XXII. *Supplementary Report on the best Method of proportioning the Excise upon Spirituous Liquors. By* Charles Blagden, *M. D. S. R. S.*

Read June 28, 1792.

THE Report to which this paper is intended as a Supplement, was drawn up, and published, when our experiments on the specific gravities of the spirituous liquors had been continued only to equal quantities of alcohol and water by weight. It was foreseen that a further set of experiments, on more dilute liquors, would be wanted: but as these must necessarily take up a considerable time, the persons concerned thought it best to submit those already made to the public; that if any errors or inaccuracies should be discovered they might be avoided, and if any person should suggest a better method it might be adopted, in the subsequent proceedings. Want of ice, and some other hinderances, prevented the experiments on what may be called watery mixtures from being entered upon earlier than the beginning of last winter. Fresh spirit was distilled for the purpose by Mr. SCHMEISSER, who brought some of it to the specific gravity of ,817; but it had a smell somewhat different from that employed in the former experiments, and more approaching to the odour of ether. On inquiry we found, that, whereas Dr. DOLLFUSS had drawn the former spirit off vegetable alkali, Mr. SCHMEISSER used GLAUBER'S salt calcined by exposure to the air. In order to try whether this circumstance made any difference in the quality of the new spirit, Mr. GILPIN mixed some of it with an equal weight of water, and afterwards brought the mixture to all the different temperatures from 30° to 100°, operating in the same manner as he had done with Dr. DOLLFUSS's spirit; when the specific gravities were found to come out the same. Mr. SCHMEISSER's alcohol, therefore, was used without hesitation. As no censure had yet been passed on our former experiments, the same general method was pursued for the new series; with a small variation, however, the reason of which is now to be explained.

In the Report on the first experiments I introduced the following remark. "It must be observed, that Mr. GILPIN "used the same mixture throughout all the different temperatures, heating it up from 30° to 100°; hence some "small error in its strength may have been occasioned, in the "higher degrees, by more spirit evaporating than water; but "this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing "a fresh mixture." The consciousness that such a source of error existed, made us desirous of ascertaining to what quantity it amounted, by some previous experiments, before the new set should be begun. These shewed that it was somewhat greater than had been supposed, though not such as ever to cause a difference of more than a single unit in the third place of decimals, even in the temperature of 100°. The greatest difference found, in that degree of heat, was ,00094; and in a heat of 80°, the highest to which the tables for use were to be carried, it amounted only to ,00064; being in both cases greatest when the mixture consisted of 85 parts of water, by weight, to 100 of alcohol. This difference, however, small as it was, afforded sufficient reason for repeating all the former experiments, conjointly with the new set for dilute spirits, so as to make one entire series, with the same spirit, and executed throughout in an uniform manner. To obviate the error from evaporation in this series, and ascertain what each mixture really lost of its strength during the operation, all the fluids were first weighed at 60°, before they were cooled down to 30°; from 30° to 100°, they were weighed at every 5 degrees, as before, consequently a second time at 60°; and lastly, after having been heated to 100°, they were again brought to 60°, and weighed at that point a third time. The difference between these weights, at the beginning, middle, and end of the experiment, was applied, in due proportion, to correct the numbers of the respective intervals between them; by which means it is believed that the error arising from the gradual evaporation of the spirit, during the experiment, has been made to disappear. Mr. Gilpin having also observed, that the spirits adhering to the sides of the funnel which he employed to fill up the weighing-bottle, grew weak by the evaporation, and so diluted the fresh spirit poured into the funnel, determined to use a smaller instrument of this kind, namely, such an one as would not hold more than 15 grains of spirit; in which a less surface being left wet when the spirit ran out, the error from this cause would be proportionably diminished.

Under all these precautions were the experiments made, of which the results are given in the following tables. They are drawn up exactly like the tables in the former Report;

but, as alcohol was taken for the fixed quantity in the first half, so water is taken for the fixed quantity in the last half, which, therefore, consists of mixtures containing all 100 grains of water, with 95 grains, 90, 85, and so on successively, of alcohol, till the last column is pure water. This arrangement will be clear to every one, on reading the title of each column of the tables. The first table gives the actual weights, at the even degree of the thermometer, corrected for the evaporation; and the second table gives the specific gravities, calculated from those weights, with the same allowances and corrections as were specified in the original Report.

WHEN all the experiments had been completed, and the tables here given were just brought into order, an ingenious member of the Royal Society, scarcely less celebrated for his theoretical knowledge than his skill as an artist, published a pamphlet containing censures on our first experiments, and proposing other methods, as much superior to those we had adopted.* In drawing up the Report, in order to avoid prolixity, the reasons for choosing some of the methods were not given, where they did not seem likely to be a subject of controversy; but this pamphlet makes it necessary to assign the motives of our preference, that the public may judge how far we are justified.

First, as to the proportions of the mixtures; which were made by taking an equal quantity of spirit in every instance, and adding to it successively larger quantities of distilled water, as far as to an equal weight; with the intention of going through the watery mixtures on the same plan. This was done for the following reasons: 1. Because it was thought more likely to avoid blunders, if the quantity of only one of the ingredients was changeable, that the operator might not have his attention distracted with computing and weighing out two different quantities for each mixture. 2. Because by this progression the experiments come closer together about the medium degrees of strength, where it was supposed most accuracy would be wanted for practice. 3. As it was thought, from the first, that the best method of adjusting the duty would be by the absolute quantity of alcohol in any mixture, rather

* An account of Experiments to determine the Specific Gravity of Fluids; by J. RAMSDEN. London, 1792.

than the proportion *per cent.*, or the strength above or under proof, we judged it most expedient not to make the mixtures on either of the two last mentioned principles, lest an undue bias should be given to the judgment, merely from the mode of conducting the experiments. No real difficulty can arise in forming tables of any kind out of these numbers, which answer to an harmonic progression of strength. If the operation be tedious, to obtain the specific gravity of any single proportion, *per cent.* or otherwise, of alcohol and water, the trouble of reducing the whole to a table would not be great, and when once executed, it is done for ever.

Secondly, though the chief reasons for making the mixtures by weight, rather than by measure, have been already assigned in the Report, it is now proper to add something further on that subject. Nothing but arithmetic is required for obtaining the proportions by measure with the utmost exactness; and, as in the former case, though the operation be a little laborious singly, the computation of the entire table will be sufficiently easy. Such a table was recommended in the Report, and can be constructed by any person tolerably conversant with figures. In the pamphlet mentioned above, a method is recommended for proportioning the mixtures by measure, while the actual quantity of spirit is determined by weight, at one operation. The idea is ingenious, but in the execution it seems liable to the following objections. 1. The difficulty of obtaining the full penetration of the spirit and water, in a vessel of the shape required, where, by the intervention of such a narrow neck as is wanted, the free agitation of the fluid must be greatly impeded. 2. The difficulty of getting out all the air-bubbles, produced by the shaking, &c. in a vessel so shaped.

Weights at the different degrees of temperature.

