Q1. In which one of the following reactions is the role of the reagent stated correctly?

	Reaction	**Role of reagent**
A	$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$	TiO_2 is an oxidising agent
B	$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$	HNO_3 is a Brønsted-Lowry acid
C	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	$AlCl_3$ is a Lewis base
D	$2CO + 2NO \rightarrow 2CO_2 + N_2$	CO is a reducing agent

(Total 1 mark)

Q2. Which one of the following statements is **not** correct?

A The first ionisation energy of iron is greater than its second ionisation energy.

B The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

C The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

D The boiling point of C_3H_8 is lower than that of CH_3CH_2OH

(Total 1 mark)

Q3. In which one of the following reactions does hydrogen **not** act as a reducing agent?

A $H_2 + Ca \rightarrow CaH_2$

B $2H_2 + O_2 \rightarrow 2H_2O$

C $H_2 + CH_2{=}CH_2 \rightarrow CH_3CH_3$

C $2H_2 + CH_3COCH_3 \rightarrow CH_3CH_2CH_3 + H_2O$

(Total 1 mark)

Q4. Chlorine and bromine are both oxidising agents.

(a) Define an *oxidising agent* in terms of electrons.

.....

(1)

(b) In aqueous solution, bromine oxidises sulphur dioxide, SO_2, to sulphate ions, SO_4^{2-}

(i) Deduce the oxidation state of sulphur in SO_2 and in SO_4^{2-}

SO_2 .....

SO_4^{2-} .....

(ii) Deduce a half-equation for the reduction of bromine in aqueous solution.

.....

(iii) Deduce a half-equation for the oxidation of SO_2 in aqueous solution forming SO_4^{2-} and H^+ ions.

.....

(iv) Use these two half-equations to construct an overall equation for the reaction between aqueous bromine and sulphur dioxide.

.....

(5)

(c) Write an equation for the reaction of chlorine with water. Below each of the chlorine-containing products in your equation, write the oxidation state of chlorine in that product.

.....

.....

(3)

(d) Give a reason why chlorine is not formed when solid potassium chloride reacts with concentrated sulphuric acid.

.....

(1)

(e) Write an equation for the reaction between solid potassium chloride and concentrated sulphuric acid.

.....

(1)

(f) Solid potassium bromide undergoes a redox reaction with concentrated sulphuric acid.

(i) Give the oxidation product formed from potassium bromide.

.....

(ii) Give the reduction product formed from sulphuric acid.

.....

(2)

(Total 13 marks)

Q5. The vanadium does **not** have an oxidation state of +3 in

A $[V(H_2O)_6]^{3+}$

B $[V(C_2O_4)_3]^{3-}$

C $[V(OH)_3(H_2O)_3]$

D $[VCl_4]^{3-}$

(Total 1 mark)

Q6. (a) The term oxidation was used originally to describe a reaction in which a substance gained oxygen. The oxygen was provided by the oxidising agent. Later the definition of oxidation was revised when the importance of electron transfer was recognised.

An aqueous solution of sulfur dioxide was reacted in separate experiments as follows.

Reaction **1** with HgO

$$H_2O + SO_2 + HgO \rightarrow H_2SO_4 + Hg$$

Reaction **2** with chlorine

$$2H_2O + SO_2 + Cl_2 \rightarrow H_2SO_4 + 2HCl$$

(i) In Reaction **1**, identify the substance that donates oxygen and therefore is the oxidising agent.

.....

(ii) Show, by writing a half-equation, that this oxidising agent in reaction **1** is an electron acceptor.

.....

(iii) Write a half-equation for the oxidation process occurring in reaction **2**.

.....

(iv) Write a half-equation for the reduction process occurring in reaction **2**.

.....

(4)

(b) Use the standard electrode potential data given in the able below to answer the questions which follow.

	E / V
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	–0.26
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.52

Each of the above can be reversed under suitable conditions

(i) An excess of potassium manganate(VII) was added to a solution containing $V^{2+}(aq)$ ions. Determine the vanadium species present in the solution at the end of this reaction. State the oxidation state of vanadium in this species and write a half-equation for its formation from $V^{2+}(aq)$.

Vanadium species present at the end of the reaction .....

.....

Oxidation state of vanadium in the final species .....

.....

Half-equation .....

