

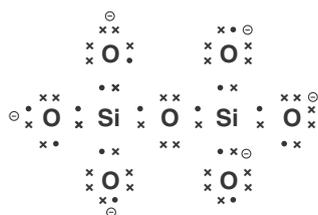
Answers to self-assessment questions in Chapters 22 to 25 (Options A to D)

22 Option A Materials

- The softness of large crystals of pure metals is due to the presence of dislocations in the crystals. These are irregularities of the crystal structure that allow atomic planes to slip much more easily than they would in a perfect crystal. A dislocation is caused by an extra plane of atoms within the crystal. Dislocations can be viewed using high resolution transmission electron microscopy (TEM) which allows the crystal planes and atomic positions within materials to be imaged.
- An amorphous (non-crystalline) solid is formed when a liquid is cooled rather rapidly, that is, super-cooled. The rapid cooling process does not give the atoms sufficient time to arrange themselves into an ordered lattice. The atoms are bonded in a short-range structure. Since the material is cooled, the movement of the atoms is reduced and this accounts for the fixed shape of glass. Glass flows very slowly under the force of gravity.

The glass-liquid transition (or glass transition for short) is the reversible transition in amorphous materials, such as glass (or in amorphous regions within semi-crystalline materials, such as some polymers) from a hard and relatively brittle state into a molten or rubber-like state. It is not a phase transition and extends over a range of temperatures.

- Individual answers.
- Dot-and-cross diagram for the ion, $\text{Si}_2\text{O}_7^{6-}$



- Individual answers.
- Gold: metal; jewelry
Polyurethane: synthetic polymer; foam for home furnishings
Solder: alloy; joining metals
Nitrocellulose nitrate: synthetic polymer; propellant or explosive or plastic film
Silicon: metalloid; transistors, photovoltaic cells
Brass: alloy; musical instruments
Gutta percha: natural polymer; dentistry, core of a golf ball
Polystyrene: synthetic polymer; disposable cutlery

- Titanium: metal; aerospace alloys, replacement hip joints
Plywood: composite; fencing
Silicon nitride: ceramic; induction coils
Porcelain: ceramic; dishes and vases
Carbon-fibre reinforced epoxy resin: composite; oars
Terracotta: ceramic; flower pots, sculptures and bricks
Talcum powder: mineral; keeps skin dry
Magnadur: ceramic; permanent magnets
Borosilicate glass: glass; laboratory glassware
Nylon: synthetic polymer; ropes
Muntz metal: alloy; corrosion-resistant machine parts
Pyrex: glass; measuring cup, baking dishes
Rayon: semi-synthetic polymer; clothing
Silicone rubber: polymer (elastomer); sportswear and footwear
Bronze: alloy; statues, bearing and electrical connectors
Silk: natural polymer (protein); clothing
Nitinol: alloy; medical applications
Thinsulate: synthetic polymer; clothing
Kevlar: synthetic polymer; body armour
Mica: mineral; wall boards, cladding, car manufacture
Rayon: semi-synthetic fibre; sportswear
Teflon (PTFE): synthetic polymer; containers, pipe work, insulating cables
Polyacetylene: conducting polymer; battery electrodes
Asbestos: mineral; ceiling insulation, fire proofing material
Bakelite: synthetic plastic; jewelry and billiard balls
Carbon fibre: composite material; the body of formula one racing cars
Cellophane: natural polymer; food packaging
Dacron: synthetic plastic; to replace or repair blood vessels
Ebonite: vulcanized rubber (elastomer); bowling balls and smoking mouthpieces
Cement: composite; used to make concrete, building construction
- Individual answers
 - GaN, polar covalent, HF, polar covalent; CsH, ionic; AlCl_3 , polar covalent; SCl_2 , covalent and KCl, ionic.