Heat.	The pure spirit.	100 grains of spirit to 5 grains of water.	100 grains of spirit to 10 grains of water.	100 grains of spirit to 15 grains of water.	100 grains of spirit to 20 grains of water.	100 grains of spirit to 25 grains of water.	100 grains of spirit to 30 grains of water.	100 grains of spirit to 35 grains of water.	100 grains of spirit to 40 grains of water.	100 grains of spirit to 45 grains of water.	100 grains of spirit to 50 grains of water.	100 grains of spirit to 55 grains of water.	100 grains of spirit to 60 grains of water.	100 grains of spirit to 65 grains of water.
°	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
30	2487,35	2519,92	2548,42	2573,80	2596,66	2617,30	2636,23	2653,73	2669,83	2684,74	2698,51	2711,14	2722,89	2733,87
35	2480,87	2513,43	2541,84	2567,26	2590,16	2610,87	2629,92	2647,47	2663,64	2678,60	2692,43	2705,14	2716,92	2727,87
40	2474,30	2506,75	2535,41	2560,74	2583,66	2604,50	2623,56	2641,08	2657,23	2672,30	2686,32	2698,94	2710,81	2721,83
45	2467,62	2500,14	2528,75	2554,09	2577,10	2597,98	2617,03	2634,64	2650,87	2666,04	2679,99	2692,77	2704,57	2715,62
50	2460,75	2493,33	2521,96	2547,47	2570,42	2591,38	2610,54	2628,21	2644,43	2659,55	2673,64	2686,54	2698,42	2709,48
55	2453,80	2486,37	2515,03	2540,60	2563,64	2584,65	2603,80	2621,50	2637,86	2653,04	2667,14	2679,98	2691,83	2702,98
60	2447,00	2479,56	2508,27	2533,83	2556,90	2577,95	2597,22	2615,03	2631,37	2646,53	2660,62	2673,55	2685,52	2696,73
65	2440,12	2472,75	2501,53	2526,99	2550,22	2571,24	2590,55	2608,37	2624,75	2640,01	2654,04	2667,07	2679,15	2690,32
70	2433,23	2465,88	2494,56	2520,03	2543,32	2564,47	2583,88	2601,67	2617,96	2633,32	2647,52	2660,63	2672,74	2684,02
75	2426,23	2458,78	2487,62	2513,08	2536,39	2557,61	2576,93	2594,80	2611,19	2626,55	2640,81	2653,99	2666,06	2677,34
80	2419,02	2451,67	2480,45	2506,08	2529,24	2550,50	2569,86	2587,93	2604,29	2619,72	2633,99	2647,12	2659,36	2670,69
85	2411,92	2444,63	2473,33	2499,01	2522,29	2543,54	2563,01	2580,93	2597,45	2613,02	2627,39	2640,60	2652,78	2664,16
90	2404,90	2437,62	2466,32	2491,99	2515,28	2536,63	2556,11	2574,02	2590,60	2606,16	2620,52	2633,74	2646,00	2657,41
95	2397,68	2430,33	2459,13	2484,74	2508,10	2529,46	2549,13	2567,03	2583,65	2599,24	2613,57	2626,94	2639,25	2650,63
100	2390,60	2423,22	2452,13	2477,64	2500,91	2522,30	2541,92	2559,96	2576,56	2592,14	2606,50	2619,75	2632,17	2643,75
Heat.	100 grains of spirit to 70 grains of water.	100 grains of spirit to 75 grains of water.	100 grains of spirit to 80 grains of water.	100 grains of spirit to 85 grains of water.	100 grains of spirit to 90 grains of water.	100 grains of spirit to 95 grains of water.	100 grains of spirit to 100 grains of water.	95 grains of spirit to 100 grains of water.	90 grains of spirit to 100 grains of water.	85 grains of spirit to 100 grains of water.	80 grains of spirit to 100 grains of water.	75 grains of spirit to 100 grains of water.	70 grains of spirit to 100 grains of water.	65 grains of spirit to 100 grains of water.
°	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
30	2744,20	2753,75	2762,72	2771,08	2778,99	2786,36	2793,22	2799,85	2806,61	2813,85	2821,35	2828,90	2836,39	2844,16
35	2738,13	2747,74	2756,91	2765,32	2773,22	2780,59	2787,54	2794,19	2801,14	2808,52	2816,07	2823,68	2831,36	2839,26
40	2732,24	2741,86	2750,96	2759,50	2767,48	2774,90	2781,84	2788,69	2795,70	2803,17	2810,73	2818,36	2826,31	2834,40
45	2726,09	2735,77	2744,82	2753,36	2761,42	2768,85	2775,94	2782,99	2789,99	2797,45	2805,08	2812,93	2821,00	2829,28
50	2719,93	2729,64	2738,74	2747,27	2755,37	2762,95	2770,14	2777,19	2784,30	2791,72	2799,58	2807,56	2815,71	2824,12
55	2713,60	2723,51	2732,64	2741,24	2749,27	2756,83	2764,09	2771,29	2778,54	2785,96	2793,82	2801,89	2810,23	2818,80
60	2707,40	2717,30	2726,52	2735,17	2743,28	2750,93	2758,17	2765,40	2772,70	2780,26	2788,25	2796,45	2804,85	2813,65
65	2701,05	2710,96	2720,25	2728,98	2737,09	2744,86	2752,21	2759,47	2766,73	2774,43	2782,62	2790,81	2799,38	2808,31
70	2694,76	2704,64	2713,87	2722,75	2730,94	2738,73	2746,06	2753,41	2760,75	2768,45	2776,72	2785,06	2793,80	2802,88
75	2688,14	2698,07	2707,49	2716,35	2724,64	2732,39	2739,89	2747,23	2754,73	2762,58	2770,93	2779,26	2788,00	2797,21
80	2681,50	2691,50	2700,94	2709,76	2718,12	2726,06	2733,53	2740,93	2748,42	2756,43	2764,87	2773,33	2782,14	2791,52
85	2674,95	2684,98	2694,53	2703,33	2711,86	2719,74	2727,25	2734,80	2742,31	2750,22	2758,80	2767,44	2776,33	2785,81
90	2668,29	2678,49	2687,99	2696,91	2705,37	2713,32	2721,01	2728,59	2736,23	2744,24	2752,76	2761,51	2770,59	2780,11
95	2661,51	2671,82	2681,34	2690,33	2698,86	2706,88	2714,61	2722,23	2729,89	2737,98	2746,57	2755,34	2764,57	2774,25
100	2654,76	2664,99	2674,62	2683,63	2692,25	2700,33	2708,04	2715,73	2723,35	2731,55	2740,43	2749,28	2758,48	2768,43
Heat.	60 grains of spirit to 100 grains of water.	55 grains of spirit to 100 grains of water.	50 grains of spirit to 100 grains of water.	45 grains of spirit to 100 grains of water.	40 grains of spirit to 100 grains of water.	35 grains of spirit to 100 grains of water.	30 grains of spirit to 100 grains of water.	25 grains of spirit to 100 grains of water.	20 grains of spirit to 100 grains of water.	15 grains of spirit to 100 grains of water.	10 grains of spirit to 100 grains of water.	5 grains of spirit to 100 grains of water.	Water.	
°	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	
30	2852,03	2859,71	2867,12	2874,43	2881,34	2887,77	2894,22	2900,85	2908,21	2917,19	2928,80	2944,53		
35	2847,45	2855,32	2863,16	2870,87	2878,21	2885,06	2892,07	2899,31	2907,45	2916,95	2928,99	2945,02	2967,14	
40	2842,62	2850,88	2859,06	2867,08	2874,81	2882,30	2889,78	2897,61	2906,39	2916,41	2928,93	2945,25	2967,45	
45	2837,64	2846,16	2854,67	2863,04	2871,22	2879,22	2887,33	2895,67	2904,98	2915,55	2928,49	2945,20	2967,40	
50	2832,76	2841,52	2850,29	2858,96	2867,52	2875,98	2884,57	2893,58	2903,39	2914,42	2927,81	2944,73	2967,05	
55	2827,68	2836,69	2845,72	2854,75	2863,75	2872,67	2881,69	2891,11	2901,42	2913,02	2926,73	2943,98	2966,34	
60	2822,65	2831,90	2841,10	2850,50	2859,87	2869,15	2878,72	2888,62	2899,35	2911,32	2925,50	2942,98	2965,39	
65	2817,49	2826,90	2836,30	2845,97	2855,65	2865,45	2875,49	2885,85	2897,09	2909,43	2923,90	2941,69	2964,11	
70	2812,16	2821,78	2831,61	2841,42	2851,53	2861,63	2872,06	2882,90	2894,56	2907,33	2922,24	2940,13	2962,66	
75	2806,75	2816,63	2826,56	2836,80	2847,14	2857,70	2868,49	2879,67	2891,79	2905,04	2920,17	2938,33	2960,97	
80	2801,25	2811,23	2821,38	2831,92	2842,56	2853,38	2864,54	2876,22	2888,73	2902,35	2917,83	2936,31	2959,07	
85	2795,69	2805,85	2816,32	2827,12	2838,07	2849,28	2860,86	2872,88	2885,56	2899,55	2915,46	2934,14	2956,94	
90	2790,13	2800,40	2811,05	2822,15	2833,38	2844,81	2856,80	2869,16	2882,25	2896,58	2912,84	2931,77	2954,70	
95	2784,36	2794,91	2805,79	2817,08	2828,46	2840,26	2852,47	2865,15	2878,71	2893,44	2910,02	2929,15	2952,08	
100	2778,64	2789,32	2800,25	2811,80	2823,55	2835,30	2848,18	2861,12	2875,07	2890,04	2906,97	2926,28	2949,34	

