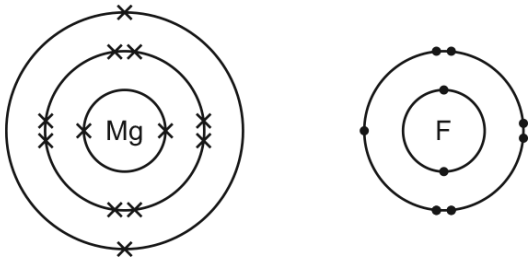
01. 0620_s20_qp_42 Q: 2

Fluorine forms both ionic and covalent compounds.

(a) Magnesium reacts with fluorine to form the ionic compound magnesium fluoride.

The electronic structures of an atom of magnesium and an atom of fluorine are shown.



(i) Complete the dot-and-cross diagrams to show the electronic structures of one magnesium ion and one fluoride ion. Show the charges on the ions.

[3]

(ii) What is the formula of magnesium fluoride?

..... [1]

(iii) Magnesium fluoride does **not** conduct electricity when it is solid.

What can be done to solid magnesium fluoride to make it conduct electricity?

In your answer explain why magnesium fluoride conducts electricity when this change is made.

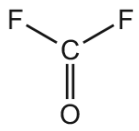
.....

.....

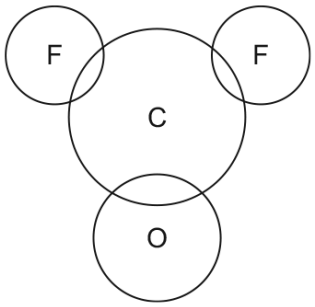
.....

..... [2]

(b) Carbonyl fluoride, COF_2, is a covalent compound. The structure of a molecule of COF_2 is shown.



Complete the dot-and-cross diagram to show the electron arrangement in a molecule of carbonyl fluoride. Show outer shell electrons only.



[3]

(c) The melting points of magnesium fluoride and carbonyl fluoride are shown.

	melting point / °C
magnesium fluoride	1263
carbonyl fluoride	–111

(i) Explain, using your knowledge of structure and bonding, why magnesium fluoride has a high melting point.

.....

.....

.....

..... [2]

(ii) Explain, using your knowledge of structure and bonding, why carbonyl fluoride has a low melting point.

.....

.....

.....

..... [2]

[Total: 13]

02. 0620_s20_qp_42 Q: 3

(a) Sulfuric acid is made from sulfur in a four-stage process.

stage 1 Sulfur is converted into sulfur dioxide.

stage 2 Sulfur dioxide is converted into sulfur trioxide.

stage 3 Sulfur trioxide is converted into oleum.

stage 4 Oleum is converted into sulfuric acid.

(i) How is sulfur converted into sulfur dioxide in **stage 1**?

..... [1]

(ii) Describe how sulfur dioxide is converted into sulfur trioxide in **stage 2**.

Your answer should include:

- an equation for the reaction
- the temperature used
- the name of the catalyst used.

.....

.....

.....

..... [3]

(iii) The reaction in **stage 2** can reach equilibrium.

What is meant by the term *equilibrium*?

.....

.....

..... [2]

(b) Sulfur trioxide is converted into oleum, $H_2S_2O_7$, in **stage 3**.

What is sulfur trioxide reacted with to convert it into oleum?

..... [1]

(c) Oleum is converted into sulfuric acid in **stage 4**.

Write a chemical equation for the conversion of oleum, $H_2S_2O_7$, into sulfuric acid.

..... [2]

(d) When copper is reacted with hot concentrated sulfuric acid, sulfur dioxide gas is formed.

Balance the chemical equation for this reaction.

$$Cu + ...H_2SO_4 \rightarrow CuSO_4 + SO_2 + ...H_2O$$ [1]

(e) Sulfur dioxide is a reducing agent.

Give the colour change that occurs when excess sulfur dioxide is bubbled into acidified aqueous potassium manganate(VII).

starting colour of the solution .....

final colour of the solution .....
[1]

(f) When sulfuric acid reacts with ammonia the salt produced is ammonium sulfate.

Write the chemical equation for this reaction.

..... [2]

(g) Barium sulfate is an insoluble salt.

Barium sulfate can be made from aqueous ammonium sulfate using a precipitation reaction.

(i) Name a solution that can be added to aqueous ammonium sulfate to produce a precipitate of barium sulfate.

..... [1]

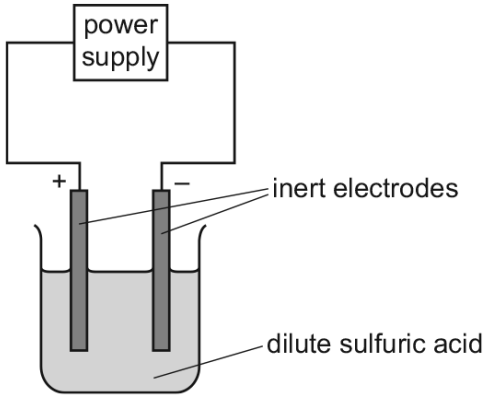
(ii) Write an ionic equation for this precipitation reaction. Include state symbols.

..... [2]

[Total: 16]

03. 0620_w20_qp_41 Q: 5

(a) Dilute sulfuric acid is electrolysed using the apparatus shown in the diagram.



(i) State what is meant by the term *electrolysis*.

.....

.....

..... [2]

(ii) Explain why inert electrodes are used.

.....

..... [1]

(iii) Name the products formed at each electrode.

negative electrode .....

positive electrode .....

[2]

(iv) Write an ionic half-equation for the reaction at the negative electrode.

..... [2]

(b) Sulfuric acid is manufactured using the Contact process. This manufacture involves four stages.

(i) **Stage 1** involves the combustion of sulfur to form sulfur dioxide.

Write the chemical equation for **stage 1**.

..... [1]

(ii) The equation for **stage 2** is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The reaction can reach equilibrium.

Explain what is meant by the term *equilibrium*.

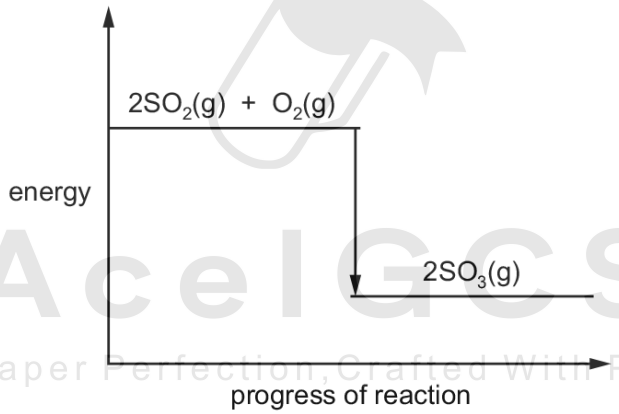
.....

