**Tasks used in the study**

**„development of a self-test for a digital learning environment“**

1. **Overview on all tasks (Mo = seminar on Monday; We = seminar on Wednesday; Lab = during laboratory internship)**

Multiple response tasks in green. Sequence / allocation task.

|  |  |  |
| --- | --- | --- |
| **Category** | **Tasks** | **Group (number of students)** |
| Periodic Table of Elements  (Per) | Subgroups, main groups, and periods  Trend “electronegativity”  Trend “ionic radius”  Trend “atomic radius”  Bonding in main groups  Octet rule | Mo (21)  We (26)  Mo (30)  We (25)  Mo (20)  We (27) |
| Chemical bonding  (Bor) | Different chemical bonds  Electron pair bonds  Electronegativity  Hydrogen bonds  Shell model  Chemical bond models | Mo (25)  We (26)  Mo (21)  We (35)  We (27)  We (27) |
| Chemical formula  (For) | Charges and partial charges  Valence bond formulas  Differences between bond-line and valence bond formulas  Several chemical formulas | Mo (20)  Mo (17)  Mo (18)  We (20) |
| Reaction equations  (Rea) | Features of reaction equations  Rules for balancing reaction equations  Correct statements regarding acid-base reactions  Correct statements regarding redox reactions  Features of reactions between electrophiles and nucleophiles  Elements of reaction equations  Chemical equilibrium  Influencing the chemical equilibrium  Information from reaction equations | We (21)  Mo (18)  We (18)  We (19)  We (14) + Mo (14)  We (17)  Mo (16) + We (12)  Mo (17)  Mo (17) |
| Reaction mechanisms  (Mec) | Differences between reaction equations and reaction mechanisms  What to take into account for reaction mechanisms  Correct statements on electrophiles and nucleophiles  Correct features of catalysts  Correct statements on resonance | Lab (14) + (24)  Lab (14) + (24)  Lab (14) + (24)  Lab (14) + (24)  Lab (14) + (24) |

1. **Examples for one task per category (in red correct answers)**

**Tasks translated from German to English**

**Category: Periodic table of elements**

**Example:**

**Seek** for appropriate endings of the sentence that result in technical correct sentences and **tick** those.

The number of possible bonds of a main group element can be determined with the help of…

* atomic size of the element
* noble gas configuration
* electronegativity
* number of the main group

**Category: Chemical bonding (Task: Electron pair bonds)**

**Example:**

**Consider** which statements about electron pair bonds are correct and then **tick** the correct answers.

* Electron pair bonds bind atoms into compact molecular lattices.
* Electron pair bonds are formed by using electron pairs mutually.
* Electron pair bonds are polar or nonpolar atomic bonds.
* Electron pair bonds are formed by merging the valence electrons.

**Category: Chemical formula**

**Example:**

**Tick** all information from valence bond formulas in contrast to molecular formulas.

* Information on number of atoms
* Information on bonding relationships
* Information on spatial arrangement
* Information on existing atom bonds

**Category: Reaction equations**

**Example:**

**Draw up** a guide for balancing reaction equations by **putting** the individual components in the **correct order**.

a) I compensate for the differences in the number of each kind of atom between the educt and product side by writing stoichiometric coefficients before the formulas.  
b) I check the number of each atomic species on the educt and product side again.  
c) I write down the number of individual atomic types (for educt and product).  
d) I look at which atomic types are present on the educt and product side and write them down.  
e) I compare the number of each type of atom between educt and product side and pay attention to differences.

**d, c, e, a, b**

Order:

**Category: reaction mechanisms**

**Example:**

**Tick** all correct statements on electrophiles and nucleophiles.

* Electrophiles are electron rich
* Electrophiles are attacked by nucleophiles
* Nucleophiles often have a free electron pair
* Nucleophiles often are Lewis bases

1. **Categories for the answers to the open questions**

Technical terms (without comment)

Meaning of technical terms (technical term with comment of not knowing what it means)

Language (suggestions for improving the language)

Design (suggestions for improving the design)

Other (fits no category)