Real specific gravities at the different temperatures.

Heat. °	The pure spirit.	100 grains of spirit to 5 grains of water.	100 grains of spirit to 10 grains of water.	100 grains of spirit to 15 grains of water.	100 grains of spirit to 20 grains of water.	100 grains of spirit to 25 grains of water.	100 grains of spirit to 30 grains of water.	100 grains of spirit to 35 grains of water.	100 grains of spirit to 40 grains of water.	100 grains of spirit to 45 grains of water.	100 grains of spirit to 50 grains of water.	100 grains of spirit to 55 grains of water.	100 grains of spirit to 60 grains of water.	100 grains of spirit to 65 grains of water.
30	,83896	,84995	,85957	,86825	,87585	,88282	,88921	,89511	,90054	,90558	,91023	,91449	,91847	,92217
35	,83672	,84769	,85729	,86587	,87357	,88059	,88701	,89294	,89839	,90345	,90811	,91241	,91640	,92009
40	,83445	,84539	,85507	,86361	,87134	,87838	,88481	,89073	,89617	,90127	,90596	,91026	,91428	,91799
45	,83214	,84310	,85277	,86131	,86907	,87613	,88255	,88849	,89396	,89909	,90380	,90812	,91211	,91584
50	,82977	,84076	,85042	,85902	,86676	,87384	,88030	,88626	,89174	,89684	,90160	,90596	,90997	,91370
55	,82736	,83834	,84802	,85664	,86441	,87150	,87796	,88393	,88945	,89458	,89933	,90367	,90768	,91144
60	,82500	,83599	,84568	,85430	,86208	,86918	,87568	,88169	,88720	,89232	,89707	,90144	,90549	,90927
65	,82262	,83362	,84334	,85193	,85976	,86686	,87337	,87938	,88490	,89006	,89479	,89920	,90328	,90707
70	,82023	,83124	,84092	,84951	,85736	,86451	,87105	,87705	,88254	,88773	,89252	,89695	,90104	,90484
75	,81780	,82878	,83851	,84710	,85493	,86212	,86864	,87466	,88018	,88538	,89018	,89464	,89872	,90252
80	,81530	,82631	,83603	,84467	,85248	,85966	,86623	,87228	,87776	,88301	,88781	,89225	,89639	,90021
85	,81283	,82386	,83355	,84221	,85006	,85723	,86380	,86984	,87541	,88067	,88551	,88998	,89409	,89793
90	,81039	,82142	,83111	,83977	,84762	,85483	,86139	,86743	,87302	,87827	,88312	,88758	,89173	,89558
95	,80788	,81888	,82860	,83724	,84511	,85232	,85896	,86499	,87060	,87586	,88069	,88521	,88937	,89322
100	,80543	,81643	,82618	,83478	,84262	,84984	,85646	,86254	,86813	,87340	,87824	,88271	,88691	,89082

Heat. °	100 grains of spirit to 70 grains of water.	100 grains of spirit to 75 grains of water.	100 grains of spirit to 80 grains of water.	100 grains of spirit to 85 grains of water.	100 grains of spirit to 90 grains of water.	100 grains of spirit to 95 grains of water.	100 grains of spirit to 100 grains of water.	95 grains of spirit to 100 grains of water.	90 grains of spirit to 100 grains of water.	85 grains of spirit to 100 grains of water.	80 grains of spirit to 100 grains of water.	75 grains of spirit to 100 grains of water.	70 grains of spirit to 100 grains of water.	65 grains of spirit to 100 grains of water.
30	,92563	,92889	,93191	,93474	,93741	,93991	,94222	,94447	,94675	,94920	,95173	,95429	,95681	,95944
35	,92355	,92680	,92986	,93274	,93541	,93790	,94025	,94249	,94484	,94734	,94988	,95246	,95502	,95772
40	,92151	,92476	,92783	,93072	,93341	,93592	,93827	,94058	,94295	,94547	,94802	,95060	,95328	,95602
45	,91937	,92264	,92570	,92859	,93131	,93382	,93621	,93860	,94096	,94348	,94605	,94871	,95143	,95423
50	,91723	,92050	,92358	,92647	,92919	,93177	,93419	,93658	,93897	,94149	,94414	,94683	,94958	,95243
55	,91502	,91837	,92145	,92436	,92707	,92963	,93208	,93452	,93696	,93948	,94213	,94486	,94767	,95057
60	,91287	,91622	,91933	,92225	,92499	,92758	,93002	,93247	,93493	,93749	,94018	,94296	,94579	,94876
65	,91066	,91400	,91715	,92010	,92283	,92546	,92794	,93040	,93285	,93546	,93822	,94099	,94388	,94689
70	,90847	,91181	,91493	,91793	,92069	,92333	,92580	,92828	,93076	,93337	,93616	,93898	,94193	,94500
75	,90617	,90952	,91270	,91569	,91849	,92111	,92364	,92613	,92865	,93132	,93413	,93695	,93989	,94301
80	,90385	,90723	,91042	,91340	,91622	,91891	,92142	,92393	,92646	,92917	,93201	,93488	,93785	,94102
85	,90157	,90496	,90818	,91119	,91403	,91670	,91923	,92179	,92432	,92700	,92989	,93282	,93582	,93902
90	,89925	,90270	,90590	,90891	,91177	,91446	,91705	,91962	,92220	,92491	,92779	,93075	,93381	,93703
95	,89688	,90037	,90358	,90662	,90949	,91221	,91481	,91740	,91998	,92272	,92562	,92858	,93170	,93497
100	,89453	,89798	,90123	,90428	,90718	,90992	,91252	,91513	,91769	,92047	,92346	,92646	,92957	,93293

