CHEMISTRY

Unit 3 – Written examination

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2021 Trial Examination

The following breakdown of the exam shows which topic is covered in each question. This can be used to inform students of areas that need attention

Topic	Multiple choice	Short answer questions
Fuel choices	1	1(b)
Obtaining energy from fuels	2,3,4,5	1(a) , 2
Redox and Galvanic cells	6,7,8	3
Fuel cells	9,10	1(b)
Rate of reactions	11,12	4
Extent of chemical reactions	13,14,15,16	4
Production of chemicals by electrolysis	17,18,19	6
Rechargeable batteries	20	5

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Answer: D

Explanation:

D is incorrect, because as biodiesel has a higher viscosity than petrodiesel, this means it flows less easily along fuel lines than petrodiesel.

A is correct, as biodiesel has a lower energy content than petrodiesel and so more biodiesel must be burned than petrodiesel to produce the same amount of energy.

B is correct as biodiesel produces less particulates than petrodiesel.

C is correct as biodiesel is more hygroscopic than petrodiesel as it is slightly more polar due to the presence of polar bonds with the two highly electronegative oxygen atoms in the ester functional group and therefore absorbs water molecules. Also it is more likely to freeze than petrodiesel in colder climates.

Question 2

Answer: C

Explanation:

$M(C_3H_8) = 44\ g.mol^{-1}$

$n(C_3H_8) = m/M = 250/44 = 5.68\ mol$

$Energy = n \times \Delta H_c = 5.68 \times 2220 = 12613.6\ kJ = 12.61\ MJ$

Another method.

$\Delta H_c\ (C_3H_8) = 50.5 kJ/g$

$Energy = m \times \Delta H_c = 50.5 \times 250 = 12625\ kJ = 12.63\ MJ$

Question 3

Answer: B

Explanation:

$M(C_3H_8) = 44\ g.mol^{-1}$

$n(C_3H_8) = m/M = 250/44 = 5.68\ mol$

$n(CO_2) = 3\ n(C_3H_8) = 3 \times 5.68 = 17.05\ mol$

$V(CO_2) = n \times V_m = 17.05 \times 24.8 = 422.7\ L$

Question 4

Answer: B

Explanation:

q = m x c x ΔT = 50 x 4.18 x 21.7 = 4535.3 J = 4.5353 kJ
Energy = m x ΔH_c
m = energy / ΔH_c = 4.5353 / 22.7 = 0.1998 g

Question 5

Answer: D

Explanation:

A, B and C are all correct statements.
D is incorrect because if the temperature recorded was too low, the energy calculated to have heated the water would have been too low, and so the mass calculated would have been underestimated.

Question 6

Answer: A

Explanation:

As it was a galvanic cell, using the electrochemical series it can be seen that Pb is a stronger reducing agent than Ag and so Pb is oxidised while Ag^+ ions are reduced, as it is the stronger oxidising agent.
Answer C is incorrect as the equation is not balanced

Question 7

Answer: A

Explanation:

At standard conditions,
E^o_{cell} = E^o cathode(half cell containing the oxidant) - E^oanode (half cell containing the reductant)
= 0.80 – (-0.13) = 0.93 V

Question 8

Answer: D

Explanation:
Solid calcium is a strong reductant in the presence of water and be oxidised, causing reduction of the water to form hydrogen gas. The Fe^{3+}/Fe^{2+} cell does not require an iron electrode. There are soluble calcium compounds. The two half cells are separated and so the Fe^{3+} ions will not be in contact with the Ca.

Question 9

Answer: C

Explanation:
In an alkaline hydrogen fuel cell, the oxygen gas is reduced at the cathode producing OH^- ions. Answer D is incorrect as it occurs in presence of an acid [H^+ions].

Question 10

Answer: B

Explanation:
The energy content of ethanol is less than that of octane.

Question 11

Answer: D

Explanation:
From the graph it can be seen that the average kinetic energy of the particles is greater at T_2 and so T_2 represents a higher temperature. The activation energy remains constant for the reaction and does not change at a different temperature. The section under the graph for energy $\geq E_A$ is larger at T_2 so at T_2, a greater number of particles have sufficient energy to react.

Question 12

Answer: C

Explanation:
A, B and D would all increase the rate of the reaction, while C would not increase the reaction rate.

