SCIENCE TEACHERS ASSOCIATION VICTORIA 2024

TRIAL EXAMINATION

CHEMISTRY
UNITS 3 & 4

Section A (30 marks)

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

Comments for Section A answers

Question 1
A and B are incorrect statements. Bioethanol is the same compound as fossil fuel-derived ethanol so releases the same amount of CO_2 when combusted, so C is incorrect. **Correct Answer: D**

Question 2
When 2.00 mol of C_3H_8 is combusted, 6.00 mol of CO_2 is released $\therefore$ 264 g. The molar enthalpy of combustion of propane is -2220 kJ mol^{-1} (from Data Book page 10) $\therefore$ when 2.00 mol is combusted, 4440 kJ of energy is released. **Correct Answer: D**

Question 3
$q = mc\Delta T = 85.24 \times 4.18 \times (38.25 - 22.50) = 5.612 \times 10^3$ J $= 5.612$ kJ
energy content in kJ g$^{-1} = \dfrac{5.612}{3.40} = 1.65$ kJ g^{-1} **Correct Answer: B**

Question 4
The resolution of the measuring cylinder is a less important source of error in this experiment than the others. **Correct Answer: D**

Question 5
Per 100 g the energy from protein $= 24.2 \times 17$ (Data Book page 10) $= 411$ kJ
$\therefore$ for 17 g the energy $= 0.17 \times 411 = 70$ kJ **Correct Answer: C**

Question 6
Alkanes have the lowest boiling points due to being non-polar so dispersion forces are the only intermolecular forces. Although the others are all polar and can form hydrogen bonds as well as dispersion forces, primary amines have the lowest boiling points due to the $H-N$ bond being less polar than the $H-O$ bond, so weaker hydrogen bonds. Carboxylic acids have the highest boiling points due to being able to form two hydrogen bonds per molecule and they also form dimers with a higher molecular mass so have stronger dispersion forces. **Correct Answer: C**

Question 7
The reaction is endothermic. At 4 mins there was an equilibrium shift to the right, so the temperature increased. CO was removed at 10 mins as [CO] spiked down. At 14 mins, all concentrations suddenly decreased due to an increase in the volume of the container.
Correct Answer: A

Question 8
The hydroxyl group is of higher priority than the amino group. **Correct Answer: B**

Question 9
Hydrogen bonds are responsible for the secondary structure and can be part of the tertiary and quaternary structures. The primary structure is due to covalent bonding. **Correct Answer: A**

Question 10
In the addition reaction, a Br atom is added to each C either side of the C=C bond.

Correct Answer: C

Question 11
Any impurities present in a sample will lower the melting point due to disruption of the solid crystalline structure and make it melt over a larger range due to a higher number of types of bonds present. **Correct Answer: C**

Question 12
The C and H environments in the 3 methyl groups are identical to each other so a total of 3 H environments and 4 C environments. **Correct Answer: A**

Question 13
Due to the non-polar stationary phase, the substance with the highest retention time (peak D) will best match the polarity of the stationary phase i.e. be the least polar. Peak B represents the substance with the highest concentration and peak A the substance with the weakest affinity to the stationary phase. **Correct Answer: C**

Question 14
A peak area of 2500000 indicates a concentration of 25 μg per L in diluted urine. As the urine was diluted 10 times (from 10.0 mL to 100.0 mL), the concentration of the drug in the undiluted urine would be 10 times more = 250 μg per L = 62.5 or 63 μg in 250 mL. **Correct Answer: C**

Question 15
The $CH_3\underline{C}HOHCH_2CH_3$ atom has four different substituents attached to it so is chiral. None of the other molecules contain a C atom that has four different substituents attached to it.

Correct Answer: D

Question 16
The new K will be the inverse of the square root of the previous value i.e. $\frac{1}{\sqrt{2}} = 0.707$.

