APPENDIX A

CALCULATION OF COGNITIVE COMPLEXITY RATING

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equations	**easy**
1.2 Determination of the coefficients in the given oxidation-reduction reaction equations	**medium**
1.3 Writing oxidation-reduction reaction equations and determination of the coefficients	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (mass:mass, amount:amount, volume:volume)	**easy**
2.2 Given and required substances are expressed as the following physical quantities, amount:x (x = volume, mass, number of particles)	**medium**
2.3 Given and required substances are expresses as different physical quantities excluding amount (mass:volume, mass:number of particles)	**difficult**
3. MIXTURE CONCEPT	
3.1 Given or required substance is mixture and expressed through quantitative composition (mass fraction, molar concentration and mass concentration)	**easy**
3.2 Given and required substances are mixtures and expressed as various physical quantities (mass fraction and mass concentration)	**difficult**
4. ADDITIONAL CONCEPTS	
4.1 Partial reduction of nitrate ion	
4.2 Calculation of the number of atoms from the obtained number of molecules	
4.3 Different states of substances	
4.4 Reactivity series of metals	
4.5 Calculation of relative atomic mass from molecular mass	
4.6 Archimedes' principle	
INTERACTIVITY OF CONCEPTS	
Task contains up to two concepts	**0**
Task contains three concepts	**1**
Task contains more than three concepts	**2**

1. Calculate the mass of the aluminum oxide that is produced in reaction of iron(III) oxide and elemental aluminum if 2.7 g of aluminum reacted completely with iron(III) oxide according to the following chemical equation:

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (mass:mass)	**easy**
TOTAL COMPLEXITY	**1**

2. How many moles of hydrogen could be produced in the reaction of 1.31 g of zinc with hydrochloric acid according to the following chemical equation?

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.2 Given and required substances are expressed as the following physical quantities:	**medium**

amount:mass	
TOTAL COMPLEXITY	**2**

3. Determine the amount of nitrogen(II) oxide, that is produced in the reaction of 6.35 g of copper with the required amount of dilute nitric acid?

$$Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO + H_2O$$

1. CHEMICAL EQUATION CONCEPT	
1.2 Determination of the coefficients in the given oxidation-reduction reaction equations	**medium**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.2 Given and required substances are expressed as the following physical quantities: amount:mass	**medium**
4. ADDITIONAL CONCEPTS	
Partial reduction of nitrate ion	
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**4**

4. Calculate the amount of gaseous hydrogen chloride that is dissolved in water, if this solution can dissolve 25 g of calcium carbonate.

$$CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equation	**easy**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.2 Given and required substances are expressed as the following physical quantities: amount:mass	**medium**
TOTAL COMPLEXITY	**3**

5. How many oxygen molecules are formed in the reaction of potassium permanganate with 11.33 g of 30 % hydrogen peroxide solution in the presence of sulfuric acid?

1. CHEMICAL EQUATION CONCEPT	
1.3 Writing oxidation-reduction reaction equation and determination of the coefficients	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:number of particles)	**difficult**
3. MIXTURE CONCEPT	
3.1 Mass fraction	**easy**
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**7**

6. How many iodine atoms are built in iodine molecules, produced in the reaction of 100 g of 8.3% potassium iodide solution with the corresponding amount of potassium dichromate in the acidic medium?

1. CHEMICAL EQUATION CONCEPT

1.3 Determination of the coefficients in non-oxidation-reduction reaction equation	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:number of particles)	**difficult**
3. MIXTURE CONCEPT	
3.1 Mass fraction	**easy**
4. ADDITIONAL CONCEPTS	
Calculation of the number of atoms from the obtained number of molecules	
INTERACTIVITY OF CONCEPTS	
Task contains four concepts	**2**
TOTAL COMPLEXITY	**8**

7. What is the volume of liquid water obtained in the reaction of 2.8 dm^3 of oxygen with the corresponding amount of hydrogen (STP)? Density of liquid water is 1 g/cm^3.

$$2H_2 + O_2 \rightarrow 2H_2O$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (volume:volume)	**easy**
4. ADDITIONAL CONCEPTS	
Different states of substances	
TOTAL COMPLEXITY	**1**

8. How many molecules of water is produced in the reaction of 3.4 g of hydrogen sulfide with corresponding amount of oxygen according to the following equation:

$$2H_2S + 3O_2 \rightarrow 2H_2O + 2SO_2$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:number of particles)	**difficult**
TOTAL COMPLEXITY	**4**

9. Calculate the volume of carbon monoxide (STP), which is produced by oxidation of 3.6 g of carbon by the following chemical equation:

$$2C + O_2 \rightarrow 2CO?$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:volume)	**difficult**
TOTAL COMPLEXITY	**4**

10. Determine the number of molecules of phosphorus(V) oxide which are produced in the reaction of 16 g of oxygen, according to the following chemical equation.