.....

.....

..... [2]

(iii) The energy level diagram for the forward reaction in **stage 2** is shown.



Explain what the diagram shows about the energy changes in the forward reaction.

.....

.....

.....

..... [2]

(c) In **stage 3** sulfur trioxide, SO_3, is converted to oleum, $H_2S_2O_7$.

In **stage 4** oleum reacts to form sulfuric acid, H_2SO_4.

State what oleum reacts with in **stage 4**.

..... [1]

(d) A sample of sulfuric acid, H_2SO_4, has a concentration of $0.75\,mol/dm^3$.

Calculate the concentration of sulfuric acid in g/dm^3.

..... g/dm^3 [2]

[Total: 15]

---

04. 0620_w19_qp_41 Q: 2

(a) Sulfur exists as a number of different isotopes.

What is meant by the term *isotopes*?

.....

.....

..... [2]

(b) A sulfide ion has the symbol shown.

$^{34}_{16}S^{2-}$

(i) How many neutrons are contained in this sulfide ion?

..... [1]

(ii) How is a sulfide ion, S^{2-}, formed from a sulfur atom?

..... [1]

(iii) Which element forms an ion with a 2+ charge that has the same number of electrons as a S^{2-} ion?

..... [1]

(c) The manufacture of sulfuric acid by the Contact process occurs in four stages.

stage 1 Molten sulfur is burned in air to produce sulfur dioxide gas.

stage 2 Sulfur dioxide is reacted with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide is combined with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4 Oleum is added to water to form sulfuric acid.

(i) Complete the chemical equation for **stage 1** by adding the appropriate state symbols.

$$S(.....) + O_2(.....) \rightarrow SO_2(.....)$$ [1]

(ii) Name the catalyst used in **stage 2** and state the temperature used.

catalyst .....

temperature ..... °C

[2]

(iii) Write chemical equations for the reactions in **stage 3** and **stage 4**.

stage 3 .....

stage 4 .....

[2]

(d) Sulfur dioxide is a toxic gas.

(i) State one **environmental** reason why sulfur dioxide should **not** be released into the atmosphere.

..... [1]

(ii) Describe the test for sulfur dioxide.

test .....

.....

observations .....

.....

[2]

(e) Sulfur dioxide reacts with aqueous sodium sulfite to produce a compound with the following composition by mass: 29.1% Na, 40.5% S and 30.4% O.

Calculate the empirical formula of this compound.

empirical formula = ... [3]

[Total: 16]

05. 0620_w19_qp_42 Q: 3

Ammonia is an important chemical.

(a) Ammonia is manufactured by the Haber process. The reaction is reversible.

(i) What is the sign for a reversible reaction?

..... [1]

(ii) State the essential conditions for the manufacture of ammonia by the Haber process starting from hydrogen and nitrogen. Include a chemical equation to show the reaction which occurs.

.....

.....

.....

.....

.....

..... [5]

(iii) Name **one** raw material which is a source of the hydrogen used in the Haber process.

..... [1]

(b) Ammonia is a base and reacts with sulfuric acid to form the salt, ammonium sulfate.

(i) What is meant by the term *base*?

..... [1]

(ii) Name the industrial process used to manufacture sulfuric acid.

..... [1]

(iii) Write a chemical equation for the reaction between ammonia and sulfuric acid.

..... [2]

(c) When aqueous ammonia is added to aqueous iron(II) sulfate a green precipitate is seen. This green precipitate turns red-brown at the surface.

(i) Name the green precipitate.

..... [1]

(ii) Suggest why the green precipitate turns red-brown at the surface.

.....

..... [2]

(iii) State what happens when an excess of aqueous ammonia is added to the green precipitate.

..... [1]

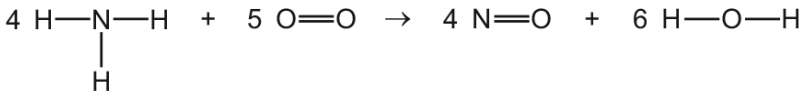
(d) Ammonia reacts with oxygen as shown.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

(i) Calculate the volume of oxygen at room temperature and pressure, in dm^3, that reacts with 4.80 dm^3 of ammonia.

volume = ... dm^3 [3]

(ii) The chemical equation for the reaction can be represented as shown.



Use the bond energies in the table to calculate the energy change, in kJ/mol, which occurs when **one** mole of NH_3 reacts.

bond	N–H	O=O	N=O	O–H
bond energy in kJ/mol	391	498	587	464

- Energy needed to break bonds.

..... kJ

- Energy released when bonds are formed.

..... kJ

- Energy change when **one** mole of NH_3 reacts.

energy change = ... kJ/mol
[4]

[Total: 22]

06. 0620_s18_qp_42 Q: 2

This question is about the elements in Period 3 of the Periodic Table.

Na	Mg	Al	Si	P	S	Cl	Ar

For each of the following, identify a Period 3 element which matches the description. Each element may be used once, more than once or not at all.

State which Period 3 element:

(a) forms an oxide with a macromolecular structure

..... [1]

(b) is extracted from the ore bauxite

..... [1]

(c) is soft, metallic and stored in oil

..... [1]

(d) is a green gas at room temperature and pressure

..... [1]

(e) provides an inert atmosphere in lamps

..... [1]

(f) forms **two** different oxides during the Contact process

..... [1]

(g) is non-metallic and an important component of fertilisers.

..... [1]

[Total: 7]

07. 0620_s18_qp_43 Q: 1

The following are the symbols and formulae of some elements and compounds.

Ar $Ca(OH)_2$ Cl_2 CO_2 Cu Fe SO_2 V_2O_5

Answer the following questions using only the elements or compounds in the list.
Each element or compound may be used once, more than once or not at all.

State which element or compound is used:

(a) to kill bacteria in drinking water ..... [1]

(b) as a food preservative ..... [1]

(c) as an electrical conductor in cables ..... [1]

(d) as an inert atmosphere in lamps ..... [1]

(e) to neutralise excess acidity in soil ..... [1]

(f) as a catalyst in the Contact process. ..... [1]

[Total: 6]

08. 0620_w18_qp_41 Q: 4

(a) Sulfuric acid is made industrially by a four-step process.

step 1 Sulfur is burned in air to produce sulfur dioxide.

step 2 Sulfur dioxide is converted into sulfur trioxide.

step 3 Sulfur trioxide is reacted with concentrated sulfuric acid to produce oleum.

step 4 Oleum is reacted with water to produce concentrated sulfuric acid.

