Neap

Trial Examination 2021

VCE Chemistry Unit 3

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1 C

C is correct. The composition of coal seam gas is mostly methane, but other gases are present. **A**, **B** and **D** are incorrect. Coal seam gas is a fossil fuel formed naturally in deposits of porous rocks under the ground.

Question 2 B

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

Thus the magnitude of the equilibrium constant will be $\left(\frac{1}{K_c}\right)^{\frac{1}{2}} = \left(\frac{1}{4.5}\right)^{\frac{1}{2}} = 0.47$.

Question 3 D

D is correct. The temperature of the original equilibrium mixture has doubled. As the reaction is endothermic, it is expected that the forward reaction would be favoured when the temperature is doubled, and so the magnitude of the equilibrium constant would be greater than 4.5 M. However, as the concentration of the gaseous reactants and products are not known, the value of the equilibrium constant cannot be determined.

Question 4 A

A is correct and **C** is incorrect. If the temperature was decreased, the peak would be increased in height and moved to the left, but the position of the activation energy (E_a) would remain unchanged. **B** and **D** are incorrect. There would be less area under the curve to the right of E_a and so fewer particles would have the energy required in collisions to form products. Reaction rate would decrease. The area under the curve represents the total number of particles and would remain unchanged.

Question 5 B

B is correct. A catalyst lowers the activation energy for a reaction and so the position of the E_a would move to the left. The curve would not change in position or height.

Question 6 B

Double reaction I: $\Delta H = -395 \times 2$

Double and reverse reaction II: $\Delta H = +295 \times 2$

Add the values to give –200.

Question 7 C

C is correct. The K_c values given have a unit of M^{-1}. For the reaction in **C** the unit of the equilibrium constant is M^{-1}. **A** is incorrect. The equilibrium constant for this reaction has no unit. **B** is incorrect. The unit of the equilibrium constant is M^{-2}. **D** is incorrect. The unit of the equilibrium constant is M^{-2}.

Question 8 D

D is correct. The value of the equilibrium constant decreases with increasing temperature. The reaction must be exothermic as the reactants are favoured when more heat is added to the equilibrium system; thus the reverse reaction is energy-absorbing (endothermic). In an exothermic reaction, the reactants have a higher heat content or enthalpy than the products.

Question 9 B

B is correct. Adding argon at constant volume changes neither Q_c nor K_c, as no concentrations are altered, and temperature is not changed. Altering volume and adding H_2 gas both change concentrations, and so change the Q_c. As temperature has not changed, K_c will be unchanged. II and III are required responses. Changing temperature alters the value of K_c. However, the value of Q_c does not immediately change when the temperature is changed because no concentrations are altered.

Question 10 C

C is not a correct prediction and is therefore the required response. The series does not predict how fast a redox reaction will occur. So even though a reaction is predicted to occur, it may be so slow that it appears that no reaction is occurring. **A**, **B** and **D** are all correct statements regarding the use of the electrochemical series. It can be used to identify the stronger oxidising agent and the stronger reducing agent in two pairs of redox conjugates, and a spontaneous reaction should occur if these two reactants are mixed.

Question 11 D

D is correct. Enthalpy change (ΔH) is defined as $H_{\text{products}} - H_{\text{reactants}}$. On the energy profile, this is equivalent to N. As this is an exothermic reaction, the correct answer is –N.

Question 12 B

B is correct. In the reverse reaction, the products become the reactants and the activation energy is equivalent to the energy required to reach the peak from the heat of the reactants. In the energy profile, this is given by M + N.

Question 13 A

A is not common to all fuel cells and so is the required response. Oxidation occurs at the negatively charged anode. **B**, **C** and **D** are not the required responses. Porous, catalytic electrodes and gaseous reactants are common to all fuel cells and reactions at each electrode are influenced by the electrolyte. For example, acidic and alkaline electrolytes lead to different electrode half-equations.

Question 14 A

A is correct. Metal ions are positively charged and so will move towards the negative electrode, where they will gain electrons when being discharged in an electrolytic cell. In an electrolytic cell the negative electrode is the cathode, and reduction always involves a gain of electrons.

Question 15 D

As the current and time durations were identical for each cell, the same number of mole of electrons passed through each cell. Thus, the mass of metal X deposited is related to the charge on the ion (X^{x+})and the molar mass of the metal.

$$n\left(\text{X for X}^{x+}\right) = \frac{1}{x}n\left(e^{-}\right)$$

$$m\left(\text{X deposited}\right) = n\left(\text{X}\right) \times M\left(\text{X}\right)$$

Using molar masses of the metals and the charges on the metal ions, the mass ratio is:

$$\text{Ag : Zn : Au : Ni} = \frac{107.9}{1} : \frac{65.4}{2} : \frac{197.0}{3} : \frac{58.7}{2}.$$

Cell 4, which deposited nickel, has the smallest mass deposited.

