

1 Chromium, Cr, and its compounds are widely used in many chemical reactions.

(a) Cr exists as four stable isotopes.

(i) The most common isotope of Cr is chromium-52.

Determine the number of protons, neutrons and electrons in an atom of chromium-52.

number of protons ..... neutrons ..... electrons ..... [1]

(ii) Describe how an atom of chromium-54 differs from an atom of chromium-52. Refer to numbers of particles in your answer.

..... [1]

(iii) The relative isotopic masses of the isotopes of Cr can be determined using mass spectrometry.

State what other information is needed to calculate the relative atomic mass,  $A_r$ , of Cr.

..... [1]

(iv) Atoms of  $^{52}\text{Cr}$ ,  $^{53}\text{Cr}$  and  $^{54}\text{Cr}$  make up more than 95% of naturally occurring chromium atoms. The  $A_r$  of naturally occurring Cr is 51.996.

Suggest what these statements imply about the relative isotopic mass of the fourth stable isotope of chromium.

..... [1]

(b) The shorthand electronic configuration of chromium is  $[\text{Ar}] 3d^5 4s^1$ .

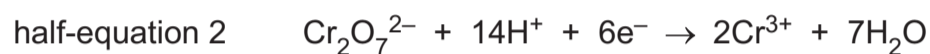
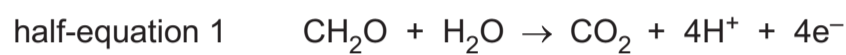
(i) Complete the full electronic configuration of chromium.

.....  $3d^5 4s^1$  [1]

(ii) Deduce the total number of unpaired electrons in an atom of chromium.

..... [1]

(c) Acidified dichromate(VI) ions will convert methanal,  $\text{CH}_2\text{O}$ , to carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.



(i) Identify the species that is reduced in half-equation 2. Explain your answer.

..... [1]

(ii) The oxidation state of the carbon atom in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

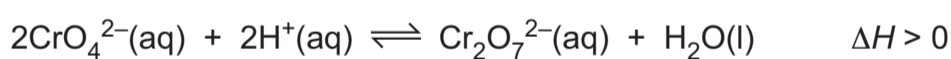
(iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

..... [2]

(iv) Methanal is a liquid at  $-30^\circ\text{C}$  but carbon dioxide is a gas at this temperature. Explain why.

..... [2]

(d) In acidic conditions, a dynamic equilibrium is established between  $\text{CrO}_4^{2-}(\text{aq})$  and  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ .



(i) State what is meant by dynamic equilibrium.

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii)  $\text{CrO}_4^{2-}(\text{aq})$  ions are yellow and  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$  ions are orange.

State what is observed when the following changes are made to an equilibrium mixture of acidified  $\text{CrO}_4^{2-}(\text{aq})$  and  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$  ions.

Explain your answers.

- The equilibrium mixture is warmed gently.

observation .....

explanation .....

.....

- Dilute  $\text{HCl}(\text{aq})$  is added to the equilibrium mixture.

observation .....

explanation .....

..... [4]

(e) Chromium(IV) fluoride,  $\text{CrF}_4$ , is a covalent molecule that shows similar chemical properties to  $\text{SiCl}_4$ .

Suggest the type of reaction that occurs when  $\text{CrF}_4$  is placed in water.

Construct a relevant equation for this reaction.

type of reaction .....

equation .....

[2]

[Total: 20]