

XII. *Cryostat especially for temperatures from*
— 252° to — 259°.

§ 1. *The principle.* In X § 1 I have said that we succeeded in pouring into the cryostat of Comm. N°. 94^d VIII a bath of liquid hydrogen, maintaining it there and making measurements in it, but then the vacuum glass cracked. By mere chance it happened that the measuring apparatus which contained the work of several series of measurements came forth uninjured after removal of the sherds and fragments of the vacuum glass. With the arrangement which I am going to describe now we need not be afraid of an adversity as was imminent then. Now the bath of liquid hydrogen is protected against heat from outside by its own vapour. The new apparatus reminds us in many respects of that which I used to obtain a bath of liquid oxygen when the vacuum glasses were not yet known; the case of the cryostat then used has even been sacrificed in order to construct the apparatus described now.

The principal cause of the cracking of vacuum glasses, which I have pointed out in several communications as a danger for placing precious pieces of apparatus into them are the great stresses caused by the great differences in temperature between the inner and the outer wall and which are added to the stresses which exist already in consequence of the vacuum. To the influence of those stresses it was to be ascribed, for instance, that only through the insertion of a metal spring the vacuum tubes (described in Comm. N°. 85, April '05) could resist the cooling with liquid air. It sometimes happens that a vacuum flask used for liquid air cracks without apparent cause and with the same cooling the wide vacuum cylinders are still less trustworthy than the flasks. At the much stronger cooling with liquid hydrogen the danger of cracking increases still. Habit makes us inclined to forget dangers, yet we should rather wonder that a glass as used for the cryostat of Comm. N°. 94^d VIII filled with liquid hydrogen does *not* crack than that it does.

In the new cryostat of Pl. V the cause of the cracking of the vacuum glass has been removed as much as possible and in case it should break in spite of this we have prevented that the measuring apparatus in the bath should be injured. The hydrogen is not poured directly into the vacuum glass B'_{02} , but into a glass beaker Ba , placed in the vacuum glass (comp. Comm. N°. 23, Jan. '96 at the end of § 4) but separated from it by a new-silver case, which forms, as it were, a lining (see X, L Pl. I). Further the evaporated hydrogen is led along the outer wall of the vacuum glass B'_{01} . To be able to work

also at reduced pressure and to prevent any admixtures of air from entering into the pure hydrogen used, the whole bath has been placed in a stout cylindrical copper case *Ub*, which can be exhausted.

This cryostat is especially fit for hydrogen, yet may profitably replace those described till now, at least when it is not necessary that we should see what takes place inside the bath. A modified pattern, where this has become possible, in the same way as in the cryostat with liquid oxygen of Comm. N°. 14, Dec. '94, I hope to describe ere long.

In the cryostat now to be described, as in the former, the measuring apparatus, without our changing anything in the mounting of them, will go through the whole range of temperatures from -23° to -90° with methyl chloride, from -103° to -160° with ethylene, from -183° to -217° with oxygen and from -252° to -259° with hydrogen (only for the temperatures between -160° and -180° we still require methane).

§ 2. Description.

a. The new cryostat is represented on Pl. V. The letters, in so far as the parts have the same signification, are the same, as for the descriptions of the other cryostats; modified parts are designated by new accents and new parts by analogous letters, so that the explanations of Comms. N°. 83, N°. 94^c and N°. 94^d on the attainment of uniform and constant temperatures, to which I shall refer for the rest, can serve also here. Pl. II shows how the cryostat is inserted into the hydrogen cycle. In chapter X § 7 is described how the liquid hydrogen is led into the cryostat. Especially for the regulation of the temperature this plate should be compared with Pl. VI of Comm. N°. 83, March '03. Instead of *Bu Vac* on the latter plate, the compressor *©* serves as vacuum pump here (see Pl. II of the present paper).

b. The measuring apparatus (as on the plate of Comm. N°. 94^d VIII I have represented here the comparison of a thermoelement with a resistance thermometer) are placed within the protecting cylinder ξ_0 of the stirring apparatus. This is held in its place by 4 glass tubes ξ_{40} fitted with caps of copper tubing ξ_{41} and ξ_{42} at the ends of the rods.