Correct Answer: B

Question 17
The activation energy for the reverse reaction is 400 – 40 = 360 kJ. Activation energies do not have a sign. **Correct Answer: D**

Question 18
$\left(NO_3^-(aq) + 2H^+(aq) + e^- \rightarrow NO_2(g) + H_2O(l) \right) \times 3$ reduction $\therefore$ oxidising agent

$\left(Ru(s) \rightarrow Ru^{3+}(aq) + 3e^- \right) \times 2$ [Also oxidation number of N in NO_3^- is +5 and in NO_2 is +4 so reduction]

Correct Answer: B

Question 19
The positive electrode during discharge is the cathode so reduction. C and D are incorrect as they are oxidation half-equations. B shows acidic conditions. **Correct Answer: A**
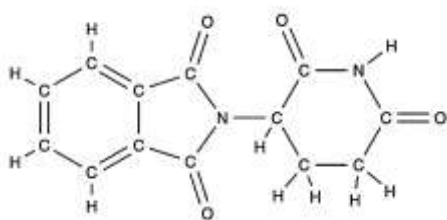
Question 20

$Q = It = 0.550 \times 10.0 \times 60 \times 60 = 19\,800$ C

$n(e^-) = \dfrac{Q}{F} = \dfrac{19\,800}{96\,500} = 0.205$ mol; $n(Zn) = \frac{1}{2} \times n(e^-) = 0.103$ mol; $m(Zn) = 0.103 \times 65.4 = 6.71$ g

Correct Answer: B

Question 21

Although the reaction is exothermic, to increase the rate of any reaction, the temperature is increased. An equilibrium shift to the right does not necessarily mean the forward reaction speeds up and the backward reaction slows down. It means the forward reaction is temporarily faster than the backward reaction. Increasing the pressure (increasing the concentration of the particles) and the use of a catalyst increase the rate of all reactions. **Correct Answer: A**

Question 22

$C_{13}H_{10}N_2O_4$ **Correct Answer: A**

Question 23

Zwitterions have a protonated amino group and deprotonated carboxyl group on the alpha C. They have a net charge of zero and any side chain amino groups or carboxyl groups are uncharged. **Correct Answer: C**

Question 24

Catalysts provide an alternative reaction pathway with a lowered activation energy. They do not affect the change in enthalpy, ΔH, or equilibrium constant of reactions. **Correct Answer: B**

Question 25

The reaction is endothermic with more product than reactant particles. Increasing the temperature and decreasing the pressure will cause an equilibrium shift to the right so increased yield of NO_2. **Correct Answer: C**

Question 26

The negative electrode during discharge is the anode so oxidation. B and C are incorrect as they are reduction half-equations. During recharge, the oxidation number of Ni increased from +2 to +3, therefore it was oxidised, so M is reduced. The MH will therefore be oxidised during discharge. **Correct Answer: A**

Question 27

Due to the many polar hydroxyl, ether and carbonyl groups in the molecule, it will be soluble in a polar solvent such as a water and ethanol mix. The other solvents are non-polar.

Correct Answer: A

Question 28

He is comparing the heats of combustion of different alcohols so the type of alcohol is the independent variable. **Correct Answer: D**

Question 29

Reproducibility refers to how close the results are when the same variable (same types of alcohol) is being measured but under different conditions (different groups of students). Option A will verify the repeatability, not reproducibility of the experiment. **Correct answer: C**

Question 30

Enzymes are denatured (shape of active site is altered) at higher, not lower temperatures than the optimum temperature. The lower temperatures decrease the kinetic energy and the frequency of collisions of the particles and the proportion of collisions that are successful.

Correct Answer: B

Section B (90 marks)

Question 1 (9 marks)

a. Palmitoleic acid has 1 C=C bond per molecule $\therefore$ triglyceride has 3 C=C bonds

$\therefore$ $n(I_2) = 3 \times n(\text{triglyceride})$

$n(\text{triglyceride}) = \dfrac{100}{800.0} = 0.125$ mol **(1 mark)** $\therefore$ $n(I_2) = 0.375$ mol **(1 mark)**

$\therefore$ $m(I_2) = 0.375 \times 253.8 = 95.2$ g **(1 mark)**

b. $CH_3(CH_2)_5CH=CH(CH_2)_7COOCH_3$ **(1 mark)**

c. **i.** $C_{17}H_{32}O_2(l) + 24O_2(g) \rightarrow 17CO_2(g) + 16H_2O(l)$

(1 mark for correctly balanced equation (semi-structural formula OK) and 1 mark for correct states of matter)

ii. As the reaction is occurring at SLC, the only greenhouse gas is CO_2.

