## Chapter 44  Introduction to selected homologous series

- **Class Practice**
- **Chapter Exercise**

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## Chapter 45  Isomerism

- **Class Practice**
- **Chapter Exercise**

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## Chapter 46  Typical reactions of various functional groups

- **Class Practice**
- **Chapter Exercise**

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## Chapter 47  Inter-conversions of carbon compounds

- **Class Practice**
- **Chapter Exercise**

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## Chapter 48  Important organic substances

- **Class Practice**
- **Chapter Exercise**
- **Part Exercise**

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## Chapter 49  Periodic variation in physical properties of the elements Li to Ar

- **Class Practice**
- **Chapter Exercise**

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### Chapter 50  Bonding, stoichiometric composition and acid-base properties of oxides of the elements Na to Cl

- **Class Practice**  
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### Chapter 51  General properties of transition metals

- **Class Practice**  
  41

- **Chapter Exercise**  
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- **Part Exercise**  
  43
Chapter 44  Introduction to selected homologous series

Class Practice

A44.1
1. Butane, ethane, ethanol, ethanoic acid, urea (Accept other reasonable answers.)
2. Carbon dioxide, sodium carbonate, potassium hydrogen carbonate (Accept other reasonable answers.)
3. Each carbon atom can form four strong single covalent bonds with carbon or other elements. Besides, carbon atoms can form strong single, double and triple covalent bonds with other carbon atoms. Carbon atoms are able to join up with one another to form chains and rings.

A44.2
1. (a) C=C, alkene
   (b) –OH, alcohol
   (c) –COOH, carboxylic acid
2. (a) CH₃CH₂CH=CHCH₂CH₂CH₃
   (b) CH₃CH₂CH₂CH₂CH₃
   (c) CH₃CCH₃

A44.3
(a) Propan-1-ol molecules are held together by hydrogen bonds and van der Waals’ forces while propene molecules are held only by van der Waals’ forces.
(b) Both of them can form hydrogen bonds with water molecules.
(c) Ethanoic acid has more extensive intermolecular hydrogen bonds than propan-1-ol.

A44.4
1. (a) 1,1,1-trichloroethane
   (b) 1,1-dichloro-2,2-dimethylpropane
   (c) 1,2-dibromo-4-chloro-3,3-difluoropentane
2. (a) H  Cl  Br  H  H  H
      H—C—C—C—C—C—H
      H  H  Cl  H  H  H
A44.5
(a) The boiling points of the chloroalkanes increase with the number of chlorine atoms.
(b) This is because the strength of dispersion forces increases with the molecular size of the chloroalkanes.

A44.6
(a)

(b)

A44.7
(a) (i) Ethyl butanoate
(ii) Butanamide
(b) Butanamide has a higher boiling point as intermolecular hydrogen bonds can form between its molecules while there is no intermolecular hydrogen bond in ethyl butanoate.
Butanamide is more soluble in water as more extensive hydrogen bonds can form between its molecules and water molecules. Although hydrogen bonds also exist between ethyl butanoate molecules and water molecules, the longer hydrocarbon chain of ethyl butanoate reduces its solubility.

A44.8
(a)
A44.9
(a) CH₃COOH has a pungent smell while HCOOCH₃ has a distinctive, pleasant smell.
(b) CH₃COOH has a higher boiling point than that of CH₃CHO.
(c) CH₃CH₂CH₃ is a gas while CH₃CH₂CH₂CH₂CH₃ is a liquid.
(d) CH₃CH₂NH₂ is soluble in water while CH₃CH₂CH₂CH₂CH₃ is not.

A44.10
1. (a) 3,3-dichloro-4-oxopentanoic acid
   (b) 1-bromo-3-chloro-2-methylbut-3-enamine
   (c) Butenedioic acid
2. (a) 
   (b) 
   (c) 
   (d)
Chapter 44   Introduction to selected homologous series

Chapter Exercise

1. condensed
2. general
3. van der Waals’, lower
4. hydrogen, higher
5. higher, hydrogen
6. higher
7. carbonyl, higher
8. carboxylic acid, alcohol, aldehydes, ketones
9. higher
10. lower
11. increases, dispersion
12. chloroform
13. isopropyl alcohol
14. formaldehyde
15. acetone
16. acetic acid
17. C
18. D
19. B
20. C
21. A
22. A

23. (a)  (i)  1-bromo-2,3-dichloropropane  
          (ii) 2,4-dimethylpentan-3-one  
          (iii) Methyl propanoate  

       (b)  (i)  

          \[ \text{CH}_3 \text{C} \text{CH}_2 \text{C} \text{H} \]  
          \[ \text{CH}_3 \]  

       (ii)  

          \[ \text{CH}_3 \text{C} \text{CH}_2 \text{CH}_2 \text{C} \text{NH}_2 \]  
          \[ \text{CH}_3 \]  

       (iii)  

          \[ \text{CH}_3 \text{C} \text{CH}_2 \text{CH}_2 \text{C} \text{O} \]  
          \[ \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \]
24. (a) Hexane:
\[ \text{H}_3\text{C} \quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_3 \]

Hexan-1-ol:
\[ \text{H}_3\text{C} \quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-OH} \]

Butane:
\[ \text{H}_3\text{C} \quad \text{-CH}_2\quad \text{-CH}_2\quad \text{-CH}_3 \]

2-methylpropane:
\[ \text{CH}_3 \quad \text{H}_3\text{C} \quad \text{-CH} \quad \text{-CH}_3 \]

(b) Hexane and hexan-1-ol
(c) Butane and 2-methylpropane
(d) 2-methylpropane, butane, hexane, hexan-1-ol.
(e) Hexan-1-ol. This is because hexan-1-ol molecules can form hydrogen bonds with water molecules.

