1 Zirconium (Zr) is a metal in Period 5. Its main oxidation state is +4.

(a) The following are all zirconium atoms: $^{90}_{40}Zr$, $^{91}_{40}Zr$ and $^{92}_{40}Zr$.

In terms of numbers of electrons, neutrons and protons, how are these three atoms the same and how are they different?

They are the same because .....

.....

They are different because .....

..... [3]

(b) Containers for fuel rods in nuclear reactors are made of zirconium.
Nuclear reactors are used to produce energy and to make radioactive isotopes.

(i) Which isotope of a different element is used as a fuel in nuclear reactors?

..... [1]

(ii) State one medical and one industrial use of radioactive isotopes.

.....

..... [2]

(iii) Above 900 °C, zirconium reacts with water to form zirconium(IV) oxide, ZrO_2, and hydrogen. Write an equation for this reaction.

..... [2]

(iv) In a nuclear accident, water may come in contact with very hot zirconium.
Explain why the presence of hydrogen inside the reactor greatly increases the danger of the accident.

..... [1]

(c) It is possible to determine whether zirconium(IV) oxide is acidic, neutral, basic or amphoteric using an acid and an alkali. Complete the table of possible results. If the oxide is predicted to react write 'R', if it is predicted not to react write 'NR'.

if the oxide is	predicted result with hydrochloric acid	predicted result with aqueous sodium hydroxide
acidic		
neutral		
basic		
amphoteric		

[4]

[Total: 13]

2 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) (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]

3 The major use of sulfur dioxide is to manufacture sulfuric acid.

(a) (i) Another use of sulfur dioxide is as the food additive E220.
How does it preserve food?

.....

..... [1]

(ii) Why is sulfur dioxide used in the manufacture of wood pulp?

..... [1]

(iii) How is sulfur dioxide manufactured?

..... [1]

(b) Complete the following description of the manufacture of sulfuric acid.

Sulfur dioxide reacts with ..... to form sulfur trioxide.

The above reaction is catalysed by ..... .

The optimum temperature for this reaction is ..... °C.

Sulfur trioxide needs to react with ..... to form sulfuric acid. [4]

(c) (i) Define the term *acid*.

..... [1]

(ii) Sulfuric acid is a strong acid. Ethanedioic acid is a weak acid.
Given solutions of both acids, how could you show that sulfuric acid is a strong acid and ethanedioic acid is a weak acid?

method .....

..... [1]

result for each acid .....

..... [1]

(d) 20.0 cm^3 of sulfuric acid, concentration 0.30 mol/dm^3, was added to 40 cm^3 of sodium hydroxide, concentration 0.20 mol/dm^3.

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

(i) How many moles of H_2SO_4 were added? ..... [1]

(ii) How many moles of NaOH were used? ..... [1]

(iii) Which reagent is in excess? Give a reason for your choice.

reagent in excess ..... [1]

reason .....

..... [1]

(iv) Is the pH of the final mixture less than 7, equal to 7 or more than 7?

..... [1]

[Total: 15]

4 Hydrogen reacts with the halogens to form hydrogen halides.

(a) Bond energy is the amount of energy, in kJ, that must be supplied (endothermic) to break one mole of a bond.

bond	**bond energy in kJ / mol**
H–H	
C*l*–C*l*	+2
H–C*l*	+4

Use the above data to show that the following reaction is exothermic.

H–H + C*l*–C*l* → 2H–C*l*

.....

.....

.....

.....

..... [3]

(b) They react with water to form acidic solutions.

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl$$

$$HF + H_2O \rightleftharpoons H_3O^+ + F$$

(i) Explain why water behaves as a base in both of these reactions.

.....

..... [2]

(ii) At equilibrium, only 1% of the hydrogen chloride exists as molecules, the rest has formed ions. In the other equilibrium, 97% of the hydrogen fluoride exists as molecules, only 3% has formed ions.

What does this tell you about the strength of each acid?

.....

..... [2]

(iii) How would the pH of these two solutions differ?

..... [1]

[Total: 8]