$n(C_{17}H_{32}O_2) = \dfrac{14.26}{268.0} = 0.05321$ mol **(1 mark)**

$n(CO_2) = 17 \times n(C_{17}H_{32}O_2) = 0.9046$ mol **(1 mark)**

$V(CO_2) = n \times V_m = 0.9046 \times 24.8 = 22.4$ L **(1 mark)**

Question 2 (7 marks)

a. $CF = \dfrac{VIt}{\Delta T} = \dfrac{5.45 \times 1.80 \times 6.00 \times 60}{6.9} = 5.1 \times 10^2$ J° C^{-1} **(1 mark)** $= 0.51$ kJ °C^{-1} **(1 mark)**

b. **i.** $n(HCl) = 0.100 \times 0.20 = 0.020$ mol; $n(Mg) = \dfrac{0.18}{24.3} = 0.0074$ mol **(1 mark)**

$n(HCl)$ required $= 2 \times n(Mg) = 0.0148$ mol $\therefore$ HCl in excess $\therefore$ Mg limiting

(1 mark for Mg being the limiting reactant with appropriate working)

ii. $E = CF \times \Delta T = 0.51 \times 5.1 = 2.6$ kJ **(1 mark)**

$\Delta H = \dfrac{E}{n} = \dfrac{2.6}{0.0074} = 351 = -3.5 \times 10^2$ kJ mol^{-1} **(1 mark)**

iii. The experimental value for ΔH was lower than the published value of 457 kJ mol^{-1} on the previous page.

(Note: poor insulation of the polystyrene cup would have been accounted for during the calibration stage, giving a high calibration factor. This would not produce a lower than expected ΔH value.)

(Any one of the following for 1 mark)

- loss of heat to surroundings during experiment before the lid was replaced
- incomplete reaction
- less than 0.18 g of Mg was actually weighed out
- less than 0.18 g Mg was placed in the cup

Question 3 (7 marks)

a. $[N_2] = \dfrac{n}{V} = \dfrac{2.0}{2.0} = 1.0$ M; $[H_2] = \dfrac{1.8}{2.0} = 0.90$ M; $[NH_3] = \dfrac{0.50}{2.0} = 0.25$ M **(1 mark)**

$Q = \dfrac{[NH_3]^2}{[N_2][H_2]^3} = \dfrac{0.25^2}{1.0 \times 0.90^3} = 0.086$ M^{-2} **(1 mark)**

The system is not at equilibrium Q ≠ K, **OR** Q > K, **OR** 0.086 ≠ 0.052, **OR** 0.086 > 0.052

**(1 mark for the system not being at equilibrium with evidence)**

b.   Increasing the pressure would increase the yield of NH_3 **(1 mark)** as it would favour the reaction that produces fewer particles in order to decrease the pressure **(1 mark)**. In this case, it is the forward reaction as there are fewer product than reactant particles in the balanced equation **(1 mark)**.

c.   Decrease **(1 mark)**
(A decrease in product will favour the forward reaction. The reverse reaction rate will initially decrease as there are fewer particles of ammonia to collide, and then slowly increase as more ammonia particles are produced. Initially, there is no change in the rate of the forward reaction, but it will then decrease as the concentrations of the reactants decreases and fewer collisions occur between reactant particles per given time.)

Question 4 (8 marks)

