Suggested Answers VCE Chemistry 2007 Trial Exam Unit 4

Section A

Q1. B The formation of **complex-ions** in which the ligand is NH_3 is a characteristic of **transition metal cations**, i.e. Ni^{2+} but not cations of group 1 and 2 cations, i.e. Na^+, Mg^{2+}, Li^+

Q2. C The atomic number of ^4He is 2 and the atomic number of ^1n (a neutron) is 0.

So equation 2. becomes

$$X + X \rightarrow {}^{4}_{2}He + 2\,{}^{1}_{0}n$$

Since **atomic numbers and mass numbers must equal out on both sides of the equation** the two X nuclei must have a total atomic number of 2 and a total mass number of 6, i.e. X has atomic number 1 and mass number 3 – an isotope of hydrogen.

Equation 1. becomes

$$Y + {}^{1}_{0}n \rightarrow {}^{4}_{2}He + {}^{3}_{1}H$$

So **Y** has **atomic number 3** and **mass number 6**, and is lithium-6; $\mathbf{{}^{6}_{3}Li}$

Q3. A Pauli – an orbital may contain 0, 1 or 2 electrons but never more than 2.

Bohr – used emission spectrum of hydrogen as an insight to propose the existence of energy levels for electrons.

Rutherford – used the 'gold foil' experiment as the basis of the nuclear model of the atom.

Dalton – proposed the first atomic theory.

Q4. D When current passes through a sodium lamp, Na atoms are excited and electrons move to higher energy levels. Specific quantities of energy, equal to the difference between starting and finishing energy levels are required for these electron transitions to occur. (These energy quantities appear as black lines on the ROYGBIV background on an absorption spectrum).**When excited atoms return to their ground states**, i.e. electrons move from higher energy levels to lower energy levels, **specific quantities of energy are emitted**, again corresponding to the difference between the initial and final energy levels. These specific quantities of energy (**differences between energy levels**) **correspond to specific wavelengths of light**, each of which is shown by a **coloured line** on the emission spectrum.

Q5. C An element with a high electronegativity has a strong attraction for valence electrons. The most electronegative element is fluorine, which exists as F^- ions, i.e. anions, in many of its compounds.

Electronegativity increases across a period. Oxide properties change from basic to acidic across a period. So an element with high electronegativity would be expected to form an acidic oxide.

First ionisation energy – the energy needed to remove the highest energy (outermost) electron from an atom – **increases with increasing attraction for valence electrons**. So **an element with high electronegativity will have high first ionisation energy**.

Reductants cause reduction and are themselves oxidised. Reductants give up electrons in chemical reactions hence do not have particularly strong attraction for their valence electrons, so will not have a high electronegativity.

Q6. B Mendeleev arranged the elements on his periodic table in order of increasing atomic weight and grouped them on the basis of similar chemical properties. He also left gaps in the table and accurately predicted the properties of then yet to be discovered elements.

However **Mendeleev gave precedence to chemical properties and so placed Iodine (I) after Tellurium (Te) even though the atomic of tellurium was greater.**

Mendeleev decided his atomic weight of Te was incorrect. However, the discovery and eventual understanding of isotopes showed that the higher atomic weight of Te compared to I reflects the relative isotopic composition of the elements.

Q7. D The fusion reaction occurring in the Sun is generally represented by the equation

$4\,{}^{1}_{1}H^{+} \rightarrow {}^{4}_{2}He^{2+} + 2\,{}^{0}_{1}e^{+}$ or $4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e$

This equation shows that the **number of nuclei decreases** as four H-1 nuclei are converted to one He-4 nucleus.
During fusion mass is converted into energy according to Einstein's $E = mc^2$, so the **mass of the star is continuously decreasing**.

Q8. D Reaction at the cathode is $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$

$n(e^{-}) = Q / F$
$= 20000 / 96500$
$= 0.207$ mol
$n(Cu^{2+})$ reacting $= ½ \times n(e^{-})$
$= ½ \times 0.207$
$= 0.104$ mol
$n(Cu^{2+})$ initially $= cV = 1.0 \times 1 = 1$ mol
$n(Cu^{2+})$ remaining $= 1 – 0.104$
$= 0.9$ mol
$c(Cu^{2+})$ remaining $= c / V = 0.9 / 1$
$=$ **0.9 M**

Q9. D The species present in the solution are show below as they appear in the electrochemical series

