Neap

Trial Examination 2023

VCE Chemistry Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

1	A	B	C	[✓ D]	11	A	[✓ B]	C	D	21	A	B	[✓ C]	D
2	A	[✓ B]	C	D	12	[✓ A]	B	C	D	22	A	[✓ B]	C	D
3	A	B	C	[✓ D]	13	A	B	C	[✓ D]	23	A	B	[✓ C]	D
4	A	[✓ B]	C	D	14	[✓ A]	B	C	D	24	A	B	[✓ C]	D
5	A	B	C	[✓ D]	15	A	B	C	[✓ D]	25	A	B	[✓ C]	D
6	[✓ A]	B	C	D	16	[✓ A]	B	C	D	26	[✓ A]	B	C	D
7	A	[✓ B]	C	D	17	[✓ A]	B	C	D	27	[✓ A]	B	C	D
8	A	B	C	[✓ D]	18	A	[✓ B]	C	D	28	A	B	[✓ C]	D
9	A	B	C	[✓ D]	19	A	B	[✓ C]	D	29	A	[✓ B]	C	D
10	A	B	[✓ C]	D	20	[✓ A]	B	C	D	30	A	B	[✓ C]	D

ABN 43 634 499 791 Level 1 223 Hawthorn Rd Caulfield North VIC 3161 Tel: (03) 9639 4318

Question 1 D

D is correct. Similar to natural gas, coal seam gas is composed largely of methane gas and is used to generate electricity in power plants.

A and **B** are incorrect. Coal seam gas is a deposit of methane gas that naturally occurs near coal deposits.

C is incorrect. Coal seam gas is not currently used as a raw material in manufacturing chemicals but is mainly used as a fuel.

Question 2 B

B is correct. Rechargeable cells use spontaneous redox reactions to generate electricity and use electrical energy to drive non-spontaneous redox reactions to store energy. These latter reactions are electrolytic in nature.

A is incorrect. Fuel cells cannot be recharged with an input of electrical energy and are therefore not a type of secondary cell.

C is incorrect. Primary cells are often less efficient than fuel cells. In a primary cell an appreciable amount of chemical energy is converted to heat and wasted.

D is incorrect. Some galvanic cells use electrodes that are reactants in the overall redox reaction; therefore, galvanic cells electrodes are not always inert.

Question 3 D

D is correct and **C** is incorrect. An omega-6 fatty acid has a C=C bond between the sixth and seventh carbon atoms from the omega end of the molecule. The omega end does not have the COOH group and is situated opposite to the alpha end, which has the COOH group.

A and **B** are incorrect. The 6 in omega-6 refers to the position of the C=C bond, not the number of double bonds present.

Question 4 B

B is correct. Aspartame is about 200 times sweeter than an equivalent mass of sucrose and so less aspartame is required to achieve the same level of sweetness.

A is incorrect. Aspartame is about 200 times sweeter than an equivalent mass of sucrose.

C is incorrect. Aspartame has approximately the same energy content as sucrose on a mass basis, not on a mole basis.

D is incorrect. Aspartame is soluble in water and is absorbed by the body.

Question 5 D

D is correct. Aspartame is a methyl ester of a dipeptide. During a hydrolysis reaction, the ester link and the peptide bond are broken, producing an alcohol and two amino acids.

A and **B** are incorrect. Aspartame contains a peptide bond and an ester link as it is a methyl ester of a dipeptide.

C is incorrect. The basic structure of monosaccharides is different to a methyl ester of a dipeptide.

Question 6 A

A is correct. The hydroxyl groups in the vitamin C molecule enable the formation of hydrogen bonds with water molecules.

B is incorrect. Vitamin D2 has 28 carbon atoms and vitamin D3 has 27 carbon atoms, so their molecular formulas must be different.

C is incorrect. The hydroxyl group in vitamin D is polar but most of the molecule is non-polar.

D is incorrect. Vitamin C is water soluble and so is not stored in fat tissue.

Question 7 B

B is correct. The porous electrodes provide a large surface area that allows gaseous reactants to penetrate and increases contact between the reactants. This results in an efficient transfer of electrons between electrodes along the wire.

A is incorrect. The overall cell reaction and the combustion reaction are identical.

C is incorrect. Electrons do not flow through the electrolyte; they travel via the external circuit along a wire.

D is incorrect. Hydrogen ions are produced at one electrode and consumed at the other. Therefore, there is no overall consumption of hydrogen ions and the pH of the acidic electrolyte does not increase.

Question 8 D

D is correct. A food constituent is classified as essential if the body is unable to make the compound, and it must therefore be consumed in a person's diet.

A is incorrect. Essential food constituents are sourced from animals and plants.

B is incorrect. The mass of essential constituents is relatively small compared to other food sources and so would not make up a large proportion of the diet.

C is incorrect. The largest sources of energy in the body are carbohydrates and fats, not essential food constituents.

Question 9 D

D is correct. The results of the trials are all close in value and therefore close to the average measured value. This is the definition of precision.

A and **C** are incorrect. The standard value of the density of water at 25°C is 0.997 g mL^{-1}, while the average measured value from the experiment is 1.101 g mL^{-1}. The experimental results are not accurate as accuracy refers to the closeness of measured values to a standard value.

B is incorrect. This is not the definition of precision.

Question 10 C

The use of calibrated glassware to take readings in volumetric analysis is a common source of random error. Sodium hydroxide pellets absorb moisture from the air and react with carbon dioxide gas to produce sodium carbonate. Thus, the composition of the hydroxide pellets would be uncertain and would be a source of systematic error.

Question 11 B

B is correct. Chloride ions travel to the positively charged anode in the electrolytic cell and are discharged to produce chlorine gas.

A is incorrect. Sodium ions are attracted to the negatively charged cathode where they gain electrons to form sodium metal.

C and **D** are incorrect. There is no water present in a molten electrolyte; therefore, neither hydrogen gas nor oxygen gas would be formed.

Question 12 A

$n(\mathrm{e}^-) = 1$ mol (1 Faraday is the charge on 1 mol of electrons.)

$\mathrm{Cu^{2+}(aq)} + 2\mathrm{e}^- \rightarrow \mathrm{Cu(s)}$

$$n(\mathrm{Cu}) = \frac{1}{2} \times n(e^-) = \frac{1}{2} \times 1 = \frac{1}{2}\ \mathrm{mol}$$

$$m(\mathrm{Cu}) = n \times M = \frac{1}{2} \times 63.5 = 31.75\ \mathrm{g} = 32\ \mathrm{g}$$

Question 13 D

D is correct. Using the electrochemical series, the reaction is $\mathrm{Cd^{2+}} + \mathrm{Mn} \rightarrow \mathrm{Cd} + \mathrm{Mn^{2+}}$. Mn is oxidised and the electrons flow to the Cd electrode.

