

Past-paper walk-through

Isotopes ■ 1.2

eXercise

Questions in this set

- 9701/21 N25 Q1 ■ 20 marks
- 9701/22 N25 Q1 ■ 10 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- **//** separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = “or words to that effect” – the wording need not match.

Question 1

9701/21 N25 ■ Q1 ■ 20 marks

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.

Question 1

[1]

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

Question 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.

Question 1

- (iv) Atoms of ^{52}Cr , ^{53}Cr and ^{54}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.

Question 1

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

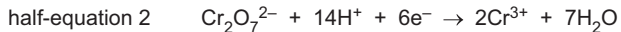
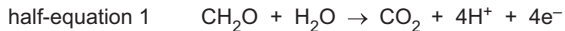
(i) Complete the full electronic configuration of chromium.

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

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

Question 1

- (c) Acidified dichromate(VI) ions will convert methanal, CH_2O , 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.

Question 1

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

Calculate the oxidation state of carbon in carbon dioxide.

Question 1

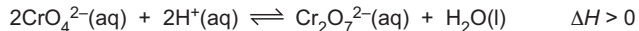
- (iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

Question 1

- (iv) Methanal is a liquid at -30°C but carbon dioxide is a gas at this temperature. Explain why.

Question 1

- (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.

Question 1

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

Question 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.

Question 1

Question 1

- Dilute HCl(aq) is added to the equilibrium mixture.

Question 1

Question 1

[4]

- (e) Chromium(IV) fluoride, CrF_4 , is a covalent molecule that shows similar chemical properties to SiCl_4 .

Suggest the type of reaction that occurs when CrF_4 is placed in water.

Construct a relevant equation for this reaction.

Question 1

Question 1

[2]

[Total: 20] _

Solution 1

(a)(i)

Mark scheme

- 24 protons
- 28 neutrons 24 electrons
- 1

Solution 1

(a)(ii)

Mark scheme

- (54Cr has two) more neutrons (than 52Cr)
- 1

(a)(iii)

Mark scheme

- (relative) abundance (of each isotope)
- 1

Solution 1

(a)(iv)

Mark scheme

- The fourth isotope has any value of RIM less than 51.996
- 1

Solution 1

(b)(i)

Mark scheme

- $1s^2 2s^2 2p^6 3s^2 3p^6 (3d^5 4s^1)$
- 1

(b)(ii)

Mark scheme

- 6
- 1

Solution 1

(c)(i)

Mark scheme

- Cr / $\text{Cr}_2\text{O}_7^{2-}$ AND it gains electrons
- 1

(c)(ii)

Mark scheme

- (+)4
- 1

Solution 1

(c)(iii)

Mark scheme

- Due to an issue with question 1(c)(iii), the question has been removed from the question paper.
- N/A

Solution 1

(c)(iv)

Mark scheme

- M1 CO₂ has only instantaneous / temporary dipole–induced dipole forces
- AND methanal has permanent dipole–permanent dipole (and id-id) forces **M2**
- IMF's in methanal are stronger than IMF's in CO₂
- 2
- 9701/21
- October/November 2025

Solution 1

(d)(i)

Mark scheme

- rate of forward and backward (reaction) are the same / equal
- OR concentrations of reactants and products are constant
- 1

Solution 1

(d)(ii)

Mark scheme

- closed system
- 1

Solution 1

(d)(iii)

Mark scheme

- M1 (mixture becomes more) orange M2
- forward reaction is endothermic M3
- (mixture becomes more) orange M4
- equilibrium moves (forwards/right) to compensate for extra acid / H^+
- 4

Solution 1

(e)

Mark scheme

- M1 hydrolysis (M2)
- $\text{CrF}_4 + 2\text{H}_2\text{O} \rightarrow \text{CrO}_2 + 4\text{HF}$
- 2
- 9701/21
- October/November 2025

Question 1

9701/22 N25 ■ Q1 ■ 10 marks

- 1 Manganese, Mn, and its compounds are widely used in many chemical reactions.
 - (a) Mn is usually found as a single isotope, manganese-55.
 - (i) Determine the number of protons, neutrons and electrons in an atom of manganese-55.

Question 1

[1]

(ii) Define isotopes.

Question 1

- (iii) A sample of manganese from the Moon is found to contain manganese-53 in addition to manganese-55.

State the two pieces of information needed to determine the relative atomic mass, A_r , of manganese in this sample.

Question 1

Question 1

[2]

(b) The shorthand electronic configuration of manganese is $[\text{Ar}] 3d^5 4s^2$.

(i) Complete the full electronic configuration of manganese.

..... $3d^5 4s^2$

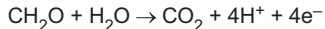
[1]

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

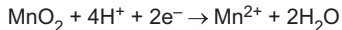
Question 1

- (c) Manganese(IV) oxide reacts with methanal, CH_2O , in acidic conditions to produce carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.

half-equation 1



half-equation 2



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

Question 1

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

Calculate the oxidation state of carbon in carbon dioxide.

Question 1

- (iii) Construct the ionic equation for the reaction of manganese(IV) oxide with methanal in acidic conditions.

Question 1

[Total: 10]

Solution 1

(a)(i)

Mark scheme

- 25 protons 30 neutrons 25 electrons
- 1

(a)(ii)

Mark scheme

- (atoms of an element) with the same number of protons and different number of neutrons
- 1

Solution 1

(a)(iii)

Mark scheme

- M1 (relative) isotopic mass.
- OR (relative isotopic) mass of Mn-55 and Mn-53 **M2**
- (relative) abundance of each isotope
- 2

Solution 1

(b)(i)

Mark scheme

- $1s^2 2s^2 2p^6 3s^2 3p^6 (3d^5 4s^2)$
- 1

(b)(ii)

Mark scheme

- 5
- 1

Solution 1

(c)(i)

Mark scheme

- Mn / MnO₂ AND it gains electrons
- 1

(c)(ii)

Mark scheme

- (+)4
- 1

Solution 1

(c)(iii)

Mark scheme

- Due to an issue with question 1(c)(iii), the question has been removed from the question paper.
- N/A