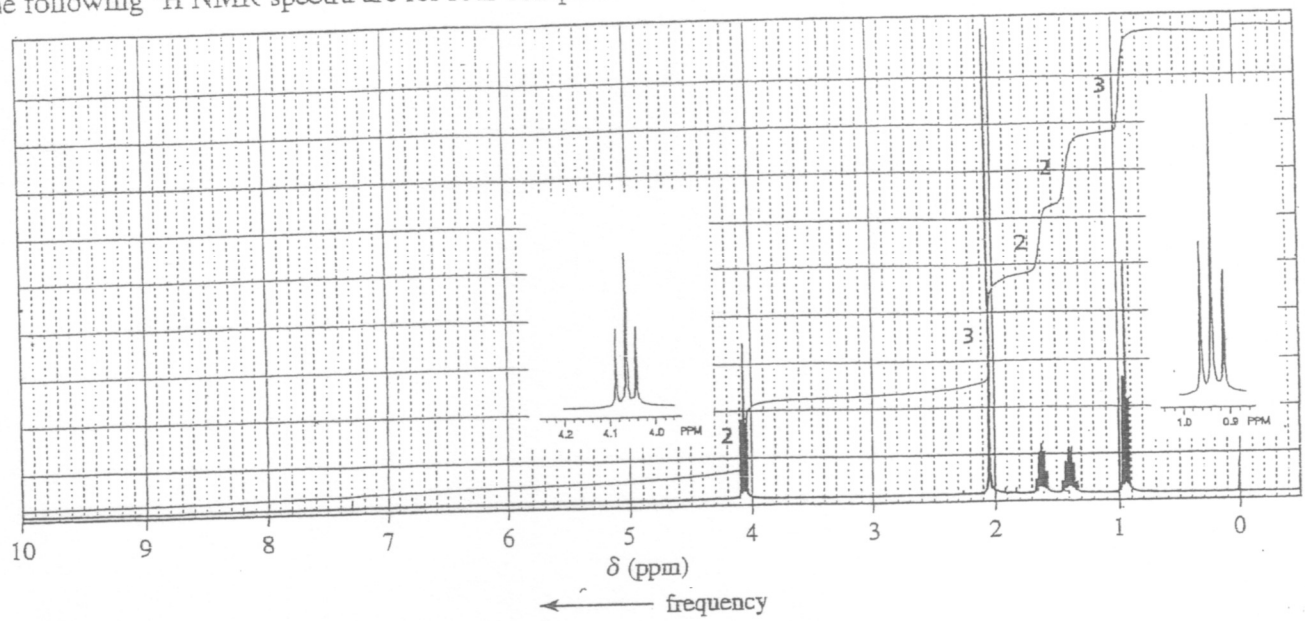
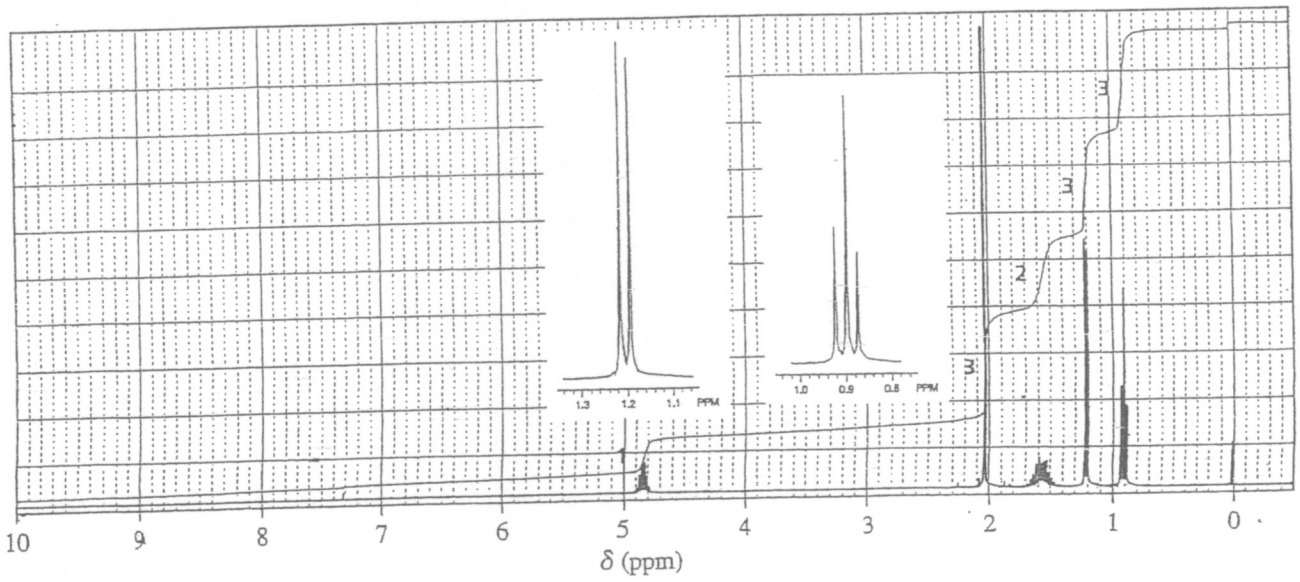
69. The following ^{1}H NMR spectra are for four compounds each with molecular formula $C_6H_{12}O_2$. Identify the compounds.