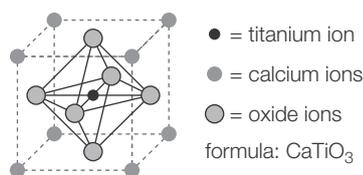
- 9 (i) Lead(II) oxide, gold(I) oxide, manganese(IV) oxide and zinc oxide can all be reduced by heating with carbon.
(ii) Gold(I) oxide can be reduced by heating with hydrogen gas.
- 10 $\text{HgO(s)} + \text{C(s)} \rightarrow \text{Hg(l)} + \text{CO(g)}$;
 $2\text{HgO(s)} + \text{C(s)} \rightarrow 2\text{Hg(l)} + \text{CO}_2\text{(g)}$
 $\text{HgO(s)} + \text{H}_2\text{(g)} \rightarrow \text{Hg(l)} + \text{H}_2\text{O(l)}$
 $3\text{HgO(s)} + 2\text{Cr(s)} \rightarrow \text{Cr}_2\text{O}_3\text{(s)} + 3\text{Hg(l)}$
- 11 Mass of cadmium electrolysed = $\frac{(A_r \times I \times t)}{(z \times 96500 \text{ C mol}^{-1})}$
= $\frac{(112.41 \text{ g mol}^{-1} \times 0.755 \text{ A} \times 10800 \text{ s})}{(2 \times 96500 \text{ C mol}^{-1})} = 4.75 \text{ g}$
- 12 Mass of gold electrolysed = $\frac{(A_r \times I \times t)}{(z \times 96500 \text{ C mol}^{-1})}$
Time to deposit gold = $\frac{(5.00 \text{ g} \times 1 \times 96500 \text{ C mol}^{-1})}{(196.97 \text{ g mol}^{-1} \times 2.68 \text{ A})}$
= 914 s (15 minutes 4 seconds)
- 13 Quantity of charge passed = $0.500 \text{ A} \times 1800 \text{ s} = 900 \text{ C}$;
mass of copper deposited = 2.299 g;
amount of copper atoms = $\frac{2.299 \text{ g}}{63.55 \text{ g mol}^{-1}} = 0.0362 \text{ mol}$;
 $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$; amount of electrons = 0.0724 mol;
Faraday constant = $\frac{900 \text{ C}}{0.0724 \text{ mol}} = 12430 \text{ C mol}^{-1}$
- 14 Quantity of charge passed = mass of silver deposited
= $\frac{(A_r \times z \times 96500 \text{ C mol}^{-1})}{A_r}$
= $\frac{(0.785 \text{ g} \times 1 \times 96500 \text{ C mol}^{-1})}{107.87 \text{ g mol}^{-1}}$
= 702 C (which will be the same quantity of charge for cell 2).
Mass of chromium electrolysed = $\frac{(52 \text{ g mol}^{-1} \times 702 \text{ C})}{3 \times 96500 \text{ C mol}^{-1}}$
= 0.126 g
- 15 Sodium (paramagnetic), magnesium (diamagnetic), tin (diamagnetic), lead (diamagnetic); all first row transition metals are paramagnetic except zinc, which is diamagnetic. Iron, cobalt and nickel are also ferromagnetic.
- 16 Anti-ferromagnetism is a type of magnetism in solids where adjacent ions that behave as tiny magnets spontaneously align themselves at relatively low temperatures into opposite, or antiparallel, arrangements throughout the material so that it exhibits almost no gross external magnetism. In anti-ferromagnetic materials, which include certain metals and alloys in addition to some ionic solids, the magnetism from magnetic atoms or ions oriented in one direction is canceled out by the set of magnetic atoms or ions that are aligned in the reverse direction.
- 17 The gas could be collected in a gas syringe or via displacement of water in a measuring cylinder (or eudiometer). The temperature of the reactants could be controlled via a water bath with a thermostat. Total volumes of oxygen gas and times should be recorded at five or more different temperatures. Tangents should be drawn against various points on graphs of total volume of oxygen versus time to generate values of rate, which should be plotted against time for the different temperatures.
- 18 Individual answers.
- 19 Individual answers.
- 20 A monotropic liquid crystal is a type of material that exhibits the liquid crystalline state only when the temperature changes in one direction. This is generally a result of the liquid crystal phase being below the melting temperature of the solid, where the liquid crystal phase is only observed if the liquid is supercooled below the melting point. Enantiotropic liquid crystals exhibit the liquid crystal state when the temperature rises from the solid state side or when it falls from the liquid state. Monotropic liquid crystals exhibit the liquid crystalline state only when the temperature changes in one direction.
- 21 Individual answers.
- 22 Cold drawing causes the polymer chains to become orientated along the length of the fibre. This means that the chains can get closer together and so there are more points where intermolecular forces can act, thus leading to a large increase in the polymer's tensile strength.
- 23 The atom economy of nylon synthesis should be calculated. Weighed quantities of reactants should be left to react until the reaction has gone to completion. The dried and purified product should be weighed and the atom economy calculated.
- 24 Individual answers.
- 25 In the laser ablation technique, a high-power laser is used to vaporize carbon from a graphite target at high temperature. Both multiple and single-walled carbon nanotubes can be produced with this technique. In order to generate single-walled nanotubes, metal particles as catalysts must be added to the graphite targets in a similar way to the arc discharge technique. The quantity and quality of produced carbon nanotubes depend on several factors such as the amount and type of catalysts, laser power and wavelength, temperature, pressure, type of inert gas, and the fluid dynamics near the carbon target. Carbon nanotubes produced by laser ablation are purer (up to 90% purity) than those produced in the arc discharge process and have a very narrow distribution of diameters.

