CHAPTER

4

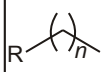
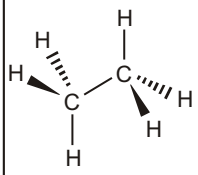
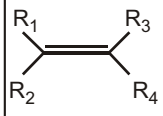
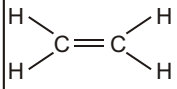
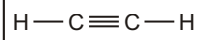
Functional Groups

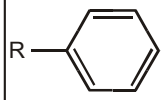
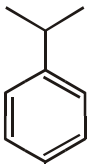
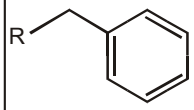
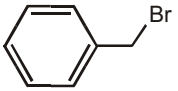
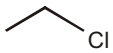
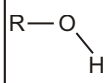
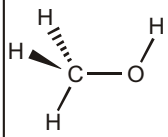
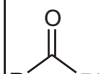
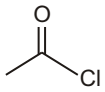
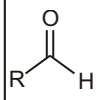
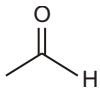
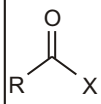
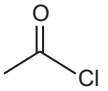
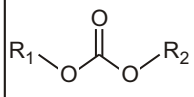
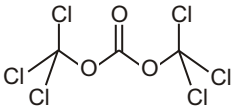
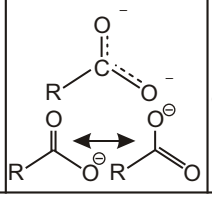
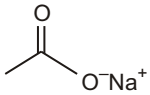
FUNCTIONAL GROUPS

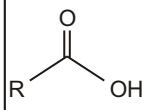
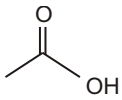
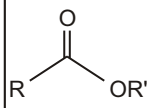
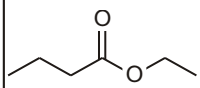
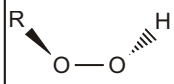
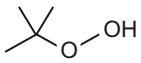
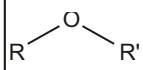
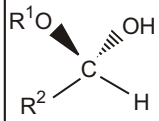
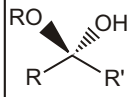
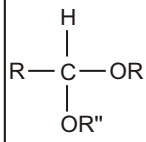
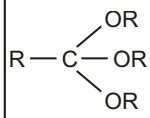
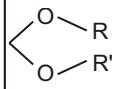
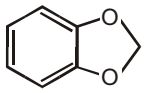
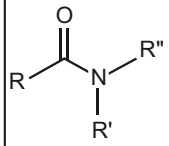
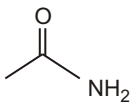
In organic chemistry, functional groups are specific groups of atoms or bonds within molecules that are responsible for the characteristic chemical reactions of those molecules. The same functional group will undergo the same or similar chemical reaction(s) regardless of the size of the molecule it is a part of.

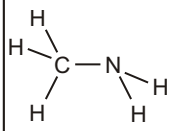
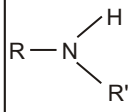
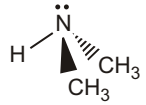
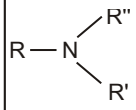
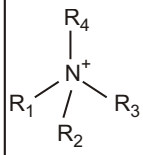
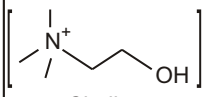
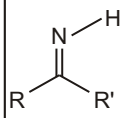
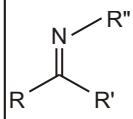
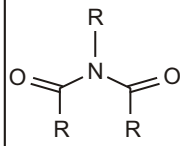
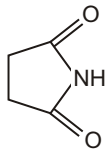
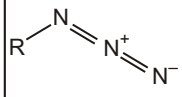
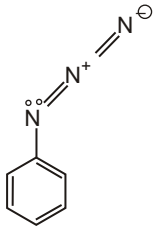
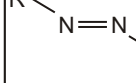
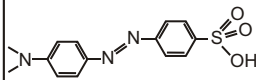
Combining the names of functional groups with the names of the parent alkanes generates a powerful systematic nomenclature for naming organic compounds.

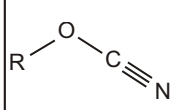
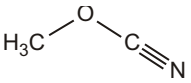
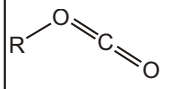
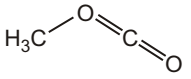
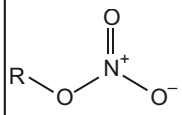
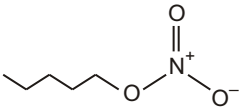
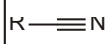
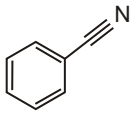
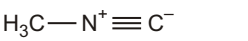
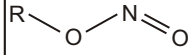
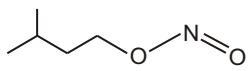
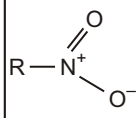
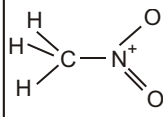
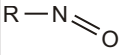
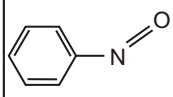
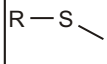
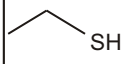
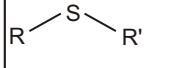
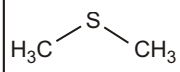
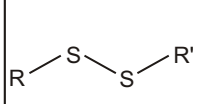
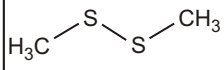
TABLE OF COMMON FUNCTIONAL GROUPS