Question 16 C

C is correct. Using the electrochemical series, it can be predicted that a reaction will only occur with cadmium when oxidising agents stronger than cadmium ions are present as reactants. The only group of ions from the list that are all stronger oxidising agents than cadmium ions are Ag^{+}, Cu^{2+} and Pb^{2+} ions. **A** is incorrect. Mg^{2+} and Na^{+} ions are weaker oxidising agents than cadmium ions. **B** is incorrect. $Zn^{2+}$and K^{+} ions are weaker oxidising agents than cadmium ions. **D** is incorrect. Mg^{2+} ions are weaker oxidising agents than cadmium ions.

Question 17 C

$$p = \frac{nRT}{V} = \frac{mRT}{MV} = \frac{1.5 \times 8.31 \times 298}{28.0 \times 4.00} = 33 \text{ kPa}$$

Question 18 D

D is correct. The volume of hydrogen gas was double that produced in the initial experiment. As the acid was in excess, only doubling the mass of magnesium could produce this result.

Question 19 A

A is correct. Changing the volume of the acid alone will not result in an increased rate of reaction. **B**, **C** or **D** are incorrect. The initial rate of reaction has increased in graph III compared to that in graph II. The factors that increase the rate of reaction are increased temperature, increased concentration of reactants and increased surface area of solid reactants.

Question 20 A

A is correct. For a cell to be recharged, the products of the discharge reaction must remain in contact with the electrodes, as they become the reactants for the recharge reaction. These products are solid or liquid but never gaseous, because a gas will dissipate and not be available at the electrode to complete the recharge reaction. **B** is incorrect. In a secondary cell, the electrode can be made of a reactive metal, a non-reactive metal or graphite. **C** is incorrect. If the reactants come into direct contact, only heat energy would be produced. Thus, in a galvanic cell, the reactants are separated physically but are in electrical contact. **D** is incorrect. During the recharge reaction, electrical energy is transformed into mostly chemical energy, but heat energy and possibly other forms of energy are also generated.

SECTION B

Question 1 (12 marks)

a. Coal is non-renewable as it took many millions of years to form and it is unable to be replaced by natural processes within a relatively short period of time. 1 mark

b. Complete combustion of 1 mole of each fuel will produce:

1 mole of CO_2 from CO $\left(CO + \frac{1}{2}O_2 \rightarrow CO_2\right)$ and

1 mole of water from H_2 $\left(H_2 + \frac{1}{2}O_2 \rightarrow H_2O\right)$ 1 mark

At constant temperature and pressure, $V \propto n$. 1 mark

10.0 L of each fuel will produce 10.0 L of either CO_2 or H_2O.

Given $m = n \times M$, the mass of each gas produced will depend on molar mass.

As $M(CO_2) > M(H_2O)$, CO produces the greater mass of greenhouse gas. 1 mark

c. **i.** chemical energy to electrical energy 1 mark

ii. There is only one energy transformation using fuel cells, so the energy losses are minimal. 1 mark

Using combustion of fuels to generate electricity requires many transformations of energy; this involves loss of energy at each step, so this method is less efficient. 1 mark

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

ii. *For example:*

Hydrogen gas is explosive when mixed with air and exposed to a spark, so particular caution must be used to prevent leaks during storage or transfer. 1 mark

e. **i.** $CO(g) + CO_3^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$ 1 mark

ii. Each mole of CO produces 2 moles of electrons, which carries 2 × 96 500 C of charge. 1 mark

$E = VQ$ and so the energy provided by the cell is:

1.33 × 2 × 96 500 = 256 690 J = 257 kJ per mole of CO consumed 1 mark

Question 2 (10 marks)

a. $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ 1 mark

b. In the electrolytic cell, the products are generated in a non-spontaneous reaction by using electrical energy to force the reaction. If the products are not kept separate from each other, they become the reactants for a spontaneous reaction. 1 mark

Thus, the products of the electrolytic cell will spontaneously reform the reactants of the cell and the electrolytic process will be wasted. 1 mark

c. Both copper and iron are stronger reducing agents than chloride ions. 1 mark

Thus, either of these metals will react more easily at the positive electrode, forming Cu^{2+} or Fe^{2+}, instead of chloride ions forming chlorine gas. 1 mark

d. **i.** Water is just a stronger reducing agent than chloride ions. Thus, under standard conditions, water should react to form oxygen gas and hydrogen ions. 1 mark

ii. As concentrated sodium chloride solution is being electrolysed, any predictions using the electrochemical series may be unreliable. Having a high concentration of chloride ions allows the ions to be discharged preferentially at the anode. 1 mark

e. $Q = I \times t = 2000 \times 24 \times 60 \times 60 = 1.728 \times 10^8$ C

$n(e^-) = \frac{Q}{F} = \frac{1.728 \times 10^8}{96\ 500}$ 1 mark

$n(Cl_2) = \frac{1}{2}n(e^-) = \frac{0.5 \times 1.728 \times 10^8}{96\ 500} = 895.34$ mol 1 mark

$m(Cl_2) = n \times M = 895.34 \times 71.0 = 6.36 \times 10^4$ g 1 mark

Question 3 (14 marks)

a. **i.** $C_{12}H_{26}(l) + \frac{37}{2}O_2(g) \rightarrow 12CO_2(g) + 13H_2O(g)$ $\Delta H = -7.3 \times 10^3$ kJ mol^{-1} 2 marks