25. (a)

(b)

(c) In addition to the NH\(_2\) group, the C=O group of amide has two lone pairs of electrons that enable ethanamide to form more hydrogen bonds. This leads to a higher boiling point and thus ethanamide is less volatile than ethanamine.
26. (a) (i) CH₃CH₂CH₂COOH is a carboxylic acid while CH₃CH₂COOCH₃ is an ester that has a fruity smell.
(ii) CH₃CH₂CH₂COOH molecules can form hydrogen bonds with water molecules while CH₃CH₂COOCH₃ molecules cannot.
(iii) CH₃CH₂CH₂COOH molecules are attracted by hydrogen bonds while CH₃CH₂COOCH₃ molecules are attracted by dipole-dipole forces.
(b) A mixture of CH₃CH₂CH₂COOH and CH₃CH₂COOCH₃ has a strong acidic smell due to CH₃CH₂CH₂COOH. Upon dissolving in water, CH₃CH₂CH₂COOH is soluble in water but CH₃CH₂COOCH₃ is not. The insoluble CH₃CH₂COOCH₃ floats on water and gives a fruity smell for the resultant mixture.
(c) It is possible. As CH₃CH₂COOCH₃ has a lower boiling point than that of CH₃CH₂CH₂COOH, it can be distilled out first during fractional distillation.
Chapter 45  Isomerism

Class Practice

A45.1
1.  (a)

(b)
2. Butane is a straight-chain alkane which has a larger surface area than that of 2-methylpropane. As a result, the dispersion forces among butane molecules are stronger and more energy is needed to overcome the forces in boiling.

A45.2

A45.3

1. (a) Rotation about the C–C single bond is possible and the two compounds are identical.
   (b) They are structural isomers in which their atoms are joined in different orders.

2.

Hex-1-ene

Cis-hex-2-ene
A45.4

(a)

(b)
Chapter 45 Isomerism

Chapter Exercise

1. molecular
2. length
3. position
4. functional groups
5. Chain, position
6. Functional group
7. Stereoisomers
8. Geometrical, alkenes, cis-, trans-
9. Enantiomers
10. B
11. A
12. A
13. C
14. D
15. D

16. (a) 

H₃C — CH≡CH — CH₂ — OH

(b) 

O

H₃C — CH₂ — CH₂ — C — H

(c) 

O

H₃C — CH₂ — C — CH₃
17. (a) No geometrical isomerism. One of the doubly-bonded carbon atoms is attached to two identical groups (methyl group).

(b) Yes.

(c) No geometrical isomerism. The compound does not contain C=C double bond.

18. Since $X$ has only one oxygen atom and can form hydrogen bonds, it is likely to be an alcohol. The possible structures of $X$ are:

\[
\begin{align*}
H_3C & \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{OH} \\
\text{H}_3\text{C} & \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]

$Y$ should not have hydrogen atoms attached to the oxygen atom, so the possible structure of $Y$ is:

\[
\begin{align*}
\text{H}_3\text{C} & \quad \text{CH}_2 \quad \text{O} \quad \text{CH}_3 \\
\end{align*}
\]

19. (a) 

(b) They are both haloalkanes and thus possess the same functional group.

(c) (+)-2-chloropentane and (−)-2-chloropentane

(d) Measure the optical activity of the isomers by using a polarimeter. The two optical isomers can rotate the plane of polarized light to the same extent but in the opposite direction. When one of them rotates the plane-polarized light in clockwise direction, the other rotates the plane-polarized light in anticlockwise direction to the same extent.
Chapter 46  Typical reactions of various functional groups

Class Practice

A46.1

\[
\begin{align*}
\text{1-chloropropane} & : & \text{2-chloropropane} & : & \text{1,1-dichloropropane} \\
\text{1,2-dichloropropane} & : & \text{1,3-dichloropropane} & : & \text{2,2-dichloropropane}
\end{align*}
\]

A46.2

(a)

\[
\begin{align*}
\text{major product}
\end{align*}
\]

(b)

\[
\begin{align*}
\text{major product}
\end{align*}
\]
A46.3
(a)

\[
\begin{array}{ccccc}
& & & H & H \\
& & \text{H} & \text{C} & \text{C} \\
& H & \text{C} & \text{C} & \text{C} & \text{H} \\
H & H & OH & & \\
\end{array}
\]

propan-1-ol

(b)

\[
\begin{array}{ccccc}
& & & H & H \\
& & \text{H} & \text{H} & \text{H} \\
& & \text{HO} & \text{C} & \text{C} \\
& H & \text{C} & \text{C} & \text{C} & \text{H} \\
& H & H & OH & & \\
\end{array}
\]

propane-1,3-diol

A46.4
1. (a) Concentrated sulphuric acid, 180°C
   (b) Acidified potassium dichromate solution, under reflux
   (c) Concentrated hydrochloric acid
2. (a) \( \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{Cl} \)
   1-chloropentane
   (b) \( \text{CH}_2=\text{CH} \text{CH}_2 \text{CH}=\text{CH}_2 \)
   Penta-1,4-diene
   (c) \( \text{CH}_3 \text{C}=\text{C} \text{CH}_2 \text{CH}_2 \text{C}=\text{O} \)
   4-oxopentanoic acid

A46.5
(a)

\[
\begin{array}{ccccc}
& & & O & H \\
& & \text{HO} & \text{C} & \text{C} \\
& & \text{C} & \text{C} & \text{C} & \text{H} \\
& & \text{H} & H & & \\
\end{array}
\]

(b)

\[
\begin{array}{ccccc}
& & & H & OH \\
& & \text{H} & \text{H} & \text{OH} \\
& & \text{H} & \text{C} & \text{C} \\
& \text{H} & \text{C} & \text{C} & \text{C} & \text{H} \\
& \text{H} & H & H & & \\
\end{array}
\]
A46.6
1. (a)

(b)

2. (a)

(b)