Heat. °	60 grains of spirit to 100 grains of water.	55 grains of spirit to 100 grains of water.	50 grains of spirit to 100 grains of water.	45 grains of spirit to 100 grains of water.	40 grains of spirit to 100 grains of water.	35 grains of spirit to 100 grains of water.	30 grains of spirit to 100 grains of water.	25 grains of spirit to 100 grains of water.	20 grains of spirit to 100 grains of water.	15 grains of spirit to 100 grains of water.	10 grains of spirit to 100 grains of water.	5 grains of spirit to 100 grains of water.	Water.	
30	,96209	,96470	,96719	,96967	,97200	,97418	,97635	,97860	,98108	,98412	,98804	,99334		
35	,96048	,96315	,96579	,96840	,97086	,97319	,97556	,97801	,98076	,98397	,98804	,99344	1,00090	
40	,95879	,96159	,96434	,96706	,96967	,97220	,97472	,97737	,98033	,98373	,98795	,99345	1,00094	
45	,95705	,95993	,96280	,96563	,96840	,97110	,97384	,97666	,97980	,98338	,98774	,99338	1,00086	
50	,95534	,95831	,96126	,96420	,96708	,96995	,97284	,97589	,97920	,98293	,98745	,99316	1,00068	
55	,95357	,95662	,95966	,96272	,96575	,96877	,97181	,97500	,97847	,98239	,98702	,99284	1,00038	
60	,95181	,95493	,95804	,96122	,96437	,96752	,97074	,97409	,97771	,98176	,98654	,99244	1,00000	
65	,95000	,95318	,95635	,95962	,96288	,96620	,96959	,97309	,97688	,98106	,98594	,99194	,99950	
70	,94813	,95139	,95469	,95802	,96143	,96484	,96836	,97203	,97596	,98028	,98527	,99134	,99894	
75	,94623	,94957	,95292	,95638	,95987	,96344	,96708	,97086	,97495	,97943	,98454	,99066	,99830	
80	,94431	,94768	,95111	,95467	,95826	,96192	,96568	,96963	,97385	,97845	,98367	,98991	,99759	
85	,94236	,94579	,94932	,95297	,95667	,96046	,96437	,96843	,97271	,97744	,98281	,98912	,99681	
90	,94042	,94389	,94748	,95123	,95502	,95889	,96293	,96711	,97153	,97637	,98185	,98824	,99598	
95	,93839	,94196	,94563	,94944	,95328	,95727	,96139	,96568	,97025	,97523	,98082	,98729	,99502	
100	,93638	,93999	,94368	,94759	,95152	,95556	,95983	,96424	,96895	,97401	,97969	,98625	,99402	

3. The difficulty, or almost impossibility, of bringing the mixture, by the repeated fillings, to coincide exactly with the ring on the neck: for this purpose, the last quantities of water must be put in by such small portions at a time, that scarcely any attention will be equal to the task; and if at length too much be added, it cannot be taken out again without injuring, in some degree, the accuracy of the experiment, which depends on combining the precise quantity of water required to fill the vessel up to the mark, when the full penetration has taken place. 4. In opening the vessel so frequently, to fill it up, a sensible part of the spirit must be lost by evaporation. 5. Moreover it is necessary that, at the end of the operation, the fluid should throughout be exactly of the same temperature as the pure spirit was in the preparatory experiment with it alone; the difficulty of effecting and determining which must be obvious to every one, especially in a vessel of such a size and shape. Lastly, as this vessel is much less manageable than the weighing-bottle, I think the fluid in it cannot be brought to the mark with nearly the same degree of accuracy. These objections, joined to the consideration that no object can be attained in this way, which was not accomplished, with at least equal accuracy, and probably no greater trouble, by weighing the spirit and water separately, determined us not to attempt any experiments with such an instrument.

Thirdly, it is now to be explained why we undertook to determine the effect of heat and cold on the fluids, by means of the weighing-bottle. When, preparatory to our former experiments, that part of the subject came under consideration, the method of ascertaining the expansions and contractions, by means of instruments like thermometers, was one of the first that presented itself. On this occasion, Mr. CAVENDISH was so good as to mention some experiments made by his father, Lord CHARLES CAVENDISH, with instruments on that construction, for the very purpose of determining the expansion of fluids; and other experiments, of the same nature, have appeared in print. The application of this method, however, was thought liable to a most important objection, from the great difficulty there is of being sure that the spirits in the ball are exactly of the temperature indicated by the thermometer placed by the side of it. To enlarge upon this circumstance would be useless, as every person accustomed to experiments is aware, that all possible precautions, joined to the utmost attention in the observer, are scarcely sufficient to ensure this essential correspondence of temperature; which reason alone would have induced us to prefer the method by weight. But there was another argument which still more forcibly determined us in favour of the latter; namely, that the effect of mixture was found in that way, and therefore we were sure it admitted of as great accuracy as was obtained in the other part of the experiments. Greater nicety, if there had been a method which allowed of it, would have been superfluous; and to incur the risk of less accuracy would have been absolutely unjustifiable. By using the same method to determine all the changes of specific gravity, those from heat as well as those from mixture, an uniformity is given to the whole series of experiments, and no one part of the results is liable to more suspicion than another.

Till this time, I believe, the instruments with a ball and tube, for trying expansions, had all been constructed in the manner of real thermometers, to be filled by means of heat;

which circumstance, and the trouble attending it, was a further objection to their use: but in the pamphlet abovementioned are proposed two instruments of this nature, to be filled without heat; one being provided with two equal tubes, the other with a short tube, closed by a stopper. Though both these instruments, and especially the latter, seemed liable to several causes of error, yet, to remove doubts, and bring the method by weight to a proper test, Mr. Gilpin was desired to make some trials with them; Mr. Ramsden, the author of the pamphlet, having been previously requested to go through the whole series of experiments on his own plan, which he declined to do. With no small difficulty Mr. Gilpin got the instruments executed; and an account of the experiments to which he subjected them shall be given, in his own words, at the end of this Report. From the perusal of that account, it will be perceived, that the disagreement of the experiments among themselves, is nearly equal to the quantity by which any of them differ from the expansions as obtained by weight. On the whole, however, they give the expansion somewhat less, the cause of which I do not see; possibly it may depend on the fluid in the ball not being quite heated and cooled to the degree shown by the accompanying thermometer; possibly there may be a difference in the expansion of the glass with which the instruments were made, and that of the weighing-bottle, for these numbers are in both cases the excess of the expansion of the fluid over glass; or it may turn on some other circumstance, which has eluded our attention. Whatever may have occasioned the deficiency, I think the experiments will satisfy any one, that most dependence is to be placed on the weights; and at all events the difference is not such as to affect the third place of decimals, or consequently the tables intended for practice.

Probably no one will be surprised that we did not think it necessary to make trial of the weighing-bottle proposed by Mr. RAMSDEN. Not to mention other inconveniences attending this instrument, it seems evident that a piece of flat glass, with a thermometer projecting from it, laid down on the mouth of a bottle, cannot be depended upon to push off the superfluous liquor equally every time; and that the proper wiping of the bottle, when so covered, will be attended with difficulties of various kinds.

