391. *Studies in the Polyene Series. Part XXX. The Synthesis of* cyclo*Pentenyl and* cyclo*Heptenyl Analogues of β-Ionone.*

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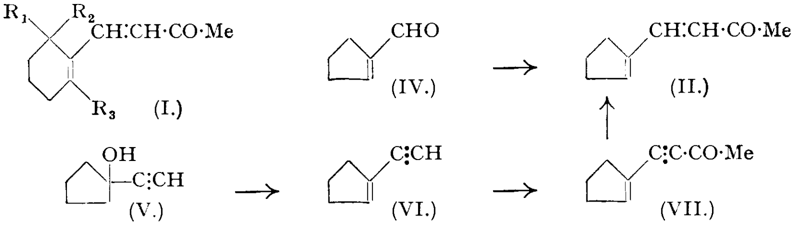
Methods previously developed for the preparation of analogues of β-ionone have now been applied to the synthesis of related compounds possessing *cyclo*pentenyl and *cyclo*heptenyl groups.

The diene ketone (II) was readily obtained by condensation of *cyclo*pentenealdehyde with acetone.

Ethynyl*cyclo*pentene (VI) and ethynyl*cyclo*heptene (IX) were prepared by dehydration of the corresponding acetylene carbinols. Treatment of the ethynyl*cyclo*alkenylmagnesium chlorides with acetic anhydride gave the acetylenic ketones (VII) and (X), which on partial hydrogenation yielded the diene ketones (II) and (III).

In Part XXVI of this series (Heilbron, Jones, Richardson, and Sondheimer, this vol., p. 737) attention was drawn to the importance of compounds of the type (I; R_1, R_2, and R_3 = H or Me), both for the preparation of analogues of vitamin A, and also for comparisons with β-ionone, particularly in light-absorption properties and reaction behaviour. As part of the general scheme for the synthesis of compounds with modified β-ionone structures, the *cyclo*pentenyl and *cyclo*heptenyl ketones (II) and (III) have now been prepared by the methods previously developed for the synthesis of the ketone (I; $R_1 = R_2 = R_3 =$ H).

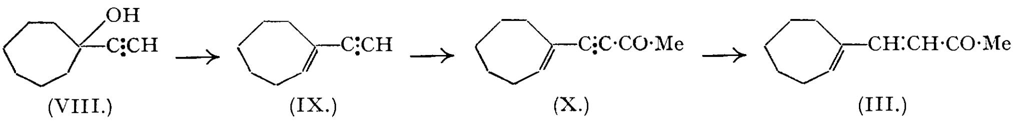
4-cyclo*Pent*-1′-*enylbut*-3-*en*-2-*one* (II) was readily obtained in 70% yield by condensation of *cyclo*pentenealdehyde (IV) (Urion, *Ann. Chim.*, 1934, **1**, 5) with acetone in the presence of sodium hydroxide.



(I.) (IV.) (II.) (V.) (VI.) (VII.)

The same ketone was also synthesised by the following route. Vapour-phase dehydration of ethynyl*cyclo*pentanol (V) over aluminium phosphate at 300—310° yielded *ethynyl*cyclo*pentene* (VI) (55%). By condensation of ethynyl*cyclo*pentenylmagnesium chloride with acetic anhydride, the acetylenic *ketone* (VII) was formed (40% yield), and this on partial hydrogenation in the presence of a quinoline-poisoned palladium–charcoal catalyst gave (II), isolated in 20% yield after regeneration from the *semicarbazone*, m. p. 186°.

Similarly, *ethynyl*cyclo*heptene* (IX) was prepared (85% yield) from ethynyl*cyclo*heptanol (VIII) and converted into the *ketone* (X) (70% yield). Partial hydrogenation of the latter gave 4-cyclo*hept*-1′-*enylbut*-3-*en*-2-*one* (III) which was obtained in 15% yield after regeneration from the *semicarbazone*, m. p. 183°.

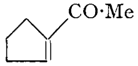


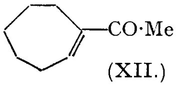
(VIII.) (IX.) (X.) (III.)