- 26 Individual answers.
 27 Individual answers.
 28 Individual answers.
 29 The C–H bonds are causing the peaks at 3000 cm^{-1} ; the benzene ring is responsible for the peaks between 2800 and 3200 cm^{-1} and 600 to 1000 cm^{-1} .
 30 Individual answers.
 31 $\text{YBa}_2\text{Cu}_3\text{O}_6$ [Y^{3+} 2Ba^{2+} 3Cu^{n+} 6O^{2-}]; $(+7 + -12) = -5$,
 hence average oxidation number of copper = $+\frac{5}{3} = 1.6$.
 32 Individual answers.
 33 $T_c = 92\text{K}$ (This is experimental data that shows the curved low-temperature tail of a transition).

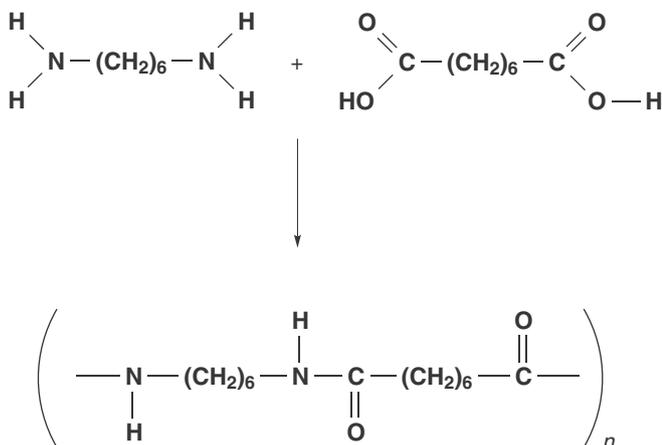
$$34 \text{ Frequency (Hz)} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.00 \times 10^{-9} \text{ m}} = 3.00 \times 10^{17} \text{ Hz (s}^{-1}\text{)}$$

$$35 a = \frac{4r}{\sqrt{3}} = \frac{4 \times 0.124 \text{ nm}}{\sqrt{3}} = 0.2864 \text{ nm}$$

36 Unit of cell of the perovskite structure:



- 37 Individual answers.
 38



- 39 Individual answers.
 40 Individual answers.

23 Option B Biochemistry

- 1 a Reduction is the loss of electrons; oxidation the gain.
 b Reduction is the gain of hydrogen; oxidation the loss.
 c Reduction is the loss of oxygen; oxidation the gain.

d Reduction is a lowering of oxidation state; oxidation is an increase in oxidation state.

- 2 a Propan-2-ol has been oxidized to propanone; 2-oxopropanoic acid has been reduced to 2-hydroxypropanoic acid.
 b $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{C}(\text{O})\text{CH}_3 + \text{H}_2\text{O}$
 $\text{CH}_3\text{C}(\text{O})\text{COOH} + 2[\text{H}] \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}$
 or
 $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 + 2\text{OH}^- \rightarrow \text{CH}_3\text{C}(\text{O})\text{CH}_3 + 2\text{H}^+ + 2\text{e}^-$ (oxidation)
 $\text{CH}_3\text{C}(\text{O})\text{COOH} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}$ (reduction)

- 3 a 2-Aminopropanoic acid
 b See Figure 23.14. It does not contain a chiral centre as there are not four different substituents on the central carbon atom.
 c Optical isomerism. It is a white crystalline solid at room temperature.
 d $\text{NH}_2\text{CH}_2\text{COOH} + \text{HCl} \rightarrow [\text{NH}_3^+\text{CH}_2\text{COOH}] \text{Cl}^-$
 $\text{NH}_2\text{CH}_2\text{COOH} + \text{CH}_3\text{OH} \rightarrow \text{NH}_2\text{CH}_2\text{COOCH}_3 + \text{H}_2\text{O}$

- 4 a The amino group, $-\text{NH}_2$, and the carboxylic acid group, $-\text{COOH}$.
 b Proline, the amino group is cyclised (becomes an imino group).
 c Alanine, valine, phenylalanine, leucine, isoleucine
 d Serine, threonine, tyrosine
 e Aspartic acid, glutamic acid

- 5 a The lone pair of (non-bonding) electrons on the nitrogen atom (the amino group acts as a Lewis base).
 b The R group can act as a base and gain a proton; becoming positively charged.

- 6 a Re-draw in the zwitterion form; see Figure 23.17.
 b The overall charge = 0.

- 7 a The amino acid is in the zwitterion form in the solid so there are ionic interactions between the molecules resulting in a relatively high melting point.

b The ionic nature of the zwitterion form means that the molecules can interact with water as a polar solvent.

- 8 Solid state: draw the zwitterion form.

