End-of-topic questions

Topic review

1. Using your knowledge from the *Structure 1.1* topic, answer the guiding question as fully as possible:

   How can we model the particulate nature of matter?

Exam-style questions

Multiple-choice questions

2. Which of the following are examples of homogeneous mixtures?

   I. Air
   II. Steel
   III. Aqueous potassium manganate(VII), $KMnO_4(aq)$.

   A. II only
   B. III only
   C. I and II only
   D. I, II and III

3. What correctly describes the sublimation of dry ice (carbon dioxide)?

	Exothermic or endothermic?	Equation describing the process
A	exothermic	$CO_2(s) \rightarrow CO_2(g)$
B	exothermic	$CO_2(s) \rightarrow C(g) + O_2(g)$
C	endothermic	$CO_2(s) \rightarrow CO_2(g)$
D	endothermic	$CO_2(s) \rightarrow C(g) + O_2(g)$

4. Which of the following methods could be used to obtain solid sodium chloride from a solution of sodium chloride in water?

   I. evaporation
   II. filtration
   III. distillation

   A. I only
   B. I and II only
   C. I and III only
   D. I, II and III

5. Which changes of state are opposite to each other?
   A. melting and condensation
   B. vaporization and deposition
   C. deposition and sublimation
   D. sublimation and freezing

6. Which of the following statements is incorrect?
   A. solids and liquids are almost incompressible
   B. particles in both solids and liquids are mobile
   C. liquids and gases have no fixed shape
   D. particles in solids, liquids and gases can vibrate

7. Which elements can be separated from each other by physical methods?
   A. oxygen and nitrogen in air
   B. hydrogen and oxygen in water
   C. carbon and oxygen in dry ice
   D. magnesium and sulfur in magnesium sulfide

8. Which change in temperature on the Celsius scale is equivalent to the increase in temperature by 20 K?
   A. decrease by 20 °C
   B. increase by 20 °C
   C. decrease by 293.15 °C
   D. increase by 293.15 °C

Extended-response questions

9. Explain why the Kelvin temperature is directly proportional to average kinetic energy but the Celsius temperature is not, even though a 1-degree temperature increment is the same in each scale? [2]

10. Ionic salts can be broken down in electrolysis. The unbalanced ionic equation for the electrolysis of molten lead(II) bromide is:

    $Pb^{2+} + Br^- \rightarrow Pb + X$

    a. One of the products is lead, Pb. State the formula of product X. [1]
    b. Balance the equation. [1]
    c. The electrolysis of molten lead(II) bromide is carried out at 380 °C. With reference to melting point and boiling point data, deduce the state of matter of each of the species in the equation at this temperature. Write state symbols in the balanced equation you gave in (b). [2]

11. The kinetic energy of particles is equal to half of their mass × the square of the velocity of the particles: $E_k = \frac{1}{2}mv^2$. Determine how much the speed of molecules in a pure gaseous substance will increase when the Kelvin temperature is doubled. [2]

12. Pure caffeine is a white powder with melting point 235 °C.

    a. State the melting point of caffeine in kelvin. [1]

    b. A chemist is investigating the efficacy of three caffeine extraction methods. The theoretical yield in all three cases is 0.960 g. She uses each method once and collects the following data for the yield and melting point of the product:

	Method 1	Method 2	Method 3
Mass of caffeine obtained / g	0.229	0.094	0.380
Melting point of caffeine product / °C	190–220	229–233	188–201

    i. Calculate the mean and range of the mass of caffeine obtained. [2]

    ii. Calculate the percentage yield of Method 1. Give your answer to an appropriate number of significant figures. [2]

    iii. Determine, giving a reason, which method gave the purest caffeine product. [1]

    c. Suggest one way to minimize the random error in this experiment. [1]

13. A student prepares a copper(II) sulfate solution by reacting dilute sulfuric acid with excess copper(II) oxide. Copper(II) oxide is insoluble in water.