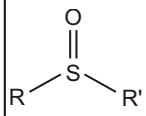
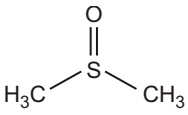
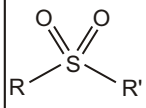
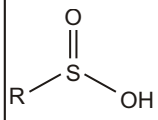
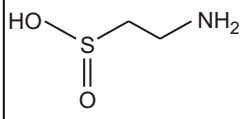
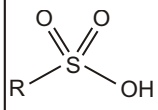
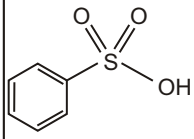
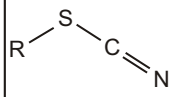
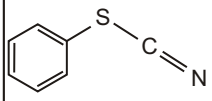
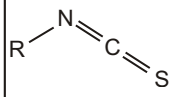
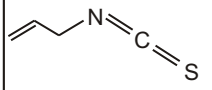
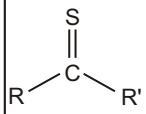
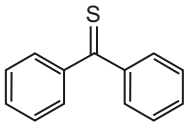
S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
1.	Alkane	Alkyl	$R(CH_2)_nH$		alkyl	-ane	 Ethane
2.	alkene	alkenyl	$R_2C \quad CR_2$		alkenyl-	-ene	
3.	Alkyne	Alkynyl	RC CR	R—C C—R	alkynyl-	-yne	 Acetylene (Ethyne)

S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
4.	Benzene derivative	Phenyl	RC_6H_5(RPh)		phenyl-	-benzene	 Cumene (2-phenylpropane)
5.	Toluene derivative	Benzyl	$RCH_2C_6H_5$ (R—Ph)		benzyl-	1-(substituent) toluene	 Benzyl bromide (α-Bromotoluene)
6.	haloalkane	halo	RX		halo-	alkyl halide	 Chloroethane (Ethylchloride)
7.	Alcohol	Hydroxyl	ROH		hydroxy-	-ol	 Methanol
8.	Ketone	Carbonyl	RCOR		-oyl-(-COR) or OXO or keto	-one	 Acetyl chloride (Ethanoyl chloride)
9.	Aldehyde	Aldehyde	RCHO		formyl-(—COH)	-al	 Acetaldehyde
10.	Acyl halide	Haloformyl	RCOX		carbonofluoridoyl- carbonochloridoyl- carbonobromidoyl- carbonoiodidoyl-	-oyl **halide**	 Acyl chloride (Ethanoyl chloride)
11.	Carbonate	Carbonate ester	ROCOOR		(alkoxycarbonyl) oxy-	alkyl **carbonate**	 Triphosgene (bis(trichloromethyl) carbonate)
12.	Carboxylate	Carboxylate	RCOO		carboxy-	-oate	 Sodium acetate (Sodium ethanoate)

S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
13.	Carboxylic acid	Carboxyl	RCOOH		carboxy-	-oic **acid**	 Acetic acid (*Ethanoic acid*)
14.	Ester	Ester	RCOOR		alkanoyloxy- or alkoxycarbonyl	alkyl alkanoate	 Ethyl butyrate (*Ethyl butanoate*)
15.	Hydroperoxide	Hydroperoxy	ROOH		hydroperoxy-	alkyl **hydroperoxide**	 tert-Butyl hydroperoxide
16.	Ether	Ether	ROR		alkoxy-	alkyl **ether**	 Diethyl ether (Ethoxyethane)
17.	Hemiacetal	Hemiacetal	RCH(OR) (OH)		alkoxy-ol	-one alkyl **hemiacetal**	
18.	Hemiketal	Hemiketal	RC(OR)(OH)R		alkoxy-ol	-one alkyl **hemiketal**	
19.	Acetal	Acetal	RCH(OR)(OR)		dialkoxy-	-al dialkyl **acetal**	
20.	Orthoester	Orthoester	RC(OR)(OR) (OR)		trialkoxy-		
21.	Heterocycle	Methylenedioxy	ROCOR		methylene- dioxy-	-dioxole	 1,2-Methylenedioxy-benzene (1,3-Benzodioxole)
22.	Amide	Carboxamide	$RCONR_2$		Carboxamido- or carbamoyl-	-amide	 Acetamide (*Ethanamide*)

