

VCE Chemistry Unit 3

Suggested Solutions

2024 Trial Examination

Section A – Multiple-choice questions

1	☐ A	☐ B	☒ C	☐ D
2	☐ A	☐ B	☒ C	☐ D
3	☐ A	☒ B	☐ C	☐ D
4	☐ A	☐ B	☐ C	☒ D
5	☐ A	☒ B	☐ C	☐ D
6	☐ A	☒ B	☐ C	☐ D
7	☒ A	☐ B	☐ C	☐ D
8	☐ A	☐ B	☒ C	☐ D
9	☐ A	☐ B	☐ C	☒ D
10	☐ A	☐ B	☒ C	☐ D
11	☒ A	☐ B	☐ C	☐ D
12	☐ A	☐ B	☐ C	☒ D
13	☐ A	☒ B	☐ C	☐ D
14	☐ A	☒ B	☐ C	☐ D
15	☒ A	☐ B	☐ C	☐ D
16	☒ A	☐ B	☐ C	☐ D
17	☐ A	☐ B	☒ C	☐ D
18	☒ A	☐ B	☐ C	☐ D
19	☐ A	☐ B	☐ C	☒ D
20	☒ A	☐ B	☐ C	☐ D

Question 1 C

C is correct. The combustion of a fuel occurs by an exothermic reaction that has a large enthalpy change (ΔH) and a reasonably small activation energy. This is best represented by energy profile 3.

A is incorrect. This energy profile represents an exothermic reaction; however, ΔH is too small and the activation energy is too large for the diagram to represent the combustion of a fuel.

B is incorrect. This energy profile represents an endothermic reaction.

D is incorrect. This energy profile represents an exothermic reaction; however, ΔH is too small for the diagram to represent the combustion of a fuel.

Question 2 C

C is correct. System III would have an equilibrium constant (K) with no units. Thus, in the equilibrium expression, the volume would cancel out and only the number of moles of each component present at equilibrium would remain. As the system does not require the concentration of the components to be known to calculate K , the volume of the reaction vessel is not required.

A, **B** and **D** are incorrect. These systems require the concentration of components to be known to calculate K ; thus, the volume of the reaction vessel must be known.

Question 3 B

B is correct. Decreasing the volume while the system is maintained at a constant temperature results in an increase in pressure. According to Le Chatelier's principle, increasing the pressure of the system will cause the reaction to move towards the side with fewer moles of gas to partially oppose the change. To increase the yield of these systems, the products must have fewer moles of gas so that they are favoured. Only systems I and IV meet this requirement.

A, **C** and **D** are incorrect. In system II, the reactants will be favoured as there are fewer moles of gas; thus, changing the volume would decrease the yield. In system III, the reactants and products have equal moles of gas; thus, changing the volume would not alter the yield.

Question 4 D

D is correct and **C** is incorrect. In a galvanic cell, electrons that are produced by oxidation at the anode travel towards the cathode. Anions (negatively charged ions) complete the circuit of charge by travelling from the cathode towards the anode via the salt bridge. This balances the charges in each half-cell and maintains half-cell neutrality.

A is incorrect. The ionic compound chosen for the salt bridge must be water soluble so that ions can move between the half-cells.

B is incorrect. The ionic compound chosen for the salt bridge should not contain a strong reductant or a strong oxidant as these ions could interfere with the redox reactions occurring in each half-cell.

Question 5 B

B is correct. In the galvanic cell shown, Cu^{2+} is the strongest oxidant and Cd is the strongest reductant. Therefore, the following reactions will occur.

- At the cathode: $\text{Cu}^{2+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Cu}^{+}(\text{aq})$
- At the anode: $\text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{e}^{-}$

Hence, copper(II) ions are reduced to copper(I) ions.

A is incorrect. To recharge the cell, the spontaneous electrode reactions need to be reversed, which requires a voltage higher than 0.56 V.

