LX. The periodic law, as illustrated by certain physical properties of organic compounds.—Part II. The melting-and boiling-points of the halogen and alkyl compounds of the hydrocarbon radicals

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TABLE II.—Showing the effect of Length and of Hardness on the Induction-Coefficient of Magnets.

Length of bar in centimetres.	Ratio of length to diameter.	Unit field.		Mean of numbers in columns 3 and 4.	Magnetic moment per gramme.	Remarks.
		Apparent percentage increase of moment for unit field: side-on position.	Apparent percentage increase of moment for unit field: end-on position.			
3	10	0.80	0.90	0.85	27	Glass hard
4	16	0.67	0.73	0.70	32	"
4	16	0.67	0.70	0.69	35	"
6	20	0.51	0.67	0.59	36	"
7	31	0.51	0.58	0.54	39	"
8	32	0.51	0.58	0.54	54	"
8	32	0.51	0.58	0.54	52	"
10	34	9.46	0.56	0.51	40	"
10	44	0.40	0.56	0.48	43	"
7	47	0.46	0.51	0.49	57	"
10	50	0.44	0.58	0.51	67	"
10	50	0.48	0.54	0.51	60	"
10	50	0.46	0.55	0.51	53	"
10	50	0.46	0.52	0.49	71	"
10	50	0.46	0.56	0.51	60	"
10	67	0.41	0.51	0.46	65	"
7	73	0.41	0.50	0.47	64	"
10	105	0.42	0.45	0.43	66	"
10	34	0.47	0.53	0.50	41.5	Glass hard.
10	34	0.63	0.67	0.65	44.5	Yellow.
10	34	0.84	0.98	0.91	54.1	Blue.
10	48	0.32	0.40	0.36	45	Glass hard.
10	48	0.43	0.55	0.49	46	Yellow.
10	48	0.53	0.67	0.60	71	Blue.

LX. *The Periodic Law, as Illustrated by certain Physical Properties of Organic Compounds.*—Part II. *The Melting- and Boiling-points of the Halogen and Alkyl Compounds of the Hydrocarbon Radicals.* By THOMAS CARNELLEY, D.Sc., Professor of Chemistry in University College, Dundee*.

IN the present series of papers my object is to determine whether the elements are in any way analogous to the hydrocarbon radicals of Organic Chemistry. For this purpose

* Communicated by the Author.

I have made a careful comparison of the physical properties (chiefly melting- and boiling-points) of a large number of both organic and inorganic compounds, and believe that I have been able to make out numerous and varied relationships between these properties.

My first paper (Phil. Mag. [5] xviii. p. 1) dealt with the melting- and boiling-points and heats of formation of the normal *halogen* compounds of the *elements*, and I showed that certain well-defined relationships existed as regards the above physical properties of these compounds. My second paper (ibid. [5] xx. p. 259) dealt in a similar manner with some of the physical properties of the normal *alkyl* compounds of the *elements*, which were shown to exhibit exactly the same relationships as those of the corresponding halogen compounds; proving, therefore, that the function of the alkyl radicals—methyl CH_3 , ethyl C_2H_5 , propyl C_3H_7 , &c.—was exactly analogous to that of the halogen elements—chlorine, bromine, and iodine.

In the present paper I wish to show that the normal halogen and alkyl compounds of the hydrocarbon radicals exhibit relationships similar to those of the corresponding compounds of the elements, and therefore that the elements and hydrocarbon radicals are analogous and have the same function in their several compounds. In a fourth and final paper I intend to take a general review of the whole question, and to draw certain conclusions as to the nature of the chemical elements and of the Periodic Law.

The following table contains the experimental data, with the authorities, which have been used in drawing the conclusions given below. For the purpose of avoiding minus signs all temperatures are reckoned from the absolute zero (-273). The following abbreviations are used :—Me = methyl, CH_3 ; Et = ethyl, C_2H_5 ; Pr^α = normal propyl, $\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CH}_2$ —; Pr^β = isopropyl $(\text{CH}_3)_2\text{CH}$ —.

TABLE I.—Experimental Data.

	Constitution.	Melting- and Boiling- point.	Authority.
<i>Chlorides :—</i>			
Methyl chloride	$\text{CH}_3 \cdot \text{Cl}$	b.p. 249	Regnault.
Ethyl "	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{Cl}$	b.p. 285	"
Propyl "	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{Cl}$	b.p. 319	Linnemann.
" "	$\text{CH}_3 \cdot \text{CHCl} \cdot \text{CH}_3$	b.p. 310	"
Butyl "	$\text{CH}_3 \cdot (\text{CH}_2)_3 \cdot \text{Cl}$	b.p. 351	"
" "	$\text{CHMe}_2 \cdot \text{CH}_2 \cdot \text{Cl}$	b.p. 342	"
" "	$\text{CMe}_3 \cdot \text{Cl}$	b.p. 324	Perkin.
Amyl "	$\text{CH}_3 \cdot (\text{CH}_2)_4 \cdot \text{Cl}$	b.p. 380	Lieben and Rossi.
" "	$\text{CHEt}_2 \cdot \text{Cl}$	b.p. 377	Wagner and Saytzeff.
" "	$\text{CHMePr}^\alpha \cdot \text{Cl}$	b.p. 377	"
" "	$\text{CHMe}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{Cl}$	b.p. 374	Carius and Fries.
" "	$\text{CHMePr}^\beta \cdot \text{Cl}$	b.p. 360	Butlerow.
" "	$\text{CMe}_2\text{Et} \cdot \text{Cl}$	b.p. 359	Perkin.
Hexyl "	$\text{CH}_3 \cdot (\text{CH}_2)_5 \cdot \text{Cl}$	b.p. 406	Lieben and Janacek.
" "	$\text{Me} \cdot (\text{CH}_2)_3 \cdot \text{CHCl} \cdot \text{Me}$	b.p. 397	Schorlemmer.
" "	$\text{CHMe}_2 \cdot \text{CMe}_2 \cdot \text{Cl}$	b.p. 387	Friedel and Silva.
" "	" "	m.p. 271	Kaschirsky.
Heptyl "	$\text{CH}_3 \cdot (\text{CH}_2)_6 \cdot \text{Cl}$	b.p. 432	Cross.
" "	$\text{CHMe}_2 \cdot (\text{CH}_2)_4 \cdot \text{Cl} (?)$	b.p. 423	"
" "	$\text{CMe}_3 \cdot \text{CMe}_2 \cdot \text{Cl}$	m.p. 409	Butlerow.
" "	$\text{Pr}^\beta \cdot (\text{CH}_2)_2 \cdot \text{CHMe} \cdot \text{Cl}$	b.p. 409	Rohu.
Octyl "	$\text{CH}_3 \cdot (\text{CH}_2)_7 \cdot \text{Cl}$	b.p. 456	Perkin.
" "	$\text{C}_6\text{H}_{13} \cdot \text{CHMe} \cdot \text{Cl}$	b.p. 448	Schorlemmer.
" "	$\text{C}_6\text{H}_{11} \cdot \text{CHEt} \cdot \text{Cl}$	b.p. 448	"
" "	$\text{C}_6\text{H}_{12} \cdot \text{Cl}$	b.p. 438	"
" "	$\text{CEt} \cdot \text{Pr}^\alpha \cdot \text{Cl}$	b.p. 428	Butlerow.
" "	$\text{C}_6\text{H}_{12} \cdot \text{Cl}$	b.p. 421	"
Methylene dichloride	CH_2Cl_2	b.p. 315	Thorpe.
Ethylene "	$\text{CH}_2\text{Cl} \cdot \text{CH}_2\text{Cl}$	b.p. 357	"
Ethylidene "	$\text{CH}_3 \cdot \text{CHCl}_2$	b.p. 333	"
Propylene "	$\text{Cl} \cdot (\text{CH}_2) \cdot \text{Cl}$	b.p. 392	Reboul.
" "	$\text{CH}_3 \cdot \text{CHCl} \cdot \text{CH}_2\text{Cl}$	b.p. 370	Linnemann.
" "	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CHCl}_2$	b.p. 359	Reboul.
" "	$\text{CH}_3 \cdot \text{OCl}_2 \cdot \text{CH}_3$	b.p. 343	Perkin.
Butylene "	$\text{C}_4\text{H}_8\text{Cl}_2$	b.p. 405	Wurtz.
" "	" "	b.p. 395	Kopp.
" "	$\text{CHMe}_2 \cdot \text{CHCl}_2$	b.p. 377	(Econimides.
" "	$\text{CH}_3 \cdot \text{CCl}_2 \cdot \text{CH}_2 \cdot \text{CH}_3$	b.p. 369	Bruylants.
Amylene "	$\text{C}_6\text{H}_{10}\text{Cl}_2$	b.p. 430	Buff.
" "	$\text{Pr}^\alpha \cdot \text{CCl}_2 \cdot \text{Me}$	b.p. 418	Friedel.
" "	$\text{CHMe}_2 \cdot \text{CH}_2 \cdot \text{CHCl}_2$	b.p. 402	Bruylants.
Hexylene "	$\text{CMe}_2\text{Cl} \cdot \text{CMe}_2\text{Cl}$	m.p. 433	Friedel and Silva.
" "	$\text{C}_6\text{H}_{12}\text{Cl}_2$	b.p. 455	Pelouze and Cahours.
" "	" "	b.p. 448	Wurtz.
" "	" "	b.p. 437	Henry.
Heptylene "	$\text{C}_7\text{H}_{14}\text{Cl}_2$	b.p. 463	Schorlemmer.
" "	$\text{Pr}^\alpha \cdot \text{CCl}_2 \cdot \text{Pr}^\alpha$	b.p. 454	Tawildarow.
Octylene "	$\text{C}_8\text{H}_{16}\text{Cl}_2$	b.p. 508	Thorpe and Young.
" "	" "	b.p. 481	Nieson.
" "	$\text{C}_6\text{H}_{13} \cdot \text{CCl}_2 \cdot \text{Me}$	b.p. 470	Annalen, cvi. 271.