A46.7
A: Propan-1-ol  B: Sodium ethanoate  C: Propanoic acid

A46.8
3-formylpropanoic acid  Ethane-1,2-diol
Butanedioic acid

\[
\begin{align*}
\text{O} & \quad \text{H} & \quad \text{H} & \quad \text{O} \\
\text{HO} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{OH} \\
\text{H} & \quad \text{H} & \quad \text{H} & \\
\end{align*}
\]

Ammonium ion

\[
\begin{align*}
\text{H} & \quad \text{N} & \quad \text{H} & \quad \text{H} \\
\end{align*}
\]
Chapter 46  Typical reactions of various functional groups

Chapter Exercise

1. substitution
2. addition
3. hydrogenation
4. halogenation
5. hydrohalogenation
6. larger
7. hydroxide
8. Substitution
9. 2:1
10. aldehydes, carboxylic acids
11. ketones
12. carboxylic
13. primary alcohols
14. secondary alcohols
15. alcohols
16. Esterification
17. arboxylic acid, 1cohol
18. arboxylate
19. carboxylic, mmonium
20. carboxylate, mmonia
21. A
22. D
23. A
24. B
25. A
26. C

27. (a) Bromine
    (b) Hydrogen bromide (HBr)
    (c) Sunlight provides energy for initiating the reaction.
    (d) $C_6H_{14}(l) + Br_2(l) \rightarrow C_6H_{13}Br(l) + HBr(g)$

28. (a) 1,2-dichloroethane
    (b) Ethene is insoluble in water.
    (c) Sodium hydroxide
    (d) $ClCH_2CH_2Cl + 2OH^- \rightarrow HOCH_2CH_2OH + 2Cl^-$
    (e) C–Br bond is weaker than C–Cl bond and so reaction 2 proceeds more rapidly.

29. (a) Other chloroalkanes e.g. 1,1-dichloroethane, 1,2-dichloroethane, 1,1,2-trichloroethane, etc. may be formed as side products.
    (b) Addition of bromine to an alkene would result in a dibromo- compound. In this case, 2,3-dibromopentane will be formed.
    (c) The hydrolysis does not go to completion. Some ethyl ethanoate is left in the final equilibrium mixture.
30. (a) As $A$ is not oxidized by acidified potassium dichromate solution, it must be butanone (a ketone). As $B$ can react with ethanoic acid to form a fruity smell substance (probably an ester), it is likely to be butanol. Thus, $C$ is butanal.

(b) When the mixture is poured into water, ethanoic acid will dissolve in water, leaving the fruity smell ester to float over the water surface.
Chapter 47  Inter-conversions of carbon compounds

Class Practice

A47.1

1. 

2. (a)  

(b) Butan-2-ol reacts with concentrated hydrochloric acid or liquid phosphorus trichloride.

(c) Structural isomers (Position isomers)
A47.2

\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{NH}_2 \text{H}^+ (aq) \rightarrow \text{H} - \text{C} - \text{C} - \text{C} - \text{O} \]  

1. (a) \[ \text{CH}_3\text{COOH}(l) + \text{CH}_3\text{CH}_2\text{OH}(l) \leftrightarrow \text{CH}_3\text{COOCH}_2\text{CH}_3(l) + \text{H}_2\text{O}(l) \]

2. \[ \begin{align*} 
\text{A:} & \quad \text{B:} \\
\text{C:} & \quad \text{D:} 
\end{align*} \]

A47.3

1.

[Diagrams of chemical reactions]

2. \[ \begin{align*} 
A : & \quad H - C - C - C - H \\
B : & \quad H - C - C - C - H \\
C : & \quad H - C - C - C - H \\
D : & \quad H - C - C - C - H 
\end{align*} \]

A47.4

(a) \[ \text{CH}_3\text{COOH}(l) + \text{CH}_3\text{CH}_2\text{OH}(l) \rightarrow \text{CH}_3\text{COOCH}_2\text{CH}_3(l) + \text{H}_2\text{O}(l) \]

(b) No. of moles of ethanol used = \[ \frac{5}{12.0 \times 2 + 1.0 \times 6 + 16.0} \text{ mol} = 0.109 \text{ mol} \]

No. of moles of ethanoic acid used = \[ \frac{5}{12.0 \times 2 + 1.0 \times 4 + 16.0 \times 2} \text{ mol} = 0.0833 \text{ mol} \]

From the equation, mole ratio of ethanol : ethanoic acid = 1 : 1.
Since no. of moles of ethanol > no. of moles of ethanoic acid, ethanol is in excess.

(c) Theoretical mass of ethyl ethanoate formed = \[ 0.0833 \times (12.0 \times 4 + 1.0 \times 8 + 16.0 \times 2) \text{ g} = 7.33 \text{ g} \]

(d) Percentage yield of ethyl ethanoate = \[ \frac{5.5}{7.33} \times 100\% = 75.0\% \]
Chapter 47  Inter-conversions of carbon compounds

Chapter Exercise

1. multi-step
2. lkanes, lkenes, haloalkanes
3. lcohols, ldehydes, etones, arboxylic acids, sters, mides
4. alcohol
5. starting, rate, yield, steps, products
6. potassium dichromate, reflux
7. sulphuric, catalyst, dehydrating, acidic, ethanol, water
8. C
9. B
10. C
11. D
12. C
13. A
14.

\[
\begin{align*}
H_3C&-CH_2-CH_2-CH_2-OH & \xrightarrow{\text{Cr}_2\text{O}_7^{2-}/\text{H}^+} & H_3C&-CH_2-CH_2-C&-OH \\
& & \xrightarrow{\text{PCl}_3} & \\
H_3C&-CH_2-CH_2-C&-\text{NH}_2 & \xleftarrow{\text{NH}_3} & H_3C&-CH_2-CH_2-C&-\text{Cl}
\end{align*}
\]

15. (a) Haloalkanes
(b) Alkanols
(c) A:
\[
\begin{align*}
H_2C&=C-\text{CH}_3 \\
&\quad \text{CH}_3
\end{align*}
\]

