The four problems for the hands-on using Virtual Laboratories by Prof Inga Kamp (University of Groningen) and Dr Peter Woitke (University of St Andrews) are:

1) How do ice lines in the disk change with stellar luminosity and dust properties?

Take the model series you find in the folder TTauri and investigate how the snowline changes with specific parameters of the model. The base of the model series is a standard T Tauri disk model (Woitke et al. 2016). In the various folders, the stellar luminosity, disk mass, xxx have been changed. The models contain the 2D water vapour and water ice abundance distributions and you will find that the ice reservoirs have a certain radial and vertical extent.

Think about how you would derive the snowline/iceline of such a disk model in the context of planet formation. Which is the key quantity that is relevant for planet formation? Then apply this to the various models using the standard routines in prodimopy. You may want to go here for a starting point on how to read a model and how to plot e.g. the column density of a species or the abundances of species (https://prodimopy.readthedocs.io/en/latest/plot/). Which parameters do affect the snowline positions and which ones not? What does this imply for planet formation?

2) How does the ice/rock ratio change depending on dust settling?

Take the model series you find in the folder settling-TTauri and investigate how the ice/rock ratio changes in the presence of dust settling. Dust settling implies that the larger dust grains (mm-sized) that couple less efficiently to the gas, settle closer to the midplane, while the small dust grains (submicron size) remain well mixed with the gas also at large heights in the disk. This affects the surface area available for ice formation, but also affects the local dust size distribution and hence the local gas-to-dust mass ratio. The two subdirectories contain models with low settling (settle_low) and high settling (settle high). Note that these models are rund with time-dependent chemistry. The ProDiMo.out files in both folders contain the result from 1 Myr.

Think about which species are part of the ice component in these disks. Then evaluate the total ice mass as a function of disk position and compare that to the solid mass (all dust) to derive the ice/rock ratio. You may want to go here for a starting point on how to read a model and how to plot e.g. the column density of a species or the volume densities of species (https://prodimopy.readthedocs.io/en/latest/plot/). How important is dust settling for the local ice/rock ratio in a disk? What does this imply for planet formation?

3) How does the water snowline and CO ice line change as a function of time?

Take the model series in time-dependent-TTauri. This is a standard T Tauri model (Woitke et al. 2016) with time dependent chemistry run on top of it. The time steps are [1e3,1e4,1e5,3e5,1e6,3e6,1.e7,3.e7] yr. The model contains the 2D water vapour and water ice distributions and the ice reservoirs have a certain radial and vertical extent.

Think about how you define the 2D iceline in such a disk model using the respective vapour and ice abundance distributions. Then apply this to the model time series using the standard routines in prodimopy. You may want to go here for a starting point on how to simply plot a model and how to make a movie (https://prodimopy.readthedocs.io/en/latest/plot/, https://prodimopy.readthedocs.io/en/latest/movie/). How valid is the assumption of steady state chemistry? What makes the ice reservoirs change with time? How important are the initial conditions for the disk chemistry and where do we get them from?

4) What is the mineral composition of the dust assuming phase equilibrium?

Based on the pre-calculated (p,T)-structure of a chosen disk, we can make very simple predictions about the mineral composition of the dust prior to planet formation. By running GGchem on radial and/or vertical cuts through the disk, and by plotting the results, you can find out what these predictions are, for example:

- Which condensates are predicted to be present in the disk? Try to group them into high-temperature Ca/Al/Ti oxides, silicates, iron and sulphur compounds, phyllosilicates and ices.
- Looking at radial cuts through the midplane, where do we start to find those families of condensates? And where are those condensates transformed into different ones? Consider plotting the results over temperature.
- Where are the ice-lines of H_2O and NH_3, and how does that match with the results from the kinetic chemistry in ProDiMo?
- Repeat that exercise for vertical cuts at selected radii. Think about the dependence of condensation on pressure, and note that photo-processes are not included in GGchem.