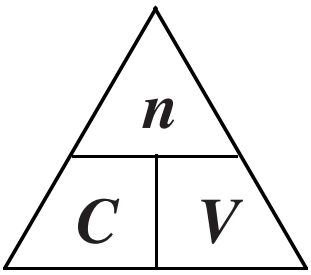
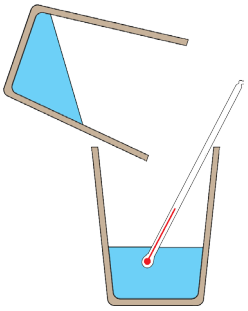


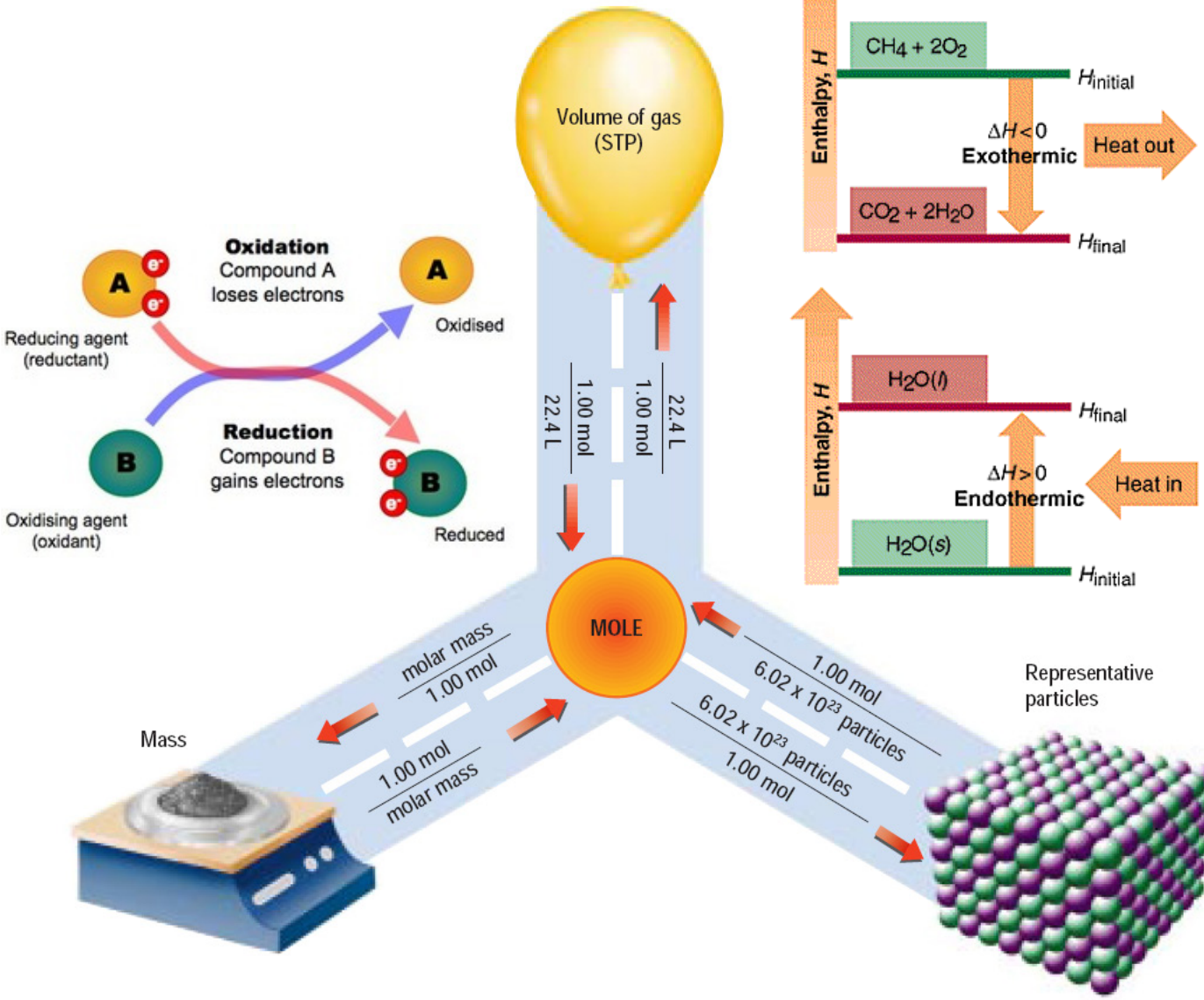
Higher Chemistry



Topic 4:

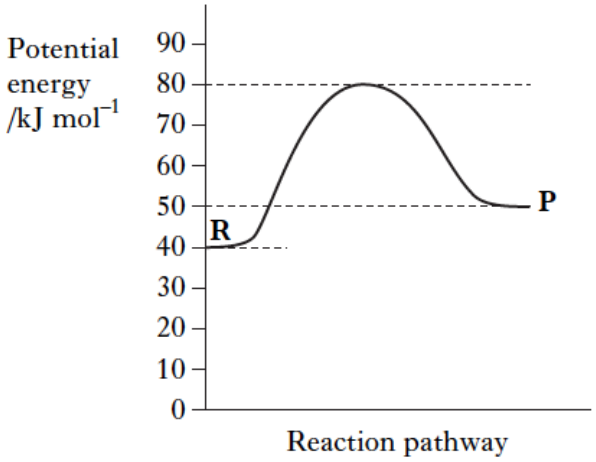
Enthalpy, Moles & RedOx

Questions



SELF CHECK 4.1

Q1. The potential energy diagram below refers to the reversible reaction involving reactants **R** and products **P**.



What is the enthalpy change, in kJ mol^{-1}, for the reverse reaction **P** → **R**?

A + 30

B + 10

C - 10

D - 40

Q2. Which of the following represents an exothermic process?

A $Cl_{2(g)} \rightarrow 2Cl_{(g)}$

B $Na_{(s)} \rightarrow Na_{(g)}$

C $Na_{(g)} \rightarrow Na^{+}_{(g)} + e^{-}$

D $Na^{+}_{(g)} + Cl^{-}_{(g)} \rightarrow Na^{+}Cl^{-}_{(s)}$

Q3. Which equation represents the first ionisation energy of a diatomic element, X_2?

A $X_{2(s)} \rightarrow X^{+}_{(g)}$

B $X_{2(g)} \rightarrow X^{-}_{(g)}$

C $X_{(g)} \rightarrow X^{+}_{(g)}$

D $X_{(s)} \rightarrow X^{-}_{(g)}$

Q4. The enthalpy of neutralisation in an acid/alkali reaction is always the energy released in

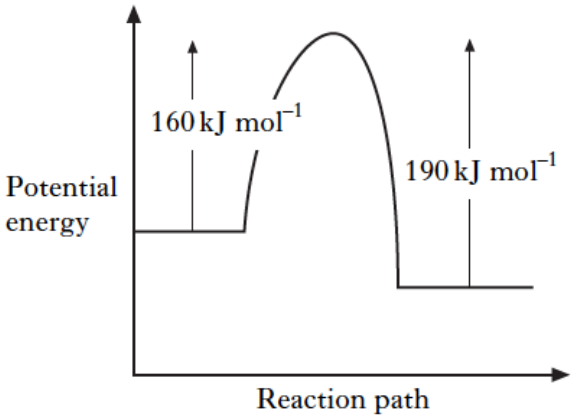
A the formation of one mole of salt

B the formation of one mole of water

C the neutralisation of one mole of acid

D the neutralisation of one mole of alkali.