A is incorrect. The mass of Mn decreases due to oxidation.

B is incorrect. $\mathrm{Cd^{2+}}$ ions are stronger oxidising agents than water molecules and Mn is a stronger reducing agent than water molecules. Thus, neither oxygen nor hydrogen gases would form at the electrodes.

C is incorrect. Positive ions (cations) move towards the $\mathrm{Cd/Cd^{2+}}$ half-cell to replace the $\mathrm{Cd^{2+}}$ ions used in the half-cell reaction, and therefore maintain the neutral charge of the half-cell.

Question 14 A

A is correct. This is the semi-structural (condensed) formula of butanoic acid. A chiral carbon atom has four different atoms or groups of atoms bonded to it. None of the carbon atoms in a butanoic acid molecule has this arrangement of atoms.

B, **C** and **D** are incorrect. These molecules each have one chiral carbon atom.

Question 15 D

A catalyst lowers the activation energy (M) but has no effect on the enthalpy change of the reaction (N) or the energy of the products (Q).

Question 16 A

A is correct and **B** is incorrect. The discharge reaction is $Zn + Ag_2O \rightarrow ZnO + 2Ag$. The reaction occurring at the positive electrode is a reduction reaction.

C and **D** are incorrect. These options show oxidation reactions.

Question 17 A

While the concentrations of the reactants and products cannot be calculated because the volume of the vessel is not specified, in this instance, the volume would cancel out in the equilibrium expression. Thus, the number of moles can be used to calculate the value of the reaction quotient (Q).

$$Q = \frac{[IBr]^2}{[Br_2][I_2]} = \frac{1^2}{1 \times 1} = 1$$

This is lower than the value of the equilibrium constant (1.2×10^2). Therefore, the system is not at equilibrium and will move towards the products; in the equilibrium expression, the numerator becomes larger and the denominator becomes smaller, heading towards the final value of 1.2×10^2.

Question 18 B

Burning propane, C_3H_8, releases 50.5 kJ per gram.

amount of energy released = $50.5 \times 2.78 = 140.39$ kJ =140 390 J.

energy used to heat the water = $mc\Delta T = 500 \times 4.18 \times \Delta T = 140\,390\text{ J}$

$$\Delta T = \frac{140\,390}{500 \times 4.18}$$
$$= 67°\text{C}$$

Question 19 C

C is correct. The area under the graph to the right of E_a represents the number of particles with sufficient energy to cause a successful collision. The lowered temperature of the gas will reduce this number and thus decrease the area.

A is incorrect. Decreasing the temperature will move the peak to the left.

B is incorrect. The area under the graph represents the total number of particles. Since the particles are in a sealed container, their number will not change.

D is incorrect. Decreasing the temperature will cause the graph to narrow, and the peak to rise and move to the left.

Question 20 A

A is correct. Lowering the temperature decreases the kinetic energy of the particles. This causes fewer collisions with the walls of the container and so the gas pressure decreases.

B, **C** and **D** are incorrect. The distribution graph does not provide information about the value of the equilibrium constant, K_c; the enthalpy change of the reaction or the position of equilibrium.

Question 21 C

In a titration, the volumetric flask and the conical flask receive a set number of moles of reactants, and it does not matter if these pieces of glassware are still wet with water. Pipettes and burettes should be rinsed with the solutions that they dispense.

Question 22 B

B is correct. The oxidation reaction is $C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2e^-$ and therefore vitamin C must have been the reducing agent because it was oxidised.

A and **C** are incorrect. The oxidation numbers of hydrogen (+1) and oxygen (–2) did not change.

D is incorrect. The triiodide ion was the oxidising agent and so it underwent reduction, not oxidation.

Question 23 C

C is correct. Biodiesel is composed of an alcohol and fatty acid joined by an ester link. The polar nature of the ester link enables moisture from the atmosphere to be absorbed through intermolecular attraction with water molecules. Biodiesel molecules are attracted to each other because of this region of polarity and so biodiesel's viscosity is higher than liquids that are non-polar. Fatty acid components that have double bonds are susceptible to attack from oxygen in the air, leading to degradation.

A, **B** and **D** are incorrect. These fuels are derived from crude oil and are composed of hydrocarbon chains, which are non-polar. There is no attraction to water from the atmosphere, low intermolecular attraction by dispersion forces and less susceptibility to degradation than biodiesel.

Question 24 C

$\Delta T = 22.5 - 21.0 = 1.5°C$

energy absorbed by the reaction $= 35 \times \dfrac{2.50}{101.1} = 0.8655\,\text{kJ}$

$\text{CF} = \dfrac{E}{\Delta T} = \dfrac{0.8655}{1.5} = 0.5770\ \text{kJ °C}^{-1} = 577\ \text{J °C}^{-1}$

Question 25 C

C is correct. The equation specifies that 1452 kJ is released when 4 mol of water is produced.

Therefore, when 1 mol (18 g) of water is produced, $\dfrac{1452}{4} = 363\,\text{kJ}$ is released.

A is incorrect. The reaction is exothermic and so energy is released, not absorbed.

B is incorrect. The equation specifies that 1452 kJ is released when 2 mol of methanol reacts.

D is incorrect. The equation specifies that 1452 kJ is released when 2 mol (88 g) of carbon dioxide is produced.

Question 26 A

Gaseous methanol changing to liquid methanol releases energy and, therefore, the enthalpy change, ΔH, is negative. Adding the equations for the two reactions (methanol gas changing to liquid methanol, and the combustion of liquid methanol) involves adding two negative values to find the overall ΔH. The ΔH would therefore be more negative than -1452 kJ mol^{-1}.

Question 27 A

A is correct. α-amino acids have the NH_2 and COOH groups attached to the same carbon atom together with a side group. In this molecule, the two hydroxyl groups and one amino group enable intermolecular hydrogen bonding to form.

B is incorrect. There are no sulfur atoms in the side groups, therefore, disulfide bonding cannot occur.

C and **D** are incorrect. The two constituents are α-amino acids.

Question 28 C

The order of decreasing reducing agent strength is Q > N > P > R. This order is derived from the results for each cell, as shown in the following table.

Half-cell combination	**Positive electrode**	**Reducing agent strength**
1 and 3	metal N	Q > N
2 and 4	metal R	P > R
1 and 2	metal P	N > P

Question 29 B

Statement I is correct. Electricity is produced from coal, natural gas, biogas and biomass.

Statement II is correct. Any incomplete combustion of a fuel produces carbon monoxide as one of the products.