1-Acetyl*cyclo*hexene is obtained conveniently by treatment of 1-ethynyl*cyclo*hexanol with formic acid (cf. Chanley, *J. Amer. Chem. Soc.*, 1948, **70**, 244). 1-Acetyl*cyclo*pentene (XI) and

1-*acetyl*cyclo*heptene* (XII), required for spectrographic purposes, have now been prepared in a similar manner from the corresponding acetylene carbinols (V) and (VIII).

The light-absorption data for the various compounds described in this paper, together with those of the corresponding *cyclo*hexenyl analogues, are set out in the accompanying Table. The position of maximal absorption of the diene ketones is practically independent of the ring size.


(XI.)


(XII.)

However, in the acetyl*cyclo*alkenes, the *cyclo*pentenyl and *cyclo*heptenyl ketones exhibit maximal absorption at slightly longer wave-lengths than the *cyclo*hexenyl analogue. A similar bathochromic effort is observed in *cyclo*pentenealdehyde as compared with *cyclo*hexenealdehyde.

			2 : 4-Dinitrophenyl-hydrazone.‡		Semicarbazone.	
	$\lambda_{max.}$, A.	$\varepsilon_{max.}$.	$\lambda_{max.}$, A.	$\varepsilon_{max.}$.	$\lambda_{max.}$, A.	$\varepsilon_{max.}$.
(VI)	2270	10,000	—	—	—	—
Ethynyl*cyclo*hexene	2230	12,500	—	—	—	—
	2280 *	9,500	—	—	—	—
(IX)	2290	11,000	—	—	—	—
(VII)	2760	9,000	3800 †	29,500	2860	17,500
	2700	9,000	—	—	—	—
	2180	7,000	—	—	—	—
4-*cyclo*Hex-1′-enylbut-3-yn-2-one [1]	2720	11,000	3800 †	28,500	2820	16,500
	2220	6,000	—	—	2880 *	15,500
(X)	2800	11,500	3840 †	26,500	2910	17,000
(II)	2810	21,000	3960 †	30,500	2920	38,000
					3020	33,500
(I; $R_1 = R_2 = R_3 = H$) [2]	2810	20,000	3950 †	32,000	2900	35,000
	2730 *	18,500	—	—	3000 *	32,000
(III)	2820	16,500	3970 †	30,000	2930	43,000
	2890 *	15,000	—	—	3040	33,000
(XI)	2390	13,000	3840 †	28,500	2620	25,500
					2650 *	24,500
1-Acetyl*cyclo*hexene	2320	13,000	3870 †	27,500	2600	24,500
(XII)	2360	10,500	3810 †	24,500	2620	27,000
	2400 *	9,000				
(IV)	2370	12,000	3770 †	29,500	2670	30,500
					2770 *	25,500
*cyclo*Hexene-1-aldehyde	2290	12,000	3770 †	28,000	2650	31,500
					2600	28,500

* Inflexion. † In chloroform. ‡ Main band only.

[1] Heilbron, Jones, and Richardson, this vol., p. 287.

[2] Heilbron, Jones, Richardson, and Sondheimer, this vol., p. 737.

Of the acetylenic ketones and ethynyl*cyclo*alkenes, those possessing a *cyclo*heptenyl group show maximal absorption at somewhat longer wave-lengths than either of the smaller ring analogues. In view of the displacements in $\lambda_{max.}$ described above, it is of interest to note that in the case of cyclic unsaturated ketones, those possessing a five-atom ring exhibit maximal absorption at shorter wave-lengths than similar six-atom-ring and acyclic compounds (Gillam and West, *J.*, 1942, 486).

EXPERIMENTAL.

Light-absorption measurements were determined in ethanol, except where stated otherwise, and the data are given in the Table. All the operations were performed in an atmosphere of nitrogen.

cyclo*Pentenealdehyde* (IV).—This was prepared by the method of Urion (*Ann. Chim.* 1934, **1**, 5) and had b. p. 45°/16 mm., n_D^{23} 1·4820 (*idem, loc. cit.*, gives b. p. 48°/11 mm., n_D^{21} 1·4828). The 2 : 4-*dinitrophenylhydrazone* crystallised from ethyl acetate in dark red plates, m. p. 215—216° (Found : C, 52·25; H, 4·3. $C_{12}H_{12}O_4N_4$ requires C, 52·15; H, 4·4%). The semicarbazone crystallised from methanol in plates, m. p. 212° (*idem, loc. cit.*, gives m. p. 209°).

