Poly(vinylpyrrolidone)-bromine complex; a mild and efficient reagent for selective bromination of alkenes and oxidation of alcohols

Moslem Mansour Lakouraj*, Mahmood Tajbakhsh and Masoud Mokhtary

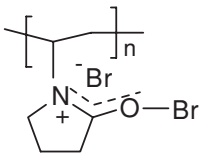
Department of Chemistry, Mazandaran University, Babolsar, 47415, Iran

Poly(vinylpyrrolidone)-bromine complex (PVP–Br_2) is easily prepared and used as a mild and convenient reagent for selective bromination of alkenes and at the position α-hydrogen of active carbonyl compounds. Selective oxidation of benzylic alcohols in the presence of aliphatic alcohols were also achieved at room temperature.

Keywords*:* PVP–Br_2, bromination, poly(vinylpyrrolidone), selective oxidation

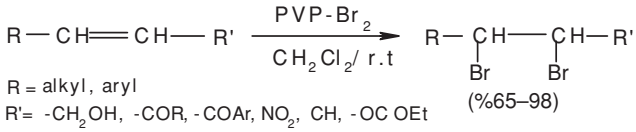
Bromination of organic compounds is a common process of considerable interest in organic synthesis, and teaching. Unfortunately bromine is very toxic and corrosive. Therefore, a number of brominating agents have been introduced to avoid these disadvantages. In recent decades much attention has been given to the synthesis and application of new brominating agents including $TBABr_3$,[1,2] (Pyrrolidone). HBr_3,[3] copper(II) halides,[4] tetradecyltrimethylammonium permanganate/trimethylbromosilane,[5] hydrohalic acid/hydrogen peroxide,[6] 2,4,4,6-tetrabromocyclohexa-2,5-dienone,[7] vanadium bromo-peroxidase,[8] 2-bromo-2-cyano-*N*,*N*-dimethylacetamide (BCDA),[9] 5,5-dibromo-2,2-dimethyl-4,6-dioxo-1,3-dioxane,[10] hydrohalic acid/H_2O_2 (TBHP),[11] and cerium(IV) ammonium nitrate (CAN)/potassium bromide,[12] which were used for the bromination of organic compounds. The utilisation of polymer supports as reagent and catalyst have received special attention due to the easy work-up of reaction products and some selectivity which are undoubtedly attractive features of this methodology.[13-15] Also, a few polymeric reagents have been described as useful brominating agents.[16-19] Many of these compounds have been immobilised on cationic polymers such as anion exchange resins and protonated poly (vinylpyridine).[20-23] Poly (vinylpyrrolidone) is useful as blood plasma extender which can act as carrier for a variety of substances in the blood stream and has been used as a retardant for drugs and eliminant for toxins.[24] Its iodine complex, povidon-iodine, is widely used as an antiinfective agent in clinical treatments.[25] In connection with our interest in design and application of functionalised polymers, we introduce here a new and stable polymeric agent namely poly(vinylpyrrolidone)-bromine complex (PVP–Br_2) as a stable bench top reagent for the bromination of alkenes and ketones and for the selective oxidation of alcohols . In contrast to some other supported oxidants which are photosensitive[26] this reagent is stable and retains its activity after several months of storage.

Interestingly, this reagent not only gives excellent yields of the products but also poly(vinylpyrrolidone) is easily regenerated and can be reused several times.



Results and discussions

In this study, the PVP–Br_2 complex is obtained by simple complexation of bromine with poly(vinylpyrrolidone) which can release *in situ* bromine species in reaction media. The PVP–Br_2 complex is a stable orange powder and decomposes at of 187 °C. This complex is soluble in water and insoluble in most organic solvents such as CH_2Cl_2, $CHCl_3$, CH_3CN, *n*-hexane and ether. Bromination reactions were carried out in dichloromethane at room temperature (Scheme 1). A variety of carbon–carbon double bonds were brominated and gave dibromides in good to excellent yields under very mild conditions (Table 1, entries 1–10). As shown in Table 1, this reagent brominates carbon–carbon double bonds in allylic systems without any rearrangement or hydroxyl group oxidation (Table 1, entries 1–4, 6, 10). It is also interesting that aromatic rings and α-positions in carbonyl compounds are not affected during bromination of an alkenic moiety (Table 1, entries 1, 3, 5, 6, 8, and 9). However activated α-positions of carbonyl compounds undergo bromination with this reagent efficiently under the reaction conditions shown (Table 1, entries 11, 12, 14).

