S4 Combined Science Practice Paper (Set 2): Measurement and Errors, Density, Specific and Latent Heat, Waves and Lenses, Refraction and Critical Angle, Atomic Structure and Bonding, Mole and Gas Volume, Titration, Energy and Efficiency (100 marks)

S4 | Combined Science | Time: 75 minutes | Total: 100 marks | 24 questions

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Part 1: Measurement and Errors (16 marks)

Give answers to 3 significant figures unless stated.

1. Write 0.00456 m in standard form and convert it to micrometres (um). [4]

Answer: 0.00456 m = 4.56 x 10^-3 m. Since 1 m = 10^6 um, 4.56 x 10^-3 m = 4560 um.

2. A ruler with a smallest division of 1 mm gives the length of a rod as 12.4 cm. Find the percentage error (2 significant figures). [4]

Answer: Maximum absolute error is half a division = 0.05 cm; percentage error = 0.05 / 12.4 x 100% = 0.40%.

3. A metal block has mass 84.6 g and dimensions 3.0 cm x 2.5 cm x 2.0 cm. Find its volume and density. [4]

Answer: Volume = 3.0 x 2.5 x 2.0 = 15.0 cm3; density = 84.6 / 15.0 = 5.64 g/cm3.

4. Evaluate (2.34 + 1.2) / 0.50 and state how many significant figures the result should carry. [4]

Answer: Addition keeps the fewest decimal places (1 d.p.): 2.34 + 1.2 = 3.5; division keeps the fewest significant figures (0.50 has 2): 3.5 / 0.50 = 7.1, i.e. 2 significant figures.

Part 2: Thermal Physics (17 marks)

Take the specific heat capacity of water as 4200 J kg^-1 K^-1.

5. Heat 0.50 kg of water from 22 C to 78 C. Find the energy required. [4]

Answer: E = mc(dT) = 0.50 x 4200 x 56 = 117600 J, about 1.18 x 10^5 J.

6. An electric heater of 1500 W has an efficiency of 80%% (only 80%% of the electrical energy heats the water). It heats 1.5 kg of water from 20 C to 100 C. Find the time needed in seconds and minutes. [5]

Answer: Energy needed = 1.5 x 4200 x 80 = 504000 J; useful power = 1500 x 0.8 = 1200 W; time = 504000 / 1200 = 420 s = 7.0 minutes.

7. Melt 0.20 kg of ice at 0 C completely into water at 0 C. The specific latent heat of fusion is 3.34 x 10^5 J kg^-1. Find the energy required. [4]

Answer: E = ml = 0.20 x 3.34 x 10^5 = 66800 J, about 6.7 x 10^4 J; the temperature stays at 0 C during melting.

8. Mix 0.30 kg of water at 80 C with 0.20 kg of water at 20 C. Assuming no heat loss, find the final temperature. [4]

Answer: Let the final temperature be T: 0.30 x 4200 x (80 - T) = 0.20 x 4200 x (T - 20), i.e. 24 - 0.30T = 0.20T - 4, so T = 56.0 C.

Part 3: Waves and Light (17 marks)

Give angles to 0.1 degree.

9. Sound travels at 340 m/s in air with a frequency of 170 Hz. Find the wavelength. [4]

Answer: v = f(lambda), so lambda = 340 / 170 = 2.0 m.

10. A convex lens has focal length 10 cm and an object is placed 15 cm in front of it. Find the image distance and magnification, and describe the image. [5]

Answer: 1/f = 1/u + 1/v: 1/10 = 1/15 + 1/v, giving v = 30 cm (real image on the far side); m = -v/u = -30/15 = 2.0, i.e. inverted and magnified 2 times.

11. Light enters glass of refractive index 1.5 from air at an angle of incidence of 30 degrees. Find the angle of refraction. [4]

Answer: n = sin i / sin r: sin r = sin 30 / 1.5 = 0.5000 / 1.5 = 0.3333, so r = 19.5 degrees (the ray bends towards the normal).

12. Find the critical angle of that glass and state the two conditions for total internal reflection. [4]

Answer: sin C = 1/n = 1 / 1.5 = 0.6667, so C = 41.8 degrees; conditions: the light travels from a denser to a less dense medium and the angle of incidence exceeds the critical angle.

Part 4: Atomic Structure and Bonding (16 marks)

Use integer relative atomic masses.