1-*Ethynyl*cyclo*pentanol* (V).—A rapid stream of acetylene was passed into liquid ammonia (4 l.) and sodium (29 g.) was added in small pieces at such a rate that no permanent blue colour developed. A solution of *cyclo*pentanone (105 g.) in ether (500 c.c.) was then added during 1 hour, and the cooled solution stirred overnight. The reaction was terminated by gradual addition of ammonium chloride

(80 g.), the ammonia was allowed to evaporate, and the product was isolated with ether. Distillation gave ethynyl*cyclo*pentanol (87 g.), b. p. 78°/40 mm., which rapidly solidified to needles, m. p. 24° (Backer and van der Bij, *Rec. Trav. chim.*, 1943, **62**, 561, give b. p. 57·5—59°/11 mm., m. p. 21°).

1-*Ethynyl*cyclo*pentene* (VI).—Ethynyl*cyclo*pentanol (50 g.) was slowly distilled (*ca.* 25 g./hour) at 110—120° (bath-temp.)/120 mm. through a Pyrex tube (70 × 2 cm.) maintained at 300—310° and containing a supported aluminium phosphate catalyst (prepared according to Heilbron, Jones, and Richardson, this vol., p. 287). The emergent gases were cooled in air- and water-condensers, and the liquid product was collected in a flask cooled in ice–salt. After the water produced had been separated, the crude material was distilled, and the fraction boiling below 70°/150 mm. was dried ($CaCl_2$) and fractionated to give *ethynyl*cyclo*pentene* (17·8 g.) as a pale yellow mobile liquid with a sharp odour and b. p. 65·5°/125 mm., n_D^{19} 1·4880 (Found: C, 90·9; H, 9·1. C_7H_8 requires C, 91·25; H, 8·8%). By distillation of the high-boiling residue ethynyl*cyclo*pentanol (20 g.), b. p. 76—78°/40 mm., was recovered.

The hydrocarbon (1·168 g. and 1·038 g.) in methyl acetate (5 c.c.) was shaken in hydrogen in the presence of platinic oxide catalyst until absorption ceased. Hydrogen absorbed was 863 c.c. at 17°/764 mm., and 770 c.c. at 19°/765 mm., respectively, equivalent to an average value of 2·9 double bonds.

4-cyclo*Pent*-1′-*enylbut*-3-*yn*-2-*ol*.—Ethynyl*cyclo*pentene (15·3 g.) in ether (40 c.c.) was added dropwise to an ethereal solution of ethylmagnesium bromide (from 4·1 g. of magnesium), and the solution heated under reflux for 1 hour. Acetaldehyde (6·0 g.) in dry ether (40 c.c.) was added and the solution stirred for 1 hour. The complex was decomposed with aqueous ammonium chloride, and the product isolated with ether in the usual manner. Distillation gave 4-cyclo*pent*-1′-*enylbut*-3-*yn*-2-*ol* (16·3 g.), b. p. 50°/0·05 mm., n_D^{18} 1·5200 (Found: C, 79·3; H, 8·9. $C_9H_{12}O$ requires C, 79·35; H, 8·9%). Light absorption: Maximum, 2280 A.; ε, 14,500. Inflexion, 2350 A., ε, 12,500. The 3 : 5-*dinitrobenzoate* crystallised from light petroleum (b. p. 60—80°) in colourless needles, m. p. 127° (Found: N, 8·6. $C_{16}H_{14}O_6N_2$ requires N, 8·5%).

4-cyclo*Pent*-1′-*enylbut*-3-*yn*-2-*one* (VII).—Ethynyl*cyclo*pentene (13 g.) in dry ether (40 c.c.) was added dropwise to an ethereal solution of ethylmagnesium chloride (from 3·5 g. of magnesium), and the mixture heated under reflux for ½ hour. After standing for ½ hour, the cold ethereal suspension of the Grignard reagent was added slowly with stirring to a solution of acetic anhydride (18·0 g.) in ether (100 c.c.) at −60°. Stirring was continued while the temperature of the mixture was allowed to rise to 10° during 7 hours, whereafter ice was added. The etherea llayer was then washed free from acid and dried. Distillation gave 4-cyclo*pent*-1′-*enylbut*-3-*yn*-2-*one* (7·4 g.) as a mildly vesicant liquid, b. p. 55°/0·3 mm., n_D^{19} 1·5276 (Found: C, 80·4; H, 8·0. $C_9H_{10}O$ requires C, 80·55; H, 7·55%). The 2 : 4-*dinitrophenylhydrazone* crystallised from alcohol in orange or yellow needles, m. p. 158° (Found: N, 17·5. $C_{15}H_{14}O_4N_4$ requires N, 17·8%). The *semicarbazone* crystallised in needles, m. p. 164°, from alcohol (Found: N, 22·35. $C_{10}H_{13}ON_3$ requires N, 22·0%).