S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
23.	Amines	Primary amine	RNH_2		amino-	-amine	 Methylamine (*Methanamine*)
24.	Amines	Secondary amine	R_2NH		amino-	-amine	 Dimethylamine
25.	Amines	Tertiary amine	R_3N		amino-	-amine	 Trimethylamine
26.	Amines	4 ammonium ion	R_4N		ammonio-	-ammonium	 Choline
27.	Imine	Primary ketimine	RC(NH) R				
28.	Imine	Secondary ketimine	RC(NR)R				
29.	Imide	Imide	$(RCO)_2NR$		imido-	imide	 Succinimide (Pyrrolidine-2,5-dione)
30.	Azide	Azide	RN_3		azido-	alkyl **azide**	 Phenyl azide (Azidobenzene)
31.	Azo compound	Azo (Diimide)	RN_2R		azo-	-diazene	 Methyl orange (*p*-dimethylamino-azobenzenesulfonic acid)

S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
32.	Cyanates	Cyanate	ROCN		Cyanato-	alkyl **cyanate**	 Methyl cyanate
33.	Cyanates	Isocyanate	RNCO		isocyanato-	alkyl **isocyanate**	 Methyl isocyanate
34.	Nitrate	Nitrate	$RONO_2$		nitrooxy-, nitroxy-	alkyl **nitrate**	 Amyl nitrate (1-nitroxypentane)
35.	Nitrile	Nitrile	RCN		cyano-	alkanenitrile alkyl **cyanide**	 Benzonitrile (Phenyl cyanide)
36.	Isonitrile	Isonitrile	RNC		isocyano-	alkaneisonitrile alkyl **isocyanide**	 Methyl isocyanide
37.	Nitrite	Nitroxooxy	RONO		nitrosooxy-	alkyl **nitrite**	 Isoamyl nitrite (3-*methyl*-1- *nitrosoxybutane*)
38.	Nitro compound	Nitro	RNO_2		nitro-		 Nitromethane
39.	Nitroso	RNO		nitroso-(Nitrosyl-)			 Nitrosobenzene
40.	Thiol	Sulfhydryl	RSH		sulfanyl-(-SH)	**-thiol**	 Ethanethiol
41.	Sulfide (Thioether)	Sulfide	RSR		*substituent* sulfanyl- (-SSR)	di(substituent) **sulfide**	 (Methylsulfanyl) methane (prefix) or Dimethyl sulfide (sulfix)
42.	Disulfide	Disulfide	RSSR		*substituent* disulfanyl- (-SSR)	di(substituent) **dissulfide**	 (Methyldisulfanyl) methane (prefix) or Dimethyl disulfide (sulfix)

S.N.	Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
43.	Sulfoxide	Sulfinyl	RSOR		-sulfinyl-(-SOR)	di(substituent) **sulfoxide**	 (Methanesulfinyl) methane (prefix) or Dimethyl sulfoxide (suffix)
44.	Sulfone	Sulfonyl	RSO_2R		-sulfonyl- ($-SO_2R$)	di(substituent) **sulfone**	 (Methanesulfonyl) methane (prefix) or Dimethyl sulfone (suffix)
45.	Sulfinic acid	Sulfino	RSO_2H		sulfino- ($-SO_2H$)	**-sulfinic acid**	 2-Aminoethane sulfinic acid
46.	Sulfonic acid	Sulfo	RSO_3H		sulfo- ($-SO_3H$)	**-sulfonic acid**	 Benzenesulfonic acid
47.	Thiocyanate	Thiocyanate	RSCN		thiocyanato- (-SCN)	*substituent* **thiocyanate**	 Phenyl thiocyanate
48.	Isothio-cyanate	Isothiocyanate	RNCS		isothiocyanato- (-NCS)	*substituent* ***isothiocyanate***	 Allyl isothiocyanate
49.	Thione	Carbonothioyl	RCSR		-thioyl- (-CSR) or sulfanylidene- (=S)	-thione	 Diphenylmethanethione (Thiobenzophenone)

IDENTIFY FUNCTIONAL GROUPS

Solved Example

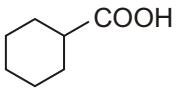
- Classify each of the following compounds. the possible classifications are as follows :

  alcohol ketone carboxylic acid ether

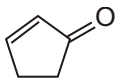
  aldehyde alkene

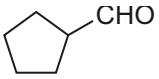
  (a) CH_2CH_2CHO **(b)** $CH_3CH_2CH(OH)CH_3$

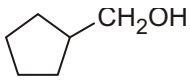
  (c) $CH_3COCH_2CH_3$ **(d)** $CH_3 — CH_2OCH_2CH_6$

(e) 

(f) 

(g) 

(h) 

(i) 

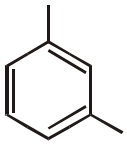
Sol. (a) aldehyde (b) alcohol (c) ketone (d) ether
(e) carboxylic acid (f) ether, alkene (g) ketone, alkene (h) aldehyde
(i) alcohol

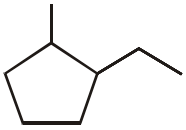
Solved Example

- For each molecule circle and name the functional group. If the functional group is an alcohol identify it as a primary (1º), secondary (2º), or tertiary (3º) alcohol. Some molecules will have more than one functional group; in those case circle and name all functional groups present. Functional groups: Alkane, alkene, alkyne, cyclic, aromatic, alcohol, ether.