Q5.



When a catalyst is used, the activation energy of the forward reaction is reduced to 35 kJ mol^{-1}.

What is the activation energy of the catalysed reverse reaction?

A 30 kJ mol^{-1}

B 35 kJ mol^{-1}

C 65 kJ mol^{-1}

D 190 kJ mol^{-1}

Q6. A potential energy diagram can be used to show the activation energy (E_A) and the enthalpy change (ΔH) for a reaction.

Which of the following combinations of E_A and ΔH could ***never*** be obtained for a reaction?

A E_A = 50 kJ mol^{-1} and ΔH = +100 kJ mol^{-1}

B E_A = 50 kJ mol^{-1} and ΔH = −100 kJ mol^{-1}

C E_A = 100 kJ mol^{-1} and ΔH = +50 kJ mol^{-1}

D E_A = 100 kJ mol^{-1} and ΔH = −50 kJ mol^{-1}

Q7.

$$5N_2O_{4(l)} + 4CH_3NHNH_{2(l)} \rightarrow 4CO_{2(g)} + 12H_2O_{(l)} + 9N_{2(g)}$$

ΔH = −5116 kJ

The energy released when 2 moles of each reactant are mixed and ignited is

A 2046 kJ

B 2558 kJ

C 4093 kJ

D 5116 kJ.

HOME PRACTICE 4.1

Q1. The standard enthalpy of combustion of propane is -2219 kJ mol^{-1}.

a) Write the molecular formula for propane. **1**

b) Write an equation for the complete combustion of propane. **1**

c) What is the enthalpy change for the complete combustion of one gram of propane? **2**

d) Propane is used as a fuel. How much energy will be produced when 1kg of propane is completely burnt? **1**

Q2. A student investigated how well different hydrocarbon fuels would heat up 100 g of water.

Her hypothesis was:

The more carbon atoms there are in a molecule of any fuel, the better the fuel is.

Her results are shown in the table. The student investigated only hydrocarbons.

Name of hydrocarbon fuel	Number of carbon atoms in a molecule of hydrocarbon fuel	Temperature change of water in °C after 2 minutes	Temperature change per g of fuel burned	Observations
Pentane	5	30	60	no smoke
Hexane	6	40	57	very small amount of smoke
Octane	8	55	55	small amount of smoke
Decane	10	57	52	large amount of smoke
Dodecane	12	60	43	very large amount of smoke

a) Look carefully at her results. How well do the student's results support her hypothesis? Give reasons for your answer. **2**

b) Suggest an improvement the student could make to this investigation. **1**

Q3. The reaction between hydrazine and hydrogen peroxide can be used for propelling rockets.

$$N_2H_{4\ (l)} + 2H_2O_{2\ (l)} \longrightarrow N_{2\ (g)} + 4H_2O_{\ (g)} \qquad \Delta H = -685\ kJ\ mol^{-1}$$

From the information given in the equation suggest ***two*** reasons for its suitability. **2**

Total ***(10)***

SELF CHECK 4.2/4.3

Items 1 to 2 refer to 50 cm³ $NaOH_{(aq)}$ at 19 °C being mixed with 50 cm³ $HCl_{(aq)}$ at 17 °C.

Q1. If the temperature rose to 25 °C, what was the temperature change caused by the reaction?

A 6°C

B 7°C

C 8 °C

D 9°C

Q2. To calculate the enthalpy change, what mass of water should be used in the calculation?

A 0.025 kg

B 0.050 kg

C 0.100 kg

D 0.500 kg

Q3. If **c** = 4.18 kJ kg^{-1} $°C^{-1}$ is the specific heat capacity for water, what is the expression for calculating the enthalpy change?

A $\Delta H = -c\,m\,\Delta T$	**B** $\Delta H = \frac{-c\,m}{\Delta T}$
C $\Delta H = \frac{-c\,\Delta T}{m}$	**D** $\Delta H = \frac{-m\,\Delta T}{c}$

Q4. If dissolving $NaOH_{(s)}$ in 80 g of water at 20 °C raises the temperature to 40 °C, what is the enthalpy change?

A - 6.69 kJ

B +6.69 kJ

C - 13.38 kJ

D +13.38 kJ

Q5. If the enthalpy change for 1.00 g of solid NaOH (RFM = 40) reacting with excess hydrochloric acid is -1.25 kJ, what is the enthalpy change for 1 mole fully reacting?

A - 32 kJ

B - 50 kJ

C - 64 kJ

D - 100 kJ

Q6. Ethanol (C_2H_5OH) has a different enthalpy of combustion from dimethyl ether (CH_3OCH_3).

This is because the compounds have different

A boiling points

B molecular masses

C products of combustion

D bonds within the molecules.

Q7. Which of the following equations represents an enthalpy of combustion?

A $C_2H_5OH_{(l)} + O_{2(g)} \rightarrow CH_3COOH_{(l)} + H_2O_{(l)}$

B $CH_3CHO_{(l)} + O_{2(g)} \rightarrow CH_3COOH_{(l)}$

C $CH_{4(g)} + {}^3/_2\, O_{2(g)} \rightarrow CO_{(g)} + 2H_2O_{(l)}$

D $C_2H_{6(g)} + 3\, O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$

Q8. Aluminium reacts with oxygen to form aluminium oxide.

$2Al_{(s)} + {}^3/_2\, O_{2(g)} \rightarrow Al_2O_{3(s)} \quad \Delta H = -1670 \text{ kJ mol}^{-1}$

What is the enthalpy of combustion of aluminium in kJ mo^{l-1}?

A − 835

B −1113

C −1670

D +1670

HOME PRACTICE 4.2/4.3

Q1. Chloroethane can be produced by the reaction of ethene with hydrogen chloride:

$$H_2C{=}CH_{2(g)} + H{-}Cl_{(g)} \rightarrow H_3C{-}CH_2Cl_{(g)}$$

Calculate the standard enthalpy change for this reaction given the following average bond enthalpies.

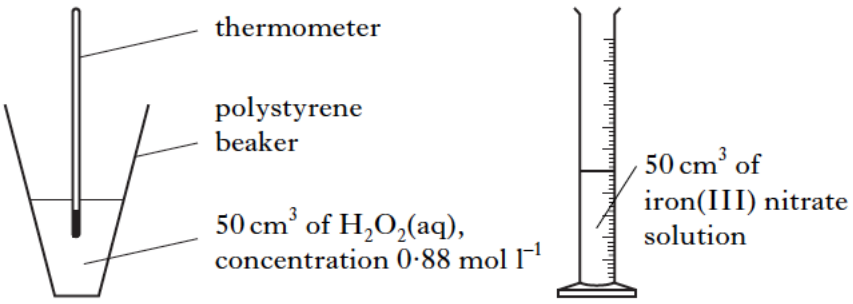
Bond	*Average bond enthalpy/kJ mol^{-1}*
C=C	*612*
C–H	*467*
C–C	*347*
H–Cl	*432*
C–Cl	*346*

3

Q2. Hydrogen peroxide decomposes as shown:

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

The reaction can be catalysed by iron(III) nitrate solution. In order to calculate the enthalpy change for the decomposition of hydrogen peroxide, a student added iron(III) nitrate solution to hydrogen peroxide solution.