It is true that the experiments by weight took up much time, and demanded great patience. But I believe that similar experiments, by the methods recommended in the pamphlet, if executed with the same degree of accuracy, would be found not much less tedious. However this may be, it is a consideration of no consequence, provided the results at length obtained be right. Now of these there is no direct impeachment, though some doubts are thrown upon them, on four accounts; evaporation; condensation of moisture on the weighing-bottle; difficulty of shaking the fluid in it; and uncertainty in determining the heat. With regard to evaporation, its effect, we hope, has been ascertained, and allowed for, in these new experiments. All error from condensation of moisture was obviated by careful wiping. The fluid in the weighing-bottle was agitated, and mixed together, by means of the thermometer immersed in it; besides which, a considerable degree of motion could be given to it, even when the ball was very nearly full, by shaking the bottle in various directions. Mr. GILPIN'S known accuracy, and the care he bestowed on these experiments, must gain him credit for having duly watched the thermometer, so as to seize the moment when it gave the just temperature of the mass.

Our experiments were finished, and the tables now given were drawn out, before the appearance of Mr. RAMSDEN's pamphlet. Yet if any of the methods he proposed had been really preferable, the whole series should have been repeated on that new plan, and particularly with regard to the effect of heat, if the instruments for that purpose had been found to answer the character given of them. But as this was not the case, we have thought it right to adhere to an obvious and direct method, in which, however laborious, there can be no fallacy, and the uniformity of which ensures an equal degree of accuracy to every part of the operation.

SINCE the publication of our first tables, several hydrometers have been contrived, with the view of applying them to practice. Those of copper were rejected on account of the errors which small and almost imperceptible bruises in them might occasion; and for the same reason no other metal was tried. Mr. GILPIN has constructed two areometers of glass; one with the stem so divided, that an easy table may be formed for the correction necessary according to the different weights with which it is used; the other with a separate scale fixed to each of those weights, made to slip into the tubular stem of the instrument; a contrivance that obviates the necessity of a table. Mr. RAMSDEN also has invented a balance hydrometer, with several varieties of construction, one of which is detailed in his pamphlet. All the above-mentioned instruments appear to have fully as much accuracy as can be required ; of their preference in other respects, the practical officers who are to use them will probably be found the best judges. That which can be managed with the greatest facility and quickness, which affords the least opportunity of making blunders, which is least liable to be out of order, and shews most immediately if it be so, will unquestionably prove the most satisfactory in practice. Hydrometers having a thermometer inclosed within them must be condemned, as not ascertaining the temperature with the requisite precision. An attempt to supersede the use of the thermometer, by employing for the hydrometer, a substance which "has the same "degree of expansion as the mean of the compounds," is very inconsistent with the kind of accuracy sought by these experiments.

As an allowance is made, in our table of specific gravities, for the expansion and contraction of the glass weighing-bottle, this must be taken into the account, with every areometer, whenever much exactness is desired.

I am still of opinion, that the best way of laying the duty would be directly on the quantity of alcohol contained in any composition ; and though this might require too great a change in the present system of laws, yet as the same principle may be applied in estimating the strength, and taking stock, I will just mention in what manner the computation can be most readily made. From the numbers in this Supplementary Report a table must be constructed, on the top of which shall stand every degree of heat from 40, or 30, to 80, and at the side every specific gravity from ,825 to 1,000, if it be thought necessary, or as much less as will answer the purpose. The places of this table are to be filled up, by computing, from the original tables, the quantity by measure of alcohol and water corresponding to each specific gravity and degree of heat; and then dividing the quantity of alcohol by the whole quantity of the mixture; thus a decimal multiplier will be obtained, which must be put in the compartment of the table formed by the intersection of the columns of that particular heat and specific gravity. When the table is completed in this manner, we have only to multiply the contents of any cask, as found on gauging it, by the decimal number given in the table for the heat and specific gravity of the liquor, and the product will be the quantity of pure alcohol it contains. Hence it must be evident, that no objection can lie to this method on account of difficulty; if, however, it be thought more eligible, for different reasons, to adopt the proportion of alcohol *per cent.*, the relation of strength to the point of proof, or any other method, the numbers in this Report will equally apply to all, with the proper variation in the table to be employed.

As to the calculation necessary for constructing the table of decimal multipliers, what has been already said with respect to the reduction of the harmonic numbers applies also to it. The labour of the whole will not be very great, and it is once for all. The process is not an approximation, but a plain arithmetical computation, which may be carried on true to as many decimal places as the experiments will allow. For this purpose, indeed, it is necessary to have the weight of a known measure of water. Mr. RAMSDEN'S method of obtaining this, by means of a cylinder, is far preferable to that of hollow cubes, particularly if the ends of the cylinder can be made as true as the body of it. But in applying this instrument to fix the term of proof, as proposed by that gentleman, it must be remembered, that 7lb. 13 oz. is not the weight of a gallon of proof spirit, but of spirit one to six under proof. On that proportion the value of proof was computed in the Report, by the same rule as Mr. RAMSDEN has since given, but which it was not thought necessary to detail at full length.

Although, as was said in the original Report, the quantity of extraneous substances usually found in spirituous liquors does not increase their specific gravity so much as to be worth the consideration of Government, yet this is by no means the case when such substances are added intentionally. The effect of alkalies is well known. Mr. RAMSDEN's experiments shew how great a change of specific gravity is produced by sugar, when dissolved plentifully in weak liquors; and in an experiment made by order of the Board of Excise, $\frac{1}{64}$ part of sugar, put into very strong spirit, reduced its apparent strength no less than 17 *per cent.* by CLARKE's hydrometer.

I conclude with observing, that the *execution* of the experiments, and of the computations, rested entirely with Mr. GILPIN, who is responsible for their accuracy, and entitled to the praise they may be found to merit. For the general plan, as well as the particular methods adopted, I hold myself accountable, and have now so fully stated my reasons for what I recommended to be done, that any competent person will readily judge of their validity. In this and the foregoing Report, I have purposely avoided all philosophical deductions, and a comparison with former experiments; that the narrative might not be loaded with any foreign matter, to interfere with the practical object for which this business was undertaken.

C. BLAGDEN.

Appendix to the foregoing Report. In a Letter from Mr. George Gilpin, *Clk. R. S. to* Charles Blagden, *M. D. Sec. R. S.*

SIR,

HAVING completed two instruments for trying the expansion of fluids, according to the method described by Mr. RAMSDEN, with a stopper going into a tube on the side of the ball, I now present you with an account of the experiments which I have made with them, that you may judge how far such instruments are deserving of notice. The scale of the longest admits of ,26 of an inch for each degree of the thermometer, and that of the shortest ,17 of an inch for each degree.

They were charged with pure spirit: some of the same that was made use of in our experiments by weight, specific gravity ,82514: and having hung them up by the side of each other to a piece of wood, provided for the purpose, with the same sensible thermometer hanging between them that was used in our experiments by weight, I immersed them in a large quantity of water brought to the temperature of 60°, the one quite, the other nearly, to the height of the fluid in the stem. In this water they were suffered to continue until they had arrived at that temperature, when it was observed that the spirit in the tube of the long instrument stood at o, or the commencement of the scale, and the spirit in the tube of the short instrument stood at $\frac{15}{10000}$ above o, which I shall in future for shortness call 1,5, and which it is evident must be applied with the sign + or — to the quantity of expansion or contraction read off from above or below o, as the case may require. They were then cooled down to 30° of temperature, when the spirit in the long instrument was found to stand 165, and that in the short instrument 163,5 below o. They were again brought to the temperature of 60°, when the spirit in the long instrument was found to stand 0,5, below o, and in the short instrument 1,5 above o as before. They were then heated to 100°, when the spirit in the long instrument stood at 231, and in the short instrument at 233,5 above o. I brought them again to the temperature of 60°, when the spirit in the long instrument was found to stand 3 below o, but in the short instrument 1,5 above o as before.