(i) Some sulfur is obtained by mining.

Name **one** other major source of sulfur.

..... [1]

(ii) What is the name of the process by which sulfuric acid is made industrially?

..... [1]

(iii) Describe the conversion of sulfur dioxide into sulfur trioxide in **step 2**.

In your answer, include:
- a chemical equation for the reaction
- the essential reaction conditions.

.....

.....

.....

.....

.....

.....

..... [5]

(b) When concentrated sulfuric acid is added to glucose, $C_6H_{12}O_6$, a black solid is produced. The concentrated sulfuric acid acts as a dehydrating agent.

(i) What is removed from the glucose in this reaction?

..... [1]

(ii) Name the black solid produced in this reaction.

..... [1]

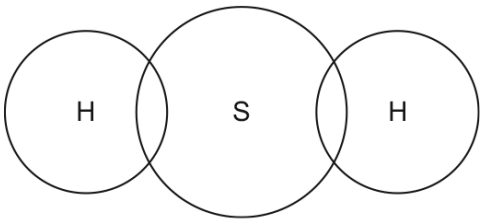
(c) The gas hydrogen sulfide, H_2S, is produced when concentrated sulfuric acid is added to solid potassium iodide.

The reaction involves oxidation.

(i) Define the term *oxidation* in terms of electron transfer.

..... [1]

(ii) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of hydrogen sulfide. Show outer shell electrons only.



[2]

(iii) Hydrogen sulfide has a simple molecular structure.

Explain why hydrogen sulfide has a low boiling point.

.....

.....

..... [2]

(d) Dilute sulfuric acid reacts with aqueous sodium hydrogencarbonate in a neutralisation reaction.

$$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

In a titration, 0.200 mol / dm^3 aqueous sodium hydrogencarbonate was used to neutralise 20.0 cm^3 of dilute sulfuric acid of concentration 0.150 mol / dm^3.

(i) Calculate the number of moles of dilute sulfuric acid used in the titration.

..... mol [1]

(ii) Calculate the number of moles of sodium hydrogencarbonate needed to neutralise the dilute sulfuric acid.

..... mol [1]

(iii) Calculate the volume, in cm^3, of 0.200 mol / dm^3 aqueous sodium hydrogencarbonate needed to neutralise the dilute sulfuric acid.

..... cm^3 [1]

[Total: 17]

09. 0620_w18_qp_42 Q: 3

Sulfur is an important element.

(a) Explain how burning fossil fuels containing sulfur leads to the formation of acid rain.

.....

.....

..... [2]

(b) Sulfuric acid is manufactured by the Contact process. One step in the Contact process involves a reversible reaction in which sulfur trioxide, SO_3, is formed.

(i) Write a chemical equation for this reversible reaction. Include the correct symbol to show that the reaction is reversible.

..... [2]

(ii) State the conditions and name the catalyst used in this reversible reaction.

temperature .....

pressure .....

catalyst .....

[3]

(iii) Describe how the sulfur trioxide formed is converted into sulfuric acid in the next steps of the Contact process.

.....

.....

..... [2]

(c) Dilute sulfuric acid is used to make salts known as sulfates.

A method consisting of three steps is used to make zinc sulfate from zinc carbonate.

step 1 Add an excess of zinc carbonate to 20 cm^3 of 0.4 mol/dm^3 dilute sulfuric acid until the reaction is complete.

step 2 Filter the mixture.

step 3 Heat the filtrate until a saturated solution forms and then allow it to crystallise.

(i) Name a suitable piece of apparatus for measuring 20 cm^3 of dilute sulfuric acid in **step 1**.

..... [1]

(ii) State **two** observations which would show that the reaction is complete in **step 1**.

1 .....

2 .....
[2]

(iii) Why is it important to add an excess of zinc carbonate in **step 1**?

..... [1]

(iv) What is meant by the term *saturated solution* in **step 3**?

.....

..... [2]

(v) The equation for the reaction is shown.

$$ZnCO_3(s) + H_2SO_4(aq) \rightarrow ZnSO_4(.....) + H_2O(l) + CO_2(g)$$

Complete the equation by inserting the state symbol for zinc sulfate. [1]

(vi) Name another zinc compound which could be used to make zinc sulfate from dilute sulfuric acid using this method.

..... [1]

(vii) Suggest why this method would **not** work to make barium sulfate from barium carbonate and dilute sulfuric acid.

..... [1]

(d) In a titration, a student added 25.0 cm^3 of 0.200 mol/dm^3 aqueous sodium hydroxide to a conical flask. The student then added a few drops of methyl orange to the solution in the conical flask.
Dilute sulfuric acid was then added from a burette to the conical flask. The volume of dilute sulfuric acid needed to neutralise the aqueous sodium hydroxide was 20.0 cm^3.

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

(i) What was the colour of the methyl orange in the aqueous sodium hydroxide?

..... [1]

(ii) Determine the concentration of the dilute sulfuric acid in g/dm^3.

- Calculate the number of moles of aqueous sodium hydroxide added to the conical flask.

..... mol

- Calculate the number of moles of dilute sulfuric acid added from the burette.

..... mol

- Calculate the concentration of the dilute sulfuric acid in mol/dm^3.

..... mol/dm^3

- Calculate the concentration of the dilute sulfuric acid in g/dm^3.

..... g/dm^3
[4]

(e) Iron(II) sulfate decomposes when heated strongly.

$$2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

15.20 g of $FeSO_4(s)$ was heated and formed 4.80 g of $Fe_2O_3(s)$.

[M_r, $FeSO_4$ = 152; M_r, Fe_2O_3 = 160]

Calculate the percentage yield for this reaction.

..... % [3]

[Total: 26]

10. 0620_w18_qp_43 Q: 1

Answer the following questions using only the substances in the list.
Each substance may be used once, more than once or not at all.

ammonia	**bauxite**	**carbon dioxide**	**carbon monoxide**
hematite	**oxygen**	**sodium chloride**	**sulfur dioxide**

State which substance is:

(a) an element ..... [1]

(b) an ore of iron ..... [1]

(c) used to bleach wood pulp ..... [1]

(d) used to manufacture fertilisers ..... [1]

(e) a toxic gas produced during the incomplete combustion of hydrocarbons

..... [1]

(f) an ionic compound ..... [1]

(g) a reactant in photosynthesis ..... [1]

(h) a product of photosynthesis. ..... [1]

[Total: 8]

11. 0620_m16_qp_42 Q: 6

Iron pyrite, FeS_2, is known as Fool's Gold because it is a shiny yellow solid which is similar in appearance to gold. Iron pyrite is an ionic compound. Gold is a metallic element.