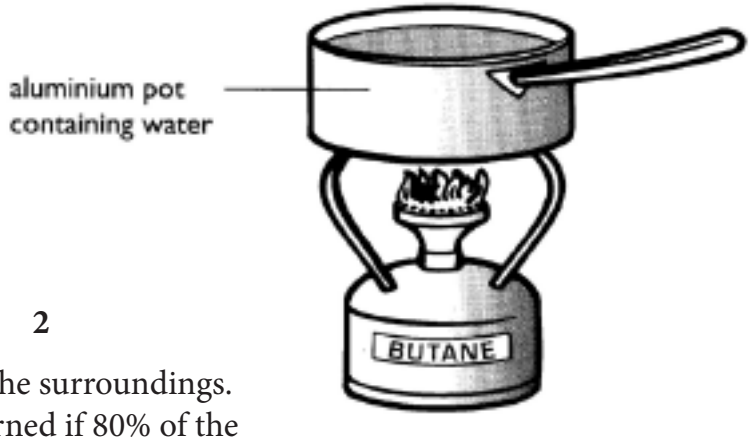


As a result of the reaction, the temperature of the solution in the polystyrene beaker increased by 16 °C.

a) What is the effect of the catalyst on the enthalpy change (ΔH) for the reaction? **1**

b) Use the experimental data to calculate the enthalpy change, in kJ mol^{-1}, for the decomposition of hydrogen peroxide. **3**

Q3. Two litres of water, initially at 25°C, were heated using a butane burner as shown.



a) Using appropriate data from your Data Book, calculate the number of moles of butane needed to boil this quantity of water. **2**

b) In practice, some heat is lost to the surroundings. Calculate the mass of butane burned if 80% of the heat produced by the burner is transferred to the water. **2** ***Total (11)***

SELF CHECK 4.4

Q1. Hess's Law states that the overall enthalpy change in a reaction depends only on the

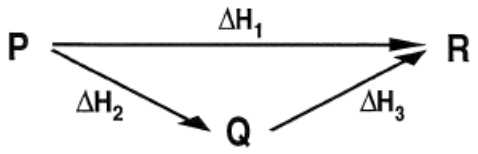
A type of catalyst used.

B particular reaction route.

C overall rate of the reaction.

D initial reactants and final products.

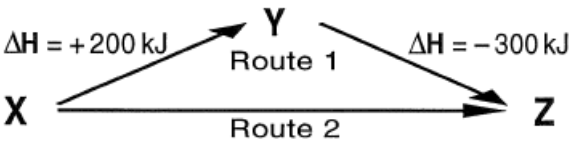
Q2. The products at R can be made from the reactants at P by two routes as shown.



According to Hess's Law, what relationship between the enthalpy changes should be true?

A $\Delta H_1 = \Delta H_2 + \Delta H_3$	**B** $\Delta H_1 = \frac{\Delta H_2 + \Delta H_3}{2}$
C $\Delta H_1 = \frac{\Delta H_3 - \Delta H_2}{2}$	**D** $\Delta H_1 = \Delta H_3 - \Delta H_2$

Q3. The products at Z can be made from the reactants at X twice as fast by route 1.



What is ΔH for route 2?

A + 250 kJ

B +100 kJ

C - 50 kJ

D - 100 kJ

Questions 4 to 6 refer to calculating ΔH for the following target reaction.

$$2\,Na_{(s)} + S_{(s)} \longrightarrow Na_2S_{(s)}$$

The following combustion information is to be used. ***ΔH***

a) $Na_{(s)} + {}^1/_4\,O_{2(g)} \longrightarrow {}^1/_2\,Na_2O_{(s)}$ -208 kJ

b) $S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$ -297 kJ

c) $Na_2S_{(s)} + {}^3/_2\,O_{2(g)} \longrightarrow Na_2O_{(s)} + SO_{2(g)}$ -340 kJ

Q4. To achieve the target equation, ***equation a)*** requires to be

A left as it is.

B doubled (only).

C reversed (only).

D reversed and doubled.

Q5. To achieve the target equation, ***equation c)*** requires to be

A left as it is.

B doubled (only).

C reversed (only).

D reversed and doubled.

Q6. What is the enthalpy change for the target equation?

A -373 kJ

B -170 kJ

C +170 kJ

D +373 kJ

Q7. The ΔH value stated below refers to

$4\,Al_{(s)} + 3\,O_{2(g)} \rightarrow 2\,Al_2O_{3(s)} \quad \Delta H = -3350$ kJ

A one mole of aluminium combusting in an excess of oxygen.

B the reaction when each substance in the equation is present as one mole.

C one mole of aluminium oxide being formed from its elements.

D the reaction when the molar quantities are given by the balancing numbers.

HOME PRACTICE 4.4

Q1. The equation for the enthalpy of formation of ethyne is:

$$2C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$$

Use the enthalpies of combustion of carbon, hydrogen and ethyne given in the data booklet to calculate the enthalpy of formation of ethyne, in kJ mol^{-1}. **2**

Q2. When in danger, bombardier beetles can fire a hot, toxic mixture of chemicals at the attacker.

This mixture contains quinone, $C_6H_4O_2$, a compound that is formed by the reaction of hydroquinone, $C_6H_4(OH)_2$, with hydrogen peroxide, H_2O_2. The reaction is catalysed by an enzyme called catalase and the equation for the overall reaction is:

$$C_6H_4(OH)_{2(aq)} + H_2O_{2(aq)} \rightarrow C_6H_4O_{2(aq)} + 2H_2O_{(l)}$$

Use the following data to calculate the enthalpy change, in kJ mol^{-1}, for the above reaction.

$C_6H_4(OH)_{2(aq)}$	→	$C_6H_4O_{2(aq)} + H_{2(g)}$	$\Delta H = +177.4$ kJ mol^{-1}
$H_{2(g)} + O_{2(g)}$	→	$H_2O_{2(aq)}$	$\Delta H = -191.2$ kJ mol^{-1}
$H_{2(g)} + O_{2(g)}$	→	$H_2O_{(g)}$	$\Delta H = -241.8$ kJ mol^{-1}
$H_2O_{(g)}$	→	$H_2O_{(l)}$	$\Delta H = -43.8$ kJ mol^{-1}

2

Q3. Silane, silicon hydride (SiH_4), is formed in the reaction of silicon with hydrogen.

$$Si_{(s)} + 2H_{2(g)} \rightarrow SiH_{4(g)}$$

The enthalpy change for this reaction is called the *enthalpy of formation* of silane. The *combustion of silane* gives silicon dioxide and water.

$$SiH_{4(g)} + 2O_{2(g)} \rightarrow SiO_{2(s)} + 2H_2O_{(l)} \qquad \Delta H = -1517 \text{ kJ mol}^{-1}$$

The enthalpy of *combustion of silicon* is –911 kJ mol^{-1}.
Use this information and the enthalpy of *combustion of hydrogen* in the data booklet to calculate the *enthalpy of formation of silane*, in kJ mol^{-1}. **2**

Q4. The enthalpy of formation of glycerol is the enthalpy change for the reaction:

$$\underset{(graphite)}{3C_{(s)}} + 4H_{2(g)} + 1\tfrac{1}{2}O_{2(g)} \rightarrow C_3H_8O_{3(l)}$$

Calculate the enthalpy of formation of glycerol, in kJ mol^{-1}, using information from the data booklet and the following data.

$$C_3H_8O_{3(l)} + 3\tfrac{1}{2}O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)} \qquad \Delta H = -1654 \text{ kJ mol}^{-1}$$ **2**

Total (8)

SELF CHECK 4.5/4.6

Q1. How many moles of oxygen atoms are in 0.5 mol of carbon dioxide?