In water at $\text{pH} = 1$: draw the molecule with a charged $-\text{NH}_3^+$ group.

At $\text{pH} = 5.7$: draw the zwitterion.

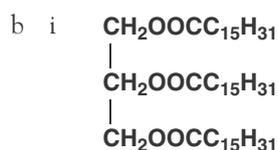
At $\text{pH} = 14$: draw the molecule with a charged $-\text{COO}^-$ group.

- See Figure 23.18.
- 9 Estimate the R_f of the middle spot in the right-hand diagram (it has moved furthest in the second solvent): $R_f = 0.8$.
- 10 a 5
- b Spraying with the locating agent, ninhydrin; or observing the chromatogram under UV light.
- c Sketch showing just four spots (take guidance from the movement to the right); the first two spots move well up the chromatogram, spots three and four are quite close together – the fourth spot (closest to the origin) is made up of two solutes.
- 11 a Condensation polymerization.
- b See Figure 23.26 for the bonding and 23.27 for the bond angles.
- The peptide bond region is arranged in the *trans* conformation (Figure 23.27).
- c i The peptide link region is planar and rigid because of the formation of a delocalized pi (π) bond over the region.
- ii Most R groups are bulky and steric factors favour the *trans* conformation to accommodate their presence.
- 12 a Covalent bonding
- b Polypeptide chains have an amino-terminal (N-terminal) and a carboxy-terminal (C-terminal) end; they are linear polymers and synthesised from the N-terminal end to the C-terminal end.
- 13 Look closely at the R groups along the chain; the sequence is Phe-Ser-His-Ala.
- 14 a The amide (or peptide) link.
- b Both N terminus and C terminus: draw the structure of alanine.
- c Two; alanine and lysine (glycine is the third residue but this is not optically active).
- 15 Secondary structure: Hydrogen-bonding between the peptide link regions formed between any of these amino acids can contribute to the formation of an alpha helix (see Figure 23.39, particularly the simplified sketch on the right).
- Tertiary structure: Describe the different interactions the R groups of these amino acids can participate in:
- Valine: hydrophobic, non-polar interactions via London forces.
- Glutamic acid: ionic or charged group interactions.
- Cysteine: covalent disulfide bridging.
- These interactions can take place between amino acid residues in the same chain (tertiary structure); see Figure 23.46.
- 16 The R groups of aspartic acid, asparagine and lysine will contribute to hydrogen bonding; the R group of valine will not.
- 17 a and b See Figure 23.58
- 18 a The substrate must be in excess so that molecules of the substrate are freely available and their accessibility is not limiting on enzyme activity.
- b For many enzymes a fall in temperature of 10°C halves the rate of reaction or turnover number (this generalisation applies to reactions where the activation energy is around $+50\text{ kJ mol}^{-1}$).
- 19 a $1.5\text{ g of iodine} = 0.59 \times 10^{-2}\text{ moles iodine}$
- This reacted with $1.0 \times 10^{-2}\text{ moles of linoleic acid}$
- Molar ratio of fatty acid:iodine (to nearest whole number) = 2 : 1
- There are two C=C double bonds in a molecule of linoleic acid
- b Iodine number = number of grams of iodine reacting with 100 g of lipid
- 0.01 mol of linoleic acid ($\text{C}_{17}\text{H}_{31}\text{COOH}$)
 $= 0.01 \times 280.5 = 2.8\text{ g}$
 Iodine number = $\left(\frac{100}{2.8}\right) \times 1.5 = 53.5$
- 20 a Improved solubility of fat/oil (and iodine) in ethanol compared with water.
- b Soft margarine: 7 drops; polyunsaturated margarine: 11 drops.
- c Olive oil
- 21 a Mol iodine reacting = $\frac{0.5 \times 19}{1000} = 9.5 \times 10^{-3}\text{ mol}$
- Mass of iodine = $9.5 \times 10^{-3} \times 253.8 = 2.41\text{ g}$
- Iodine number = $\frac{100}{2.5} \times 2.41 = 9.64$
- b Mol vegetable oil = $\frac{2.5}{865} = 2.89 \times 10^{-3}\text{ mol}$
- Molar ratio of oil: iodine (to nearest whole number) = 3 : 1.
- An average of three C=C double bonds in a molecule of the oil.
- c The vegetable oil will contain a mixture of different long-chain acid molecules.
- 22 a i Stearic acid
- ii Oleic acid
- b i To prevent the chocolate manufactured melting too readily in the hotter climate.
- ii They are likely to be made of longer chains and a higher proportion of saturated fats.
- 23 a Lipid: a varied group of non-polar molecules containing carbon, hydrogen and oxygen; they have a lower proportion of oxygen than carbohydrates.

Triglyceride: a molecule consisting of three long-chain fatty acids linked by ester links to a glycerol molecule.