It appears from these experiments, that the contraction of the spirit, by the long instrument, for 30 degrees, that is, in cooling down from 60° to 30°, is 165; but in heating it up again to 60°, it was found not to stand at o, as before, but 0,5 below; therefore the expansion will be only 164,5, the mean is 164,75. The expansion, on heating up from 60° to 100°, will be 231+0,5=231,5; but on cooling down from 100° to 60° again, the spirit was found to sink 3 below o, therefore it will be 231+3=234; the mean 232,75, and the total expansion, from 30° to 100°=397,5; differing from ours, in defect, by 0,05 of a division. But the two methods of heating from 60° to 100°, and cooling from 100° to 60° again, differ 2,5 divisions, or so many ten thousandth parts of the whole.

The contraction from 60° to 30°, by the short instrument, appears to be 163,5+1,5=165, and the expansion, on heating up again to 60°, the same; from 60° to 100° it was found to be 233,5 — 1,5 = 232, and the contraction in cooling down again from 100° to 60° the same; the total expansion 397, differing from ours 0,55 of a division, in defect.

After the above experiments, the instruments were emptied of the spirit; and another day, preparatory to a repetition of the experiments, they were charged again with some of the same spirit that was used before, and the results found to be as follow.

Having brought them to the temperature of 60°, I found the spirit in the long instrument to stand 3 above 0, and in the short instrument 5 below 0. They were then cooled down to 30° of temperature; when the spirit in the long instrument was found to sink to 161,5, and in the short instrument to 167,5. They were afterwards brought back again to 60° of temperature; when the spirit in the long instrument stood 3 above 0, as before, but in the short instrument 5,5 below 0. I then heated them up to 100°, and it stood in the long instrument at 234, and in the short instrument at 226, above 0. They were again brought to the temperature of 60°; when it was found to stand in the long instrument at 0, and in the short instrument at 8 below 0.

From the above experiments it appears, that the contraction by the long instrument, in cooling down from 60° to 30°, is 161,5 + 3 = 164,5, and the expansion in heating up again to 60°, the same. In heating up from 60° to 100°, 234 — 3 = 231; but the contraction in cooling down again from 100° to 60°, 234; the mean is 232,5, and the total expansion from 30° to 100° = 397, differing from the experiments by weight 0,55 of a division, in defect: but if no mean be taken, the deficiency will appear greater. The difference between heating up from 60° to 100°, and cooling down again from 100° to 60°, is 3 divisions, still more considerable in this than in the last experiment.

The contraction by the short instrument from 60° to 30° is $167,5 - 5 = 162,5$, and the expansion from 30° to 60° again $167,5 - 5,5 = 162$; the mean is 162,25. On heating up from 60° to 100°, $226 + 5,5 = 231,5$; but the contraction, in cooling down again from 100° to 60° was $226 + 8 = 234$; the mean is 232,75, and the total expansion from 30° to 100° = 395; differing from the experiments by weight 2,55 divisions, in defect. The difference between heating up from 60° to 100°, and cooling down again from 100° to 60°, is 2,5 divisions.

After the above experiments had been made, the spirit was let out, and, on a subsequent day, the two instruments were charged again with some of the same spirit, previous to the following experiments.

After bringing the spirit to the temperature of 60°, I found it to stand in the long instrument 6 above 0, and in the short instrument 2 below 0. I cooled the spirit down to 30°, when it stood in the long instrument 158,5, and in the short instrument 166, below 0. I brought it again to the temperature of 60°, and it returned to the same point it set off from, in both instruments. The spirit was then heated to 100°; when it rose in the long instrument to 235, and in the short instrument to 230, above 0. I cooled it again to the temperature of 60°, when it was found to stand in the long instrument 1 below 0, and in the short instrument 5 below 0.

It appears, from the above experiments, that the contraction by the long instrument in cooling down from 60° to 30° is 158,5

$+6 = 164,5$, and the expansion in heating up from 30° to 60°, the same. On heating up to 100°, $235-6 = 229$, but the contraction in cooling down from 100° to 60° again, $235+1 = 236$; the mean is 232,5, and the total expansion from 30° to 100° $= 397,0$; differing from the experiments by weight 0,55 of a division, in defect; but the two methods in this experiment differ very considerably from each other, namely, by no less a quantity than 7 divisions. In this experiment it seems probable either that some of the spirit leaked out at the stopper, or that the stopper shifted its place a little, so as to enlarge the capacity of the ball.

The contraction by the short instrument in cooling down from 60° to 30° was $166 - 2 = 164$, and the expansion on heating up again to 60°, the same. On heating up to 100°, it was $230 + 2 = 232$, but on cooling down again to 60° the contraction was $230 + 5 = 235$; the mean is 233,5, and the total expansion 397,5; differing from the experiments by weight 0,05 of a division, in defect. The difference between the two methods, in heating up from 60°, to 100°, and in cooling down again from 100° to 60°, is three divisions.

It appears from the preceding experiments, that the mean of all the quantities found on heating up from 30° to 100°, and cooling down from 100° to 30°, taken together, gives for the total expansion 397,16 by the long instrument, and 396,5 by the short; the former errs 0,39, and the latter 1,05 divisions from the experiments by weight, in defect. It appears also that the mean of all the quantities found by the long instrument, on heating up from 30° to 100°, gives for the total expansion 4,34 divisions less than the mean of all the quantities taken together, by the same instrument, on cooling down from

100° to 30°; and the difference by the short instrument is 2 divisions.

The following experiments were made with a mixture of equal parts of spirit and water by weight; the spirit being of the strength already mentioned.

Having charged the instruments with the mixture, and brought it to the temperature of 60°, it was found to stand in both of them at 1 above 0. The mixture was then cooled down to 30°, when it stood at 125 below 0 in the long instrument, and 124,5 in the short instrument. It was brought back to the temperature of 60°, when, in the long instrument it was found to stand 1,5 above 0, but in the short instrument 1 above 0 as before. I heated the mixture to 100°, when it stood at 185 in the long instrument, and in the short instrument at 183,5 above 0. The mixture was afterwards cooled to the temperature of 60°, when it was found to stand 2,5 above 0 in the long instrument, but in the short instrument 1,5 below 0. After keeping them upright in the temperature of 60° two hours, I found the mixture in the long instrument to stand 3 above 0, but in the short instrument 2 below 0. I heated it again to 100°, when the mixture in the long instrument was found to stand 185, and in the short instrument 180,5 above 0. I brought the mixture again to the temperature of 60°, and found it stand 2,5 above 0 in the long instrument, and in the short instrument 4 below 0.

From the above experiments the contraction of this mixture from 60° to 30° was found to be, by the long instrument, $125 + 1 = 126$; but in heating up to 60° again, the expansion was $125 + 1,5 = 126,5$; the mean is 126,25. The expansion in heating up from 60° to 100° was $185 - 1,5 = 183,5$, but the contraction in cooling down from 100° to 63° was 185 — 2,5 = 182,5. In heating up again to 100° it was 185 — 3 = 182, but in cooling down again to 60°, 185 — 2,5 = 182,5; the mean of the four is 182,62, and the total expansion from 30° to 100° = 308,87; differing from the experiments by weight 1,7 division, in defect. The difference between the two methods of heating up from 60° to 100°, and cooling down again from 100° to 60°, taking a mean of the two heatings, and the mean of the two coolings, is 0,75 of a division.

