Quiz (Boiling Point and Solubility)

1. The condensed structural formulae of three compounds are shown below:

$CH_3CH{=}CH_2$	$CH_3CH_2CH_2CH_3$	$CH(CH_3)_3$
A	*B*	*C*

(a) Write the structural formula of compound *C*.

(b) Give the systematic names of compounds *A*, *B* and *C*.

(c) Arrange the three compounds in order of increasing boiling point. Explain your answer.

(d) Are the three compounds soluble in water? Explain briefly.

2. The table below summarizes physical properties of six carbon compounds. Three of them are alkanes (propane, butane and pentane) while the other three are alcohols (ethanol, propan-1-ol and butan-1-ol).

Name	Boiling point (°C)	Melting point (°C)	Density at 20°C (g cm^{-3})	Solubility in water
A	–0.5	–138	—	—
B	–42.1	–188	—	—
C	118	–88.6	0.810	Soluble
D	97.2	–124	0.803	Very soluble
E	36.1	–130	0.626	—
F	78.3	–114	0.789	Very soluble

(a) Which of them are likely to be alcohols? Suggest a reason for your deduction.

(b) Which of them is/are gas(es) at room temperature (25°C)? Suggest a reason for your deduction.

(c) State and explain the trend in boiling points for carbon compounds of the same homologous series.

(d) Match *A*–*F* with propane, butane and pentane, ethanol, propan-1-ol and butan-1-ol.

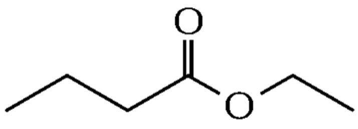
(e) Using the data in the table, deduce the physical state of hexane at room temperature and the water solubility of hexane.

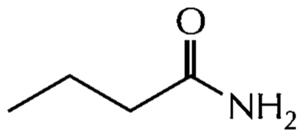
3. Explain the following properties of propan-1-ol:
   (a) It has a higher boiling point than propene.

   (b) It has similar water solubility as propan-2-ol.

   (c) It has a lower boiling point than ethanoic acid.

4. (a) Give the systematic names of the following compounds:

   (i)
   

   (ii)
   

   (b) Compare the (i) boiling points and (ii) solubilities in water of the compounds in (a).

5. Consider the following compounds:

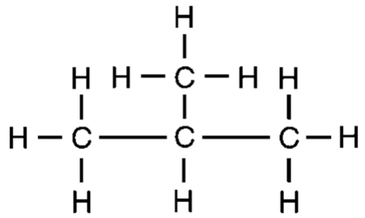
   $CH_3(CH_2)_2CONH_2$, $CH_3(CH_2)_2CH_3$, $CH_3(CH_2)_3OH$, $CH_3(CH_2)_3Cl$

   (a) Which of the above compounds can form hydrogen bonds with water molecules? Illustrate your answer by drawing suitable diagram(s).

   (b) Arrange the above compounds in increasing order of boiling points. Explain your answer.

Suggested Answer

1. (a)



(b) *A*: propene; *B*: butane; *C*: methylpropane

(c) Order of increasing boiling point: *A*, *C*, *B*

A has the smallest molecular size. The van der Waals' forces between its molecules are the weakest.

B is a straight-chain alkane and its molecules are rod-shaped.

C is a branched-chain alkane and its molecules are more spherical in shape. The molecules of *C* have a smaller area of contact than *B*.

As a result, the van der Waals' forces between molecules of *C* are weaker than those between molecules of *B*.

(d) No. This is because the molecules of alkanes or alkenes cannot form strong attractive forces (or hydrogen bonds) with water molecules.

2. (a) *C*, *D* and *F*.

This is because they are soluble in water. (The alcohol molecules can form hydrogen bonds with water molecules.)

(b) *A* and *B*. This is because their boiling points are lower than the room temperature.

(c) In the same homologous series, the boiling point increases with the molecular size.

As the molecular size of carbon compounds increases, the van der Waals' forces between the molecules are stronger.

More energy is needed to separate the molecules in the boiling process.

(d) *A* – Butane; *B* – Propane; *C* – Butan-1-ol;
D – Propan-1-ol; *E* – Pentane; *F* – Ethanol

(e) Hexane should be a liquid at room temperature. It should be insoluble in water.

3. (a) Propan-1-ol molecules are held together by hydrogen bonds in addition to weak van der Waals' forces.

   Propene molecules are held together by weak van der Waals' forces only.

   More energy is needed to separate the propan-1-ol molecules during the boiling process.

   (b) Both of their molecules can form hydrogen bonds with water molecules.