(a) Iron pyrite, FeS_2, contains positive and negative ions. The positive ion is Fe^{2+}.

Deduce the formula of the negative ion.

..... [1]

(b) A student is provided with a sample of iron pyrite and a sample of gold.

Suggest how the student could distinguish between the two substances.

.....

..... [2]

(c) Sulfur dioxide is produced on a large scale by heating iron pyrite strongly in air. The iron pyrite reacts with oxygen in the air producing iron(III) oxide, Fe_2O_3, and sulfur dioxide.

(i) Construct a chemical equation for the reaction between iron pyrite and oxygen.

..... [2]

(ii) Give **one** use of sulfur dioxide.

..... [1]

[Total: 6]

12. 0620_w16_qp_43 Q: 5

Sulfuric acid can be manufactured from the raw materials sulfur, air and water. The process can be divided into four stages.

stage 1 converting sulfur into sulfur dioxide

stage 2 converting sulfur dioxide into sulfur trioxide

stage 3 converting sulfur trioxide into oleum, $H_2S_2O_7$

stage 4 converting oleum into sulfuric acid

stage 1

(a) (i) Describe how sulfur is converted into sulfur dioxide.

..... [1]

(ii) Write a chemical equation for the conversion of sulfur into sulfur dioxide.

..... [1]

stage 2

(b) Sulfur dioxide is converted into sulfur trioxide according to the following equation.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The reaction is carried out at a temperature of 450 °C and a pressure of 1–2 atmospheres using a catalyst. The energy change, ΔH, for the reaction is –196 kJ / mol.

(i) What is the meaning of the symbol $\rightleftharpoons$?

..... [1]

(ii) Name the catalyst used in this reaction.

..... [1]

(iii) Why is a catalyst used?

..... [1]

(iv) If a temperature higher than 450 °C were used, what would happen to the amount of sulfur trioxide produced? Give a reason for your answer.

.....

..... [2]

(v) Suggest a reason why a temperature lower than 450 °C is **not** used.

.....

..... [1]

(vi) If a pressure higher than 1–2 atmospheres were used, what would happen to the amount of sulfur trioxide produced? Give a reason for your answer.

.....

..... [2]

stage 3

(c) (i) What is added to sulfur trioxide to convert it into oleum?

..... [1]

(ii) Write a chemical equation for the conversion of sulfur trioxide into oleum.

..... [1]

stage 4

(d) (i) What is added to oleum to convert it into sulfuric acid?

..... [1]

(ii) Write a chemical equation for the conversion of oleum into sulfuric acid.

..... [1]

(e) Give **one** use of sulfuric acid.

..... [1]

(f) Sulfuric acid reacts with a hydrocarbon called benzene to produce benzenesulfonic acid, $C_6H_5SO_3H$. Benzenesulfonic acid is a strong acid which ionises to produce hydrogen ions, H^+, and benzenesulfonate ions, $C_6H_5SO_3^-$.

(i) What is meant by the term *strong acid*?

..... [1]

(ii) Describe how to show that a 1 mol / dm^3 solution of benzenesulfonic acid is a strong acid.

.....

..... [2]

(iii) Write a chemical equation for the reaction between benzenesulfonic acid and sodium carbonate, Na_2CO_3.

..... [2]

[Total: 20]

13. 0620_w15_qp_31 Q: 3
Sulfuric acid is made by the Contact process.

(a) Sulfur is burned by spraying droplets of molten sulfur into air.

Suggest and explain an advantage of using this method.

.....

..... [2]

(b) The following equation represents the equilibrium in the Contact process.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Oxygen is supplied from the air.
The composition of the reaction mixture is 1 volume of sulfur dioxide to 1 volume of oxygen.

What volume of air contains 1 dm^3 of oxygen?

..... dm^3 [1]

(c) Sulfur dioxide is more expensive than air.

What is the advantage of using an excess of air?

.....

..... [2]

(d) The forward reaction is exothermic. The reaction is usually carried out at a temperature between 400 and 450 °C.

(i) What is the effect on the position of equilibrium of using a temperature above 450 °C?
Explain your answer.

.....

.....

..... [2]

(ii) What is the effect on the rate of using a temperature below 400 °C?
Explain your answer.

.....

.....

..... [3]

(e) A low pressure, 2 atmospheres, is used. At equilibrium, about 98% SO_3 is present.

(i) What is the effect on the position of equilibrium of using a higher pressure?

..... [1]

(ii) Explain why a higher pressure is **not** used.

..... [1]

(f) Name the catalyst used in the Contact process.

..... [1]

(g) Describe how concentrated sulfuric acid is made from sulfur trioxide.

.....

.....

.....

..... [2]

[Total: 15]

14. 0620_w15_qp_33 Q: 5

Sulfuric acid is a strong acid. In aqueous solution, it ionises as shown below.

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$$

(a) (i) What is meant by the term *acid*?

..... [1]

(ii) Sulfurous acid, H_2SO_3, is a weak acid.

State the difference between a weak acid and a strong acid.

.....

..... [2]

(b) Sulfurous acid forms salts called sulfites, which contain the ion SO_3^{2-}.

When barium nitrate solution is added to aqueous sulfurous acid, a white precipitate, **A**, forms.

Bromine water changes from brown to colourless when added to aqueous sulfurous acid.

Bromine oxidises sulfurous acid. When this solution is tested with acidified barium nitrate solution, a different white precipitate, **B**, is formed.

(i) Identify the white precipitate, **A**.

..... [1]

(ii) Identify the white precipitate, **B**.

..... [1]

(iii) Write an ionic equation for the reduction of the bromine molecule.

..... [1]

(iv) Name the product formed by the oxidation of sulfurous acid.

..... [1]

(c) Complete the following word equations.

(i) magnesium hydroxide + dilute sulfuric acid

..... [1]

(ii) zinc + dilute sulfuric acid

..... [1]

(iii) copper carbonate + dilute sulfuric acid

..... [1]

(d) Write equations for the reaction of dilute sulfuric acid with each of the following.

(i) ammonia

..... [2]

(ii) sodium hydroxide

..... [2]

(iii) iron

..... [2]

[Total: 16]

15. 0620_w14_qp_31 Q: 3

The main use of sulfur dioxide is the manufacture of sulfuric acid.

(a) State **two** other uses of sulfur dioxide.