|  |  |  |
| --- | --- | --- |
| **Task** | **Technical terms** | **Suggestions for improvement** |
| Per-1 | Technical terms (4)  Meaning (2) | Design (3)  Other (3) |
| Per-3 | Technical terms (5)  Meaning (3) | Language (7)  Design (10) |
| Per-4 | Technical terms (8)  Meaning (2)  Other (2) | Language (1)  Design (3) |
| Per-5 | Technical terms (1)  Meaning (3) | Design (1) |
| Per-7 | Technical terms (2)  Meaning (3) | Design (3) |
| Per-9 | -- | Language (4) |
| Bon-1 | Technical terms (5)  Meaning (2) | Language (1)  Design (1) |
| Bon-6 | Technical terms (6)  Meaning (2) | Other (1) |
| Bon-7 | Meaning (1) | Language (2)  Design (1) |
| Bon-10 | Meaning (1) | Language (2) |
| Bon-12 | Technical terms (2)  Meaning (4) | Other (1) |
| Bon-18 | Technical terms (2)  Meaning (4) | Language (1)  Design (1) |
| For-1 | Technical terms (4)  Meaning (2) | -- |
| For-7 | Technical terms (2)  Meaning (1) | -- |
| For-9 | Technical terms (1)  Meaning (2) | -- |
| For-12 | Meaning (6) | Language (1) |
| Rea-1 | Meaning (1) | Language (1) |
| Rea-2 | Technical terms (1) | -- |
| Rea-4 | Technical terms (5)  Meaning (2) | -- |
| Rea-5 | Technical terms (1)  Meaning (1) | Language (2) |
| Rea-6 | Technical terms (1)  Meaning (3) | -- |
| Rea-7 | Technical terms (2) | Language (1) |
| Rea-8 | Technical terms (2)  Meaning (1) | -- |
| Rea-9 | -- | -- |
| Rea-10 | Meaning (3) | Language (1) |
| Mec-1 | Technical terms (6)  Meaning (2) | Language (2) |
| Mec-2 | Technical terms (1)  Meaning (3) | Language (2)  Other (1) |
| Mec-4 | Technical terms (10)  Meaning (4) | Language (4) |
| Mec-5 | Technical terms (1)  Meaning (3) | Language (1)  Other (1) |
| Mec-7 | Technical terms (2)  Meaning (2) | Other (1) |

**Categories / Codes per topic**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Topic** | **Technical terms** | **Meaning** | **Language** | **Design** | **Other** |
| Periodic Table of Elements | 20 | 13 | 12 | 20 | 3 |
| Chemical bonding | 15 | 6 | 5 | 2 | 1 |
| Chemical formulas | 7 | 5 | 1 | 0 | 0 |
| Chemical reaction equations | 12 | 13 | 6 | 0 | 0 |
| Reaction mechanisms | 20 | 14 | 9 | 0 | 3 |

**Examples per category**

|  |  |
| --- | --- |
| **Code** | **Example** |
| Technical terms | *”Nucleophile”* |
| Meaning | *“I know the terms, but not the explanation (meaning)”* |
| Language | *“Formulate the task more clearly”* |
| Design | *“Maybe highlight the three technical terms to avoid overlooking something”* |
| Other | *“Perfect”* |

1. **Technical terms named by the students**

|  |  |
| --- | --- |
| Number of students | Terms |
| 1 | Melting temperature and Periodic Table of Elements  Trend  Bonding and bonding partners  Energetically suitable  Shell model  Spatial  Bonding characteristics  Electron density  Certain characteristics  Atom sorts  Material conversion  Yield  Charge preservation  Way of the arrows  Activation energy  Transition state  Separation processes |
| 2 | Potential energy  Polar / not polar  Bonding electrons  Molecular lattices  Electron bonding model  Hybridization  Polar electron pair bond  Valence bond  Reduction agent  Partial charge  Unpaired electrons  Stoichiometric coefficients  Reaction arrows  Dissociation arrows  Curved arrows  Reaction mechanisms  Electrophile  Nucleophile  Chemical equilibrium  Resonance  Electron flow |
| 3 | Attractive forces |
| 4 | Ionic radius  Electronegativity  Noble gas configuration  Electron deficient compounds |
| 5 | Period  Bond-line structure |
| 7 | Hetero atom  Lewis base |
| 9 | Ionization energy |

1. **Percentage of students who solved the tasks correctly**

Multiple response tasks in green. Sequence / allocation task.

|  |  |  |
| --- | --- | --- |
| **Category** | **Tasks** | **Percentage** |
| Periodic Table of Elements | Subgroups, main groups, and periods  Trend “electronegativity”  Trend “ionic radius”  Trend “atomic radius”  Bonding in main groups  Octet rule | 71.4 %  11.5 %  20.0 %  12.0 %  65.0 %  0.0 % |
| Chemical bonding | Different chemical bonds  Electron pair bonds  Electronegativity  Hydrogen bonds  Shell model  Chemical bonds models | 16.0 %  46.1 %  81.0 %  34.3 %  25.9 %  14.8 % |
| Chemical formula | Charges and partial charges  Valence bond formulas  Differences between bond-line and valence bond formulas  Several chemical formulas | 10.0 %  29.4 %  61.1 %  55.0 % |
| Reaction equations | Features of reaction equations  Rules for balancing reaction equations  Correct statements regarding acid-base reactions  Correct statements regarding redox reactions  Features of reactions between electrophiles and nucleophiles  Elements of reaction equations  Chemical equilibrium  Influencing the chemical equilibrium  Information from reaction equations | 52.4 %  44.4 %  0.0 %  68.4 %  71.4 %  88.2 %  50.0 %  64.7 %  11.8 % |
| Reaction mechanisms | Differences between reaction equations and reaction mechanisms  What to take into account for reaction mechanisms  Correct statements on electrophiles and nucleophiles  Correct features of catalysts  Correct statements on resonance | 13.2 %  21.1 %  7.9 %  63.2 %  44.7 % |