22. If the first step of this reaction is rate-determining, the rate equation is Rate = $k[NO_2][NO_2]$ or Rate = $k[NO_2]^2$. If the second step is the rate-determining, the rate equation for that elementary step is Rate = $k[CO][NO_3]$ and the first step must be a fast equilibrium, $K = [NO_3][NO]/[NO]^2$. The intermediate NO_3 in the second step can be replaced by solving the equilibrium expression to give $[NO_3] = K[NO_2]^2/[NO]$. Thus, the overall rate equation is Rate = $kK[CO][NO_2]^2/NO$. NO_2 appears in the rate equation regardless of which step is rate-determining.

    The correct answer is (B).

    [LO 4.7 SP 6.5]

23. The potential energy at the boiling point is converted to work energy in overcoming attractive forces between molecules, so that they may escape in the gas phase (V). This is a larger amount of energy than solid molecules need to overcome attractions to enter the liquid phase where molecules are still in some contact with one another.

    The correct answer is (C).

    [LO 5.6 SP 2.2, 2.3]

24. Kinetic energy is directly related to the temperature of a system. The change in temperature from 0°C to 100°C is larger than that from −50°C to 0°C or that from 100°C to 110°C.

    The correct answer is (B).

    [LO 5.6 SP 2.2, 2.3]

25. Entropy increases when there is an increase in disorder in a system. Such an increase in disorder occurs with an increase in temperature of a given phase and when a more organized phase is changed to a less orderly one. All five areas of the curve represent increases in entropy but Section IV (the transformation of liquid to gas) will show a greater change in ΔS than the increase in temperature of solid H_2O (section I), the conversion from solid to liquid (section II), the increase in temperature of liquid H_2O (section III) or the increase in temperature of gaseous H_2O (section V).

    The correct answer is (C).

    [LO 5.6 SP 2.2, 2.3]

26. The following calculation would give a heat of solution of +35.1 kJ:
$-(100 \times -8.4^{\circ}C \times 4.18\ J/g^{\circ}C) = 3510$ J per 10.1 g of KNO_3 dissolved. When converted to kJ per mole, that would equal +35.1 kJ/mol. The enthalpy change is included on the reactant side of the equation to show the endothermic nature of the reaction.

The correct answer is (A).

[LO 5.7 SP 4.2, 5.1]

27. The heat involved is directly related to the amount of reactant, thus both ΔT and J per reaction will be larger. The other table entries are ratios of heat/amount that will stay the same for the same reason.

The correct answer is (C).

[LO 5.7 SP 4.2, 5.1]

28. The [HA] and $[A^-]$ will be equal to one another when one half of the acid has been neutralized. This occurs halfway between the beginning of the titration and the steeply rising portion of the curve, which signals the neutralization point. Point II represents the point where $[HA] = [A^-]$.

The correct answer is (B).

[LO 6.3 SP 5.1]

29. The point with the highest electrical conductivity is the point where all of the acid has been converted from the molecular HA form to A^- ions and there is an excess of Na^+ and OH^- ions. This occurs at point IV.

The correct answer is (D).

[LO 6.3 SP 5.1]

30. The equivalence point is the point where the number of moles of NaOH added is equal (i.e. equivalent to) the number of moles of HA originally present. This corresponds to the mid-point of the portion of the curve where the pH changes most rapidly (point III).

The correct answer is (C).

[LO 6.3 SP 5.1]

31. The two gases are at the same temperature so their kinetic energies are equal. Thus (A) is correct. The masses of the two gas samples are the same but the volume of the O_2 sample is one half that of the SO_2 sample. The density of O_2 is double that of the SO_2. Statement (B) is correct. The molecular velocities of two gases at the same temperature are inversely related to the square roots of their molecular masses. The average molecular velocity of O_2 is greater than that of SO_2. (D) is correct. The equation PV = nRT would show that the pressure of O_2 is 4 × the pressure of the SO_2 sample, not twice as great as stated in (C).

The correct answer is (C).

[LO 2.6 SP 2.2, 2.3]

32. The PES diagram shows a single electron at about 1, six at an energy of ~3, two at energy of ~7 and two at an energy above 100. This would correspond to an electron configuration of $1s^2\ 2s^2\ 2p^6\ 3s^1$. There is one valence electron.

The correct answer is (A).