($\Delta H = 43 \times M(C_{12}H_{26}) = 43 \times 170$)

1 mark for correct balancing, reactants and products.
1 mark for correct enthalpy change.
Note: $H_2O(l)$ is acceptable as conditions for 43 kJ g^{-1} not stated.

ii. $C_{15}H_{31}COOCH_3$ **OR** $CH_3(CH_2)_{14}COOCH_3$ 1 mark

b. **i.** Petrodiesel consists only of non-polar hydrocarbon molecules, which have intermolecular dispersion forces as the only attraction between the molecules. 1 mark

Biodiesel consists of methyl or ethyl ester molecules, which are largely non-polar because of the hydrocarbon chain but have some degree of polarity in the ester linkage. Thus intermolecular bonding includes dipole–dipole bonds and dispersion forces. 1 mark

At a particular temperature, the viscosity is dependent on the forces of attraction between molecules, so biodiesel has higher viscosity due to the stronger intermolecular forces resulting from the degree of polarity of its molecules and the slightly larger size of the molecules. 1 mark

ii. At lower temperatures the viscosity of both biodiesel and petrodiesel is increased. At lower temperatures the viscosity of biodiesel is significantly higher than that of petrodiesel. 1 mark

Higher viscosity results in a slower flow of fuel and so biodiesel will not flow in fuel lines as readily as petrodiesel does, resulting in biodiesel being unsuitable for use in transport vehicles at low temperatures. 1 mark

c. **i.** energy = 2.15 × 29.6 = 63.64 = 63.6 kJ 1 mark

ii. energy required to heat 100.0 g of water $= 100.0 \times 4.18 \times (35.9 - 18.0)$

= 7482 J = 7.482 kJ 1 mark

% energy transferred = $\frac{7.482}{63.64} \times 100 = 11.8\%$ 1 mark

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iii. energy of petrodiesel used to heat water $= 100.0 \times 4.18 \times (42.3 - 17.5)$

$= 10\ 366$ J 1 mark

Assuming that this transfer is only 11.8% efficient, then the energy released by burning the petrodiesel $= 10\ 366 \times \frac{100}{11.8} = 87\ 850 \text{ J} = 87.85 \text{ kJ}$ 1 mark

energy per gram of petrodiesel $= \frac{87.85}{1.93}$

$= 45.5 \text{ kJ g}^{-1} = 45.5 \text{ MJ kg}^{-1}$ 1 mark

Question 4 (10 marks)

a. $K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]}\ M^{-1}$ 1 mark

b.

	PCl_3	Cl_2	PCl_5
n_i	1.15	0.30	0.60
Change	–0.15	–0.15	+0.15
n_e	1.00	0.15	0.75
$c_e = \frac{n}{0.500}$	2.00	0.30	1.50

3 marks

$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{1.50}{2.00 \times 0.30} = 2.5\ M^{-1}$ 1 mark

c. concentration fraction $= \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{1.60}{1.85 \times 0.95} = 0.91\ M^{-1}$ 1 mark

As this value does not equal 2.5 M^{-1} at 523 K, the system is not at equilibrium. 1 mark

d.

	Change to original mixture	Shift in equilibrium position 'to the product side', 'to the reactant side' or 'unchanged'?	Change to value of K_c 'increases', 'decreases' or 'unchanged'?
i.	0.1 mol of Cl_2 gas injected at 523 K	to the product side	unchanged
ii.	0.1 mol of He gas injected at 523 K	unchanged	unchanged
iii.	temperature lowered to 423 K	to the product side	increases

3 marks

1 mark for each correct row.

Question 5 (9 marks)

a. *Any two of:*

- Electrons should travel from the negative electrode to the positive electrode.
- Anions (negative ions) should travel towards half-cell 1.
- For standard conditions, chlorine gas in half-cell 2 should be at a pressure of 1 atmosphere and should be continuously flowing into the half-cell so that it is in contact with the electrode and electrolyte.

2 marks

b. i. *For example:* KNO_3 1 mark

ii. *For example, any one of:*

- compound composed of ions
- compound does not react with substances in the electrolyte or with the electrodes

1 mark

c. i. $SO_2(aq) + 2H_2O(l) \rightarrow HSO_4^-(aq) + 3H^+(aq) + 2e^-$ 1 mark

ii.

	Oxidation	**Reduction**
Anode	✓	
Cathode		

1 mark

d. $1.25 = 1.36 - X$

$X = +0.11 \text{ V}$ 1 mark

e. A power pack with variable voltage should be used to recharge the cell in a school laboratory and the voltage should be set at greater than the cell voltage of 1.25 V. 1 mark

The negative terminal of the power pack should be connected to the negative electrode of the cell as it is necessary to force electrons back onto the electrode. The positive terminal of the power pack should be connected to the positive electrode of the cell as it is necessary to withdraw electrons from the cell. 1 mark