4-cyclo*Pent*-1′-*enylbut*-3-*en*-2-*one* (II).—(*a*) A solution of the above ketone (VII; 5·7 g.) in methyl alcohol (40 c.c.) was shaken with hydrogen in the presence of a 2% palladium–charcoal catalyst (0·6 g.), partly poisoned with quinoline (Isler, Huber, Ronco, and Kofler, *Helv. Chim. Acta*, 1947, **30**, 1911) until 1 molar proportion of hydrogen had been absorbed (1006 c.c. at 18°/778 mm.). After removal of the catalyst and solvent, distillation gave a pleasant-smelling liquid (4·8 g.), b. p. 40—45°/0·01 mm., n_D^{20} 1·5310. Treatment with semicarbazide acetate (from semicarbazide hydrochloride, 5 g.) in methanol (50 c.c.) gave the *semicarbazone* (3·2 g.) which crystallised from alcohol in needles, m. p. 186° (Found: C, 62·1; H, 7·75. $C_{10}H_{15}ON_3$ requires C, 62·1; H, 7·8%). The semicarbazone (3·0 g.) was heated under reflux for 15 minutes with light petroleum (50 c.c.; b. p. 80—100°) and 2N-sulphuric acid (50 c.c.). Isolation of the product as usual gave 4-cyclo*pent*-1′-*enylbut*-3-*en*-2-*one* (1·3 g.) as a pleasant-smelling liquid, b. p. 85—87°/3 mm., n_D^{22} 1·5442, which solidified at 0° (Found: C, 79·2; H, 9·15. $C_9H_{12}O$ requires C, 79·35; H, 8·9%). The 2 : 4-*dinitrophenylhydrazone* crystallised from acetic acid in dark red prisms, m. p. 215° (Found: C, 56·8; H, 5·1. $C_{15}H_{16}O_4N_4$ requires C, 56·95; H, 5·1%).

(*b*) *cyclo*Pentenealdehyde (7·3 g.) in acetone (15 c.c.) was added slowly with stirring to a solution of sodium hydroxide (1·0 g.) in water (30 c.c.) and acetone (120 c.c.) maintained at 0°. After stirring for 1 hour at 0°, the solution was allowed to warm to 20° during 1·5 hours, poured into water (500 c.c.) and acidified. Isolation of the product with ether gave (i) recovered *cyclo*pentenealdehyde (4·0 g.) and (ii) 4-*cyclo*pent-1′-enylbut-3-en-2-one (3·3 g.), b. p. 44°/0·01 mm., n_D^{23} 1·5432. The 2 : 4-dinitrophenylhydrazone crystallised from acetic acid in dark red prisms, m. p., and mixed m. p. with sample from (*a*), 215°. The semicarbazone crystallised in needles from alcohol, m. p., and mixed m. p. with sample from (*a*), 186°.

1-*Ethynyl*cyclo*heptanol* (VIII).—A solution of sodium acetylide (from 46 g. of sodium) in liquid ammonia (1·5 l.) was prepared by the procedure of Heilbron, Jones, and Weedon (*J.*, 1945, 81). A solution of *cyclo*heptanone (214 g.) in dry ether (400 c.c.) was then added during 1·5 hours, and stirring and cooling were continued for a further 4 hours. The reaction was terminated by the gradual addition of ammonium chloride (110 g.), the ammonia allowed to evaporate, and the product isolated with ether. Distillation gave (i) recovered ketone (70 g.) and (ii) 1-ethynyl*cyclo*heptanol (118 g.), m. p. 14°, b. p. 90°/13 mm., n_D^{22} 1·4880 (Backer and van der Bij, *loc. cit.*, give b. p. 90—92°/12 mm., m. p. 13·5—14°) (Found: C, 77·8; H, 10·65. Calc. for $C_9H_{14}O$: C, 78·2; H, 10·2%). The 3 : 5-*dinitrobenzoate* crystallised from light petroleum (b. p. 60—80°) in needles, m. p. 108—109° (Found: N, 8·85. $C_{16}H_{16}O_6N_2$ requires N, 8·45%).

