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CHEMISTRY

Physical Chemistry

Level & Board	AQA (A-LEVEL)
TOPIC:	Oxidation Reducation & Redox
PAPER TYPE:	SOLUTION - 2
TOTAL QUESTIONS	10
TOTAL MARKS	47

Oxidation, Reduction and Redox Equations - 2

1.

(a)

ΔH_f for $V_2O_5(s)$ = -1560 kJ/mol

ΔH_f for $CaO(s)$ = -635 kJ/mol

The enthalpy change for the reaction can be determined by considering the difference in the sum of the enthalpies of formation of products and reactants.

ΔH reaction = $\Sigma\ \Delta H_f$ (products) - $\Sigma\ \Delta H_f$ (reactants)

ΔH reaction = [2 ΔH_f (V) + 5 ΔH_f (CaO)] - [5 ΔH_f (Ca) + ΔH_f (V_2O_5)]

ΔH reaction = [2(0) + 5(-635)] - [5(0) + (-1560)]

ΔH reaction = [-3175] - [-1560]

ΔH reaction = -3175 + 1560

ΔH reaction = -1615 kJ

V_2O_5 is being reduced to form V(s) (vanadium metal), which implies a reduction reaction.

Calcium is a (very) reactive metal and reacts with water or air.

The reactivity of calcium makes it difficult to handle and process. It requires specialized handling, storage, and precautions to prevent unwanted reactions, which could lead to increased expenses in terms of safety measures, specialized equipment, and overall operational complexity.

(5)

(b)

$2Al+Fe_2O_3 \rightarrow 2Fe+Al_2O_3$

In this reaction, aluminum (Al) undergoes a change in its oxidation state. The oxidation state of aluminum changes from 0 in its elemental form to +3 in aluminum oxide (Al_2O_3).

This change in oxidation state from 0 to +3 signifies that aluminum has been oxidized in the reaction.

(2)

(c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2 Write an equation for this reaction in which the only other product is HCl gas. Identify two hazards in this process, other than the fact that it operates at a high temperature. Deduce why this process produces pure vanadium, other than the fact that purified VCl_2 is used.

The reaction of hydrogen with purified VCl_2 to produce pure vanadium and hydrogen chloride gas can be represented as follows:
$VCl_2 + H_2 \rightarrow V + 2HCl$

Hazards in this process, other than high-temperature operation, are:

Toxicity and Corrosiveness of HCl: Hydrochloric acid (HCl) is highly acidic, corrosive, and toxic. It poses a danger upon contact with skin, eyes, or inhalation. It can cause severe burns and respiratory issues.
Explosion Risk with Hydrogen (H_2): Hydrogen gas is highly flammable and can form explosive mixtures with air. Any uncontrolled release or accumulation of hydrogen gas can lead to an explosion hazard.
Regarding the removal of HCl as a gas and why this process produces pure vanadium:
The only other product, HCl, is easily removed as a gas: HCl is gaseous at room temperature and pressure, allowing it to be easily separated from the desired solid product, vanadium. The HCl gas can be readily vented or captured, leaving behind pure solid vanadium.

(4)

2. (D)

(Total 1 mark)

3.

(a)

i.

$SiO_2 + 2Cl_2 + 2C \rightarrow SiCl_4 + 2CO$

(1)

ii.

Liquid $SiCl_4$ can be purified through fractional distillation. By heating the impure $SiCl_4$, collecting the vapor, and condensing it at its boiling point (around 57°C), impurities with different boiling points are separated, yielding purified liquid $SiCl_4$.

(1)

(b)

i.

$SiCl_4 + 2H_2 \rightarrow Si + 4HCl$

(1)

ii.

Hydrogen in this reaction act as reducing agent it reduces (silicon).

(1)

iii. Risk with the use of hydrogen gas it can be explosive or inflammable.

(1)

(c)

$2MgO + Si \rightarrow 2Mg + SiO_2$

(1)

4. **(C)**

(Total 1 mark)

5.

(a)

i.

$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

(1)

ii.

HNO_3 (Nitric acid):
Nitrogen in nitric acid (HNO3) has an oxidation state of +5.
Applying these typical values:
$01 \times H + x + 3 \times (-2) = 0$ (the sum of oxidation states equals the charge of the molecule)
$x = +5$
NO_2 (Nitrogen dioxide):
Nitrogen in nitrogen dioxide (NO_2) has an oxidation state of +4.
$2 \times (-2) + x = 0$ (the sum of oxidation states equals the charge of the molecule) $-4 + x = 0$
$x = +4$

(2)

iii.

$HNO_3 + H^+ + e^- \rightarrow NO_2 + H_2O$

(1)

(b)

i.

Two features of a reaction at equilibrium:

Constant concentrations: The concentrations of reactants and products remain unchanged at equilibrium.

Equal rates: At equilibrium, the forward and reverse reaction rates are equal.

(2)

ii.

When heated at constant pressure, the equilibrium shifts toward the right (endothermic direction) to produce more dark brown nitrogen dioxide (NO_2) gas, absorbing the added heat. This shift causes the mixture to become darker in color.

(2)

iii.

An increase in pressure at constant temperature causes the equilibrium to shift left, favoring the formation of colorless dinitrogen tetraoxide (N_2O_4) over dark brown nitrogen dioxide (NO_2) due to fewer gas molecules, reducing the total gas moles to counteract the pressure increase. Moreover there is one mole (of gas) on the left and 2 moles on the right so, the equilibrium shifts right to left to oppose the increase in pressure

(2)

6. (D)

(Total 1 mark)

7.

(a)

i.

$2MoS_2 + 7O_2 \rightarrow 2MoO_3 + 4SO_2$

(1)

ii.

The release of sulfur dioxide can cause the acid rain. An effect either from acid rain or from an acidic gas in the atmosphere.

SO_2 could be used to make H_2SO_4 or to make gypsum.

(2)

iii.

$MoO_3 + 3H_2 \rightarrow Mo + 3H_2O$

(1)

iv.

The risk in using hydrogen gas in metal extractions it can be explosive or easily ignited.

(1)

(b)

i.

Calcium chloride must be molten for electrolysis to occur as this allows ions to move.

(1)

ii.

$Ca^{2+} + 2e^{-} \rightarrow Ca$

(1)

iii.

The major cost in this extraction of calcium is electrical energy (cost).

(1)

8. (D)

(Total 1 mark)

9. (B)

(Total 1 mark)

10.

(a)

i.

$2CuFeS_2 + 2SiO_2 + 4O_2 \rightarrow Cu_2S + 2FeSiO_3 + 3SO_2$

(1)

ii.

SO_2 gas formed in this reaction is not allowed to escape into the atmosphere as it froms an acidic gas in the atmosphere or Acid rain.

(1)

iii.

SO_2 could be used to make H_2SO_4 or to make gypsum.

(1)

(b)

$Cu_2S + 2O_2 \rightarrow 2CuO + SO_2$

(1)

(c)

$2CuO + C \rightarrow 2Cu + CO_2$

(1)

(d)

i.

This is a low-cost method of extracting copper.
As (Scrap) iron is cheap or due to low energy requirement.

(1)

ii.

$Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$

(1)

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