$Cl_2(g) + 2e^{-} \rightarrow 2\mathbf{Cl^{-}}(aq)$ 1.36 V
$O_2(g) + 4H^{+}(aq) + 4e^{-} \rightarrow 2\mathbf{H_2O}(l)$ 1.23 V
$\mathbf{Cu^{2+}}(aq) + 2e^{-} \rightarrow Cu(s)$ 0.34 V
$\mathbf{Fe^{2+}}(aq) + 2e^{-} \rightarrow Fe(s)$ -0.44 V
$\mathbf{Zn^{2+}}(aq) + 2e^{-} \rightarrow Zn(s)$ -0.76 V
$2\mathbf{H_2O}(l) + 2e^{-} \rightarrow H_2(g) + 2OH^{-}(aq)$ -0.83 V

In the electrolysis of a mixture of oxidants and reductants in a dilute solution, the strongest oxidant and strongest reductant react. The strongest oxidant is reduced at the cathode whilst the strongest reductant is oxidised at the anode.
So the **initial reaction**s are
Anode (+) $2H_2O(l) \rightarrow O_2(g) + 4H^{+}(aq) + 4e^{-}$
Cathode (-) $\mathbf{Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)}$
As the electrolysis continues and all the $Cu^{2+}(aq)$ has reacted, **the next strongest oxidant**, $Fe^{2+}(aq)$, is **reduced** at the cathode according to
$\mathbf{Fe^{2+}(aq) + 2e^{-} \rightarrow Fe(s)}$.
Subsequently, the next strongest oxidant, $Zn^{2+}(aq)$, is reduced according to
$\mathbf{Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)}$.
So the **coatings on the graphite cathode**, from the inside out, would be **Cu then Fe then Zn**.

Q10 A The discharging reaction is the reverse of the recharging reaction, i.e.

$Pb(s) + PbO_2(s) + 4H^{+}(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

Since discharging is a spontaneous process, oxidation occurs at the (-) electrode and reduction occurs at the (+) electrode.
Pb is oxidised to $PbSO_4$ at the (-) electrode, as the **oxidation number** of lead **increases from 0 to +2** at this electrode.
PbO_2 is reduced to $PbSO_4$ at the (+) electrode, as the **oxidation number** of lead **decreases form +4 to +2** at this electrode.

Q11. C Reference to the electrochemical series enables the determination of the cell voltage under standard conditions (25°C, 1 M, 101.3 kPa).

$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$ 1.09 V
$\mathbf{Ag^+}(aq) + e^- \rightarrow Ag(s)$ 0.80 V
$I_2(s) + 2e^- \rightarrow \mathbf{2I^-}(aq)$ 0.54 V

A cell potential difference of **0.26 V** could be produced, under ideal conditions, from the combination of the **Ag^+/Ag (0.80 V) and I_2/I^- (0.54 V) half-cells**.
$E_{cell} = 0.80 – 0.54 = 0.26$ V
Since it is a galvanic cell, the oxidant must be higher on the electrochemical series. So the redox reaction is between $Ag^+(aq)$ and $I^-(aq)$ according to the half-equations
$Ag^+(aq) + e^- \rightarrow Ag(s)$ – at the left hand electrode, and
$2I^-(aq) \rightarrow I_2(s) + 2e^-$ – at the **right hand electrode.**

Q12. D For the combustion of **octane**

$$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g),\ \Delta H = -10090 \text{ kJ mol}^{-1}$$

A. 2 mol $C_8H_{18} \rightarrow$ 10090 kJ
2 x 114 g $C_8H_{18} \rightarrow$ 10090 kJ, so 1 g $C_8H_{18} \rightarrow$ 10090 / 228 = **44.3 kJ**
B Produces 16 mol CO_2 for 10090 kJ,
i.e. 16 / 10090 = **0.00159 mol CO_2** for 1 kJ of energy
C Uses 25 mol O_2 for 10090 kJ energy
i.e. 25 / 10090 = **0.0025 mol O_2** for 1 kJ energy
D 2 mol $C_8H_{18} \rightarrow$ 16 mol CO_2
2 x 114 g $C_8H_{18} \rightarrow$ 16 mol CO_2, so 1 g $C_8H_{18} \rightarrow$ 16 / 228 = **0.070 mol CO_2**

For the combustion of ethanol

$$C_2H_5OH(l) + 9O_2(g) \rightarrow 2CO_2(g) + 6H_2O(g),\ \Delta H = -1367 \text{ kJ mol}^{-1}$$

A. 1 mol $C_2H_5OH \rightarrow$ 1367 kJ
46 g $C_2H_5OH \rightarrow$ 1367 kJ, so 1 g $C_8H_{18} \rightarrow$ 1367 / 46 = **29.7 kJ**
B Produces 2 mol CO_2 for 1367 kJ,
i.e. 2 / 1367 = **0.00146 mol CO_2** for 1 kJ of energy
C Uses 9 mol O_2 for 1367 kJ energy
i.e. 9 / 1367 = **0.0067 mol O_2** for 1 kJ energy
D 1 mol $C_2H_5OH \rightarrow$ 2 mol CO_2
46 g $C_2H_5OH \rightarrow$ 2 mol CO_2, so 1 g $C_2H_5OH \rightarrow$ 2 / 46 = **0.043 mol CO_2**

