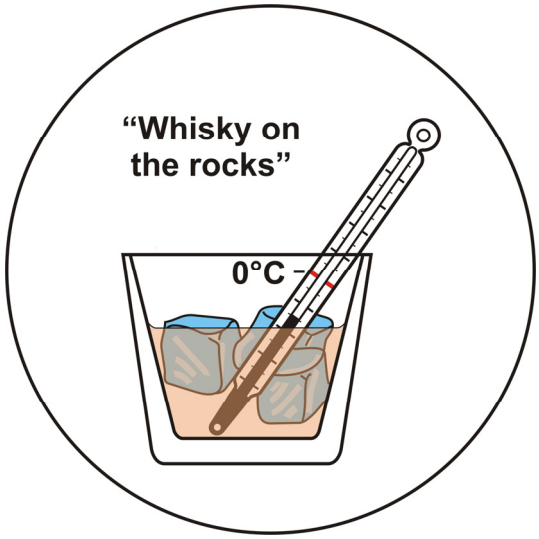
Whisky “on the Rocks”—
Freezing-Point Depression



Equipment:

large beaker (500 mL), high form
demonstration thermometer
support stand, clamp holder, extension clamp

Chemicals:

alcohol (ethanol)
crushed ice

Safety:

ethanol (C_2H_5OH):

H225
P210

It is highly recommended to wear safety glasses.

Procedure:

The demonstration thermometer is positioned with the help of an extension clamp so that its bulb nearly touches the bottom of the beaker. Subsequently, the beaker is filled with crushed ice so that the bulb of the thermometer is completely covered by ice. The position of the meniscus is marked. The precooled alcohol is then poured on the ice until the space between the pieces of ice is almost completely filled.

Observation:

After adding the alcohol, the temperature firstly increases a little bit because of the mixture rule, but then the mixture becomes noticeably colder than 0 °C, the freezing temperature of pure water. The glass also fogs visibly.

Explanation:

A frozen liquid, in our case frozen water (ice), melts more easily when a substance, here ethanol, that is soluble in the liquid but not in the solid is added. At freezing point of the pure liquid, the chemical potentials for the solid and the liquid state are just equal. If a foreign substance is dissolved in the liquid phase, the chemical potential of this phase decreases so that it falls below that of the solid phase which then begins to melt. The entropy required for the phase transition solid $\rightarrow$ liquid is not added from outside but has to be brought up by the system itself. Therefore, the entire mixture cools down and the chemical potentials rise due to their negative temperature coefficients. However, because the temperature coefficient for a liquid is smaller than for a solid, the chemical potential of the liquid grows faster with decreasing temperature than that of the solid. This causes the potential gradient to disappear again at a certain lower temperature and the melting process stops at this new freezing point.

Disposal:

Highly diluted, the solution can be poured down the drain.