TRIAL CHEMISTRY EXAM

VCE CHEMISTRY

UNIT 3 TRIAL EXAM 2024

Mark Scheme

Part A Multiple Choice

Question 1

Correct option C

A, B and D are renewable fuel sources that can be synthesized from renewable feedstocks such as animal and plant waste that can be replaced by natural processes within a relatively short period of time. Natural gas, (despite its name) is a fossil fuel and is non-renewable (unable to be replaced by natural processes within a relatively short period of time.

Question 2.

Correct option B

Both green-leafed plants and blue-green algae can photosynthesise.

Question 3

Correct option C

Bioethanol supplies the same amount of energy when completely combusted as ethanol derived from other sources. Biogas can be synthesized through the anaerobic breakdown of animal waste. The production of bioethanol is an application of the process of a circular economy.

Question 4

Correct option D

Methane is the limiting reactant

$n(CH_4) = \frac{m}{M} = \frac{5.00}{((12.0)+(4 \times 1.0))} = 0.313 \text{ mol}$

$n(O_2) = \frac{V}{V_m} = \frac{20.00}{24.8} = 0.806 \text{ mol}$

Mole ratio CH_4:O_2 = 1:2

0.313 mol of methane will react with 0.313 x 2 = 0.625 mol O_2 < 0.806 mol available, so oxygen gas is in excess.

Therefore, methane is the limiting reactant.

Oxygen is in excess by 0.806 – 0.626 = 0.180 mol

Question 5.

Correct option B

For complete combustion the products are carbon dioxide and water. At SLC the state of water is liquid. To balance the equation, the coefficient of butane is 2 so the molar enthalpy of combustion is multiplied by 2.

Options A and D are unbalanced. Option A suggests that incomplete combustion has occurred because one of the products is carbon monoxide. Option C has the incorrect state for water.

Question 6

Correct option D

The oxidation numbers of elements do not change in options A, B and C.

$\overset{0}{H_2}(g) + \overset{0}{F_2}(g) \rightarrow 2\overset{+1\ -1}{HF}(g)$

In D, $H_2(g) + F_2(g) \rightarrow 2HF(g)$

Question 7

Correct option A

Write the oxidation numbers above each element for all species. The oxidising agent causes the other species to be oxidised, but itself is reduced so the oxidation number of the element in the oxidising agent decreases (reduces) in the reaction.

The oxidation number of chromium in dichromate decreases (reduces) from +6 to +3 during the course of the reaction.

$$\overset{+6\ -2}{Cr_2O_7^{2-}}(aq) + 14H^+(aq) + 6\overset{+2}{Fe^{2+}}(aq) \rightarrow 2\overset{+3}{Cr^{3+}}(aq) + 7\overset{+1\ -2}{H_2O}(l) + 6\overset{+3}{Fe^{3+}}(aq)$$

Question 8

Correct option D

A conjugate redox pair consists of a reactant/product that will contain an element in which the oxidation number varies between the two species.

D is the correct answer, because nitrogen appears in both species. In NO_3^-, the oxidation number of nitrogen is +5, in NO_2, the oxidation number of nitrogen is +4.

$$\overset{+5\ -2}{NO_3^-}(aq) + 2H^+(aq) + e^- \rightarrow \overset{+4\ -2}{NO_2}(g) + \overset{+1\ -2}{H_2O}(l)$$

Question 9

Correct option A

According to the electrochemical series, Ag^+ is the strongest oxidising agent and Cu(s) is the strongest reducing agent. There is a negative gradient between these two species on the electrochemical series so a spontaneous reaction will take place. Silver ions will be reduced at the cathode (the silver electrode), while at the anode (copper electrode) copper metal will be oxidised to form copper(II) ions.

1 represents silver metal (the cathode), 2 represents copper metal (the anode), 5 represents the external circuit (the wires attached to the electrodes and voltmeter), and 6 represents the salt-bridge (forming the internal circuit).

Question 10

Correct option D

The electrolyte used to soak the filter paper to make a salt bridge should contain spectator ions that are highly soluble in water. Potassium nitrate satisfies these requirements.

Page 8 of the data book shows that AgCl forms a precipitate, so it is insoluble in water. Thus sodium chloride would not be a suitable choice as it would introduce chloride ions that could form a precipitate in the beaker on the left hand side.

Question 11

Correct option B

According to the electrochemical series, Ag^+ is the strongest oxidising agent and Cu(s) is the strongest reducing agent. There is a negative gradient between these two species on the electrochemical series so a spontaneous reaction will take place. Silver ions will be reduced at the cathode (the silver electrode, which has a positive polarity in a galvanic cell, Red Cat), while at the anode (copper electrode which has a negative polarity in a galvanic cell, An Ox) copper metal will be oxidised to form copper(II) ions.