   (c) Ethanoic acid can form more extensive hydrogen bonds between molecules than propan-1-ol.

4. (a) (i) Ethyl butanoate
   (ii) Butanamide

   (b) (i) Butanamide has a higher boiling point because its molecules are held together by hydrogen bonds in addition to weak van der Waals' forces.

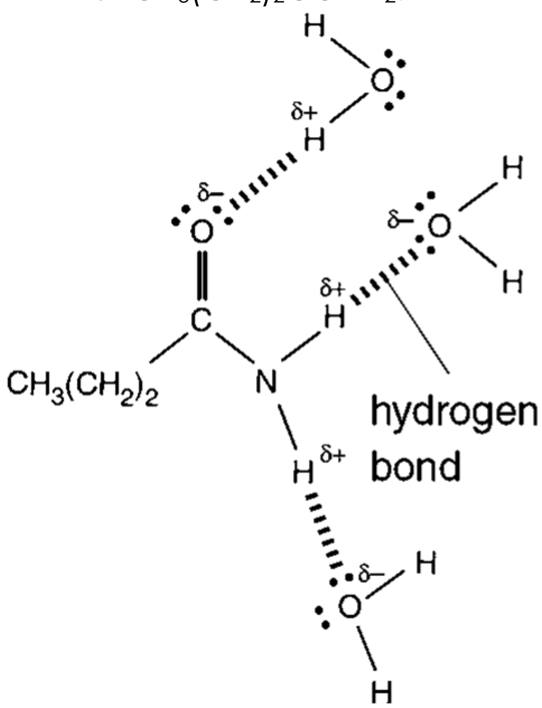
   But there are only weak van der Waals' forces between molecules of ethyl butanoate.

   More energy is needed to separate the butanamide molecules during boiling.

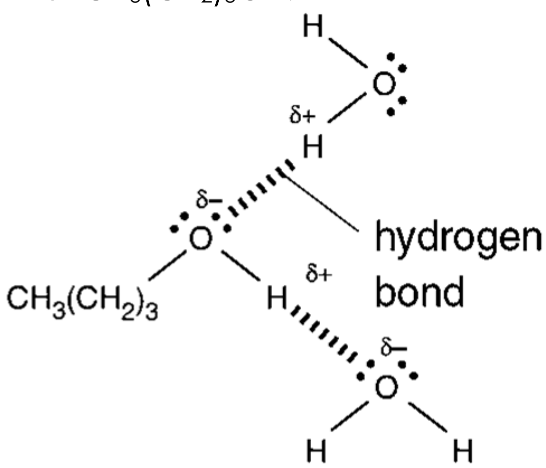
   (ii) Butanamide is more soluble in water because more extensive hydrogen bonds form between its molecules and water molecules.

5. (a) $CH_3(CH_2)_2CONH_2$ and $CH_3(CH_2)_3OH$

   For $CH_3(CH_2)_2CONH_2$:



   For $CH_3(CH_2)_3OH$:



(b) Increasing order of boiling points: $CH_3(CH_2)_2CH_3$, $CH_3(CH_2)_3Cl$, $CH_3(CH_2)_3OH$, $CH_3(CH_2)_2CONH_2$.

The boiling point of a carbon compound depends on the strength of intermolecular forces that exist among their molecules.

Both $CH_3(CH_2)_2CH_3$ molecules and $CH_3(CH_2)_3Cl$ molecules are held together by weak van der Waals' forces only.

The strength of van der Waals' forces increases with the molecular size.

As the molecular size of $CH_3(CH_2)_3Cl$ is larger, the van der Waals' forces between the molecules are stronger.

So, the boiling point of $CH_3(CH_2)_3Cl$ is higher than that of $CH_3(CH_2)_2CH_3$.

$CH_3(CH_2)_3OH$ and $CH_3(CH_2)_3Cl$ have similar molecular sizes.

But hydrogen bonds in addition to weak van der Waals' forces exist among $CH_3(CH_2)_3OH$ molecules.

The intermolecular forces between $CH_3(CH_2)_3OH$ molecules are stronger.

Hence, $CH_3(CH_2)_3OH$ has a higher boiling point than $CH_3(CH_2)_3Cl$.

Both $CH_3(CH_2)_2CONH_2$ molecules and $CH_3(CH_2)_3OH$ molecules are held together mainly by hydrogen bonds.

But $CH_3(CH_2)_2CONH_2$ can form more extensive hydrogen bonds among its own molecules than $CH_3(CH_2)_3OH$.

The intermolecular forces of $CH_3(CH_2)_2CONH_2$ are stronger.

Hence, $CH_3(CH_2)_2CONH_2$ has the highest boiling point.