Statement III is incorrect. Fatty acids from plants or animals can undergo an esterification reaction with an alcohol to produce a biodiesel.

Statement IV is correct. Petroleum gas is a fossil fuel and, therefore, is not renewable.

Question 30 C

5000 MJ requires the combustion of $\frac{5000}{3.329} = 1501.9525$ mol of pentan-1-ol.

From the molecular formula of pentan-1-ol, the combustion of 1 mol produces 5 mol of carbon dioxide.

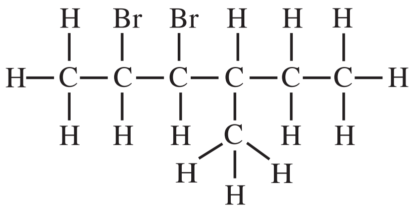
$n(CO_2) = 5 \times 1501.9 = 7509.7627$ mol

$m(CO_2) = n \times M = 7509.7627 \times 44.0 = 330\,429.5584$ g $= 0.330$ tonne

SECTION B

Question 1 (7 marks)

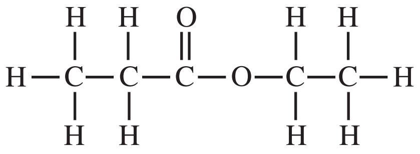
a. **i.**



1 mark

ii. 4-chloro-3-methylhexan-1-ol — 1 mark

b. **i.**



1 mark

ii. CH_3CH_2OH — 1 mark

iii. 1,2-dichloroethane — 1 mark

iv. $2C_2H_5COOH(aq) + Na_2CO_3(aq) \rightarrow 2C_2H_5COONa(aq) + CO_2(g) + H_2O(l)$

2 marks

1 mark for the correct reactants and products.

1 mark for correct balancing and state symbols.

Question 2 (10 marks)

a. **i.** nitrogen to hydrogen bond (N–H) 1 mark

ii. An $-NH_2$ group will accept a proton in an acid–base reaction. 1 mark

As there are two hydrochloric acid molecules reacting, it can be concluded that compound Q has two $-NH_2$ groups. 1 mark

b. **i.** The molecular ion peak shows the mass-to-charge (m/z) value of the complete molecule of compound Q with a positive charge. The relative molecular mass of compound Q is 102. 1 mark

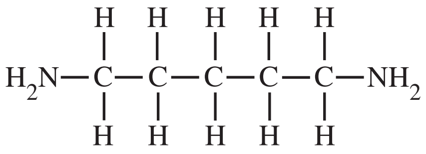
ii. $NH_2CH_2^+$ 1 mark

iii. the presence of compound Q molecules that contain isotopes of the various atoms that compose the molecule 1 mark

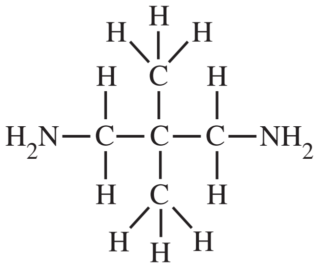
Note: These isotopes (for example, ^{13}C *and* ^{15}N*) would have a slightly larger relative mass and produce compound Q molecules that have m/z values that are slightly greater than 102 with minor signals.*

c. three 1 mark

d. *Any one of:*



$H_2N-CH_2-CH_2-CH_2-CH_2-CH_2-NH_2$



2 marks

1 mark for a symmetrical molecule with two CH_2NH_2 *groups.*

1 mark for a symmetrical molecule with a C_5H_{10} *hydrocarbon section.*

e. The ^{1}H-NMR spectrum would provide information about the distribution of hydrogen atoms in the molecule and therefore allow the correct structure to be confirmed. 1 mark

Question 3 (9 marks)

a. **i.** *Any one of:*

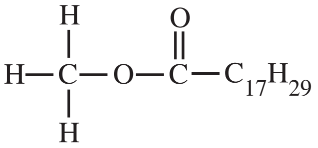
- triglycerides
- fats
- lipids
- esters

1 mark

ii. Compound B is a glycerol, which has three hydroxyl groups per molecule. 1 mark

These hydroxyl groups form hydrogen bonds with water molecules, which results in the molecule being highly soluble in water. 1 mark

iii.



$H_3C-O-C(=O)-C_{17}H_{29}$

1 mark

iv. Each fatty acid has 3 C=C bonds per molecule. 1 mark

Each molecule of compound A has 9 C=C bonds per molecule; therefore, there are 13.5 mol of C=C bonds in 1.5 mol of compound A. 1 mark

Each H_2 is added across a C=C bond, therefore, $n(H_2) = 13.5$ mole and $m(H_2) = 13.5 \times 2.0 = 27$ g 1 mark

b. *For example*:

The sourcing of diesel fuel requires the collection and refining of crude oil, which has a significant environmental impact, as the process requires massive infrastructure and extensive use of energy resources while also being a major source of toxic air pollutants. 1 mark

In comparison, the sourcing of biodiesel requires farming and harvesting crops, and transporting grains to processing centres; these activities have less impact on the environment than diesel fuel sourcing. In addition, if waste animal fats and vegetable oils are used to produce biodiesel, this reduces waste and recycles materials, further reducing the environmental impact. 1 mark

Question 4 (11 marks)

a. +5 *(sum of oxidation numbers = –2 = 2 × oxidation number (S) + 6 × (–2); therefore, oxidation number (S) = +5)* 1 mark

b. **i.** $2SO_2(g) + 2H_2O(l) \rightarrow S_2O_6^{2-}(aq) + 4H^+(aq) + 2e^-$ 1 mark

ii. $2H^+(aq) + 2e^- \rightarrow H_2(g)$ 1 mark

c. **i.** *Any one of:*

- carbon
- graphite

1 mark

ii. Iron is a reasonably strong reducing agent and could react with the hydrogen ions in the cell. 1 mark

d. **i.** In the electrolysis reaction, hydrogen ions are produced. 1 mark

The increase in the concentration of hydrogen ions causes the pH of the electrolyte to decrease. 1 mark

ii. H_3O^+ ions are a reactant in the equilibrium reaction. According to Le Chatelier’s principle, as hydrogen ions are produced by the cell reaction, this would have caused the equilibrium reaction to move forward to partially oppose the change. 1 mark

This removal of hydrogen ions from the electrolyte as they formed kept the pH relatively stable. 1 mark

e. Renewable resources can be produced from materials that are generated repeatedly by natural processes at a rate faster than they are used. 1 mark

There is only a finite amount of coal and metal ores; thus, the hydrogen gas generated from the electrolysis of the waste gases is also finite and not renewable. 1 mark

Question 5 (6 marks)

a. **i.** $PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) + Pb(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ 1 mark

ii. 2.05 V *(voltage = 1.69 –(–0.36) = 2.05 V)* 1 mark

b. The standard electrode potential, E^0, values in the electrochemical series are determined under standard conditions. The lead–acid battery uses 4 M sulfuric acid, instead of the 1 M standard condition, so the voltages are different *(that is, 6 × 2.05 = 12.3 V compared to 14 V).* 1 mark

c. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$ 1 mark

d. *For example, any one of*:

- The lead oxide formed during recharging may not be deposited with 100% efficiency. Each time the battery is recharged, a reduced amount of lead oxide is deposited until there is eventually an insufficient amount is deposited to allow the battery to function.
- Not all of the product of discharge ($PbSO_4$) may remain in contact with the electrode. Therefore, each time the battery is recharged, it is not fully recharged.

