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Misconceptions that instructors inadvertently create through their teaching


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LJUBLJANA
SLOWENIEN
TRIEST
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PÉCS
SZEGED
Subotica
KROATIEN
NOVI SAD
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Alpen
Pyrenäen

Hans-Dieter Barke · Günther Harsch · Siegbert Schmid

Essentials of Chemical Education

For everybody teaching chemistry or becoming a chemistry teacher, the authors provide a practice-oriented overview with numerous examples from current chemical education, including experiments, models and exercises as well as relevant results from research on learning and teaching. With their proven concept, the authors cover classical topics of chemical education as well as modern topics such as every-day-life chemistry, student's misconceptions, the use of media or the challenges of motivation. This is the completely revised and updated English edition of a highly successful German title.

Chemistry

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Barke · Harsch · Schmid

Essentials of Chemical Education

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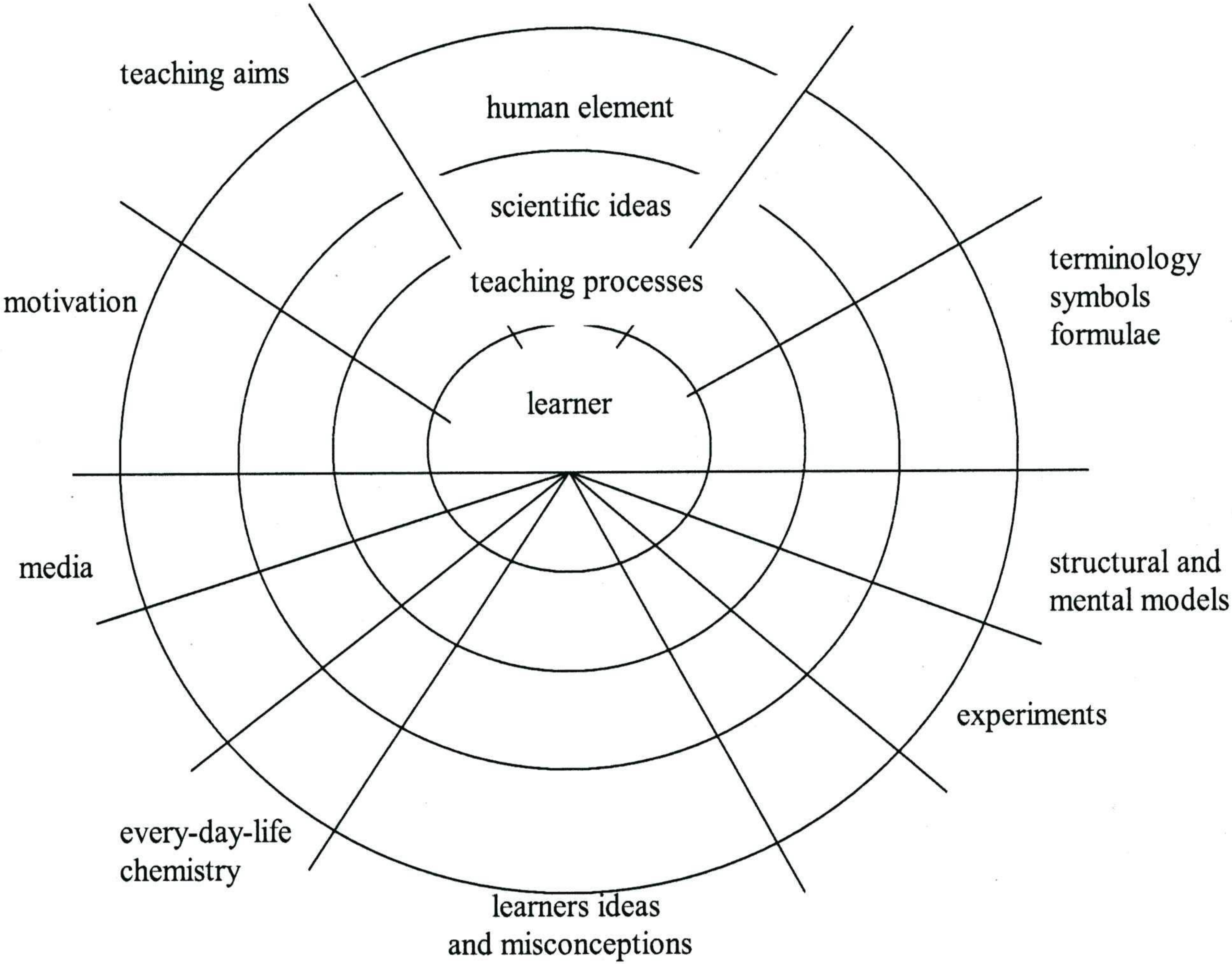
Günther Harsch
Siegbert Schmid

Essentials of Chemical Education

Springer


teaching aims
human element
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terminology
symbols
formulae
learner
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structural and
mental models
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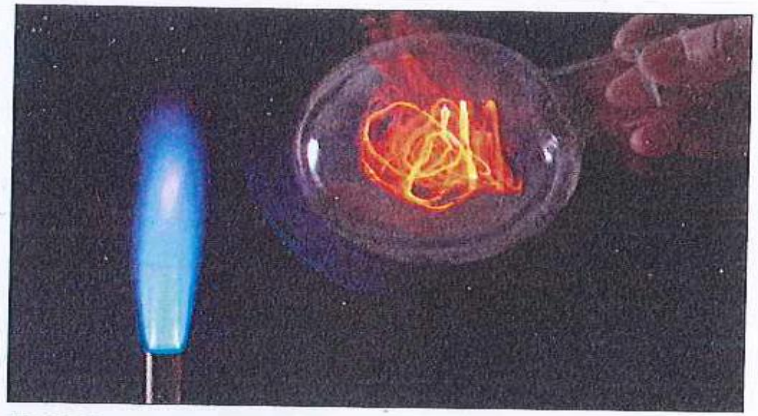
every-day-life
chemistry
learners ideas
and misconceptions

Barke's 3-level concept (1986):
phenomena – structural models – chemical symbols

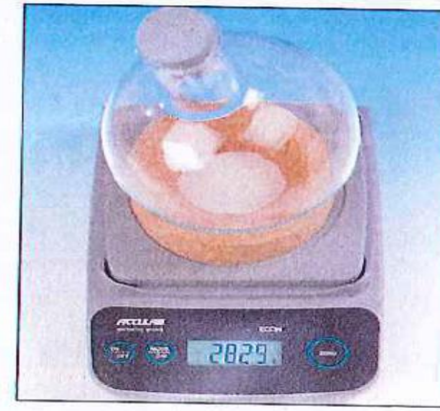
Phenomena	Substances and their properties	Chemical reactions
Structural Imaginations	Structural models of substances Connections to properties	Structural models of substances before and after the reaction
Chemical Symbols	Formulas, structural symbols	Chemical equations

Figure 2. Structural imaginations: mediator between phenomena and chemical symbols [2]

