Neap

Trial Examination 2022

VCE Chemistry Unit 3

Written Examination

Suggested Solutions

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 D

D is correct. Galvanic cells use spontaneous redox reactions to generate electrical energy whereas electrolytic cells use electricity to make non-spontaneous redox reactions occur.

A is incorrect. The anode is negative in galvanic cells.

B is incorrect. Oxidation occurs at the negative electrode (anode) in galvanic cells and at the positive electrode (anode) in electrolytic cells.

C is incorrect. Reduction occurs at the cathode in both types of cells.

Question 2 D

D is correct. Heat energy is released at every energy transformation and is mostly wasted, but it is not converted to chemical energy.

A is incorrect. Chemical energy is converted to electrical energy in the forward reaction.

B is incorrect. Some of the energy in the forward reaction is lost as heat.

C is incorrect. Electrical energy is used to recharge the cell and to reform the reactants of the energy-producing forward reaction.

Question 3 C

C is correct. For the forward reaction to be reversed, the products must remain in contact with the electrodes as these products become the reactants for the reverse reaction. This occurs so that electrons can be removed from one chemical species and forced onto another chemical species using the electricity source.

A, B and **D** are incorrect. These features may be present in a galvanic cell but do not enable the cell to be recharged.

Question 4 B

B is correct. Statement II is correct as the activation energy is high and so presents a significant barrier. Statement III is correct because the reaction is endothermic. The energy of the products is greater than that of the reactants in an endothermic reaction.

A, **C** and **D** are incorrect. Statement I is incorrect as the reaction is endothermic or heat-consuming. Statement IV is incorrect as the activation energy is set for a particular reaction, and only a catalyst would reduce its value.

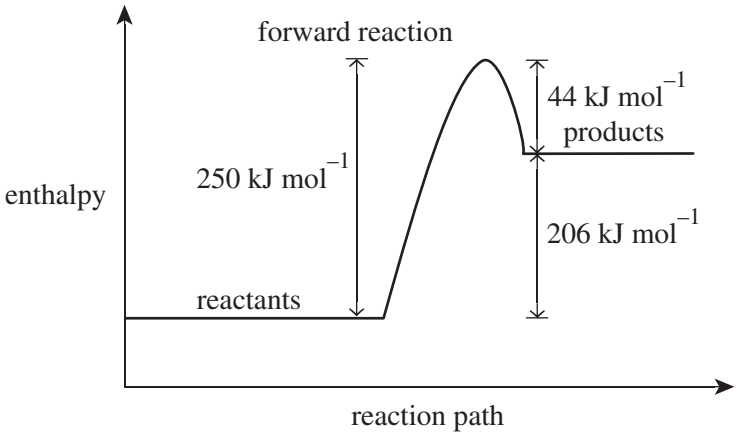
Question 5 A

A is correct. A catalyst lowers the activation energy for a reaction but does not change the difference between the heat of the products and heat of the reactants (enthalpy change).

B, **C** and **D** are incorrect. These options do not identify the correct value in the table.

Question 6 B

Activation energy is the energy required to break bonds in reactants. As shown in the following energy profile diagram, this is seen as the difference between the reactant energy and the top of the graph.
For the reverse reaction, the activation energy is 44 kJ mol^{-1}.



Question 7 D

D is correct. All fuels contain energy that can be released readily by, for example, a combustion reaction.

A is incorrect. Not all fuels rely on a combustion reaction. For instance, nuclear fuel does not produce energy by reacting with oxygen.

B and **C** are incorrect. Hydrogen gas is a useful fuel that does not contain carbon or oxygen.

Question 8 B

B is correct. $2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$

A is incorrect. $C + O_2 \rightarrow CO_2$

C is incorrect. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

D is incorrect. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

Question 9 C

C is correct. The high concentration of oxygen removes some haemoglobin (Hb) from the equilibrium reaction that forms carboxyhaemoglobin, and so this reaction moves towards the reactants, releasing carbon monoxide (CO), which is then removed from the body. The process continues as more pure oxygen is administered and the effects of poisoning are reversed.

A is incorrect. CO has approximately 20 000 times the affinity for Hb than oxygen does.

