1991

a) three points

$MgCl_2$ is ionic and $SiCl_4$ is covalent. The elctrostatic, interionic forces in $MgCl_2$ are much stronger than the intermolecular (dispersion) forces in $SiCl_4$ and lead to a higher melting point. Molten $MgCl_2$ contains mobile ions that conduct electricity whereas molten $SiCl_4$ is molecular, not ionic, and has no conductivity.

b) two points

MgF_2 has a higher melting point than $MgCl_2$ because the smaller F^- ions and smaller interionic distances in MgF_2 cause stronger forces and higher melting point.

c) one point

The bond length in Br_2 is larger than in F_2 because the Br atom is larger than the F atom.

d) two points

The bond length in N_2 is less than in F_2 because the N-N bond is triple and the F-F is single. Triple bonds are stonger and therefore shorter than single bonds.

1992

— CHEMISTRY —

Explain each of the following in terms of atomic and molecular structures and/or intermolecular forces.

(a) Solid K conducts an electric current, whereas solid KNO_3 does not.

(b) $SbCl_3$ has a measurable dipole moment, whereas $SbCl_5$ does not.

(c) The normal boiling point of CCl_4 is 77°C, whereas that of CBr_4 is 190°C.

(d) NaI(s) is very soluble in water, whereas $I_2(s)$ has a solubility of only 0.03 gram per 100 grams of water.

(a) K conducts because of its
metallic bonding
or
'sea' of mobile e's (or 'free' e's) } (1)
KNO_3 does not conduct because it is (1)
ionically bonded and has immobile ions (or imm. e's)

(b) $SbCl_3$ has a measurable dipole moment because
it has a lone pair of e's which causes a dipole
or
its dipoles do not cancel
or
it has a trigonal pyramidal structure } (1)
or
clear diagram illustrating any of the above
$SbCl_5$ has no dipole moment because
its dipoles cancel
or
it has a trigonal bipyramidal structure } (1)
or
clear diagram illustrating either of the above

(c) CBr_4 boils at a higher T than CCl_4 because
it has stronger intermolecular forces (or v.d.W. or dispersion) (1)
These stronger forces occur because CBr_4 is larger (1)
and/or has more e's than CCl_4.

(d) NaI has greater aqueous solubility than I_2 because
NaI is ionic (or polar) whereas I_2 is non-polar (or covalent) (1)
H_2O, being polar, interacts with the ions of NaI (1)
but not with I_2. (Like diss. like accepted if
polarity of H_2O clearly indicated.)

1995

(*8 pts.*)

a) V is the triple point (or point where 3 phases coexist). (*1 pt.*)

Solid, liquid, and vapor (or 3 phases) are in <u>equilibrium</u>. (*1 pt.*)

b) Each point on the curve represents the temperature and pressure where the liquid and vapor (or 2 phases) coexist. (*1 pt.*)

At these temperatures and pressures, the two phases are in <u>equilibrium.</u> (*1 pt.*)

<u>OR</u>

The points represent the vapor pressure of the liquid as a function of temperature. (*2 pts.*)

<u>OR</u>

The points represent the boiling points of the liquid as a function of (applied) pressure. (*2 pts.*)

c) Changes: sublimation or change between two phases, or energy, or density, or entropy change (*1 pt.*)

Point *Y*: change in phase occurs specifically at *Y* (*1 pt.*)

d) The solid will sink. (*1 pt.*)

The positive slope of the solid/liquid equilibrium curve indicates that the solid is more dense than the liquid. (*1 pt.*)

<u>Notes:</u> If the phase diagram is labelled and if it is done incorrectly, 1 point is deducted from the total for parts b), c), and d).

If the response for part c) indicates that a phase change from a less condensed phase to a more condensed phase (e.g., gas to solid), an additional point is deducted.

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6. For each of the following, use appropriate chemical principles to explain the observation. Include chemical equations as appropriate.

(a) In areas affected by acid rain, statues and structures made of limestone (calcium carbonate) often show signs of considerable deterioration.

Acid rain has a low pH, which means $[H^+]$ is relatively large. The acid reacts with the calcium carbonate solid in the statue according to the following: $H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ The result is the erosion of the statue as the solid calcium carbonate reacts, forming a salt (partially soluble), a liquid, and a gas.	1 point for indicating acid rain has a high $[H^+]$ 1 point for indicating calcium carbonate solid forms gaseous carbon dioxide

(b) When table salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) are dissolved in water, it is observed that

(i) both solutions have higher boiling points than pure water, and

The higher boiling point is due to the change in vapor pressure above the solution compared to the vapor pressure above pure water. The presence of a nonvolatile solute lowers the vapor pressure above the solution and results in a higher boiling point.	1 point for indicating the lower vapor pressure above the solution

(ii) the boiling point of $0.10\ M$ NaCl(aq) is higher than that of $0.10\ M$ $C_{12}H_{22}O_{11}(aq)$.