Masse vor der Reaktion

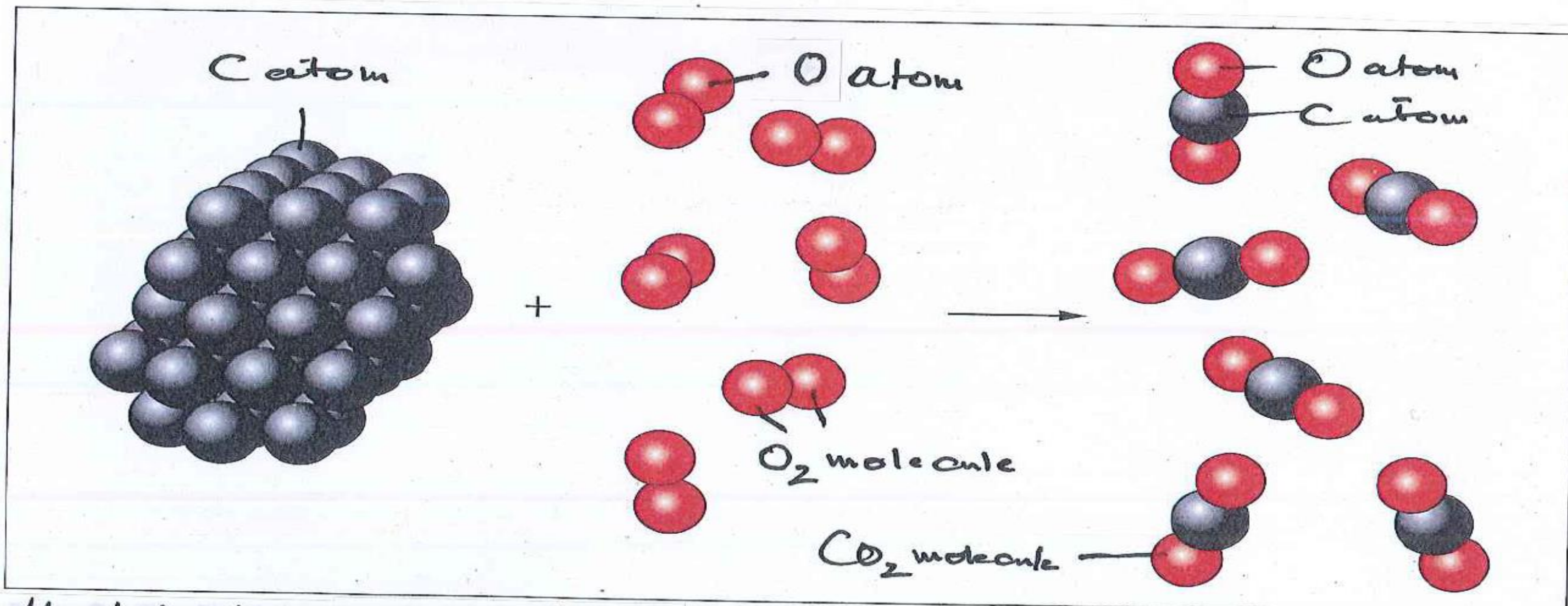


Kohlekörner verbrennen vollständig



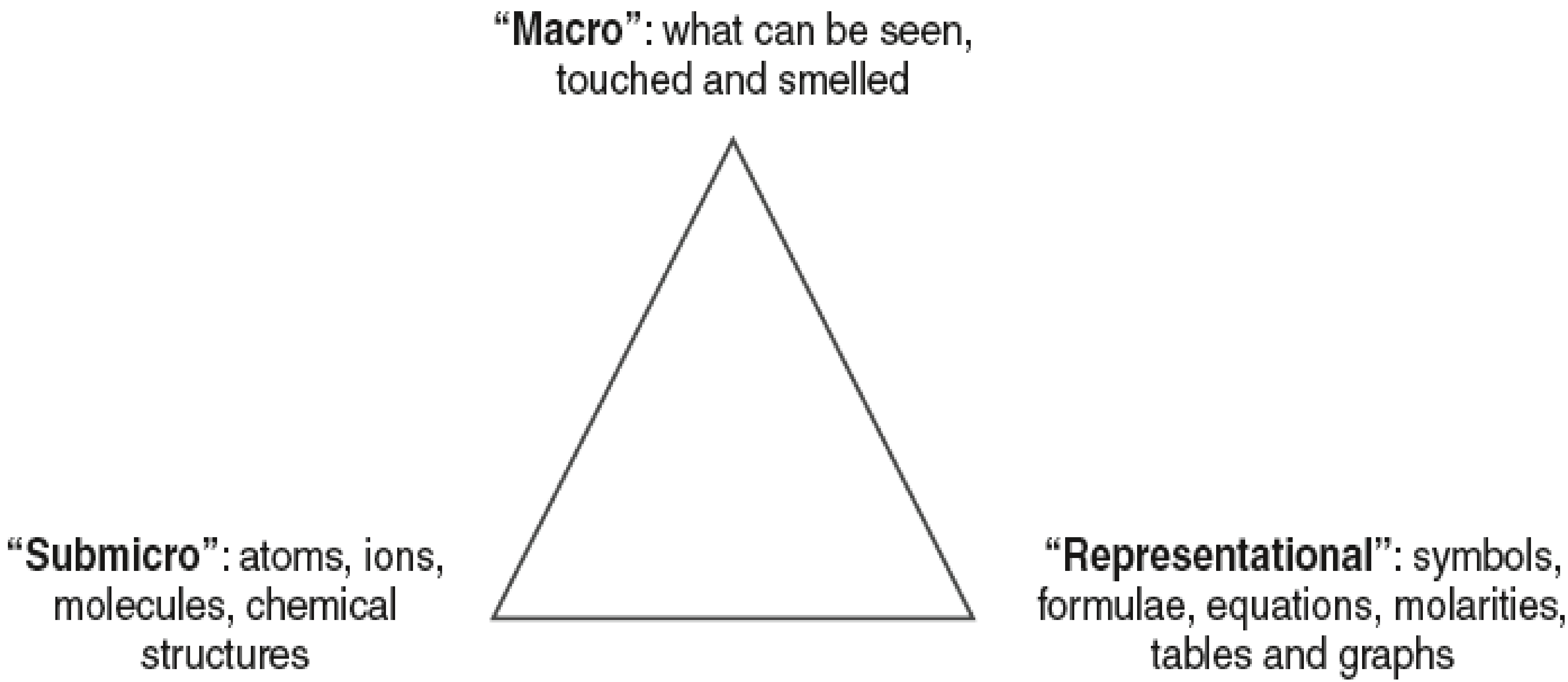
Masse nach der Reaktion

reaction of carbon and oxyen

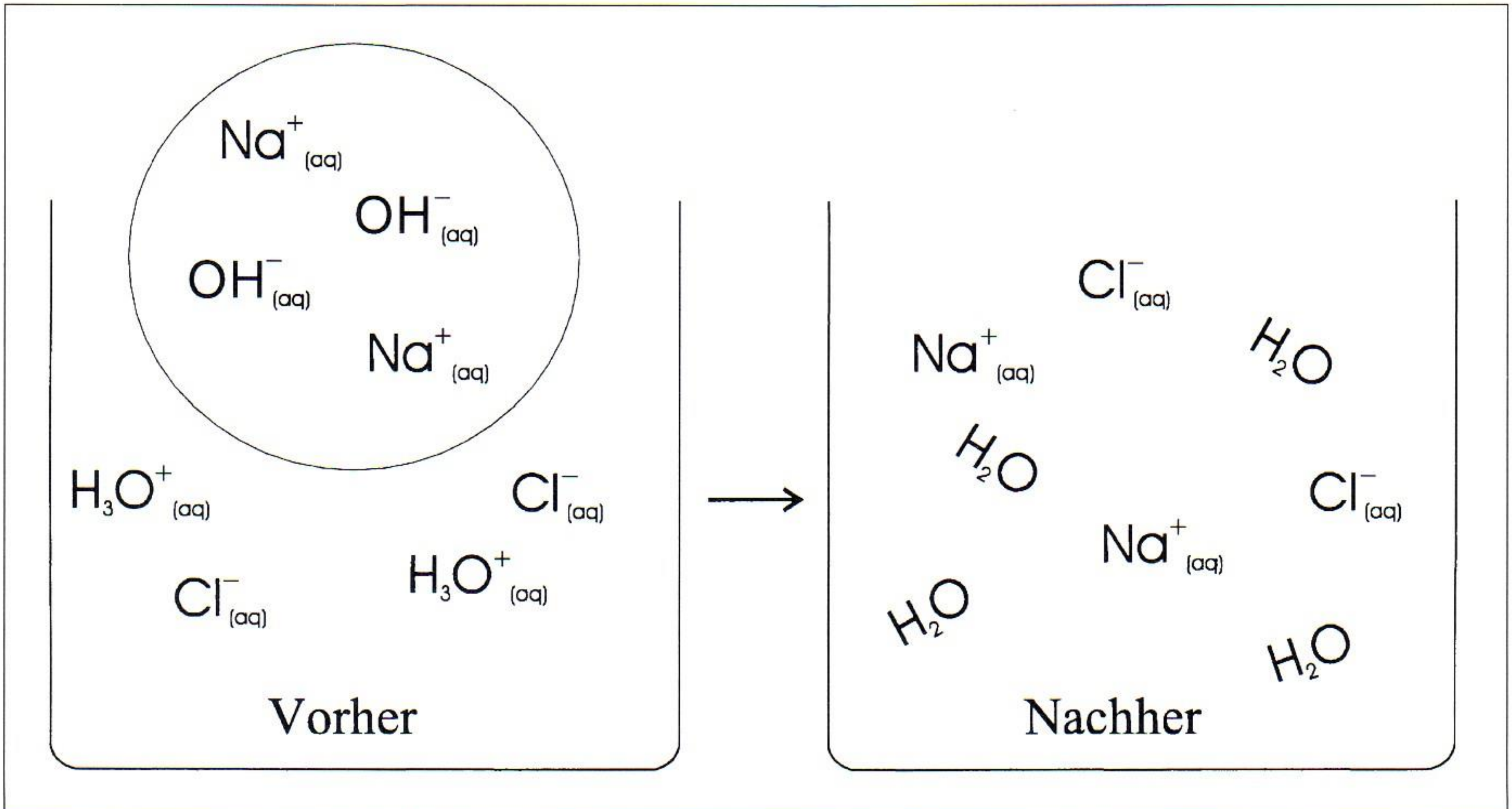


Model of regrouping C- and O atoms by the reaction

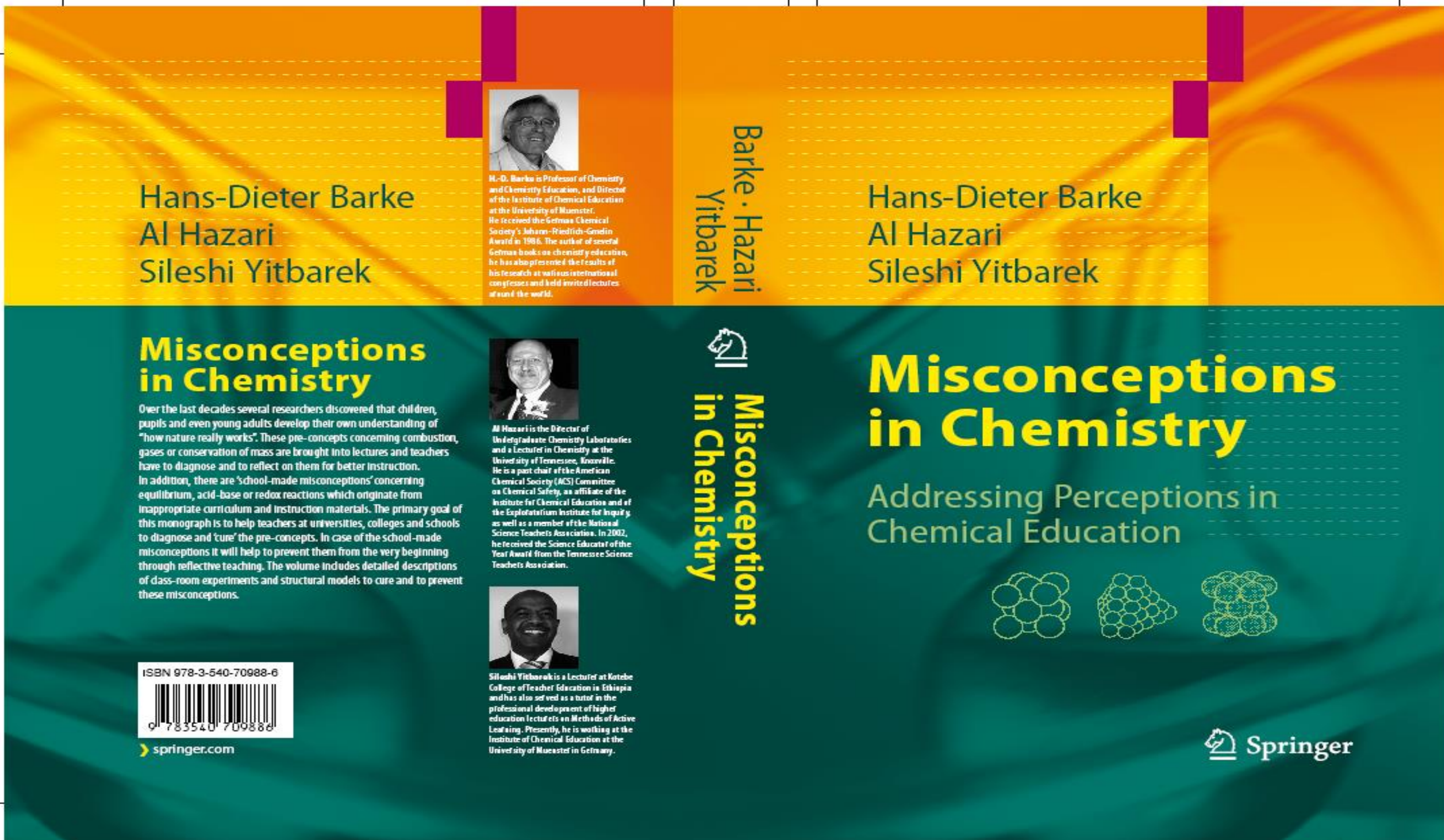
Johnstone´s triangular concept (2000)



Example for Submicro level: „beaker model" of particle arrangements for neutralization



Barke, H.-D. et al: Misconceptions in Chemistry. Berlin, Heidelberg 2009 (Springer)



Preconcepts and school-made misconceptions

- **Preconcepts:** brought by children through careful observation in their every-day life:
  - combustion („something is going away"),
  - transmutation of substances („copper changes from red to green, iron from grey to black"), -
  gases are substances? („they have no mass"), etc.

- **School-made misconceptions:** developed by inappropriate teaching on the representational level:
  - chemical equilibrium („reactants and products show same concentration, same amount of substance"),
  - weak acids („they have a pH of 3 or above"),
  - redox reactions („oxygen is always involved"), etc.

Preconcept and School-made miconception:
Formulas – but no scientific mental model (Barke, 1980)

Questionaire

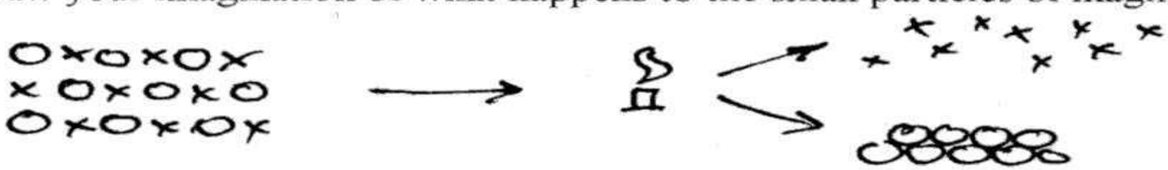
1. Write the chemical equation for the combustion of magnesium:

$2\,Mg + O_2 \longrightarrow 2\,MgO$

2. Describe what happens to the small particles of magnesium during the combustion:

magnesium contains two kinds of particles: one evaporates by combustion, the other one remains as magnesium oxide.