1-*Ethynyl*cyclo*heptene* (IX).—1-Ethynyl*cyclo*heptanol (40 g.) was slowly distilled at 100—110° (bath-temp.)/18 mm. under the conditions described above for (VI). After the water produced had been separated, the crude product was distilled and the fraction of b. p. <80°/35 mm. was dried ($CaCl_2$) and fractionated, giving 1-*ethynyl*cyclo*heptene* (18·3 g.) as a colourless liquid having a sharp odour and b. p. 78°/35 mm., n_D^{20} 1·4980 (Found: C, 89·55; H, 9·95. C_9H_{12} requires C, 89·9; H, 10·1%). By distillation of the high-boiling residue, ethynyl*cyclo*heptanol (15 g.), b. p. 90—92°/15 mm., was recovered.

The hydrocarbon (0·710 g. and 1·035 g.) in methyl acetate (5 c.c.) was shaken in hydrogen in the presence of platinic oxide catalyst until absorption ceased. Hydrogen absorbed at 17° and 764 mm. was 416 c.c. and 605 c.c., respectively, equivalent to an average value of 2·97 double bonds.

4-cyclo*Hept-1′-enylbut-3-yn-2-one* (X).—1-Ethynyl*cyclo*heptene (25 g.) in ether (50 c.c.) was added dropwise to an ethereal solution of ethylmagnesium chloride (from 5·1 g. of magnesium), and the mixture was heated under reflux for 2 hours. After cooling, the ethereal suspension of the Grignard reagent was slowly added with stirring to a solution of acetic anhydride (21 g.) in dry ether (100 c.c.) at −60°. After the mixture had been stirred at −60° for 1 hour, the temperature was allowed to rise to 20° during 2 hours. The complex was then decomposed with ice, the ether layer separated, washed free from acid, and dried. Distillation gave (i) recovered ethynyl*cyclo*heptene (5·5 g.) and (ii) 4-(cyclo*hept-1′-enyl*)*but-3-yn-2-one* (18·2 g.), b. p. 65°/0·01 mm., n_D^{21} 1·5280 (Found : C, 81·1 ; H, 8·8. $C_{11}H_{14}O$ requires C, 81·4 ; H, 8·7%). The 2 : 4-*dinitrophenylhydrazone* crystallised from alcohol in orange needles, m. p. 142° (Found : N, 16·2. $C_{17}H_{18}O_4N_4$ requires N, 16·35%). The *semicarbazone* crystallised from aqueous alcohol in needles, m. p. 163° (Found : N, 19·1. $C_{12}H_{17}ON_3$ requires N, 19·15%).

4-(cyclo*Hept-1′-enyl*)*but-3-en-2-one* (III).—A solution of the above ketone (X) (13·6 g.) in methanol (50 c.c.) was shaken with hydrogen in the presence of 2% palladium–charcoal (1·3 g.) partly poisoned with quinoline (Isler, Huber, Ronco, and Kofler, *loc. cit.*) until 1995 c.c. of hydrogen had been absorbed at 18°/768 mm. (1 molar proportion). After removal of the catalyst and solvent, the product was distilled. The fraction, b. p. 65—70°/10^{-2} mm., n_D^{22} 1·5280, was treated with semicarbazide acetate (from semicarbazide hydrochloride, 9·0 g.) in methanol (50 c.c.) and gave the *semicarbazone* (3·2 g.) which crystallised from alcohol in needles, m. p. 183° (Found : N, 18·7. $C_{12}H_{19}ON_3$ requires N, 19·0%). The semicarbazone was heated under reflux with vigorous stirring for 15 minutes with light petroleum (50 c.c. ; b. p. 80—100°) and 2N-sulphuric acid (50 c.c.). Isolation of the product as usual gave 4-cyclo*hept-1′-enylbut-3-en-2-one* (1·7 g.) as a pleasant-smelling liquid, b. p. 76—77°/0·1 mm., n_D^{24} 1·5400 (Found : C, 80·0 ; H, 9·95. $C_{11}H_{16}O$ requires C, 80·4 ; H, 9·8%). The 2 : 4-*dinitrophenylhydrazone* crystallised from acetic acid as red prisms, m. p. 188° (Found : N, 16·5. $C_{17}H_{20}O_4N_4$ requires N, 16·3%).