.....

..... [2]

(b) One source of sulfur dioxide is burning sulfur in air.
Describe how sulfur dioxide can be made from the ore zinc sulfide.

.....

..... [2]

(c) The Contact process changes sulfur dioxide into sulfur trioxide.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
the forward reaction is exothermic
temperature 400 to 450 °C
low pressure 1 to 10 atmospheres
catalyst vanadium(V) oxide

(i) What is the formula of vanadium(V) oxide?

..... [1]

(ii) Vanadium(V) oxide is an efficient catalyst at any temperature in the range 400 to 450 °C.
Scientists are looking for an alternative catalyst which is efficient at 300 °C.
What would be the advantage of using a lower temperature?

.....

.....

..... [2]

(iii) The process does not use a high pressure because of the extra expense.
Suggest **two** advantages of using a high pressure?
Explain your suggestions.

.....

.....

.....

.....

..... [4]

(d) Sulfuric acid is made by dissolving sulfur trioxide in concentrated sulfuric acid to form oleum. Water is reacted with oleum to form more sulfuric acid.
Why is sulfur trioxide not reacted directly with water?

..... [1]

[Total: 12]

---

16. 0620_w14_qp_32 Q: 6

Sulfuric acid is an important acid, both in the laboratory and in industry.
Sulfuric acid is manufactured in the Contact Process. Originally, it was made by heating metal sulfates and by burning a mixture of sulfur and potassium nitrate.

(a) Give a major use of sulfuric acid.

..... [1]

(b) A group of naturally occurring minerals have the formula of the type $FeSO_4.xH_2O$ where x is 1, 4, 5, 6 or 7. The most common of these minerals is iron(II) sulfate-7-water.

(i) When this mineral is heated gently it dehydrates.

$$\underset{\text{green}}{FeSO_4.7H_2O} \rightleftharpoons \underset{\text{pale yellow}}{FeSO_4} + 7H_2O$$

Describe how you could show that this reaction is reversible.

.....

.....

..... [2]

(ii) When the iron(II) sulfate is heated strongly, further decomposition occurs.

$$2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

The gases formed in this reaction react with water and oxygen to form sulfuric acid.
Explain how the sulfuric acid is formed.

.....

..... [2]

(iii) A mineral of the type $FeSO_4.xH_2O$ contains 37.2% of water.
Complete the calculation to determine x.

mass of one mole of H_2O = 18 g

mass of water in 100 g of $FeSO_4.xH_2O$ = 37.2 g

number of moles of H_2O in 100 g of $FeSO_4.xH_2O$ = ...

mass of $FeSO_4$ in 100 g of $FeSO_4.xH_2O$ = ... g

mass of one mole of $FeSO_4$ = 152 g

number of moles of $FeSO_4$ in 100 g of $FeSO_4.xH_2O$ = ...

x = ...

[4]

(c) When a mixture of sulfur and potassium nitrate is burned and the products are dissolved in water, sulfuric acid is formed.

(i) The sulfuric acid formed by this method is not pure. It contains another acid.
Deduce the identity of this acid.

..... [1]

(ii) The heat causes some of the potassium nitrate to decompose.
Write the equation for the action of heat on potassium nitrate.

..... [2]

[Total: 12]

---

17. 0620_w13_qp_33 Q: 4

Sulfuric acid is a strong acid. Hexanesulfonic acid is also a strong acid. It has similar properties to sulfuric acid.

(a) Sulfonic acids are made from alkanes and oleum, $H_2S_2O_7$.

$$C_6H_{14} + H_2S_2O_7 \rightarrow C_6H_{13}SO_3H + H_2SO_4$$

(i) Describe how oleum is made from sulfur by the Contact process. Give equations and reaction conditions.

.....

.....

.....

.....

.....

.....

..... [6]

(ii) How is concentrated sulfuric acid made from oleum?

..... [1]

(b) The formula of the hexanesulfonate ion is $C_6H_{13}SO_3^-$.

The formula of the barium ion is Ba^{2+}. What is the formula of barium hexanesulfonate?

..... [1]

(c) Complete the following equations.

(i) magnesium + hexanesulfonic acid $\rightarrow$ ..... + ...
.....
[1]

(ii) calcium oxide + hexanesulfonic acid $\rightarrow$ ..... + ...
.....
[1]

(iii) .....$C_6H_{13}SO_3H + Na_2CO_3 \rightarrow$ ..... + ... + ... [2]

(d) (i) Sulfuric acid is a strong acid.
You are given aqueous sulfuric acid, concentration 0.1 mol / dm^3, and aqueous hexanesulfonic acid, concentration 0.2 mol / dm^3. Describe how you could show that hexanesulfonic acid is also a strong acid.

.....

..... [2]

(ii) Deduce why, for a fair comparison, the two acid solutions must have different concentrations.

.....

..... [1]

(iii) Explain the terms *strong acid* and *weak acid*.

.....

.....

..... [2]

[Total: 17]

18. 0620_s12_qp_31 Q: 4

Vanadium is a transition element. It has more than one oxidation state.
The element and its compounds are often used as catalysts.

(a) Complete the electron distribution of vanadium by inserting one number.

2 + 8 + ... + 2

[1]

(b) Predict **three** physical properties of vanadium which are typical of transition elements.

1. .....

2. .....

3. ..... [2]

(c) Vanadium(V) oxide is used to catalyse the exothermic reaction between sulfur dioxide and oxygen in the Contact Process.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The rate of this reaction can be increased either by using a catalyst or by increasing the temperature. Explain why a catalyst is used and not a higher temperature.

.....

.....

..... [2]

(d) The oxidation states of vanadium in its compounds are V(+5), V(+4), V(+3) and V(+2). The vanadium(III) ion can behave as a reductant or an oxidant.

(i) Indicate on the following equation which reactant is the oxidant.

$$2V^{3+} + Zn \rightarrow 2V^{2+} + Zn^{2+}$$

[1]

(ii) Which change in the following equation is oxidation? Explain your choice.

$$V^{3+} + Fe^{3+} \rightarrow V^{4+} + Fe^{2+}$$

.....

..... [2]

[Total: 8]

19. 0620_w12_qp_32 Q: 5

The food additive E220 is sulfur dioxide. It is a preservative for a variety of foods and drinks.

(a) State **two** other uses of sulfur dioxide.

.....

..... [2]

(b) How is sulfur dioxide manufactured?

.....

..... [2]

(c) Sulfur dioxide is a reductant (reducing agent). Describe what you would see when aqueous sulfur dioxide is added to acidified potassium manganate(VII).