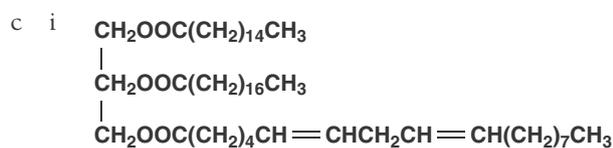
Saturated fatty acid: a long-chain carboxylic acid containing only C–C single bonds in the molecule (no double bonds).

Polyunsaturated fatty acid: a long-chain carboxylic acid containing more than one C=C double bond in the hydrocarbon chain.

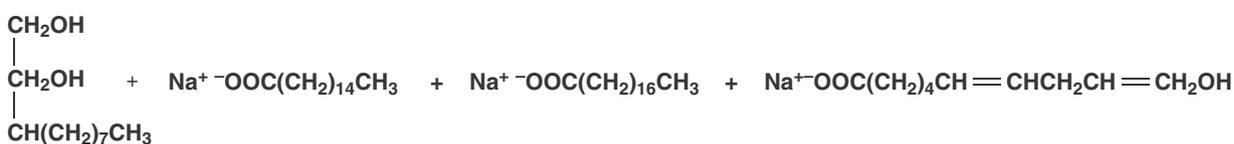
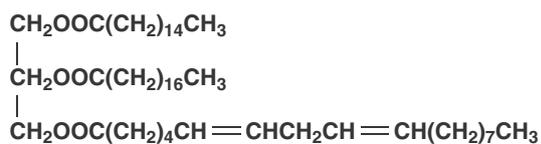


ii The ester link.

iii Solid



ii



24 a They have long, non-polar chains ('tails') that enable them to sit across the membrane, but a polar end ('head') to the molecule which interacts with the aqueous environment.

b i The fluid mosaic model.

ii A = hydrophobic 'tail' of the phospholipid molecule (long-chain hydrocarbon tail)

B = hydrophilic 'head' of the phospholipid molecule

C = transmembrane protein

D = carbohydrate side-chain on the protein

E = non-membrane protein

iii W = 7 to 10 nm for the plasma membrane (the bilayer is estimated to be 4 to 5 nm thick).

iv Cholesterol gives some rigidity to the membrane.

25 Ketone = B

Aldehyde = A and C

Triose = C

Pentose = A

Hexose = B

26 a They are isomers.

b The molecule contains a number of hydroxyl groups (–OH) which can interact with water molecules through hydrogen bonding – see Figure 23.114.

c A is α -glucose.

27 a α -1,4 and α -1,6 glycosidic links.

b Hydrolysis

c See the structure of α -glucose in Figure 23.108.

d Amylopectin.

e The polymer contains many glucose molecules which are not able to react while they are 'stored' in the polymer, whereas the monomer is readily able to react.

28 Starch contains α -glycosidic links which enzymes present in humans are able to hydrolyse – hence starch is a useful dietary source of energy; cellulose contains β -glycosidic links and humans do not have enzymes capable of hydrolysing such bonds. Cellulose is useful in human diet as 'dietary fibre'.

29 a Hydroxyl group and amide group

b Hydroxyl group and ketone group

c I is water soluble as it has several hydroxyl groups to hydrogen bond with water

II is lipid soluble as it has a long, hydrophobic hydrocarbon chain.

30 a i 17%

ii 8%

iii 10%

b 0.13%

c i 4×10^6 times more concentrated.

ii 5.8 times; 9.0 times; 6.7 times.

31 Vancomycin is a glycopeptide antibiotic most effective against Gram-positive bacteria.

32 Research the location and nature of the Grand Pacific garbage patch, and the impact of plastic waste on the oceans in general including the leaching out of environmentally harmful chemicals.

- 33 a i See Figure 23.143.
 ii See Figure 23.144.
 b i See Figure 23.151.
 ii The inhibitor competes with the substrate for active sites on the enzyme thus slowing the rate of reaction / the rate will eventually reach the same plateau value (V_{\max}) as that achieved without inhibitor.
 c i See Figure 23.153.
 ii The inhibitor binds to a site on the enzyme other than the active site, altering the conformation of the enzyme and reducing its activity / the rate will not reach the same plateau value (V_{\max}) as the uninhibited enzyme.