3. Draw your imagination of what happens to the small particles of magnesium:



Ox = magnesium   O = magnesium oxide   x = gas

Figure 1. Questionnaire about the combustion of magnesium (teacher questions in block letters, student responses hand-written)

School-made misconceptions (Sopandi 2003): molecules and ions in „Bonaqua“ mineral water

3. <u>Mineralwasser</u>

Auf dem Etikett eines Mineralwassers (siehe unten) liest man „mit Kohlensäure“ und die Namen mehrerer Salze: Im Mineralwasser sind Salze und Kohlenstoffdioxid gelöst.

O.. stimmt **O.. stimmt nicht** **O.. Ich weiß es nicht**

Mögliche Gründe für Deine Antwort :

O.. Mineralwasser enthält CO_2-Moleküle

O.. Mineralwasser enthält kleine Salzkristalle

O.. Mineralwasser enthält Moleküle mehrerer Salze

O.. Mineralwasser enthält Ionen mehrerer Salze

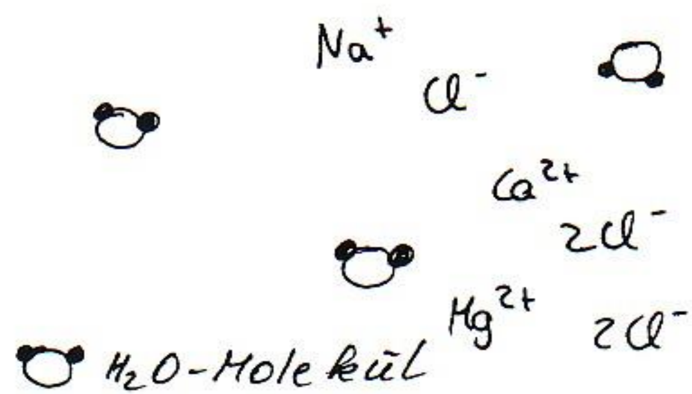
O.. deine eigene Begründung: ……………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Zeichne Deine Vorstellung von ***allen Teilchen*** *auf, die mit H_2O-Molekülen gemischt vorliegen. Lies dazu das Etikett genau.*

Etikett eines Mineralwassers



Teilchenvorstellung des Mineralwassers

School-made misconceptions (Sopandi 2003): molecules and ions in mineral water

Gründe für deine Antwort :

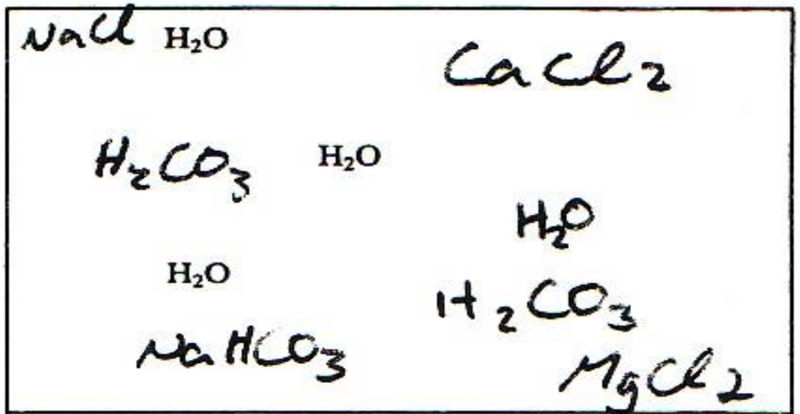
O.. Mineralwasser enthält Kohlendioxid-Moleküle

O.. Mineralwasser enthält kleine Salzkristalle

O.. Mineralwasser enthält Moleküle mehrerer Salze

O.. Mineralwasser enthält Ionen mehrerer Salze

O.. deine eigene Begründung: ...Enthält...
gelöstes Kohlendioxid
und Ionen der Salze........