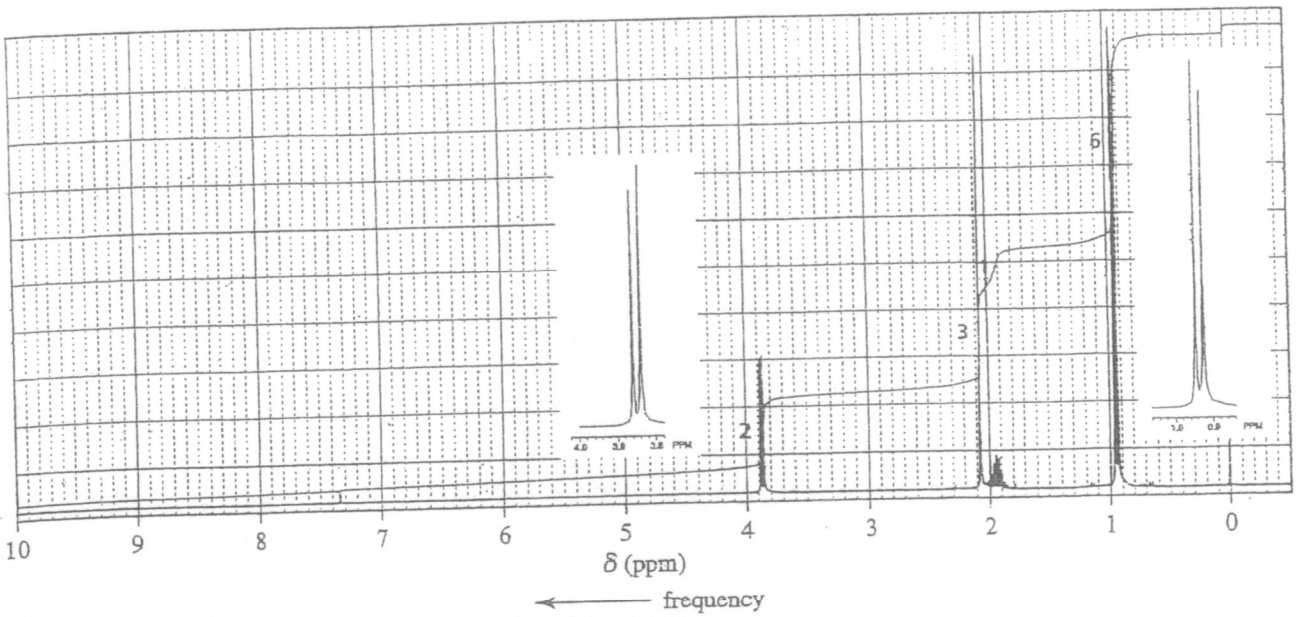
a.