4-cyclo*Heptylbutan-2-one*.—A solution of the ketone (X) (1·3 g.) in methyl acetate (10 c.c.) was shaken with hydrogen in the presence of platinic oxide until absorption ceased. Hydrogen absorbed at 15° and 722 mm. was 585 c.c., equivalent to 3·0 double bonds. Removal of the catalyst and solvent, and distillation of the residue, gave 4-cyclo*heptylbutan-2-one* (1·15 g.) as a pleasant-smelling liquid, b. p. 57°/0·1 mm., n_D^{20} 1·4685 (Found : C, 78·1 ; H, 11·7. $C_{11}H_{20}O$ requires C, 78·5 ; H, 12·0%). The *semicarbazone* crystallised from aqueous alcohol in plates, m. p. 182° (Found : C, 64·05 ; H, 10·45. $C_{12}H_{23}ON_3$ requires C, 63·95 ; H, 10·2%).

1-*Acetyl*cyclo*pentene* (XI).—A solution of 1-ethynyl*cyclo*pentanol (6·0 g.) in 90% formic acid (60 c.c.) was heated under reflux for 2½ hours. The mixture was poured into 2N-sodium carbonate solution (600 c.c.), and the product was isolated with ether. Distillation gave 1-acetyl*cyclo*pentene (3·0 g.), b. p. 67°/16 mm., n_D^{22} 1·4780. Treatment with semicarbazide acetate (from semicarbazide hydrochloride, 3 g.) in methanol (25 c.c.) gave the semicarbazone (3·55g.) which crystallised from alcohol in needles, m. p. 211—212° (Rapson and Robinson, *J.*, 1935, 1285, give m. p. 210—211°). The semicarbazone (3·3 g.) was heated under reflux for 15 minutes with light petroleum (50 c.c. ; b. p. 60—80°) and 2N-sulphuric acid (50 c.c.). Isolation of the product as usual gave 1-acetyl*cyclo*pentene (1·75 g.), b. p. 69°/17 mm., n_D^{23} 1·4776 (*idem, loc. cit.*, give b. p. 75—78°/22 mm.). The 2 : 4-*dinitrophenylhydrazone* crystallised from alcohol in bright red needles, m. p. 203° (Found : C, 54·1 ; H, 5·0. $C_{13}H_{14}O_4N_4$ requires C, 53·8 ; H, 4·9%).

1-*Acetyl*cyclo*heptene* (XII).—A solution of 1-ethynyl*cyclo*heptanol (5·3 g.) in 90% formic acid (50 c.c.) was heated under reflux for 2½ hours. The mixture was poured into 2N-sodium carbonate solution (600 c.c.), and the product isolated with ether. Distillation yielded the ketone (2·5 g.), b. p. 90—97°/17 mm., n_D^{23} 1·4878, which gave no colour with Schiff's reagent. Treatment with semicarbazide acetate (from semicarbazide hydrochloride, 3 g.) in methanol (30 c.c.) gave the *semicarbazone* (2·8 g.) which crystallised from alcohol in needles, m. p. 197° (Found : C, 61·65 ; H, 8·4. $C_{10}H_{17}ON_3$ requires C, 61·5 ; H, 8·75%). The semicarbazone (1·6 g.) was heated under reflux for 15 minutes with light petroleum (40 c.c. ; b. p. 60—80°) and 2N-sulphuric acid (40 c.c.). Isolation of the product as usual gave 1-*acetyl*cyclo*heptene* (0·9 g.), b. p. 97°/16 mm., n_D^{25} 1·4900 (Found : C, 78·05 ; H, 10·0. $C_9H_{14}O$ requires C, 78·2 ; H, 10·2%). The 2 : 4-*dinitrophenylhydrazone* crystallised from alcohol in crimson plates, m. p. 178° (Found : C, 56·3 ; H, 5·4. $C_{15}H_{18}O_4N_4$ requires C, 56·6 ; H, 5·15%).

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