B is incorrect. This reaction does not occur in the body.

D is incorrect. The equilibrium constant (K_c) is only altered by temperature change, not oxygen concentration.

Question 10 B

B is correct. The graphite casing holds molten electrolyte and so must not be affected by reasonably high temperatures, so property II is used. The casing must not react with the cell contents, so property III is used. The high temperature required to change the state of graphite and its general inertness make it highly suitable for the application.

A, **C** and **D** are incorrect. Only the electrodes are involved in electrical conduction; as the graphite casing does not have electricity flowing through it, property I is not used.

Question 11 C

C is correct. Water is a stronger oxidant than calcium ions and so water would react to form hydrogen gas at the cathode preferentially if an aqueous solution were used. No calcium would deposit.

A is incorrect. There is no evidence that any aqueous solutions are being transported.

B is incorrect. Aqueous solutions of ionic substances also allow ions to be present and so this option does not explain why a molten electrolyte is required.

D is incorrect. Water is a much weaker reductant than calcium. The oxidant strengths, not the reductant strengths, of water and calcium ions are relevant to the cathode reaction for production of the metal.

Question 12 A

25.0 mL of gas at standard laboratory conditions (SLC) equates to $\frac{0.0250}{24.8} = 1.008 \times 10^{-3}$ mol.

The molar heat of combustion of ethyne is 1300 kJ mol^{-1}.

Burning the ethyne releases $1.008 \times 10^{-3} \times 1300 = 1.31$ kJ.

Question 13 B

Only temperature change can alter the value of K_c, so once equilibrium is reached again, $K_c = 0.95\ M^{-1}$.

Question 14 C

This reaction is the reverse of the initial reaction, and the coefficients have been halved.

Thus, K_c is $\left(\frac{1}{K_c}\right)^{\frac{1}{2}} = \left(\frac{1}{0.95}\right)^{\frac{1}{2}} = 1.03.$

Question 15 D

D is correct. The biodiesel molecule has some polarity. At cold temperatures, the molecules are closer together, causing the dipole–dipole attraction of the molecules to each other to intensify. Viscosity increases, and this phenomenon can cause problems with flow of the fuel along fuel lines. Petrodiesel molecules are non-polar and very weakly attracted to each other by dispersion forces. The intensity of attraction is much less affected by low temperatures and so viscosity shows very little change when temperatures are lowered.

A is incorrect. This description applies to petrodiesel only.

B is incorrect. This description applies to petrodiesel only. Biodiesel absorbs moisture from the air because of the polarity of the ester functional group, which forms dipole–dipole attractions with water molecules.

C is incorrect. Viscosity increases when temperatures are lowered for both types of fuel.

Question 16 C

C is correct. Biogas is a renewable resource containing methane. If this source of methane is used, method II is sustainable. If methane is sourced from fossil fuels, this method is not sustainable.

A is incorrect. Electrolysis uses an electricity source. If fossil fuels are used to generate electricity, then the environment is damaged. If a renewable resource were used to generate electricity for this electrolysis – for example, a hydroelectric source – the infrastructure required would likely have some detrimental impact on the environment.

B is incorrect. Electricity can be produced through methods other than burning fossil fuels.

D is incorrect. If methane sourced from biogas were used in method II, the net result would be a lowering of the amount of greenhouse gases in the atmosphere, as the reactants are water and the very potent greenhouse gas methane. Thus, this method may not always damage the environment even though carbon dioxide is produced.

Question 17 A

A is correct. Leakage of hydrogen, H_2, gas fuel could cause an explosion, property damage and injury to people, and so is a major safety concern.

B is incorrect. H_2 gas has a very high heat of combustion per gram compared to other fuels. Thus, it is not a significant issue.

C is incorrect. H_2 is a gas at room temperature and unusual conditions of low temperature and high pressure are needed to store a sufficient amount of H_2 in a car's fuel tank for it to be a useful fuel.

D is incorrect. Extensive infrastructure could be built and H_2 gas production could be scaled up to meet future demand for H_2 to be widely used as a transport fuel.

Question 18 D

D is correct. Decreasing the temperature would cause the peak of the curve to move to the left, increase in height and flatten near the activation energy value. Thus, the area of the shaded region would decrease.

