Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Suggested Solutions

Test 2: What are the current and future options for supplying energy?

- Primary galvanic cells and fuel cells as sources of energy

SECTION A – MULTIPLE-CHOICE QUESTIONS

Question 1 A

A is correct. A redox reaction always involves a change in oxidation numbers. In option **A**, the oxidation number of nitrogen changes from +4 (NO_2) to +5 (HNO_3) and +2 (NO). Nitrogen undergoes both oxidation and reduction.

B is incorrect. This is a precipitation reaction. There is no change in oxidation numbers.

C is incorrect. This is an organic substitution reaction. There is no change in oxidation numbers.

D is incorrect. This is an acid–base reaction. A transfer of protons (H^+) occurs.

Question 2 B

B is correct. Predictions using the electrochemical series are based on standard conditions (1.0 M, 25°C). The concentration of the solutions used is not specified, so may well have been other than 1.0 M, resulting in a cell voltage different from that predicted.

A is incorrect. Incorrectly connecting the electrodes would result in a negative reading on the voltmeter, not an altered numeric value.

C is incorrect. 25°C is the standard temperature so this is not a valid explanation.

D is incorrect. $NaNO_3$ and KNO_3 would behave similarly in the salt bridge.

Question 3 C

The relevant oxidation numbers are as follows.

S in PbS: –2; S in $PbSO_4$: +6

O in H_2O_2: –1; O in H_2O: –2

Thus S changes from –2 to +6, an oxidation reaction, and O changes from –1 to –2, a reduction reaction. As O has undergone reduction, H_2O_2 is acting as an oxidising agent. Note that the oxidation numbers of Pb and H do not change.

Question 4 B

B is correct. A chemical will oxidise Sn^{2+} if it is an oxidising agent and has an $E°$ value greater than +0.15 V. Oxidising agents with $E°$ values less than 0.77 V will not oxidise Fe^{2+}. Referring to the electrochemical series shows that I_2 will not oxidise Fe^{2+}, but it will oxidise Sn^{2+}.

A and **C** are incorrect. Br_2 and H_2O_2 will oxidise both Sn^{2+} and Fe^{2+}.

D is incorrect. Pb^{2+} will oxidise neither Sn^{2+} nor Fe^{2+}.

Question 5 A

A is correct and **C** is incorrect. The Ag^+ ion is a stronger oxidising agent than the Ni^{2+} ion, and so it is reduced at the cathode during the operation of the cell.

B and **D** are incorrect as metals are reducing agents, not oxidising agents.

Question 6 A

The equation for the overall reaction is $2Ag^+(aq) + Ni(s) \rightarrow 2Ag(s) + Ni^{2+}(aq)$.

$$n(\text{Ag}) = \frac{m}{M} = \frac{0.016}{107.9} \text{ mol}$$

$$n(\text{Ni}) = \frac{1}{2} \times n\left(\text{Ag}\right)$$

$$m(\text{Ni}) = n \times M = \frac{1}{2} \times \frac{0.016}{107.9} \times 58.7 = 0.0044 \text{ g}$$

Question 7 C

C is correct. The salt bridge allows ion flow to balance the charges created in each half-cell as oxidation and reduction occur.

A is incorrect. Electrons flow from anode to cathode.

B is incorrect. Anions flow from cathode half-cell to the anode half-cell.

D is incorrect. The salt bridge is not the site of conversion of energy.

Question 8 B

B is correct. Balancing the electrons in each half-equation to ensure that electrons gained equals electrons lost requires that the reduction reaction for oxygen is doubled. The ratio therefore becomes $CH_4 : O_2 = 1 : 2$.

A, **C** and **D** are incorrect as they do not show the coefficients for a balanced equation.

Question 9 C

C is an incorrect statement and so is the required response. While they have a high efficiency for converting chemical energy to electrical energy, fuel cells are not 100% efficient. Some energy will be 'lost' in the form of heat.

A is a correct statement and so is not the required response. The mass of CO_2 per gram of CH_4 used will be the same, whichever device is used. It is the energy per gram of CH_4 that will differ for different devices.

B is a correct statement and so is not the required response. Biogas as a methane source is a renewable feedstock.

D is a correct statement and so is not the required response. Biogas use approaches carbon neutral, as the process of photosynthesis that produces the organic matter that in turn produces the biogas removes CO_2 from the atmosphere. Combustion of the biogas returns the CO_2 to the atmosphere. The overall effect is one of minimal contribution to the CO_2 level in the atmosphere.

Question 10 B

For cell 1, the electrons flow towards the strongest oxidising agent, B^{2+}. This means that in oxidising agent strength, $B^{2+} > A^{2+}$ (with a difference of 0.28). Similarly, from cell 2, $B^{2+} > C^{2+}$ (with a difference of 0.47), and from cell 3, $A^{2+} > D^{2+}$ (with a difference of 0.35). Therefore, the strongest oxidising agent is B^{2+} (then A^{2+}, C^{2+} and finally D^{2+}).

SECTION B

Question 1 (5 marks)

a. i. $C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$ 1 mark

ii. $MnO_4(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ 1 mark

b. i. Mn 1 mark

(the reducing agent with the lowest E° value)

ii. $3Mn(s) + 2Au^{3+}(aq) \rightarrow 2Au(s) + 3Mn^{2+}(aq)$ 1 mark

(the reducing agent with the lowest E° value reacting with the oxidising agent with the highest E° value)

iii. 2.68 V (1.50 – (–1.18)) 1 mark

Question 2 (9 marks)

a. i. → 1 mark

(Electrons move from the Cu electrode to the Ag electrode.)

ii. Cu 1 mark

(Oxidation occurs at the anode.)

iii. NO_3^- 1 mark

(Electrons flow away from the copper half-cell. As the positive charge in the half-cell increases, the negative ions migrate in to maintain electrical neutrality.)

iv. *Any two of:*

- The blue colour of the copper(II) ion increases.
- The silver electrode increases in mass.
- The copper electrode decreases in mass.

2 marks

1 mark for each correct response.

v. The chloride ion would precipitate the silver ion in the half-cell, disrupting the correct cell function. 1 mark

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ 1 mark

b. i. metal cap: –

(Zn is the reducing agent.)

nickel/steel: + 1 mark

(Ag_2O is the oxidising agent.)

ii. $Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$ 1 mark

Question 3 (11 marks)

a. **i.** $CH_3OH(aq) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$ 1 mark

ii. $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ 1 mark

b. **i.** → 1 mark

(*The H^+ ion moves towards electrode Q.)*

ii. → 1 mark

(Electrons move from electrode P to electrode Q.)

iii. electrode Q 1 mark

(the site of reduction)

c. It is costly and requires more complex equipment to maintain high temperatures and pressures. Satisfactory performance can be achieved without the extreme, uneconomical conditions. 1 mark

d. *Any two of:*

- They are the site of oxidation and reduction.
- They catalyse the reactions.
- They separate the reactant gases.
- They are porous to allow reactant gases to come into contact with the electrolyte.

2 marks

1 mark for each correct response.

e. *Any two of:*

- high cost
- slow rate of reaction at electrodes requiring catalyst use
- potential poisoning of the catalytic electrodes and consequent costs
- difficulty of storing gaseous reactants

2 marks

1 mark for each correct response.

f. *For example:*

A primary cell has a limited amount of chemical energy, and when this is depleted the cell cannot be recharged. The DMFC has fuel continuously fed into it without stopping its operation. 1 mark