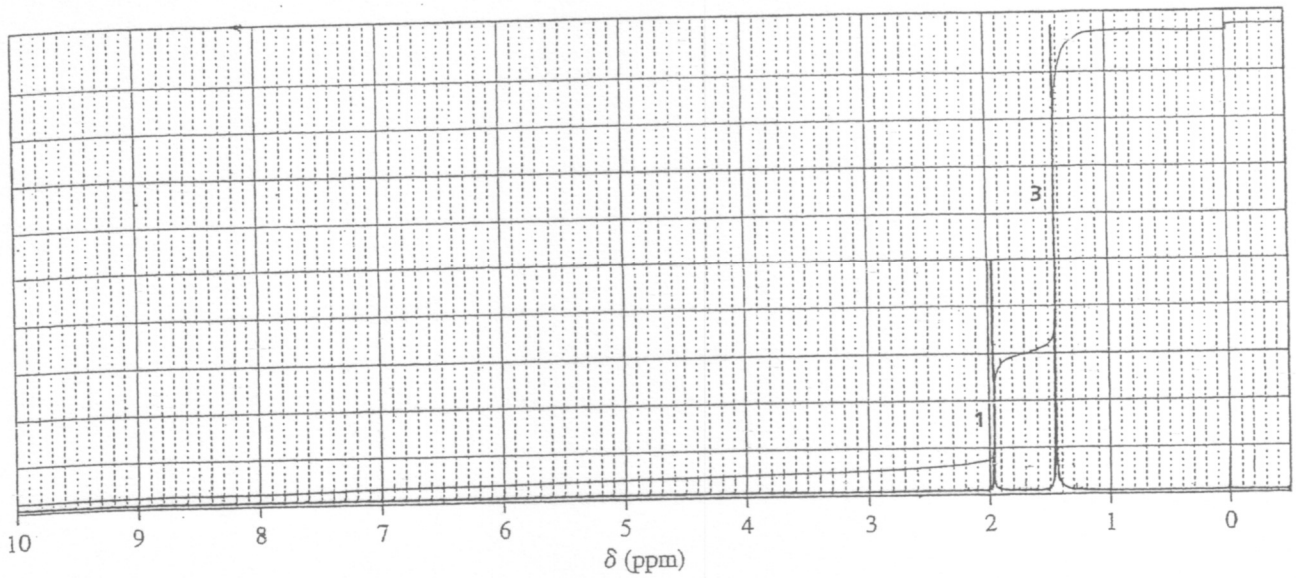
b.



c.