A 0.25

B 0.5

C 1

D 2

Q2. A fullerene molecule consists of 60 carbon atoms.

Approximately how many such molecules are present in 12 g of this type of carbon?

A 1.0×10^{22}

B 1.2×10^{23}

C 6.0×10^{23}

D 3.6×10^{25}

Q3. Avogadro's Constant is the same as the number of

A molecules in 16.0 g of oxygen

B atoms in 20.2 g of neon

C formula units in 20.0 g of sodium hydroxide

D ions in 58.5 g of sodium chloride.

Q4. A mixture of sodium chloride and sodium sulphate is known to contain 0.6 mol of chloride ions and 0.2 mol of sulphate ions.

How many moles of sodium ions are present?

A 0.4

B 0.5

C 0.8

D 1.0

Q5. The mass of 1 mol of sodium is 23 g.

What is the approximate mass of one sodium atom?

A 6×10^{23} g

B 6×10^{-23} g

C 3.8×10^{-23} g

D 3.8×10^{-24} g

Q6. In which of the following pairs do the gases contain the same number of oxygen atoms?

A 1 mol of oxygen and 1 mol of carbon monoxide

B 1 mol of oxygen and 0.5 mol of carbon dioxide

C 0.5 mol of oxygen and 1 mol of carbon dioxide

D 1 mol of oxygen and 1 mol of carbon dioxide

Q7. Which of the following gas samples has the same volume as 7 g of carbon monoxide?

(All volumes are measured at the same temperature and pressure.)

A 1 g of hydrogen

B 3.5 g of nitrogen

C 10 g of argon

D 35.5 g of chlorine

Q8. Which of the following gases would contain the greatest number of molecules in a 100 g sample, at room temperature?

A Fluorine

B Hydrogen

C Nitrogen

D Oxygen

HOME PRACTICE 4.5/4.6

Q1. In the lab, nitrogen dioxide gas can be prepared by heating copper(II) nitrate.

$$Cu(NO_3)_{2(s)} \rightarrow CuO_{(s)} + 2NO_{2(g)} + O_{2(g)}$$

Calculate the volume of nitrogen dioxide gas produced when 2.0g of copper(II) nitrate is completely decomposed on heating.

(Take the molar volume of nitrogen dioxide to be 24 litres mol^{-1}.) **2**

Q2. Hydrogen fluoride gas is manufactured by reacting calcium fluoride with concentrated sulphuric acid.

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$$

What volume of hydrogen fluoride gas is produced when 1.0 kg of calcium fluoride reacts completely with concentrated sulphuric acid?

(Take the molar volume of hydrogen fluoride gas to be 24 litres mol^{-1}.) **2**

Q3. Ozone can be produced in the laboratory by electrical discharge.

$$3O_{2(g)} \rightarrow 2O_{3(g)}$$

Calculate the number of $O_{3(g)}$ molecules produced from 6g of $O_{2(g)}$ molecules. **2**

Q4. A student bubbled 240 cm^3 of carbon dioxide into 400 cm^3 of 0·10 mol l^{-1} lithium hydroxide solution.

The equation for the reaction is:

$$2LiOH_{(aq)} + CO_{2(g)} \rightarrow Li_2CO_{3(aq)} + H_2O_{(l)}$$

Calculate the number of moles of lithium hydroxide that would not have reacted.

(Take the molar volume of carbon dioxide to be 24 litres mol^{-1}.) **2**

Q5. Chlorine gas can be produced by heating calcium hypochlorite, $Ca(OCl)_2$, in dilute hydrochloric acid.

$$Ca(OCl)_{2(s)} + 2HCl_{(aq)} \rightarrow Ca(OH)_{2(aq)} + 2Cl_{2(g)}$$

Calculate the mass of calcium hypochlorite that would be needed to produce 0·096 litres of chlorine gas.

(Take the molar volume of chlorine gas to be 24 litres mol^{-1}.) **2**

Total (10)

SELF CHECK 4.7

Q1. The equation for the complete combustion of propane is:

$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$

30 cm^3 of propane is mixed with 200 cm^3 of oxygen and the mixture is ignited.

What is the volume of the resulting gas mixture? (All volumes are measured at the same temperature and pressure.)

A 90 cm^3

B 120 cm^3

C 140 cm^3

D 210 cm^3

Q2. A mixture of carbon monoxide and hydrogen can be converted into water and a mixture of hydrocarbons.

$nCO + (2n + 1)H_2 \rightarrow nH_2O$ + hydrocarbons

What is the general formula for the hydrocarbons produced?

A C_nH_{2n-2}

B C_nH_{2n}

C C_nH_{2n+1}

D C_nH_{2n+2}

Q3. $2\,NO_{(g)} + O_{2(g)} \rightarrow 2\,NO_{2(g)}$

How many litres of nitrogen dioxide gas would be produced in a reaction, starting with a mixture of 5 litres of nitrogen monoxide gas and 2 litres of oxygen gas?

(All volumes are measured under the same conditions of temperature and pressure.)

A 2

B 3

C 4

D 5

Q4. 20 cm^3 of ammonia gas reacted with an excess of heated copper(II) oxide.

$3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Assuming all measurements were made at 200 °C, what would be the volume of gaseous products?

A 40 cm^3

B 30 cm^3

C 20 cm^3

D 10 cm^3

Q5. What volume of oxygen (in litres) would be required for the complete combustion of a gaseous mixture containing 1 litre of carbon monoxide and 3 litres of hydrogen?

(All volumes are measured at the same temperature and pressure.)

A 1

B 2

C 3

D 4

Q6. 20 cm^3 of butane is burned in 150 cm^3 of oxygen.

$C_4H_{10(g)} + 6\,O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$

What is the total volume of gas present after complete combustion of the butane?

A 80 cm^3

B 100 cm^3

C 180 cm^3

D 210 cm^3

Q7. Which of the following pairs of gases occupy the same volume?

(All volumes are measured at the same temperature and pressure.)