Compared to the combustion of octane, the combustion of ethanol

- releases **less** energy for each gram combusted (29.7 kJ against 44.3 kJ
- produces **less** CO_2 for each kJ of energy released (0.00146 mol against 0.00159 mol)
- uses **more** O_2 for each kJ of energy produced (0.0067 mol against 0.0025 mol)
- **produces less CO_2 for each gram combusted** (0.043 mol against 0.070 mol)

Q13. B Use the specific heat of water, 4.18 J g^{-1} $°C^{-1}$, calculate the energy needed to raise the temperature of 150 g of water by one degree.

$\boldsymbol{E} = 4.18 \text{ J g}^{-1}\ °C^{-1} \times m(H_2O) \times \Delta T$
$= 4.18 \times 150 \times 1$
$= 627$ J

The calibration factor is the energy required to raise the temperature of the calorimeter and its contents by one degree. Since 627 J is required just for the 150 mL of water, the calibration factor must be higher because the other components, e.g. the reaction container, stirrer, etc must also have their temperature increased by one degree. Since these have lower heat capacities than water, the calibration factor will be greater, but not significantly greater than 627 J K^{-1}. So **700 J K^{-1}** is the best alternative.

NB Since we are considering a temperature change, J K^{-1} and J $°C^{-1}$ are equivalent.

Q14. A The electrolysis of $NaCl(l)$ to produce $Na(l)$ and $Cl_2(l)$ is carried out industrially in the **Down's Cell.**

Anode (+) – Oxidation: **$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$**

Cathode (-) – Reduction: **$Na^+(l) + e^- \rightarrow Na(l)$**

Q15. B The choice between alternatives A, B and C can be made with some reference to the electrochemical series.

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	1.36 V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.44 V
$\mathbf{Na}^+(aq) + e^- \rightarrow Na(s)$	-0.76 V
$\mathbf{Ca}^{2+}(aq) + 2e^- \rightarrow Ca(s)$	-2.87 V

Alternative A is not correct because, even though sodium is a stronger reductant than iron. Reductants are not reduced; they cause reduction and consequently are oxidized.
Alternative C is not correct because Na^+ is a stronger reductant than Ca^{2+} and so is preferentially reduced. Also the role of $CaCl_2$ in the cell is to lower the melting temperature of NaCl.
Alternative D is not correct because, since Fe is used as the cathode it clearly does not react with the electrolyte, $NaCl(l)$ $lC_aCl_2(l)$.
According to the electrochemical series (even allowing for conditions well beyond the standard 25°C) **Fe is a stronger reductant and would be oxidised in preference to $Cl^-(l)$.**

Q16. C According to the electrochemical series, O_2, can be produced by the oxidation of $H_2O(l)$ or $OH^-(aq)$. The respective oxidation half-equations are

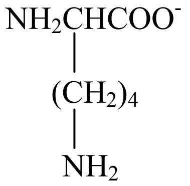
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$, or
$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

If oxygen is not produced during the electrolysis of the 1 M aqueous solution, it will be because of the presence of a reductant stronger than $H_2O(l)$ or, in the case of 1 M NaOH, stronger than $OH^-(aq)$.
Considering the positions of the reductants on the electrochemical series

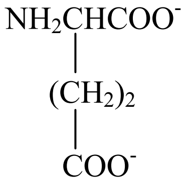
$F_2(g) + 2e^- \rightarrow 2F^-(aq)$	2.87 V
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	1.36 V
$\mathbf{O_2}(g) + 4H^+(aq) + 4e^- \rightarrow \mathbf{2H_2O}(l)$	1.23 V
$Br_2(g) + 2e^- \rightarrow 2Br^-(aq)$	1.09 V
$\mathbf{O_2}(g) + 2H_2O(l) + 4e^- \rightarrow \mathbf{4OH^-}(l)$	0.40 V

In 1 M NaOH, the strongest reductant is $OH^-(aq)$
In 1 M $MgCl_2$ the strongest reductant is $H_2O(l)$
In **1 M LiBr the strongest reductant is $Br^-(aq)$, so it is oxidized in preference to $H_2O(l)$ and $Br_2(l)$ is produced at the anode instead of $O_2(g)$.**
In 1 M KF(aq), the strongest reductant is $H_2O(l)$.

