InkChemistry

ANSWER BOOK

The mole, the Avogadro constant and molar mass

Amount of substance · Unit C02

AQA 3.1.2.1, 3.1.2.2 · OCR A 2.1.3; PAG 1

17 questions · 54 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 MAC-Q1

B1 one mole is the amount of substance containing 6.022×10^{23} particles, the same number as there are atoms in 12 g of carbon-12; allow either half alone. **B1** the Avogadro constant is 6.022×10^{23} mol^{-1}; the unit is needed for the mark. [2]

A2 MAC-Q11

B1 iron(II) is oxidised to iron(III) by oxygen in the air when it is heated. **B1** the mass then changes for a reason other than the loss of water, so the mass loss does not give the mass of water. [2]

A3 MAC-Q20

B1 the crystals lose some of their water of crystallisation to the air while they stand in the open dish. **B1** less water is then driven off for each mole of sodium carbonate left, so the ratio of water to Na_2CO_3, x, comes out below 10. [2]

SECTION B · Standard, 3 to 5 marks

B1 MAC-Q3

M1 $M(Al_2(SO_4)_3) = 2 \times 27.0 + 3 \times (32.1 + 4 \times 16.0) = 342.3$ g mol^{-1}. **M1** $n(Al_2(SO_4)_3) = 8.55 \div 342.3 = 0.02498$ mol. **M1** each formula unit gives 2 Al^{3+} and 3 SO_4^{2-}, five ions, so $n(\text{ions}) = 5 \times 0.02498 = 0.1249$ mol. **A1** $N = 0.1249 \times 6.022 \times 10^{23} = 7.52 \times 10^{22}$ ions, to three significant figures; allow error carried forward from a wrong Mr. [4]

B2 MAC-Q10

M1 mass of water = 2.86 - 1.06 = 1.80 g. **M1** $n(Na_2CO_3) = 1.06 \div 106.0 = 0.0100$ mol. **M1** $n(H_2O) = 1.80 \div 18.0 = 0.100$ mol, and the ratio $H_2O : Na_2CO_3 = 0.100 \div 0.0100$. **A1** x = 10, a whole number with no unit, so the formula is $Na_2CO_3 \cdot 10H_2O$. [4]

B3 MAC-Q13

B1 a single heating and weighing does not show constant mass, so water may remain and x is likely to be low. **B1** the mass of water from 0.50 g is under 0.2 g, and a mass by difference on this balance is two readings of ±0.01 g, ±0.02 g, an uncertainty of over 10%. **B1** incomplete heating can only make x too low, so the true value is above 4.2 and rounding down to 4 is not justified. **B1** the conclusion is not supported; heating to constant mass with a larger sample would give x close to 5. [4]

B4 MAC-Q2

M1 $M(Na_2CO_3 \cdot 10H_2O) = 106.0 + 10 \times 18.0 = 286.0$ g mol^{-1}; allow 286 g mol^{-1}. **A1** mass of washing soda $= 0.0150 \times 286.0 = 4.29$ g, to three significant figures; error carried forward from M1. **A1** mass of water $= 0.0150 \times 10 \times 18.0 = 2.70$ g, to three significant figures. [3]

B5 MAC-Q4

M1 $n(CO_2) = 4.40 \div 44.0 = 0.100$ mol. **M1** each CO_2 molecule has three atoms, so $n(\text{atoms}) = 3 \times 0.100 = 0.300$ mol, and $N = 0.300 \times 6.022 \times 10^{23}$. **A1** 1.81×10^{23} atoms, to three significant figures. [3]

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B6 MAC-Q6 **M1** n(Mg) = 1.20 ÷ 24.3 = 0.04938 mol. **M1** the ratio Mg : MgO is 1 : 1, so n(MgO) = 0.04938 mol, and M(MgO) = 40.3 g mol^{-1}. **A1** mass of MgO = 0.04938 × 40.3 = 1.99 g, to three significant figures. [3]