A 2 g hydrogen and 14 g nitrogen

B 32 g methane and 88 g carbon dioxide

C 7 g carbon monoxide and 16 g oxygen

D 10 g hydrogen chloride and 10 g sulphur dioxide

HOME PRACTICE 4.7

Q1. One of the methods used to synthesize urea, $(NH_2)_2CO$, is to react ammonia, NH_3, with carbon dioxide, CO_2. The balanced reaction for this process is shown here

$$2NH_3 + CO_2 \rightarrow (NH_2)_2CO + H_2O$$

We carry out this reaction by combining 7.5 g NH_3 and 4.5 *l* of CO_2. (*Molar volume* = 25 *l*).

a) Calculate the limiting reagent. **2**

b) Calculate the mass of urea produced. **1**

Q2. Sodium phosphate, Na_3PO_4, and barium nitrate, $Ba(NO_3)_2$, are soluble salts. Barium phosphate, $Ba_3(PO4)_2$, however, is insoluble. As shown here

$$2Na_3PO_{4(aq)} + 3Ba(NO_3)_{2(aq)} \rightarrow Ba_3(PO_4)_{2(s)} + 6NaNO_{3(aq)}$$

mixing together solutions of Na_3PO_4 and $Ba(NO_3)_2$ produces a precipitate of $Ba_3(PO_4)_2$. 50 cm^3 0.2 mol l^{-1} Na_3PO_4 is mixed with 75 cm^3 0.15 mol l^{-1} $Ba(NO_3)_2$.

a) Calculate the limiting reagent. **2**

b) Calculate the mass of barium phosphate produced. **1**

Q3. Titanium, which is used to make airplane engines and bicycle frames, is obtained from titanium dioxide, TiO_2, in a two-step process. In the first step, TiO2 is converted to titanium tetrachloride, $TiCl_4$; the reaction is

$$3TiO_2 + 4C + 6Cl_2 \rightarrow 3TiCl_4 + 2CO_2 + 2CO$$

4.15 g TiO_2, 5.67 g C, and 6.78 g Cl_2 are reacted together.

a) Calculate the limiting reagent. **3**

b) Calculate the mass of barium phosphate produced. **1**

Total ***(10)***

SELF CHECK 4.8

Q1. Which of the following is a redox reaction?

A $Mg + 2HCl \rightarrow MgCl_2 + H_2$

B $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

C $MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$

D $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

Q2. In which of the following reactions is the hydrogen ion acting as an oxidising agent?

A $Mg + 2HCl \rightarrow MgCl_2 + H_2$

B $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

C $CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2$

D $CH_3COONa + HCl \rightarrow NaCl + CH_3COOH$

Q3. In which reaction is hydrogen gas acting as an oxidising agent?

A $H_2 + CuO \rightarrow H_2O + Cu$

B $H_2 + C_2H_4 \rightarrow C_2H_6$

C $H_2 + Cl_2 \rightarrow 2HCl$

D $H_2 + 2Na \rightarrow 2NaH$

Q4. A redox reaction occurs when Zn metal is addded to $AgNO_3$ solution. Which statement is ***not*** true about this reaction?

A silver metal is displaced

B nitrate ions are spectator ions

C silver ions are reduced

D zinc is the oxidising agent

Q5. $HgCl_{2(aq)} + SnCl_{2(aq)} \rightarrow Hg_{(l)} + SnCl_{4(aq)}$

What ion is oxidised in the above reaction?

A $Sn^{4+}_{(aq)}$

B $Sn^{2+}_{(aq)}$

C $Hg^{2+}_{(aq)}$

D $Cl^{-}_{(aq)}$

Q6. Which of the following is a redox reaction?

A $Pb^{2+}_{(aq)} + 2I^{-}_{(aq)} \rightarrow PbI_{2(s)}$

B $H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)}$

C $Cl_{2(g)} + 2Br^{-}_{(aq)} \rightarrow 2Cl^{-}_{(aq)} + Br_{2(aq)}$

D $NH_{3(g)} + H_2O_{(l)} \rightarrow NH_4^{+}{}_{(aq)} + OH^{-}_{(aq)}$

Questions 7 and 8 refer to the redox reaction between potassium iodide and potassium permanganate which also contains sulphuric acid.

The redox reaction is:

$$10\ I^{-}_{(aq)} + 2\ MnO_4^{-}{}_{(aq)} + 16\ H^{+}_{(aq)} \longrightarrow 2\ Mn^{2+}_{(aq)} + 4\ H_2O_{(l)} + 5\ I_{2(aq)}$$

Q7. The reducing agent in this reaction is:

A $I^{-}_{(aq)}$

B $MnO_4^{-}{}_{(aq)}$

C $H^{+}_{(aq)}$

D $Mn^{2+}_{(aq)}$

Q8. The spectator ions in this reaction are

A $H^{+}_{(aq)}$ and $K^{+}_{(aq)}$

B $H^{+}_{(aq)}$ and $MnO_4^{-}{}_{(aq)}$

C $I^{-}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$

D $K^{+}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$

HOME PRACTICE 4.8

Q1. ***a)*** Copy and complete each of the following ion-electron equations.

i) $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)}$

ii) $Sn^{4+}_{(aq)} \rightarrow Sn^{2+}_{(aq)}$

iii) $ClO^{-}_{(aq)} \rightarrow Cl^{-}_{(aq)}$

iv) $FeO_4^{2-}{}_{(aq)} \rightarrow Fe^{3+}_{(aq)}$ **2**

b) For each completed ion-electron equation describe the process as oxidation or reduction **2**

Q2. For each of the following reactions write

a) the oxidation ion-electron equation **2**

b) the reduction ion-electron equation **2**

i) $Zn_{(s)} + Pb^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Pb_{(s)}$

ii) $2Al_{(s)} + 6H^{+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3H_{2(g)}$

iii) $Cl_{2(g)} + 2I^{-}_{(aq)} \rightarrow 2Cl^{-}_{(aq)} + I_{2(s)}$

iv) $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$

Q3. In a nickel/cadmium cell the following half-reactions take place:

$$Cd_{(s)} + 2OH^{-}_{(aq)} \rightarrow Cd(OH)_{2(s)} + 2e^{-}$$

$$Ni(OH)_{3(s)} + e^{-} \rightarrow Ni(OH)_{2s)} + OH^{-}_{(aq)}$$

a) Combine these to write the overall equation for the redox reaction. **1**

b) Identify the oxidising agent in the above reaction. **1**

Total (10)

SELF CHECK 4.9/4.10

Q1. The iodate ion, IO_3^-, can be converted to iodine.

Which is the correct ion-electron equation for the reaction?

A $2IO_{3\,(aq)}^- + 12H^+_{(aq)} + 12e^- \rightarrow 2I^-_{(aq)} + 6H_2O_{(l)}$

B $IO_{3\,(aq)}^- + 6H^+_{(aq)} + 7e^- \rightarrow I^-_{(aq)} + 3H_2O_{(l)}$

C $2IO_{3\,(aq)}^- + 12H^+_{(aq)} + 11e^- \rightarrow I_{2(aq)} + 6H_2O_{(l)}$

D $2IO_{3\,(aq)}^- + 12H^+_{(aq)} + 10e^- \rightarrow I_{2(aq)} + 6H_2O_{(l)}$

Q2. The ion-electron equations for a redox reaction are:

$$2I^-_{(aq)} \rightarrow I_{2(aq)} + 2e^-$$

$$MnO_{4\,(aq)}^- + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$$

How many moles of iodide ions are oxidised by one mole of permanganate ions?