a. **(1 mark for labelling each of the following = 5 marks)**
- anode and cathode and their polarity
- electrode materials
- electrolytes
- direction of electron flow
- possible salt bridge composition and direction of ion flow
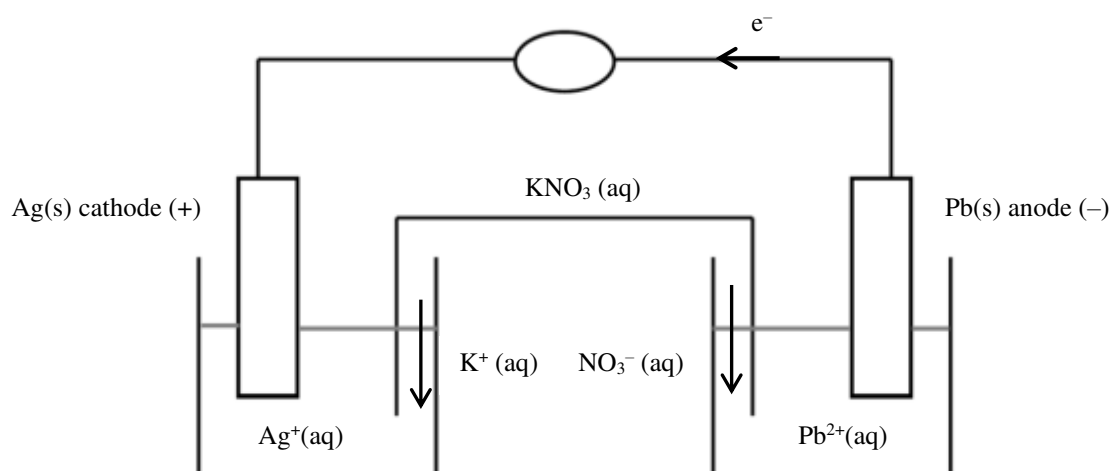
b. $+0.80 - -0.13 = 0.93$ V **(1 mark)** (values from Data Book page 2)

c. **(Any two of the following for 1 mark each = 2 marks)**
- resistance within the internal circuit / salt bridge
- resistance within the external circuit
- oxide coatings on the electrodes

Question 5 (10 marks)

a.
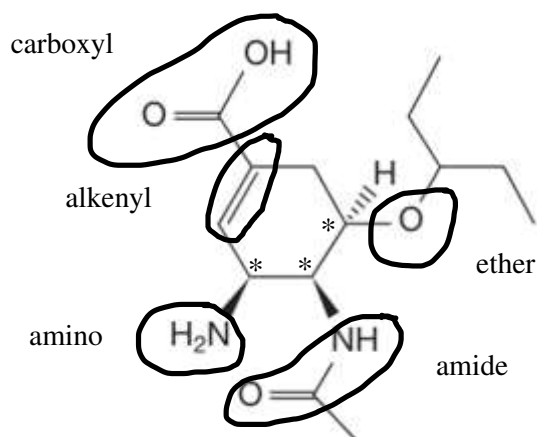
(Any 3 of the circled and labelled groups for 1 mark each = 3 marks)

b. 3 **(1 mark)** (marked * on the diagram above)

c. Tamiflu binds to the active site of the neuraminidase enzyme, preventing the natural substrate, sialic acid, from binding (**1 mark**). This inhibits the enzyme. The shape of Tamiflu and sialic acid are similar so both can bind to the active site. Tamiflu must bind more strongly than sialic acid if it is to be a competitive inhibitor (**1 mark**).
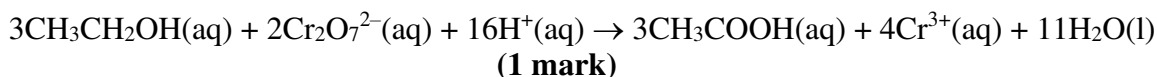**OR**
diagram(s) to show this (**2 marks**)

d.   **i.** temperature $\approx 37°C$ (**1 mark**) and pH ≈ 7 (**1 mark**)

     ii. If these were not controlled, the shape of the enzyme's active site may be altered therefore the medicine may no longer bind properly as it no longer has the complementary shape (**1 mark**). It is no longer a valid experiment (**1 mark**).