2 marks

1 mark for identifying the factor.

1 mark for explaining the factor.

Question 6 (6 marks)

a. ether **OR** glycosidic 1 mark

b. The weakest attraction to the stationary phase results in the compound moving with the solvent, that is, it has the shortest retention time. 1 mark

Dextrins are least attracted to the stationary phase. 1 mark

c. The peak area in the graph relates to the concentration of each compound. 1 mark

Ethanoic acid has the smallest peak area and therefore has the lowest concentration *(assuming the column and detector have the same sensitivity for all compounds shown).* 1 mark

d. Cellulose is a structural material in plants and consists of thousands of monosaccharide monomers bonded together. Its large size prevents it from dissolving in the solvent used in the analysis and so prevents analysis with HPLC. 1 mark

Question 7 (9 marks)

a. energy from carbohydrates = 16 × 48.70 = 779.2 kJ 1 mark

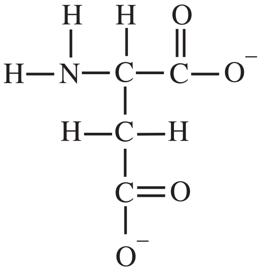
$$\% \text{ energy} = \frac{779.2}{1080} \times 100 = 72\%$$ 1 mark

b. Palmitic acid is a saturated fatty acid as it has no C=C bonds. Palmitoleic acid is an unsaturated fatty acid as it has a C=C bond. Each acid could be shaken separately with bromine water, which has a red–brown colour. 1 mark

Palmitic acid would have no effect, whereas palmitoleic acid would cause the bromine water to de-colourise as the bromine is added across the C=C bond in the fatty acid molecule. 1 mark

c. **i.** Gly-Val-Asp 1 mark

ii.



2 marks

1 mark for selecting aspartic acid.

1 mark for the deprotonation of both carboxyl groups.

d. The glycaemic index (G.I.) is a rating for how readily glucose is released by the body. 1 mark

The low G.I. bread will have a larger proportion of complex carbohydrates than the bread with the higher G.I. For example, low G.I. foods contain more starch and less sugars. The complex carbohydrates take longer for the body to digest and so the glucose is released very slowly into the blood. 1 mark

Question 8 (10 marks)

a. **i.** When the volume of the equilibrium mixture was halved, the intensity of the brown colour increased. 1 mark

This would have been caused by the coloured molecules being put into a smaller volume. 1 mark

ii. Halving the volume results from doubling the pressure. Therefore, the equilibrium mixture would have responded by favouring the side of the reaction that has fewer particles of gas in order to partially oppose the increase in pressure. 1 mark

The colourless product was favoured and thus the brown colour would have been less intense than immediately after the volume change, but nonetheless more intense than before the change. 1 mark

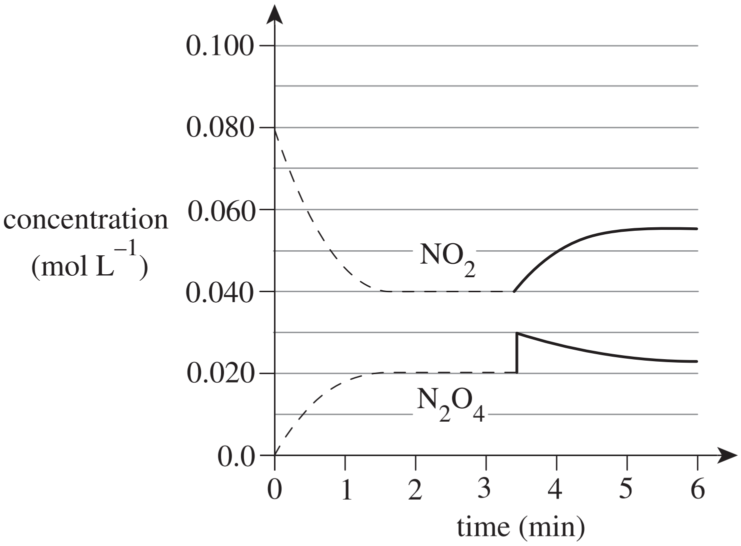
b. **i.** $K_c = \frac{[N_2O_4]}{[NO_2]^2}$ 1 mark

$= \frac{0.020}{0.040^2} = 12.5 = 13\,M^{-1}$ 1 mark

ii. The equilibrium constant value at T_2 is greater than 13 and so at T_2 $[N_2O_4]$ must have increased and $[NO_2]$ must have decreased, that is, the forward reaction was favoured. 1 mark

The forward reaction is favoured when an exothermic equilibrium reaction is cooled because the system responds to partially oppose the decrease in heat. This means that the formation of N_2O_4 is exothermic. 1 mark

c.



2 marks

1 mark for correct placement of the N_2O_4 graph. Note: The graph of N_2O_4 should fall gradually to plateau before 6 minutes. The plateau should be slightly above 0.020.

1 mark for the correct placement of the NO_2 graph. Note: The graph of NO_2 should rise gradually to plateau before 6 minutes. The plateau should be slightly below 0.060.

Question 9 (11 marks)

a. The complete reaction produces 48 mL of oxygen at standard laboratory conditions (SLC).