    The word equation for this reaction is as follows:

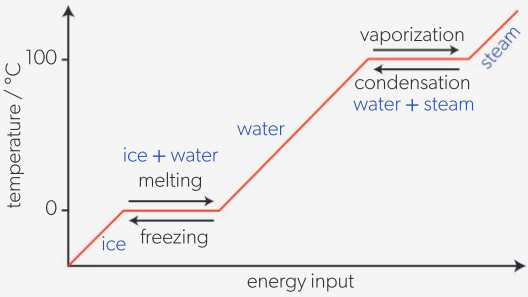
    sulfuric acid + copper(II) oxide → copper(II) sulfate + water

    a. Write a balanced chemical equation, including state symbols, for this reaction. [2]

    b. The acid was heated, then copper(II) oxide powder was added until it was in excess and could be observed suspended in the solution, quickly sinking to the bottom of the beaker. Suggest, giving a reason, a method the student could use to remove the excess copper(II) oxide. [2]

    c. Once the excess copper(II) oxide had been removed, the student needed to figure out how to obtain pure crystals of copper(II) sulfate from the solution. Describe a method the student could follow to obtain pure, dry copper(II) sulfate crystals. [3]

14. Study the figure below.



    a. Explain why, in spite of the increasing energy input, the temperature of the sample remains constant at 0 °C for a period of time. [2]

    A solution of 5.00 g of sodium chloride in 100.0 g of pure water (at standard atmospheric temperature and pressure) has the following properties:

    - melting point: –3 °C
    - boiling point: 101 °C

    b. Sketch a graph similar to the one in figure 16 to show the heating curve for a sample of this sodium chloride solution. [2]

15. Elemental iodine exists as diatomic molecules, I_2. At room temperature and pressure, it is a lustrous purple-black solid that readily forms violet fumes when heated gently. When cooled, gaseous iodine deposits on cold surfaces without condensing. Under increased pressure, solid iodine melts at 114 °C to form a deep-violet liquid.

    a. Formulate equations that represent all changes of state mentioned above. [3]

    b. State the melting point of iodine in kelvin. [1]

    c. Suggest how liquid iodine can be obtained from gaseous iodine. [1]

End-of-topic questions

Topic review

1. Using your knowledge from the *Structure 1.2* topic, answer the guiding question as fully as possible:

   How do nuclei of atoms differ?

Exam-style questions

Multiple-choice questions

2. What is correct for $^{63}_{29}Cu^{2+}$?

	Protons	Neutrons	Electrons
A	29	34	27
B	29	34	31
C	34	63	31
D	34	29	27

3. Which values are the same for both $^{1}H_2$ and $^{2}H_2$?

   I. boiling point
   II. ΔH of combustion
   III. number of protons
   IV. density

   A. I and III only
   B. I and IV only
   C. II and III only
   D. I, II and III

4. The naturally occurring isotopes of lithium are ^{6}Li and ^{7}Li. Which shows the correct approximate percentage abundances for lithium?

	Percentage abundance of ^{6}Li	Percentage abundance of ^{7}Li
A	75	25
B	50	50
C	35	65
D	10	90

5. Which of the following statements are correct?

   I. Nearly all mass of the atom is contained within its nucleus.
   II. The mass number shows the number of protons in an atomic nucleus
   III. Isotopes of the same element have equal numbers of protons.

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

6. Which of the following species contain equal numbers of neutrons in their nuclei?

   A. cobalt-58 and nickel-58
   B. cobalt-58 and nickel-59
   C. cobalt-59 and nickel-58
   D. cobalt-58 and cobalt-59

Extended-response questions

7. The gold foil experiment involved firing alpha particles at gold foil. This experiment is depicted in figure 1 on page 20.

   a. An alpha particle is a helium nucleus. State the nuclear symbol for an alpha particle. [1]

   b. Suggest the results of the gold foil experiment that would have been observed in each of the following alternative scenarios:

      i. Atoms are instead hard, dense, solid balls of positive charge. [1]

      ii. Atomic nuclei are instead negatively charged. [1]

AHL

8. There are two stable isotopes of potassium: ^{39}K and ^{41}K. The A_r of potassium is 39.10. Use this information to determine the relative abundances of the two isotopes and sketch the mass spectrum of potassium metal. [3]

9. "Dutch metal" is an alloy composed of 86% copper and 14% zinc. This alloy closely resembles gold, so it is often used for making costume jewellery. Explain how Dutch metal can be distinguished from gold using mass spectrometry. [2]

End-of-topic questions

Topic review

1. Using your knowledge from the *Structure 1.3* topic, answer the guiding question as fully as possible:

   How can we model the energy states of electrons in atoms?