C is incorrect. As cadmium is the anode, it will be oxidised to produce cadmium ions.

D is incorrect. To recharge the cell, the positive terminal of the power supply would need to be attached to the positive electrode of the cell, and the negative terminal would need to be attached to the negative electrode.

Question 6 B

B is correct. To recharge the secondary cell, an electrolytic reaction is required; that is, electrical energy is used to force a non-spontaneous redox reaction to occur.

A is incorrect. Chemical energy is not converted to electrical energy only in a secondary cell; for example, heat energy is also produced.

C is incorrect. The electrodes of fuel cells, not secondary cells, act as catalysts.

D is incorrect. No new reactants are added in a secondary cell. When recharging occurs, the secondary cell uses the products of the galvanic cell reaction as the reactants of an electrolytic cell reaction.

Question 7 A

A is correct. In a secondary cell, the products of the energy-producing reaction must be kept in contact with the electrodes because they become the reactants for the non-spontaneous redox reaction that recharges the cell. This does not occur in a primary cell as the products of the reaction are not available at the electrodes.

B is incorrect. In a secondary cell, electrons move away from the positively charged anode when the cell is recharging.

C and **D** are incorrect. These statements are true for both primary and secondary cells.

Question 8 C

$$n(\text{V}) = \frac{m}{M} = \frac{0.318}{50.9} = 0.006248 \text{ mol}$$

The formula of a vanadium ion is V^{3+} . Thus:

$$n(\text{e}^{-}) = 3 \times n(\text{V}) = 3 \times 0.006248 \text{ mol} = 0.01874 \text{ mol}$$

$$n(\text{e}^{-}) = \frac{Q}{F}, \quad \therefore Q = n(\text{e}^{-}) \times F = 0.01874 \times 96\,500 = 1809 \text{ C}$$

$$Q = It, \quad \therefore t = \frac{Q}{I} = \frac{1809}{0.598} = 3024 \text{ seconds} = 50.4 \text{ minutes}$$

Question 9 D

D is correct, and **A** and **B** are incorrect. It is unknown whether the reaction is exothermic or endothermic; thus, it cannot be determined whether raising the temperature of the reaction would increase or decrease the value of K .

C is incorrect. Changing the temperature would change the value of K ; thus, it would not remain at 120.

Question 10 C

This reaction has been derived from the previous reaction by reversing the equation and halving the coefficients. Thus, the value of K is given by:

$$\left(\frac{1}{K}\right)^{\frac{1}{2}} = \left(\frac{1}{120}\right)^{\frac{1}{2}} = 0.09128 = 9.13 \times 10^{-2}$$

Question 11 A

At $t = 0$, two reactants are present and one product has not yet formed. Therefore, the reaction must be $X + Y \rightleftharpoons Z$. At t_1 , the mixture is heated and the product increases in concentration. Hence, according to Le Chatelier's principle, the forward reaction must be endothermic.

Question 12 D

D is correct. The product of the fermentation is a dilute ethanol solution. To produce a more concentrated and sustainable ethanol solution that will ignite in a car engine, distillation must occur.

A is incorrect. Respiration in living things is the process of oxidising glucose to produce energy.

B is incorrect. Electrolysis is not used after fermentation in the production of ethanol for use as a fuel.