A 0.2

B 0.4

C 2

D 5

Q3. During a redox process in acid solution, carbon dioxide molecules are converted into oxalic (ethandioc) acid molecules.

$$CO_{2(g)} + 2H^+_{(aq)} + xe^- \rightarrow H_2C_2O_{4(aq)}$$

To balance the equation, what is the value of x?

A 1

B 2

C 3

D 4

Q4. The following reactions take place when nitric acid is added to zinc.

$$NO_{3\,(aq)}^- + 4H^+_{(aq)} + 3e^- \rightarrow NO_{(g)} + 2H_2O_{(l)}$$

$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$$

How many moles of $NO_{3\,(aq)}^-$ are reduced by one mole of zinc?

A $^2/_3$

B 1

C $^3/_2$

D 2

Q5. In one of the lead-acid battery reactions, lead oxide, $PbO_{2(s)}$, is converted into lead(II) ions, $Pb^{2+}_{(aq)}$.

$$PbO_{2(s)} \rightarrow Pb^{2+}_{(aq)}$$

The numbers of $H^+_{(aq)}$ and $H_2O_{(l)}$ required to balance the ion-electron equation for the formation of 1 mol of $I_{2(aq)}$ are, respectively

A 4 and 1

B 6 and 3

C 4 and 2

D 6 and 2.

Q6. Denitrifying bacteria are capable of converting nitrate ions into ammonia.

$$NO_{3\,(aq)}^- \rightarrow NH_{3(aq)}$$

The numbers of $H^+_{(aq)}$ and $H_2O_{(l)}$ required to balance the ion-electron equation for the formation of 1 mol of $NH_{3(aq))}$ are, respectively

A 3 and 3

B 6 and 3

C 9 and 3

D 12 and 3.

HOME PRACTICE 4.9/4.10

Q1. Seaweeds are a rich source of iodine in the form of iodide ions. The mass of iodine in a seaweed can be found using the procedure outlined below.

a) Step 1 The seaweed is dried in an oven and ground into a fine powder. Hydrogen peroxide solution is then added to oxidise the iodide ions to iodine molecules.

The ion-electron equation for the reduction reaction is shown.

$$H_2O_{2(aq)} + 2H^+_{(aq)} + 2e^- \rightarrow 2H_2O_{(l)}$$

Write a balanced redox equation for the reaction of hydrogen peroxide with iodide ions. **1**

b) Step 2 Using starch solution as an indicator, the iodine solution is then titrated with sodium thiosulphate solution to find the mass of iodine in the sample. The balanced equation for the reaction is shown.

$$2Na_2S_2O_{3(aq)} + I_{2(aq)} \rightarrow 2NaI_{(aq)} + Na_2S_4O_{6(aq)}$$

In an analysis of seaweed, 14.9cm^3 of 0.00500 mol l^{-1} sodium thiosulphate solution was required to reach the end-point.

Calculate the mass of iodine present in the seaweed sample. **3**

Q2. Oxalic acid is found in rhubarb. The number of moles of oxalic acid in a carton of rhubarb juice can be found by titrating samples of the juice with a solution of potassium permanganate, a powerful oxidising agent.

The equation for the overall reaction is:

$$5(COOH)_{2(aq)} + 6H^+_{(aq)} + 2MnO^-_{4\ (aq)} \rightarrow 2Mn^{2+}_{(aq)} + 10CO_{2(aq)} + 8H_2O_{(l)}$$

a) Write the ion-electron equation for the reduction reaction. **1**

b) Why is an indicator not required to detect the end-point of the titration? **1**

c) In an investigation using a 500 cm^3 carton of rhubarb juice, separate 25.0 cm^3 samples were measured out. Three samples were then titrated with 0.040 mol l^{-1} potassium permanganate solution, giving the following results.

Titration	Volume of potassium permanganate solution used/cm^3
1	27·7
2	26·8
3	27·0

Average volume of potassium permanganate solution used = 26.9 cm^3.

i) Why was the first titration result not included in calculating the average volume of potassium permanganate solution used? **1**

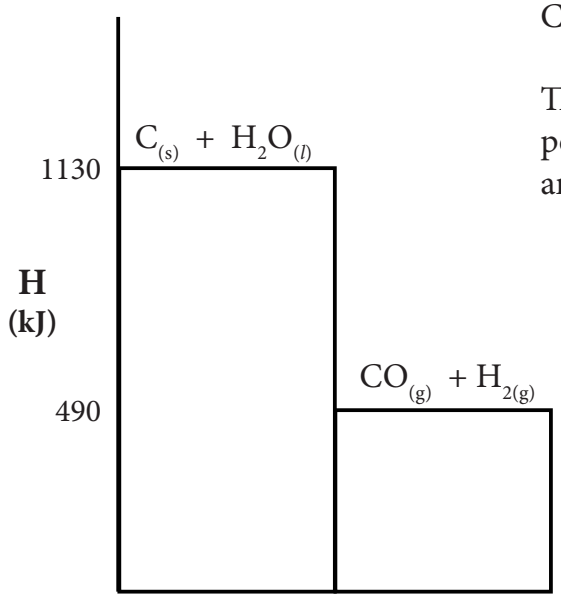
ii) Calculate the number of moles of oxalic acid in the 500 cm^3 carton of rhubarb juice. **2**

Total (9)

CONSOLIDATION A

Q1. The following reaction takes place between carbon and steam and is one method of making hydrogen for the Haber Process.

$$C_{(s)} + H_2O_{(l)} \rightarrow CO_{(g)} + H_{2(g)}$$



Though only enthalpy changes can be measured it is possible to estimate the energy stored within chemicals and represent this in diagramatic form.

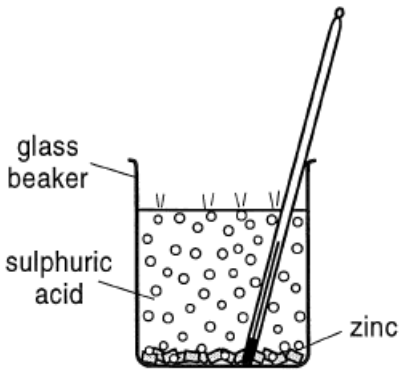
a) What is the total enthalpy of the reactants? **1**

b) What is the enthalpy change for the reaction? **1**

c) State, with reason, whether the reaction is exothermic or endothermic. **1**

Q2. In an investigation into Hess's Law, a student compared the enthalpy changes for zinc reacting in 2 M sulphuric acid with, and without, a catalyst.