Question 12

Correct option C

The presence of the power supply indicates that this is an electrolytic cell. Fuel cells usually show an inlet for the continuous supply of reactants and an outlet for the continuous removal of products.

In an electrolytic cell the negative terminal of the power supply is connected to the cathode which is electrode X in this cell.

Question 13.

Correct option A

In a fuel cell, the anode has a negative polarity and the products are continuously removed.

B is incorrect, because the products are not continuously removed from primary cells.

C is incorrect, because the polarity of the anode is positive in an electrolytic cell.

D is incorrect, because products are not continuously removed from primary cells.

Question 14

Correct option C

In an electrolytic cell, the negative terminal of the power supply is connected to the cathode, which is the Cu-Zn electrode in this cell. The graphite electrode (anode) is connected to the positive terminal of the power supply.

Question 15.

Correct option B

Options A, C and D all result in an increased reaction rate according to collision theory.

Option B has no effect on the rate of the reaction.

Question 16

Correct option A

1 represents the enthalpy change of the reaction. 2 represents the activation energy of a catalysed reaction. 3 represents the activation energy of an uncatalyzed reaction. 4 represents the energy released as new bonds are formed in the products.

Question 17

Correct option C

The forward reaction is endothermic. According to Le Chatelier's Principle, when the temperature of a system at equilibrium is increased, the endothermic reaction is favoured (forward) resulting in a gradual increase in the concentration of products and decrease in the concentration of reactants.

Question 18

Correct option C

If the volume of the equilibrium system is halved, the concentration of all species will immediately double. According to Le Chatelier's Principle, the system will partially oppose this change my moving in the direction of fewer particles to partially decrease the concentration of particles. Hence the equilibrium will shift to the left hand side (1:2).

Question 19

Correct option A

When the reaction is reversed, the new K value is the reciprocal of the original K (at constant temperature). In this case $\frac{1}{120} = 8.3 \times 10^{-3}$

Question 20

Correct option A

Pressure and volume are inversely related. A high pressure occurs when the volume of the container is reduced. The graph shows a higher yield with increasing pressure (400 atmospheres). The greatest yield is obtained when the pressure is maintained at 400 atmospheres and the temperature is 350 ^{o}C.

Section B

Question 1

a.

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

Correct formulas of reactants and products (**1 mark**)
Balanced equation and correct states (**1 mark**)

b.

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Or

$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$

Or

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$

Correct formulas of reactants and products (**1 mark**)
Balanced equation and correct states (**1 mark**)

Question 2.

a.

non-renewable (**1 mark**)

b.

$n(C_4H_{10}) = \frac{m}{M} = \frac{1.87}{(4 \times 12.0)+(10 \times 1.0)} = 0.0322$ mol (**1 mark**)

energy(C_4H_{10}) = 0.0322 mol x 2880 kJ mol^{-1} = 92.9 kJ (**1 mark**)

Energy absorbed by the water = mcΔT
= 202.12 x 4.18 x (48.7 – 20.4)
= 2.39 x 10^4 J
= 23.9 kJ (**1 mark**)

% energy transferred to water = $\frac{\text{energy absorbed by water}}{\text{energy provided by butane}} = \frac{23.9}{92.9}$ x 100 = 25.7 % (**1 mark**)

Question 3.

a.

$K = \frac{[NH_3]^2}{[H_2]^3[N_2]}$ M^{-2} (1 mark)

b.
According to collision theory, increasing temperature of the reaction system results in an increase in the average kinetic energy of the reactant particles, (**1 mark**)leading to a greater proportion of particles with energy equal to or greater than the activation energy, and a greater frequency of collisions resulting in a greater frequency of successful collisions, (and thus an increase in reaction rate). (**1 mark**)

c.
The reaction as written is an exothermic reaction (**1 mark**)According to Le Chatelier's Principle, reducing temperature of the system will remove energy from the system, so the system will move to the right (net forward) in order to partially oppose the temperature change by favouring the exothermic (heat releasing) reaction and increasing the yield of ammonia (**1 mark**)

d.

(i) moderate temperature (**1 mark**)

(ii) *one of*
excess reactant / remove product / increase pressure / decrease volume
(**1 mark**)

(iii) *one of*
presence of a catalyst / increase pressure / decrease volume (**1 mark**)

Question 4

a.

Reduction equation	$2H^+(aq) + 2e^- \rightarrow H_2(g)$	(**1 mark**)
Oxidation equation	$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$	(**1 mark**)
Overall equation	$2H_2O(l) \rightarrow O_2(g) + 2H_2(g)$	(**1 mark**)

b.