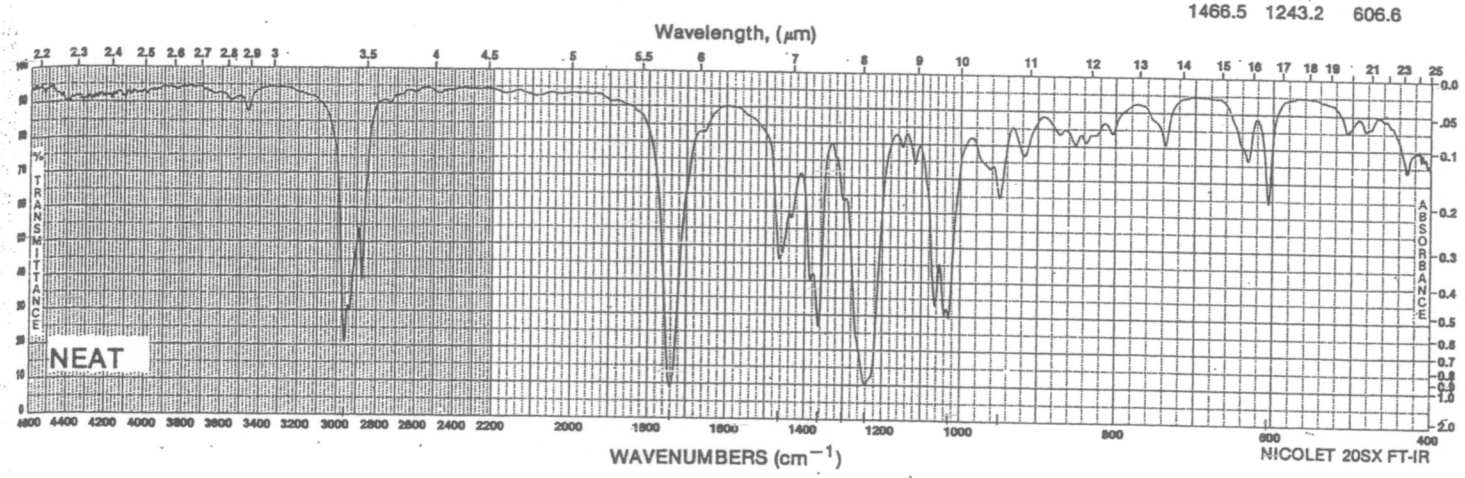


d.