Question 13

Answer: C

Explanation:
The equilibrium constant at 250^{o} C is 0.73 M.
The set of values that gives this answer when substituted into the K_c expression are those given in C.
$K_c = [NO_2]^2/[N_2O_4] = (0.04)^2/0.0022 = 0.73M$

Question 14

Answer: A

Explanation:
An increase in temperature causes the colour intensity to lessen, indicating that there is a decrease in the concentration of $Fe(SCN)^{2+}$. This indicates that an increase in temperature causes the equilibrium position to shift to the left. An increase in temperature favours the endothermic reaction. The reverse reaction is endothermic. Thus the forward reaction is exothermic.

Question 15

Answer: D

Explanation:
At time t, the concentration of SCN^- decreases with the addition of $AgNO_3$ as there is a precipitation reaction occurring which removes the SCN^- ions from the solution. Because of the decrease in the concentration of the SCN^- the equilibrium position shifts to the left and so the concentration of SCN^- and Fe^{3+} increase while the concentration of $Fe(SCN)^{2+}$ decreases until a new equilibrium is established. The change in concentration is 1:1:1 ratio.

Question 16

Answer: B

Explanation:
$2NO(g) + 2H_2(g) \leftrightharpoons N_2(g) + 2H_2O(g)$ $\quad K_c = 6.5 \times 10^2$
Therefore, K_c of $\frac{1}{2} N_2(g) + H_2O(g) \leftrightharpoons NO(g) + H_2(g)$
is given by

$$\frac{1}{\sqrt{6.5 \times 10^2}}$$

Therefore, the correct answer is 3.9×10^{-2} which is B.

Question 17

Answer: B

Explanation:
Oxidation occurs at the anode by definition.

Question 18

Answer: B

Explanation:
$Q = It = 0.75 \times 2 \times 60 = 90$ C
$n(e^-) = Q/F = 90 / 96500 = 9.326 \times 10^{-4}$
The ratio of $n(M):n(e^-) = 9.326 \times 10^{-4} / 4.66 \times 10^{-4} = 2$
Therefore, the charge the metal ion, x, is +2

Question 19

Answer: A

Explanation:
When a concentrated solution of KCl is electrolysed, H_2O is the strongest oxidant and is reduced at the cathode, forming H_2. Because the solution is concentrated, Cl^- is oxidised at the anode, forming Cl_2.

Question 20

Answer: D

Explanation:
During discharging, the half-cell reaction occurring at the negative anode, is the oxidation of cadmium according to the half reaction $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$. During the recharging process, this reaction is reversed.

Therefore, during the recharging process, cadmium is formed at the negative cathode. D is the correct answer.

A is incorrect, as during the recharging process, electrons are generated at the anode and consumed at the cathode and so the electrons will flow through the external circuit from the anode to the cathode.

B is incorrect, because the same numbers of OH^- are being formed at the cathode as are being consumed at the anode. Therefore, there is no overall change in pH in the cell.

C is incorrect because oxidation of the $Ni(OH)_2$ in the recharging process occurs at the positive anode.

SECTION B: Short-answer questions

Question 1 (12 marks)

a. i. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \quad \Delta H = -1360 \text{ kJ mol}^{-1}$

2 marks

ii. $n(C_2H_5OH) = m/M = 1000/46 = 21.7$ mol
1 mole of CH_2H_5OH releases 1360 kJ
21.7 mol releases 1360 x 21.7 = 29565 kJ = 29.6 MJ

2 marks

iii. $n(CO_2) = 2 \times n(C_2H_5OH) = 43.48$ mol
$n = V/V_m$ so $V = n \times V_m = 43.48 \times 24.8 = 1.08 \times 10^3$ L

1 mark

b. i. anode

1 mark

ii. $C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$

1 mark

iii. $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

1 mark

iv. Electrodes are porous to allow reactants to diffuse through them so that they may react with ions in the electrolyte.
Electrodes usually contain catalysts to increase the rate of reaction.

2 marks

v. Bioethanol is a renewable fuel and so can be replenished faster than it is consumed.
The production of bioethanol is more carbon neutral than the production of ethanol.

2 marks

Question 2 (5 marks)

a. This is an exothermic reaction. The enthalpy of the products is less than the enthalpy of the reactants.