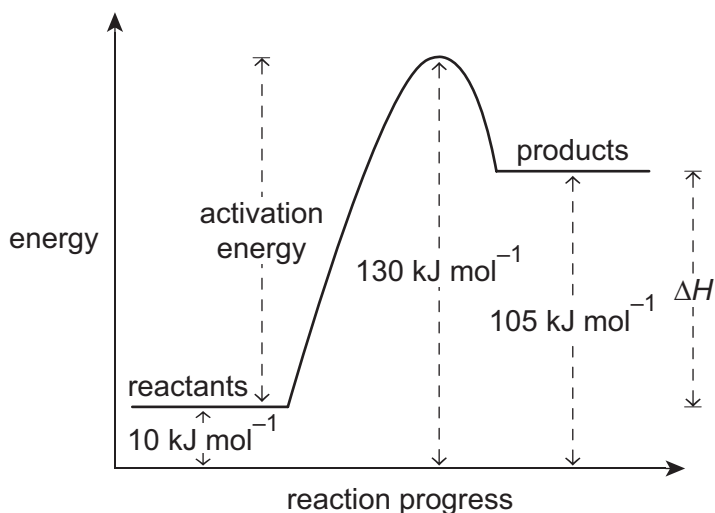
C is incorrect. Catalysts increase the rate of a reaction, but they are not used to produce a more sustainable transport fuel.

Question 13 B

Regardless of the source of ethanol, the molecule has the same energy content.

Question 14 B

The energy profile of the catalysed reaction is shown below.



Thus, the activation energy is $130 - 10 = 120 \text{ kJ mol}^{-1}$ and $\Delta H = 105 - 10 = +95 \text{ kJ mol}^{-1}$. For the uncatalysed reaction, ΔH would remain the same, but the activation energy would be higher than 120 kJ mol^{-1} .

Question 15 A

To find the energy content of a food, the sum of the energy contributed by protein, fats and carbohydrates needs to be found. Using the energy values from the Data Booklet to find the energy content of baked beans gives:

$$\text{energy content} = (4.9 \times 17) + (0.5 \times 37) + (14.3 \times 16) = 331 \text{ kJ}$$

To find the energy content per gram, $\frac{331}{100} = 3.31 \text{ kJ g}^{-1}$. This is closest to 5 kJ g^{-1} .

Question 16 A

A is correct.

$$\text{heat energy of methanol} = 0.40 \times \frac{726}{32.0} = 9.08 \text{ kJ}$$

As this is lower than the energy transferred to the water (9.15 kJ), methanol could not have been used in the fuel burner in the experiment.

$$\text{heat energy of ethanol} = 0.40 \times \frac{1370}{46} = 11.9 \text{ kJ}$$

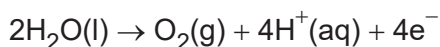
This is greater than the energy transferred to the water. Thus, using ethanol in the fuel burner could have produced the temperature rise and energy transfer observed in the experiment. The additional heat energy of ethanol would have allowed for loss of heat to the environment and the container.

B, C and D are incorrect. These statements describe what may have occurred in the experiment, but they do not explain the higher-than-expected heat transfer.

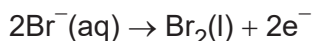
Question 17 C

The anode (positive electrode) is where oxidation occurs. The stronger reductant is discharged preferentially.

In the NaCl cell, water is a stronger reductant than the chloride ions, which results in the following reaction.

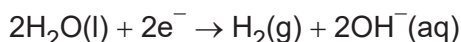


In the KBr cell, the bromide ions are a stronger reductant than water, which results in the following reaction.



At the cathode (negative electrode), the stronger oxidant is reduced.

In both the NaCl and KBr cells, water is a stronger oxidant than the metal ions (sodium or potassium), so the following reaction occurs.



Thus, the same products are produced at the negatively charged cathodes of each cell, but different products are produced at the positively charged anodes of each cell.

Question 18 A

The oxidation numbers of Mn in these compounds are found by using the oxidation number of oxygen as -2 , and summing the oxidation numbers to equal the charge on the species.

For example, for Mn_3O_4 :

$$\text{ON}(\text{Mn}) \times 3 + (-2 \times 4) = 0$$

$$\begin{aligned}\text{ON}(\text{Mn}) &= \frac{8}{3} \\ &= +2.7\end{aligned}$$

Thus, the oxidation numbers for Mn in each compound are:

Mn_3O_4	+2.7
KMnO_4	+7
Mn_2O_3	+3
MnO_2	+4

Hence, the oxidation number of Mn is lowest in compound **A**.