Question 6 (8 marks)

a. oxidation: $CH_3CH_2OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$ (**1 mark**)

overall:
$3CH_3CH_2OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \rightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$
(**1 mark**)

b. $n(Cr_2O_7^{2-}) = 0.175 \times 0.01820 = 0.00319$ mol (**1 mark**)

c. $n(CH_3CH_2OH) = \dfrac{3}{2} \times n(Cr_2O_7^{2-}) = 0.00478$ mol (**1 mark**)

d. $\dfrac{250.0}{20.00} \times 0.00478 = 0.0597$ mol (**1 mark**)

e. $c = \dfrac{n}{V} = \dfrac{0.0597}{0.02500} = 2.39$ mol L^{-1} (**1 mark**)

f. Their calculated concentration would be higher than expected (**1 mark**) as each 20.00 mL aliquot would contain a higher than expected $n(CH_3CH_2OH)$ therefore require a higher than expected titre volume of $Cr_2O_7^{2-}$ (**1 mark**). This results in a higher than expected calculated $n(Cr_2O_7^{2-})$, $n(CH_3CH_2OH)$ and $[CH_3CH_2OH]$.

Question 7 (9 marks)

a. A and B (**1 mark**)
Both of these contain a carboxyl group and there was a broad peak at ≈ 3000 cm^{-1}, corresponding to O−H (acid) (**1 mark**).
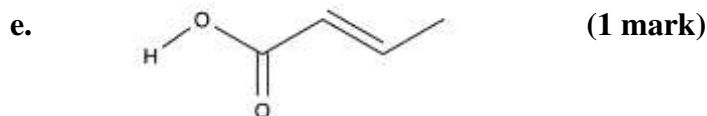Molecules C and D would not have this peak (**1 mark**).

b. B (**1 mark**)
The peak at ≈ 172 ppm corresponds to RCOOH which both A and B have. The peaks at $\approx$ 148 ppm and ≈ 122 ppm correspond to $R_2C=CR_2$ which only B has (**1 mark**).
OR
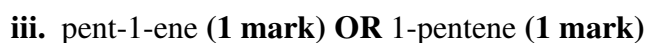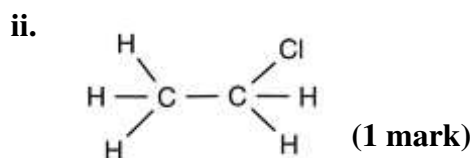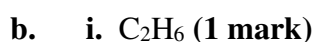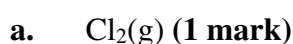The R-CH$_2$-R in A would produce two peaks at 20-45 ppm that are not present in the spectrum (**1 mark**).

c. 4 (**1 mark**) (due to 4 unique H environments)

d.   **i.** $[C_3H_5]^+$ **(1 mark) OR** $[CH_3CHCH]^+$ **(1 mark)**

     ii. (Any one of the following for 1 mark)
- Compound B has the fragment CH_3CHCH, whereas A does not.
- The molecular ion peak is at 86 m/z and the relative mass of compound B is 86 whereas it is 88 for compound A.

e.   **(1 mark)**

Question 8 (12 marks)

a. $Cl_2(g)$ **(1 mark)**

b.   **i.** C_2H_6 **(1 mark)**

     ii.

    (1 mark)

     iii. pent-1-ene **(1 mark) OR** 1-pentene **(1 mark)**

     iv. $CH_3(CH_2)_3COOH$ **(1 mark)**

c.   **i.** lower boiling point **(1 mark)**
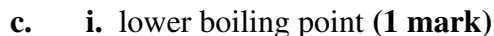
     ii. React a sample of each fraction with acidified $Cr_2O_7^{2-}$ or MnO_4^- and heat it. The resulting mixture must be distilled to isolate the organic compound. Then test the pH of this fraction with blue litmus paper. If it turns red, the original fraction contained pentan-1-ol. If it stays blue, it contained pentan-2-ol.
       OR
       React the produced organic compound fraction with sodium carbonate or sodium hydrogen carbonate. If a gas is produced that turns limewater milky, the original fraction contained pentan-1-ol.
       (1 mark for a relevant qualitative test. 1 mark for the expected results)

d. $CH_3CH_2OH(l) + CH_3CH_2CH_2CH_2COOH(l) \rightarrow CH_3CH_2OOCCH_2CH_2CH_2CH_3(l) + H_2O(l)$
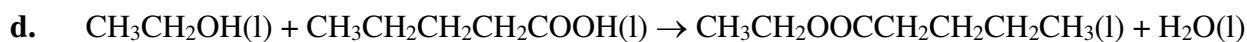
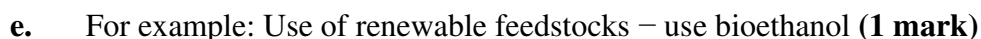 M_r: 46.0   102.0   130.0   18.0

$$\% \text{ atom economy} = \frac{\text{molar mass of desired product}}{\text{molar mass of all reactants or products}} \times 100$$

$$= \frac{130.0}{46.0 + 102.0} \times 100 = 87.8\% \quad \textbf{OR} \quad = \frac{130.0}{130.0 + 18.0} \times 100 = 87.8\%$$