2 marks

b. $\Delta H = -70 \text{ kJ mol}^{-1}$

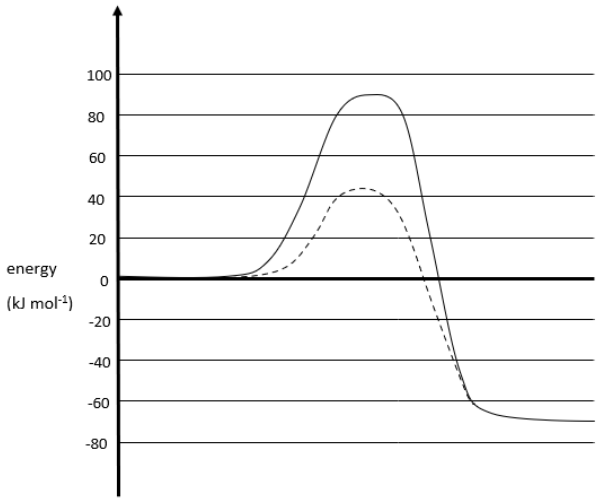
1 mark

c. E_A for the reverse reaction = $+160 \text{ kJ mol}^{-1}$

1 mark

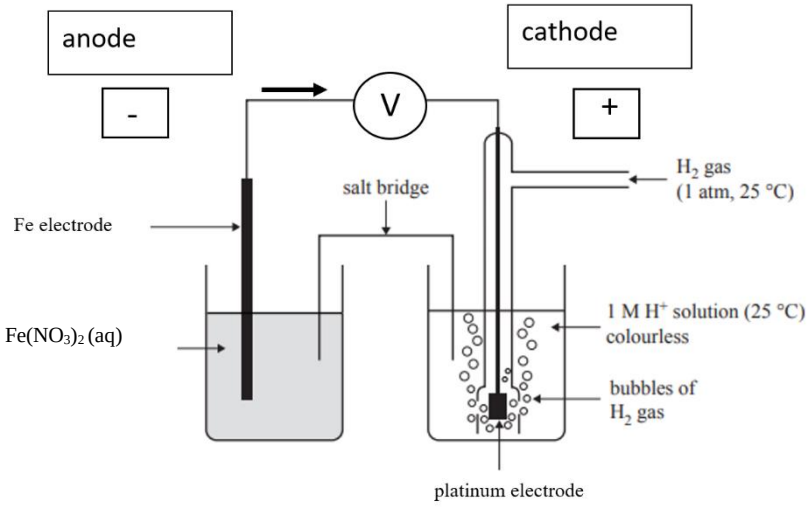
d. Shown on diagram with a dashed line. No change to enthalpy of reactants or products.
Activation energy is less but heat of reaction is unchanged.

1 mark



Question 3 (12 marks)

a.



i. see above

ii. see above

iii. see above

3 marks

e. **i.** $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

1 mark

ii. $2H^+(aq) + 2e^- \rightarrow H_2(g)$

1 mark

f. $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$

1 mark

g. H^+ or hydrogen ion

1 mark

h. KNO_3 or $NaNO_3$

1 mark

i. The two half-cells are separated so that electrons can flow through the external circuit (connecting wire).
A salt bridge connects the two half cells and completes the circuit, allowing electrons to flow through the connecting wire (external circuit)

2 marks

j. Any 2 of:
The colour of the $Fe(NO_3)_3$ becomes deeper green as the concentration of Fe^{2+} ions increases.
The size of the Fe electrode becomes smaller.

2 marks

Question 4 (15 marks)

a. i. Decrease
Reasoning: Decreasing temperature decreases the average kinetic energy of reactant molecules and so there are fewer collisions with an energy greater than the activation energy and the proportion of successful collisions decreases.

ii. Increase
Reasoning: Increasing pressure increases the concentration of the reactant particles and so the frequency of collisions increases.

4 marks

b. i. Increase
Reasoning: System moves to partially oppose the increase in pressure by favouring the forward reaction which produces less gaseous particles.