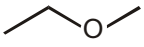
(a) 

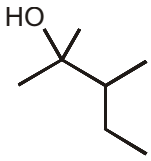
(b) 

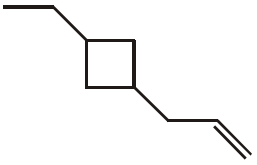
(c) 

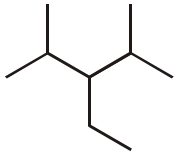
(d) 

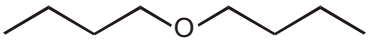
(e) CH_3CH_2OH

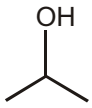
(f) 

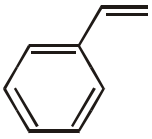
(g) 

(h) 

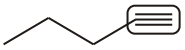
(i) 

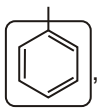
(j) 

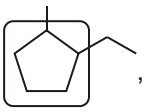
(k) 

(l) 

Ans. **(a)**  , alkene

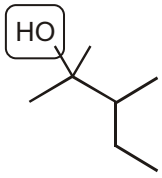
(b)  , alkyne

(c)  , aromatic

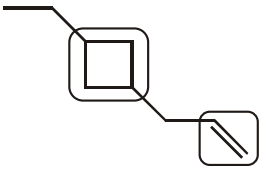
(d)  , cyclic

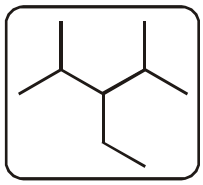
(e) $CH_3\boxed{CH_2OH}$ or $H_3C-\boxed{CH_2-OH}$, 1 Alcohol

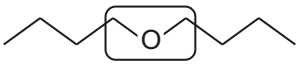
(f)  , ether

(g) 

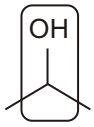
, 3°alcohol

(h) 
,cyclic and alkene

(i) 
, alkane

(j) 

, ether

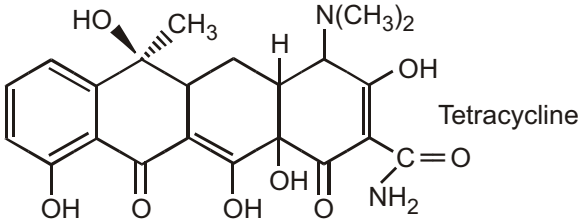
(k) 

, 2° alcohol

(l) 
,aromatic and alkene

Solved Example

- The discovery of penicillin in 1928 marked the beginning of what has been called the "golden age of chemotherapy," in which previously life-threatening bacterial infections were transformed into little more than a source of discomfort. For those who are allergic to penicillin, a variety of antibiotics, including tetracycline, are available. Identify the numerous functional groups in the tetracycline molecule.

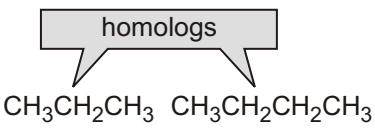


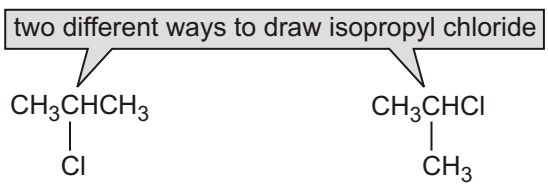
Tetracycline

Sol. The compound contains an aromatic ring fused to three six-membered rings. It is also an alcohol and phenol (with five — OH groups), a ketone (with C O groups at the bottom of the second and fourth rings), an amine [the — $N(CH_3)_2$ substituent at the top of the fourth ring], and an amide (the — $CONH_2$ group at the bottom right-hand corner of the fourth ring.)