TABLE I. (continued).

	Constitution.	Melting- and Boiling- point.	Authority.
Trichlor-methane	CHCl_3	b.p. 334	Thorpe.
Trichlor-ethane.....	$\text{CH}_2\text{Cl} \cdot \text{CHCl}_2$	m.p. 203	Berthelot.
" "	$\text{CH}_3 \cdot \text{CCl}_3$	b.p. 387	Staedel.
Trichlor-propane	$\text{CH}_2\text{Cl} \cdot \text{CHCl} \cdot \text{CH}_2\text{Cl}$	b.p. 347	"
" "	$\text{CH}_2\text{Cl} \cdot \text{CH}_2 \cdot \text{CHCl}_2$	b.p. 431	Perkin.
" "	$\text{CH}_3 \cdot \text{CHCl} \cdot \text{CHCl}_2$	b.p. 420	Romburgh.
" "	$\text{CH}_3 \cdot \text{CCl}_2 \cdot \text{CH}_2\text{Cl}$	b.p. 413	Friedel and Silva.
Trichlor-pentane	$\text{C}_6\text{H}_6\text{Cl}_3$	b.p. 398	"
" "	"	b.p. 460	Buff.
Trichlor-hexane	$\text{C}_8\text{H}_{11}\text{Cl}_3$	b.p. 448	Bauer.
" "	"	b.p. 490	Felouze and Cahours.
Tetrachlor-methane.....	CCl_4	b.p. 350	Thorpe.
" "	"	m.p. 248	Regnault.
Tetrachlor-ethane.....	$\text{CHCl}_2 \cdot \text{CHCl}_2$	b.p. 420	Staedel.
" "	$\text{CH}_2\text{Cl} \cdot \text{CCl}_3$	b.p. 403	"
Tetrachlor-propane	$\text{C}_3\text{H}_4\text{Cl}_4$	m.p. 418	} Berthelot.
" "	"	b.p. 473	
" "	$\text{CH}_2\text{Cl} \cdot \text{CCl}_2 \cdot \text{CH}_2\text{Cl}$	b.p. 453	
" "	$\text{C}_3\text{H}_4\text{Cl}_4$	b.p. 437	
" "	"	b.p. 426	Borsche.
Tetrachlor-butane	$\text{C}_4\text{H}_6\text{Cl}_4$	m.p. 451	Schorlemmer.
" "	"	Liquid.	Thurnlackl.
" "	"	m.p. 346	<i>Bull. Chim.</i> xxxiv. 195.
Tetrachlor-pentane	$\text{C}_5\text{H}_8\text{Cl}_4$	b.p. 508	Bauer.
Trichlor-ethylene	$\text{CCl}_2 \cdot \text{CHCl}$	b.p. 360	Paterno.
Trichlor-propylene, β	$\text{C}_3\text{H}_3\text{Cl}_3$	b.p. 415	Pfeffer and Fittig.
" "	$\text{C}_3\text{H}_3\text{Cl}_3$	b.p. 388	Borsche.
Trichlor-amylene	$\text{C}_6\text{H}_7\text{Cl}_3$	b.p. 473	Bauer.
Dichlor-acetylene	$\text{CCl} \equiv \text{CCl}$	b.p. 460	} Watts Dict. i. 768.
Dichlor-allylene	$\text{CH}_2 : \text{C} : \text{CCl}_2$	m.p. 460	
Chlornicene	$\text{C}_5\text{H}_5\text{Cl}$	b.p. 351	Pinner.
" "	"	b.p. 566	St. Evre.
<i>Bromides:—</i>			
Methyl bromide	$\text{CH}_3 \cdot \text{Br}$	b.p. 278	Perkin.
Ethyl "	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{Br}$	b.p. 312	"
Propyl "	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{Br}$	b.p. 344	"
" "	$\text{CH}_3 \cdot \text{CHBr} \cdot \text{CH}_3$	b.p. 334	Linnemann.
Butyl "	$\text{CH}_3 \cdot (\text{CH}_2)_3 \cdot \text{Br}$	b.p. 373	"
" "	$\text{CHMe}_2 \cdot \text{CH}_2 \cdot \text{Br}$	b.p. 365	"
" "	$\text{CMe}_3 \cdot \text{Br}$	b.p. 344	Perkin.
Amyl "	$\text{CH}_3 \cdot (\text{CH}_2)_4 \cdot \text{Br}$	b.p. 402	Lieben and Rossi.
" "	$\text{CHMe}_2 \cdot (\text{CH}_2)_2 \cdot \text{Br}$	b.p. 393	Perkin.
" "	$\text{CHMe}_2 \cdot \text{CHMe} \cdot \text{Br}$	b.p. 386	Wurtz.
" "	$\text{CMe}_2\text{Et} \cdot \text{Br}$	b.p. 382	Wischegradsky.
Hexyl "	$\text{CH}_3 \cdot (\text{CH}_2)_5 \cdot \text{Br}$	b.p. 428	Lieben.
" "	$\text{C}_4\text{H}_9 \cdot \text{CHMe} \cdot \text{Br}$	b.p. 417	Schorlemmer.
" "	$\text{CHMePr} \cdot \text{CH}_2\text{Br}$	b.p. 416	<i>Monatschrift</i> , iv. 34.
Heptyl "	$\text{CH}_3 \cdot (\text{CH}_2)_6 \cdot \text{Br}$	b.p. 452	Cross.
" "	$\text{CH}_3 \cdot (\text{CH}_2)_4 \cdot \text{CHMe} \cdot \text{Br}$	b.p. 439	Venables.
" "	$\text{CMe}_3 \cdot \text{CMe}_2 \cdot \text{Br}$	m.p. 425	Kaschirsky.