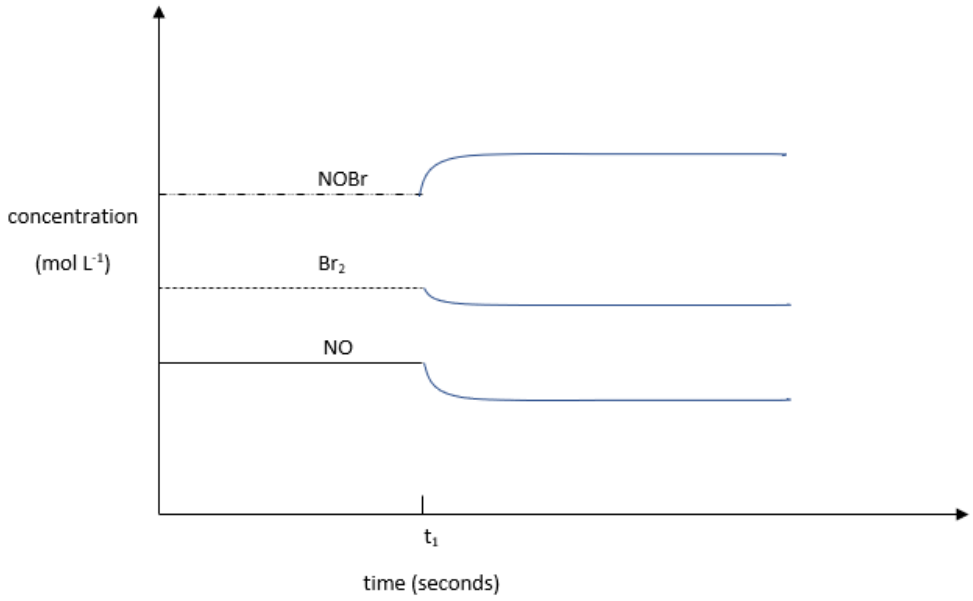
ii. Increase
Reasoning: System moves to compensate for the removal of product by favouring the forward reaction to produce more NOBr.

4 marks

c. 1 mark for showing each of the following:

- increase in NOBr and decrease in Br_2 and NO
- equilibrium is re-established at the same time for all species
- the correct ratio for change in concentration 2:1:2

3 marks



d. i. $K_c = \frac{[NOBr]^2}{[NO]^2[Br_2]}$

1 mark

ii.

	2NO	Br_2	2NOBr
I (mol)	1.3	1.11	0
C (mol)	-0.1	-0.05	+0.1
E (mol)	1.2	1.06	0.1
E (conc)	1.2 / 2 = 0.6	1.06 / 2 = 0.53	0.1 / 2 = 0.05

$$K_c = \frac{[NOBr]^2}{[NO]^2[Br_2]} = \frac{[0.05]^2}{[0.6]^2[0.53]} = 0.0131M^{-1}$$

3 marks

1 mark was awarded for:

- Correct concentrations of each species at equilibrium
- Substitution of values into equilibrium expression
- Correct calculation of the value of the equilibrium constant.

Question 5 (10 marks)

a. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

1 mark

b. $PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$
PbO_2 is the oxidising agent.
Oxidation number on lead ions has decreased from +4 to +2 through gain of electrons (reduction)

2 mark

c. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

1 mark

d. Oxidation occurs at the anode and reduction occurs at the cathode in both cells. The negative electrode in the discharge reaction is still the negative electrode in the recharging reaction OR The positive electrode in the discharge reaction is still the positive electrode in the recharging reaction.

1 mark

e. Discharging cells: chemical energy is converted into electrical energy; while in recharging cells, electrical energy is converted into chemical energy;
Or, in a discharging cell the anode is negative / oxidation occurs at the negative electrode / the cathode is positive / reduction occurs at the positive electrode while in a recharging cell, the anode is positive / oxidation occurs at the positive electrode / the cathode is negative / reduction occurs at the negative electrode

1 mark

f. It can be recharged because its products remain in contact with the electrodes.

1 mark

g. When the battery is recharged, the concentration of H^+ ions increases as H^+ ions are produced during recharging. This means that the pH of the solution would decrease.

2 marks

h. A voltage slightly more than 12 V

1 mark

Question 6 (13 marks)

a. A is the anode (positive electrode – connected to the positive terminal of the battery)

1 mark

b. i. brown discolouration of the solution from the formation of bromine. Some brown gas might be seen.

1 mark

ii. A gray deposit would form on the electrode

1 mark

c. i. $2Br^-(l) \rightarrow Br_2(l) + 2e^-$

1 mark

ii. $Mg^{2+}(l) + 2e^- \rightarrow Mg(l)$

1 mark

d. $n(Mg) = m/M = 1.0 / 24.3 = 0.041$ mol
$n(e^-) = 2 \times n(Mg) = 2 \times 0.041 = 0.082$ mol
$Q = n(e^-) \times F = 0.082 \times 96500 = 7942.4$ C

t = Q/I = 7942.4 / 1.62 = 4902.7 seconds = 81.7 minutes

4 marks

e. At electrode B, magnesium would not be produced because water would be the strongest oxidising agent present.
Water would be preferentially reduced instead of the Mg^{2+} ion.
At electrode B, hydrogen gas would be produced and bubbles would be seen instead of the deposit of metal seen previously.
The half equation would be:
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

4 marks