[LO 1.6 SP 5.1]

33. The number of moles of Na_2CO_3 can be calculated from 0.212 g/106 g mol^{-1} = 0.00200 mol. According to the equation given, two moles of HCl are required for every mole of Na_2CO_3 so 0.004 moles of HCl are needed. The molarity of the HCl = 0.00400 mol/0.025 L. The molarity is 0.16 *M*.

The correct answer is (A).

[LO 3.4 SP 2.2]

34. A linear plot of [ ] vs time is not first order and a linear plot of 1/[ ] vs time is not zero order so choice (A) is not correct. A linear plot of ln [ ] vs time is first order and a linear plot of 1/[ ] vs time is second order so choice (B) is correct. A linear plot of [ ] vs time is not indicative of a second order reaction although a linear plot of ln[ ] vs time is found for a first order reaction. Choice (C) is not correct. In choice (D), a linear plot of [ ] vs time is obtained for a zero order reaction but a first order reaction does not show a linear plot when 1/[ ] is plotted vs time. Choice (D) is not correct.

The correct answer is (B).

[LO 4.2 SP 5.1]

44. The reaction involves the transfer of an O atom from NO_2 to CO so that a successful collision should have a molecular orientation that makes this likely. Option (A), in which one of the Os of NO_2 is in contact with the C of CO, would promote that transfer. In alternative (B) an O in NO_2 is in contact with the O in CO, which would not facilitate the formation of a bond. Choices (C) and (D) involve contact between the N of NO_2 and either the C or the O of CO, which would not promote the desired O transfer.

    The correct answer is (A).

    [LO 4.4 SP 7.1]

45. At any temperature, the molecules in a collection are described as having a range of kinetic energies in keeping with the Maxwell Boltzman energy distribution but have an average kinetic energy, choice (B), rather than having a single energy, as stated in option (A). Selections (C) and (D) are incorrect statements, because the average kinetic energy change is proportional to the change in Kelvin temperature, and at 0 Kelvin, the average kinetic energy of the water molecules would fall to zero.

    The correct answer is (B).

    [LO 5.2 SP 1.1, 1.4, 7.1]

46. The ionization constants given indicate that ascorbic acid, $H_2C_6H_6O_6$, ionizes only slightly. The most abundant species will be the un-ionized acid, choice (A). The concentration of $HC_6H_6O_6^-$, option (B), will be about 1/100 of the acid, with the $[H^+]$, alternative (C), being slightly greater than $[HC_6H_6O_6^-]$, due to further ionization to form $C_6H_6O_6^{2-}$, selection (D), which will have the lowest concentration.

    The correct answer is (A).

    [LO 6.17 SP 6.4]

47. Hydrogen bonds are formed between an H atom attached to a highly electronegative atom (F, O or N) in one molecule and a lone pair of electrons on an electronegative atom in a nearby molecule. The H atoms in ethane, option (A), dimethyl ether, choice (C), and methyl fluoride, selection (D), are all attached to C atoms. Only ethanol, alternative (B), has a H atom attached to another atom (O) that would polarize the H and make it suitable for H bonding with an O on another molecule of ethanol.

    The correct answer is (B).

    [LO 2.13 SP 1.4]

48. The best sacrificial anode would be the element with the most positive oxidation potential, which would be found by changing the sign of the reduction potential. When this is done the oxidation potentials for the four metals are +2.36 V (Mg), +0.12 V (Pb), −0.34 V (Cu) and −0.80 V (Ag). Mg(*s*) is the most reactive metal and would thus be more likely to give up electrons than any of the other metals.

    The correct answer is (D).

    [LO 3.12 SP 2.2, 2.3, 6.4]

49. The equation for the reaction in question can be obtained by adding the equation for reaction 1 to the reverse of the equation for reaction 2. $K = [N_2O_4]/[NO]^2[O_2]$ for the overall reaction. This can be obtained by multiplying K_1 by $1/K_2$, option (C).

    The correct choice is (C).

    [LO6.2 SP 2.2]

50. SiO_2, alternative (A), is a network solid that would not conduct electricity when it is melted. Ice, choice (B), and wax, selection (C), are molecular solids that would not conduct electricity when melted. Molten NaCl would consist of mobile anions and cations that would conduct electricity.

    The correct answer is (D).

    [LO 2.24 SP 1.1, 6.2, 7.1]

51. Points I, alternative (A), and III, choice (C), represent activated complexes and point IV, selection (D), represents the final product. Point II, choice (B), represents the reaction intermediate O(*g*) that is produced in the first reaction and consumed in the second.

    The correct answer is (B).

