S4 Chemistry Practice Paper: Atomic Structure and Isotopes, Ionic and Covalent Bonding, Mole Calculations and Gas Volumes, Solution Concentration and Titration, Combustion and Enthalpy Change, Acids, Bases and pH

Chemistry · S4

S4 chemistry practice paper: 24 parts, 100 marks, 75 minutes on atomic structure, bonding, moles and gas volumes, titration, combustion enthalpy and pH.

Question 1 - Atomic Structure and Isotopes (16 marks)

Element Q has proton number 12. The natural abundances of its three isotopes are: Q-24 78.99%, Q-25 10.00% and Q-26 11.01%.

#	Question	Answer and marking notes
1	State the number of protons, neutrons and electrons in an atom of Q-25.	Protons 12, neutrons 13, electrons 12.
2	Calculate the relative atomic mass of Q to two decimal places, showing working.	Relative atomic mass = (24 x 78.99 + 25 x 10.00 + 26 x 11.01) / 100 = 24.32.
3	Explain why the three isotopes of Q have identical chemical properties.	Chemical properties depend on the number of outermost electrons; all three isotopes have the electronic arrangement 2, 8, 2 with 2 outermost electrons, and a different number of neutrons does not affect chemical reactions.
4	Give the electronic arrangement of a Q atom and state its group and period.	Electronic arrangement 2, 8, 2; the 2 outermost electrons place Q in Group II, Period 3.

Question 2 - Ionic Bonding, Covalent Bonding and Structure (16 marks)

Consider sodium chloride (NaCl), water (H2O), magnesium oxide (MgO) and graphite.

#	Question	Answer and marking notes
5	State the type of chemical bond present in NaCl and in H2O respectively.	NaCl contains ionic bonds formed by electrostatic attraction between Na+ and Cl-; H2O contains covalent bonds in which electron pairs are shared.
6	Explain why the melting point of NaCl is much higher than that of H2O.	NaCl is a giant ionic lattice and melting requires overcoming many strong electrostatic attractions throughout the lattice; H2O is a simple molecular substance and melting only overcomes weak intermolecular forces, so its melting point is much lower.

#	Question	Answer and marking notes
7	Magnesium (proton number 12) reacts with oxygen (proton number 8) to form magnesium oxide. Give the electronic arrangements of the magnesium ion and the oxide ion, and state the number of electrons transferred.	A magnesium atom (2, 8, 2) loses 2 electrons to form Mg2+ (2, 8); an oxygen atom (2, 6) gains 2 electrons to form O2- (2, 8); each magnesium atom transfers 2 electrons to one oxygen atom.
8	Graphite conducts electricity but diamond does not. Explain in terms of structure.	In graphite each carbon atom bonds covalently to three others, leaving one delocalised electron per atom that can move within the layer, so graphite conducts; in diamond each carbon atom bonds to four others with no free electrons, so it does not conduct.

Question 3 - Mole Calculations and Molar Volume of Gases (18 marks)

At room temperature and pressure the molar volume of a gas is 24.0 dm3/mol. Relative atomic masses: C = 12.0, O = 16.0, Mg = 24.3, H = 1.0. Avogadro constant = 6.02 x 10^23 /mol.

#	Question	Answer and marking notes
9	Calculate the number of moles in 4.4 g of carbon dioxide (CO2), showing working.	Molar mass = 44.0 g/mol; number of moles = 4.4 / 44.0 = 0.100 mol.
10	Find the number of molecules and the total number of atoms in the 4.4 g of carbon dioxide.	Molecules = 0.100 x 6.02 x 10^23 = 6.02 x 10^22; each molecule has 3 atoms, so total atoms = 3 x 6.02 x 10^22 = 1.806 x 10^23.
11	Find the volume occupied by the 4.4 g of carbon dioxide at room temperature and pressure.	Volume = 0.100 x 24.0 = 2.40 dm3.
12	12.0 g of magnesium reacts with excess dilute hydrochloric acid. Write the balanced equation and calculate the mass and the room-temperature volume of hydrogen formed.	Mg + 2HCl -> MgCl2 + H2; moles of Mg = 12.0 / 24.3 = 0.494 mol; moles of hydrogen = 0.494 mol; mass = 0.494 x 2.0 = 0.988 g; volume = 0.494 x 24.0 = 11.9 dm3.