$n(O_2) = \frac{V}{V_m} = \frac{48}{24\,800} = 1.9355 \times 10^{-3}$ mol 1 mark

$n(H_2O_2) = 2 \times n(O_2) = 1.9355 \times 10^{-3} \times 2 = 3.8710 \times 10^{-3}$ mol 1 mark

$c(H_2O_2) = \frac{n}{V} = \frac{3.8710 \times 10^{-3}}{0.0500} = 0.0774$ mol $L^{-1} = 0.077$ mol L^{-1} 1 mark

b. the rate of oxygen gas production at SLC 1 mark

c. **i.** The Cu catalyst must be used as fine particles (such as filings). A wire, block or sheet of Cu must not be used as it would affect the experiment's validity. 1 mark

A valid experiment changes only one variable so that any result can be linked to the change. If two variables are changed at the same time (in this case, the nature of the catalyst and the form of the catalyst), then the results cannot be linked to one variable. 1 mark

ii. *For example*:

repeating the experiment to get further results and taking the average 1 mark

d. **i.** At the start of a reaction, there are many reactant particles available to collide, and a high proportion of successful collisions produces product particles. 1 mark

As the reaction proceeds, there are fewer reactant particles available to collide and so there are fewer successful collisions, generating fewer product particles. Therefore, the rate of reaction decreases. 1 mark

ii. The reaction using CuO as catalyst is still in the initial phase of the reaction, so it is much slower than the other reaction catalysed by Cu. 1 mark

As time proceeds, the graph for the CuO catalyst will plateau like the other graph, indicating a slowing of the rate of reaction. 1 mark

Question 10 (11 marks)

a. The tertiary structure of the protein from which an enzyme is made has an active site, a flexible cavity formed on the surface of the enzyme. 1 mark

When the substrate molecule collides with the enzyme molecule, the active site changes in shape to fit the substrate snugly. 1 mark

Weak bonds form between the substrate and the enzyme, lowering the reaction activation energy, and so the reaction is catalysed. The products of the reaction leave the active site, which then returns to being a flexible cavity. 1 mark

Any one of:

- In the dehydrogenation reaction of ethanol to form ethanal, two hydrogen ions and two electrons are removed from the ethanol molecule. The coenzyme NAD helps the process by accepting a hydrogen ion and two electrons, converting from the NAD^+ form to NADH. 1 mark

  The NADH will later release the hydrogen and be reformed as NAD^+ to enable further coenzyme activity. 1 mark
- The vitamin C coenzyme binds to the surface of the enzyme, either directly to part of the active site, or to another part of the enzyme causing a change to the active site. 1 mark

  The enzyme becomes active and is able to bind to the substrate and subsequently catalyse the reaction. 1 mark

b. *For example, any two of*:

- Enzymes are made of protein.

  Coenzymes are not made of protein *(for example, vitamin C)*.
- Enzymes are unchanged after their role in catalysis.

  Coenzymes may be altered after their role in catalysis *(for example, NADH, which may later be restored to its useful coenzyme form)*.
- Enzymes form weak bonds with the substrate, lowering activation energy for the reaction.

  Coenzymes may not always directly interact with the substrate.

2 marks

1 mark for each difference stated.

c. **i.** At 15°C, the reactant molecules have very little energy and are moving slowly, so collisions are relatively infrequent. 1 mark

As a result, interactions with the enzyme molecules do not occur as often or with sufficient energy, and so catalysis cannot happen optimally. 1 mark

ii. At 65°C, the weak bonding holding the secondary and tertiary structures of the enzyme has been disrupted progressively and so many of the active sites on the enzyme molecules have been altered. 1 mark

As a result, the reaction cannot be efficiently catalysed with fewer active sites available and so the yield is low. 1 mark

Trial Examination 2023

VCE Chemistry Units 3&4

Written Examination

Data Booklet

Instructions

This data booklet is provided for your reference.
A question and answer booklet is provided with this data booklet.

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1. Periodic table of the elements

atomic number	79	symbol of element	
relative atomic mass	**Au** 197.0 gold	name of element	

1 **H** 1.0 hydrogen																	2 **He** 4.0 helium
3 **Li** 6.9 lithium	4 **Be** 9.0 beryllium											5 **B** 10.8 boron	6 **C** 12.0 carbon	7 **N** 14.0 nitrogen	8 **O** 16.0 oxygen	9 **F** 19.0 fluorine	10 **Ne** 20.2 neon
11 **Na** 23.0 sodium	12 **Mg** 24.3 magnesium											13 **Al** 27.0 aluminium	14 **Si** 28.1 silicon	15 **P** 31.0 phosphorus	16 **S** 32.1 sulfur	17 **Cl** 35.5 chlorine	18 **Ar** 39.9 argon
19 **K** 39.1 potassium	20 **Ca** 40.1 calcium	21 **Sc** 45.0 scandium	22 **Ti** 47.9 titanium	23 **V** 50.9 vanadium	24 **Cr** 52.0 chromium	25 **Mn** 54.9 manganese	26 **Fe** 55.8 iron	27 **Co** 58.9 cobalt	28 **Ni** 58.7 nickel	29 **Cu** 63.5 copper	30 **Zn** 65.4 zinc	31 **Ga** 69.7 gallium	32 **Ge** 72.6 germanium	33 **As** 74.9 arsenic	34 **Se** 79.0 selenium	35 **Br** 79.9 bromine	36 **Kr** 83.8 krypton
37 **Rb** 85.5 rubidium	38 **Sr** 87.6 strontium	39 **Y** 88.9 yttrium	40 **Zr** 91.2 zirconium	41 **Nb** 92.9 niobium	42 **Mo** 96.0 molybdenum	43 **Tc** (98) technetium	44 **Ru** 101.1 ruthenium	45 **Rh** 102.9 rhodium	46 **Pd** 106.4 palladium	47 **Ag** 107.9 silver	48 **Cd** 112.4 cadmium	49 **In** 114.8 indium	50 **Sn** 118.7 tin	51 **Sb** 121.8 antimony	52 **Te** 127.6 tellurium	53 **I** 126.9 iodine	54 **Xe** 131.3 xenon
55 **Cs** 132.9 caesium	56 **Ba** 137.3 barium	**57–71** lanthanoids	72 **Hf** 178.5 hafnium	73 **Ta** 180.9 tantalum	74 **W** 183.8 tungsten	75 **Re** 186.2 rhenium	76 **Os** 190.2 osmium	77 **Ir** 192.2 iridium	78 **Pt** 195.1 platinum	79 **Au** 197.0 gold	80 **Hg** 200.6 mercury	81 **Tl** 204.4 thallium	82 **Pb** 207.2 lead	83 **Bi** 209.0 bismuth	84 **Po** (210) polonium	85 **At** (210) astatine	86 **Rn** (222) radon
87 **Fr** (223) francium	88 **Ra** (226) radium	**89–103** actinoids	104 **Rf** (261) rutherfordium	105 **Db** (262) dubnium	106 **Sg** (266) seaborgium	107 **Bh** (264) bohrium	108 **Hs** (267) hassium	109 **Mt** (268) meitnerium	110 **Ds** (271) darmstadtium	111 **Rg** (272) roentgenium	112 **Cn** (285) copernicium	113 **Nh** (280) nihonium	114 **Fl** (289) flerovium	115 **Mc** (289) moscovium	116 **Lv** (292) livermorium	117 **Ts** (294) tennessine	118 **Og** (294) oganesson