The beaker *Ba*, containing the bath of liquid hydrogen, is supported by a new-silver cylinder *Ba*₁, in the cylindrical rim *Ba*₀ of which the glass fits exactly; the beaker is held in its place by 4 flat, thin, new-silver suspension bands running downwards from *Ba*₀ and uniting below the bottom of *Ba*. The ring *Ba*₀ is the cylinder *Ba*₁,

continued, with which it is connected by six strengthened supporting ribs Ba_1 . At the top it is strengthened by a brass rim Ba_2 with a protruding part, against which presses the upper rim Ua of the case U . On Ba_2 rests the cover N'_{01} in which a stopper is placed carrying the measuring apparatus. The india rubber band effects the closure (comp. also Comm. Nos. 83, 94^c and 94^d).

c. In the case U the vacuumglass B'_0 , of which the inner wall B'_{01} is protected by the thin new-silver cup Bb , is suspended by bands L'_0 and supported by the wooden block L'_1 . The card-board cover B'_4 forces the evaporated hydrogen, which escapes between the interstices of the supporting ridges, over the paste-board screen B'_{030} with notches B'_{031} along the way indicated by arrows, to escape at T'_{12} . The case is lined with felt, covered with nickel paper (comp. Comm. N^o. 14, Dec. '94, and Comm. N^o. 51, Sept. '99).

d. The keeping of liquid hydrogen within an enclosed space, or which the walls have for a great part a much higher temperature than the critical temperature of hydrogen, involves special safety arrangements. That this was no needless precaution appeared when the vacuum glass cracked unexpectedly (comp. X § 1) and of a quantity of more than 1,5 liter of liquid hydrogen nothing was to be seen after a few seconds. Now this disappearance is equivalent with the sudden formation of some hundreds of liters of gas, which would explode the case if no ample opportunity of escape were offered to the gas as soon as the pressure rises a little above the atmospheric.

In the new cryostat I have avoided this danger in the same way as at the time when I first poured off a bath of liquid oxygen within a closed apparatus (comp. Comm. N^o. 14, Dec. '94).

The bottom of the case U is made a safety valve of very large dimensions; as cover W_2 of perforated copper with strengthened ridges it fits into the cylindrical case Ub , which is strengthened with the rim W . Over the external side of this cover (as in the safety tubes for the hydrogen liquefactor) a thin india rubber sheet W_1 — separated from the copper by a sheet of paper — is stretched, which at the least excess of pressure swells and bursts, while moreover the entire vacuum glass or pieces of it, if they should be forced out of the case, push the cover W_2 in front of them without resistance. As the airtight fit of the sheet of india rubber W_1 on the ring W is not trustworthy and diffusion through contact of the india-rubber with the air must be prevented, it is surrounded with hydrogen; this is done by filling the india rubber cylinder Wa , drawn over the supporting ring Ub , and the auxiliary cover Wb , with hydrogen along Wc .

The cords Wd serve to press the auxiliary cover Wb with a certain force against the safety sheet, namely by so much as the excess of pressure amounts to, which for one reason or other we want to admit into the case. To prevent the india rubber from cooling down, for then the arrangement would no longer satisfy the requirements, the lower end of the case is lengthened by the cylindrical piece Ub_2 , which between the rim Ub_4 and the principal body of the case is made of new-silver to prevent the cooling of the lower rim. The entire lower part is stuffed with layers of felt and wool while also a copper flange Ub_3 by conduction of heat from outside protects the lower wall from cooling.

e. The hydrogen is admitted through the new-silver tube a , on which the siphon tube of a vacuumglass (X § 7) is connected with a piece of india rubber tubing a_2 (which otherwise is closed with a stopper a_1 , comp. X § 4 a). The new-silver tube is put into the new-silver side piece Ud , which is soldered on the case and, being stuffed with capoc held back by a paper tube Ue , carries at the end a piece of cork Uf for support. When the vacuum glass B_0 with the case U are placed round the beaker Ba , the tube a_1 is pulled back a little. When subsequently the case is fastened in its position the tube is pushed forward until a ridge on a_1 is checked by a notch in Ud , so that its end projects into the beaker Ba and the hydrogen can flow into it. The india rubber tube a_2 forms the closure on a_1 and Ud .

§ 3. *Remarks on the measurements with the cryostat.*

* In chapter X § 7 I have communicated how the preliminary cooling is obtained. In one of the experiments, for instance, 3 liters of liquid air were used for it and the temperature was diminished to -110° . Then hydrogen was very carefully siphoned into the cryostat under constant stirring; a quantity of 5 liters was sufficient to obtain a bath of 1.5 liter. About 0.2 liter per hour evaporated after this. During the reduction of the pressure to about 60 m.m. \pm 0.2 liter evaporated, and then the evaporation remained about the same. The temperature could be kept constant to within 0.01° in the way described in the former papers. The temperature curves obtained were no less regular than those of Pl. III in Comm. N°. 83 (Febr. and March '03).

If the pressure is reduced down to 54 m.m. the tapping noise of the valves of the stirring apparatus becomes duller. This is a warning that solid hydrogen begins to deposit.