Teilchenvorstellung des Mineralwassers

Mögliche Gründe für Deine Antwort :

~~O~~.. Mineralwasser enthält CO_2-Moleküle

O.. Mineralwasser enthält kleine Salzkristalle

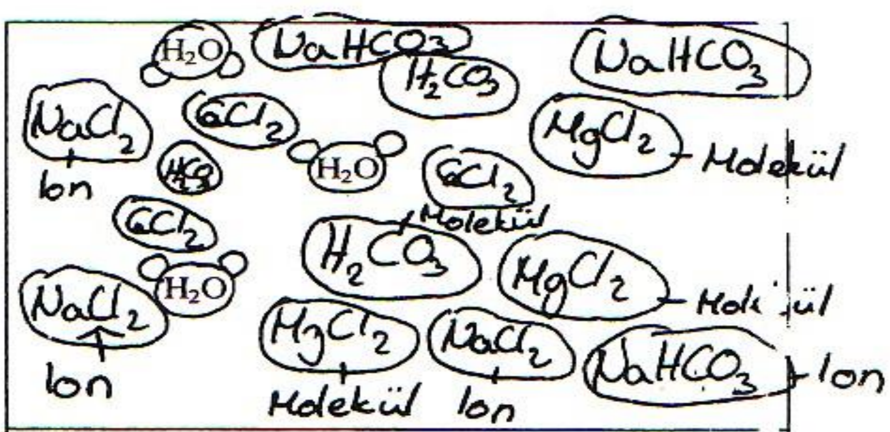
O.. Mineralwasser enthält Moleküle mehrerer Salze

~~O~~.. Mineralwasser enthält Ionen mehrerer Salze

O.. deine eigene Begründung: ....

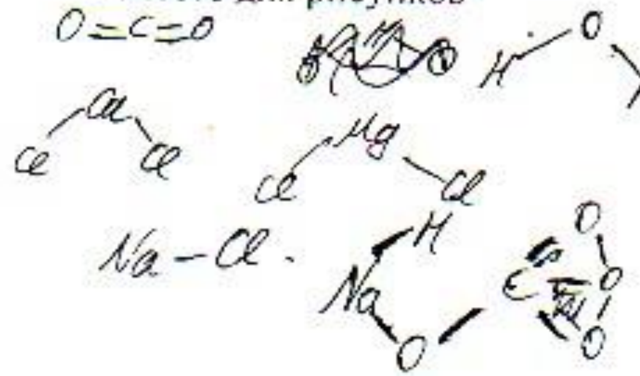
....

....



Teilchenvorstellung des Mineralwassers

Место для рисунков



Место для рисунков

$H_2O + CO_2$ H_2CO_3

$CaCl_2$ $MgCl_2$

$NaCl$ $NaHCO_3$

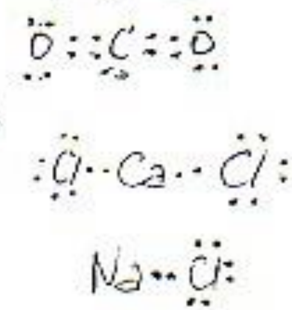
Место для рисунков

CO_2

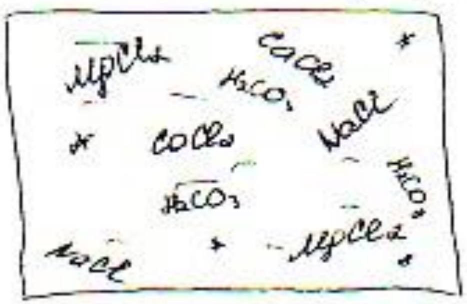
$NaHCO_3$

$CaCl_2$

$NaCl$



Место для рисунков



Место для рисунков

H_2O, CO_2 (H_2CO_3);

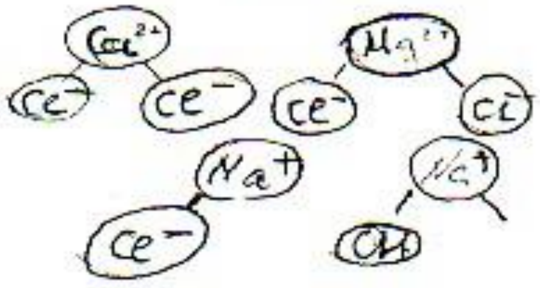
$CaCl_2$; $Na(HCO_3)$

$MgCl_2$.

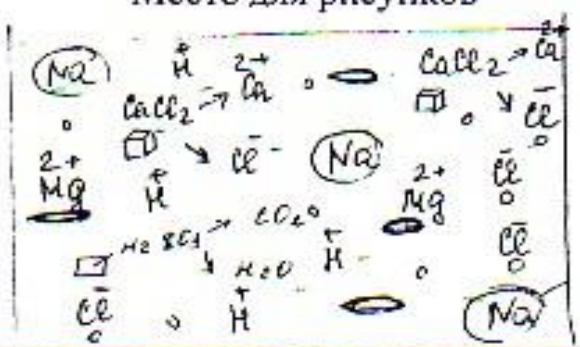
$NaCl$;

Место для рисунков

Место для рисунков



Место для рисунков



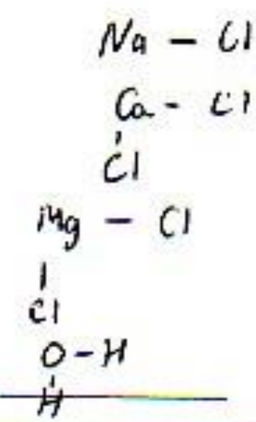
Место для рисунков

$Na^+ + Cl^-$

$Ca^{2+} + 2Cl^-$

$Mg^{2+} + 2Cl^-$

H_2O, CO_2



School-made misconceptions:
Mental models of salt crystals and salt solutions

Kristallisation von Kochsalz aus der Lösung 2

4. Eine Natriumchloridlösung enthält Na^+-Ionen und Cl^--Ionen. Verdampft das Wasser, so bilden sich weiße Natriumchloridkristalle.
a) Zeichnen Sie Ihre Teilchenvorstellung auf, **b) kreuzen Sie an.**

a)

vor d. Verdampfen	--->	während	--->	nach d. Verdampfen
Na^+ Cl^- Na^+ Na^+ Cl^- Na^+ Cl^- Na^+ Cl^- Cl^-		Na^+ NaCl NaCl Na^+ Cl^- Cl^-		NaCl NaCl NaCl

b) Die Lösung ist "neutral": ☒ ja, ☐ nein **Begründen Sie:** Na^+ und Cl^-
Der Kristall ist "neutral": ☒ ja, ☐ nein gleichen sich aus

School-made misconceptions:
Mental model of ionic bonding (Taber, 2002)