$$P_4 + 5O_2 \rightarrow P_4O_{10}?$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:number of particles)	**difficult**
TOTAL COMPLEXITY	**4**

11. Calculate the volume of barium chloride solution, concentration of which is 0.1 mol/dm^3, necessary to yield 2.33 g of barium sulfate in reaction with sodium sulfate.

$$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + NaCl$$

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equation	**easy**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.2 Given and required substances are expressed as the following physical quantities: amount:mass	**medium**
3. MIXTURE CONCEPT	
3.1 Molar concentration	**Easy**
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**5**

12. A piece of zinc weighing 4.6792 g was put in dilute sulfuric acid solution. After some time, this piece was removed, dried and measured. It has been found that its current mass was twice less than its initial mass. Calculate the volume of gas (STP) produced during this reaction.

1. CHEMICAL EQUATION CONCEPT	
1.3 Writing oxidation-reduction reaction equations and determination of the coefficients	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:volume)	**difficult**
4. ADDITIONAL CONCEPTS	
Reactivity series of metals	
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**6**

13. How many cm^3 of 40% phosphoric acid, density of which is 1.25 g/cm^3, needs to be added for complete neutralization of 50 cm^3 of sodium hydroxide solution, mass concentration of which is 4 g/dm^3?

$$H_3PO_4 + NaOH \rightarrow Na_3PO_4 + H_2O$$

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equation	**easy**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (mass:mass)	**easy**
3. MIXTURE CONCEPT	
3.2 Given and required substances are mixtures and expressed as various physical quantities	**difficult**
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**7**

14. Calculate the number of oxygen molecules that are produced by decomposition of $6.023 \cdot 10^{23}$ "molecules" of mercury(II) oxide according to the following equation:

$$2HgO \rightarrow 2Hg + O_2$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (number of particles:number of particles)	**easy**
TOTAL COMPLEXITY	**1**

15. What is the mass of sodium oxide, needed to react with water, to yield 4 moles of sodium hydroxide?

$$Na_2O + H_2O \rightarrow 2NaOH$$

2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.2 Given and required substances are expressed as the following physical quantities: amount:mass	**medium**
TOTAL COMPLEXITY	**2**

16. Calculate the mass of potassium chlorate, necessary for obtaining 3.2 g of oxygen by thermal decomposition to potassium chloride.

$$KClO_3 \rightarrow KCl + O_2$$

1. CHEMICAL EQUATION CONCEPT	
1.2 Determination of the coefficients in the given oxidation-reduction reaction equation	**medium**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (mass:mass)	**easy**
TOTAL COMPLEXITY	**3**

17. At higher temperatures, boron burn to form boron(III) oxide. How many moles of oxygen is necessary for combustion of 0.1 mol of boron?

1. CHEMICAL EQUATION CONCEPT	
1.3 Writing oxidation-reduction reaction equation and determination of the coefficients	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (amount:amount)	**easy**
TOTAL COMPLEXITY	**5**

18. Silver coin weighing 9.70 g was dissolved in nitric acid. The reaction of dissolution is represented by the following chemical equation:

$$3Ag + 4HNO_3 \rightarrow 3AgNO_3 + NO + 2H_2O$$

The whole silver from the solution is then precipitated as silver chromate by adding the saturated solution of potassium dichromate:

$$AgNO_3 + K_2Cr_2O_7 + H_2O \rightarrow Ag_2CrO_4 + KNO_3 + HNO_3$$

The mass of precipitate after drying was 13.88 g. Calculate the mass percentage of silver in the coin.

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equation	**easy**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.1 Given and required substances are the same physical quantities (mass:mass)	**easy**
3. MIXTURE CONCEPT	
3.1 Mass fraction	**easy**
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**4**

19. 23.4 g sample of trivalent metal carbonate was annealed and 6.72 dm^3 of carbon dioxide (STP) was produced. Calculate the relative atomic mass of metal.

$$M_2(CO_3)_3 \rightarrow M_2O_3 + CO_2$$

1. CHEMICAL EQUATION CONCEPT	
1.1 Determination of the coefficients in non-oxidation-reduction reaction equation	**easy**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:volume)	**difficult**
4. ADDITIONAL CONCEPTS	
Calculation of relative atomic mass from molecular mass	
INTERACTIVITY OF CONCEPTS	
Task contains three concepts	**1**
TOTAL COMPLEXITY	**6**

20. A sample of aluminum and copper alloy has a density of 1.13 g/cm^3. Inserting the sample into the beaker with distilled water, the level of water increases by 9.70 cm^3. Dissolving the sample in hydrochloric acid releases 6.72 dm^3 of hydrogen measured under STP. Calculate the percentage of aluminum in the alloy. The reactivity series of metals table is given below.