34 a Solid state: $\text{NH}_3^+\text{CH}(\text{CH}_2\text{OH})\text{COO}^-$

pH = 1: $\text{NH}_3^+\text{CH}(\text{CH}_2\text{OH})\text{COOH}$

pH = 14: $\text{NH}_2\text{CH}(\text{CH}_2\text{OH})\text{COO}^-$

pH = 5.7: $\text{NH}_3^+\text{CH}(\text{CH}_2\text{OH})\text{COO}^-$

b $\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]}} \right)$
 $\text{pH} = 9.1 + \log_{10} \left(\frac{[\text{anionic form}]}{[\text{zwitterion}]} \right) = 9.1 + \log_{10} \left(\frac{0.2}{0.8} \right)$
 $\text{pH} = 9.1 + \log_{10} 0.25 = 9.1 - 0.6 = 8.5$

35 Glycine species are $\text{NH}_3^+\text{CH}_2\text{COOH}$ and $\text{NH}_3^+\text{CH}_2\text{COO}^-$

$$\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right)$$

$$3.0 = 2.31 + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right)$$

$$\log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right) = 0.69$$

$$\frac{[\text{base}]}{[\text{acid}]} = 4.9$$



Initial concentrations: 0.500 0 0

Equilibrium: (0.500 - x) x x

$$\text{Therefore: } \frac{x}{(0.500 - x)} = 4.9$$

$$x = 0.415 \text{ mol dm}^{-3}$$

$$[\text{NH}_3^+\text{CH}_2\text{COOH}] = 0.085 \text{ mol dm}^{-3}$$

$$[\text{NH}_3^+\text{CH}_2\text{COO}^-] = 0.415 \text{ mol dm}^{-3}$$

36 a Equilibrium is $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$

$$\text{Therefore } K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

Making the approximation that the equilibrium concentrations of ethanoic acid and ethanoate ions are the same as their initial concentrations. This is a reasonable assumption because the dissociation of ethanoic acid in pure water is very low, and

therefore the dissociation is going to be even lower if some CH_3COO^- is already present.

$$K_a = 1.74 \times 10^{-5} = \frac{0.250 \times [\text{H}^+]}{0.200}$$

$$[\text{H}^+] = (1.74 \times 10^{-5}) \times \left(\frac{0.200}{0.250} \right) = 1.39 \times 10^{-5}$$

$$\text{pH} = -\log_{10}(1.39 \times 10^{-5}) = 4.86$$

Could also use the equation $\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right)$ directly if you work out the $\text{p}K_a$ first.

b $\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right) = 7.21 + \log_{10} \left(\frac{0.045}{0.055} \right)$

$$\text{pH} = 7.21 - 0.09 = 7.12$$

c $\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{base}]}{[\text{acid}]} \right) = 8.30 + \log_{10} \left(\frac{0.750}{0.650} \right)$

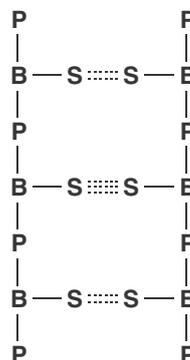
$$\text{pH} = 8.30 + 0.06 = 8.36$$

37 Concentration = $\frac{A}{\epsilon} = \frac{0.29}{0.08} = 3.6 \text{ ppm}$

38 a Concentration = $\frac{A}{\epsilon} = \frac{0.31}{500} = 6.2 \times 10^{-4} \text{ mol dm}^{-3}$

b Concentration = $\frac{A}{\epsilon} = \frac{0.23}{63.5} = 3.6 \times 10^{-3} \text{ mol dm}^{-3}$

39 a Based on Figure 23.169.



b i Each strand has direction / the two strands run in opposite directions / the 5'-3' phosphodiester linkages run in opposite directions.

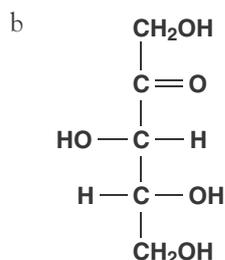
ii The strands are antiparallel.

iii The ends of each strand are designated 5' ('5-prime') and 3' ('3-prime').

c The gentle heating disrupts the hydrogen bonding between the bases / the number of hydrogen bonds between strands depends on the proportion of GC base pairs as they have three hydrogen bonds between them compared to AT base pairs with only two.

40 a Hydrogen bonds play a part in the recognition of the possible base pairs that can form / A always pairs with T, and G with C / AT pairing involves two hydrogen bonds whereas GC pairing involves three.