TABLE I. (continued).

	Constitution.	Melting- and Boiling- point.	Authority.
Octyl bromide	$\text{CH}_3 \cdot (\text{CH}_2)_7 \cdot \text{Br}$	b.p. 476	Perkin.
" " (sec.) ...	$\text{C}_8\text{H}_{17} \cdot \text{Br}$	b.p. 461	Lachowicz.
Methylene dibromide ...	CH_2Br_2	b.p. 370	Perkin.
Ethylene " ...	$\text{CH}_2\text{Br} \cdot \text{CH}_2\text{Br}$	m.p. b. 261	Henry. }
Ethylidene " ...	$\text{CH}_3 \cdot \text{CHBr}_2$	b.p. 405	Thorpe.
Propylene " ...	$\text{Br} \cdot (\text{CH}_2)_3 \cdot \text{Br}$	m.p. 282	Perkin.
" " ...	$\text{CH}_3 \cdot \text{CHBr} \cdot \text{CH}_2\text{Br}$...	b.p. 382	Freund.
" " ...	$\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CHBr}_2$	b.p. 438	Perkin.
" " ...	$\text{CH}_3 \cdot \text{CBr}_2 \cdot \text{CH}_3$	b.p. 415	Reboul.
Butylene " ...	$\text{CHMeBr} \cdot \text{CHMeBr}$...	b.p. 405	"
" " ...	$\text{CHEtBr} \cdot \text{CH}_2\text{Br}$	b.p. 387	Wurtz.
" " ...	$\text{CMe}_2\text{Br} \cdot \text{CH}_2\text{Br}$	b.p. 439	Perkin.
Amylene " ...	$\text{C}_5\text{H}_{10}\text{Br}_2$	b.p. 431	Thorpe and Young.
" " ...	$\text{CHEtBr} \cdot \text{CHMeBr}$	b.p. 422	Wagner.
" " ...	$\text{CHMe}_2 \cdot \text{CHBr} \cdot \text{CH}_2\text{Br}$...	b.p. 459	Bruylants.
Hexylene " ...	$\text{C}_6\text{H}_{11} \cdot \text{CHBr}_2$	b.p. 451	<i>Annalen</i> , cxxiv. 293.
" " ...	$\text{C}_6\text{H}_{12} \cdot \text{Br}_2$	b.p. 448	Helbing.
" " ...	$\text{CMe}_2\text{Br} \cdot \text{CMe}_2\text{Br}$	b.p. 483	Rizza.
" " ...	$\text{C}_6\text{H}_{13}\text{Br}_2$	b.p. 458	Eltekoff.
" " ...	$\text{Pr}^8 \cdot \text{CHBr} \cdot \text{CHMe} \cdot \text{Br}$...	m.p. 413	"
Octylene " ...	$\text{C}_8\text{H}_{16}\text{Br}_2$	m.p. 412	Nieson.
Tribrom-methane	CHBr_3	b.p. 473 ^d	Thorpe. }
Tribrom-ethane	$\text{CH}_2\text{Br} \cdot \text{CHBr}_2$	b.p. 424	Perkin. }
" "	$\text{CH}_3 \cdot \text{CBr}_2$	m.p. 281	Perkin.
Tribrom-propane	$\text{CH}_2\text{Br} \cdot \text{CHBr} \cdot \text{CH}_2\text{Br}$ {	b.p. 462	Perkin.
" "	$\text{CH}_3 \cdot \text{CHBr} \cdot \text{CHBr}_2$...	b.p. 461	Denzel.
" "	$\text{CH}_3 \cdot \text{CBr}_2 \cdot \text{CH}_2\text{Br}$	b.p. 493	Henry.
Tribrom-butane	$\text{Me} \cdot \text{CBr} \cdot \text{CHBr}_2$	m.p. 289	Reboul.
" "	$\text{C}_4\text{H}_7\text{Br}_3$	b.p. 473	"
Tetrabrom-methane	CBr_4	b.p. 463	Linnemann.
Tetrabrom-ethane.....	$\text{CH}_2\text{Br} \cdot \text{CBr}_3$	b.p. 489	Caventou.
" "	$\text{CHBr}_2 \cdot \text{CHBr}_2$	b.p. 485	Bolas and Groves.
" "	$\text{CH}_2\text{Br} \cdot \text{CBr}_2 \cdot \text{CH}_2\text{Br}$ {	b.p. 462	Kessel. "
Tetrabrom-propane	$\text{C}_3\text{H}_5\text{Br}_3$	b.p. 493	Burgoin.
" "	$\text{CHBr}_2 \cdot \text{CHBr} \cdot \text{CH}_2\text{Br}$..	b.p. 482	Tawildarow.
" "	$\text{CH}_3 \cdot \text{CBr}_2 \cdot \text{CHBr}_2$	m.p. b. 249	Anschütz.
Tetrabrom-butane.....	$\text{C}_4\text{H}_8\text{Br}_4$	m.p. 468	Hartenstein.
" "	$\text{CHBr}_2 \cdot \text{CBr}_2 \cdot \text{CH}_2\text{Me}$..	m.p. 342	<i>Annalen</i> , cxxvi. 64.
" "	$\text{C}_4\text{H}_9\text{Br}_4$	b.p. 513 ^d	Reboul.
Tetrabrom-pentane.....	$\text{CMe}_2\text{Br} \cdot \text{CBr}_2 \cdot \text{CH}_2\text{Br}$..	b.p. 524	Oppenheim.
" "	$\text{Pr}^8 \cdot \text{CBr}_2 \cdot \text{CHBr}_2$	b.p. 503	Caventou.
" "	$\text{C}_6\text{H}_{10}\text{Br}_4$	m.p. 389	Prunier.
Tetrabrom-hexane	$\text{C}_6\text{H}_{10}\text{Br}_4$	m.p. 372	<i>Annalen</i> , clxxii. 291.
" "	$\text{Pr}^8 \cdot \text{CBr}_2 \cdot \text{CHBr}_2$	m.p. 388	Hoffmann.
" "	$\text{C}_6\text{H}_{10}\text{Br}_4$	b.p. 548	Bruylants.
" "	"	b.p. 548	"
" "	"	m.p. 415	Bouchardat.
" "	"	m.p. 393	<i>Zeit. Chem.</i> 1871.

TABLE I. (continued).