57 **La** 138.9 lanthanum	58 **Ce** 140.1 cerium	59 **Pr** 140.9 praseodymium	60 **Nd** 144.2 neodymium	61 **Pm** (145) promethium	62 **Sm** 150.4 samarium	63 **Eu** 152.0 europium	64 **Gd** 157.3 gadolinium	65 **Tb** 158.9 terbium	66 **Dy** 162.5 dysprosium	67 **Ho** 164.9 holmium	68 **Er** 167.3 erbium	69 **Tm** 168.9 thulium	70 **Yb** 173.1 ytterbium	71 **Lu** 175.0 lutetium

89 **Ac** (227) actinium	90 **Th** 232.0 thorium	91 **Pa** 231.0 protactinium	92 **U** 238.0 uranium	93 **Np** (237) neptunium	94 **Pu** (244) plutonium	95 **Am** (243) americium	96 **Cm** (247) curium	97 **Bk** (247) berkelium	98 **Cf** (251) californium	99 **Es** (252) einsteinium	100 **Fm** (257) fermium	101 **Md** (258) mendelevium	102 **No** (259) nobelium	103 **Lr** (262) lawrencium

The value in the brackets indicates the mass number of the longest-lived isotope.

2. Electrochemical series

Reaction	Standard electrode potential (E^0) in volts at 25°C
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	−0.28
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	−1.66
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.37
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	−2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.04

3. Chemical relationships

Name	Formula
number of moles of a substance	$n = \frac{m}{M}$; $n = cV$; $n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$\text{CF} = \frac{VIt}{\Delta T}$
heat energy released in the combustion of a fuel	$q = mc\Delta T$
enthalpy of combustion	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
number of moles of electrons	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
charge on one electron (elementary charge)	e	-1.60×10^{-19} C
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25°C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25°C	d	997 kg m^{-3} or 0.997 g mL^{-1}

5. Unit conversions

Measured value	Conversion
0°C	273 K
100 kPa	750 mm Hg or 0.987 atm
1 litre (L)	1 dm^3 or 1×10^{-3} m^3 or 1×10^3 cm^3 or 1×10^3 mL

6. Metric (including SI) prefixes

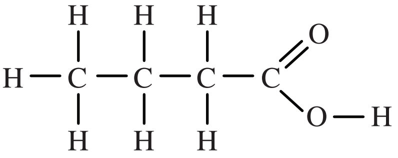
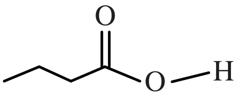
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

7. Acid–base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

8. Representations of organic molecules

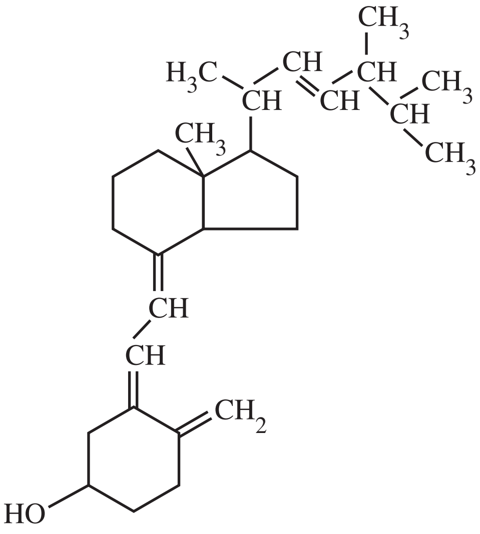
The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

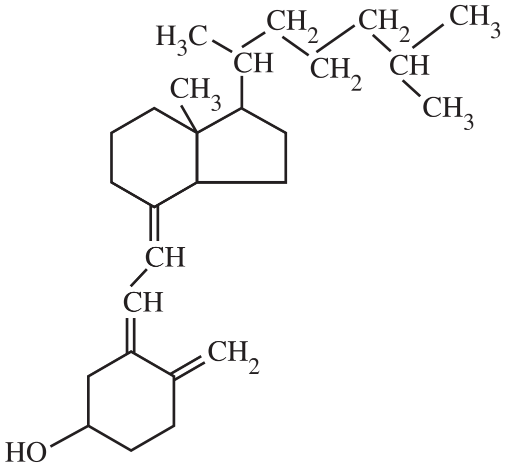
9. Formulas of some fatty acids

Name	Formula	Semi-structural formula
lauric	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{15}H_{29}COOH$	$CH_3(CH_2)_4CH_2CH{=}CHCH_2(CH_2)_5CH_2COOH$
stearic	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{17}H_{33}COOH$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic	$C_{17}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$
linolenic	$C_{17}H_{29}COOH$	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$
arachidic	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{17}CH_2COOH$
arachidonic	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

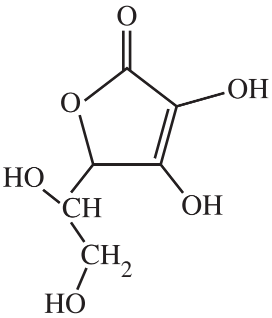
10. Formulas of some biomolecules



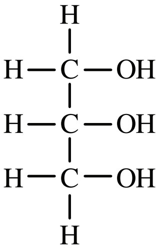
vitamin D_2 (ergocalciferol)



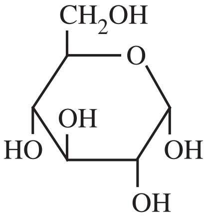
vitamin D_3 (cholecalciferol)



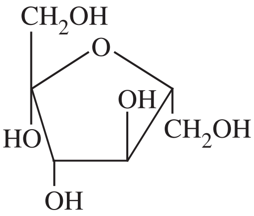
vitamin C (ascorbic acid)



