equilibrium concentration of the Pb^{2+} ions and hence on the Process 4. Ageing of the battery and the operating conditions (high currents, small currents and pulse currents) have a significant impact on the overvoltages caused by Processes 1 and 4. This is mainly caused by changes in the inner active surface on the charged active material side (Pb) as well as on the $PbSO_4$ side.

The nominal voltage of a lead acid battery is 2.0 V; the open-circuit voltage of a charged battery is about 2.1 V, depending on the concentration of the electrolyte.

The open-circuit potential of the positive electrode in a fully charged battery is approximately +1.75 V against the standard hydrogen electrode. The negative electrode potential is approximately −0.35 V against the standard hydrogen electrode. The relationship between the electrolyte concentration and the electrode potential with respect to the cell potential can be seen from Figure 18.14. The dependence of the open-circuit potential on the temperature is as small as 0.2 mV/K. Therefore, it can be neglected for practical reasons.

In addition, there is the main side reaction – the water electrolysis. As the electrolyte is aqueous and the cell voltage is approximately 2 V and can be as high as 2.5 V, water electrolysis takes place continuously. Hydrogen and oxygen are produced at the negative and the positive electrodes, respectively. Hydrogen production starts at electrode potentials more negative than 0 V against the standard hydrogen electrode. Oxygen evolution starts at electrode potentials more positive than 1.23 V. Fortunately, the so-called overvoltages at lead electrodes for the gas production are very high and therefore the gas production is inhibited to a high extent. This allows the lead acid battery to be stable even at the high cell potential of 2 V. The self-discharge rate caused by the gassing is approximately 2 to 5% per month.

Positive electrode $$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \tag{18.8}$$

Negative electrode $$4H^+ + 4e^- \rightarrow 2H_2 \tag{18.9}$$

Cell reaction $$2H_2O \rightarrow 2H_2 + O_2 \tag{18.10}$$

Very comprehensive handbooks on lead acid batteries have been written by Bode [15] on the fundamentals and by Berndt [3] on valve-regulated batteries.

18.4.7.2 Lead acid batteries – technology, fundamentals, concepts and applications

All the different types of lead acid batteries discussed in the following text are based on the reaction equation presented above. Whereas Figure 18.11 shows a complete battery system in an autonomous power supply system, Figure 18.12 shows the schematic construction of the electrochemical $Pb/H_2SO_4/PbO_2$ cell.

Solid lead grids, rods or plates serve to conduct the current (grid) and to mechanically stabilise the porous active mass in both electrodes. Depending on the battery type, different lead alloys for the grid are used to increase the stability, improve the tooling properties and to reduce corrosion. The porous active material is attached to the grid