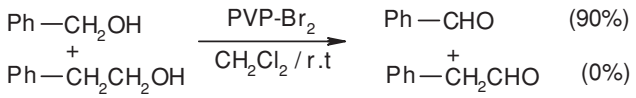


Scheme 1

Acetophenone was treated with PVP–Br_2 complex at room and higher temperatures for up to six hours, but no bromination at the α-positions or on the aromatic ring occurred. Bromination of other ketones such as cyclohexanone, 4-phenylcyclohexanone and 2-butanone with a high molar ratio of brominating agent, longer reaction time and higher temperature only afforded a low yield of the monobrominated products. Attempts to brominate alkynes were unsuccessful. During our work we noticed that the reagent was able to oxidise alcohols, so we decided to investigate this further.

Benzylic alcohols bearing electron releasing and electron withdrawing groups in the aromatic ring are oxidised with PVP–Br_2 complex at room temperature and give good yields of the corresponding carbonyl compounds. The results, summarised in Table 2, indicate that aliphatic alcohols are not oxidised under the reaction conditions. Therefore, chemoselective oxidation of benzylic alcohols is achieved in the presence of aliphatic alcohols. In a typical experiment when equimolar amounts of benzyl alcohol and 2-phenylethanol were treated with one equivalent of reagent for 0.5 h in CH_2Cl_2 at room temperature, only benzyl alcohol was selectively oxidised to benzaldehyde and 2-phenylethanol was remained unchanged (Scheme 2).

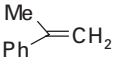
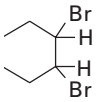
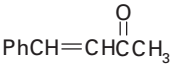
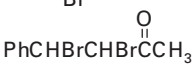
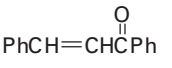
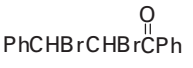
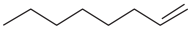
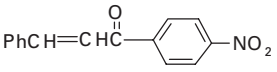
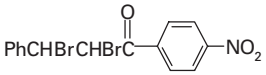
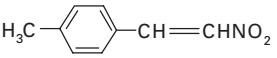
The oxidation of other functional groups with this complex is under investigation in our laboratory.



Scheme 2

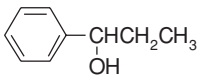
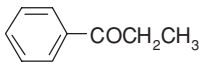
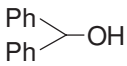
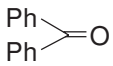
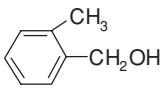
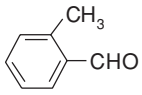
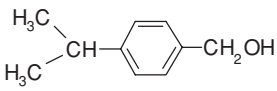
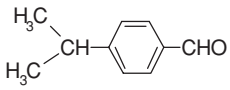
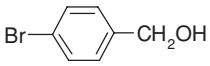
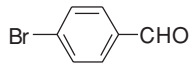
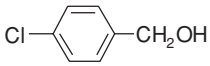
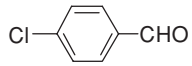
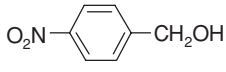
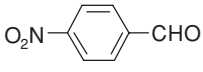
* Correspondent. E-mail: lakouraj@umz.ac.ir

Table 1 Bromination of some alkenes and activated carbonyl compounds with the PVP–Br_2 complex.