NaCl has a higher boiling point because the change in boiling point, ΔT_{bp}, is directly dependent on the <u>number</u> of solute particles in solution. NaCl is an ionic compound which dissociates into two particles, whereas $C_{12}H_{22}O_{11}$ is a covalent compound and does not dissociate.	1 point for indicating NaCl forms two moles of particles and $C_{12}H_{22}O_{11}$ forms one mole of particles.

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(c) Methane gas does not behave as an ideal gas at low temperature and high pressures.

Two factors contribute to nonideal gas behavior: attractive forces and excluded volume. At low temperature, the molecules are moving slower and are closer together. The attractive forces between the molecules are more important relative to their kinetic energy. At high pressure, the molecules of methane are closer together and the volume occupied by the molecules is a greater percentage of the volume of the container. Since the molecules take up some volume, there is less volume available to the methane molecules.	1 point for identifying and discussing attractive forces 1 point for identifying and discussing excluded volume

(d) Water droplets form on the outside of a beaker containing an ice bath.

Water vapor in the air in contact with the lower temperature on the surface of the glass condenses because the equilibrium vapor pressure for water at the lower temperature is lower than the pressure exerted by the water in the vapor phase in the room.	1 point for indicating that the water droplets on the glass surface comes from water in the vapor phase (in the room) 1 point for indicating that condensation occurs because the equilibrium vapor pressure at the temperature on the glass surface is lower than the pressure due to water vapor in the air in the room **OR** 1 point for clearly indicating that moisture is forming from the air and that there is sufficient energy transfer (loss) to cause a change of state (condensation)

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Use appropriate chemical principles to account for each of the following observations. In each part, your response must include specific information about both substances.

(a) At 25°C and 1 atm, F_2 is a gas, whereas I_2 is a solid.

Both F_2 and I_2 are nonpolar, so the only intermolecular attractive forces are London dispersion forces. I_2 is solid because the electrons in the I_2 molecule occupy a larger volume and are more polarizable compared to the electrons in the F_2 molecule. As a result, the dispersion forces are considerably stronger in I_2 compared to F_2.	1 point for indicating that both molecules have dispersion forces as IMFs 1 point for indicating that I_2 molecules are more polarizable than F_2 molecules

(b) The melting point of NaF is 993°C, whereas the melting point of CsCl is 645°C.

Both NaF and CsCl are ionic compounds with the same charges on the cations and anions. The ionic radius of Na^+ is smaller than the ionic radius of Cs^+ and the ionic radius of F^- is smaller than the ionic radius of Cl^-. Therefore, the ionic centers are closer in NaF than in CsCl. Melting occurs when the attraction between the cation and the anion are overcome due to thermal motion. Since the lattice energy is inversely proportional to the distance between the ion centers (Coulomb's Law), the compound with the smaller ions will have the stronger attractions and the higher melting point.	1 point for indicating that NaF and CsCl are both ionic compounds (or are composed of M^+ and X^- ions) 1 point for indicating that the strength of these forces is determined by the distance between the ionic centers (or the size of the ions)

(c) The shape of the ICl_4^- ion is square planar, whereas the shape of the BF_4^- ion is tetrahedral.

The central iodine atom in ICl_4^- has four bonding pairs and two lone pairs of electrons on the central iodine atom, so the molecular geometry is square planar. BF_4^- has four bonding pairs and no lone pairs on the central boron atom, so the molecular geometry is tetrahedral.	2 points for indicating that ICl_4^- has two unshared electron pairs, but BF_4^- has no unshared pairs Note: 1 point earned if student gives incorrect numbers of unshared electron pairs but indicates that difference in number of unshared electron pairs determines difference in geometry.

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(d) Ammonia, NH_3, is very soluble in water, whereas phosphine, PH_3, is only moderately soluble in water.

Ammonia has hydrogen-bonding intermolecular forces, whereas phosphine has dipole-dipole and/or dispersion intermolecular forces. Water also has hydrogen-bonding intermolecular attractive forces. Ammonia is more soluble in water than phosphine because ammonia molecules can hydrogen-bond with water molecules, whereas phosphine molecules cannot hydrogen-bond with water molecules.	1 point for indicating that NH_3 can form hydrogen bonds but PH_3 cannot 1 point for indicating that NH_3 can form hydrogen bonds with water, but PH_3 cannot