Exam-style questions

Multiple-choice questions

2. Which row is correct for the following regions of the electromagnetic spectrum?

	Ultraviolet (UV)		Infrared (IR)	
A.	high energy	short wavelength	low energy	low frequency
B.	high energy	low frequency	low energy	long wavelength
C.	high frequency	short wavelength	high energy	long wavelength
D.	high frequency	long wavelength	low frequency	low energy

3. Which of the following sources of light will produce a line spectrum when placed behind a prism?

   I. a gas discharge tube
   II. an incandescent lamp
   III. an alkali metal salt placed in a Bunsen burner flame

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

4. An electron transition between energy levels $n = 4$ and $n = 2$ in an isolated atom produces a line in the visible spectrum. Which electron transition in the same atom is likely to produce a line in the UV spectrum?

   A. from $n = 4$ to $n = 1$
   B. from $n = 4$ to $n = 3$
   C. from $n = 3$ to $n = 2$
   D. from $n = 5$ to $n = 3$

5. What is the maximum possible number of electrons in the third energy level?

   A. 3
   B. 6
   C. 9
   D. 18

6. What is the electron configuration of chromium ($Z = 24$) in the ground state?

   A. [Ar] $3d^7$
   B. [Ar] $4s^2\ 3d^4$
   C. [Ar] $4s^1\ 3d^5$
   D. [Ar] $4s^1\ 4p^5$

AHL

7. Which of the following is correct?

   A. $IE_3 > IE_4$
   B. Molar ionization energies are measured in kJ.
   C. The third ionization energy of the atom X represents the process:

      $$X^{2+}(g) \rightarrow X^{3+}(g) + e^-$$

   D. Ionization energies decrease across a period going from left to right.

8. Which statement about the first ionization energies of nitrogen and oxygen atoms is correct?

   A. $IE_1(N) < IE_1(O)$ because oxygen has two paired electrons in its partly filled sublevel
   B. $IE_1(N) > IE_1(O)$ because oxygen has two paired electrons in its partly filled sublevel
   C. $IE_1(N) < IE_1(O)$ because oxygen loses an electron from a higher sublevel than nitrogen
   D. $IE_1(N) > IE_1(O)$ because oxygen loses an electron from a higher sublevel than nitrogen

9. The first five successive ionization energies for an unknown element are 578, 1817, 2745, 11 577 and 14 842 kJ mol^{-1}. In which group of the periodic table is this element is likely to be found?

   A. 1
   B. 2
   C. 13
   D. 14

Extended-response questions

10. Explain, in your own words, why gaseous atoms produce line spectra instead of continuous spectra. [3]

11. State the full and condensed electron configurations for the following species in their ground states:
    a. titanium atom [1]
    b. selenium atom [1]
    c. silicon atom [1]
    d. Ti^{3+} cation [1]
    e. S^{2-} anion [1]

12. Determine which of the configurations below is impossible. Explain why it cannot exist. [2]
    $1s^2\,2s^2\,2p^7\,3s^2\,3p^5$
    $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$

13. Deduce and explain, which of the following electron configurations represents a ground state. [2]
    $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^{10}\,4p^5\,5s^1$
    $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^{10}\,4p^6\,5s^1$

14. Sketch the shape of an s orbital. [1]

15. The diagram below (not to scale) represents some of the electron energy levels in the hydrogen atom.

    $n = 7$
    $n = 6$
    $n = 5$
    $n = 4$
    $n = 3$
    $n = 2$
    $n = 1$

    Draw an arrow on the diagram to represent the lowest energy transition in the visible region of the emission spectrum of hydrogen. [1]

16. Sketch an orbital filling diagram for Al and deduce the number of unpaired electrons. [2]

17. A transition element ion, X^{3+}, has the electron configuration [Ar] $3d^5$. Determine the atomic number of element X. [1]

18. Sketch the condensed orbital filling diagram for germanium and deduce the total number of p orbitals containing one or more electrons. [2]

AHL

19. Describe, in your own words, how the first ionization energy of an atom can be determined from its emission spectrum. [2]

20. Using the data booklet, explore the first ionization energies of the period 3 elements, from sodium to argon. Explain the general trend and discontinuities in these energies. [3]

21. The first four successive ionization energies for an unknown element X are given in table 3. Deduce the group of the periodic table in which element X is likely to be found. [1]

n	IE_n / kJ mol^{-1}
1	738
2	1451
3	7733
4	10543

▲ Table 3 Successive ionization energies for element X

End-of-topic questions

Topic review

1. Using your knowledge from the *Structure 1.4* topic, answer the guiding question as fully as possible:

   How do we quantify matter on the atomic scale?