B:
\[
\begin{align*}
\text{Cl} & \\
H_3C&-C-\text{CH}_3 \\
&\quad \text{CH}_3
\end{align*}
\]

C:
\[
\begin{align*}
\text{OH} & \\
H_3C&-C-\text{CH}_3 \\
&\quad \text{CH}_3
\end{align*}
\]

(d) Dehydration using concentrated sulphuric acid at 180°C
16. (a) To prevent the escape of any reactant or product.
(b) To avoid over-heating.
(c) Water
(d) Orange to green
(e) \(A\): Propanoic acid
\(B\): Propanal

17. (a) No. of moles of butan-1-ol used = \(\frac{7 \times 0.81}{12.0 \times 4 + 1.0 \times 10 + 16.0 \times 1}\) mol = 0.0766 mol

No. of moles of butanoic acid formed = 0.0766 mol
\[\therefore \text{theoretical mass of butanoic acid formed} = 0.0766 \times (12.0 \times 4 + 1.0 \times 8 + 16.0 \times 2) \text{ g} = 6.74 \text{ g}\]

Percentage yield of butanoic acid = \(\frac{4.8}{6.74} \times 100\% = 71.2\%\)

(b) Ethyl butanoate

(c) No. of moles of butanoic acid used = \(\frac{4.8}{12.0 \times 4 + 1.0 \times 8 + 16.0 \times 2}\) mol = 0.0545 mol

No. of moles of ester formed = 0.0545 mol
\[\therefore \text{theoretical mass of ester formed} = 0.0545 \times (12.0 \times 6 + 1.0 \times 12 + 16.0 \times 2) \text{ g} = 6.32 \text{ g}\]

Percentage yield of ester = \(\frac{3.4}{6.32} \times 100\% = 53.7\%\)

(d) Overall percentage yield of the process = 71.2\% \times 53.7\% = 38.2\%
Chapter 48  Important organic substances

Class Practice

A48.1
(a) They exhibit functional group isomerism. In the chain form, the functional
groups of glucose and fructose are aldehyde and ketone respectively.
(b) They both have five –OH groups that can form hydrogen bonds with water
molecules.
(c) Their molecules are held firmly together by intermolecular hydrogen bonds,
which require more energy to break.

A48.2
(a) It possesses –COOH group.
(b) 18
(c) Unsaturated
(d) No. It has a long, non-polar hydrocarbon chain which is insoluble in water.

A48.3

\[
\text{CH}_3
\]

A48.4
There is no covalent bond between O and K. The structural formula should be written
as –COO\text{K}^+.

A48.5
1. (a) Yes. Sea water contains considerable amounts of both calcium and
magnesium ions (especially magnesium ions).
(b) No. Soap anions form scum in sea water.
2. (a) (ii) and (iii)
(b) Soapless detergent particles have ionic head (–SO\text{3}^-) which does not form
scum with either calcium or magnesium ions.
(c) (ii). Its particles possess the shortest hydrophobic hydrocarbon tail.
A48.6

1. (a) They have high proportions of non-polar, hydrophobic hydrocarbon chains in their structures.
   (b) Nylon has higher tensile strength than polyester.
2. (a) Corn oil and ethyl ethanoate
   (b) Aspirin
   (c) Hydroxyl (–OH) group
   (d) Ester (–COO–) group
Chapter 48  Important organic substances

Chapter Exercise

1.  glucose, ructose, C₆H₁₂O₆
2.  hydroxyl, ldehyde, etone
3.  fats, oils, triesters, propane-1,2,3-triol, carboxylic
4.  saturated, unsaturated
5.  amino
6.  acetylsalicylic acid, inflammatory, platelet, heart
7.  water
8.  ionic, ydrocarbon, hydrophilic, hydrophobic
9.  lipids, long-chain carboxylic
10.  alkylsulphate
11.  surface tension
12.  emulsifying
13.  ionic heads
14.  scum
15.  form precipitate
16.  amide
17.  ester
18.  D
19.  B
20.  D
21.  B
22.  A
23.  A

24.  (a)  Each castor oil molecule contains three ester groups.
      (b)  CH₃(CH₂)₅C(OH)HCH₂CH=CH(CH₂)₇COOH
      (c)  The cis configuration of the long hydrocarbon chain causes the castor oil
           molecules to pack less efficiently. Therefore, castor oil has a low melting
           point.

25.  (a)  ![salicylic acid](image)
      (b)  ![aspirin](image)

      (c)  It is an anti-inflammatory drug used in the treatment of arthritis. Furthermore, it has an anti-platelet effect and can be used to prevent heart attacks and stroke.

      (d)  As there is a carboxyl (–COOH) group on its molecule, aspirin is acidic. To avoid irritation to the stomach, aspirin is usually served with antacid.
26. (a) Soapless detergent particle  
(b) \( \text{CH}_3(\text{CH}_2)_n\text{OSO}_3^- \)  
(c) \( \text{CH}_3(\text{CH}_2)_2\text{C} \equiv \text{CH}_2 \)  
(d) \( \text{CH}_3(\text{CH}_2)_7\text{CH} \equiv \text{CH}_2 \xrightarrow{\text{H}_2\text{SO}_4} \text{CH}_3(\text{CH}_2)_9\text{OSO}_3\text{H} \xrightarrow{\text{NaOH}} \text{CH}_3(\text{CH}_2)_9\text{OSO}_3^- \)

27. (a) Add the detergent solution to a mixture of oil and water. Upon shaking, the two separate layers should form a foamy emulsion which remains as a single layer even on standing. 