Entry	Substrate	Time/min	Product	Yield [a]/%	M.p. /°C (lit.)	Ref.
1	$PhCH{=}CHCH_2OH$	10	$PhCHBrCHBrCH_2OH$	98	73–74(74)	27
2	$CH_2{=}CHCH_2OH$	15	$CH_2BrCHBrCH_2OH$	98	Oil	28
3		30	$PhCMeBrCH_2Br$	90	Oil	29
4		30		94	Oil	4, 5, 10
5		180		96	124–125 (125–126)	17
6		180		92	157–158 (156–158)	12
7		30	$CH_3(CH_2)_5CHBrCH_2Br$	96	Oil	2, 8
8		360		90	192–194 (194)	30
9		120	$CH_3C_6H_4CHBrCHBrNO_2$	65[b]	78–80 (79–80)	31
10	$H_2C{=}CHCO_2Et$	30	$BrCH_2CHBrCH_2CO_2Et$	94	Oil	32
11	$CH_2(CO_2ET)_2$	30	$BrCH(CO_2Et)_2$	88	Oil	17
12	$PhCH_2COCH_3$	120	$PhCHBrCOCH_3$	87	Oil	9
13	$PhCOCH_3$	360	$PhCOCH_2Br$	0		–
14	$CNCH_2CO_2Et$	30	$NCCHBrCO_2Et$	90	Oil	33

[a]Isolated yield.
[b]Reflux condition.

Table 2 Oxidation of alcohols with the PVP–Br_2 complex in dichloromethane.

Entry	Substrate	Time/min	Product[28,34]	Yield [a]/%
1	$Ph{-}CH_2OH$	0.5	$Ph{-}CHO$	90
2		1		96
3		2		85
4		2		84
5		2.5		82
6		0.5		98
7		0.5		97
8		2		65
9	$Ph{-}CH_2CH_2OH$	12	$Ph{-}CH_2CHO$	0
10	1-Octanol	12	1-Octanal	0
11	5-Nonanol	12	5-Nonanal	–[b]

[a]Yields refer to isolated product.
[b]Trace of unidentified compound.

Experimental

Melting points were recorded on an electrothermal melting point apparatus and are uncorrected. The NMR spectra were recorded in $CDCl_3$ with TMS as an internal standard on a Brucker WM 500 NMR spectrometer. The purity determination of the products was accomplished by TLC on silica gel poly gram SIL G/UV 254 plates. Products were separated and purified by different chromatography techniques, and were also identified by the comparison of their m.p., IR and NMR spectra, with those reported for authentic samples.

Preparation of poly(vinylpyrrolidone)-bromine complex PVP–Br_2

To a solution of poly(vinylpyrrolidone) (PVP) 4 g in CH_2Cl_2 (25 ml), a solution of bromine (5 ml) in CH_2Cl_2 (15 ml) was added dropwise and the mixture was stirred for 0.5 h at room temperature. The resulting dark-orange resin was filtered off and washed with CH_2Cl_2 (2 × 20 ml), and then dried in a desiccator to give a stable non-hygroscopic powder. The IR spectrum shows a characteristic absorption at 1643 cm^{-1} corresponding to the carbonyl group. The capacity of the reagent was determined by iodometric titration and found to be 3.7 mmol bromine per gram of polymeric reagent.

General procedure for the bromination of alkenes and oxidation of alcohols by the PVP–Br_2 complex

To a solution of substrate (1 mmol) in dichloromethane (10 ml), PVP–Br_2 (3 mmol) was added and the mixture was stirred for 0.1–6 h at room temperature. Progress of the reaction was monitored by TLC. On completion the reaction mixture turned yellowish. The mixture was filtered and the residue was washed with dichloromethane (2 × 5 ml). The filtrate was poured into a 100 ml separating funnel, washed first with water and then with aqueous (5 %) sodium thiosulfate solution. Finally, the organic layer was dried over sodium sulfate. The solvent was evaporated and the remaining material was purified on a silica gel plate to give the corresponding product. The procedure for ketones was performed with a (2:1) ratio of reagent to substrate.

Regeneration of the PVP–Br_2 complex

The reagent (4 g) was washed with diethyl ether (2 × 10 ml), and treated with a dilute bromine solution in CH_2CL_2 which was added drop wise using a separating funnel. The mixture was stirred for 0.5 h at room temperature. The reagent was then filtered off, washed with dichloromethane (2 × 20ml) and dried in a desiccator.

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