.....

..... [2]

(d) Sulfur dioxide can also be made by the reaction between a sulfite and an acid.

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + SO_2 + H_2O$$

Excess hydrochloric acid was added to 3.15 g of sodium sulfite. Calculate the maximum volume, measured at r.t.p., of sulfur dioxide which could be formed.
The mass of one mole of Na_2SO_3 is 126 g.

.....

.....

..... [3]

[Total: 9]

01. 0620_s20_ms_42 Q: 2

(a)(i)	magnesium 2.8 (all crosses) (1) fluorine 2.8 (seven dots and one cross in outer shell) (1) Mg^{2+} **and** F^-(1)	3
(a)(ii)	MgF_2	1
(a)(iii)	heat until molten **or** dissolve in water (1) moving ions / mobile ions (1)	2

(b)	two single bonds (1) one double bond (1) six non-bonding electrons on both F atoms and four non- bonding electrons on O atom to complete the octet in each case (1)	3
(c)(i)	forces of attraction between oppositely charged ions / ionic bonds (1) strong / need a lot of energy to break / weaken (1)	2
(c)(ii)	forces of attraction between molecules (1) weak / need a small of energy to break / weaken (1)	2

02. 0620_s20_ms_42 Q: 3

(a)(i)	heat in air	1
(a)(ii)	$2SO_2 + O_2 \rightarrow 2SO_3$ (1) 450°C (1) vanadium(V) oxide (1)	3
(a)(iii)	rate of forward reaction and rate of backward reaction are equal (1) concentrations of reactants and products are constant (1)	3
(b)	concentrated sulfuric acid	1
(c)	$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	2
(d)	$Cu + \mathbf{2}H_2SO_4 \rightarrow CuSO_4 + SO_2 + \mathbf{2}H_2O$	1
(e)	purple to colourless	1
(f)	$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$	2
(g)(i)	barium nitrate / barium chloride	1
(g)(ii)	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ formulae (1) state symbols (1)	2

03. 0620_w20_ms_41 Q: 5

Question	Answer	Marks
(a)(i)	breakdown by (the passage of) electricity (1) of an ionic compound in molten/aqueous (state) (1)	2
(a)(ii)	they do not react	1
(a)(iii)	negative electrode: hydrogen (gas) (1) positive electrode: oxygen (gas) (1)	2

Question	Answer	Marks
(a)(iv)	$H^+ + e(^-)$ as the only species on the left (1) equation fully correct (1) $2H^+ + 2e(^-) \rightarrow H_2$ (scores 2)	2
(b)(i)	$S + O_2 \rightarrow SO_2$	1
(b)(ii)	rate of forward reaction is equal to rate of reverse reaction (1) constant concentration (of reactants and products) (1)	2
(b)(iii)	exothermic / heat / energy is released / surroundings warm up products have lower energy than reactants / ORA	2
(c)	water / H_2O	1
(d)	(M_r =) 98 (0.75 × 98 =) 73.5	2

04. 0620_w19_ms_41 Q: 2

(a)	atoms with same number of protons **or** atoms of the same element **or** atoms with same atomic number (1) atoms with different number of neutrons **or** atoms with different mass number **or** atoms with different nucleon number (1)	**2**
(b)(i)	18	**1**
(b)(ii)	gain of two electrons	**1**
(b)(iii)	Ca / calcium	**1**
(c)(i)	l.....g.....g.	**1**
(c)(ii)	vanadium (V) oxide **or** vanadium pentoxide (1) 450 (°C) (1)	**2**
(c)(iii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ (1) $H_2S_2O_7 + H_2O \rightarrow 2\,H_2SO_4$ (1)	**2**
(d)(i)	(it causes) acid rain	**1**
(d)(ii)	test – (aqueous) potassium manganate (VII) (1) (purple to) colourless (1)	**2**
(e)	29.1 / 23 40.5 / 32 30.4 / 16 **or** 1.2(65) 1.2(65) 1.9 (1) 1:1:1.5 (1) $Na_2S_2O_3$ (1)	**3**

05. 0620_w19_ms_42 Q: 3

(a)(i)	⇌	**1**
(a)(ii)	pressure 100–300 atmospheres / atm (1) temperature in range 330 to 500 °C (1) iron (catalyst) (1) species: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1) fully correctly equation (1)	**5**
(a)(iii)	water / steam or methane / natural gas	**1**
(b)(i)	proton acceptor	**1**
(b)(ii)	Contact (process)	**1**
(b)(iii)	$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$ $(NH_4)_2SO_4$ (1) rest of the equation (1)	**2**
(c)(i)	iron(II) hydroxide	**1**
(c)(ii)	any **two** from: □ it (iron(II) hydroxide) is oxidised □ to form iron(III) (hydroxide) / (oxide) □ by (iron(II) hydroxide reacting with) air / oxygen	**2**
(c)(iii)	(green ppt) Remains	**1**
(d)(i)	mol of NH_3 = 4.8(0) / 24 = 0.2(0) (1) mol of O_2 = 0.2 □ 5 / 4 = 0.25 (1) mol of O_2 = 0.25 □ 24 = 6.(0) (1)	**3**

(d)(ii)	**M1** Bonds broken [4 □ 3 □ 391] + [5 □ 498] = 4692 + 2490 = 7182 **M2** Bonds formed [4 □ 587] + [12 □ 464] = 2348 + 5568 = 7916 **M3** Energy change = 7182 – 7916 = –734 **M4** = **M3** / 4 = –734 / 4 = –183.5	**4**

06. 0620_s18_ms_42 Q: 2

(a)	silicon / Si	1
(b)	aluminium / A*l*	1
(c)	sodium / Na	1
(d)	chlorine / Cl_2 / C*l*	1
(e)	argon / Ar	1
(f)	sulfur / S	1
(g)	phosphorus / P	1

07. 0620_s18_ms_43 Q: 1

(a)	Cl_2 / chlorine	1
(b)	SO_2 / sulfur dioxide	1
(c)	Cu / copper	1
(d)	Ar / argon	1
(e)	$Ca(OH)_2$ / calcium hydroxide	1
(f)	V_2O_5 / vanadium(V) oxide	1