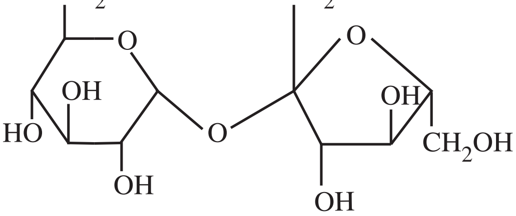
glycerol



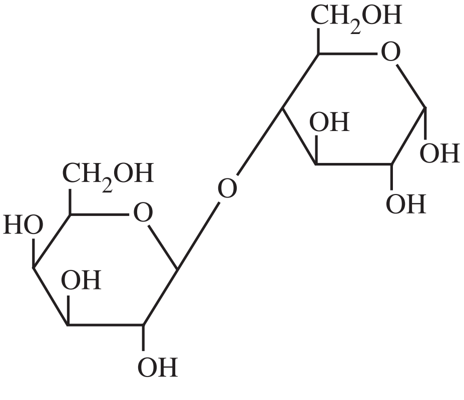
α-glucose



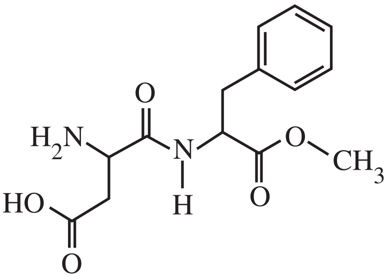
β-fructose



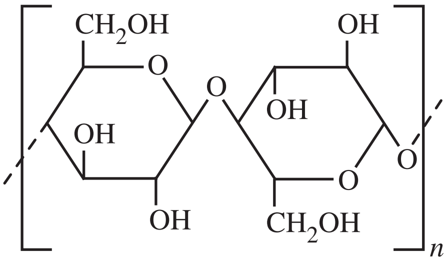
sucrose



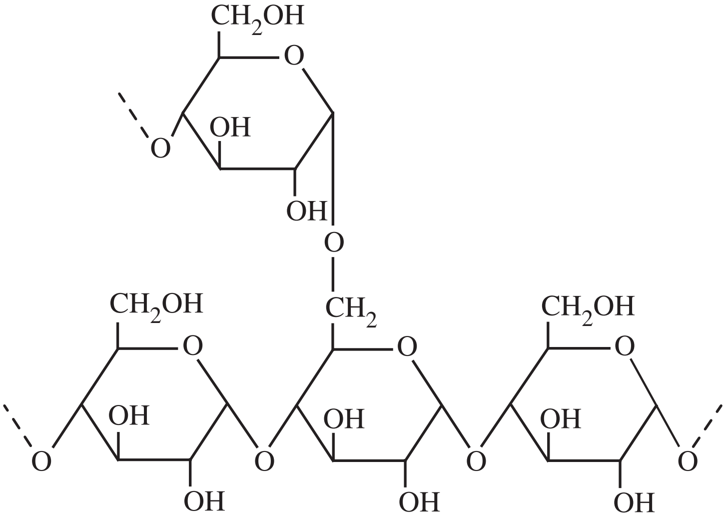
α-lactose



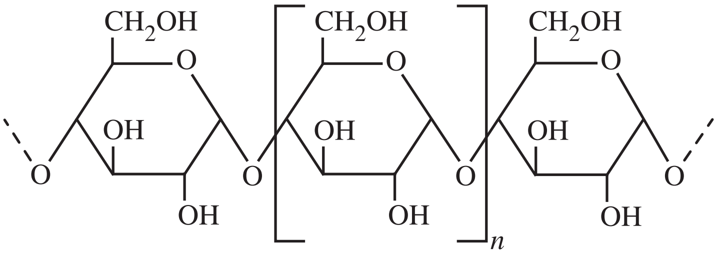
aspartame



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

The heats of combustion in the following table are calculated at SLC (25°C and 100 kPa) with combustion products being CO_2 and H_2O. Heat of combustion may be defined as the heat energy released when a specified amount of a substance burns completely in oxygen and is, therefore, reported as a positive value, indicating a magnitude. Enthalpy of combustion, ΔH, for the substances in this table would be reported as negative values, indicating the exothermic nature of the combustion reaction.

Fuel	Formula	State	Heat of combustion (kJ g^{-1})	Molar heat of combustion (kJ mol^{-1})
hydrogen	H_2	gas	141	282
methane	CH_4	gas	55.6	890
ethane	C_2H_6	gas	51.9	1560
propane	C_3H_8	gas	50.5	2220
butane	C_4H_{10}	gas	49.7	2880
octane	C_8H_{18}	liquid	47.9	5460
ethyne (acetylene)	C_2H_2	gas	49.9	1300
methanol	CH_3OH	liquid	22.7	726
ethanol	C_2H_5OH	liquid	29.6	1360

12. Heats of combustion of common blended fuels

Blended fuels are mixtures of compounds with different mixture ratios and, hence, determination of a generic molar enthalpy of combustion is not realistic. The values provided in the following table are typical values for heats of combustion at SLC (25°C and 100 kPa) with combustion products being CO_2 and H_2O. Values for heats of combustion will vary depending on the source and composition of the fuel.

Fuel	State	Heat of combustion (kJ g^{-1})
kerosene	liquid	46.2
diesel	liquid	45.0
natural gas	gas	54.0

13. Energy content of food groups

Food	Heat of combustion (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

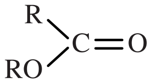
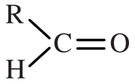
14. Characteristic ranges for infra-red absorption

Bond	Wave number (cm^{-1})	Bond	Wave number (cm^{-1})
C–Cl (chloroalkanes)	600–800	C=O (ketones)	1680–1850
C–O (alcohols, esters, ethers)	1050–1410	C=O (esters)	1720–1840
C=C (alkenes)	1620–1680	C–H (alkanes, alkenes, arenes)	2850–3090
C=O (amides)	1630–1680	O–H (acids)	2500–3500
C=O (aldehydes)	1660–1745	O–H (alcohols)	3200–3600
C=O (acids)	1680–1740	N–H (amines and amides)	3300–3500

15. ^{13}C NMR data

Typical ^{13}C shift values relative to TMS = 0

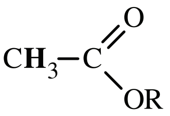
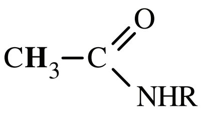
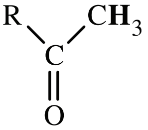
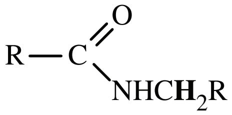
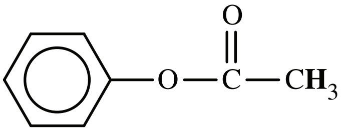
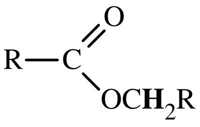
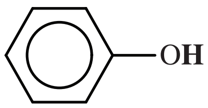
These can differ slightly in different solvents.