	Constitution.	Melting- and Boiling- point.	Authority.
Tetrabrom-hexane	$C_6H_{10}Br_4$	m.p. 385 b.p. 591	} <i>Annalen</i> , cxxxix. 251.
" "	$(CH_2)_2(CHBr \cdot CH_2Br)_2$	m.p. 336	
Tribrom-ethylene	$CHBr : CBr_2$	b.p. 435	Wagner.
Tribrom-propylene	$CHBr : CBr \cdot CH_2Br$	non-vol.	Anschütz.
" "	$C_2H_3Br_3$	b.p. 457	Henry.
Dibrom-diallyl	$C_2H_4Br \cdot C_3H_4Br$	b.p. 483	Oppenheim.
Brom-diallylene	C_6H_7Br	b.p. 423	Henry.
Caprylidene bromide	$C_8H_{11}Br$	b.p. 477	<i>Annalen</i> , cxlii. 300.
<i>Iodides:—</i>			
Methyl iodide	CH_3I	b.p. 315	Perkin.
Ethyl "	$CH_3 \cdot CH_2I$	b.p. 345	Linnemann.
Propyl "	$CH_3 \cdot CH_2 \cdot CH_2I$	b.p. 375	"
" "	$CH_3 \cdot CHI \cdot CH_3$	b.p. 362	Perkin.
Butyl iodide	$CH_3 \cdot (CH_2)_3 \cdot I$	b.p. 403	Linnemann.
" "	$CHMe_3 \cdot CH_2I$	b.p. 393	Perkin.
" "	$CHMeEt \cdot I$	b.p. 392	Lieben.
" "	$CMe_3 \cdot I$	b.p. 373	Puchot.
Amyl "	$CH_3 \cdot (CH_2)_4 \cdot I$	b.p. 429	Lieben and Rossi.
" "	$CHMe_3 \cdot (CH_2)_2 \cdot I$	b.p. 421	Perkin.
" "	$CH_3 \cdot (CH_2)_2 \cdot CHI \cdot CH_3$	b.p. 419	Wurtz.
" "	$CHEt_2 \cdot I$	b.p. 418	Wagner.
" "	$CHMe_3 \cdot CHI \cdot CH_3$	b.p. 411	Wischnegradsky.
" "	$CMe_2Et \cdot I$	b.p. 401	"
Hexyl "	$CH_3 \cdot (CH_2)_5 \cdot I$	b.p. 454	Lieben.
" "	$CHMe_3 \cdot (CH_2)_3 \cdot I$	b.p. 446	Pelouze.
" "	$CH_3 \cdot (CH_2)_3 \cdot CHI \cdot CH_3$	b.p. 440	Wanklyn.
" "	$CHEtPr^a \cdot I$	b.p. 438	Connick.
" "	$CMe_3 \cdot CHI \cdot CH_3$	b.p. 415	<i>Jahresb.</i> 1873.
" "	$CMe_2Pr^a \cdot I$	b.p. 415	<i>Annalen</i> , cxcv. 254.
" "	$CMe_2Pr^b \cdot I$	b.p. 414 s. 273	} Kaschirsky.
Heptyl "	$CH_3 \cdot (CH_2)_6 \cdot I$	b.p. 474	Cross.
" "	$CHPr^a_3 \cdot I$	b.p. 458	<i>Jahresb.</i> 1869.
" "	$Pr^b \cdot (CH_2)_2 \cdot CHI \cdot CH_3$	b.p. 443	Rohu.
" "	$CMeEtPr^b \cdot I$	b.p. 419	Kaschirsky.
" "	$CMe_3 \cdot CMe_3 \cdot I$	b.p. 414	Butlerow.
Octyl "	$CHMe_3 \cdot (CH_2)_7 \cdot I$	b.p. 494	Zincke.
" "	$C_8H_{13} \cdot CHI \cdot CH_3$	b.p. 484	Bouis.
Methylene diiodide	CH_2I_2	b.p. 453 m.p. 277	} Hofmann.
Ethylene "	$CH_2I \cdot CH_2I$	m.p. 355	Aronstein.
Ethylidene "	$CH_3 \cdot CHI_2$	b.p. 453	Plimpton.
Propylene "	$CH_3I \cdot CH_2 \cdot CH_2I$	b.p. 500 <i>d</i>	Freund.
" "	$C_3H_5I_2$	b.p. 421 <i>d</i>	Semenoff.
Triiodo-methane	CHI_3	m.p. 392	Serullas.
Tetraiodo-methane	CI_4	m.p. 420 b.p. 620	} Calculated.
Tetraiodo-hexane	$(CH_2)_2(CHI \cdot CH_2I)_2$	m.p. a. 373	} <i>Phil. Mag.</i> [5] xviii. 17.
Triiodo-propylene	$CI : CI \cdot CH_3$	m.p. 337	<i>Annalen</i> , c. 363.
" "	$CHI : CI \cdot CH_2I$	m.p. 314	Liebermann.
" "			Henry.

TABLE I. (*continued*).

	Constitution.	Melting- and Boiling- point.	Authority.
<i>Alkyl compounds (Hydrocarbons):—</i>			
Propane.....	Normal	b.p. 245	Lefebvre.
Butane	"	b.p. 274	Schorlemmer.
"	CHMe ₃	b.p. 256	Butlerow.
Pentane	Normal	b.p. 311	Schorlemmer.
"	CHMe ₂ . CH ₂ . Me	b.p. 303	Pelouze.
"	CMe ₄	b.p. 282 s. 253	Lwow.
Hexane	Normal	b.p. 344	Schorlemmer.
"	CHMe ₂ . (CH ₂) ₂ . Me	b.p. 335	"
"	CHMeEt ₂	b.p. 337	Wislicenus.
"	CHMe ₂ . CHMe ₂	b.p. 331	Schorlemmer.
"	CMe ₃ Et	b.p. 318	Butlerow.
Heptane.....	Normal	b.p. 371	Thorpe.
"	CHEt ₃	b.p. 370	Ladenburg.
"	CHMeEtPr ^α	b.p. 364	Just.
"	CHMe ₂ . (CH ₂) ₂ . Et.....	b.p. 363	Thorpe.
"	CMe ₂ Et ₂	b.p. 360	Friedel.
Octane	Normal	b.p. 398	Thorpe.
"	CHMe ₂ . (CH ₂) ₂ . CHMe ₂	b.p. 381	Williams.
"	CMe ₃ . CMe ₃	b.p. 379 m.p. 369	Lwow.
Nonane	Normal	b.p. 422	Krafft.
"	CHMe ₃ . (CH ₂) ₃ . CHMe ₂	m.p. 222	"
"	Pr ^β . CH ₂ . CHMePr ^β	b.p. 405	Wurtz.
"	"	b.p. 403	Silva.
Decane	Normal	b.p. 446 m.p. 241	Krafft.
Undecane	"	b.p. 468 m.p. 247	"
Amylene	CMe ₂ : CHMe	b.p. 309	Flawitzky.
Hexylene	CMe ₂ : CMe ₂	b.p. 346	Rizza.
"	CHMe: CMeEt	b.p. 343	Jawein.
"	CMe ₂ : CHEt	b.p. 339	"
Heptylene	CMe ₂ : CMeEt	b.p. 366	Kaschirsky.
"	CHMe ₂ . CH: CMe ₂	b.p. 355	Markownikow.
"	CMe ₃ . CMe: CH ₂	b.p. 352	Eltekoff.
Octylene	C ₈ H ₁₆ Me ₃	b.p. 395	Williams.
"	CHPr ^β : CHPr ^β	b.p. 391	Fossek.
"	CMe ₂ : CH. CMe ₃	b.p. 376	Butlerow.
Methylethyl-acetylene	CMe: CEt	b.p. 324	Eltekoff.
Valerylene.....	CMe ₂ : C: CH ₂	b.p. 318	Reboul.
Isopropyl-acetylene	CH: CPr ^β	b.p. 301	Flawitzky.
Valylene.....	CH ₂ : CMe. C: CH	b.p. 323	Reboul.
Hexine	CMe: CPr ^α	b.p. 355	Hecht.
Heptine	CHMe: C: CHPr	b.p. 376	Tilden.
"	CMe ₂ : C: CMe ₂	b.p. 343	Henry.

By the normal halogen or alkyl compounds of the hydrocarbon radicals we mean the compounds formed by the following radicals with the halogens chlorine, bromine, and iodine, or with methyl, ethyl, propyl, &c.; viz. :—

	Series 1.	Series 2.	Series 3.	Series 4.	Series 5.	
Group I			$(C_3H)X_1$	$(C_4H_3)X_1$	$(C_5H_5)X_1$	Series 6, 7, 8, &c. being similarly constructed.
„ II. ...	.....	$(C_2)X_2$	$(C_3H_2)X_2$	$(C_4H_4)X_2$	$(C_5H_6)X_2$	
„ III. ...	.....	$(C_2H)X_3$	$(C_3H_3)X_3$	$(C_4H_5)X_3$	$(C_5H_7)X_3$	
„ IV. ...	CX_4	$(C_2H_2)X_4$	$(C_3H_4)X_4$	$(C_4H_6)X_4$	$(C_5H_8)X_4$	
„ V. ...	$(CH)X_3$	$(C_2H_3)X_3$	$(C_3H_5)X_3$	$(C_4H_7)X_3$	$(C_5H_9)X_3$	
„ VI. ...	$(CH_2)X_2$	$(C_2H_4)X_2$	$(C_3H_6)X_2$	$(C_4H_8)X_2$	$(C_5H_{10})X_2$	
„ VII. ...	$(CH_3)X_1$	$(C_2H_5)X_1$	$(C_3H_7)X_1$	$(C_4H_9)X$	$(C_5H_{11})X_1$	

In the above, $X = Cl, Br, I, CH_3, C_2H_5, \text{ or } C_3H_7, \&c.$

The above series, of course, might be considerably extended ; but I have not thought it necessary to carry my investigations beyond the 8th series for the halogen compounds, nor beyond the 5th series for the alkyl compounds*.