(b) 

(c) Soapy detergent forms insoluble scum with magnesium sulphate solution:  
\[ \text{Mg}^{2+}(\text{aq}) + 2\text{RCOO}^-(\text{aq}) \rightarrow (\text{RCOO}^-)_2\text{Mg}(\text{s}) \]  
However, soapless detergent forms lather when it is stirred with the magnesium sulphate solution.
Part XI  Chemistry of carbon compounds

Part Exercise

1. B
2. B
3. A
4. D
5. C
6. A
7. C
8. B
9. C
10. C
11. D
12. C
13. D
14. A
15. B

16. (a) Dispersion forces
(b) Propanoic acid, butan-1-ol, butanamide
(c) Butanamide. It can use both the C=O and NH₂ groups to form more hydrogen bonds and thus more energy is needed to separate its molecules in boiling.
(d) Hexane. Its molecules are attracted by weak dispersion forces only. Less energy is needed to separate its molecules in boiling.
(e) Butanoic acid is relatively less soluble than propanoic acid. This is because butanoic acid has a larger alkyl group that is hydrophobic.

17. (a) 
(b) 

\[
\text{cis-butenedioic acid}
\]
\[
\text{hydrogen bond}
\]

(c) As \textit{cis}-butenedioic acid forms intramolecular hydrogen bond, less hydrogen bonds are formed between molecules and thus less energy is needed to separate the molecules in boiling.
(d) \(\text{HOOCCH=CHCOOH} + \text{H}_2 \rightarrow \text{HOOCCH}_2\text{CH}_2\text{COOH}\)

(e) The two isomers rotate plane-polarized light to the same extent but in the opposite directions.

18. | Structural formula | Name       |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Structural formula A" /></td>
<td>2,2-dichloropropane</td>
</tr>
<tr>
<td><img src="image" alt="Structural formula B" /></td>
<td>1,3-dichloropropane</td>
</tr>
<tr>
<td><img src="image" alt="Structural formula C" /></td>
<td>1,2-dichloropropane</td>
</tr>
<tr>
<td><img src="image" alt="Structural formula D" /></td>
<td>1,1-dichloropropane</td>
</tr>
</tbody>
</table>

19. (a)
(b)  

(c)  

(d) It should be used in dried organic solvents.
20. (a) Ester and C=C double bond

(b)

\[
\begin{align*}
A & : \quad \text{H}_3\text{C} - \text{CH}_2 - \text{CH}_2 - \text{O} - \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \\
B & : \quad \text{HO} - \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \\
C & : \quad \text{H}_2\text{C} = \text{CH} - \text{CH}_2 - \text{OH} \\
D & : \quad \text{Cl} \\
E & : \quad \text{H}_2\text{C} - \text{CH}_2 - \text{CH}_2 - \text{OH}
\end{align*}
\]

(c)

\[
\begin{align*}
\text{H}_3\text{C} - \text{CH}_2 - \text{CH}_2 - \text{O} - \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 & \xrightarrow{\triangle} \text{HO} - \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \\
& \xrightarrow{\text{SOCl}_2} \text{NH}_3 \\
& \xrightarrow{\text{Cl}} \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3
\end{align*}
\]

21. (a) 

\[
\begin{align*}
\text{H}_3\text{C} - \text{C} - \text{CH}_3 & \xrightarrow{(1) \text{LiAlH}_4 / \text{dry ether}} \text{H}_3\text{C} - \text{C} - \text{CH}_3 \\
& \xrightarrow{(2) \text{H}^+} \text{H}_3\text{C} - \text{C} - \text{CH}_3 \\
& \xrightarrow{\text{con. H}_2\text{SO}_4} \xrightarrow{180^\circ\text{C}} \text{H}_2\text{C} = \text{CH} - \text{CH}_3 \\
& \xrightarrow{\text{H}_2 / \text{Ni} \quad 200^\circ\text{C}} \text{H}_3\text{C} - \text{CH}_2 - \text{CH}_3
\end{align*}
\]
22. (a) Upon reduction by lithium aluminium hydride, a carboxylic acid will be reduced directly to an alcohol. To accomplish the conversion, the acid should be reduced to alcohol first. The alcohol so formed will then be oxidized by acidified potassium dichromate solution. Then the aldehyde is distilled out once formed.

(b) Since the ester is hydrolysed in an alkaline medium, sodium propanoate, not propanoic acid, is obtained in the product mixture. To get the propanoic acid, dilute hydrochloric acid should be added after the alkaline hydrolysis.

23. (a) C=C double bond

(b) When they are mixed with bromine solution, the red-orange colour of bromine disappears rapidly.

(c) Carbonyl group (–CO–)

(d) All of them react with acidified potassium dichromate solution to give carboxylic acids and causes the orange dichromate solution to change to green.

(e) LiAlH₄ / dry ether, followed by H⁺(aq)

(f) Simple hydrogenation of C will give a saturated alcohol:

That is, it is difficult to add hydrogen atoms to a designated C=C bond while leaving the rest behind.
24. (a) It is bromine (Br₂) in water. It is formed from the oxidation of HBr. However, Br₂ cannot react with pentan-1-ol to give the desired product.

(c) No. of moles of 1-bromopentane to be made
$$\frac{10}{12.0 \times 5 + 1.0 \times 11 + 79.9} \text{ mol} = 0.0663 \text{ mol}$$
No. of moles of pentan-1-ol needed
$$\frac{0.0663}{58\%} \text{ mol} = 0.114 \text{ mol}$$
Mass of pentan-1-ol needed
$$= (0.114)(12.0 \times 5 + 1.0 \times 12 + 16.0) \text{ g}$$
$$= 10.0 \text{ g}$$

25. (a) It does not possess an anionic head of CO₂⁻, SO₃⁻ or OSO₃⁻.
(b) The non-polar part of polyoxyethylene dissolves in grease. Water molecules attract the polar group of polyoxyethylene, lifting up the grease from the surface. By stirring, the grease forms tiny droplets, forming an emulsion. They can then be washed away.
A detergent enables water to wet the object thoroughly.

The hydrophobic tails of detergent anions dissolve in grease.

Water molecules attract the hydrophilic heads of detergent anions, lifting up the grease from the surface.

By stirring, the grease forms tiny droplets, forming an emulsion.