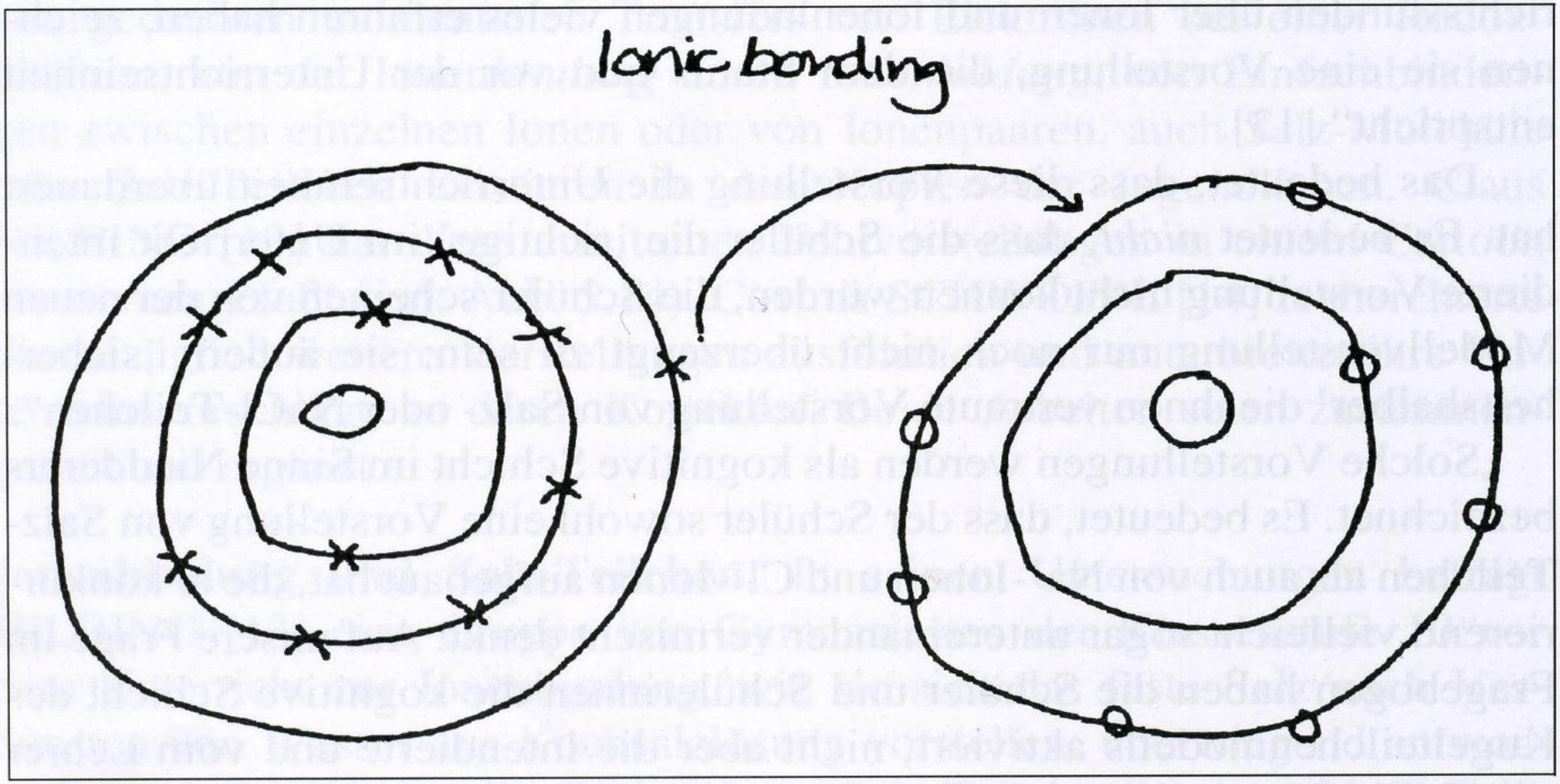
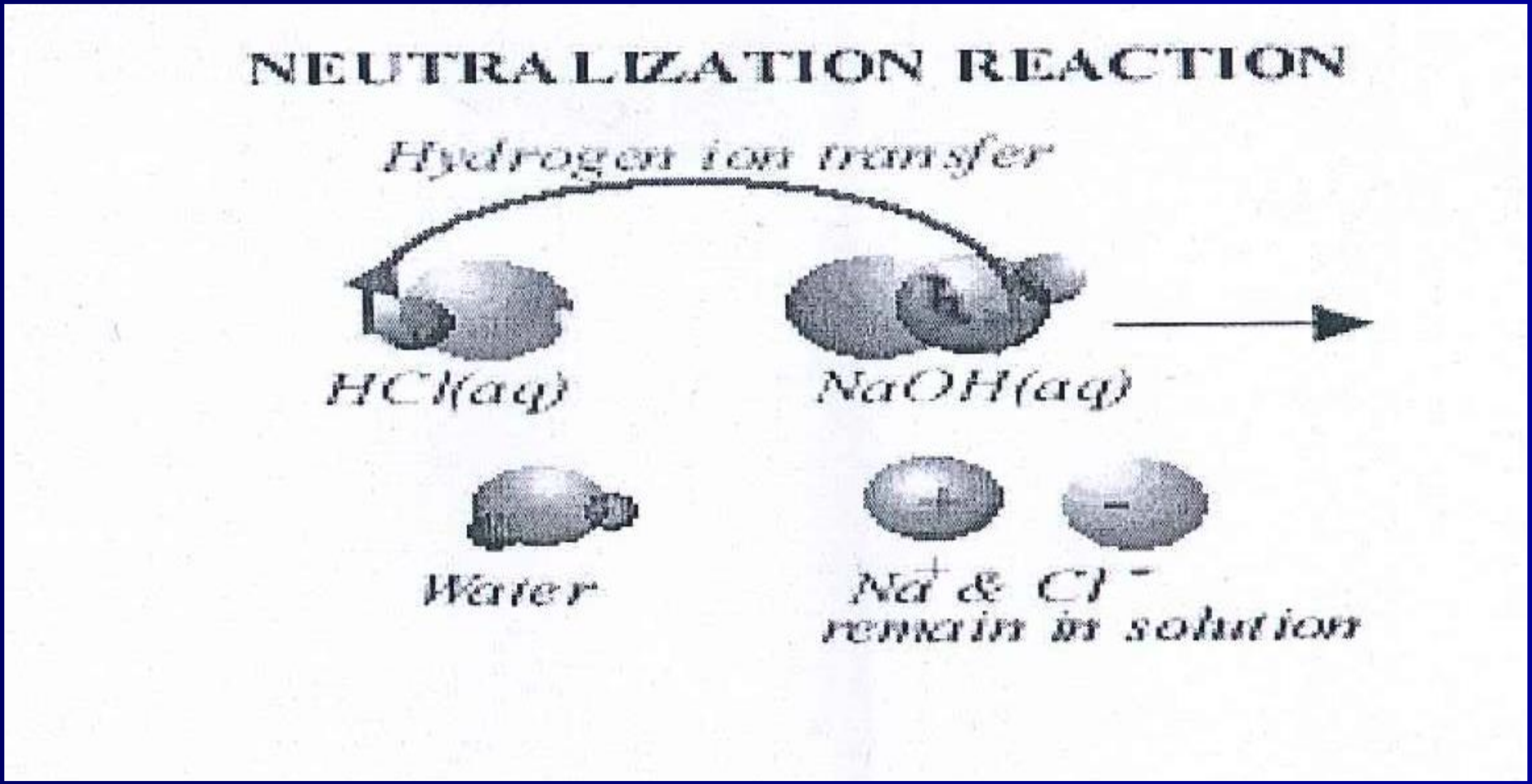
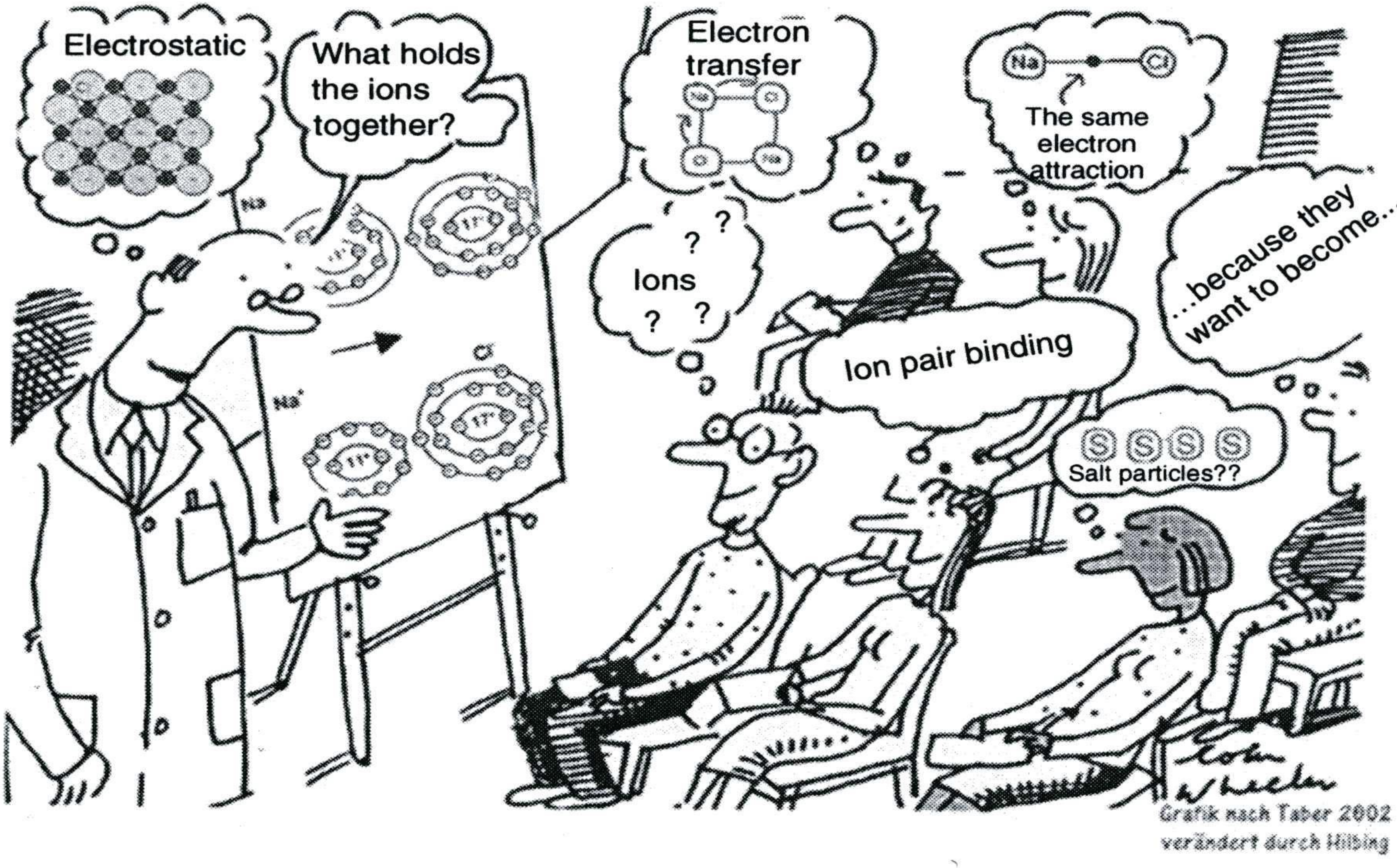