When there are several isomeric modifications of the same empirical formula, only those which are strictly analogous should be compared ; thus, normal compounds should be compared with normal, and iso-compounds with iso-, &c. In some instances, however, this is not possible, owing to the data being incomplete, or to the constitution being unknown, or when the compounds belonging to *different groups* of the *same series* are to be compared ; in this case the mean of the melting- or boiling-points of the several isomeric compounds is employed. As a general rule, however, the same results are obtained, no matter whether we use the mean melting- or boiling-point for all the isomeric compounds, or whether we compare only those compounds which are strictly analogous.

Now the same general rule that we have already shown (*ibid.* xviii. p. 2) to hold good as regards the corresponding compounds of the elements also holds in the case of the above hydrocarbon radicals ; for in whatever way we may arrange the melting- or boiling-points of their normal halogen or alkyl compounds, provided only that we arrange them systematically, we always find that certain definite and regular relations may be traced between them. The following are examples of such relations :—

RELATION 1. *If the above hydrocarbon radicals be arranged in the order of their atomic weights, then the melting-points and boiling-points of both their halogen and alkyl compounds rise and fall periodically.*

This periodicity is such that the values increase from the

* The methide curve in the diagram which accompanies the paper has, however, been completed to the end of the eighth series.

first (monad) up to the fourth or middle (tetrad) member of each series, and then diminish to the seventh (monad) or last member (see Table II.*).

This periodicity is not *exactly* the same as that in the case of the corresponding compounds of the elements; I shall not, however, discuss this point at present, but defer it to my next communication.

TABLE II.—Illustrating Relations 1 and 2.

		CHLORIDES.		BROMIDES.		IODIDES.	
		M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
HALOGEN COMPOUNDS.	.....	.....	.....	.....	.....	.....	.....
							
							
	C ^{iv} ...	248	350	364	462	420	620
	(CH) ⁱⁱⁱ	203	334	281	424	392	.....
	(CH ₂) ⁱⁱ	Liquid.	315	b. 261	370	277	453
	(CH ₃) ⁱ	Liquid.	249	Liquid.	278	Liquid.	315
							
	C ₂ ⁱⁱ ...	460 ¹ (?)	460 ¹(?)	.....	.....	.....	.....
	(C ₂ H) ⁱⁱⁱ	Liquid.	360	Liquid.	435	.....	.....
	(C ₂ H ₂) ^{iv}	Liquid.	411	327	488	.....	.....
	(C ₂ H ₃) ⁱⁱⁱ	Liquid.	367	Liquid.	462	.....	.....
	(C ₂ H ₄) ⁱⁱ	Liquid.	345	.....	393	355	453 <i>d.</i>
	(C ₂ H ₅) ⁱ	Liquid.	285	Liquid.	312	Liquid.	345
							
	(C ₃ H) ⁱ	.....	.....	.....	.....	.....	.....
	(C ₃ H ₂) ⁱⁱ	Liquid.	351	.....	.....	.....	.....
	(C ₃ H ₃) ⁱⁱⁱ	Liquid.	402	Liquid.	457	326	.....
	(C ₃ H ₄) ^{iv}	.....	434	405	513	.....	.....
	(C ₃ H ₅) ⁱⁱⁱ	b. 263	415	289	476	.....	.....
	(C ₃ H ₆) ⁱⁱ	Liquid.	366	Liquid.	411	Liquid.	460
	(C ₃ H ₇) ⁱ	Liquid.	315	Liquid.	339	Liquid.	368
							
	(C ₄ H ₂) ⁱ	.....	.....	.....	.....	.....	.....
	(C ₄ H ₃) ⁱⁱ	.....	.....	.....	.....	.....	.....
	(C ₄ H ₄) ⁱⁱⁱ	.....	.....	.....	.....	.....	.....
	(C ₄ H ₅) ^{iv}	346	.....	383	.....	.....	.....
	(C ₄ H ₆) ⁱⁱⁱ	.....	.....	.....	487	.....	.....
	(C ₄ H ₇) ⁱⁱ	Liquid.	386	Liquid.	431	.....	.....
	(C ₄ H ₈) ⁱ	Liquid.	339	Liquid.	361	Liquid.	390
							
	(C ₅ H ₆) ⁱ	Liquid.	566(?) ²	.....	.....	.....	.....
	(C ₅ H ₇) ⁱⁱ	Liquid.	419	.....	.....	.....	.....
	(C ₅ H ₈) ⁱⁱⁱ	Liquid.	473	.....	.....	.....	.....
	(C ₅ H ₉) ^{iv}	Liquid.	508	388	548	.....	.....
	(C ₅ H ₁₀) ⁱⁱⁱ	Liquid.	454	Solid.	.....	.....	.....
	(C ₅ H ₁₁) ⁱⁱ	Liquid.	417	Liquid.	453	.....	.....
	(C ₅ H ₁₂) ⁱ	Liquid.	371	Liquid.	391	Liquid.	416

* The periodicity is rendered still more evident by the curves for the methides, chlorides, and bromides shown in the diagram (p. 514).

TABLE II. (*continued*).—Illustrating Relations 1 and 2.

		METHIDES.		ETHIDES.		NORMAL PROPIDES.	
		M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
ALKYL COMPOUNDS.	.....	.....	.....	.....	.....	.....	.....
							
							
	$C_{iv} \dots$	Solidifies	282	.....	.....	.....	.....
	$(CH)^{iii}$	253	256	Liquid.	370	.....	.....
	$(CH_2)^{ii}$	Liquid.	245	Liquid.	311	Liquid.	371
	$(CH_3)^i$	Liquid.	Gas.	Liquid.	245	Liquid.	274
							
	$C_{ii} \dots$	.....	.....	.....	.....	.....	.....
	$(C_2H)^{iii}$	Liquid.	309	.....	.....	.....	.....
	$(C_2H_2)^{iv}$	Liquid.	325	.....	.....	.....	.....
	$(C_2H_3)^{iii}$	Liquid.	293	.....	.....	.....	.....
	$(C_2H_4)^{ii}$	Liquid.	265	Liquid.	341	Liquid.	398
	$(C_2H_5)^i$	Liquid.	245	Liquid.	274	Liquid.	311
							
	$(C_3H)^i$	.....	.....	.....	.....	.....	.....
	$(C_3H_2)^{ii}$	Liquid.	314	.....	.....	.....	.....
	$(C_3H_3)^{iii}$	Liquid.	343	.....	.....	.....	.....
	$(C_3H_4)^{iv}$	Liquid.	360	.....	.....	.....	.....
	$(C_3H_5)^{iii}$	Liquid.	330	.....	.....	.....	.....
	$(C_3H_6)^{ii}$	Liquid.	299	Liquid.	366	222	422
	$(C_3H_7)^i$	Liquid.	265	Liquid.	307	Liquid.	340
							
	$(C_4H_3)^i$	Liquid.	323	.....	.....	.....	.....
	$(C_4H_4)^{ii}$	Liquid.	355	.....	.....	.....	.....
	$(C_4H_5)^{iii}$	Liquid.	358	.....	.....	.....	.....
	$(C_4H_6)^{iv}$	369	380	.....	.....	.....	.....
	$(C_4H_7)^{iii}$	Liquid.	364	.....	.....	.....	.....
	$(C_4H_8)^{ii}$	Liquid.	333	Liquid.	398	241	446
	$(C_4H_9)^i$	Liquid.	299	Liquid.	333	Liquid.	366
							
	$(C_5H_5)^i$	Liquid.	360	.....	.....	.....	.....
	$(C_5H_6)^{ii}$	Liquid.	387	.....	.....	.....	.....
	$(C_5H_7)^{iii}$	Liquid.	404	.....	.....	.....	.....
	$(C_5H_8)^{iv}$	Liquid.	381	.....	.....	.....	.....
	$(C_5H_9)^{iii}$	Liquid.	365	.....	.....	.....	.....
	$(C_5H_{10})^{ii}$	Liquid.	365	222	422	247	468
	$(C_5H_{11})^i$	Liquid.	333	Liquid.	365	Liquid.	398

N.B.—In the above table the mean value is given when there are several isomers having the same empirical composition. Sometimes, however, in the case of the melting-points, there are several pairs or triplets of isomeric substances of which the melting-point of one only is known, the others being liquid; a mean number is therefore impossible; in this case the known melting-point is given.

