Past-paper walk-through

Relative masses of atoms and molecules ▪ 2.1

eXercise

Questions in this set

- 9701/11 N25 Q40 ▪ 1 mark
- 9701/14 N25 Q40 ▪ 1 mark
- 9701/21 N25 Q1 ▪ 20 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 40

9701/11 N25 ▪ Q40 ▪ 1 mark

40 A sample of magnesium contains the isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg only.

The percentage abundance of ^{25}Mg and ^{26}Mg is the same.

The relative atomic mass of magnesium in the sample is 24.3.

What is the percentage abundance of ^{24}Mg?

A 10% **B** 20% **C** 60% **D** 80%

Question 40

Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

	13	14	15	16	17	18
						2 He helium 4.0
	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
ı	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
ım	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The Periodic Table of Elements

Group

		1 H hydrogen 1.0				
I						
6	7	8	9	10	11	12
24 Cr hromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4
42 Mo ybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4
74 W ungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6
106 Sg aborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –

60 Nd odymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5
92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –

1	2				
			Key		
3 **Li** lithium 6.9	4 **Be** beryllium 9.0		atomic number atomic symbol name relative atomic mass		
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3	3	4	5	
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	cl
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	mo
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	t
87 **Fr** francium –	88 **Ra** radium –	89–103 actinoids	104 **Rf** rutherfordium –	105 **Db** dubnium –	se

lanthanoids	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	ne
actinoids	89 **Ac** actinium –	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	u

Solution 40

Answer: **D**

Why

- Let the ^{24}Mg abundance be $x\%$; the other two share $(100 - x)$ equally, so each is $(100 - x)/2$.
- Their average mass is 25.5, so $24x + 25.5(100 - x) = 2430$.
- $-1.5x = -120$, giving $x = 80\%$.

Question 40

9701/14 N25 ▪ Q40 ▪ 1 mark

40 A sample of gallium contains two isotopes only.

In every 10 atoms in the sample, there are 6 that have 38 neutrons and 4 that have 40 neutrons.

What is the relative atomic mass, A_r, of the gallium in the sample?

A 69.7 **B** 69.8 **C** 70.0 **D** 70.2

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Question 40

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62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	e 1
94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	fe

l	2					

Key

atomic number
atomic symbol
name
relative atomic mass

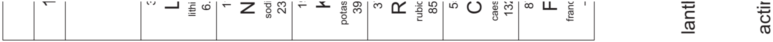
3	4					
.i	Be					
um	beryllium					
9	9.0					
1	12					
a	Mg					
ium	magnesium	3	4	5	6	7
.0	24.3					
9	20	21	22	23	24	25
(	Ca	Sc	Ti	V	Cr	Mn
sium	calcium	scandium	titanium	vanadium	chromium	manganese
.1	40.1	45.0	47.9	50.9	52.0	54.9
7	38	39	40	41	42	43
b	Sr	Y	Zr	Nb	Mo	Tc
ium	strontium	yttrium	zirconium	niobium	molybdenum	technetium
.5	87.6	88.9	91.2	92.9	95.9	–
5	56	57–71	72	73	74	75
s	Ba	lanthanoids	Hf	Ta	W	Re
ium	barium		hafnium	tantalum	tungsten	rhenium
2.9	137.3		178.5	180.9	183.8	186.2
7	88	89–103	104	105	106	107
r	Ra	actinoids	Rf	Db	Sg	Bh
ium	radium		rutherfordium	dubnium	seaborgium	bohrium
–	–		–	–	–	–

57	58	59	60	61
La	Ce	Pr	Nd	Pm
lanthanum	cerium	praseodymium	neodymium	promethium
138.9	140.1	140.9	144.2	–
89	90	91	92	93
Ac	Th	Pa	U	Np
actinium	thorium	protactinium	uranium	neptunium
–	232.0	231.0	238.0	–

hanoids

noids

Question 40



Solution 40

Answer: **B**

Why

- Gallium has 31 protons, so the two isotopes are ^{69}Ga and ^{71}Ga.
- $A_r = (6 \times 69 + 4 \times 71)/10 = 698/10.$
- $= 69.8.$

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 [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.

half-equation 1 $CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$

half-equation 2 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

(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 $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l) \qquad \Delta H > 0$$

(i) State what is meant by dynamic equilibrium.

Question 1

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

Question 1

(iii) $CrO_4^{2-}(aq)$ ions are yellow and $Cr_2O_7^{2-}(aq)$ ions are orange.

State what is observed when the following changes are made to an equilibrium mixture of acidified $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$ 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

- 1s2 2s2 2p6 3s2 3p6 (3d5 4s1)
- 1

(b)(ii)

Mark scheme

- 6
- 1

Solution 1

(c)(i)

Mark scheme

- Cr / Cr2O72– 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 CO_2 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 CO_2
- 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
- $CrF_4 + 2H_2O \rightarrow CrO_2 + 4HF$
- 2
- 9701/21
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