Question 19 D

D is correct. Systematic errors are caused by limitations in the equipment, materials or calibration. Repeating the experiment or averaging the results will not minimise the error because the source of the error remains. If an incorrectly labelled solution is used, this will result in a systematic error.

A and **B** are incorrect. These options are random errors caused by unpredictable variations in the measurement process. Repeating the experiment and taking an average of the results will minimise the effect that random errors have on the results of the experiment.

C is incorrect. This option is a mistake or personal error that invalidates the experiment. The correct equipment and materials, which are in line with the aim of the experiment, must be used for an investigation to be valid.

Question 20 A

The combustion of ethane is given by the equation $\text{C}_2\text{H}_6(\text{g}) + 3\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$.

Multiplying the equation by 2 gives 2 mol of ethane and the simplest whole number coefficients. Thus, the equation becomes $2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$.

Molar heat of combustion for ethane, $\Delta H = 1560 \text{ kJ mol}^{-1}$. Thus, for 2 mol of ethane:

$$\Delta H = 2 \times 1560 = 3120 \text{ kJ mol}^{-1}$$

As combustion is an exothermic reaction, ΔH is negative; thus, $\Delta H = -3120 \text{ kJ}$.

Section B

Question 1 (10 marks)

a. For example, any one of:

- $\text{C}_8\text{H}_{18}(\text{l}) + 12\text{O}_2(\text{g}) \rightarrow 7\text{CO}_2(\text{g}) + \text{CO}(\text{g}) + 9\text{H}_2\text{O}(\text{l})$
- $\text{C}_8\text{H}_{18}(\text{l}) + 11\text{O}_2(\text{g}) \rightarrow 5\text{CO}_2(\text{g}) + 3\text{CO}(\text{g}) + 9\text{H}_2\text{O}(\text{l})$
- $\text{C}_8\text{H}_{18}(\text{l}) + 10\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 5\text{CO}(\text{g}) + 9\text{H}_2\text{O}(\text{l})$

2 marks

1 mark for providing the correct reactants and products.

1 mark for balancing the equation and providing states.

Note: Accept other suitable equations.

b. i. For example:

Bioethanol is a renewable resource, meaning that an endless supply is available, whereas petrol is derived from fossil fuels and thus has finite reserves.

1 mark

Bioethanol does not increase the levels of greenhouse gases in the atmosphere. The carbon dioxide released during its combustion is offset by the carbon dioxide that was absorbed during photosynthesis that occurred in the plant materials used to produce the bioethanol.

1 mark

ii. $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$

2 marks

1 mark for providing the correct reactants and products.

1 mark for balancing the equation and providing states.

c. i. The unit MJ kg^{-1} is used because biodiesel is a blended fuel. If there was only one compound present in biodiesel, its molar mass could be determined and the unit MJ mol^{-1} could be used.

1 mark

ii. $q = mc\Delta T = 2560 \times 4.18 \times (65 - 25) = 428\,032 \text{ J} = 0.4280 \text{ MJ}$

1 mark

$$m(\text{biodiesel}) = \frac{\text{energy}}{\text{energy per gram}} = \frac{0.4280}{36.5} = 0.01173 \text{ kg}$$

1 mark

$$V(\text{biodiesel}) = \frac{\text{mass}}{\text{density}} = \frac{0.01173}{0.91} = 0.0129 = 0.013 \text{ L}$$

1 mark

Question 2 (10 marks)