Abb. 5.15. Modellvorstellung eines Schülers zur Ionenbindung [16]

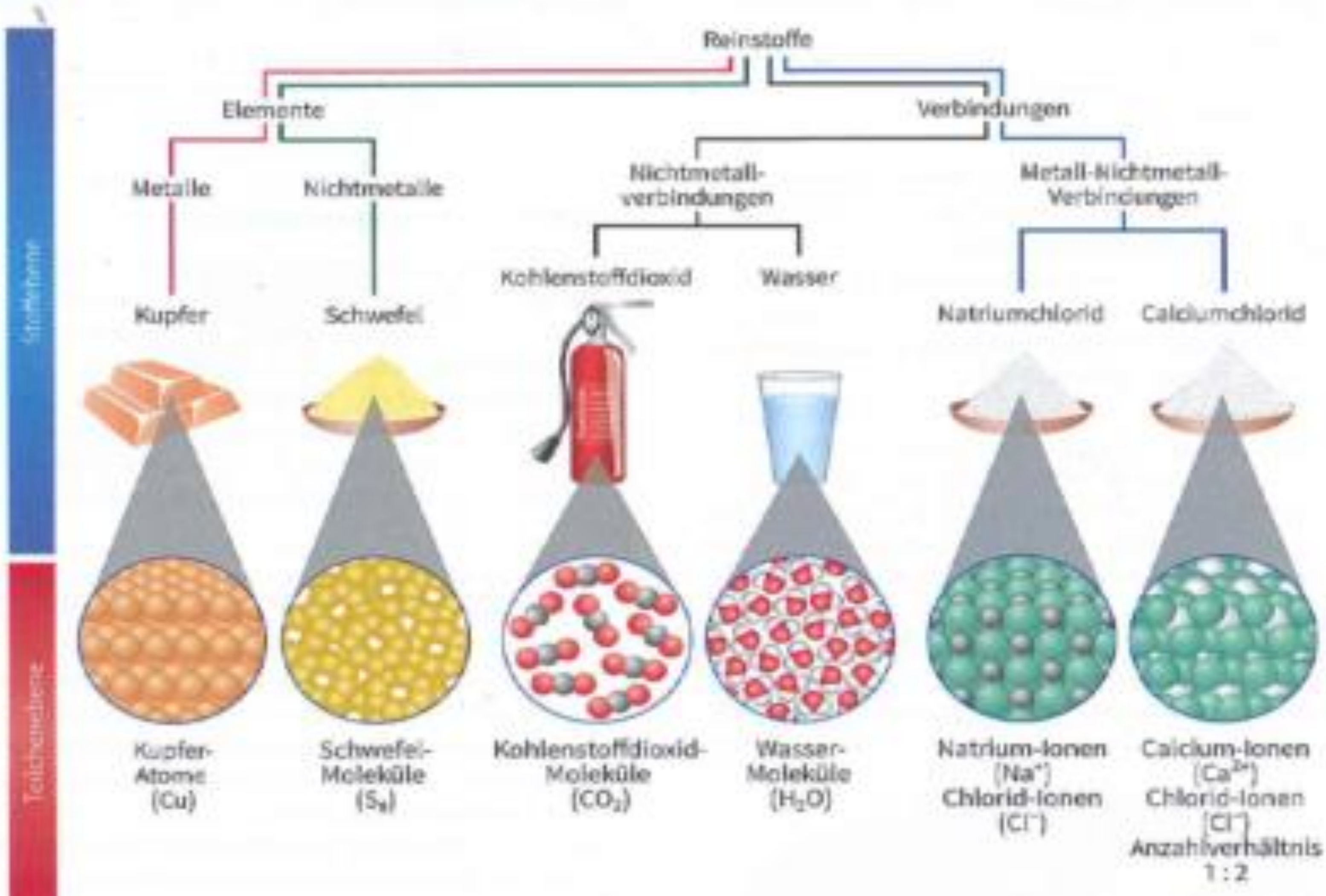
Textbook-made misconceptions: a picture from a Tanzanian chemistry book for Secondary schools



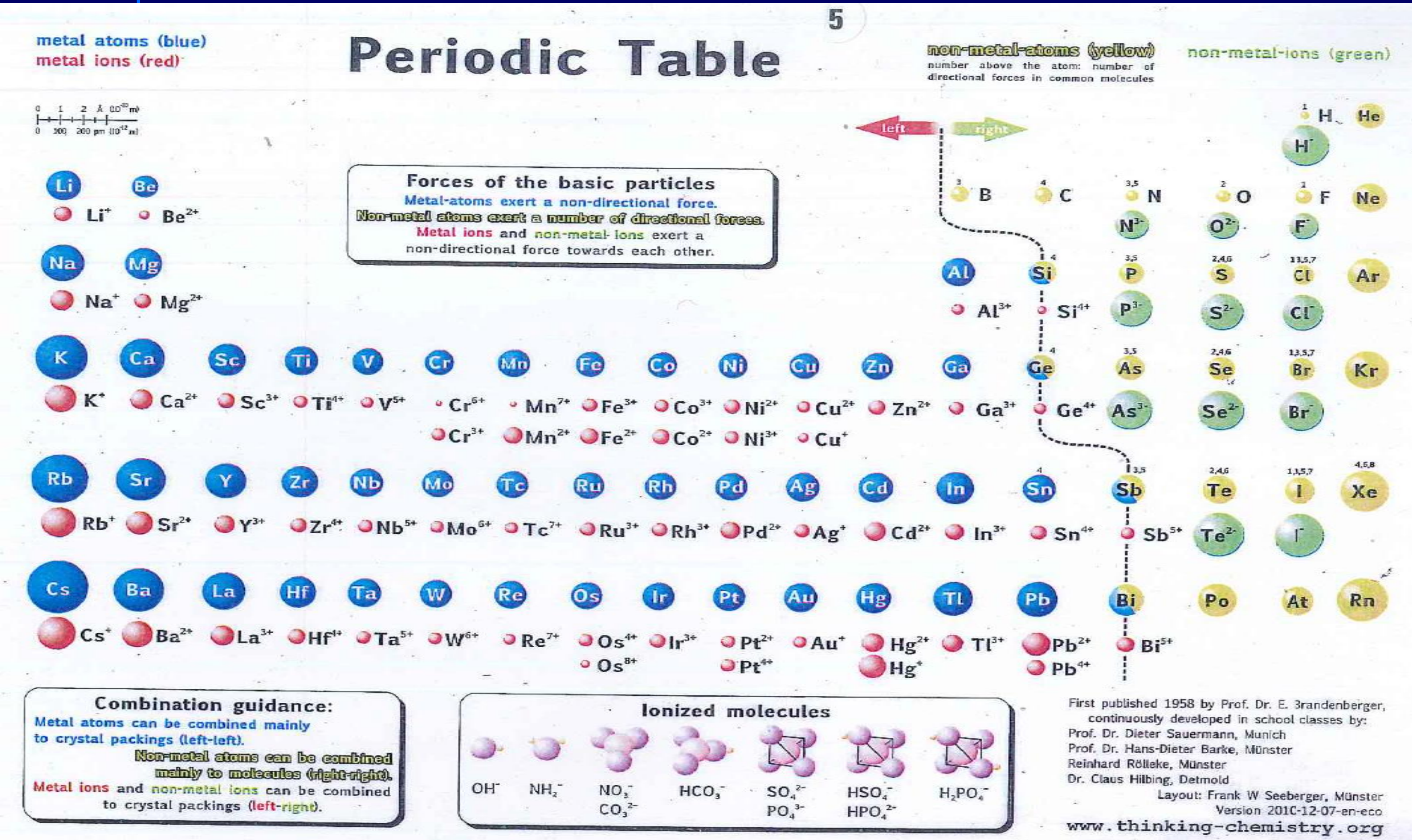
School-made misconceptions:
NaCl structure and ionic bonding (Hilbing 2003)



