**Table 3** Oxidative hydrolysis of yellow phosphorus with copper(II) acetate and copper(II) acetate – PVA at 60 °C.

| Runs | Composition of solution, mol/L | | | | *T*, °C | Time, min | Yield of products, % | |
|---|---|---|---|---|---|---|---|---|
| | Cat | $P_4$ | $H_2O$ | $C_7H_8$ | | | I | II |
| Cat $Cu(OAc)_2 \cdot H_2O$ | | | | | | | | |
| 1 | 1.07 | 1.07 | 50 | 0.94 | 60 | 120 | 21 | 40 |
| 2 | 3.21 | 1.07 | 50 | 0.94 | 60 | 120 | 27 | 47 |
| 3 | 6.42 | 1.07 | 50 | 0.94 | 60 | 120 | 33 | 55 |
| Cat $Cu(PVA)_2(OAc)_2$ | | | | | | | | |
| 1 | 1.07 | 1.07 | 50 | 0.94 | 60 | 120 | 27 | 47 |
| 2 | 3.21 | 1.07 | 50 | 0.94 | 60 | 120 | 37 | 53 |
| 3 | 6.42 | 1.07 | 50 | 0.94 | 60 | 120 | 40 | 57 |

Note: I – $(HO)_2HPO$; II – $(HO)_3PO$.

The $P_4$ molecule, its inorganic and organic derivatives are prone to two-electron oxidation in aqueous solutions: $P_4 \rightarrow 4P^+$; $P^+ \rightarrow P^{3+}$; $P^{3+} \rightarrow P^{5+}$. It is known that the products of two-electron oxidation of $P_4$ are stable compounds $P_4(OR)_2$, $P_4(OR)_4$, $P_2(OR)_4$, $P(OR)_3$, $P(OR)_5$, while the products of one-electron oxidation of $P_4$ are unstable radicals [25]. They are strong two-electron reducing agents and impose the role of a two-electron oxidizer on Cu(II) complexes [26]. The standard reduction potentials of Cu(II) indicate that, depending on the redox partner, Cu(II) can be reduced to Cu(I) or Cu. The Cu(II) ion is prone to both single-electron ($E_{Cu(II)/Cu(I)}$ = 0,538 V) and two-electron reduction ($E_{Cu(II)/Cu(o)}$ = 0,337 V).

## 4. Conclusions

In this study, the ratio of components in a complex compound based on copper(II) acetate and polyvinyl alcohol was determined by the potentiometric method. Two monolinks of polymers connect to one complex – forming metal ion. In addition, the results of the conducted conductometric work also proved that the metal-ligand ratio is 1:2. Microphotographs taken with SEM showed the formation of porous spherolites of various sizes. As a result of IR spectroscopy, it was shown that the peak corresponding to the $\nu_{O-H}$ subgroup in the polymer-ligand shifted in a complex compound from 2390 to 2410 $cm^{-1}$.

The thermodynamic characteristics of the complex compound based on copper(II) acetate and polyvinyl alcohol were calculated, and it was found that the Gibbs' energy value is a negative. The process of complex formation occurs spontaneously. The value of the enthalpy is also negative, and with an increase in temperature, it is assumed that the reaction will shift in the opposite direction.

The maximum oxygen absorption rate was observed in the case of the molar ratio $[Cu(PVA)_2(OAc)_2]:[P_4]$ = 6:1 with yield of final products up to 97%.

## Supplementary materials

No supplementary materials are available.

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## Author contributions

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## Conflict of interest

The authors declare no conflict of interest.

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