¹ This is the mean of 448° – 473° , which are the temperatures given in Watts's Dictionary (i. p. 768) as those between which protochloride of carbon melts and boils. Chlorine does not act upon this compound even in sunshine. It is most probably a polymer $(C_2Cl_2)_n$. Berthelot in fact regards it as $C_{10}Cl_{10}$. Its vapour-density, however, does not appear to have been determined.

² This is the boiling-point of chlornicene, as given by St. Evre (*Jahresbericht*, i. p. 530). This substance, if a definite compound, is probably a polymer $(C_3H_5Cl)_n$.

RELATION 2. *The melting-points and boiling-points of either the halogen or alkyl compounds of any hydrocarbon radical increase as we pass from the chloride to the bromide and thence to the iodide; or from the methide to the ethide, and thence to the propide, &c. (See Tables II. and III.)*

TABLE III.—Illustrating Relations 2 and 3.

	Halogen compounds.	CHLORIDES.		BROMIDES.		IODIDES.	
		M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
Normal primary halides of Group VII. $\text{CH}_3(\text{CH}_2)_n \cdot \text{X}$.	$\text{CH}_3 \dots$	Liquid.	249	Liquid.	278	Liquid.	315
	$\text{C}_2\text{H}_5 \dots$	Liquid.	285	Liquid.	312	Liquid.	345
	$\text{C}_3\text{H}_7 \dots$	Liquid.	319	Liquid.	344	Liquid.	375
	$\text{C}_4\text{H}_9 \dots$	Liquid.	351	Liquid.	373	Liquid.	403
	$\text{C}_5\text{H}_{11} \dots$	Liquid.	380	Liquid.	402	Liquid.	429
	$\text{C}_6\text{H}_{13} \dots$	Liquid.	406	Liquid.	428	Liquid.	454
	$\text{C}_7\text{H}_{15} \dots$	Liquid.	432	Liquid.	452	Liquid.	474
	$\text{C}_8\text{H}_{17} \dots$	Liquid.	456	Liquid.	476	Liquid.	a. 494
	Alkyl compounds.	METHIDES.		ETHIDES.		α -PROPIDES.	
Normal primary alkides of Group VII. $\text{CH}_3(\text{CH}_2)_n \cdot \text{X}$.	$\text{CH}_3 \dots$	.....	Gas.	.....	245	Liquid.	274
	$\text{C}_2\text{H}_5 \dots$	.....	245	Liquid.	274	Liquid.	311
	$\text{C}_3\text{H}_7 \dots$	Liquid.	274	Liquid.	311	Liquid.	344
	$\text{C}_4\text{H}_9 \dots$	Liquid.	311	Liquid.	344	Liquid.	371
	$\text{C}_5\text{H}_{11} \dots$	Liquid.	344	Liquid.	371	Liquid.	398
Normal alkides of Group VI. $\text{X} \cdot (\text{CH}_2)_n \cdot \text{X}$.	$(\text{CH}_2)'' \dots$	.....	245	Liquid.	311	Liquid.	371
	$(\text{C}_2\text{H}_4)'' \dots$	Liquid.	274	Liquid.	344	Liquid.	398
	$(\text{C}_3\text{H}_6)'' \dots$	Liquid.	311	Liquid.	371	222	422
	$(\text{C}_4\text{H}_8)'' \dots$	Liquid.	344	Liquid.	398	241	446
	$(\text{C}_5\text{H}_{10})'' \dots$	Liquid.	371	222	422	247	468

RELATION 3. *The melting- and boiling-points of either the halogen or alkyl compounds of the hydrocarbon radicals of any one group increase as the atomic weight of the hydrocarbon radical increases. (See Table III.)*

RELATION 4. *The differences between the boiling-points (and also between the melting-points) of the chlorides and bromides, bromides and iodides, chlorides and iodides (or between those of the methides and ethides, ethides and propides, propides and butides, &c.), increase algebraically from the first member of each series of hydrocarbon radicals up to the fourth or middle (tetrad)*

member and then diminish to the seventh or last member. (See Table IV.)

TABLE IV.—Illustrating Relations 4 and 5.

	Br—Cl.	I—Br.	I—Cl.	Et—Me.	Pr—Et.	Pr—Me.
Diff. in at. wts.	44.5	47	91.5	14	14	28
	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.
C ^{iv}	112	158	270	.....	.....	.....
(CH) ⁱⁱⁱ	90	.....	.....	114	.....	.....
(CH ₂) ⁱⁱ	55	83	138	66	60	126
(CH ₃) ⁱ	28	39	66	.....	29	.....
(C ₃ H) ⁱ .....	.....	.....	.....	.....	.....	.....
(C ₃ H ₂) ⁱⁱ .....	.....	.....	.....	.....	.....	.....
(C ₃ H ₃) ⁱⁱⁱ	55	.....	.....	.....	.....	.....
(C ₃ H ₄) ^{iv}	66	.....	.....	.....	.....	.....
(C ₃ H ₅) ^v	61	.....	.....	.....	.....	.....
(C ₃ H ₆) ^{vi}	45	42	94	60	51	111
(C ₃ H ₇) ^{vii}	24	29	53	37	33	70

The number of cases in which Relation 4 can be applied is unfortunately very limited ; but, in so far as it is applicable, the data obey exactly the same rule as those of the halogen and alkyl compounds of the elements.

RELATION 5. *The differences referred to in (4) increase as the difference between the atomic weights of the halogens (or of the alkyl radicals) increases. In the case where the difference between the alkyl radicals is the same, the differences between the boiling-points (or melting-points) diminish as the sum of the atomic weights of the several pairs of alkyl radicals increases.* (See Tables IV. and V.)

RELATION 6. *The differences referred to in (4) diminish algebraically as the atomic weight of the hydrocarbon radical increases.* (See Table V.)

TABLE V.—Illustrating Relations 5 and 6.