13. Chlorine has two isotopes, Cl-35 and Cl-37, with abundances of 75% and 25% respectively. Find the relative atomic mass of chlorine and the number of neutrons in Cl-35. [4]

Answer: Relative atomic mass = 0.75 x 35 + 0.25 x 37 = 35.5; Cl-35 has 35 - 17 = 18 neutrons.

14. Magnesium (atomic number 12) reacts with oxygen (atomic number 8) to form magnesium oxide. Write the electronic configurations of Mg2+ and O2- and explain why each is stable. [4]

Answer: A magnesium atom (2,8,2) loses 2 electrons, so Mg2+ is 2,8 (same as neon); an oxygen atom (2,6) gains 2 electrons, so O2- is 2,8 (same as neon). Both reach an octet.

15. Sodium chloride melts at 801 C but iodine (I2) melts at only 114 C. Explain the difference in terms of structure and bonding. [4]

Answer: NaCl is ionic: a giant ionic lattice held by strong electrostatic attraction between ions, so melting requires much energy. I2 is molecular: strong covalent bonds within molecules but only weak van der Waals forces between molecules, so it melts easily.

16. 50.0 cm3 of 0.10 M AgNO3 is mixed with 100.0 cm3 of 0.10 M NaCl and AgCl precipitates. Write the net ionic equation and find the mass of precipitate (molar mass of AgCl = 143.3 g/mol). [4]

Answer: Net ionic equation: Ag+(aq) + Cl-(aq) -> AgCl(s). Moles: Ag+ = 0.050 x 0.10 = 0.005 mol, Cl- = 0.100 x 0.10 = 0.010 mol; Ag+ is limiting, so precipitate = 0.005 x 143.3 = 0.717 g.

Part 5: Mole and Solutions (17 marks)

Take the Avogadro constant as 6.02 x 10^23 mol^-1 and the molar volume at room conditions as 24 dm3/mol.

17. Find the number of moles and the number of molecules in 8.8 g of carbon dioxide (molar mass 44 g/mol). [4]

Answer: Moles = 8.8 / 44 = 0.20 mol; number of molecules = 0.20 x 6.02 x 10^23 = 1.20 x 10^23.

18. What volume does 4.4 g of carbon dioxide occupy at room conditions? [5]

Answer: Moles = 4.4 / 44 = 0.10 mol; volume = 0.10 x 24 = 2.4 dm3 (2400 cm3).

19. A 2.0 M stock solution is available. To prepare 250 cm3 of 0.20 M solution, what volume of stock is needed? [4]

Answer: Moles are unchanged on dilution: C1V1 = C2V2, 2.0 x V1 = 0.20 x 250, so V1 = 25 cm3, then make up to 250 cm3 with water.

20. 25.0 cm3 of sodium hydroxide solution needs 20.0 cm3 of 0.100 M hydrochloric acid to reach the end point (1:1 mole ratio). Find the concentration of the sodium hydroxide. [4]

Answer: Moles of HCl = 0.100 x 20.0 = 2.0 mmol; moles of NaOH are the same; concentration = 2.0 / 25.0 = 0.0800 M.

Part 6: Energy and Efficiency (17 marks)

Take g = 10 m/s2.

21. A crane lifts a 20 kg load through 5 m at constant speed in 10 s. Find the work done and the average power. [4]

Answer: W = mgh = 20 x 10 x 5 = 1000 J; P = W / t = 1000 / 10 = 100 W.

22. A lamp takes 60 W of input power, of which 9 W becomes light. Find its efficiency. If it is used 5 hours a day at $1.2 per kWh, find the cost for 30 days. [5]

Answer: Efficiency = 9 / 60 x 100% = 15%; daily energy = 0.060 x 5 = 0.30 kWh, 30 days = 9.0 kWh, cost = 9.0 x 1.2 = $10.8.

23. Burning 0.50 kg of coal (energy value 3.0 x 10^7 J/kg) heats 20 kg of water with an efficiency of 40%. Find the temperature rise of the water. [4]

Answer: Energy released = 0.50 x 3.0 x 10^7 = 1.5 x 10^7 J; useful energy = 1.5 x 10^7 x 0.4 = 6.0 x 10^6 J; dT = 6.0 x 10^6 / (20 x 4200) = 71.4 C.

24. A hydroelectric plant takes 200 kg of water per second falling 10 m, with an efficiency of 60%. Find the output power. [4]

Answer: Potential energy available per second = mgh = 200 x 10 x 10 = 20000 J; output power = 20000 x 0.6 = 12000 W = 12 kW.