The student used the expression $E_h = - cm \Delta T$ to calculate the enthalpy change (where m was the mass of the sulphuric acid).



a) Suggest why the experimental value of MI was likely to be smaller than the theoretical value. **1**

b) Suggest an improvement that the student could make to the experiment. **1**

Q3. Calculate the number of nitrogen atoms in 3.4 g of ammonia gas. **2**

Q4. Propane burns to form carbon dioxide and water.

$$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(l)}$$

a) Calculate the amount in moles of carbon dioxide formed from burning 0.2 mol of propane. **1**

b) If the molar volume of carbon dioxide is 23 l mol^{-1} calculate the volume of carbon dioxide formed from burning 0.2 mol of propane. **1**

CONSOLIDATION A

Q5. Nitrogen dioxide can be produced by sparking a mixture of nitrogen and oxygen.

$$N_{2(g)} + 2\,O_{2(g)} \rightarrow 2\,NO_{2(g)}$$

In an experiment, a mixture of 80 l of nitrogen and 20 l of oxygen is sparked in an apparatus that allows the pressure to remain constant.

a) Calculate which reactant gas is in excess and by how much. **2**

b) Assuming complete conversion of available reactants, calculate the total volume of gas at the end of the reaction once the temperature has returned to normal. **2**

Q6. The following change takes place when vitamin C is reacted with iodine solution.

$$C_6H_8O_{6(aq)} \rightarrow 2\,H^+_{(aq)} + C_6H_6O_{6(aq)} + 2\,e^-$$

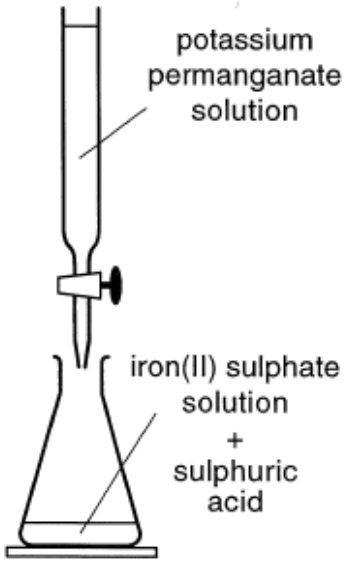
vitamin C

a) Write the corresponding ion-electron equation for the change that happens to the iodine solution. **1**

b) Work out the balanced ionic equation for the overall redox reaction. **1**

c) Does the vitamin C act as an oxidising agent or a reducing agent in its reaction with the iodine? **1**

Q7. In the titration shown, potassium permanganate solution is added to the flask until the first hint of purple remains in the flask after swirling the mixture.



a) What effect, if any, would the addition of 5 drops of sulphuric acid to the mixture in the flask have? **1**

b) What effect, if any, would the addition of 5 more drops of iron(II) sulphate solution have on the colour of the solution in the flask? **1**

CONSOLIDATION B

Q1. Magnesium reacts with sulphur according to the following equation.

$$Mg + S \rightarrow MgS$$

Using Hess's law, the enthalpy change for this reaction can be worked out from the enthalpy changes for other reactions.

a) What does Hess's Law state? **1**

b) In addition to the following two equations:

$$S + O_2 \rightarrow SO_2$$
$$2\,Mg + O_2 \rightarrow 2\,MgO$$

what other combustion equation would be needed to work out the enthalpy change for the formation of magnesium sulphide? **1**

c) Which of the enthalpy changes for the three combustion equations would have its sign changed before combining to give the enthalpy change for the formation of magnesium sulphide? **1**

Q2. Ammonium sulphate fertiliser can be manufactured by neutralising sulphuric acid with ammonia.

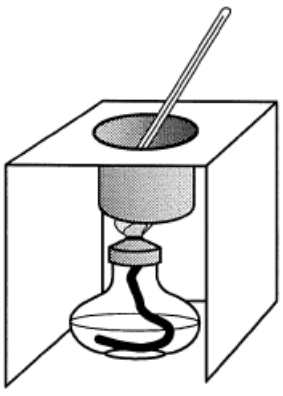
$2\,NH_{3(g)}$	+	$H_2SO_{4(l)}$	→	$(NH_4)_2SO_{4(s)}$
(GFM = 17 g)		*(GFM = 98 g)*		*(GFM = 132 g)*

a) Calculate the number of ammonium ions in 132 g of ammonium sulphate. **1**

b) If 20 tonnes of ammonia is reacted with 49 tonnes of sulphuric acid, show by calculation that sulphuric acid is the limiting reactant. (*1 tonne = 1000 kg*) **2**

Q3. Write the balanced equation for the enthalpy of combustion of hydrogen. **1**

Q4. The enthalpy of combustion of ethanol can be measured by heating 50 g of water using an ethanol burner.



a) What measurements must be made to allow the enthalpy of combustion of ethanol to be calculated? **2**

b) Using this experiment a student calculated the enthalpy of combustion of ethanol to be -950 kJ mol^{-1}.

i) Use a data booklet to find the enthalpy of combustion of ethanol. **1**

ii) Explain why the student's result was significantly different from the value in the data booklet. **1**

CONSOLIDATION B

Q5. Calculate the volume of hydrogen gas required to reduce one mole of iron(III) oxide to iron if the molar volume of hydrogen is 23.2 *l* mol^{-1}. **2**

Q6. Hydrogen peroxide (H_2O_2) is a colourless liquid that can be analysed by titration with acidified potassium permanganate solution.

$$2MnO_{4\,(aq)}^{-} + 6H^{+}_{(aq)} + 5H_2O_{2(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)} + 5O_{2(g)}$$

A titration was carried out using 25 cm^3 portions of hydrogen peroxide solution and produced the following results.

Titration	1	2	3
Titre volume (cm^3)	16.5	15.8	15.6

a) What would indicate of the end-point of the titration? **1**

b) What value for volume of permanganate would you use in any calculation of the hydrogen peroxide concentration? **2**

Q7. Vitamin C is often taken in tablet form to supplement the quantity in a person's normal diet.

a) Describe how you would prepare accurately 100 cm^3 of a solution of a vitamin C tablet suitable for analysis by titration. **1**

b) The vitamin C content can be determined by titrating the solution of its tablet with iodine solution. Describe how the end-point of this titration could be recognised. **1**

Q8. The $ClO_{4\,(aq)}^{-}$ ion can be converted to the $Cl^{-}_{(aq)}$ ion in a redox reaction.

a) Work out the ion-electron equation for the change to the $ClO_{4\,(aq)}^{-}$ ion. **1**

b) Suggest why this redox change is also likely to involve a pH change. **1**

CONSOLIDATION C

Q1. As part of an investigation to verify Hess's Law, two solutions - each of mass 100 g and each at 24 °C - were mixed in a vacuum flask. The temperature of the resultant mixture was measured as 22 °C.

a) Calculate the change in enthalpy (with the appropriate sign) that took place when the solutions were mixed.
(Specific heat capacity of water= 4.18 kJ kg^{-1} $°C^{-1}$) **2**

b) Suggest one feature of the procedure (rather than accuracy of measurement) which could cause inaccuracy in the final value for the enthalpy change. **1**

Q2. This equation describes the Haber process for manufacturing ammonia.

