5.2 Hess's Law

Question Paper

Course	DP IB Chemistry
Section	5. Energetics / Thermochemistry
Topic	5.2 Hess's Law
Difficulty	Hard

Time allowed: 50

Score: /40

Percentage: /100

Question 1a

a)
Vanadium is commonly found in different ores such as magnetite, vanadinite and patronite. The vanadium is commonly extracted from these ores by reduction and displacement.

Vanadium can be extracted by the reduction of vanadium pentoxide, V_2O_5, with calcium at high temperatures, according to the following equation.

$$V_2O_5\,(s) + 5Ca\,(s) \rightarrow 2V\,(s) + 5CaO\,(s)$$

The enthalpy of formation of vanadium pentoxide is -1560 kJ mol^{-1} and the standard enthalpy change for the reaction is -1615 kJ mol^{-1}.

Construct a Hess's Law cycle for this reaction.

[2]

[2 marks]

Question 1b

b)
Use the data in part a) to calculate the enthalpy of formation, ΔH_f, of calcium oxide in kJ mol^{-1}.

[3]

[3 marks]

Question 1c

c)
Define *standard enthalpy of neutralisation*, ΔH_{neut}.

[2]

[2 marks]

Question 2a

a)
The compound diborane, B_2H_6, is used as a rocket fuel. The equation for the combustion of diborane is shown below.

$$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(l)$$

Calculate the standard enthalpy change of this reaction using the following data

I. $2B(s) + 3H_2(g) \rightarrow B_2H_6(g)$ $\quad \Delta H = 36\ kJ\ mol^{-1}$
II. $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H = -286\ kJ\ mol^{-1}$
III. $2B(s) + 1½O_2(g) \rightarrow B_2O_3(s)$ $\quad \Delta H = -1274\ kJ\ mol^{-1}$

[3 marks]

Question 2b

b)
Ethyne, C_2H_2, is a useful gas as it gives a high temperature flame when burnt with oxygen. State the equation for the combustion of ethyne gas.

[1]

[1 mark]

Question 2c

c)
Use your answer to part b) to construct a Hess's Law cycle for the combustion of ethyne gas.

[3]

[3 marks]

Question 2d

d)
Use sections 12 and 13 in the data booklet to determine the enthalpy of formation, ΔH_f, of ethyne gas.

[3]

[3 marks]

Question 3a

a)
Coal gasification converts coal into a combustible mixture of carbon monoxide and hydrogen known as coal gas, in a gasifier.

$$H_2O\,(l) + C\,(s) \rightarrow CO\,(g) + H_2\,(g)$$

Using the following equations, calculate the enthalpy change of reaction, ΔH_r, in kJ for cola gasification.

I. $2C\,(s) + O_2\,(g) \rightarrow 2CO\,(g)$ $\quad \Delta H = -222$ kJ
II. $2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g)$ $\quad \Delta H = -484$ kJ
III. $H_2O\,(l) \rightarrow H_2O\,(g)$ $\quad \Delta H = +44$ kJ

[3]

[3 marks]

Question 3b

b)
This coal gas can be used as a fuel as the following equation shows.

$$CO(g) + H_2(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$$

Calculation the enthalpy change of reaction, ΔH_r, in kJ for this combustion reaction from the following equations.

I. $2C(s) + O_2(g) \rightarrow 2CO(g)$ $\Delta H = -222$ kJ
II. $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -394$ kJ
III. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H = -484$ kJ

[3]

[3 marks]

Question 3c

c)
Blending amounts of alternative fuel with conventional fuel is one way to replace petroleum. A fuel blend of 51% to 83% ethanol and the remaining being gasoline is known as E85.

If the fuel blend is vaporised before combustion, predict whether the amount of energy released would be greater, less or the same. Explain your answer.

[2]

[2 marks]

Question 3d

d) Use sections 6 and 13 of the Data booklet to calculate the following.

i)
The amount, in moles, of ethanol in 1 kg of E85 containing 60% ethanol.

[2]

ii)
The energy released, in kJ, by ethanol if 1 kg of E85 is burnt.

[1]

[3 marks]

Question 4a

a)
Strontium salts have a number of applications such as fireworks, flares, glow in the dark paint and toothpaste for sensitive teeth. The strontium required for these salts can be extracted from the ore strontia, SrO, by displacement with powdered aluminium in a vacuum.

i)
Write a balanced symbol equation, including state symbols, for the reaction of strontia with aluminium.

[2]

ii)
State the role of the aluminium in this reaction.

[1]

[3 marks]

Question 4b

b)
The standard enthalpy change for this extraction of strontium is 99.3 kJ mol^{-1} and the standard enthalpy of formation of aluminium oxide is -1676.7 kJ mol^{-1}

Use this information to calculate the standard enthalpy of formation, ΔH_f, in kJ mol^{-1} of strontia.

[3]

[3 marks]

Question 4c

c)
Manganese is too brittle for use as a pure metal, so it is often alloyed with other metals. Manganese is used in steel to increase the strength and resistance to wear. Manganese steel (13% Mn) is extremely strong and used for railway tracks, safes and prison bars. Alloys of 1.5% manganese with aluminium are used to make drinks cans due to the improved corrosion resistance of the alloy.

Manganese is extracted from different ores by reduction with carbon monoxide.

$$Mn_2O_3\,(s) + 3CO\,(g) \rightarrow 2Mn\,(s) + 3CO_2\,(g)$$

The enthalpy of formation, ΔH_f, of $Mn_2O_3\,(s)$ is –971 kJ mol^{-1}. Use this information and section 12 of the data booklet to calculate the enthalpy change of reaction, ΔH_r, in kJ mol^{-1}.

[3 marks]

Question 4d

d)
The reaction in part c) reaches equilibrium at high temperatures.

Use your answer to part c) to explain how temperature can be altered to increase the yield of the reaction and explain the effect that this would have on the rate of reaction.

[3 marks]