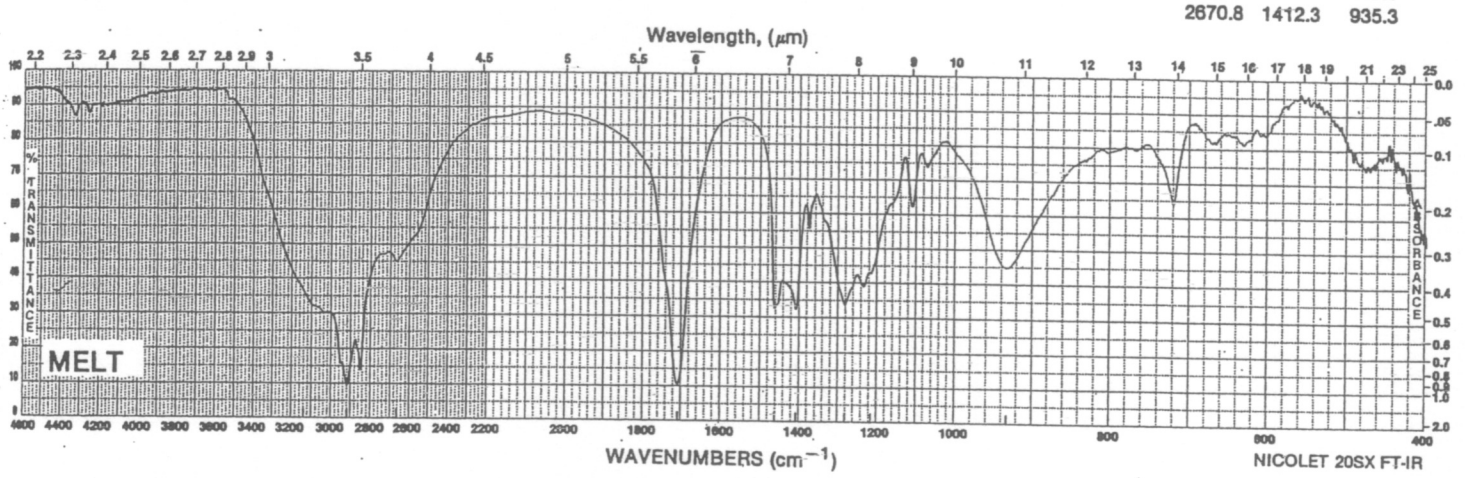
PROBLEM 3.4 SPECTRUM E

2962.1 1366.3 1031.3
1743.1 1303.6 950.8
1466.5 1243.2 606.6



PROBLEM 3.4 SPECTRUM F

3148.2 1712.1 1285.0
2925.9 1466.3 1218.9
2670.8 1412.3 935.3



PROBLEM 3.3 SPECTRUM D

2927.1 1467.1 909
1822.5 1378.9 724
1641.7 993.3 634

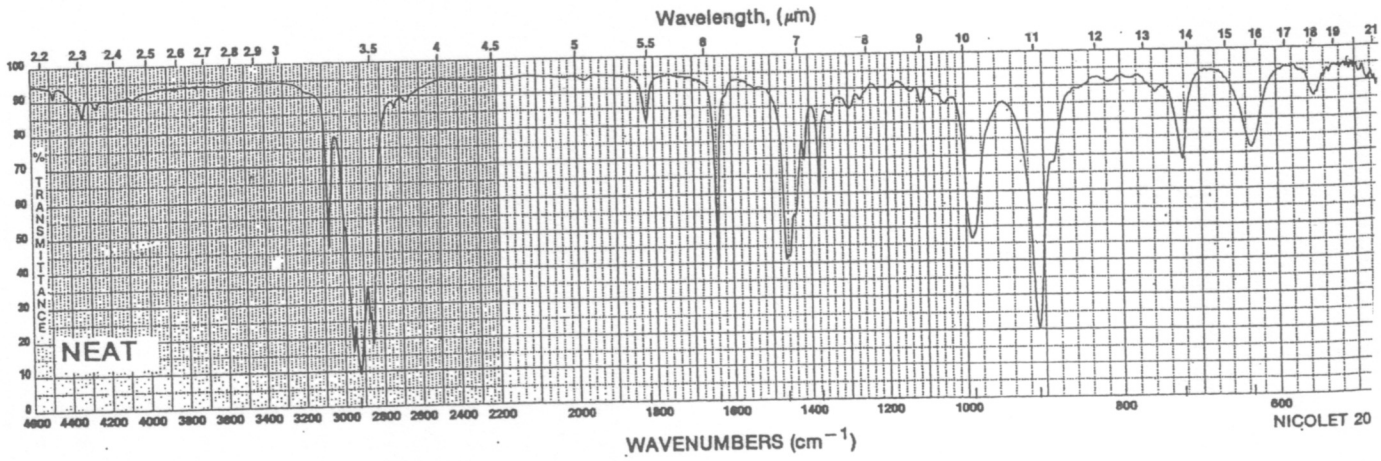


TABLE 13-3 Typical Values of Chemical Shifts

Type of Proton	Approximate δ	Type of Proton	Approximate δ
alkane ($-CH_3$)	0.9	$>C=C<_{CH_3}$	1.7
alkane ($-CH_2-$)	1.3	Ph—H	7.2
alkane ($-CH<$)	1.4	Ph—CH_3	2.3
$-C(=O)-CH_3$	2.1	R—CHO	9–10
$-C\equiv C-H$	2.5	R—COOH	10–12
$R-CH_2-X$ (X = halogen, O)	3–4	R—OH	variable, about 2–5
		Ar—OH	variable, about 4–7
$>C=C<_{H}$	5–6	$R-NH_2$	variable, about 1.5–4

Note: These values are approximate, as all chemical shifts are affected by neighboring substituents. The numbers given here assume that alkyl groups are the only other substituents present. A more complete table of chemical shifts appears in Appendix 1.

TABLE 12-2 Summary of IR Stretching Frequencies

Frequency (cm^{-1})	Functional Group		Comments
3300	alcohol	O—H	always broad
	amine, amide	N—H	may be broad, sharp, or broad with spikes
	alkyne	$\equiv C-H$	always sharp, usually strong
3000	alkane	$-\overset{|}{\underset{|}{C}}-H$	just below 3000 cm^{-1}
	alkene	$=C<_{H}$	just above 3000 cm^{-1}
	acid	O—H	very broad
2200	alkyne	$-C\equiv C-$	just below 2200 cm^{-1}
	nitrile	$-C\equiv N$	just above 2200 cm^{-1}
1710 (very strong)	carbonyl	$>C=O$	ketones, aldehydes, acids esters higher, about 1735 cm^{-1} conjugation lowers frequency amides lower, about 1650 cm^{-1}
1660	alkene	$>C=C<$	conjugation lowers frequency aromatic C=C about 1600 cm^{-1}
	imine	$>C=N<$	stronger than C=C
	amide	$>C=O$	stronger than C=C (see above)

Ethers, esters, and alcohols also show C—O stretching between 1000 and 1200 cm^{-1}.

ALDEHYDES 2700, 2800