Q17. B In solutions of pH 12, i.e. alkaline solutions, the amino acids will act as 'acids' and donate a proton from their carboxyl (COOH) functional groups. So the structures of the amino acids become



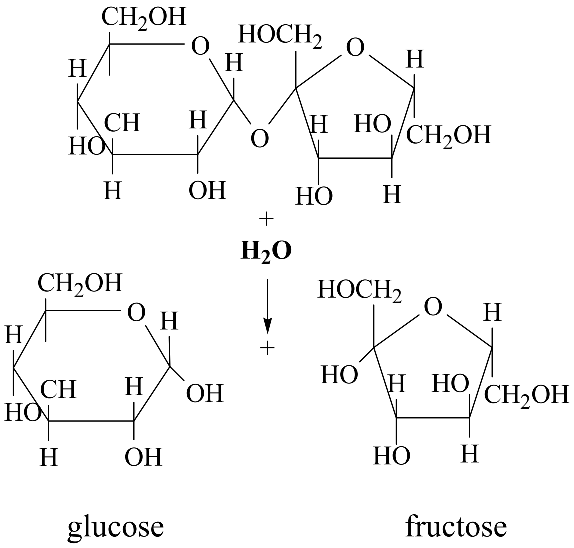
$NH_2CHCOO^- \,|\, (CH_2)_4 \,|\, NH_2$



$NH_2CHCOO^- \,|\, (CH_2)_2 \,|\, COO^-$

So the lysine molecules will assume an overall (-1) charge and the glutamic acid molecules will assume an overall (-2) charge.

Q18. A The carbohydrate shown is a disaccharide (sucrose) and digestion involves a reaction with water (hydrolysis reaction) at the ether functional group**.**



The products of digestion – glucose and fructose – both have the molecular formula, $C_6H_{12}O_6$, and thus are structural isomers.

Q19. C Linoleic and linolenic acids both have 18 carbon atoms in their molecules.
A saturated fatty acid with 18 carbon atoms has the molecular formula $C_{18}H_{36}O_2$ ($C_nH_{2n}O_2$).
Each C=C double bond in a molecule of an unsaturated fatty acid decreases the number of H atoms in the molecule by two compared to the number present in a molecule of a saturated fatty acid with the same number of C atoms.
Linoleic acid molecules – $C_{18}H_{32}O_2$ – each have two C=C double bonds.

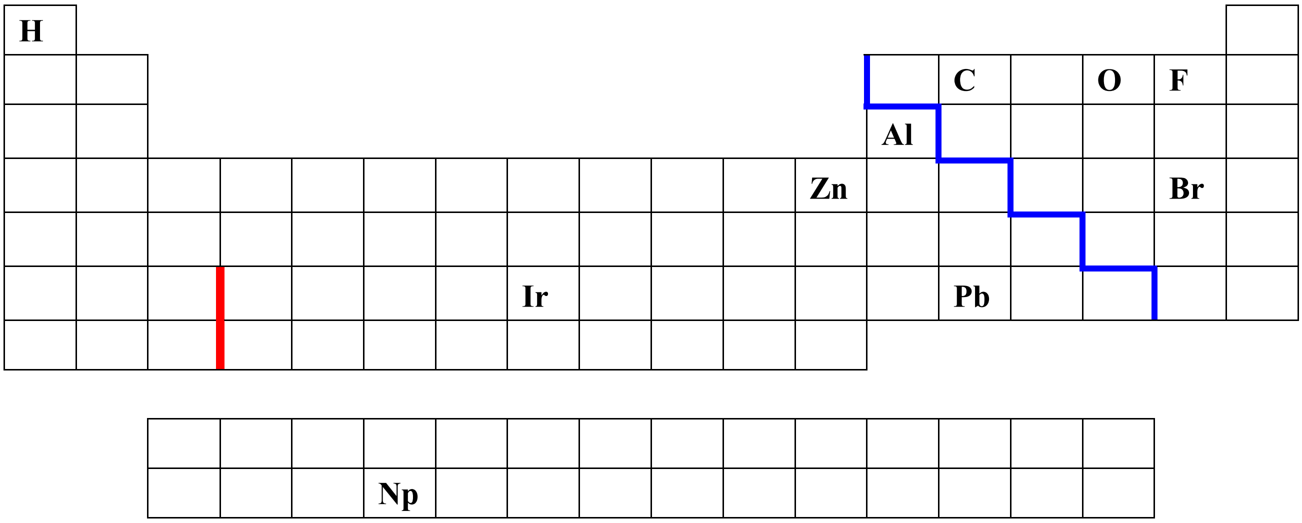
$$M_r(C_{18}H_{32}O_2) = 18 \times 12 + 32 \times 1 + 2 \times 16$$
$$= 280.$$

Since M_r (linolenic acid) – 278 – is two smaller than M_r (linoleic acid) it must have two fewer H atoms, thus one more C=C double bonds.
So **linolenic acid ($C_{18}H_{30}O_2$) has three C=C double bonds**
Semistructural formulae of the fatty acids are
Linolenic acid $CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$.
Linoleic acid $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$.