HOMOLOGS

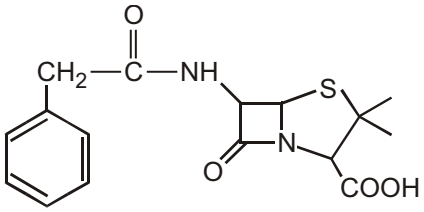
The family of alkanes shown in the table is an example of a homologous series. A **homologous series** (homos is Greek for "the same as") is a family of compounds in which each member differs from the one before it in the series by **one methylene (CH_2) group**. The members of a homologous series are called **homologs**



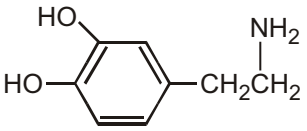


Solved Example

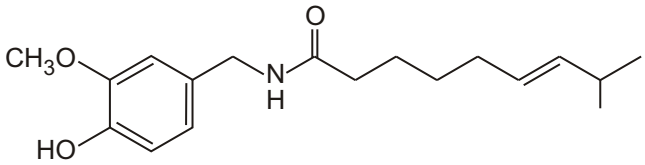
- Many naturally occurring compounds contain more than one functional group. Identify the functional groups in the following compounds:
  (a) Penicillin G is a naturally occurring antibiotic.
  (b) Dopamine is the neurotransmitter that is deficient in Parkinson's disease.
  (c) Capsaicin gives the fiery taste to chili peppers.
  (d) Thyroxine is the principal thyroid hormone.
  (e) Testosterone is a male sex hormone.



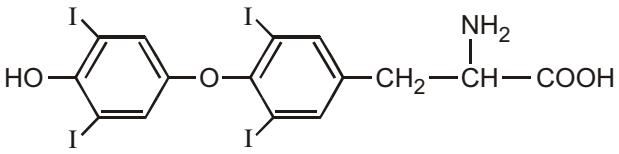
penicillin G



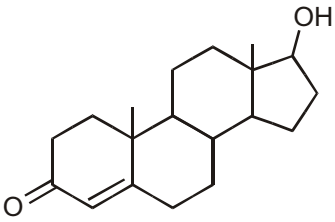
dopamine



capsaicin



thyroxine-T_4



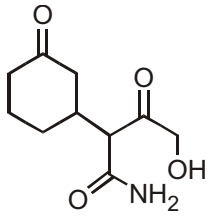
testosterone

Sol. **(a)** Penicillin-G: Carboxylic acid, thioether, amide
(b) Dopamine: Amine, aromatic alcohol (Phenol)
(c) Capsaicin: Phenol, ether, amide, alkene
(d) Thyroxine: Aryl iodide, phenol, ether, amine, carboxylic acid
(e) Testosterone: Alcohol, ketone, alkene

EXERCISE

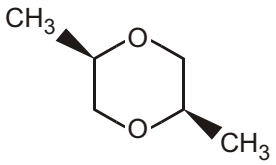
SINGLE CHOICE QUESTIONS

1. Functional group not present in given compound is/are?



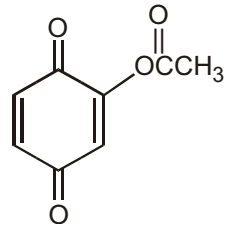
(A) Alcohol (B) Ketone (C) Carboxylic acid (D) Amide

2. Present functional group is :



(A) ketone (B) ester (C) ether (D) alcohol

3. Present functional group is/ are :



(A) ketone (B) ester (C) ether (D) A and B both

4. What is the lowest molecular weight possible for Ester?

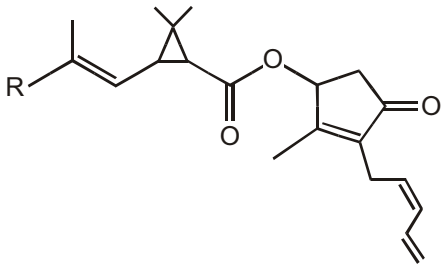
(A) 30 (B) 46 (C) 56 (D) 60

5. Which of the following compounds belong to the same homologous series ?

(1) 1-chloropropene (2) 1-chloropropane (3) 2-chlorobutane

(A) (1) and (2) only (B) (1) and (3) only (C) (2) and (3) only (D) (1), (2) and (3)

6. Pyrethrum flowers contain a natural insecticide called pyrethrin. Pyrethrin has the following structure:



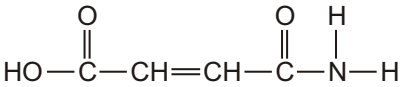
Which of the following functional groups are present in pyrethrin?

(1) Carbon-carbon double bond (2) Ester group

(3) Ketone group

(A) (1) and (2) only (B) (1) and (3) only (C) (2) and (3) only (D) (1), (2) and (3)

7. Consider the following compound :



Which of the following functional groups does it contain?

(1) Carboxyl group (2) Carbonyl group (3) Amide group

(A) (1) and (2) only (B) (1) and (3) only (C) (2) and (3) only (D) (1), (2) and (3)

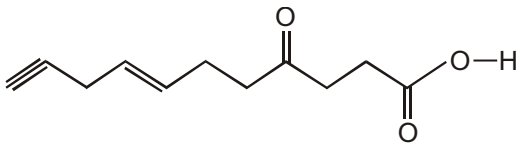
8. Which of the following statements is/are correct?

(1) Two organic compounds with the same general formula must belong to the same homologous series.

(2) Two organic compounds with main functional groups the same must belong to the same homologous series.