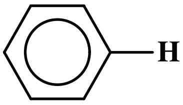
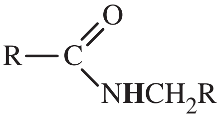
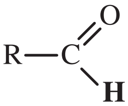
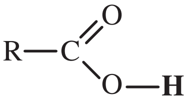
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

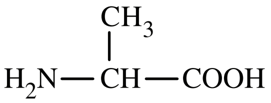
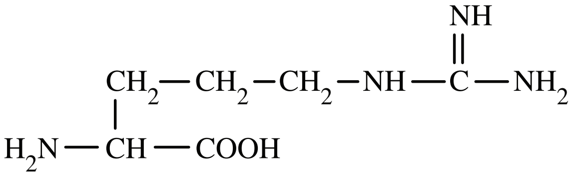
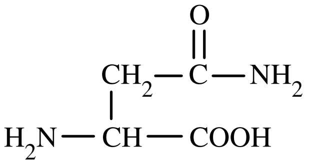
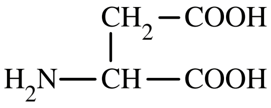
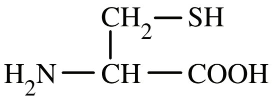
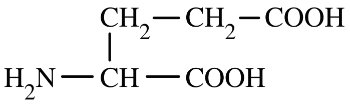
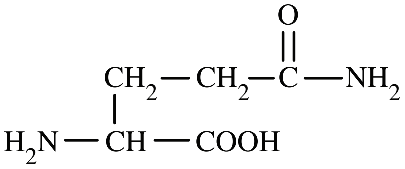
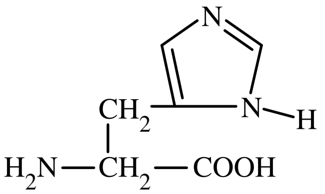
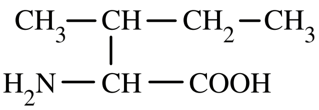
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

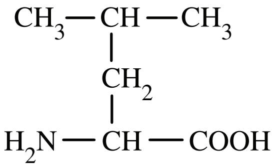
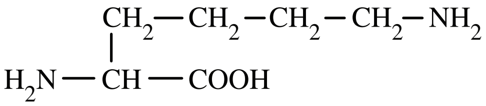
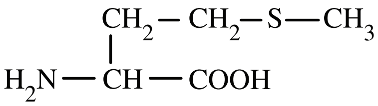
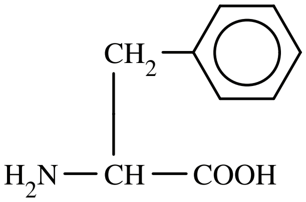
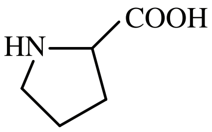
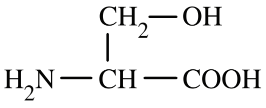
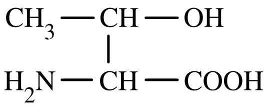
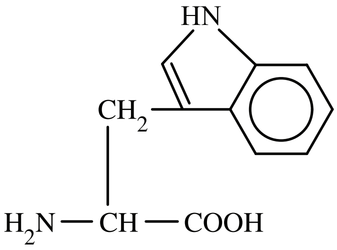
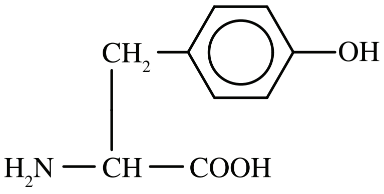
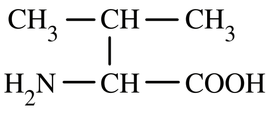
Type of proton	**Chemical shift (ppm)**
$R{-}C\mathbf{H}_3$	0.9–1.0
$R{-}C\mathbf{H}_2{-}R$	1.3–1.4
$RCH{=}CH{-}C\mathbf{H}_3$	1.6–1.9
$R_3{-}C\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$R{-}C\mathbf{H}_2{-}X$ (X = F, Cl, Br or I)	3.0–4.5
$R{-}C\mathbf{H}_2{-}OH$, $R_2{-}C\mathbf{H}{-}OH$	3.3–4.5
	3.2
$R{-}O{-}C\mathbf{H}_3$ or $R{-}O{-}C\mathbf{H}_2R$	3.3–3.7
	2.3
	3.7–4.8
$R{-}O{-}\mathbf{H}$	1–6 (varies considerably under different conditions)
$R{-}N\mathbf{H}_2$	1–5
$RHC{=}C\mathbf{H}R$	4.5–7.0
	4.0–12.0

Type of proton	Chemical shift (ppm)
	6.9–9.0
	8.1
	9.4–10.0
	9.0–13.0

17. 2-amino acids (α-amino acids)

The table below provides simplified structures to enable the drawing of zwitterions, the identification of products of protein hydrolysis and the drawing of structures involving condensation polymerisation of amino acid monomers.

Name	Symbol	Structure
alanine	Ala	 $H_2N-\overset{\overset{CH_3}{\vert}}{CH}-COOH$
arginine	Arg	 $H_2N-\overset{\overset{CH_2-CH_2-CH_2-NH-\overset{\overset{NH}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
asparagine	Asn	 $H_2N-\overset{\overset{CH_2-\overset{\overset{O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
aspartic acid	Asp	 $H_2N-\overset{\overset{CH_2-COOH}{\vert}}{CH}-COOH$
cysteine	Cys	 $H_2N-\overset{\overset{CH_2-SH}{\vert}}{CH}-COOH$
glutamic acid	Glu	 $H_2N-\overset{\overset{CH_2-CH_2-COOH}{\vert}}{CH}-COOH$
glutamine	Gln	 $H_2N-\overset{\overset{CH_2-CH_2-\overset{\overset{O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	 $H_2N-\overset{\overset{CH_3-CH-CH_2-CH_3}{\vert}}{CH}-COOH$

Name	Symbol	Structure
leucine	Leu	 $\begin{array}{ccccc} CH_3 & - & CH & - & CH_3 \\ & & \vert & & \\ & & CH_2 & & \\ & & \vert & & \\ H_2N & - & CH & - & COOH \end{array}$
lysine	Lys	 $\begin{array}{ccccccccccc} & & CH_2 & - & CH_2 & - & CH_2 & - & CH_2 & - & NH_2 \\ & & \vert & & & & & & & & \\ H_2N & - & CH & - & COOH & & & & & & \end{array}$
methionine	Met	 $\begin{array}{ccccccccc} & & CH_2 & - & CH_2 & - & S & - & CH_3 \\ & & \vert & & & & & & \\ H_2N & - & CH & - & COOH & & & & \end{array}$
phenylalanine	Phe	
proline	Pro	
serine	Ser	 $\begin{array}{ccccc} & & CH_2 & - & OH \\ & & \vert & & \\ H_2N & - & CH & - & COOH \end{array}$
threonine	Thr	 $\begin{array}{ccccc} CH_3 & - & CH & - & OH \\ & & \vert & & \\ H_2N & - & CH & - & COOH \end{array}$
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	 $\begin{array}{ccccc} CH_3 & - & CH & - & CH_3 \\ & & \vert & & \\ H_2N & - & CH & - & COOH \end{array}$

END OF DATA BOOKLET