(c) It does not form scum with Ca$^{2+}$ or Mg$^{2+}$.
(d) It can be done by reducing the length of the non-polar alkyl part.
26. (a) CH₃(CH₂)nCOO⁻Na⁺
    (b) The ionic head of soapy detergent is −COO⁻ while those of soapless
detergents are either −SO₃⁻ or −O−SO₃⁻.
    (c) Sodium hydroxide and sodium chloride
    (d) By mixing the detergent solutions with a saturated calcium chloride
solution, the one that forms scum is a soapy detergent while the other one is
a soapless detergent.

27. (a) Oils
    (b) Firstly, vegetable oils have a higher percentage of double bonds. Secondly,
the double bonds of oils usually adopt cis configuration. Thus, the oil
molecules pack less efficiently and the intermolecular forces are less
effective in holding the molecules. As a result, vegetable oils have lower
melting points than animal fats.
    (c) When bromine solution is mixed with an alkene, addition reaction occurs
and two bromine atoms will add to each double bond. In general, the larger
the number of double bonds in a fat or oil molecule, the more the bromine
solution is needed for complete reaction.
For arachidic acid [CH₃(CH₂)₁₈COOH], there is no double bond in the
compound and thus it has no reaction with bromine solution. It is a saturated
fatty acid.
For oleic acid [CH₃(CH₂)₇CH=CH(CH₂)₇COOH], one bromine molecule
will be added to one acid molecule. The fatty acid and bromine react in a
stoichiometric ratio of 1:1.
\[
\text{CH}_3\text{(CH}_2)_7\text{CH}=\text{CH(CH}_2)_7\text{COOH} + \text{Br}_2 \\
\rightarrow \text{CH}_3\text{(CH}_2)_7\text{CHBrCHBr(CH}_2)_7\text{COOH}
\]
Therefore, the stoichiometric ratio of the reactants reveals the number of
double bonds (or degree of unsaturation) in a fatty acid molecule.
    (d) Both saturated and unsaturated fatty acids have large hydrophobic parts
(non-polar hydrocarbon chains). These make them insoluble in water which
is polar in nature.
Chapter 49  Periodic variation in physical properties of the elements Li to Ar

Class Practice

A49.1
W – Period 4, Group 0, non-metal
X – Period 5, Group V, non-metal
Y – Period 3, Group I, metal
Z – Period 6, Group IV, metal

A49.2
(a) P₄, S₈ and Cl₂
(b) Covalent bond
(c) Chlorine, phosphorus, sulphur
(d) Van der Waals’ forces (Dispersion forces)

A49.3
(a) Group I elements have giant metallic structure and their atoms are held together by strong metallic bonds. In melting, a large amount of energy is needed to overcome the strong bonds. However, Group VII elements have simple molecular structure and their molecules are held by weak van der Waals’ forces only. In melting, less energy is needed to separate the molecules.
(b) Across the period, the number of delocalized electrons increases and so is the strength of metallic bonds.
(c) For Group IV element in Period 2, i.e. carbon, it has giant covalent structure and its atoms are held together by strong covalent bonds. A large amount of energy is needed to overcome the strong covalent bonds during melting. For Groups V to 0 elements, the molecules/atoms are held together by weak van der Waals’ forces. The order of molecular size across Period 2 is N₂ > O₂ > F₂ > Ne. As van der Waals’ forces decrease with the molecular size, the melting point decreases across Period 2.

A49.4
(a)
(b) Both potassium and calcium have giant metallic structure with delocalized electrons and so they are electrical conductors. As calcium has more outermost shell electrons, it has a higher conductivity.

Bromine is a simple molecular substance that contains no mobile ions or delocalized electrons for conducting electricity.
Chapter 49  Periodic variation in physical properties of the elements Li to Ar

Chapter Exercise

1. periodicity
2. semi-metals
3. metallic, ionic, metallic, ionic, molecular
4. delocalized, electron, metallic
5. IV, covalent
6. low, intermolecular, size
7. metallic, high
8. A
9. A
10. C
11. C
12. C
13. A

14. (a)

(b) Carbon
(c) Neon
(d) In carbon (diamond), atoms are linked by strong covalent bonds, much energy is needed to overcome the strong bonds for melting to occur. In neon, atoms are attracted by weak van der Waals’ forces only, so less energy is needed to separate the atoms during melting.
15. (a) Melting point order: aluminium > magnesium > sodium. During the melting of metals, energy is needed to overcome the metallic bonds between the metal cations and delocalized electrons. A metal with higher metallic bond strength requires more energy in melting.

(b) Melting point order: sulphur (S₈) > phosphorus (P₄) > chlorine (Cl₂) > argon (Ar). A larger molecule has stronger van der Waals’ forces between molecules. Hence, more energy is needed to separate the molecules in melting.

(c) In melting a giant covalent substance, a large amount of energy is needed to overcome the strong covalent bonds. However, in melting a metal, the metallic bonds do not have to be substantially broken and so less energy is required.

16. (a) | Element | Physical state at 25°C | Melting point (1=highest;4=lowest) | Electrical conductivity |
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Solid</td>
<td>2</td>
<td>depends on temperature</td>
</tr>
<tr>
<td>X</td>
<td>Gas</td>
<td>4</td>
<td>insulator</td>
</tr>
<tr>
<td>Y</td>
<td>Solid</td>
<td>1</td>
<td>depends on its structure</td>
</tr>
<tr>
<td>Z</td>
<td>Solid</td>
<td>3</td>
<td>conductor</td>
</tr>
</tbody>
</table>

(b) Metal: Z; semi-metal: W; non-metals: X and Y

(c) It has a giant covalent structure with no free electrons at room temperature and so it is an insulator. However, at higher temperatures, they become very good conductors of electricity.

(d) Another allotrope of Y (i.e. graphite) which contains delocalized electrons can conduct electricity.

17. (a) [Diagram of a sulphur molecule]

(b) [Diagram of a phosphorus molecule]

(c) A sulphur molecule is larger than a phosphorus molecule.