- a. i. beaker 3 < beaker 1 < beaker 2 1 mark
- ii. For a reaction to occur, the reactant particles must collide with sufficient energy in the correct orientation. At room temperature, it is evident that the reaction will occur. 1 mark
- When the stalks have a larger surface area exposed, more of the oxalic acid molecules are available to react with permanganate ion particles when collisions occur. 1 mark
- Beaker 2 contains the stalk with the greatest surface area exposed and, thus, this solution will decolourise most rapidly. This is followed by the solution in beaker 1, as this stalk has less surface area exposed. The solution in beaker 3 will decolourise most slowly, as this stalk has not been cut and thus has the least surface area exposed. 1 mark
- iii. In an experiment, all the variables except the one being tested should be kept consistent. Cutting the three 50 mm sections from one stalk ensures that the only variable changed is the amount of surface area exposed, and thus any effect seen in the investigation must have been caused by that variable being changed. 1 mark
- b. i. $n(\text{MnO}_4^-) = cV = 0.0650 \times 0.01000 = 6.50 \times 10^{-4} \text{ mol}$ 1 mark
- ii. The fastest rate of reaction occurred at 55°C and the solution took 50 seconds to decolourise. 1 mark
- Therefore:
- $$\text{average rate} = \frac{6.50 \times 10^{-4}}{\frac{50}{60}} = 7.8 \times 10^{-4} \text{ mol of MnO}_4^- \text{ min}^{-1}$$
- 1 mark
- Note: Consequential on answer to Question 2b.i.*
- c. For example, any one of:
- The reaction uses hydrogen ions as a reactant and so the pH will increase as the reaction proceeds. 1 mark
 - A pH meter could be used to accurately measure the changes in pH over time and thus the rate of reaction as a change in hydrogen ion concentration per unit time could be determined. 1 mark
 - Carbon dioxide gas is given off as a product of the reaction, so the open system will lose mass. 1 mark
 - Conducting the experiment on a balance will allow the mass loss per unit time, and thus the rate of reaction, to be determined. 1 mark

Question 3 (7 marks)

a. $[\text{SO}_2] = \frac{1.00}{2.00} = 0.500 \text{ M}, [\text{O}_2] = \frac{2.00}{2.00} = 1.00 \text{ M}$

$$K = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} \quad 1 \text{ mark}$$

$$[\text{SO}_3] = \left(K \times [\text{SO}_2]^2 \times [\text{O}_2] \right)^{\frac{1}{2}}$$

$$= \left(81 \times 0.500^2 \times 1.00 \right)^{\frac{1}{2}} \quad 1 \text{ mark}$$

$$= 4.5 \text{ M}$$

$$n(\text{SO}_3) = cV = 4.5 \times 2.00 = 9.0 \text{ mol} \quad 1 \text{ mark}$$

- b. One advantage of using a high temperature is that it will result in a higher rate of reaction. 1 mark

At higher temperatures, a higher proportion of reactant molecules have energies equal to or greater than the activation energy, so a higher proportion of collisions are successful; this leads to an increased rate of reaction. 1 mark

One disadvantage of using a high temperature is that it will produce a lower yield of products. 1 mark

Heating an exothermic reaction will cause the reactants to be favoured because the reverse reaction consumes heat and so partially opposes any temperature increase; this leads to a lower yield of products. 1 mark

Question 4 (8 marks)

- a. i. Given that water is a molecular species that ionises only to a very slight extent, there are few ions in pure water to conduct electricity. Adding a small number of K^+ and NO_3^- ions creates an electrolyte that will conduct electricity very well. 1 mark



Note: The overall reaction is $2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$. Two volumes of hydrogen gas are produced for every one volume of oxygen gas; thus, hydrogen gas is produced at electrode X and oxygen gas is produced at electrode Y.