Question 4 - Concentration, Dilution and Acid-Base Titration (18 marks)

5.85 g of sodium chloride (NaCl, molar mass 58.5 g/mol) is dissolved in water to make 250.0 cm3 of solution. A bottle of 0.100 mol/dm3 sodium hydroxide solution and a bottle of 0.0500 mol/dm3 sulphuric acid are also provided.

#	Question	Answer and marking notes
13	Calculate the concentration of the sodium chloride solution in mol/dm3, showing working.	Moles = 5.85 / 58.5 = 0.100 mol; volume = 250.0 cm3 = 0.250 dm3; concentration = 0.100 / 0.250 = 0.400 mol/dm3.
14	25.0 cm3 of this solution is diluted with water to 250.0 cm3. Find the concentration of the diluted solution.	Moles are unchanged on dilution: 0.400 x 0.0250 = c x 0.250, so c = 0.0400 mol/dm3 (a tenfold dilution gives one tenth of the concentration).

#	Question	Answer and marking notes
15	25.0 cm3 of 0.100 mol/dm3 sodium hydroxide is titrated with 0.0500 mol/dm3 sulphuric acid until complete neutralisation. Write the balanced equation and calculate the volume of acid required in cm3.	2NaOH + H2SO4 -> Na2SO4 + 2H2O; moles of NaOH = 0.100 x 0.0250 = 0.00250 mol; moles of acid = 0.00250 / 2 = 0.00125 mol; volume = 0.00125 / 0.0500 = 0.0250 dm3 = 25.0 cm3.
16	Explain why a titration is repeated three times and the average volume used, and why the burette is rinsed with the titrant first.	Repeating reduces random error and the mean volume is more reliable; rinsing with the titrant removes residual water that would dilute the titrant and change its concentration, making the result too high or too low.

Question 5 - Combustion and Enthalpy Change (16 marks)

Propane (C3H8, molar mass 44.0 g/mol) is a fuel that burns completely. In an experiment 0.500 mol of propane burns completely and releases 1 110 kJ of energy.

#	Question	Answer and marking notes
17	Write the balanced equation for the complete combustion of propane.	C3H8 + 5O2 -> 3CO2 + 4H2O.
18	When 22.0 g of propane burns completely, calculate the mass of oxygen needed and the mass of carbon dioxide formed.	Moles of propane = 22.0 / 44.0 = 0.500 mol; moles of oxygen = 5 x 0.500 = 2.50 mol; mass of oxygen = 2.50 x 32.0 = 80.0 g; moles of carbon dioxide = 3 x 0.500 = 1.50 mol; mass = 1.50 x 44.0 = 66.0 g.
19	Find the enthalpy change of combustion of propane in kJ/mol, giving the sign.	Energy released per mole = 1 110 / 0.500 = 2 220 kJ; combustion is exothermic, so the enthalpy change of combustion is -2 220 kJ/mol.
20	Explain why the heat measured in an experiment is usually less than the theoretical value (give two reasons).	Some energy is lost to the surroundings; combustion may be incomplete, forming carbon monoxide and soot and releasing less energy.

Question 6 - Strong Acids, Strong Bases and pH (16 marks)

A 0.0100 mol/dm3 hydrochloric acid solution and a 0.0100 mol/dm3 sodium hydroxide solution are provided. Both are strong electrolytes and are fully ionised at 25 °C.

#	Question	Answer and marking notes
21	Calculate the pH of the 0.0100 mol/dm3 hydrochloric acid solution.	Hydrochloric acid is fully ionised, so [H+] = 0.0100 mol/dm3 and pH = -log(0.0100) = 2.00.
22	Calculate the pH of the 0.0100 mol/dm3 sodium hydroxide solution.	Sodium hydroxide is fully ionised, so [OH-] = 0.0100 mol/dm3 and pOH = 2.00; pH = 14.00 - 2.00 = 12.00.
23	Each solution is diluted ten times. Find the pH of each diluted solution.	After dilution [H+] = 0.00100 mol/dm3 and pH = 3.00 for the acid; [OH-] = 0.00100 mol/dm3 and pH = 11.00 for the alkali.

#	Question	Answer and marking notes
24	Explain why continuous dilution of a strong acid makes the pH approach 7 but never exceed 7.	Dilution lowers [H+] so the pH rises; however water itself ionises to give about 1 x 10^-7 mol/dm3 of H+, so even after infinite dilution the solution still has slightly more H+ than pure water and the pH approaches 7 without exceeding it.