A, **B** and **C** are incorrect. These options do not correctly describe the changes that would occur in the curve and shaded area.

Question 19 A

A is correct. Test tubes 3 and 4 are identical except for the higher temperature of the contents in test tube 3. Thus, the rate of reaction of 3 is greater than 4. Test tubes 2 and 4 are identical except for the zinc in test tube 4 being a powder, which has a much greater surface area than the granules in test tube 2. Thus, the rate of reaction of 4 is greater than 2. Test tubes 1 and 2 are identical except for the acid in test tube 2 being twice the concentration of the acid in test tube 1. Thus, the rate of reaction of 2 is greater than 1.

B, **C** and **D** are incorrect. These options do not give the correct order of the decreasing rate of reaction.

Question 20 A

A is correct. The volume of the contents in the test tubes would not change to any appreciable extent during the investigation and so could not be used to determine the rate of reaction.

B, **C** and **D** are incorrect. Changes in these variables over time should match the progress of the reaction and so these factors could be used to determine the rate of reaction.

SECTION B

Question 1 (9 marks)

a. According to collision theory, reactant particles must collide with sufficient energy to break bonds so that products can form. 1 mark

The greater the pressure, the more likely it is that particles will collide and so the frequency of successful collisions increases, which results in a higher rate of reaction. 1 mark

b. There are three reactant molecules for two product molecules, so the forward reaction is pressure reducing. 1 mark

If the pressure is increased, the system will move forward to lower the pressure according to Le Chatelier's principle. High pressure, therefore, favours a higher yield. 1 mark

c. The rate of reaction and yield increase with high pressure, but it is costly to build high pressure vessels and to maintain pressure above atmospheric pressure. 1 mark

It is more economically advantageous to use atmospheric pressure and less expensive methods to improve the rate of reaction and yield, such as excess air and a catalyst. 1 mark

d.

Feature	Explanation
The catalyst $V_2O_5(s)$ is spread out over a number of shallow trays.	**The reactant molecules must come into contact with the catalyst. Spreading it over shallow trays increases the surface area of the catalyst and maximises interaction with reactants.**
Reactant gases are passed progressively over each catalyst tray.	**As the reaction is an equilibrium reaction, complete conversion does not occur with one pass over the catalyst. More contact with the catalyst will enable a higher percentage of conversion to occur.**
Reactant gases are cooled after being passed over each catalyst tray before being passed over the next catalyst tray.	**As the reaction is exothermic, heat is produced, which favours the formation of the reactants. Cooling the gases ensures that the forward reaction is promoted.**

3 marks

1 mark for each correct explanation.

Question 2 (9 marks)

a. i. $X^{2+}(aq) + e^- \rightarrow X^+(aq)$ 1 mark

ii. $2X^{2+}(aq) + Cd(s) \rightarrow 2X^+(aq) + Cd^{2+}(aq)$ 2 marks

1 mark for correct balancing and states.
1 mark for the correct reactants and products.

iii. $0.56\ V = E^0(\text{oxidant}) - E^0(\text{reductant}) = E^0(\text{oxidant}) - (-0.40)$

$E^0 = 0.56 - 0.40 = 0.16\ V$ 1 mark

iv. half-cell 2 *(This balances the decreasing positive charge in half-cell 2.)* 1 mark

b. **i.** $Mn^{2+}(aq)$ 1 mark

Note: As half-cell C contains the anode, this reaction is the oxidation process with Pb as the reductant. MnO_2 is the stronger oxidant and its conjugate Mn^{2+} is the weaker reductant.

ii. $Au^{3+}(aq)$ 1 mark

Note: As the pH in half-cell A decreased, hydrogen ions must be produced in the reaction and so the reaction involves Mn^{2+} as the reductant. Au^{3+} is the stronger oxidant present.

iii. D, A, C, B 2 marks

Note: Award 1 mark only for any three letters in the correct order.