Early introduction of three kinds of particles: atoms, molecules, ions (German textbook for grade 7, Schroedel 2016)



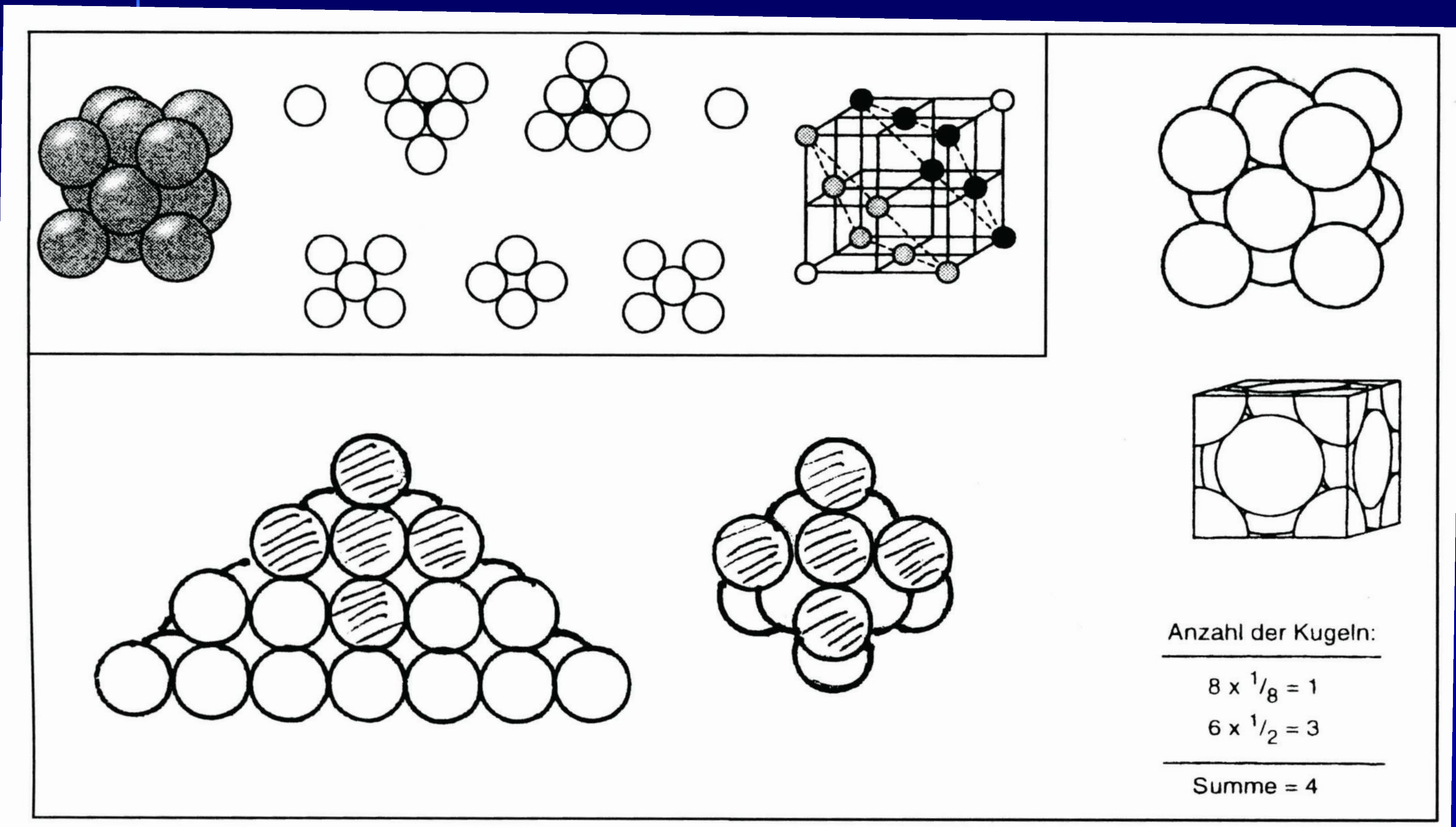
Periodic table of basic particles of matter - atoms and ions: (see also: www.educhem.edu)



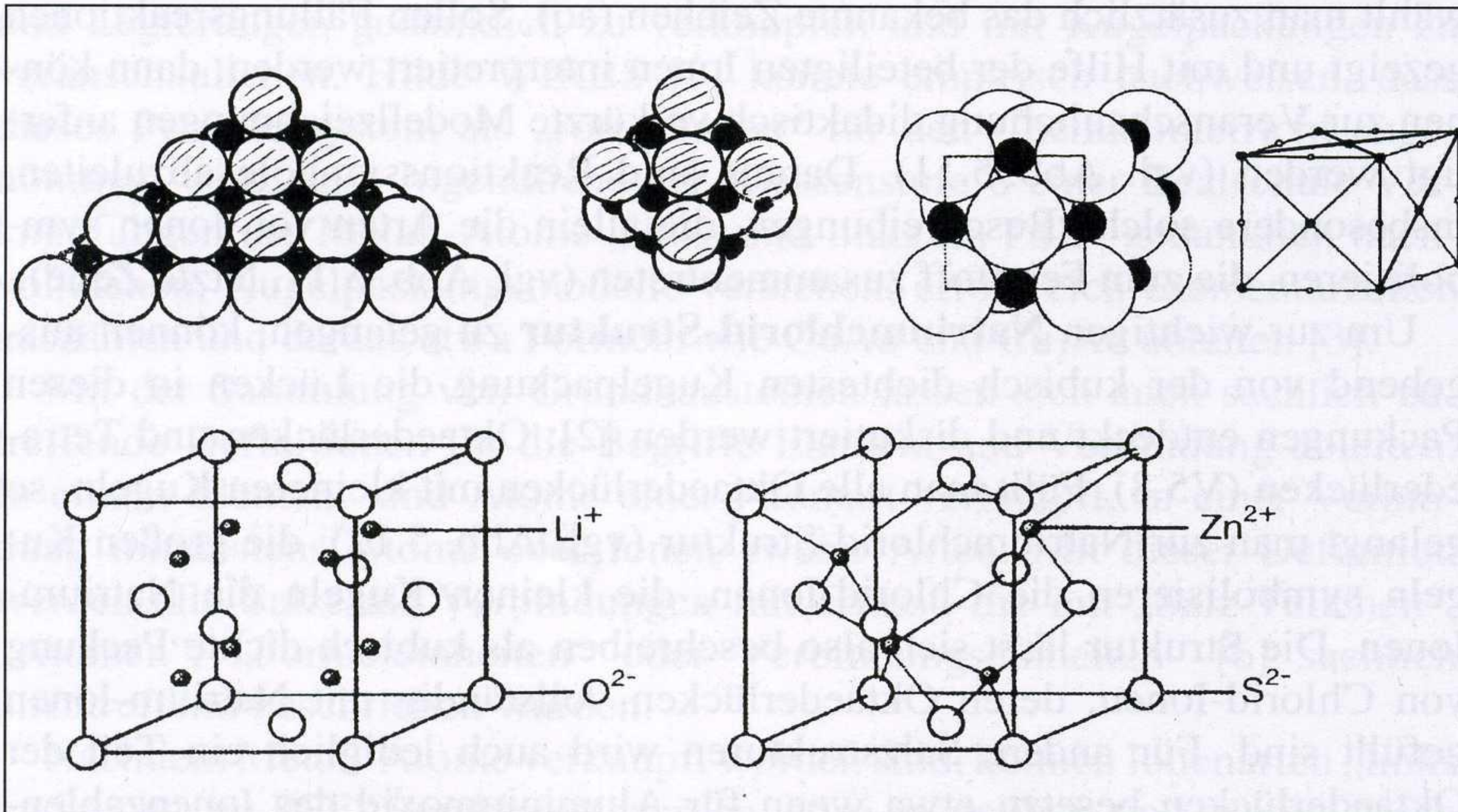
Prevention of misconceptions:
Combination of basic particles – without altering them (Sauermann, Barke 1997)