- b After replication the daughter molecules contain one parent strand and one new strand / each new molecule contains one old strand and one new strand.
- c i Hydrogen bonding (and London forces referred to as 'base stacking')
- ii Phosphodiester links
- 41 a RNA contains the sugar, ribose / DNA the sugar, deoxyribose.
RNA is single stranded / DNA is double stranded.
RNA contains the base uracil / DNA contains thymine.
- b i Purine: adenine or guanine
Pyrimidine: cytosine or thymine
- ii I is a purine (with two rings); II is a pyrimidine (with one ring).
- 42 A is D-form / B is L-form / C is D-form.
- 43 A is L-alanine / B is D-phenylalanine / C is D-serine.
- 44 a Isomerism
- b The several hydroxyl groups can all participate in hydrogen bonding with the water molecules.
- c A is α -glucose as the -OH on carbon-1 is on the opposite side of the plane of the ring to the carbon-6 / C is β -glucose.
- 45 a They all contain an aldehyde group.
- b They are all D-form as the -OH on carbon-5 is to the right in this representation.
- c Carbon-2 in A is different from B and C / carbon-4 in B is different from A and C optical isomers.
- 46 Research the origins of chirality and the importance of molecular shape in biochemical processes.
- 47 a See Figure 23.251.
- b The presence of several -OH groups in the structure of glucose leads to hydrogen bonding with water molecules and the enhanced solubility of glucose: see Figure 23.114.
- 48 a The β -form.
- b It is a reducing sugar.
- c See structure on left in Figure 23.247.
- 49 a
- $$\begin{array}{c}
 \text{H}-\text{C}=\text{O} \\
 | \\
 \text{HO}-\text{C}-\text{H} \\
 | \\
 \text{H}-\text{C}-\text{OH} \\
 | \\
 \text{H}-\text{C}-\text{OH} \\
 | \\
 \text{H}-\text{C}-\text{OH} \\
 | \\
 \text{CH}_2\text{OH}
 \end{array}$$



24 Option C Energy

- 1 Specific energy: 49.9 MJ kg^{-1}
Energy density: 24.7 MJ dm^{-3}
- 2 $4800000 \text{ MJ per hour}$; 1333 MW
- 3 a $\text{C}_{10}\text{H}_{22} \rightarrow 5\text{C}_2\text{H}_4 + \text{H}_2$
b $\text{C}_{20}\text{H}_{42} \rightarrow \text{C}_8\text{H}_{18} + 4\text{C}_3\text{H}_6$
- 4 Total volume of fuel = $70000 \text{ dm}^3 = 70000000 \text{ cm}^3$
Mass of fuel = $70000000 \text{ cm}^3 \times 0.703 \text{ g cm}^{-3} = 49210000 \text{ g}$
Amount of fuel = 430800 mol
Equation for combustion is:
 $\text{C}_8\text{H}_{18} + 12.5\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$
Amount of $\text{CO}_2 = 8 \times 430800 \text{ mol} = 3446400 \text{ mol}$
Mass of $\text{CO}_2 = 3446000 \text{ mol} \times 44 \text{ g mol}^{-1} = 151641600 \text{ g} = 152 \text{ tonnes CO}_2$
- 5 ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{18}_8\text{O} + {}^1_1\text{H}$; oxygen-17
- 6 ${}^{12}_6\text{C} + {}^1_1\text{H} \rightarrow {}^{13}_7\text{N}$
 ${}^{13}_7\text{N} \rightarrow {}^{13}_6\text{C} + {}^0_1\text{e}$
 ${}^{13}_6\text{C} + {}^1_1\text{H} \rightarrow {}^{14}_7\text{N}$
Unknown: ${}^{13}_6\text{C}$
- 7 $t = t_{\frac{1}{2}} \frac{\ln\left(\frac{N_0}{N}\right)}{\ln 2} = 2.14 \times 10^6 \times \frac{\ln\left(\frac{100}{10}\right)}{\ln 2}$
 $= 2.14 \times 10^6 \times 3.32$
 $= 7.11 \times 10^6 \text{ years}$
- 8 Carbon in CO_2 : +4
Carbon in glucose: 0
- 9 $(\text{C}_{17}\text{H}_{31}\text{COO})_3\text{CH}(\text{CH}_2)_2 + 3\text{CH}_3\text{CH}_2\text{OH} \rightleftharpoons 3\text{C}_{17}\text{H}_{31}\text{COOCH}_2\text{CH}_3 + (\text{CH}_2\text{OH})_2\text{CHOH}$
- 10 $\frac{-237}{-286} \times 100 = 82.9\%$
- 11 $E_{\text{cell}} = 0.78 \text{ V} - \frac{0.0257}{2} \ln \frac{0.0200}{0.100} = 0.76 \text{ V}$
- 12 $E = \frac{0.0257}{2} \ln \frac{0.1}{0.0005} = 0.0681 \text{ V}$

- 13 Mass difference: mass of reactants – mass of products
 $= 2.2 \times 10^{-3} \text{ amu}$

$$\text{Mass difference in kg: } 2.2 \times 10^{-6} \times 1.660539 \times 10^{-27} \\ = 3.65319 \times 10^{-30} \text{ kg}$$

$$\text{Energy} = 3.65319 \times 10^{-30} \times (299792500)^2 \\ = 3.28332 \times 10^{-13} \text{ J/nucleus}$$

Expressed in electronvolts this becomes 2.05 MeV.