(d) A sulphur molecule is larger and has a stronger instantaneous dipole. Hence, more energy is needed to overcome the van der Waals’ forces between molecules in melting.
Chapter 50 Bonding, stoichiometric composition and acid-base properties of oxides of the elements Na to Cl

Class Practice

A50.1
(a) $A_2O_3$ – giant ionic structure 
   $B_2O_3$ – simple molecular structure 
   $CO_2$ – giant covalent structure 
   $DO_2$ – simple molecular structure 
(b) A – metal 
   B – non-metal 
   C – semi-metal 
   D – non-metal 
(c) A – aluminium 
   B – phosphorus 
   C – silicon 
   D – sulphur

A50.2
(a) $Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$ 
(b) $Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2[Al(OH)_4]^-$(aq)

A50.3
(a) Magnesium oxide dissolves in water and gives out hydroxide ions to form a slightly alkaline solution while phosphorus pentoxide dissolves in water to form phosphoric acid. 
(b) Dichlorine oxide dissolves in water to form hypochlorite ions, which can bleach dyes.
Chapter 50  Bonding, stoichiometric composition and acid-base properties of oxides of the elements Na to Cl

Chapter Exercise

1. increases
2. give up, share
3. sodium, magnesium, hydroxides
4. aluminium, dilute acids, dilute alkalis
5. sulphur, acidic oxides
6. acidic, alkaline solution, salts
7. D
8. A
9. D
10. C
11. C
12. D

13. (a) Sodium. The difference in electronegativity value between sodium and oxygen is the largest, so they form a compound with the highest ionic character.
   (b) Na$_2$O
   (c) Covalent bond. They have only a small difference (3.0 − 2.1 = 0.9) in electronegativity value.
   (d) PCl$_3$ (or PCl$_5$)
   (e) Na$_2$O has a higher melting point than that of PCl$_3$ (or PCl$_5$) as much energy is needed to overcome the strong ionic bonds in melting.

14. (a) Sodium oxide reacts vigorously with water to form a strongly alkaline solution which is corrosive in nature.
   (b) Magnesium oxide neutralizes the acidity of soil to provide a proper pH environment for plant growth.
   (c) Silica glass (containing silicon dioxide) reacts with alkalis to form salts and water.

15. (a) When sulphur dioxide in polluted air dissolves in water, an acidic solution is formed;
    \[ \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_3(\text{aq}) \]
    (b) Aluminium oxide is amphoteric as it can react with both acids and alkalis. Reaction with an acid:
    \[ \text{Al}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) \]
    Reaction with an alkali:
    \[ \text{Al}_2\text{O}_3(\text{s}) + 2\text{NaOH}(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaAl(OH)}_3(\text{aq}) \]
16.

- Take a small sample of oxide (about 1 g) from each of the four unlabelled bottles and add them to four separate test tubes. To each test tube, add 10 cm³ of water and observe any change.
- To each soluble sample, add three drops of universal indicator solution and note the colour changes.
- The one that turns the indicator solution blue would be magnesium oxide while the one that turns the indicator solution red would be phosphorus pentoxide.
- To each insoluble sample, add 5 cm³ of dilute hydrochloric acid and observe any change.
- The one that dissolves would be aluminium oxide while the insoluble solid would be silicon dioxide.
Chapter 51  General properties of transition metals

Class Practice

A51.1
(a) The statement is correct. Because of the similar outer electron arrangement, transition metals across a period have similar chemical properties.
(b) This statement is incorrect. It is because electrons in both the outermost shell and the next inner shell of most transition metal atoms contribute to the ‘sea of electrons’. Much energy is needed to overcome the metallic bonds during melting and boiling.

A51.2
(a) Pink
(b) Orange
(c) Green
(d) Green

A51.3
(a) A variable number of electrons can be removed from the outermost shell and the next inner shell of the atoms of transition metals.
(b) The oxidation number of manganese is +4 in manganese(IV) oxide. It can be reduced to +2 or +3 (acting as an oxidizing agent) or oxidized to +5, +6 or +7 (acting as a reducing agent).

A51.4
1. (a) To increase the surface area of V₂O₅(s) so that more active sites are available for the reaction to occur.
   (b) VO₂
   (c) It cannot be regenerated in the absence of oxygen. A catalyst must not be consumed in the reaction.
2. (a) \(2\text{ClO}^- (aq) \rightarrow 2\text{Cl}^- (aq) + \text{O}_2(g)\)
   (b) Co(OH)₂
   (c) Co(OH)₂ reduces ClO⁻ to Cl⁻ and itself is oxidized to an intermediate, Co(OH)₃ in the presence of water.

A51.5
(a) Nickel
(b) Titanium
(c) Copper
(d) Copper, zinc
Chapter 51  General properties of transition metals

Chapter Exercise

1. higher, III, VII
2. 4, titanium, chromium, iron, nickel, zinc
3. purple, green, orange, purple
4. electrons, oxidation
5. 2, 3, +2, +4, +7
6. oxidizing, reducing
7. manganese(II) ions, manganese(IV) oxide
8. industrial, metals, interconvert
9. protein, catalysts, life
10. B
11. C
12. B
13. C
14. B
15. D

16. (a) Many transition metal ions are coloured when they dissolve in water. Cr\(^{3+}\)(aq) is green in colour while Cr\(_2\)O\(_7\)\(^{2-}\)(aq) is orange in colour.
(b) Variable number of electrons can be removed from the outermost shell and the next inner shell of the atoms of transition metals. Therefore, transition metals have variable oxidation states. The oxidation numbers of chromium in Cr\(^{3+}\) and Cr\(_2\)O\(_7\)\(^{2-}\) are +3 and +6 respectively.