The contraction by the small instrument, in cooling down from 60° to 30°, was 124,5 + 1 = 125,5. On heating up again to 60°, the expansion was the same. In heating up from 60° to 100° the expansion was 183,5 — 1 = 182,5; but in cooling down to 60° again, the contraction was 183,5 + 1,5 = 185. In heating again up to 100°, the expansion was 180,5 + 2 = 182,5; but in cooling again to 60° the contraction was 180,5 + 4 = 184,5. The mean of these four gives 183,62, for the expansion from 60° to 100°; and therefore the total expansion from 30° to 100° will be 309,12, differing from the expansion found by the experiments by weight 1,45 division, in defect. The difference between the mean of the two heatings up from 60° to 100°, and the two coolings down from 100° to 60° again, is 2,75 divisions.

The mixture made use of in the above experiment was now emptied out, and the instruments were charged with more of the same, preparatory to the following experiments.

The mixture being brought to the temperature of 60°, was found to stand in each of the instruments at 1,5 above 0. It was then cooled down to 30°, and it stood in the long instrument 124,5, and in the short instrument 125, below o. It was then brought back to the temperature of 60°, and it stood in the long instrument 1,5 above o as before, but in the short instrument 1 above o only. I heated the mixture to 100°, when it stood at 182,5 in the long instrument, and in the short instrument at 183,5 above o. The mixture was afterwards brought to the temperature of 60°, when it was found to stand at o in both instruments.

It appears from the preceding experiments, that the contraction of this mixture in cooling down from 60° to 30°, by the long instrument is 124,5 + 1,5 = 126, and the expansion in heating up again from 30° to 60°, the same. The expansion in heating up from 60° to 100° was 182,5 — 1,5 = 181; but in cooling down again from 100° to 60°, the contraction was 182,5; the mean is 181,75, and the total expansion from 30° to 100° will be 307,75, differing from the experiments by weight 2,82 divisions, in defect. The difference between the two methods of heating up from 60° to 100°, and cooling down again from 100° to 60°, is 1,5 division.

The contraction of the mixture in cooling down from 60° to 30°, by the short instrument is 125 + 1,5 = 126,5; but in heating up again to 60°, the expansion was 125 + 1 = 126; the mean is 126,25. The expansion in heating up from 60° to 100° was 183,5 — 1 = 182,5, but in cooling down again from 100° to 60° the contraction was 183,5; the mean is 183; and therefore the total expansion from 30° to 100° will be 309,25, differing from the experiments by weight 1,32 division, in defect. The difference between the two methods of heating up from 60° to 100°, and cooling down again from 100° to 60°, is 1 division.

It appears from all the preceding experiments with the mixture of equal parts of spirit and water, that the mean of all the quantities found on heating up from 30° to 100°, and cooling down again from 100° to 30°, taken together is, for the total expansion, 308,46 by the long instrument, and by the short instrument 309,29; the former errs 2,11, and the latter 1,28 divisions, in defect, from the experiments by weight; and that the mean of all the quantities found by the long instrument, in heating up from 30° to 100°, gives for the total expansion 0,33 division less than the mean of all the quantities taken together, by the same instrument, in cooling down from 100° to 30°. The difference by the short instrument is 1,83 division.

Although the results found from the preceding experiments come nearer those of the experiments by weight than might have been expected, considering the many objections that instruments of this kind must naturally present, and the great differences which were actually found among themselves on repeating the experiments, especially in the expansion of pure spirit, where the difference has been equivalent to 1,68 grains in weight, upon the quantity used in our experiments with the weighing-bottle; yet I think, after a careful perusal of the foregoing facts, I shall not be thought too precipitate when I say, that these instruments neither do nor can possess that accuracy which we have been led to expect from them. We have seen, in the foregoing experiments, that there has sometimes been apparently a loss of some part of the fluid, after an alteration of the temperature; at other times there appeared to be no loss at all; and sometimes there appeared to be even more spirit in the instrument than there was at first. These contradictory facts may, I apprehend, be accounted for in the following manner. The mechanical operation of grinding a stopper that will fit so delicate a tube, as is here necessary, perfectly tight, must be acknowledged to be difficult; and should it happen to be done accurately, so that none of the fluid is lost in one degree of temperature, it is very doubtful whether, on exposing this instrument to a different temperature, the expansion would be the same in both the tube and stopper. It appears most probable, from these experiments, that they actually did not expand alike, as perhaps no two pieces of glass ever do; and the effect to be expected from a less expansion of the stopper than of the tube is, either that some of the fluid would leak out, or that the capacity of the ball would be enlarged. But the chief reason why there may sometimes seem to be a loss, at other times no loss at all, I apprehend to be, that more of the fluid will adhere to the upper part of the tube, on filling it, at one time than at another. In the use of this instrument also, a small error may arise from the stopper not being always put in exactly alike; in which case the capacity of the instrument would be altered; and, of course, the divisions on its stem would not give the expansion of the fluid accurately. Care was always taken in these experiments to put the stopper in as nearly alike as possible; but it might not perhaps always be done exactly so.

It is also obvious, that experiments with this instrument will be affected by another source of error, if made in the manner which is recommended, namely, by heating the fluid up from 60° to 100°, and cooling it down again to 30°: for it must be evident that the whole length of the tube will then be left wet by the fluid, in sinking from 100° to 30°, and consequently the expansion will be made to appear too great. The effect of this circumstance will be very considerable; but in the use of this instrument we have no certain means of ascertaining with accuracy the quantity of error occasioned by it, because that quantity falls in with other errors. Of this I shall speak more hereafter, in my remarks on another instrument which I constructed, without a stopper, and which was also recommended by the same gentleman.

THE former experiments were all made with that kind of instrument which has a tube rising from the side of the ball, with a ground-glass stopper inserted into it; an instrument we have seen by no means to be considered as sufficiently accurate for ascertaining the expansion of fluids; I therefore constructed another, similar to the other of the two recommended by Mr. RAMSDEN, which has two tubes rising from the ball, one on each side.

Having charged this instrument with some of the same spirit which was made use of in the former experiments, and brought it to the temperature of 60°, the spirit in the two tubes was found to stand at 4 above o. It was then cooled down to 30°, when the spirit in the two tubes was found to stand at 161 below o, the instrument being always so held as to bring it to the same point in both tubes. I then heated it up to 100°, and it stood in the two tubes at 236 above o. I cooled it again to 30°, when it was found to stand in the two tubes at 162 below o. It was again heated up to 100°, and it stood in the two tubes at 236 above o. I then brought it again to the temperature of 60°, and found it to stand in the two tubes at no more than 3 above o.

It appears from the above experiments, that the contraction of the spirit from 60° to 30° is $161 + 4 = 165$, and the expansion in heating up again to 60°, the same. On heating up from 60° to 100°, $236 - 4 = 232$, and therefore the total expansion from 30° to 100° is 397; but in cooling down from 100° to 30°, the total expansion will be $236 + 162 = 398$; the former quantity differs 0,55, in defect, and the latter 0,45 of a division, in excess, from the experiments by weight. Now it is evident that the method of heating up from 30° to 100° can only be admitted as giving a true result, for it was found on cooling the spirit down from 100° to 30°, that the contraction from 60° to 30° had been increased by 1; so much of the fluid being left behind in the upper part of the two tubes, as appears on its being heated up again to 60°, for then it stood lower in the two tubes by 1 than it did before; care having been taken that the upper part of the two tubes should be as dry as possible before the experiment commenced, for which purpose the instrument was charged over night, and constantly kept in a vertical position. It must also be obvious that 397, which was found for the total expansion in heating up from 30° to 100°, must likewise be too great by nearly the same quantity, it having been cooled down from 60° to 30° previous to its being heated up to 100°, as this would tend to make it sink so much lower than it would have done in the first instance had that not been the case.