K, Na, Ca, Mg, Al, Zn, Cr, Fe, Cd, Co, Ni, Sn, Pb, H, Cu, Hg, Ag, Pd, Pt, Au

1. CHEMICAL EQUATION CONCEPT	
1.3 Writing oxidation-reduction reaction equation and determination of the coefficients	**difficult**
2. STOICHIOMETRIC CALCULATIONS CONCEPT	
2.3 Given and required substances are expresses as different physical quantities (mass:volume)	**difficult**
3. MIXTURE CONCEPT	
3.1 Mass fraction	**easy**
4. ADDITIONAL CONCEPTS	
Archimedes' principle	
INTERACTIVITY OF CONCEPTS	
Task contains four concepts	**2**
TOTAL COMPLEXITY	**8**

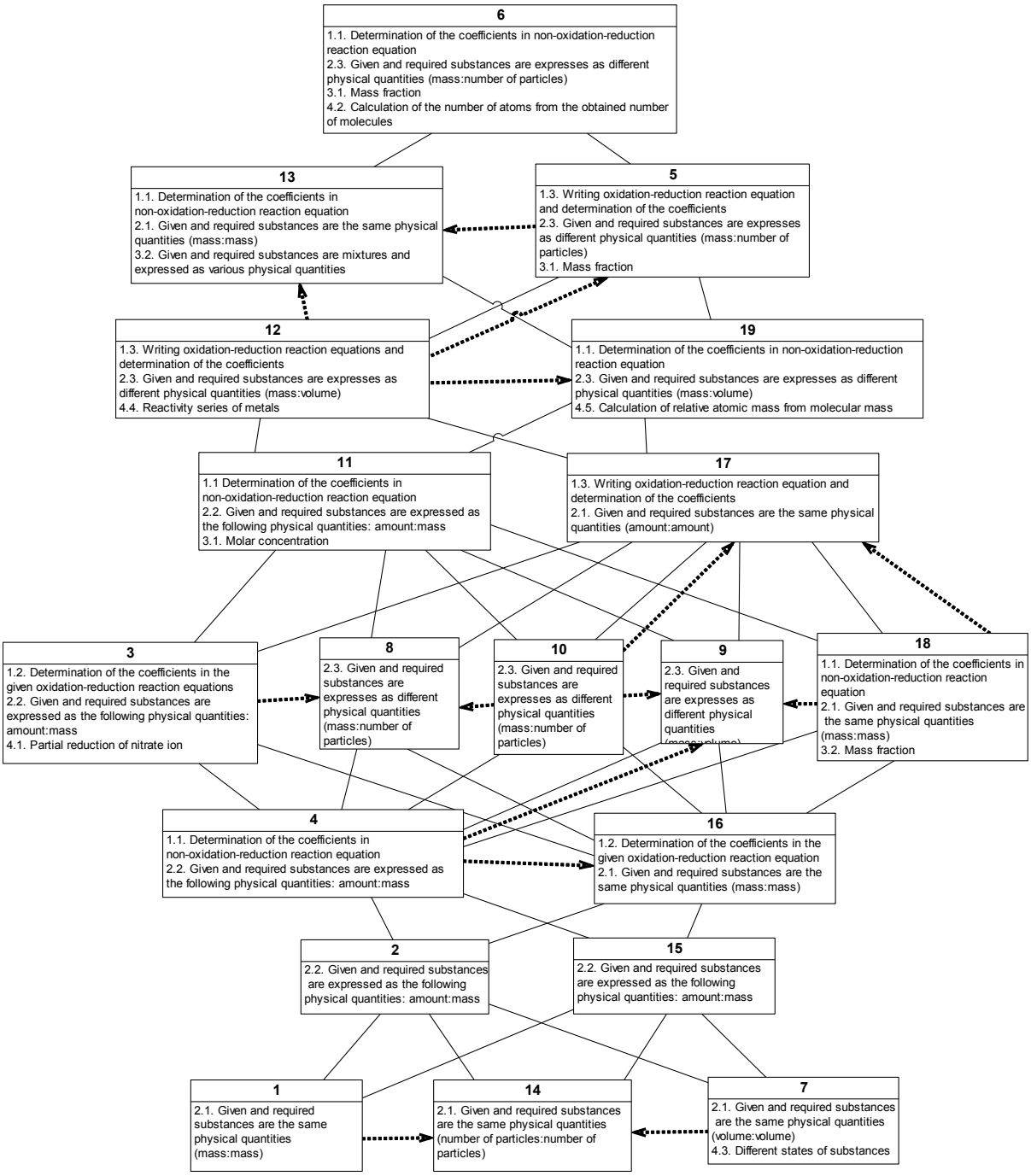

Figure 1 – The expected knowledge space annotated with concepts and extended with the relations from the real knowledge space.