Question 3 (10 marks)

a. Electrolysis uses electricity to force a non-spontaneous redox reaction to occur. A single container such as a beaker can be used because the reaction can only occur at the electrodes when energy is provided. 1 mark

A galvanic cell uses a spontaneous redox reaction to produce electrical energy. If the reactants were not separated, a reaction would occur that produces heat energy only. 1 mark

b. **i.** negative (*Forced reduction occurs at the cathode.*) 1 mark

ii. $Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$ 1 mark

c. **i.** $n(\text{Fe}) = \dfrac{m}{M} = \dfrac{0.567}{55.8} = 0.01016 \text{ mol}$ 1 mark

$n(e^-) = 3 \times n(\text{Fe}) = 3 \times 0.01016 = 0.03048 = 0.0305 \text{ mol}$ 1 mark

ii. $Q = It = 3.216 \times 15.0 \times 60 = 2894.4 = 2.89 \times 10^3 \text{ C}$ 1 mark

iii. If 0.0305 mol of electrons carry 2.89×10^3 C, then 1 mol of electrons carries $\dfrac{2.89 \times 10^3}{0.0305} = 94\,754$ C.

Faraday's constant (F) = $94\,754 = 9.48 \times 10^4 \text{ C mol}^{-1}$ 1 mark

d. *For example:*

The mass of iron deposited may have been recorded as greater than the actual mass due to incomplete drying of the electrode. The calculated amount, in moles, would be greater. 1 mark

A greater mass would mean that the $F = \dfrac{Q}{m}$ value would be lower. 1 mark

Question 4 (7 marks)

a. **i.** $O_2(g) + 4e^- \rightarrow 2O^{2-}(g)$ 1 mark

ii. The cathode is metallic as it must be able to conduct electrons, which are received from the anode to allow the oxygen molecules to be reduced to oxide ions. 1 mark

The cathode is catalytic because the electrode reaction is too slow to enable efficient electricity generation. 1 mark

iii. $CH_4(g) + 4O^{2-}(g) \rightarrow CO_2(g) + 2H_2O(g) + 8e^-$ 2 marks

1 mark for correct balancing and states.
1 mark for the correct reactants and products.

b. At a power generation facility, there are many energy conversions and at each energy conversion, some energy is lost as heat. Overall, the efficiency is low because so much energy is lost. 1 mark

In the fuel cell, chemical energy is converted directly to electrical energy. As there is only one energy conversion, less energy is lost and the efficiency is much greater. 1 mark

Question 5 (9 marks)

a. Two reactant gases were injected initially, and the amount of each gas decreased while the amount of the product gas increased from zero. 1 mark

Both gases X and Y decreased by 0.02 mol and gas Z increased by 0.04 mol. This indicates the stoichiometric ratios in the balanced equation. 1 mark

b. $K_c = \dfrac{[Z]^2}{[X][Y]}$ 1 mark

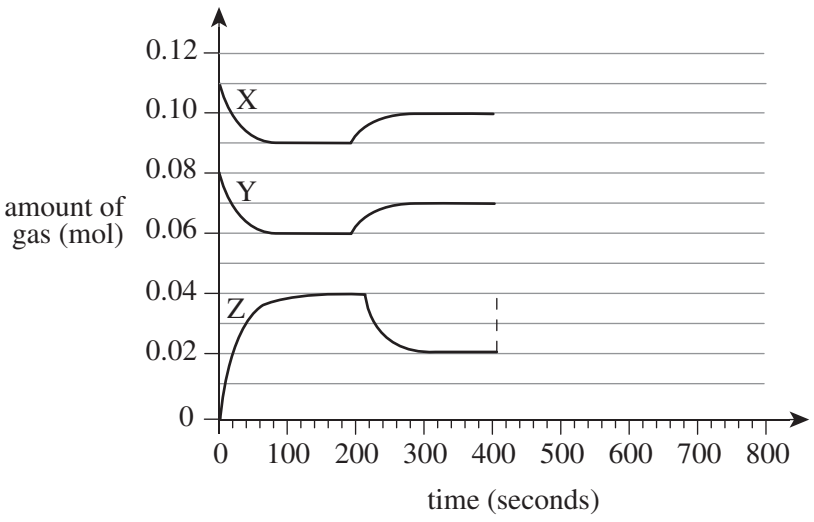
$= \dfrac{\left(\dfrac{0.04}{2.00}\right)^2}{\left(\dfrac{0.09}{2.00}\right)\left(\dfrac{0.06}{2.00}\right)}$ 1 mark