- **1. Metal atoms „left and left in PSE":**
-
- x Ag → Ag_x (metal structure, closest sphere packing)
-
- **2. Nonmetal atoms „right and right in PSE":**
-
- 1 C atom + 4 H atoms → 1 CH_4 molecule (tetrahedral)
- **3. Ions „left and right in PSE":**
-
- n Na^+ + n Cl^- → $(Na^+)_n(Cl^-)_n$ (ionic lattice, ionic bonding)
-

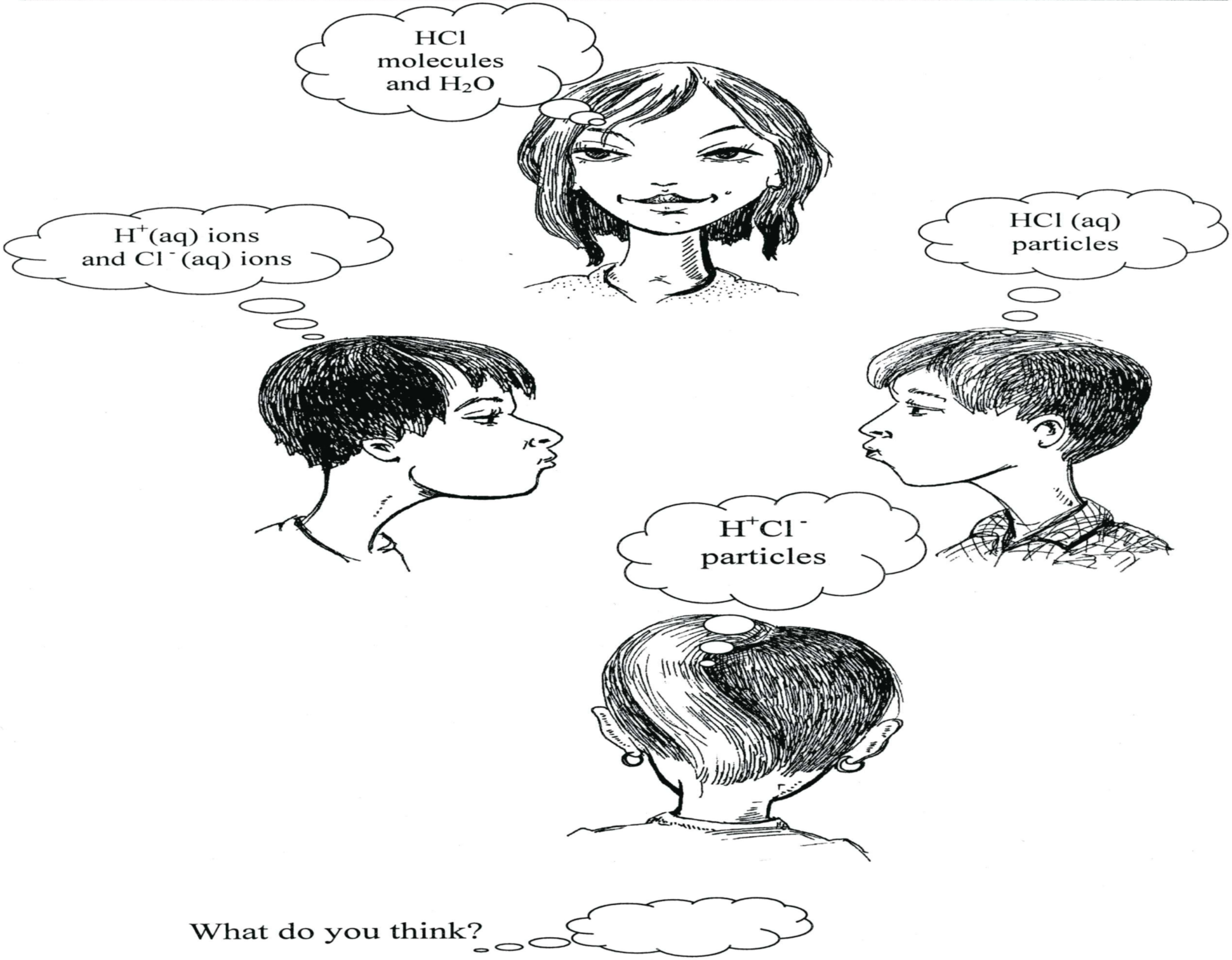
Prevention of misconceptions:
building sphere packings to visualize metal structures



Prevention of misconceptions: building sphere packings or ball-stick models to visualize salt structures



What species are present in hydrochloric acid ?



Questionnaire „Which atoms, ions or molecules react?" (Asih Wisudawati, AJCE 2019)

Explain following reaction equations in four ways:

a) Which atoms, ions or molecules are involved in the reaction?
b) Write down the equation of those atoms, ions or molecules which react.
c) Which atoms, ions or molecules are NOT reacting?
d) Redox or acid-base reaction? Explain transfer of electrons or protons.

One example:

Zinc reacts with diluted sulfuric acid, gaseous hydrogen is observed:
Given equation: $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

a) $Zn + 2\,H^+ + SO_4^{2-} \rightarrow Zn^{2+} + SO_4^{2-} + H_2$
b) Zn atom + 2 $H^+(aq)$ ions $\rightarrow$ $Zn^{2+}(aq)$ ion + H_2 molecule
c) $SO_4^{2-}(aq)$ ions do not change, they are spectator ions
d) Redox: Zn atom gives two electrons to 2 $H^+(aq)$ ions

Challenge of misconceptions by Submicro level: Which atoms, ions or molecules are reacting? Acid-base or redox reaction?

$Mg + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2$

Mg atom + 2 $H^+(aq)$ ions → $Mg^{2+}(aq)$ ion + H_2 molecule

Electron transfer – Redox reaction:

Donor: Mg atom → $Mg^{2+}(aq)$ ion + 2 e^- (Ox.)

Acceptor: 2 $H^+(aq)$ ions + 2 e^- → H_2 molecule (Red.)

Challenge of misconceptions by Submicro level: Which atoms, ions or molecules are reacting? Acid-base or redox reaction?

$MgO(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2O$

O^{2-} ion + 2 $H_3O^+(aq)$ ions $\rightarrow$ 3 H_2O molecules

Proton transfer – Acid-base reaction:

Donors: 2 $H_3O^+(aq)$ ions $\rightarrow$ 2 H_2O molecules + 2 H^+

Acceptor: O^{2-} ion + 2 H^+ ions $\rightarrow$ H_2O molecule

Challenge of misconceptions by Submicro level: Which atoms, ions or molecules are reacting? Acid-base or redox reaction?

$Mg(OH)_2(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + 2\ H_2O$

$2\ OH^-$ ions + $2\ H_3O^+(aq)$ ions $\rightarrow$ $4\ H_2O$ molecules

Proton transfer – Acid-base reaction:

Donors: $2\ H_3O^+(aq)$ ions $\rightarrow$ $2\ H_2O$ molecules + $2\ H^+$

Acceptors: $2\ OH^-$ ions + $2\ H^+$ $\rightarrow$ $2\ H_2O$ molecules

Questionnaire „Which atoms, ions or molecules react?" (Asih Wisudawati, AJCE 2019)

At the end of the questionnaire it was asked:

9. Which of the alternatives (a) – (d) is the most difficult for you?

„Most difficult answer" is „(d) Explain transfer of electrons or protons". Comments are: „proton or electron transfer confuses me, because I need basic concepts of chemistry, because we need to understand (a) – (c), because one has to understand function of particles".

10. Do you like to go with (a) – (d) so deep into the Submicro level?

Comments: „Yes – to differentiate redox and acid-base reactions, it can help to understand chemistry better, yes - because it can support to be a better teacher, yes – because I can improve my understanding of chemistry".

Johnstone´s triangular concept (2000)