Q = It = 15.0 x 24 x 60 x 60 x 7 x 2.0= 1.8×10^7 C (**1 mark**)

$n(e^-) = \frac{Q}{F} = \frac{1.8 \times 10^7}{96500} = 1.9 \times 10^2$ mol (**1 mark**)

$$\frac{n(hydrogen)}{n(e-)} = \frac{2}{4}$$

$n(H_2)$ = ½ x 1.9 x 10^2 = 94 mol
$V(H_2) = n \times V_m$
= 94 x 24.8 = 2.3 x 10^3 L (**1 mark**)

c. Hydrogen gas is highly explosive/flammable **(1 mark)** so it should be stored away from ignition sources / stored in appropriate pressurised containers to avoid leakage. (**1 mark**)

d.

For example:

Goal 7 of the United Nations Sustainable Development Goals (**1 mark**)focusses on the provision of affordable and clean energy. Using renewable energy to synthesise green hydrogen is an example of an application of this goal. (**1 mark**)

Or

One of the green chemistry principles is to 'design for energy efficiency' (**1 mark**)The only products of the green hydrogen synthesis are green hydrogen and oxygen, which is a normal component of air. Alternatively, the pure oxygen also generated could be used for medical purposes. (**1 mark**)

e.

"

A source of reactants or reagents used in chemical processes. (**1 mark**)

f. $3H_2 + CO_2 \rightarrow CH_3OH + H_2O$ (**1 mark**)

g. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1452$ kJ

Balanced equation (**1 mark**)
Correct states and enthalpy value (the state of methanol is given in the databook on p. 10). (**1 mark**)

h.

According to the databook

Bond	**Bond enthalpy kJ mol^{-1}**
C-H	414
O-H	463
C-O	358

The O-H bond has the greatest bond enthalpy. (**1 mark**)

Question 5

a.

$\overset{+3}{V^{3+}}(aq) + e^- \rightleftharpoons \overset{+2}{V^{2+}}(aq)$ $E^0 = -0.26$ V

$\overset{+5}{VO_2^+}(aq) + 2H^+(aq) + e^- \rightleftharpoons \overset{+4}{VO^{2+}}(aq) + H_2O(l)$ $E^0 = +1.00$ V

(**1 mark**)

b.

$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$ (**1 mark**)

c.
1.00 - -0.26 = 1.26 V (**1 mark**)

d.

$VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq) \rightarrow VO^{2+}(aq) + V^{3+}(aq) + H_2O(l)$ discharge

Therefore during recharge

$VO^{2+}(aq) + V^{3+}(aq) + H_2O(l) \rightarrow VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq)$ (**1 mark**)

e. right to left (**1 mark**)

f. anode/negative (**1 mark**)

g.

There is a continuous supply of reactants from outside the cell - this is typical of a fuel cell AND The cell can be recharged (reverse of discharge reaction) which is typical of a secondary cell. (**1 mark**)

Question 6

a.

Convert percentages to g per 100g. Parmesan cheese contains 35.8 g protein/100g, 25.0 g fat /100g and 3.2 g carbohydrate per 100g.

Energy from protein = 35.8 x 17 kJ g^{-1} = 609 kJ = 6.1 x 10^2 kJ

Energy from fat = 25.0 x 37 kJ g^{-1} = 925 = 9.3 x 10^2 kJ

Energy from carbohydrate = 3.2 x 16 kJ g^{-1} = 51 kJ = 0.51 x 10^2 kJ (**1 mark**)

Total energy per 100 g Parmesan cheese = 6.1 x 10^2 + 9.3 x 10^2 + 0.51 x 10^2 = 1.6 x 10^3 kJ (**1 mark**)

b.

Energy in 100 g = 1.6 x 10^3 kJ

Energy in 30 g = 1.6 x 10^3 x $\frac{30}{100} = 480$ kJ (**1 mark**)

Energy provided by consuming 30 g of daily intake = $\frac{energy\ per\ 30\ g\ Parmesan\ cheese}{daily\ energy\ intake} \times 100 = \frac{480}{8700} \times 100 = 5.5\%$ (**1 mark**)

c.

The type of food. (**1 mark**)

d.(i).

Parmesan cheese contains more energy per 100 g than apples. (**1 mark**)

d.(ii).

Fat provides 37 kJ per g which is a greater energy value provided by both carbohydrates and protein per g. (**1 mark**)

Parmesan cheese contains significantly more fat per 100 g than apples which contributes significantly more energy per 100 g than the other components of food (**1 mark**)

Question 7 (5 marks)

a.