    [LO 4.7 SP 6.5]

52. If the two isotopes were equally abundant in a 1/1 ratio, alternative (A), the average atomic mass would be 36. If the ratio were 2/1, as in option (B), the average atomic mass would be 107/3 or 35.67. For a ratio of 3/1, selection (C), the average atomic mass would be $[3(35) + 37]/4$ or 35.5. For a ratio of 4/1, choice (D), the average atomic mass would be found from $[4(35) + 37]/5$ or $177/5 = 35.4$.

    The correct answer is (C).

    [LO 1.14 SP 1.4]

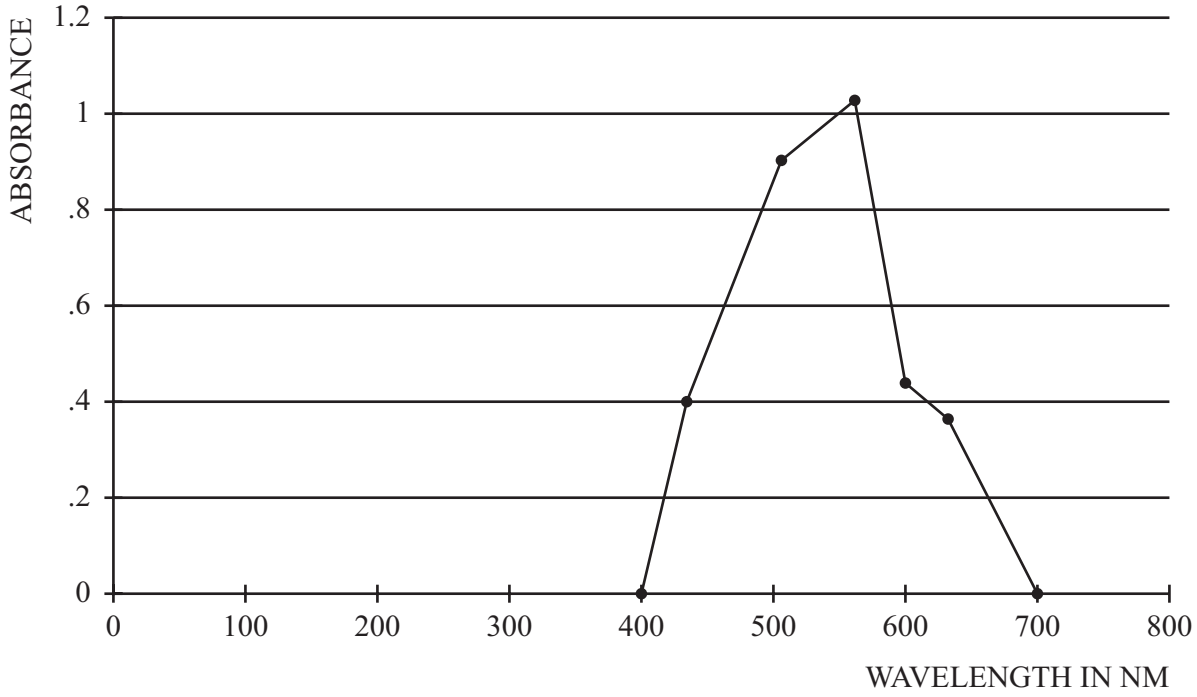
CONSTRUCTED-RESPONSE SOLUTIONS

Question 1 (Big Idea 1 spectroscopy)

1. (a) $\nu = c/\lambda = (2.998 \times 10^8 \text{ m/s}) / (650 \times 10^{-9} \text{m}) = 4.62 \times 10^{14}/\text{s}$

   (b) $E = hc/\lambda = (6.626 \times 10^{-34} \text{J s})(2.998 \times 10^8 \text{m/s}) / (650 \times 10^{-9} \text{m}) = 3.06 \times 10^{-19} \text{J}$

2. (a) Sketch of absorbance curve:



   (b) The permanganate anion absorbs in the yellow but reflects everything else. The apparent color (purple) is a combination of those reflected wavelengths.

3. (a) $2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g)$

   (b) The function of the concentration that would give a straight line would be ln $[N_2O_5]$ vs t. The slope of that line is equal to $-k$, the rate constant.

   (c) Use the Arrhenius equation: $\ln(k_2/k_1) = (E_a/R)(1/T_1 - 1/T_2)$. In order to avoid unit errors, be sure that all temperatures used are expressed in absolute temperature (Kelvins) and that all energy values are expressed in kJ.