(3) Two organic compounds with the molecular mass differing by 14 must belong to the same homologous series.

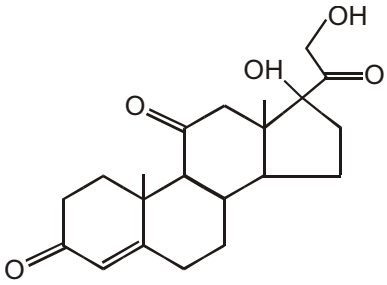
(A) (1) only (B) (2) only (C) (1) and (3) only (D) (2) and (3) only

9. 

Number of Functional group in above compound is

(A) 3 (B) 4 (C) 5 (D) 6

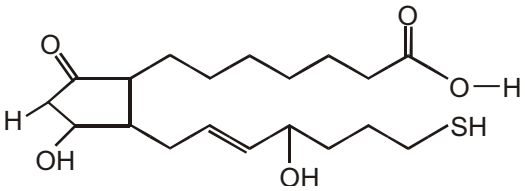
10. The functional groups in Cortisone are :



Cortisone

(A) Ether, alkene, alcohol (B) Alcohol, ketone, alkene

(C) Alcohol, ketone, amine (D) Ether, amine ketone

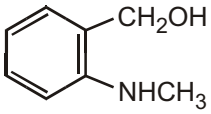
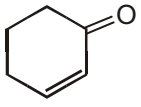
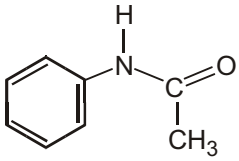
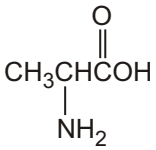
11. 

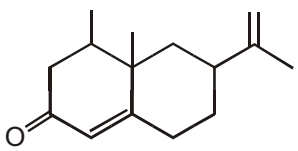
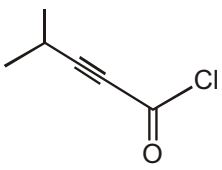
How many types of functional groups are present in given compound.

(A) 6 (B) 5 (C) 4 (D) 7

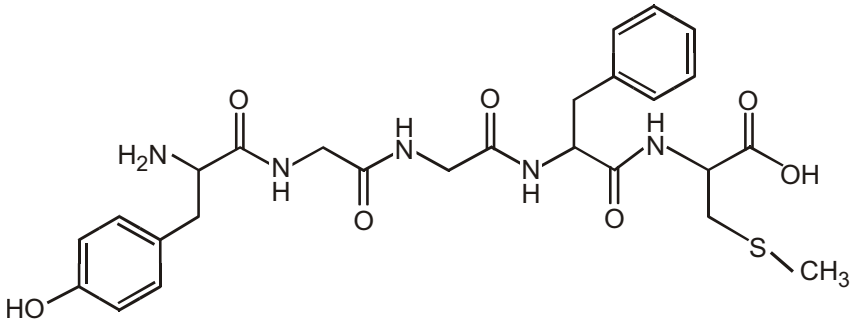
UNSOLVED EXAMPLE

1. Locate and identify the functional groups in the following molecules.

(a)  **(b)**  **(c)**  **(d)** 

(e)  **(f)** 

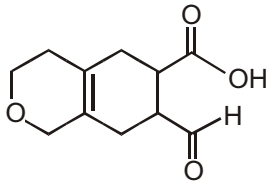
2. Met-enkephalin, an endorphin, serves as natural pain reliever that changes or removes the perception of nerve signals. Label all of the functional groups present in Met-enkephalin.



3. *x* Types of functional group

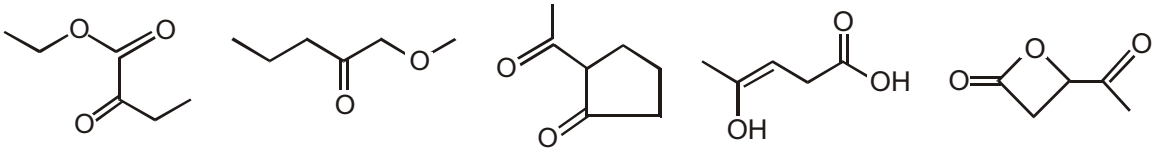
y Double bond equivalent

Value of (*x* *y*) in given compound is :



(A) 7 (B) 8 (C) 9 (D) 10

4. Which compound can be classified as an ester as well as a Ketone?

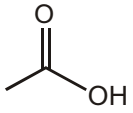


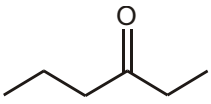
(A) (B) (C) (D) (E)

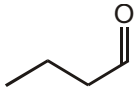
(A) A, B, E (B) E, B, C (C) A, E (D) C, E

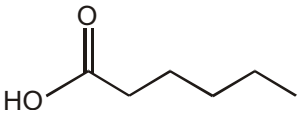
WORK SHEET

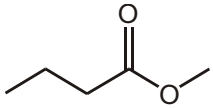
1. For each molecule circle and name the functional group. If the functional group is an amine identify it as a primary (1°), secondary (2°), or tertiary (3°) amine. some molecules will have more than one functional group; in those case circle and name all functional groups present. functional groups: Aldehyde, ketone, carboxylic acid, ester, amide, amine.