Q20. A Consider the role of each of the alternatives in the nitrogen cycle.
Nitrogen fixing bacteria convert atmospheric nitrogen to NH_4^+. This is **not** shown in the section of the nitrogen cycle given in the question.
High temperature combustion converts N_2 to NO according to $N_2(g) + O_2(g) \rightarrow 2NO(g)$. This reaction can also be initiated by lightning.
Denitrifying bacteria complete the nitrogen cycle by converting NO_3^- to N_2. They can use the oxygen to oxidise their glucose and obtain energy.

Section B

Question 1.



(a) **H ❶**

Hydrogen is the most abundant element in the universe - over 990 out of every 1000 atoms present.

(b) **Br ❶**

Molten potassium bromide contains $K^+(l)$ and $Br^-(l)$ ions. When electrical current flows through molten KBr, the anions, Br^-, move towards their anode where they are oxidised according to

$$2Br^-(l) \rightarrow Br_2(g) + 2e^-$$

(c) **Pb ❶**

According to the relative positions on the electrochemical series

$$\mathbf{Pb}^{2+}(aq) + 2e^- \rightarrow Pb(s) \qquad -0.13\text{ V}$$

$$Ni^{2+}(aq) + 2e^- \rightarrow \mathbf{Ni}(s) \qquad -0.23\text{ V}$$

The strongest oxidant $Pb^{2+}(aq)$ reacts with the strongest reductant Ni(s).

The reduction $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ occurs at the cathode which is Pb.

(d) **Ir ❶**

When a nucleus emits a β-particle, its atomic number increases by 1, which means the element changes to the one following it on the Periodic Table, but the mass number stays the same, as shown in the balanced equation

$${}^{192}_{76}Os \rightarrow {}^{192}_{77}Ir + {}^{0}_{-1}e$$

(e) **O ❶**

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6\mathbf{O_2}(g)$

(f) **F ❶**

Electronegativity increase across a period and decreases down a group.

(g) **Zn ❶**

Based on the order of subshell filling and the maximum number of electrons in each subshell, the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$, shows that atoms of the element contain 30 electrons. So the element has atomic number 30, i.e. Zn.

(h) **C ❶**

Aluminium is produced by the electrolysis of alumina, Al_2O_3, dissolved in cryolite. The anode reaction $C(s) + O^{2-}(l) \rightarrow CO_2(g) + 4e^-$, gradually consumes the carbon anodes which are periodically replaced.

(i) **Al ❶**

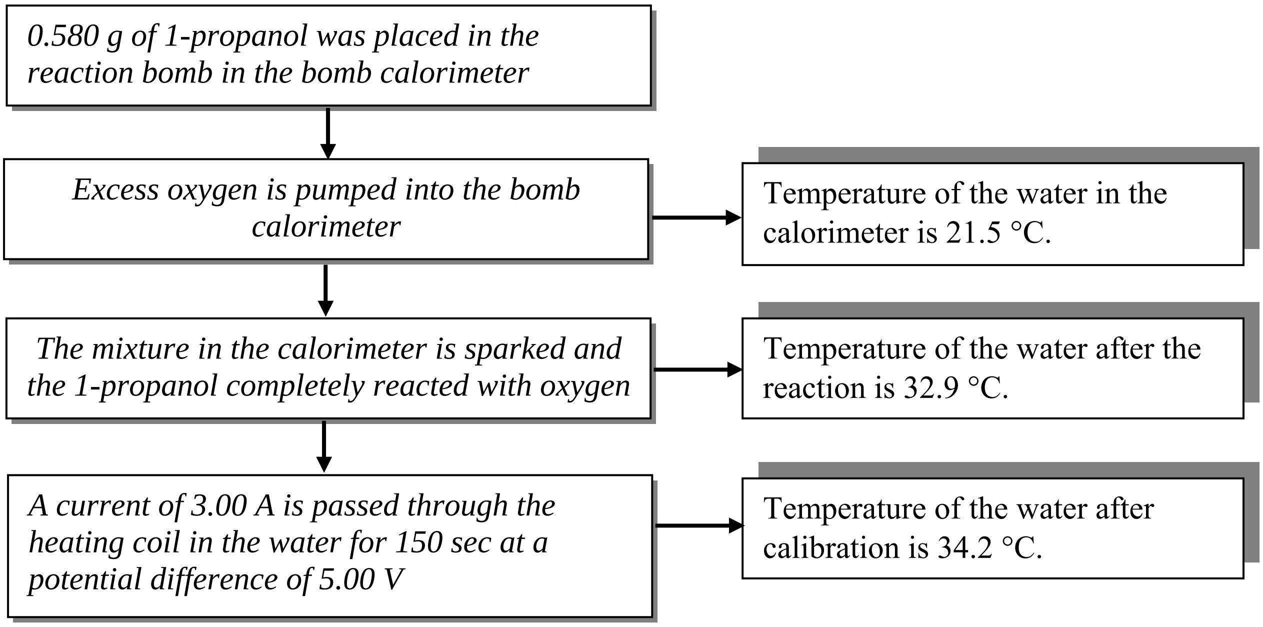
Al_2O_3 is an amphoteric oxide, reacting according to

$Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_4^-(aq)$

(j) **Np** ❶
The transuranium elements are the ones following uranium on the periodic table. They have been synthesised by artificial transmutation, based on the bombardment of uranium and subsequent elements with neutrons and small nuclei.

Question 2.



0.580 g of 1-propanol was placed in the reaction bomb in the bomb calorimeter

Excess oxygen is pumped into the bomb calorimeter

Temperature of the water in the calorimeter is 21.5 °C.

The mixture in the calorimeter is sparked and the 1-propanol completely reacted with oxygen

Temperature of the water after the reaction is 32.9 °C.

A current of 3.00 A is passed through the heating coil in the water for 150 sec at a potential difference of 5.00 V

Temperature of the water after calibration is 34.2 °C.

(a) Energy added during calibration $= VIt$
$= 5.00 \times 3.00 \times 150$
$= 2.25\text{x}10^3$ J
= 2.25 kJ ❶
Temperature change during calibration (ΔT_c) = 34.2 – 32.9
= 1.3 °C
Calibration Factor $= E / \Delta T_c$
= 2.25 kJ / 1.3 °C
= 1.73 kJ °C^{-1} ❶

(b) Temperature change during reaction (ΔT_r) = 32.9 – 21.5
= 11.4 °C ❶
Energy released = Calibration Factor x ΔT_r
= 1.73 kJ °C^{-1} x 11.4 °C
= 19.7 kJ ❶

(c) (i) Heat of combustion = energy released / $m(C_3H_8O)$
= 19.7 kJ / 0.580 g
= 34.0 kJ g^{-1} ❶
(ii) $n(C_3H_gO) = m / M$ = 0.580 / 60.0
= 0.00967 mol
Heat of combustion = energy released / $n(C_3H_8O)$
= 19.7 kJ / 0.00967 mol
= 2.04×10^3 kJ mol^{-1} ❶

(d) $2C_3H_8O(\text{l or g}) + 9O_2(g) \rightarrow 6CO_2(g) + 8H_2O(\text{g or l})$ ❶ for balanced equation; ❶ for correct states

(e) The ΔH value must reflect the number of mole of 1-propanol as shown in the equation. Also because the reaction is exothermic it must have a negative sign.
ΔH $= - 2 \times 2.04 \times 10^3$ kJ mol^{-1}
$= -4.08 \times 10^3$ kJ mol^{-1} ❶❶

(f) Because **petrol is a mixture** (of octane and other alkanes) it **does not have a specific chemical formula nor molar mass**. Hence its heat of combustion is expressed in kJ g^{-1} or kJ L^{-1}. ❶

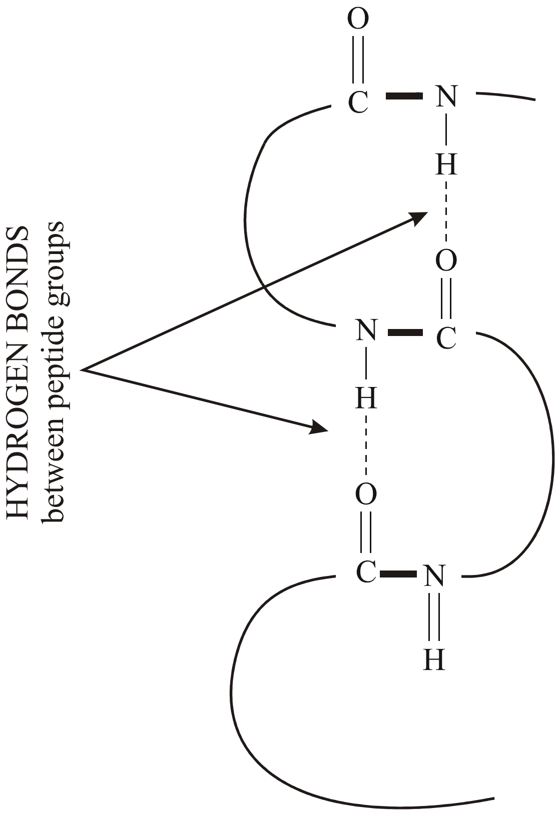
Question 3.