After the above experiments, the spirit was poured out, and, previous to the repetition of the foregoing experiments on a future day, it was charged with more of the same spirit which was used in the former experiments, and the instrument was hung up as before.

Having brought it to the temperature of 60°, the spirit in the two tubes was found to stand at 4 above o. I cooled it down to 30°, when it stood in the two tubes at 160,5 below o. I brought it again to the temperature of 60°, and it was found to stand in the two tubes at 4 above o as before. It was then heated up to 100°, and was found to stand in the two tubes at 236 above o. I cooled it down again to 30°, and found it to stand in the two tubes at 162 below o. It was then brought again to the temperature of 60°, and was found to stand in the two tubes at no more than 2,5 above o.

From the preceding experiments it appears, that the contraction in cooling down from 60° to 30°, is 160,5 + 4 = 164,5, and in heating up from 30° to 60° again, the expansion was the same. In heating up from 60° to 100°, the expansion was 236 — 4 = 232, therefore the total expansion in heating up from 30° to 100° will be 396,5; but in cooling down again from 100° to 30°, we shall have for the total expansion 236 + 162 = 398. The former quantity of 396,5 differs 1,05 in defect, and the latter 0,45 of a division in excess, from the experiments by weight: but it is obvious from this, as well as from the preceding experiment, that the method of heating up from 30° to 100° can only give the true expansion, as has already been observed: for when the spirit is cooled down from 60° to 30° the expansion will be made greater than it ought to be; as it was found on setting off, that the spirit in the two tubes at 60° of temperature stood at 4 above o; and after having been cooled down to 30°, and heated up again to 60°, it was found to stand the same: but after having been heated up to 100°, and cooled down again to 30°, the contraction from 60° to 30° was found greater by 1,5 than before; and on heating up to 60° again, it was found to stand only 2,5, instead of 4, above 0. It is therefore very reasonable to conclude, that a quantity equal to 1,5 had adhered to the upper part of the tubes, and no well-grounded objection can be made to this, when we consider that 1 division is only equal to ,015 of a grain of spirit, in this instrument.

It appears then from the preceding experiments, that the mean of the quantities found, on heating up from 30° to 100°, including the error that must arise from some of the fluid adhering to the tube, in cooling it down from 60° to 30°, previous to its being heated up from 30° to 100°, gives for the total expansion of the spirit 396,75; and in cooling down from 100° to 30°, 398,0; the difference is 1,25: but I have already shewn that this difference is not so great as it would have been had it not been cooled down from 60° to 30°: if therefore we say, as 232 : 1,25 : : 164 : 0,88, it is evident that the latter quantity must be subtracted from 396,75, and there will remain for the total expansion of the spirit by this instrument, in heating up from 30° to 100°, 395,87, which is different from the experiments by weight 1,68 division, in defect.

The following are experiments made with the same instrument, and a mixture of equal parts of spirit and water, being some of the same which was used in the former experiments.

Having charged the instrument with this mixture, it was immediately put into a vessel of water, whose temperature was 60°, and the mixture was found to stand in the two tubes at 3,5 above 0. I then cooled it down to 30°, and it sunk to 122 below o. I heated it up to 100°, when it was found to rise to 188 above o. It was afterwards brought to the temperature of 60°, and suffered to remain in that temperature for three hours, when it was found to stand at 6 above o.

It appears from the above experiments, that the contraction in cooling down from 60° to 30°, is $122 + 3{,}5 = 125{,}5$; and on heating it up to 100°, we have for the total expansion from 30° to 100°, $122 + 188 = 310$; but it is obvious that this total expansion cannot be the true one; for it appears, on suffering the instrument to remain three hours in the temperature of 60°, that it was found to have collected a quantity $= 2{,}5$, that had undoubtedly adhered to the upper part of the tube when charged, and the fluid having arrived at the temperature of 60° sooner than what adhered could descend, it was of course left behind on cooling the mixture down to 30°; if therefore that quantity had been collected while it remained at the temperature of 60°, it would have stood at 6 above o, and the contraction from 60° to 30° would have been $119{,}5 + 6 = 125{,}5$ below o; and the total expansion from 30° to 100°, $= 119{,}5 + 188 = 307{,}5$ instead of 310, as was found before; and differing from the experiments by weight 3,07 divisions, in defect.

The same mixture having been suffered to remain in the instrument, which was hung up as before, the following experiments were tried two days afterwards.

Having brought the mixture to the temperature of 60°, it was found to stand in the two tubes at 5,5 above o. It was cooled down to 30°, and was found to sink to 120 below o. I then heated it up to 60°, and found the mixture in the two tubes to stand at 5,5 above o as before. It was afterwards heated up to 100°, when the mixture in the two tubes was found to have risen to 187 above 0. I again cooled it down to 30°, and found it to stand in the two tubes at 122 below 0. Lastly, I heated it again up to 60°, and found it to stand in the two tubes at no more than 4 above 0.

From the above experiments it appears, that the contraction of the mixture in cooling down from 60° to 30°, is 120 + 5,5 = 125,5; and the total expansion on heating up from 30° to 100°, including the error arising from cooling it down from 60° to 30°, will be 120 + 187 = 307; but in cooling down again from 100° to 30°, we shall have for the contraction 187 + 122 = 309. The former quantity of 307 errs from the experiments by weight 3,57, and the latter 1,57 division, in defect.

But by taking a mean of the quantities found on heating the mixture up from 30° to 100°, including the error arising from some of the fluid being left adhering to the tube, in cooling down from 60° to 30° previous to its being heated up from 30° to 100°, we shall have for the total expansion 307,25, and it was found in cooling down from 100° to 30° to be 309; the difference is 1,75; if then we say, as 182 : 1,75 : : 125,5 : 1,21, the last number being subtracted from 307,25, we shall have for the true expansion in heating up from 30° to 100°, 306,04; differing from the experiments by weight 4,53 divisions, in defect.

From what was advanced by Mr. RAMSDEN respecting the accuracy of the two instruments with which the foregoing experiments have been made, there was great reason to expect that different results would have been found. It appears that no dependance ought to be placed on experiments made with that kind of instrument which has a tube rising from the side of the ball, to be closed with a stopper. More accuracy may undoubtedly be expected from experiments made with the other kind of instrument which has two tubes, because one of the inconveniences attending the former is removed in it: but we have seen that even experiments made with this instrument do not bear the same marks of accuracy as the experiments by weight; nor can this be much wondered at, if it be considered that the trifling error of ,027 of an inch, in constructing the instrument, will produce an error of one division, which is equal to 0,24 of a grain on the quantity contained in our weighing-bottle; and how difficult and uncertain it is in such an instrument to ascertain the exact temperature, by placing a thermometer only by the side of it. It is not uncommon to see the fluid in the expansion instrument, and the mercury in the thermometer, move contrary ways: and I have more than once observed an alteration in the thermometer, of more than half a degree, when no alteration whatever has been produced in the fluid in the expansion instrument. Indeed, on the least reflection it must be obvious to every one, that the changes of temperature of the fluid in a ball of $1\frac{1}{4}$ inch diameter, cannot be expected to be so quick as in one of 0,22 of an inch. It is also of the utmost consequence in making experiments with this instrument, though it will render it extremely tiresome to the experimenter, that it be in continual motion; for should that precaution not be observed, very considerable errors indeed will take place.

I am, &c.

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G. GILPIN.