- iv. If the electricity source used during the electrolysis reaction was renewable, such as solar or wind energy, then the hydrogen gas produced could be classified as green hydrogen. 1 mark

- b. i. $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ 1 mark
- ii. catalyst (or enzyme) that increases the rate of reaction 1 mark
- iii. For example:
Hydrogen contains a high amount of stored energy per gram; for example, it contains about three times more energy than octane per gram of fuel. 1 mark
- iv. For example:
Given that hydrogen is a gas at room temperature, it must be compressed and/or cooled to store an appropriate amount of energy in a container of reasonable size. 1 mark

Question 5 (10 marks)

- a. i. $2\text{Ag}^+(\text{aq}) + \text{Sn}^{2+}(\text{aq}) \rightarrow 2\text{Ag}(\text{s}) + \text{Sn}^{4+}(\text{aq})$ 2 marks
1 mark for providing the correct reactants and products.
1 mark for balancing the equation and providing states.
- ii. $\text{Sn}^{2+}(\text{aq}) \rightarrow \text{Sn}^{4+}(\text{aq}) + 2\text{e}^-$ 1 mark
- iii. $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$ 1 mark
- b. i. The cell reactions occur on the surface of the electrodes, and having porous electrodes allows the gaseous reactants to permeate the electrodes. 1 mark
Given that porous electrodes will allow a higher concentration of gaseous reactants and a greater surface area for the reactions to occur, the efficiency of the cell is greatly increased. 1 mark
- ii. $Q = It = 0.49 \times 2.0 \times 60 \times 60 = 3528 \text{ C}$
 $n(\text{e}^-) = \frac{Q}{F} = \frac{3528}{96\,500} \text{ mol}$ 1 mark
 $n(\text{CH}_4) = \frac{n(\text{e}^-)}{8} = \frac{3528}{96\,500 \times 8} = 4.5699 \times 10^{-3} \text{ mol}$ 1 mark
 $m(\text{CH}_4) = n \times M = 4.5699 \times 10^{-3} \times 16.0 = 0.073 \text{ g}$ 1 mark
- iii. For example:
A primary cell has a limited amount of reactants stored within the cell, whereas a fuel cell has reactants continuously being fed into the cell from outside storage. 1 mark

Question 6 (10 marks)

- a. i. It is quite difficult to measure heat changes in a reaction directly, but temperature changes can be measured easily using a calorimeter. Calibration involves linking the energy change to a temperature change by determining a calibration factor. 1 mark
- ii. The water molecules close to the heating element would have a higher average kinetic energy than the water molecules that are further away. As these high-energy molecules disperse after heating has ceased, they collide with low-energy molecules and increase the energy of these molecules. Thus, the temperature continues to rise because temperature is a measure of the average kinetic energy of the molecules. 1 mark
- iii. After heating has ceased and the maximum temperature is reached, the contents of the calorimeter will cool down; this is shown in the graph at 4.5 minutes. The temperature decreases at a very slow rate after 4.5 minutes, which indicates that the calorimeter is insulated effectively. 1 mark
- iv. $E = VIt = 5.5 \times 1.5 \times 180 = 1485 \text{ J}$ 1 mark
 $CF = \frac{E}{\Delta T} = \frac{1485}{21.5 - 18.5} = 495 \text{ J } ^\circ\text{C}^{-1}$ 1 mark
- b. i. The calorimeter was calibrated using 100.0 mL of water, so the calibration factor can only be used accurately for this volume. (*If a different volume of water is used, the results could still be used but the calculations would be more complex.*) 1 mark
- ii. energy absorbed = $CF \times \Delta T = 495 \times 1.2 = 594 \text{ J}$ 1 mark
 $n(\text{KNO}_3) = \frac{m}{M} = \frac{2.50}{101.1} = 0.02472 \text{ mol}$ 1 mark
 $\Delta H = \frac{\text{energy absorbed}}{n} = \frac{594}{0.02472} = 24.029 \text{ kJ mol}^{-1}$
Given that the dissolution reaction is an endothermic process:
 $\Delta H = +24 \text{ kJ mol}^{-1}$ 1 mark
- iii. *For example:*
If some $\text{KNO}_3(\text{s})$ did not dissolve in the water, the measured temperature change would be lower than expected. Thus, the energy change calculated would be lower than expected, resulting in a ΔH value that is lower than the accepted value. 1 mark