08. 0620_w18_ms_41 Q: 4

(a)(i)	from petroleum or (crude) oil or fossil fuels	1
(a)(ii)	Contact (process)	1
(a)(iii)	**M1** vanadium pentoxide **or** vanadium(V) oxide **or** V_2O_5 (catalyst);	1
	M2 1–5 atmospheres; (Units required)	1
	M3 450°**C**; units required	1
	M4 $2SO_2 + O_2 \rightarrow 2SO_3$;	1
	M5 equilibrium / reversible reaction in equation or text	1
(b)(i)	water / H_2O	1
(b)(ii)	carbon / C	1
(c)(i)	(oxidation is) loss of electrons	1
(c)(ii)	**M1** one shared pair between each H and S	1
	M2 four unpaired electrons on S giving S a total of 8 outer shell electrons and no other unpaired electrons	1
(c)(iii)	**M1** weak (attractive) forces **OR** (attractive) forces need little energy to overcome	1
	M2 forces between molecules / intermolecular	1
(d)(i)	0.003	1
(d)(ii)	0.006	1
(d)(iii)	30	1

09. 0620_w18_ms_42 Q: 3

(a)	M1 Sulfur dioxide / SO_2 is formed M2 SO_2 reacts with (atmospheric) water (vapour) / rain	2
(b)(i)	$2SO_2 + O_2 \rightleftharpoons 2SO_3$ M1 Balanced equation M2 reversible arrow	2
(b)(ii)	M1 450 °C (units required) M2 1–5 atmospheres (units required) M3 Vanadium (V) oxide **or** vanadium pentoxide **or** V_2O_5	3
(b)(iii)	M1 SO_3 added to (concentrated) H_2SO_4 M2 (Oleum) diluted with / added to water	2
(c)(i)	Measuring cylinder	1
(c)(ii)	M1 No more fizzing; M2 ($ZnCO_3$) stops dissolving or a (white) solid remains / is visible	2
(c)(iii)	To use up all the acid / H^+ ions	1
(c)(iv)	M1 A solution that can hold no more solute M2 at the specified temperature	2
(c)(v)	(aq)	1
(c)(vi)	Zinc oxide **or** zinc hydroxide	1
(c)(vii)	Barium sulfate is insoluble	1

(d)(i)	yellow	1
(d)(ii)	M1 0.2 □ 25 / 1000 = 5(.00) □ 10^{-3} or 0.005(00) (mol) M2 5(.00) □ 10^{-3} / 2 = 2.5(.0) □ 10^{-3} or 0.0025(0) (mol) M3 2.5(.0) □ 10^{-3} □ 1000 / 20 = 0.125 (mol / dm^3) M4 0.125 □ 98 = 12.25 (g / dm^3)	4
(e)	M1 Mol $FeSO_4$ = 15.2 / 152 = 0.1(00) M2 Expected mol of Fe_2O_3 = 0.1 / 2 = 0.05(00)) **or** Actual mol of Fe_2O_3 = 4.80 / 160= 0.03(00) M3 Percentage yield = 100 □ 0.03(00) / 0.05(00) = 60%	3

10. 0620_w18_ms_43 Q: 1

(a)	oxygen	1
(b)	hematite	1
(c)	sulfur dioxide	1
(d)	ammonia	1
(e)	carbon monoxide	1
(f)	sodium chloride	1
(g)	carbon dioxide	1
(h)	oxygen	1

11. 0620_m16_ms_42 Q: 6

(a)	S_2^{2-}; **or** S^-;	**1**
(b)	test conductivity; gold conducts / ora; **or** malleability / hit with a hammer; gold malleable / only gold produces ringing sound / ora; **or** density; gold denser / ora; **or** add acid / any named / formula of acid; gold does not react (ignore products with pyrites) / ora; **or** heat (both strongly) in air / oxygen; iron pyrite reacts (ignore products); **or** melting point; gold lower / ora; **or** heat with a more reactive metal than iron; gold does not react / ora;	**2**
(c)(i)	$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$ all formulae; balancing;	**2**

(c)(ii)	bleaching (in the manufacture of) wood pulp (for paper or straw or wool or cotton) / (food) preservative or killing bacteria in food or wine / fumigant / refrigerant / tanning(leather);	**1**

12. 0620_w16_ms_43 Q: 5

(a)(i)	burned / heated in air	**1**
(a)(ii)	$S + O_2 \rightarrow SO_2$	**1**
(b)(i)	equilibrium / reversible	**1**
(b)(ii)	vanadium(V) oxide / vanadium pentoxide	**1**
(b)(iii)	increase rate (of reaction) / allow lower temperature to be used / allow lower pressure to be used	**1**
(b)(iv)	less SO_3 forward reaction is exothermic / it is exothermic / reverse reaction is endothermic	**1** **1**
(b)(v)	rate too low / reaction too slow / slower	**1**
(b)(vi)	more SO_3 fewer moles or molecules (of gas) on right-hand side / more moles or molecules(of gas) on left-hand side	**1** **1**
(c)(i)	concentrated sulfuric acid / concentrated H_2SO_4	**1**
(c)(ii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$	**1**

(d)(i)	water	**1**
(d)(ii)	$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	**1**
(e)	detergents / car batteries / dyes / paints / synthetic resins / printing inks / metal extraction / cleaning metals /	**1**
(f)(i)	exists completely as ions (in solution) / completely dissociates (in solution) / completely ionises (in solution)	**1**
(f)(ii)	Universal Indicator / pH paper / pH indicator / pH meter Universal Indicator or pH paper or pH indicator turns red / pH 0–1	**1** **1**
(f)(iii)	$Na_2CO_3 + 2C_6H_5SO_3H \rightarrow 2C_6H_5SO_3Na + CO_2 + H_2O$ formula of $C_6H_5SO_3Na$ all formulae correct and balancing correct	**2**

13. 0620_w15_ms_31 Q: 3

(a)	fast(er) reaction; large(r) surface area;	1 1
(b)	4.76 (dm^3);	1
(c)	moves equilibrium to right; increases yield (of sulfur trioxide) / uses up more sulfur dioxide;	1 1
(d)(i)	moves equilibrium to left; (forward reaction) exothermic;	1 1
(d)(ii)	decrease rate; molecules have less energy / move slower; fewer collisions (per second) / fewer particles have the activation energy / fewer collisions have the activation energy;	1 1 1
(e)(i)	moves to right;	1
(e)(ii)	high yield at 2 atm;	1
(f)	vanadium(V) oxide / vanadium pentoxide;	1
(g)	**M1** dissolve / react sulfur trioxide in (concentrated) sulfuric acid; add water to product of **M1**;	1 1