(a) 

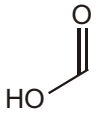
(b) 

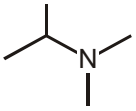
(c) 

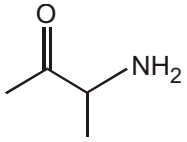
(d) 

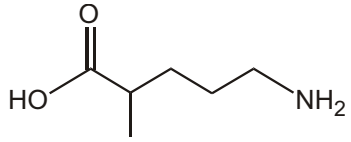
(e) 

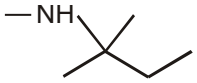
(f) CH_3COOH

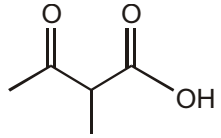
(g) 

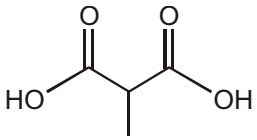
(h) 

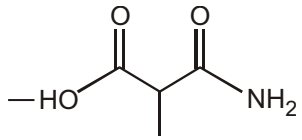
(i) 

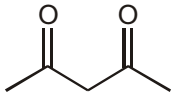
(j) 

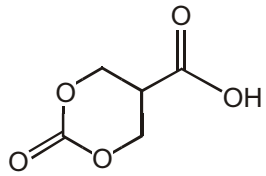
(k) 

(l) 

(m) 

(n) 

(o) 

(p) 

(q) HCHO

(r) HCOOH

(s) $CH_3(CO)CH_3$

SUBJECTIVE TYPE QUESTIONS

1. Suggest at least six different structures that would fit the formula C_4H_7NO. Make good realistic diagrams of each one and identify which functional groups(s) are present.

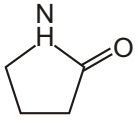
Purpose of the Problem

The identification and naming of functional groups is more important than the naming of compounds. This was your chance to experiment with different functional groups as well as different carbon skeletons.

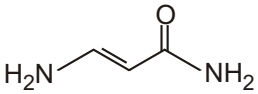
Suggested solution

You will have found the carbonyl and amino groups very useful, but did you also use alkenes and alkynes, rings, ethers, alcohols, and cyanides? Here are twelve possibilities but there are many more. The functional group names in brackets are alternatives. Some you will not have known. You need not to have classify the alcohols and amines.

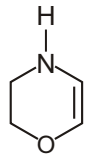
alkyne, primary alcohol, primary amine



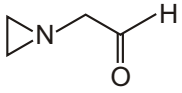
cyclic amide



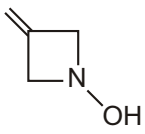
Amide, alkene, primary amine (enamine)



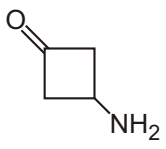
Ether, alkene, secondary amine



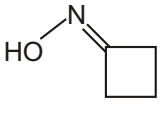
cyclic tertary amine, aldehyde



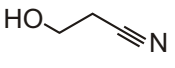
alkene, secondary amine, alcohol (cyclic hydroxylamine)



cyclic ketone, primary amine

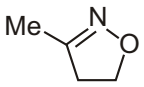


oxime, imine + alcohol

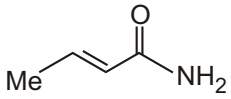


alcohol, nitrile (cyanide)

primary alcohol, nitrile (cyanide)



imine, ether (isoxazoine)



alkene, primary amide

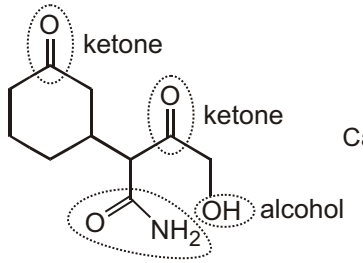
Answers

Single Choice Questions

1. (C) **2.** (C) **3.** (D) **4.** (D) **5.** (C) **6.** (D) **7.** (B) **8.** (B)

9. (B) **10.** (B) **11.** (B)

1.