(ii) The cell represented below was set up under standard conditions.

$$Pt|H_2SO_3(aq),SO_4^{2-}(aq),H^+(aq)||Fe^{3+}(aq),Fe^{2+}(aq)|Pt$$

Calculate the e.m.f. of this cell and state, with an explanation, how this e.m.f. will change if the concentration of $Fe^{3+}(aq)$ ions is increased.

Cell e.m.f. .....

Change in cell e.m.f. .....

Explanation .....

.....

(7)

(c) Consider the cell below

$$\overset{-}{Pt|H_2(g)|H^+(aq)||O_2(g)|OH^-(aq)|Pt}\overset{+}{}$$

(i) Using half-equations, deduce an overall equation for the cell reaction.

.....

.....

.....

(ii) State how, if at all, the e.m.f. of this cell will change if the surface area of each platinum electrode is doubled.

.....

(3)

(d) Currently, almost all hydrogen is produced by the high-temperature reaction between methane, from North Sea gas, and steam. Give one economic and one environmental disadvantage of this method of producing hydrogen.

Economic disadvantage .....

Environmental disadvantage .....

(2)

(e) Hydrogen can also be produced by the electrolysis of acidified water using electricity produced using solar cells. Give one reason why this method is not used on a large scale.

.....

(1)
(Total 17 marks)

Q7. (a) By referring to electrons, explain the meaning of the term *oxidising agent*.

.....

(1)

(b) For the element **X** in the ionic compound **MX**, explain the meaning of the term *oxidation state*.

.....

(1)

(c) Complete the table below by deducing the oxidation state of each of the stated elements in the given ion or compound.

	Oxidation state
Carbon in CO_3^{2-}	
Phosphorus in PCl_4^{+}	
Nitrogen in Mg_3N_2	

(3)

(d) In acidified aqueous solution, nitrate ions, NO_3^-, react with copper metal forming nitrogen monoxide, NO, and copper(II) ions.

(i) Write a half-equation for the oxidation of copper to copper(II) ions.

.....

(ii) Write a half-equation for the reduction, in an acidified solution, of nitrate ions to nitrogen monoxide.

.....

(iii) Write an overall equation for this reaction.

.....

(3)
(Total 8 marks)

Q8. Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^+(s) + Ag^+(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass dark glass

When the photochromic glass darkens

A the Ag^+ ion is acting as an electron donor.

B the Cu^+ ion is acting as a reducing agent.

C the Ag^+ ion is oxidised.

D the Cu^+ ion is reduced.

(Total 1 mark)

Q9. Refer to the following reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^{\ominus} = -11 \text{ kJ mol}^{-1}, \qquad \Delta S^{\ominus} = +20 \text{ J K}^{-1} \text{ mol}^{-1}$$

Which one of the following statements is correct?

A This is a redox reaction.

B The reaction is **not** feasible below 298 K

C At equilibrium, the yield of hydrogen iodide is changed by increasing the pressure.

D At equilibrium, the yield of hydrogen iodide increases as the temperature is increased.

(Total 1 mark)

Q10. At high temperatures, nitrogen is oxidised by oxygen to form nitrogen monoxide in a reversible reaction as shown in the equation below.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H^{\ominus} = +180 \text{ kJ mol}^{-1}$$

(a) In terms of electrons, give the meaning of the term *oxidation*.

.....

(1)

(b) State and explain the effect of an increase in pressure, and the effect of an increase in temperature, on the yield of nitrogen monoxide in the above equilibrium.

Effect of an increase in pressure on the yield .....

Explanation .....

.....

.....

.....

.....

Effect of an increase in temperature on the yield .....

Explanation .....

.....

.....

(6)

(c) Nitrogen monoxide, NO, is formed when silver metal reduces nitrate ions, NO_3^- in acid solution.

(i) Deduce the oxidation state of nitrogen in NO and in NO_3^-

NO.....

NO_3^- .....

(ii) Write a half-equation for the reduction of NO_3^- ions in acid solution to form nitrogen monoxide and water.

.....

(iii) Write a half-equation for the oxidation of silver metal to $Ag^+(aq)$ ions.

.....

(iv) Hence, deduce an overall equation for the reaction between silver metal and nitrate ions in acid solution.

.....

(5)

(Total 12 marks)