17. (a) MnO\(_4\)\(^{-}\)(aq) + 8H\(^+\)(aq) + 5Fe\(^{2+}\)(aq) \→ Mn\(^{2+}\)(aq) + 4H\(_2\)O(l) + 5Fe\(^{3+}\)(aq)
(b) Pale yellow. It is due to the colour of Fe\(^{3+}\)(aq).
(c) Pale purple
(d) It is a strong oxidizing agent that has an obvious colour change during redox titration.

18. (a) Ultra-violet light
(b) Ag(s)
(c) The solution turns blue and silvery solid is formed.

19. (a) It acts as an oxidizing agent because the oxidation number of vanadium decreases from +5 in V\(_2\)O\(_5\) to +4 in VO\(_2\).
(b) VO\(_3\)\(^{-}\) is also an oxidizing agent that can react with SO\(_2\).
(c) 2SO\(_2\)(g) + O\(_2\)(g) \→ 2SO\(_3\)(g)
(d) Yes. In this case, the reaction of VO\(_2\) with oxygen is the first stage of the whole process.
Part XII Patterns in the chemical world

Part Exercise

1. C
2. B
3. D
4. B
5. D
6. D
7. D
8. A
9. A
10. D

11. (a) It is a metal as it is malleable, ductile and a good electrical conductor at room temperature.
(b) It is very reactive in air.
(c) \(A_2O(s) + H_2O(l) \rightarrow 2AOH(aq)\)
(d) It is a basic oxide as it dissolves to form hydroxide ions.
(e) The element next to \(A\) should have a higher electrical conductivity as it has more delocalized electrons in the metallic structure.

12. (a) Add the mixture to a beaker of water. Reaction of phosphorus pentoxide and water occurs:
\[P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)\]
The solution is then filtered. The residue is washed and dried. The solid obtained is a mixture of aluminium oxide and silicon dioxide.
(b) Mix the mixture of aluminium oxide and silicon dioxide with excess dilute hydrochloric acid. Reaction of aluminium oxide and acid occurs:
\[Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)\]
The solution is then filtered. The residue is washed and dried. The solid obtained is silicon dioxide.

13. (a) Na, Mg, Al
(b) Si
(c) P, S, Cl, Ar
(d) Na, Mg, Al. They have delocalized electrons in their giant metallic structures.
(e) Si, P, S, Cl, Ar. They have no delocalized electrons in their structures.
(f) A semi-metal usually has a giant covalent structure in which there are no delocalized electrons. Therefore, a semi-metal is an insulator at room temperature. However, at higher temperatures, it becomes a very good conductor of electricity.
(g) By passing electric current to the unknown substance at different temperatures and find out the conductivity of the substance. In general,

<table>
<thead>
<tr>
<th></th>
<th>Conduct at room temperature</th>
<th>Conduct at high temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Semi-metals</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>Non-metals</td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>

14. (a) Fe$^{2+}$(aq) and Fe$^{3+}$(aq) are green and yellow in colour respectively.
(b) The possible oxidation states of iron are +2 (e.g. Fe$^{2+}$), +3 (e.g. Fe$^{3+}$), +4, +5 and +6.
(c) Finely divided iron is used as catalyst in the manufacture of ammonia from hydrogen and nitrogen in Haber Process.
(d) Fe$^{2+}$(aq) or Fe$^{3+}$(aq) can be used to catalyse the reaction between peroxodisulphate and iodide ions.

15. (a) Al$_2$O$_3$ and SiO$_2$
(b) MgO
\[
\text{MgO(s) + H}_2\text{O(l) → Mg(OH)$_2$(s)}
\]
\[
\text{Mg(OH)$_2$(s) + water = Mg}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})
\]
(c) SO$_2$
\[
\text{SO}_2(\text{g}) + \text{H}_2\text{O(l) → H}_2\text{SO}_3(\text{aq})
\]
\[
\text{H}_2\text{SO}_3(\text{aq}) = 2\text{H}^+(\text{aq}) + \text{SO}_3^{2-}(\text{aq})
\]
(d) P$_4$O$_{10}$
\[
\text{P}_4\text{O}_{10}(\text{s}) + 6\text{H}_2\text{O(l) → 4H}_3\text{PO}_4(\text{aq})}
\]
(e) Na$_2$O
\[
\text{Na}_2\text{O(s) + H}_2\text{O(l) → 2NaOH(aq)}
\]

16. (a) Sc$^{3+}$ or Zn$^{2+}$
(b) V$^{3+}$, Cr$^{3+}$, Fe$^{2+}$ or Ni$^{2+}$
(c) Mn
(d) Cr or Mn
(e) Mn or Cu

17. (a) The direct reaction between iodide ions and peroxodisulphate ions can be represented by the following equation:
\[
2\text{I}^-(\text{aq}) + \text{S}_2\text{O}_8^{2-}(\text{aq}) → \text{I}_2(\text{aq}) + 2\text{SO}_4^{2-}(\text{aq})
\]
In the presence of the catalyst Fe$^{2+}$, the reaction goes through two steps to give the same products — sulphate ion and iodine:
Step (1):
\[
2\text{Fe}^{2+}(\text{aq}) + \text{S}_2\text{O}_8^{2-}(\text{aq}) → 2\text{Fe}^{3+}(\text{aq}) + 2\text{SO}_4^{2-}(\text{aq})
\]
Step (2):
\[
2\text{Fe}^{3+}(\text{aq}) + 2\text{I}^-(\text{aq}) → 2\text{Fe}^{2+}(\text{aq}) + \text{I}_2(\text{aq})
\]
(b) The uncatalysed reaction between iodide ions and peroxodisulphate ions is very slow at room conditions as it involves the collision of ions of the same charge.
The reactions in the catalysed pathway proceed at a faster rate as they involve the collisions of ions of opposite charges.
(c) Fe$^{2+}$ is firstly converted to Fe$^{3+}$ in the reaction with peroxodisulphate ions. The Fe$^{3+}$ formed is then converted back to Fe$^{2+}$ in the reaction with iodide ions. Therefore, Fe$^{2+}$ is regenerated.