14. 0620_w15_ms_33 Q: 5

(a)(i)	proton donor / H^+ donor / hydrogen ion donor;	1
(a)(ii)	strong acid completely or fully ionises / completely or fully dissociates / completely or fully splits into ions; weak acid partially or incompletely ionises or dissociates or splits into ions / does not ionise fully;	1 1
(b)(i)	barium sulphite / barium sulfate(IV) / $BaSO_3$;	1
(b)(ii)	barium sulfate / $BaSO_4$;	1
(b)(iii)	$Br_2 + 2e^- \rightarrow 2Br^-$ / $Br_2 \rightarrow 2Br^- - 2e^-$;	1
(b)(iv)	sulfuric acid;	1
(c)(i)	(→) magnesium sulfate + water;	1
(c)(ii)	(→) zinc sulfate + hydrogen;	1
(c)(iii)	(→) copper(II) sulfate / copper sulfate + carbon dioxide + water;	1
(d)(i)	$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$ / $NH_3 + H_2SO_4 \rightarrow (NH_4)HSO_4$;	1

(d)(ii)	$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ Na_2SO_4; rest of equation correct; **or** $H^+ + OH^- \rightarrow H_2O$ H_2O as the only product on the right hand side; rest of equation correct; **or** $NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$ $NaHSO_4$; rest of equation correct; **or** $OH^- + H_2SO_4 \rightarrow HSO_4^- + H_2O$ HSO_4^-; rest of equation correct;	2
(d)(iii)	$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$; $FeSO_4$; rest of equation correct; **or** $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$; Fe^{2+}; rest of equation correct; **or** $2Fe + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2$; $Fe_2(SO_4)_3$; rest of equation correct; **or** $2Fe + 6H^+ \rightarrow 2Fe^{3+} + 3H_2$; Fe^{3+}; rest of equation correct;	2

15. 0620_w14_ms_31 Q: 3

(a) Any **two** from:
bleach/making wood pulp/making paper
food/fruit juice/wine preservative
fumigant/sterilising/insecticide [2]

(b) heating/roasting/burning (zinc sulfides) [1]
in air/oxygen COND on M1 [1]

(c) **(i)** V_2O_5 [1]

(ii) position of equilibrium shifts right/yield increases [1]
to save energy [1]

(iii) faster reaction/rate [1]

more collisions per second/higher collision frequency [1]

fewer moles/molecules (of gas) on right [1]

(so) position of equilibrium shifts right/yield increases [1]

(d) (the reaction is) too violent/too exothermic **or** produces mist/fumes (of acid) [1]

[Total: 12]

16. 0620_w14_ms_32 Q: 6

(a) making fertilisers or pickling metals or making fibres or making phosphoric acid/phosphates making dyes or making paints/pigments/dyes or making paper making plastics or making detergents or tanning leather or battery acid. [1]

(b) (i) add water (to yellow solid or to (anhydrous) iron(II) sulfate or to $FeSO_4$ or to products [1]

goes green [1]

(ii) M1 Sulfur trioxide reacts with water to make sulfuric acid or equation [1]

M2 sulfur dioxide reacts with oxygen to form sulfur trioxide or equation [1]

(iii) M1 = 2.07 Allow 2.1 or 2.0666…7

M2 = 62.8.g

M3 =(M2/152 =) 0.41(3)

M4 (=M1/M3) rounded to the nearest whole number × = 5 [4]

(c) (i) nitric acid or nitric(V) acid or HNO_3 [1]

(ii) $2KNO_3 = 2KNO_2 + O_2$ [2]
Species (1)
Balance (1)

[Total: 12]

17. 0620_w13_ms_33 Q: 4

(a) (i) $S + O_2 \rightarrow SO_2$
or sulfur burnt / roasted / heated in air to form sulfur dioxide [1]

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ [2]
unbalanced = (1) only

(catalyst) vanadium(V) oxide / vanadium pentoxide [1]
(temperature) 440 to 460°C [1]
(dissolve) sulfur trioxide in sulfuric acid (to form oleum) [1]
ignore comments about pressure

(ii) add oleum to water [1]

(b) $Ba(C_6H_{13}SO_3)_2$ / $(C_6H_{13}SO_3)_2Ba$ [1]

(c) (i) → magnesium hexanesulfonate + hydrogen [1]

(ii) → calcium hexanesulfonate + water [1]

(iii) $2C_6H_{13}SO_3H + Na_2CO_3 \rightarrow 2C_6H_{13}SO_3Na + CO_2 + H_2O$

$C_6H_{13}SO_3Na$ = (1) [1]
remaining species correct and equation balanced = (1) [1]

(d) (i) measure pH / add universal indicator [1]
both acids have a low value / pH 0–2 / same colour / red [1]
or
measure rate with named reactive metal, Mg, Zn (1)
both fast reactions (1)
or
measure rate using piece of insoluble carbonate, $CaCO_3$ (1)
both fast reactions (1)
NOTE: must be insoluble for first mark
or
measure electrical conductivity (1)
both good conductors (1)

(ii) to have same concentration of H^+ / one acid is H_2SO_4, the other is $C_6H_{13}SO_3H$ / sulfuric acid is dibasic, hexanesulfonic is monobasic [1]

(iii) a strong acid is completely ionised, [1]
a weak acid is partially ionised [1]

[Total: 17]

18. 0620_s12_ms_31 Q: 4

(a) 2 + 8 + 11 + 2 [1]

(b) hard;
strong / high tensile strength;
high mp / bp / high fixed points;
high density; [2]

three properties = [2]
two properties = [1]
not: properties of all metals e.g. good conductor, lustre etc. or form coloured compounds

(c) catalyst would not affect yield / change position of equilibrium / affects both sides equally; [1]
(higher) temperature would reduce yield / increase in temperature would favour back reaction; [1]

(d) **(i)** V^{3+} is oxidant; [1]

(ii) V^{3+} to V^{4+}; [1]
increase in oxidation number / electron loss; [1]

[Total: 8]

19. 0620_w12_ms_32 Q: 5

(a) any two from:
bleaching (wood pulp / silk / straw);
manufacture of sulfuric acid / SO_3 / in Contact process;
fumigating / sterilising; refrigerant; making dyes; making wine; insecticide;
fungicide; [2]

(b) burn / heat / react sulfur; [1]
in air / oxygen; [1]
or
burn / heat / roast zinc sulfide or lead sulfide;
in air / oxygen;

(c) from purple / pink; **not:** red [1]
to colourless; **not** clear [1]

(d) number of moles of Na_2SO_3 = 3.15/126 = 0.025 [1]
number of moles of SO_2 formed = 0.025 [1]
volume of SO_2 = 0.025 x 24 = 0.6 dm^3/litres **or** 600 cm^3 [1]
allow: ecf
for 1.6 g of SO_2 [1] only
If used 22.4 max [2]
note: need correct units for last mark

[Total: 9]