     (1 mark for correct molar masses)
     (1 mark for correct mathematical relationship)
     (1 mark for correctly calculated answer)

e.   For example: Use of renewable feedstocks − use bioethanol **(1 mark)**

Question 9 (12 marks)

a. For example: If the current is increased then the percentage yield of tin at the cathode would increase **(1 mark)**.

b.   **i.** $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$ **(1 mark)**
    ii. $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$ **(1 mark)**

c.   % yield $= \dfrac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \dfrac{\text{actual m(Sn) at cathode}}{\text{theoretical m(Sn) at cathode}} \times 100$

actual m(Sn) at cathode $= 14.12 - 13.54 = 0.58$ g **(1 mark)**

theoretical m(Sn) from Faraday's Laws:

$Q = It = 1.35 \times 15 \times 60 = 1215$ C **(1 mark)**

$n(e^-) = \dfrac{Q}{F} = \dfrac{1215}{96500} = 0.0126$ mol; $n(Sn) = ½ \times n(e^-) = 0.00630$ mol **(1 mark)**

$\therefore$ m(Sn) $= 0.00630 \times 118.7 = 0.747$ g **(1 mark)**

$\therefore$ % yield $= \dfrac{0.58}{0.747} \times 100 = 78\%$ **(1 mark to 2 significant figures)**

d.   **i.** random error **(1 mark)**
    ii. Rewrite her aim and hypothesis to state mass lost at anode rather than percentage yield at cathode **(1 mark)**.
    OR
    Use the mass lost at cathode results as that answers the aim **(1 mark)**.

e.   **(Any two of the following for 1 mark each = 2 marks)**
- use the acetone in a fume cupboard or well-ventilated room
- wear safety glasses
- use gloves
- keep away from sources of ignition

Question 10 (8 marks)

a. It will be considered green if the electricity used for the electrolysis **(1 mark)** comes from a renewable source **(1 mark)** such as solar or wind energy.

b.   **i.** $2H^+ + 2e^- \rightarrow H_2$ **(1 mark – states of matter not required)**

    ii. (1 mark per relevant point raised re sustainability to total of 3 marks)
For example: Electrolysis of seawater is more sustainable than electrolysis of purified water due to

- The electrodes for purified water use critically endangered metals so will not be available for future generations unlike the non-precious catalysts used in seawater electrolysis **(1 mark)**.
- Electrolysis of seawater is almost 100%, whereas electrolysis of purified water is only 80% efficient. Green Chemistry Principle – design for energy efficiency, or less electricity used to make the same amount of $H_2(g)$ **(1 mark)**.
- Seawater is a more abundant resource than fresh water. Allows fresh water to be used for SD Goal 6: clean water and sanitation, or more fresh water will be available for future generations **(1 mark)**.

c.   **(Any two of the following for 1 mark each = 2 marks)**
- Grey hydrogen uses non-renewable fossil fuels so less sustainable. Green hydrogen uses renewable water **(1 mark)**.
- Grey hydrogen releases greenhouse gases that contribute to enhanced global warming. Green hydrogen does not **(1 mark)**.
- Steam reforming requires large amounts of energy to create steam and the first reaction is endothermic. If this energy comes from burning fossil fuels, they are non-renewable and greenhouse gases are released. This is not the case for green hydrogen **(1 mark)**.
- The production of green hydrogen does not release air pollutants whereas the steam reforming of methane does **(1 mark)**.
- The production of grey hydrogen involves the extraction, transport and storage of methane. If it leaks into the environment, it is a powerful greenhouse gas. Green hydrogen does not **(1 mark)**.

END OF SUGGESTED SOLUTIONS