$= 0.3$ 1 mark

c. When cooled, the equilibrium position moved towards the reactants and, by Le Chatelier's principle, the reaction would have moved to partially oppose the change in temperature. 1 mark

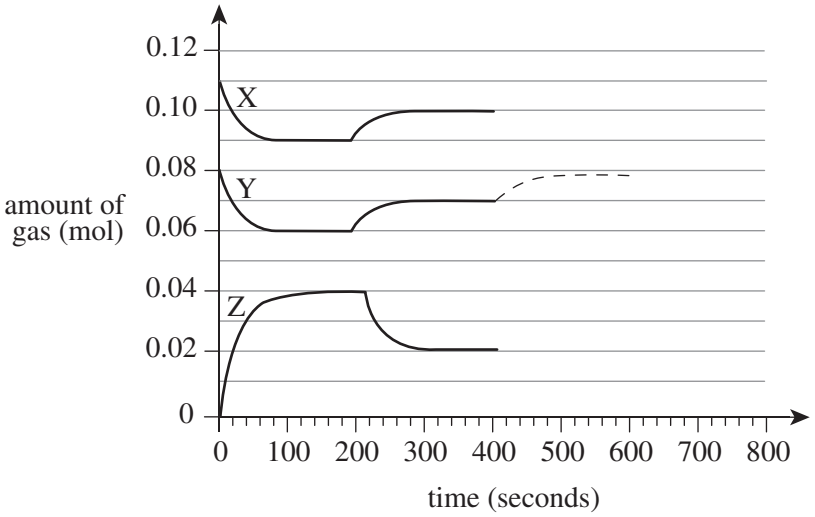
The reverse reaction must have generated heat to partially oppose the decrease in temperature and so the reverse reaction is exothermic. Therefore, the forward reaction is endothermic. 1 mark

d. **i.**



1 mark

ii.



1 mark

Note: The change must show a gradual increase in gas Y to less than 0.08 mol. The addition of more of gas Z would have moved the reaction in the reverse direction, increasing gas Y. As the change in Z was 0.02 mol, and this change would not have been overcome, the change in Y would be less than 0.01 mol.

Question 6 (11 marks)

a. $n\left(\text{benzene}\left(C_6H_6\right)\right) = \frac{m}{M} = \frac{6.154}{78.0} = 0.078897 = 0.0789 \text{ mol}$ 1 mark

Therefore, 1 mol of C_6H_6 releases $\frac{258.0}{0.0789} = 3270$ kJ. 1 mark

$2C_6H_6(l) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g) \qquad \Delta H = -6540 \text{ kJ mol}^{-1}$

OR

$C_6H_6(l) + 7.5O_2(g) \rightarrow 6CO_2(g) + 3H_2O(g) \qquad \Delta H = -3270 \text{ kJ mol}^{-1}$ 2 marks

1 mark for correct balancing and states.

1 mark for the correct enthalpy change (ΔH), including the negative sign.

b. From the equation, 3.98 mol of C_6H_6 produces $6 \times 3.98 = 23.88$ mol of CO_2. 1 mark

$V = \frac{nRT}{p} = \frac{23.88 \times 8.31 \times \left(15.0 + 273\right)}{1.15 \times 101.3}$ 1 mark

$= 491$ L 1 mark

*Note: Consequential on answer to **Question 6a**.*

c. To heat the water, $500 \times 4.18 \times (87.6 - 18.1) = 145\,255$ J = 145.255 kJ is required. 1 mark

To generate this heat, the burning of $\frac{145.255}{3270} = 0.0444$ mol of C_6H_6 is required. 1 mark

$m(C_6H_6) = n \times M = 0.0444 \times 78.0 = 3.4658$ g 1 mark

As the heating process is only 67% efficient:

actual mass that needs to be burnt $= \frac{3.465}{0.67} = 5.1713 \text{ g} = 5.17 \text{ g}$ 1 mark

*Note: Consequential on answer to **Question 6a**.*