		Br—Cl.	I—Br.	I—Cl.	Et—Me.	Pr—Et.	Pr—Me.
	Diff. in at. wts.	} 44.5	47	91.5	14	14	28
		B.P.	B.P.	B.P.	B.P.	B.P.	B.P.
Normal halides and alkides of Group VII. $\text{CH}_3 \cdot (\text{CH}_2)_n \cdot \text{X}$.	$\text{CH}_3 \dots$	29	37	66	.....	29 *	.....
	$\text{C}_2\text{H}_5 \dots$	27	33	60	29*	37	66 *
	$\text{C}_3\text{H}_7 \dots$	25	31	56	37	33	70
	$\text{C}_4\text{H}_9 \dots$	22	30	52	33	27	60
	$\text{C}_5\text{H}_{11} \dots$	22	27	49	27	27	54
	$\text{C}_6\text{H}_{13} \dots$	22	26	48	27	24	51
	$\text{C}_7\text{H}_{15} \dots$	20	22	42	24	24	48
	$\text{C}_8\text{H}_{17} \dots$	20	.....	.....	24	22	46
Normal halides and alkides of Group VI. $\text{X} \cdot (\text{CH}_2)_n \cdot \text{X}$.	$(\text{CH}_2)^{\text{ii}}$	55	83	138	66 *	61	124
	$(\text{C}_2\text{H}_4)^{\text{ii}}$	48	a. 60	a. 108	70	54	124
	$(\text{C}_3\text{H}_6)^{\text{ii}}$	45	49	94	60	51	111
	$(\text{C}_4\text{H}_8)^{\text{ii}}$	45	.....	.....	54	48	102
	$(\text{C}_5\text{H}_{10})^{\text{ii}}$	36	.....	.....	51	46	97
	$(\text{C}_6\text{H}_{12})^{\text{ii}}$	23	.....	.....	48	41	89

* These four exceptions are all due to the boiling-point of propane, C_3H_8 , being taken too high. The number used is based on the data given by Lefebvre, who states that propane is condensed to a liquid at -25° to -30°C .

RELATION 7. (a) *The differences between the boiling-points (and also between the melting-points) of the halogen (or of the alkyl) compounds of the hydrocarbon radicals of each group diminish as we pass from the chlorides to the bromides, and thence to the iodides (or from the methides to the ethides, and thence to the propides, &c.).* (See Table VI.)

(b) *These differences also increase as the difference between the atomic weights of each pair of hydrocarbon radicals increases.* (See Table VI.)

In those cases where there is a common difference between the atomic weights of several pairs of hydrocarbon radicals, then the differences between the boiling-points increase as the sum of the atomic weights of the several pairs of hydrocarbon radicals diminishes. (See Table VI.)

TABLE VI.—Illustrating Relations 7a & b.

Group VII. $\text{CH}_3 \cdot (\text{CH}_2)_n \cdot \text{X}$	X=	Chlo- rides.	Bro- mides.	Iodides.	Me- thides.	Ethides.	Pro- pides.
	Diff. in at. wts.	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.
$\text{C}_6\text{H}_{17} - \text{C}_7\text{H}_{15}$ $\text{C}_7\text{H}_{15} - \text{C}_8\text{H}_{13}$ $\text{C}_8\text{H}_{13} - \text{C}_9\text{H}_{11}$ $\text{C}_9\text{H}_{11} - \text{C}_{10}\text{H}_9$ $\text{C}_{10}\text{H}_9 - \text{C}_3\text{H}_7$ $\text{C}_3\text{H}_7 - \text{C}_2\text{H}_5$ $\text{C}_2\text{H}_5 - \text{CH}_3$	$\left. \begin{array}{l} \\ \\ \\ \\ \\ \\ \end{array} \right\} \text{CH}_2$ $=14$	24 26 26 29 32 34 36	24 24 26 29 29 32 34	20 20 25 26 28 30 30	24 27 27 33 37 29* ...	24 24 27 33 37 29* ...	21 24 24 27 27 33 37
$\text{C}_8\text{H}_{17} - \text{C}_9\text{H}_{15}$ $\text{C}_9\text{H}_{15} - \text{C}_{10}\text{H}_{13}$ $\text{C}_{10}\text{H}_{13} - \text{C}_{11}\text{H}_{11}$ $\text{C}_{11}\text{H}_{11} - \text{C}_{12}\text{H}_9$ $\text{C}_{12}\text{H}_9 - \text{C}_3\text{H}_7$ $\text{C}_3\text{H}_7 - \text{CH}_3$	$\left. \begin{array}{l} \\ \\ \\ \\ \\ \end{array} \right\} 2\text{CH}_2$ $=28$	50 52 55 61 66 70	48 50 55 58 61 66	40 45 51 54 58 60	51 54 60 70 66* ...	43 51 54 60 70 66*	45 48 51 54 60 70
$\text{C}_9\text{H}_{17} - \text{C}_{10}\text{H}_{15}$ $\text{C}_{10}\text{H}_{15} - \text{C}_{11}\text{H}_{13}$ $\text{C}_{11}\text{H}_{13} - \text{C}_{12}\text{H}_{11}$ $\text{C}_{12}\text{H}_{11} - \text{C}_{13}\text{H}_9$ $\text{C}_{13}\text{H}_9 - \text{CH}_3$	$\left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} 3\text{CH}_2$ $=42$	76 81 87 95 102	74 79 84 90 95	65 71 79 84 88	78 87 97 99 ...	75 78 87 97 99	70 75 78 87 97
$\text{C}_9\text{H}_{17} - \text{C}_{10}\text{H}_{15}$ $\text{C}_{10}\text{H}_{15} - \text{C}_{11}\text{H}_{13}$ $\text{C}_{11}\text{H}_{13} - \text{C}_{12}\text{H}_{11}$ $\text{C}_{12}\text{H}_{11} - \text{CH}_3$	$\left. \begin{array}{l} \\ \\ \\ \end{array} \right\} 4\text{CH}_2$ $=56$	105 113 121 131	103 108 116 124	91 99 109 114	111 124 126 ...	102 111 124 126	97 102 111 124
$\text{C}_9\text{H}_{17} - \text{C}_{10}\text{H}_{15}$ $\text{C}_{10}\text{H}_{15} - \text{C}_{11}\text{H}_{13}$ $\text{C}_{11}\text{H}_{13} - \text{CH}_3$	$\left. \begin{array}{l} \\ \\ \end{array} \right\} 5\text{CH}_2$ $=70$	137 147 157	132 140 150	119 129 139	148 153 ...	135 148 153	124 135 148
$\text{C}_9\text{H}_{17} - \text{C}_{10}\text{H}_{15}$ $\text{C}_{10}\text{H}_{15} - \text{CH}_3$	$\left. \begin{array}{l} \\ \end{array} \right\} 6\text{CH}_2$ $=84$	171 183	164 174	149 159	177 ...	172 177	156 172
$\text{C}_8\text{H}_{17} - \text{CH}_3$	7CH_2 $=98$	207	198	179	...	201	193

* These exceptions are all due to the boiling-point of propane, C_3H_8 , being too high; see footnote to Table V.

RELATION 8. *The differences between the boiling-points† of the halogen or of the alkyl compounds of the hydrocarbon radicals of the seventh group, and those of the hydrocarbon radicals of the other groups respectively, increase algebraically from the chlorides to the bromides, and thence to the iodides (or from the methides to the ethides, and thence to the propides, &c.).* (See Table VII.)

† Data are wanting as regards melting-points.

TABLE VII.—Illustrating Relations 8 and 9.