B7 MAC-Q7 **B1** Mr of water and its molar mass have the same numerical value, 18.0. **B1** Mr is a ratio to one twelfth of the mass of a carbon-12 atom and has no unit, whereas molar mass is the mass of one mole, 18.0 g mol^{-1}; ignore a unit given with Mr. **B1** sodium chloride is a lattice of Na^+ and Cl^- ions with no molecules, so its relative mass is that of one formula unit, NaCl. [3]

B8 MAC-Q8 **B1** the aim is to remove all of the water of crystallisation. **B1** after a single heating there is no evidence that all the water has gone; some may remain in the solid. **B1** when two successive masses after heating and cooling agree, no more water is being lost, so the dehydration is complete. [3]

B9 MAC-Q9 **B1** one mole of any substance contains the same number of particles, 6.022 × 10^{23}. **B1** a carbon dioxide molecule has a greater mass than a water molecule, Mr 44.0 against 18.0. **B1** so the molar masses differ, 44.0 g mol^{-1} against 18.0 g mol^{-1}, and the same number of molecules has a different mass. [3]

B10 MAC-Q12 **B1** the anhydrous copper(II) sulfate has started to decompose, to black copper(II) oxide and sulfur trioxide. **B1** the extra mass lost as sulfur trioxide is counted as water. **B1** the calculated moles of water are too large, so x comes out too high. [3]

B11 MAC-Q16 **M1** n($CaCl_2$) = 2.22 ÷ 111.1 = 0.01998 mol. **M1** n(Cl^-) = 2 × 0.01998 = 0.03996 mol, and N = 0.03996 × 6.022 × 10^{23}. **A1** 2.41 × 10^{22} chloride ions, to three significant figures. [3]

B12 MAC-Q18 **M1** in 100 g of crystals, n(H_2O) = 43.8 ÷ 18.0 = 2.433 mol. **M1** n($ZnSO_4$) = (100 - 43.8) ÷ 161.5 = 56.2 ÷ 161.5 = 0.3480 mol, and the ratio is 2.433 ÷ 0.3480 = 6.99. **A1** x = 7, a whole number, so the formula is $ZnSO_4 \cdot 7H_2O$. [3]

B13 MAC-Q19 **B1** each mole of octane gives eight moles of carbon dioxide, from the 2 : 16 ratio in the equation. **B1** one mole of octane, 114.0 g, gives 8 × 44.0 = 352 g of carbon dioxide, about 3.09 times the mass; accept a full calculation giving 3.09 kg. **B1** the extra mass is oxygen taken from the air, which ends up bonded to every carbon atom in the CO_2. [3]

SECTION C · Long, 6 marks or more

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C1 [6]
MAC-Q15

Indicative content

B1 weigh a clean, dry crucible and lid, add two to three grams of the hydrated salt and weigh again, so the mass of hydrate is known by difference. **B1** heat the crucible on a pipeclay triangle, gently at first so that the solid does not spit out, then more strongly for several minutes. **B1** let the crucible cool with its lid on, or in a desiccator, so that the anhydrous salt cannot absorb water from the air before it is weighed. **B1** reweigh, then repeat heating, cooling and weighing until two successive masses agree within 0.01 g, which shows that all the water has been driven off. **B1** the mass of water is the mass of hydrate minus the final mass of anhydrous salt, and each mass is divided by its molar mass to give an amount in moles. **B1** x is the moles of water divided by the moles of anhydrous MSO_4, rounded to a whole number; a larger sample reduces the percentage uncertainty in the masses.

Levels

Level 3 (5–6 marks) weighing by difference, gentle then stronger heating, cooling with the lid or in a desiccator, heating to constant mass as the check that all water is removed, and the calculation of x from the two amounts in moles are all present; the answer explains why each step makes the result reliable.

Level 2 (3–4 marks) the crucible is weighed, heated and reweighed and x comes from the mass of water lost; heating to constant mass, cooling away from moist air, or putting both masses into moles is missed or unexplained.

Level 1 (1–2 marks) the hydrate is heated once and the mass loss found; x is often taken as the mass ratio of water to salt rather than the mole ratio.

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