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

a) Calculate the volume of hydrogen gas required to exactly react with 25 cm^3 of nitrogen gas. **1**

b) Assuming excess hydrogen gas is present, what volume of nitrogen gas is required to produce 150 cm^3 of ammonia? **1**

Q3. How does the number of molecules in 0.02 mol of methane compare with the number of molecules in 0.01 mol of glucose? **1**

Q4. Magnesium reacts with 1 mol l^{-1} hydrochloric acid to form hydrogen.

$$Mg_{(s)} + 2\,HCl_{(aq)} \rightarrow MgC1_{2(aq)} + H_{2(g)}$$

If 4.86 g of magnesium is added to excess acid, what volume of hydrogen will be produced if the molar volume of hydrogen is 24 l mol^{-1}? **2**

Q5. A fall in temperature of 8 °C was recorded when some ammonium nitrate was dissolved in 0.5 kg of water.

a) Is this process exothermic or endothermic? **1**

b) Calculate the quantity of energy (in kJ) absorbed by the water if the specific heat capacity of the water is 4.18 kJ kg^{-1} $°C^{-1}$. **1**

Q6. A student added 0.65 mol of zinc to 250 cm3 of 2 mol l^{-1} sulphuric acid.

$$Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$$

Show by calculation which reactant is in excess. **2**

CONSOLIDATION C

Q7. Write a balanced equation for the enthalpy of combustion of ethanol (C_2H_5OH) **1**

Q8. An electrochemical cell in which the following changes took place was set up.

$$Cr_2O_7^{2-}{}_{(aq)} + 14\,H^+{}_{(aq)} + 6\,e^- \rightarrow 2\,Cr^{3+}{}_{(aq)} + 7\,H_2O_{(l)}$$

$$2\,Br^-{}_{(aq)} \rightarrow Br_{2(aq)} + 2\,e^-$$

a) What must be done before these ion-electron equations can be combined to give a balanced ionic equation for the overall redox reaction? **1**

b) State the overall balanced ionic equation. **1**

c) State the substance acting as the electron donor in this redox reaction. **1**

Q9. Some iron(II) sulphate was analysed by titration with permanganate solution of concentration 0.105 mo1 l^{-1}. The following reaction took place.

$$5\,Fe^{2+}{}_{(aq)} + 8\,H^+{}_{(aq)} + MnO_4^-{}_{(aq)} \rightarrow 5\,Fe^{3+}{}_{(aq)} + Mn^{2+} + 4\,H_2O_{(l)}$$

a) If 22 cm^3 of permanganate solution was needed to exactly react 25 cm^3 of the iron(II) solution, calculate the concentration of the iron(II) solution. **2**

b) Suggest what effect, if any, using twice the volume of iron(II) solution in the titration would have had on the calculated result of the concentration for the iron(II) solution. **1**

CONSOLIDATION D

Q1. Synthesis gas (a mixture of carbon monoxide and hydrogen) can be manufactured by the steam reforming of methane gas.

$$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3\,H_{2(g)}$$

The enthalpy change for this reaction can be calculated from the following:

① $CH_{4(g)} + 2\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$ $\Delta H = -882$ kJ

② $2\,CO_{(g)} + O_{2(g)} \rightarrow 2\,CO_{2(g)}$ $\Delta H = -566$ kJ

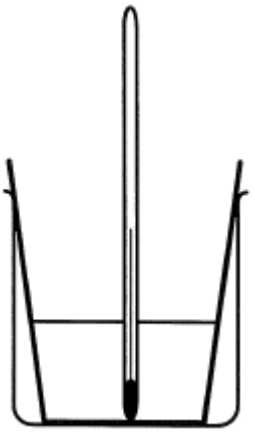
③ $H_{2(g)} + {}^1/_2\,O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -286$ kJ

a) Show how equations ① to ③ can be rearranged and combined to give the equation for the formation of synthesis gas. **1**

b) Calculate the enthalpy change for the synthesis gas equation shown above. **1**

Q2. A mixture of 80 cm^3 of carbon monoxide was reacted with 150 cm^3 of oxygen, calculate the volume of carbon dioxide formed (under the same conditions of temperature and pressure). **3**

Q3. In an experiment, 238 g of potassium bromide was dissolved in l *l* of water. The temperature of the solution decreased by 2.5 °C.



a) Calculate the enthalpy change (in kJ) in this experiment if the specific heat capacity of the water is 4.18 kJ kg^{-1} $°C^{-1}$. **2**

b) Calculate the enthalpy of solution of potassium bromide. **2**

Q4. One mole of a substance contains the as the Avogadro constant of formula units.

a) State the symbol for the Avogadro constant. **1**

b) How many moles of nitrate ions are in one mole of aluminium nitrate? **1**

c) A mixture of magnesium sulphate and magnesium bromide is known to contain 7 moles of magnesium ions and 4 moles of sulphate ions. Calculate the number of moles of bromide ions. **2**

CONSOLIDATION D

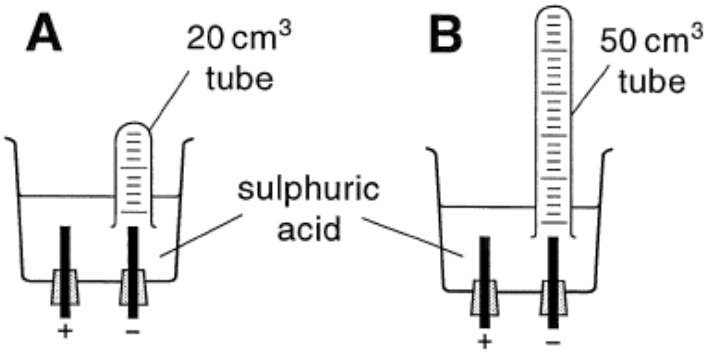
Q5. When aluminium reacts with hydrochloric acid, the following redox changes take place.

$$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3\,e^-$$
$$2\,H^+_{(aq)} + 2\,e^- \rightarrow H_{2(g)}$$

a) In any redox reaction, what always happens to the oxidising agent? **1**

b) Write the overall ionic equation (omitting spectator ions) for the reaction of aluminium with hydrochloric acid. **1**

Q6. In an investigation to determine the quantity of electricity to produce one mole of hydrogen, a student suggested that apparatus B would give more accurate results than apparatus A for two reasons.



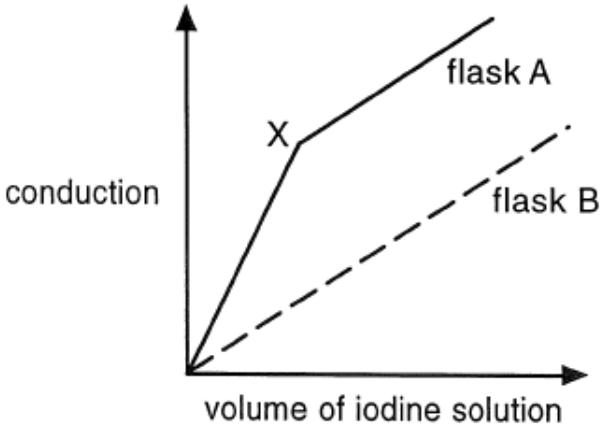
a) Suggest ***one*** of the two reasons. **1**

b) Suggest why the temperature of the laboratory could affect the results of the experiment. **1**

Q7. A student titrated a vitamin C solution using iodine solution as the oxidising agent, the iodine being dissolved in potassium iodide solution.

$$C_6H_8O_{6(aq)} + I_{2(aq)} \rightarrow 2\,H^+I^-_{(aq)} + C_6H_6O_{6(aq)}$$

The reaction was carried out in a conductivity flask so that the conduction of the solution in the flask could be measured. The same procedure was carried out with flask B containing only water and no vitamin C (as a control). The results of the conduction measurements are shown in the graph.



a) Explain why the conduction in flask B increased. **1**

b) Explain what has happened at point X in the graph for flask A. **1**