25 Option D Medicinal chemistry

- 1 Amount of 2-hydroxybenzoic acid = $\frac{9.40 \text{ g}}{138.13 \text{ g mol}^{-1}}$
 $= 0.0681 \text{ mol}$

1:1 molar ratio, hence amount of aspirin = 0.0681 mol

$$\text{Mass of aspirin} = 0.0681 \text{ mol} \times 180.17 \text{ g mol}^{-1} = 12.3 \text{ g}$$

$$\text{Percentage yield} = \frac{7.77 \text{ g}}{12.3 \text{ g}} \times 100 = 63.4\%$$

- 2 The sharp peaks at 1690 cm^{-1} and 1750 cm^{-1} indicate the presence of carbonyl groups. (The peak at 1690 cm^{-1} is due to the carbonyl in the carboxylic acid group; the peak at 1750 cm^{-1} is due to the carbonyl in the ester group.) The broad peak at approximately 3000 cm^{-1} is typical of an –OH group in a phenol and/or carboxylic acid. The broadness is due to hydrogen bonding.
- 3 At 2.2 ppm, the –CH₃ group, and at 13.1 ppm the –COOH group.
- 4 At 180: the molecular ion; at 163: loss of OH (–17); at 120: the loss of C₂H₄O₂ (actually loss of CH₂CO followed by H₂O) from the molecular ion; and at 43: the appearance of the CH₃CO⁺ ion.
- 5 Morphine: ether, alcohol, benzene ring, tertiary amine
 Codeine: ether, alcohol, ester, tertiary amine
 Diamorphine (heroin): tertiary amine, benzene ring, ester, ether
- 6 Sodium alginate has a relatively large number of hydroxyl groups, –OH, which are able to form hydrogen bonds with water molecules.
- 7 Smallpox was an infectious disease caused by either of two virus variants, *Variola major* and *Variola minor*. Smallpox was localized in small blood vessels of the

skin and in the mouth and throat. In the skin it caused a rash and fluid-filled blisters. Smallpox was eradicated by inoculation or vaccination using the live virus preparation of infectious *vaccinia* virus.

- 8 Capsid proteins are an important mechanism by which viruses infect host cells. The viral proteins interact with host cell proteins in the cell membrane, and this interaction initiates biochemical processes which allow the virus to enter the cell.

Enfuvirtide (a polypeptide) binds to viral proteins and can inhibit the protein–protein interaction and hence acts as an antiviral agent (fusion inhibitor).

- 9 a ${}^{13}_6\text{C} + {}^1_0\text{n} \rightarrow {}^4_2\text{He} + {}^{10}_4\text{Be}$
 b ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^1_0\text{n} + {}^{17}_9\text{F}$
 c ${}^{253}_{99}\text{Es} + {}^4_2\text{He} \rightarrow {}^1_0\text{n} + {}^{256}_{101}\text{Md}$
 d ${}^{53}_{24}\text{Cr} + {}^4_2\text{He} \rightarrow {}^1_0\text{n} + {}^{56}_{26}\text{Fe}$
 e ${}^{250}_{98}\text{Cf} + {}^{11}_5\text{B} \rightarrow {}^{257}_{103}\text{Lr} + 4{}^1_0\text{n}$
- 10 a ${}^{239}_{94}\text{Ra} \rightarrow {}^4_2\text{He} + {}^{235}_{92}\text{U}$
 b ${}^{40}_{19}\text{K} \rightarrow {}^0_{-1}\text{e} + {}^{40}_{20}\text{Ca}$
 c ${}^{99}_{43}\text{Tc} \rightarrow {}^{99}_{44}\text{Ru} + {}^0_{-1}\text{e}$
 d ${}^{218}_{84}\text{Po} \rightarrow {}^{214}_{82}\text{Pb} + {}^4_2\text{He}$
- 11 ${}^{231}_{92}\text{U}$
- 12 ${}^{235}_{92}\text{U} \rightarrow {}^{231}_{90}\text{Th} + {}^4_2\text{He}$; ${}^{210}_{82}\text{Pb} \rightarrow {}^{210}_{83}\text{Bi} + {}^0_{-1}\text{e}$
- 13 ${}^{131}_{54}\text{Xe}^* \rightarrow {}^{131}_{54}\text{Xe} + {}^0_0\gamma$
- 14 Polonium
- 15 Alexander Litvinenko was poisoned by polonium-210, a highly toxic radioactive heavy metal with a physical half-life of 138 days. It decays to stable lead-206 giving off 5.3 MeV alpha particles that have a range of 40–50 μm in tissue.
- 16 a Fractional distillation
 b Suction filtration
 c Distillation
 d Recrystallization