Exam-style questions

Multiple-choice questions

2. What is the number of oxygen atoms in 0.400 mol of copper(II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$?

   A. 3.60 C. 2.16×10^{24}

   B. 9 D. 5.40×10^{24}

3. A sample containing 0.70 g of calcium nitrate, $Ca(NO_3)_2$, is dissolved in water to a volume of 200 cm^3. What is the concentration of NO_3^- ions in this solution?

   A. 3.5 g dm^{-3} C. 0.021 mol dm^{-3}

   B. 7.0 g dm^{-3} D. 0.043 mol dm^{-3}

4. For which molecule is the empirical formula the same as the molecular formula?

   A. $CH_3CH_2CH_2OH$ C. $CH_3CH_2CH_2CH_3$

   B. $CH_3COOCH_2CH_3$ D. CH_3COOH

5. Which volume of a 5.0 mol dm^{-3} sulfuric acid (H_2SO_4) stock solution is required to prepare 0.50 dm^3 of a solution whose concentration of hydrogen ions is 0.10 mol dm^{-3}?

   A. 0.010 cm^3 C. 5.0 cm^3

   B. 0.0050 cm^3 D. 10 cm^3

6. A student obtained the following data during an experimental determination of the empirical formula of an oxide of tin:

   - Mass of tin before heating = 1.78 g
   - Mass of oxide of tin after heating to a constant mass = 2.26 g

   According to these data, what is the correct formula of the oxide of tin?

   A. SnO C. SnO_3

   B. SnO_2 D. SnO_5

Extended-response questions

7. Alums are salt hydrates of the general formula $XAl(SO_4)_2 \cdot 12H_2O$, where X is an alkali metal or other singly-charged cation. When heated, most alums decompose as follows:

   $$XAl(SO_4)_2 \cdot 12H_2O(s) \rightarrow XAl(SO_4)_2(s) + 12H_2O(l)$$

   Calculate:

   a. The molar mass of potassium alum, $KAl(SO_4)_2 \cdot 12H_2O$. [1]

   b. The amount of substance, in mol, in 1.00 g of potassium alum. [1]

   c. The total number of atoms in 1.00 g of potassium alum. [1]

   d. The amount of water, in mol, that can be produced by complete decomposition of 1.00 g of potassium alum. [1]

   e. The percentage composition, by mass, of potassium alum. [2]

8. To visualize the mole, a chemistry student decided to pile up 6.02×10^{23} grains of sand. Estimate the time needed to complete this project if an average grain of sand weighs 5 mg, and the student can shovel 50 kg of sand per minute. [3]

9. Deduce the empirical formulas for the following compounds:

   a. an oxide of sulfur that contains 59.95% of oxygen [1]

   b. an oxygen-containing organic compound, 5.00 g of which produces 9.55 g of carbon dioxide and 5.87 g of water upon complete combustion. [2]

10. A standard solution of potassium sulfate, K_2SO_4, was prepared from 8.714 g of the solid salt using a 250 cm^3 volumetric flask. Calculate the mass concentration, in g dm^{-3}, and the molar concentration, in mol dm^{-3}, of potassium sulfate in the final solution. [2]

11. The calibration curve in figure 7 was constructed using five standard solutions, in which the concentration of potassium permanganate, $KMnO_4$, varied from 0.100 to 0.500 mmol dm^{-3}. Describe how you would prepare these solutions using serial dilution. [3]

12. Carbon monoxide, CO, is a toxic gas. Its combustion produces carbon dioxide, CO_2(g).

    a. Deduce the balanced equation for the combustion of carbon monoxide. [1]

    b. Calculate the volumes, in dm^3, of consumed carbon monoxide and oxygen if the combustion produced 2.00 dm^3 of carbon dioxide. All volumes are measured under the same conditions. [2]