(a) **Proteins** ❶ - identified by the presence of the peptide CONH group

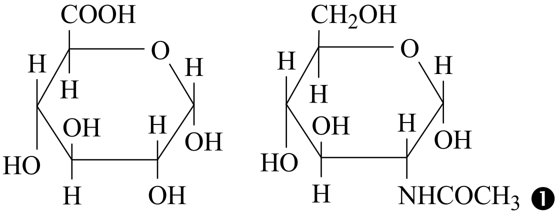
(b) **Condensation** (polymerisation) reaction ❶ - reaction between a carboxyl –COOH group and an amino –NH_2 group on adjacent amino acids.

(c) Proteins have a 'secondary structure' in which the molecules assume a helical shape. **The 'secondary' structure is held together by hydrogen bonds between peptide groups on the same chain.** ❶

The **hydrogen bonds form between the O atom on one peptide group and the H atom on another peptide group**, as shown in the diagram on the right. ❶



(d) (i) Circle one hydroxy group on each structure.



❶

Hydroxy groups on adjacent molecules react with each other.

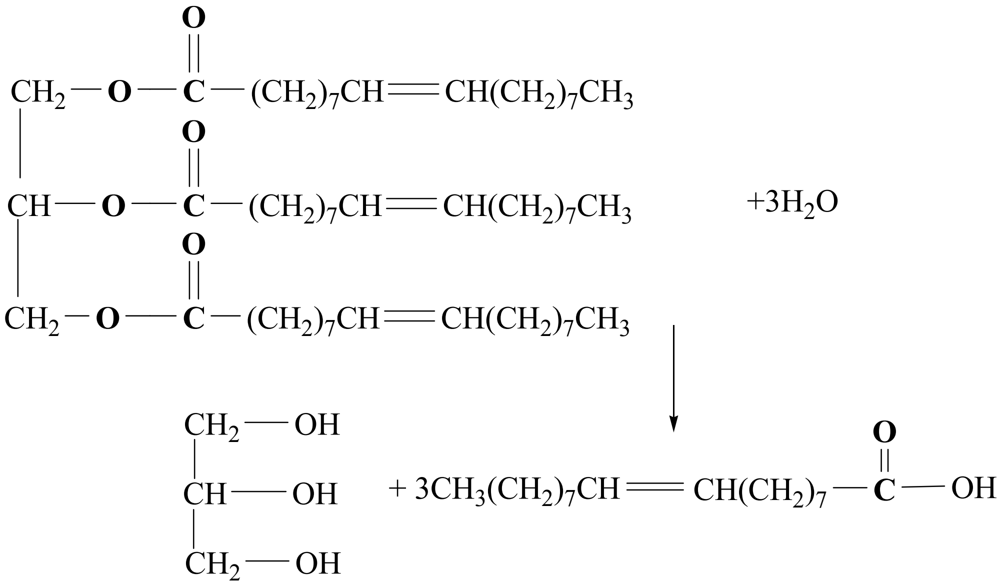
(ii) The hydroxy groups react to produce the **ether** ❶ (C)**-O-**(C) functional group

(iii) **Glucose, $C_6H_{12}O_6$** ❶

(iv) The three polysaccharides associated with the human diet are starch, cellulose and glycogen.
During digestion **starch is broken down into glucose** in an hydrolysis reaction. ❶
Glucose is stored in the body in the form of **glycogen**. ❶
Glycogen is produced from condensation polymerisation of glucose.
Cellulose is not digested (we do not have the appropriate enzyme) but it plays a significant role in the diet as **dietary fibre**. ❶

(e) The structure shown is that of an unsaturated fat. During digestion water reacts at the ester groups, and the fat is hydrolysed to form glycerol and the fatty acid, which have the semi-structural formulae

$CH_2OHCHOHCH_2OH$ ❶ and **$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$** ❶



(f) **Carbon dioxide, CO_2** ❶ and **water, H_2O** ❶ are both produced through the oxidation of carbohydrates, fats and excess protein.

Urea, $(NH_2)_2CO$ ❶ is produced so that the body can eliminate nitrogen from excess protein.

Question 4.

(a) **$2H_2(g) + O_2(g) \rightarrow 2H_2O(g\text{ or }l)$** ❶

(b) Because water is the **only product** of the combustion of **hydrogen**, there is **no CO_2 produced**. Since CO_2 production is a key factor in **global warming**, its lack of production is a significant **environmental benefit**. ❶

(c) During electrolysis, electrons are forced to travel from the positive electrode to the negative electrode. Since electrons always move from the anode (site of oxidation) to the cathode (site of reduction), the (-) electrode is the cathode and the (+) electrode is the anode.

