

- Essential microelement
- Daily need: 150-300 μg
- the best food source: sea products
- For the production of iodinated thyronines - amino acids thyroxine and triiodothyronine

# Conversion of tyrosine to thyroxine



# The iodination of table salt

- 35 mg I / kg salt
- **Sodium/potassium iodide** (NaI, KI) - not very stable due to possible oxidation and sublimation:

  $2\ NaI + \frac{1}{2}\ O_2 + CO_2 \rightarrow Na_2CO_3 + I_2\uparrow$
- **Sodium iodate** $NaIO_3$ – stable substance

# Elementary iodine is a strong disinfectant

But has some disadvantages:

- Possible allergen
- Be very carefull in thyroid gland diseases!!
- Only short-term application!!

# Solutions of elemental iodine

Elemental iodine is non-polar, insoluble in water.

| English name | Latin name | Composition |
|---|---|---|
| Tincture of iodine | tinctura iodi | $I_2$ + ethanol |
| Lugol's solution | solutio iodi aquosa | $I_2$ + KI + $H_2O$ |
| Povidone-iodine[a] | sol. povidoni iodinati | $I_2$ + povidone[b] + $H_2O$ |

[a] Commercial names: Jodisol, Betadine, Jox

[b] Synthetic polymer **po**ly**vi**nylpyrroli**done**