**Lesson 1 (2 hours)**

**Objective:**
Students will explore the concept of relative humidity by investigating the equilibrium between liquid water and water vapor in a closed plastic bottle

**Vocabulary:**
Maxwell-Boltzmann distribution, Relative Humidity, Absolute Humidity, Saturation Concentration

**Activities/Strategies**:

1. Model system: 2 L plastic or glass laboratory wide mouth bottle
2. Video of observational experiment results: increase of RH in the bottle after a small beaker with water is inserted
3. Group work: develop hypothesis for the increase of the RH and possible testing experiments
4. Class Discussion on the hypotheses and test experiments
5. Example of hypotheses: reaction, bond-breaking
6. Video: Example of test experiment - measurement of RH increase in a desiccator with liquid water but under vacuum. Bond breaking hypothesis can be retained
7. Observational experiment: simulation of velocities of 4 same mass particles initially with same velocities (Collision Lab at PhET)
8. Group discussion: Expected distribution of velocities of the water molecules in liquid water
9. GIF Simulation of 2-D collisions and Maxwell Boltzmann distribution
10. Definition of evaporation rate based on the bond breaking hypothesis
11. Definition of saturation concentration when evaporation rate = condensation rate
12. Definition of absolute humidity and relative humidity

**Materials and Technology:**

- Wide mouth plastic bottles or glass jars, volume 1 or 2 L
- Little beakers
- RH/T datalogger (if experiments are to be performed)
- Videos of experimental results
- Optional:
    - Desiccators
    - Vacuum pump
    - Plastic bottles with small computer ventilators
    - Salt solutions

**Lesson 2 (1 hour)**

**Objective:**
Students will explore the water vapour conservation diagram and list possible uses

**Vocabulary:**
Water Vapor concentration diagram, closed and inert systems, Tetens equation

**Activities/Strategies**:

1. Model system: 2 L plastic or glass laboratory wide mouth bottle
2. Group work: the RH prediction in closed and inert spaces subjected to temperature changes
3. Group work: the RH prediction in closed and inert spaces subjected to temperature gradients
4. Individual work: creating a datasheet with the Tetens equations (excel or google sheet) for the calculation of the saturation concentration
5. Group work: inert spaces - mixing air masses at different humidities. Graphical and mathematical solutions

**Materials and Technology:**
- Prints of Water vapor concentration diagram
- Datasheet (e.g. Excel or google sheet)

**Lesson 3 (1 hour)**

**Objective:**
Students will explore the sorption isotherm of hygroscopic materials

**Vocabulary:**
sorption isotherm, absorption and desorption, equilibrium moisture content (emc)

**Activities/Strategies**:
1. Individual work: definition of emc and calculation in different cases
2. Frontal lecture: Shape of the sorption isotherm for different materials
3. Frontal lecture: swelling, shrinking and capillary water

**Materials and Technology:**
- Prints of sorption isotherm

**Lesson 4 (2 hours)**

**Objective:**
Students will explore the buffering effect of hygroscopic materials in closed systems by analysing experimental results on the RH and T within a microclimate vitrine

**Vocabulary:**
buffering effect of hygroscopic materials, microclimate vitrines

**Activities/Strategies**:
1. Case study and group work “microclimate vitrine”
2. Group work: Based on T measurements (excel sheet) and initial absolute humidity, prediction of RH values if the microclimate would be empty
3. Group work: with measured absolute and relative humidity
4. Group work: Formulation of hypothesis and test experiment for the observed data in the microclimate vitrine

5. Group work Quantitative estimation
6. Work in pairs: comparison of the moisture content of equal volumes of wood and air
7. Frontal lecture: temperature dependency of the sorption isotherm (with peer instruction)
8. Graphical and mathematical solution for the prediction of the Rh in a closed system with hygroscopic materials and subjected to T changes

**Materials and Technology:**

- Datasheet (e.g. Excel or google sheet)
- Measured data in the microclimate vitrine
- Prints of sorption isotherm at different temperatures

**<u>Lesson 5 (1 hour)</u>**

**Objective:**
Students will explore further situations encountered in conservation: the packing of materials conditioned at an RH different from the RH in the environment and the buffering effect in semi-closed systems

**Vocabulary:**
Semi-closed systems, reductio ad absurdum

**Activities/Strategies**:

1. Case study: packing of materials conditioned at a different RH than the environment
2. Reductio ad absurdum
3. Conclusion: in closed system the relative humidity is determined by the moisture content of the hygroscopic materials
4. Observational experiment: RH increase in semi-closed systems containing or not hygroscopic materials
5. Hypothesis and test experiments
6. Preparation for measurements and interpretation in real cases

**Materials and Technology:**

- Videos of experimental results
- Measurements in real cases:
  - Different plastic foils to pack materials
  - Different types of boxes (isolated or not)
  - Hygroscopic materials (e.g. newspapers) conditioned at high RH and conditioned at environmental RH
  - Small RH/T dataloggers