Group VI. $X, (CH_2)_n, X$			Group VII. $CH_3, (CH_2)_n, X$		X =	Chlo- rides.	Bro- mides.	Iodides.	Me- thides.	Ethides.	Propides.
					Diff. in at. wts.	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.
CH_2	—	C_8H_{17}			—99	—141	—106	<i>b.</i> —41	—177	—135	—97
CH_2	—	C_7H_{15}	}	C_8H_{17}	—85	—117	—82	—21	—153	—111	—75
C_2H_4	—	C_8H_{17}				—99	—71	.....	—148	—102	—70
CH_2	—	C_6H_{13}	}	C_7H_{15}	—71	—91	—58	—1	—126	—87	—51
C_2H_4	—	C_7H_{15}				—75	—47	.....	—124	—78	—48
C_3H_6	—	C_8H_{17}				—64	—38	<i>b.</i> +6 <i>d.</i>	—111	—75	—46
CH_2	—	C_5H_{11}	}	C_6H_{13}	—57	—65	—32	+24	—99	—60	—27
C_2H_4	—	C_6H_{13}				—49	—23	.....	—97	—54	—24
C_3H_6	—	C_7H_{15}				—39	—14	+26 <i>d.</i>	—87	—51	—24
C_4H_8	—	C_8H_{17}				.....	.....	.....	—78	—48	—22
CH_2	—	C_4H_9	}	C_5H_{11}	—43	—36	—3	+50	—66*	—33	0
C_2H_4	—	C_5H_{11}				—23	+3	.....	—70	—27	0
C_3H_6	—	C_6H_{13}				—13	+10	+46 <i>d.</i>	—60	—27	0
C_4H_8	—	C_7H_{15}				.....	.....	.....	—54	—24	0
C_5H_{10}	—	C_8H_{17}				.....	.....	.....	—41	—24	0
CH_2	—	C_3H_7	}	C_4H_9	—29	—4	+26	+78	—29*	0	+28
C_2H_4	—	C_4H_9				+6	+32	.....	—37	0	+27
C_3H_6	—	C_5H_{11}				+13	+36	+71 <i>d.</i>	—33	0	+24
C_4H_8	—	C_6H_{13}				.....	.....	.....	—27	0	+24
C_5H_{10}	—	C_7H_{15}				.....	.....	.....	—27	0	+22
CH_2	—	C_2H_5	}	C_3H_7	—15	+30	+58	+108	0	+37	+61
C_2H_4	—	C_3H_7				+38	+61	.....	0	+33	+54
C_3H_6	—	C_4H_9				+42	+65	+97 <i>d.</i>	0	+27	+51
C_4H_8	—	C_5H_{11}				.....	.....	.....	0	+27	+48
C_5H_{10}	—	C_6H_{13}				.....	.....	.....	0	+24	+46
CH_2	—	CH_3	}	C_2H_5	—1	+66	+92	+138	.....	+66*	+98
C_2H_4	—	C_2H_5				+72	+93	.....	+29*	+70	+87
C_3H_6	—	C_3H_7				+74	+94	+125 <i>d.</i>	+37	+60	+78
C_4H_8	—	C_4H_9				.....	.....	.....	+33	+54	+75
C_5H_{10}	—	C_5H_{11}				.....	.....	.....	+27	+51	+69
C_2H_4	—	CH_3	}	C_2H_5	+13	+108	+127	.....	.....	+99	+124
C_3H_6	—	C_2H_5				+108	+126	+155 <i>d.</i>	+66*	+97	+111
C_4H_8	—	C_3H_7				.....	.....	.....	+70	+87	+102
C_5H_{10}	—	C_4H_9				.....	.....	.....	+60	+78	+96
C_3H_6	—	CH_3	}	C_2H_5	+27	+144	+160	+185 <i>d.</i>	.....	+126	+148
C_4H_8	—	C_2H_5				.....	.....	.....	+99	+124	+135
C_5H_{10}	—	C_3H_7				.....	.....	.....	+94	+111	+123
C_4H_8	—	CH_3	}	C_2H_5	+41	.....	.....	.....	.....	+153	+172
C_5H_{10}	—	C_2H_5				.....	.....	.....	+126	+148	+156
C_5H_{10}	—	CH_3			+55	.....	.....	.....	.....	+177	+193

N.B. The numbers followed by a (*d*) are not strictly comparable with the others, as one of the substances is decomposed on boiling, so that its boiling-point cannot be determined with any degree of exactness.

The numbers marked with an * are exceptions to Relation 9. They are all due to the b.p. of propane, C_3H_8 , being too high. Cf. footnote to Tables V. and VI.

RELATION 9. (a) *The differences referred to in Relation 8 increase algebraically as the algebraic difference between the atomic weights of the hydrocarbon radicals increases.* (See Table VII.)

(b) *In the case where several pairs of hydrocarbon radicals have a common difference in atomic weights, then the differences between the boiling-points of their halogen compounds increase as the sum of the atomic weights of the several pairs of hydrocarbon radicals increases.* This rule also holds for the alkyl compounds so long as the difference between the boiling-points is a minus quantity (*i. e.* so long as the boiling-point of the alkyl compound of the polyvalent hydrocarbon radical is lower than that of the corresponding alkyl compound of the monovalent hydrocarbon radical), but when this difference becomes a plus quantity the rule is reversed. (See Table VII.)

For the purpose of illustrating the above relationships we have chiefly made use of the compounds of the sixth and seventh groups of hydrocarbon radicals, because the sets of compounds belonging to these groups are much more complete than in the case of the other groups; the rules, however, hold equally with the latter as with the former.

The above nine rules have been applied in 1997 cases, of which 71 (or 3·6 per cent.) are exceptions. The exceptions are distributed as follows :—

	HALOGEN COMPOUNDS.				ALKYL COMPOUNDS.			
	Melting-points.		Boiling-points.		Melting-points.		Boiling-points.	
	No. of cases.	No. of exceptions.	No. of cases.	No. of exceptions.	No. of cases.	No. of exceptions.	No. of cases.	No. of exceptions.
Relation I.	20	2	68	1	5	0	48	0
" II.	20	0	60	1	8	0	49	0
" III.	...	...	104	1	6	0	73	0
" IV.	8	2	35	1	...	...	26	0
" V.	1	0	66	0	...	...	30	1
" VI.	...	...	78	1	...	...	42	6
" VII. <i>a.</i> ...	...	...	100	0	...	...	73	7
" VII. <i>b.</i> ...	...	...	103	0	2	0	102	14
" VIII.	...	...	108	0	...	...	285	0
" IX. <i>a</i> & <i>b.</i> ...	...	...	106	2	...	...	361	32
Total	49	4 =8%	828	7 =0·8%	21	0	1089	60 =5·5%

Of the above 71 exceptions no less than

45	are due to the b.p. of propane, C_3H_8 , being too high.
5	„ „ isobutane, $CHMe_3$, being too low.
2	„ m.p. of carbon tetrabromide, CBr_4 , being too high.
—	
52	

So that 52 of the 71 exceptions would be accounted for by errors in the boiling-points of two of the above compounds, and in the melting-point of the last one. As regards *propane* there is certainly a considerable error in its boiling-point, or rather in the number which has been assumed as the boiling-point in our investigations; for its actual boiling-point has not been determined, the value used being in fact the mean temperature of condensation, viz. -25° to -30° (cf. footnote to Table V.). With respect to *isobutane*, the boiling-point employed was that (-17°) given by Butlerow (*Annalen*, cxliv. 10). Konovaloff states that it boils below -10° (*Bull. Soc. Chim.* (2) xxxiv. 333). Finally, *carbon tetrabromide* is not only an exception to some of the relations noted above, but it was also shown, in my paper on the Halogen Compounds of the Elements, that, owing to its abnormally high melting-point, it was the most marked exception to some of the rules there stated.

In conclusion it will be seen, by a comparison of this and my previous papers, that the above nine relationships, together with others of less importance, hold good for the following four classes of compounds:—

- (1) The Halogen compounds of the Elements (*i. e.* of elements with elements).
- (2) The Alkyl compounds of the Elements (*i. e.* of elements with hydrocarbon radicals).
- (3) The Halogen compounds of the Hydrocarbon Radicals (*i. e.* of elements with hydrocarbon radicals).
- (4) The Alkyl compounds of the Hydrocarbon Radicals (*i. e.* of hydrocarbon radicals with hydrocarbon radicals).

Though the periodicity of Relation 1 holds for all the four classes of compounds, yet the nature of the periodicity is not exactly the same *throughout* for the compounds of the hydrocarbon radicals as for those of the elements.

We are therefore justified in concluding that, with the exception just stated, the physical properties of the compounds of the hydrocarbon radicals (so far as investigated) follow the same rules and exhibit exactly the same relationships as the corresponding compounds of the elements.

In my next paper I hope to indicate the theoretical significance of this general fact.

Diagram of the Boiling-Points of the Normal Methides, Chlorides, and Bromides of the Hydrocarbon Radicals.