In a dilute aqueous solution of potassium chloride there are two oxidants – $Na^+(aq)$ and $H_2O(l)$, and two reductants – $Cl^-(aq)$ and $H_2O(l)$.

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	1.36 V
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2\mathbf{H_2O}(l)$	1.23 V
$2\mathbf{H_2O}(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.83 V
$K^+(aq) + e^- \rightarrow K(s)$	-2.93 V

Reaction is between the strongest oxidant and the strongest reductant, so the half-equations are

(-) electrode **$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$** ❶

(+) electrode **$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$** ❶

(d) On the basis of the electrochemical series

$\mathbf{Cu}^{2+}(aq) + 2e^- \rightarrow 2\mathbf{Cu}(s)$	0.34V
$2\mathbf{H_2O}(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.83 V

Cu^{2+}(aq) is a stronger oxidant than H_2O ❶, and so is **preferentially reduced** according to $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$. ❶

(e) (i) The environmental advantage of solar cells is **lack of pollution**. ❶

A significant problem with solar cells is their relatively **low efficiency**. ❶

You could also comment on the large solar collection area required, use being limited to regions with significant sunshine, cost.

(ii) **Light energy to electrical energy.** ❶

(f) The Sun's energy is released via **nuclear fusion** reactions. **Nuclear energy is converted into other forms of energy by the fusion of hydrogen nuclei to form helium nuclei** ❶ , generally represented by the equation

$4{}^{1}_{1}\mathbf{H} \rightarrow {}^{4}_{2}\mathbf{He}^{2+} + 2{}^{0}_{1}\mathbf{e}^{+}$ or $4{}^{1}_{1}\mathbf{H} \rightarrow {}^{4}_{2}\mathbf{He} + 2{}^{0}_{1}\mathbf{e}^{+}$ ❶

(g) (i) The fuel, H_2, is oxidised at the anode, so use the electrochemical series to find H_2 in a half equation with an alkaline electrolyte.

$2H_2O(l) + 2e^- \rightarrow \mathbf{H_2}(g) + 2\mathbf{OH}^-(aq)$ -0.83 V

The half-equation for the anode reaction is

$\mathbf{H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-}$ ❶

(ii) The electrodes in a hydrogen-oxygen fuel cell must

- **conduct electricity**
- **not react** with the fuel, the oxidant, or the electrolyte
- must be **porous** to allow contact between the fuel and the electrolyte and the oxidant and the electrolyte. ❶❶ *for all three* / ❶ *for two*

Question 5.

(a) **Most plants require fixed nitrogen** to be present in the soil in forms that can be taken in through the roots, such as NH_4^+ and NO_3^- ions, and used t**o produce amino acids and proteins**. ❶ However, such is the demand for food production that **nitrogen fixing by bacteria in the soil does not supply enough nitrogen.**❶ This natural fixing is supplemented by the use of nitrogenous fertilisers such as NH_4NO_3

(b) The polar and non-polar regions on lecithin molecules enables it to acts as an **emulsifier**. ❶ This ensures that all components of the food – polar and non-polar – are smoothly blended as the **lecithin molecules act as chemical bridges between the polar and non-polar food components** ❶**.** The polar end of the lecithin molecules are attracted to the polar food components whilst the non-polar ends of the lecithin molecules are attracted to the non-polar food components.

(c) The ground state electronic configurations of potassium and sodium are

${}_{19}K$ – $1s^22s^22p^63s^23p^64s^1$ and ${}_{11}Na$ - $1s^22s^22p^63s^1$

K atoms are larger than Na atoms because they have four occupied electron shells compared to three for sodium. ❶

Na and K atoms both have the same **core charge** (+1) – attraction for outer shell electrons – however because this is acting over a larger distance **in K atoms** it is **less effective** and so **less energy is required to remove the electron in the highest energy level**. Therefore K atoms have a lower first ionisation energy than Na atoms. ❶

(d) The electronic configurations of Ca and Mn are

${}_{20}Ca$ - $1s^22s^22p^63s^23p^64s^2$ and

${}_{25}Mn$ - $1s^22s^22p^63s^23p^64s^23d^5$

Calcium exhibits an **oxidation state** of **+2** because it can **donate both of its 4s electrons** when bonding. ❶

The **similarity in energy of the 4s and 3d electrons means than Mn atoms can use electrons from both subshells** when bonding, and hence exhibit oxidation numbers as high as +7. ❶

(e) **The browning of freshly cut banana is due to** a reaction with atmospheric oxygen. Lemon juice contains **ascorbic acid** which **acts as an antioxidant**. ❶ It **reacts preferentially with atmospheric oxygen** ❶ and so slows down the browning of the banana.