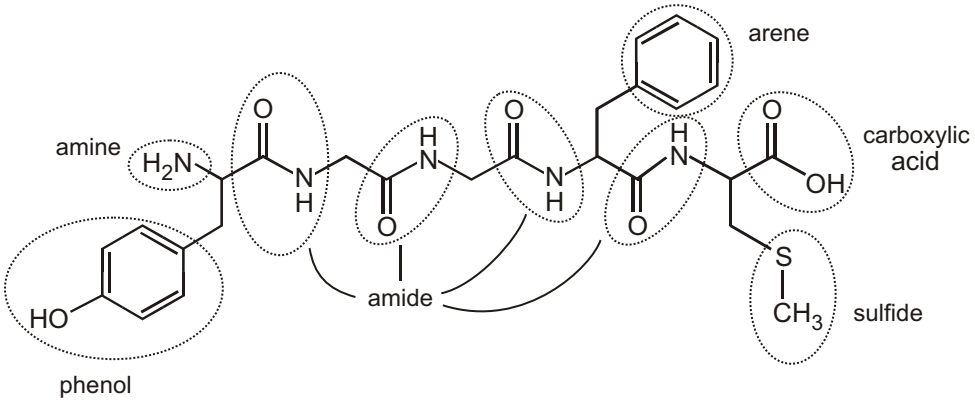
Carboxylic acid is not present

Unsolved Example

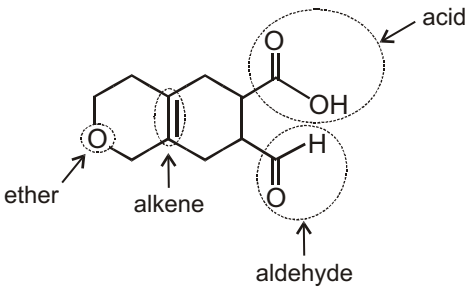
1. **(a)** alcohol, amine **(b)** ketone, alkene **(c)** amide

(d) carboxylic acid, amine **(e)** ketone,alkene **(f)** acyl halide, alkyne

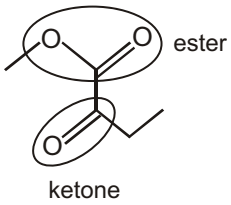
2.

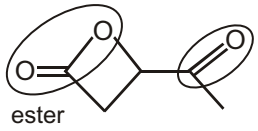


3.

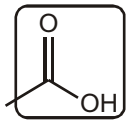


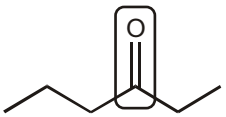
4.

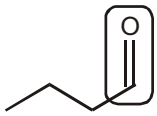


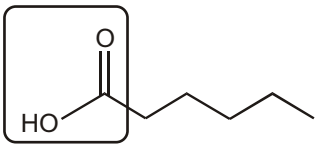


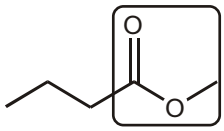
Work Sheet

1. (a)  , carboxylic acid

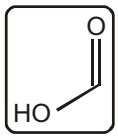
(b)  , ketone

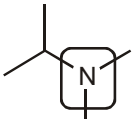
(c)  , aldehyde

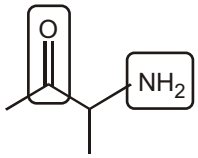
(d)  , carboxylic acid

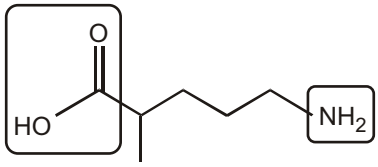
(e)  , ester

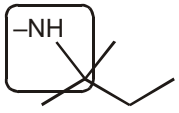
(f) CH_3 COOH or H_3C — C — OH , carboxylic acid

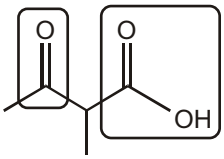
(g)  , carboxylic acid

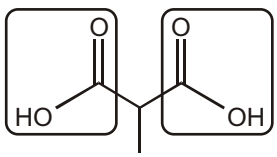
(h)  , 3° amine

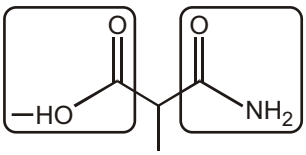
(i)  , ketone and 1° amine

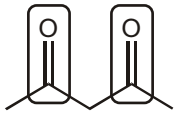
(j)  , carboxylic acid and 1°amine

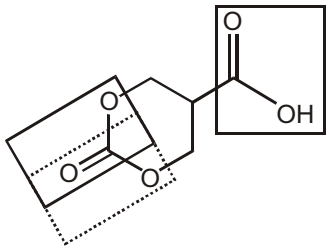
(k)  , 2° amine

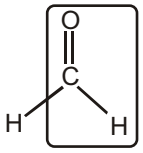
(l)  , ketone and carboxylic acid

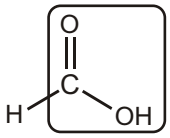
(m)  , 2 carboxylic acids

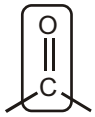
(n)  Carboxylic acid , and amide

(o)  , 2 ketones

(p)  , 2 esters and 1 carboxylic acid

(q)  , aldehyde

(r)  or , H COOH , carboxylic acid

(s)  , ketone

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