$n(CH_4) = \frac{m}{M} = \frac{3.50 \times 10^3}{(12.0)+(4 \times 1.0)} = 219 \text{ mol}$ (**1 mark**)

$n(H_2O) = \frac{V}{V_m} = \frac{1500}{24.8} = 60.5 \text{ mol}$ (**1 mark**)

$$\frac{n(unknown)}{n(known)} = \frac{n(carbon\ monoxide)}{n(steam)} = \frac{1}{1}$$

molar ratio CH_4: H_2O = 1:1

H_2O is the limiting reactant because 60.5 mol of steam will react with 60.5 mol of CH_4 < 219 mol present. (**1 mark**)

n(CO) = 60.5 mol

$V(CO) = n \times V_m = 60.5 \times 24.8 = 1.50 \times 10^3$ L (**1 mark**)

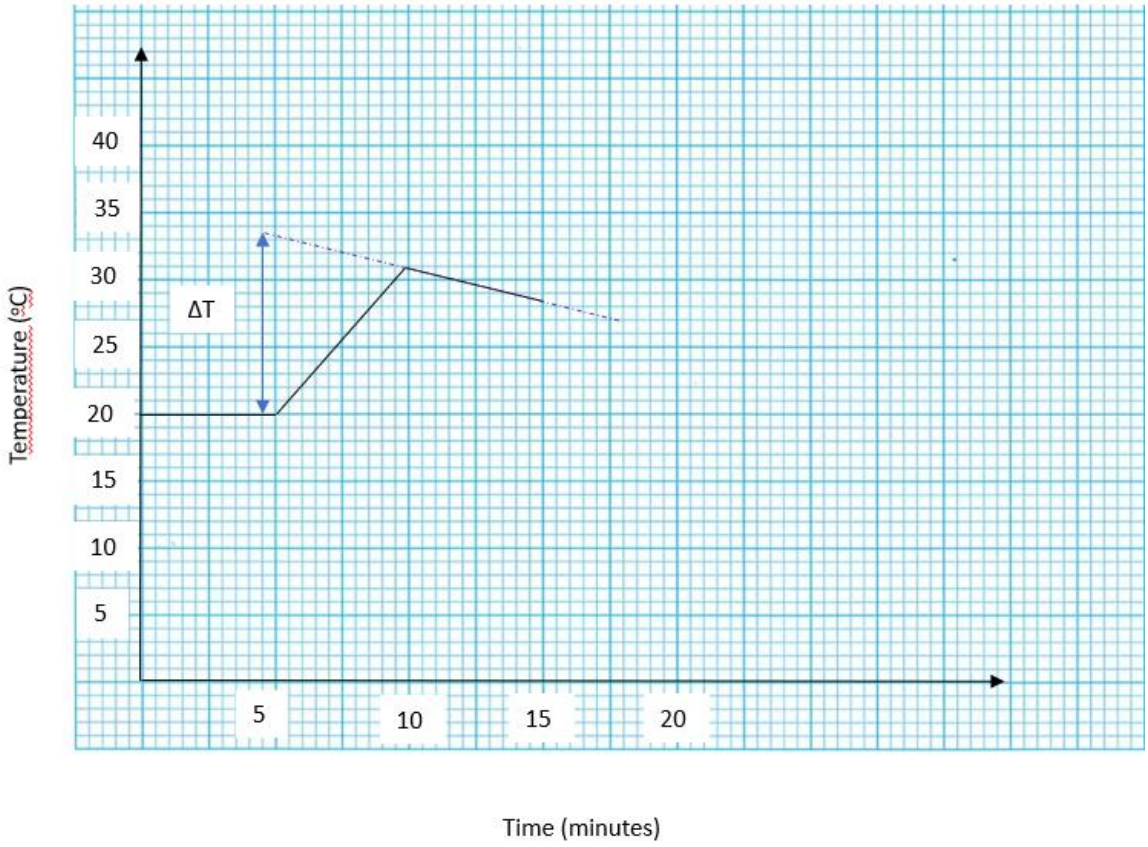
Alternatively, according to Avogadro's Law, since all reagents are gases and the temperature and pressure are assumed to remain the same, $n(H_2O)$: $n(CO) = V(H_2O) : V(CO)$ = 1:1 thus $V(CO) = V(H_2O)$ = 1500 L

b.

Work in fume cupboards / wear breathing apparatus / ensure that CO is sealed in a container. (**1 mark**)

Question 8.

E = VIt
= 5.00 x 3.12 x (5.00 x 60) = 4.68 x 10^3 J. (**1 mark**)



From the graph, extrapolating back to when the current was turned on, ΔT = 33.0 - 20.0 = 13.0 °C (**1 mark**)

CF = $\frac{E}{\Delta T} = \frac{4.68 \times 10^3}{13.0} = 3.6 \times 10^2$ J °C^{-1} (**1 mark**)

END OF MARKING SCHEME