31. (b)
32. (a)
33. (b)
34. (c)
35. (a)
36. (c)
37. (b)
38. (c)
39. (a)
40. (d)

UNIT 2 REVIEW

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Understanding Concepts

1. When most alpha particles pass through the thin foil essentially unaffected, it indicates that somehow they are meeting negligible resistance; so most of the structure of the atoms they are hitting seems to be essentially empty space. When a very few alpha particles are very significantly deflected, it indicates that a tiny part of the structure of the target atoms must be relatively massive and positively charged.
2. (a) The electron was discovered as a result of the qualitative studies of cathode rays by Crookes and, in particular, by the quantitative studies of cathode rays by Thomson.
   (b) The proton was discovered as a result of the alpha particle scattering experiments by Rutherford and, in particular, by the studies of positive rays (hydrogen ions) in a cathode ray tube by Rutherford and Thomson.
   (c) The neutron was discovered as a result of radioactive decay studies by Soddy, mass spectrometer work by Aston, and, in particular, by bombarding elements with alpha particles by Chadwick.
3. (a) Atoms of an element may have different numbers of neutrons in their nuclei. These different nuclei therefore differ in mass; and, if a nucleus containing a given number of neutrons is unstable, that nucleus will be radioactive.
   (b) The term applied to such atoms is *isotope*.
4. Max Planck suggested that energy radiated from heat sources was quantized, meaning that it could not be any frequency at all, but must be a multiple of some smallest value. He could not form an equation to correctly predict the frequencies radiated without this supposition, even though it seemed completely illogical at the time.
5. Rutherford knew that a stationary electron would be attracted by, and pulled into, the positive nucleus of an atom. He thought the electrons would be orbiting just like the planets around the Sun.
6. Bohr knew that if electrons were travelling in orbits, they would be accelerating and therefore radiating electromagnetic energy constantly. This would mean that all atoms would collapse and this is not observed.
7. Bohr's First Postulate states (assumes) that electrons do not radiate energy as they orbit the nucleus because each orbit corresponds to a state of constant energy, called a stationary state.
8. Bohr's Second Postulate assumes that electrons may increase or decrease in energy only by undergoing a transition (jump) from one stationary state to another.
9. (a)

   2*p* $\underline{\uparrow}$ $\underline{\uparrow}$ $\underline{\uparrow}$
   2*s* $\underline{\uparrow\downarrow}$

   1*s* $\underline{\uparrow\downarrow}$
   nitrogen atom, N

   (b)

   3*p* $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$
   3*s* $\underline{\uparrow\downarrow}$

   2*p* $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$
   2*s* $\underline{\uparrow\downarrow}$

   1*s* $\underline{\uparrow\downarrow}$
   sulfide ion, S^{2-}

(c)

$3p$ ↑↓ ↑↓ ↑↓
$3s$ ↑↓

$2p$ ↑↓ ↑↓ ↑↓
$2s$ ↑↓

$1s$ ↑↓
potassium ion, K^+

(d)

$2s$ ↑↓

$1s$ ↑↓
beryllium atom, Be

(e)

$4d$ ↑ ↑ _ _ _
$5s$ ↑↓

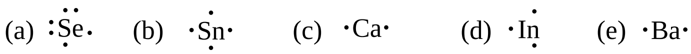
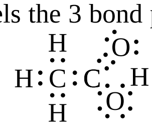
$4p$ ↑↓ ↑↓ ↑↓
$3d$ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓
$4s$ ↑↓

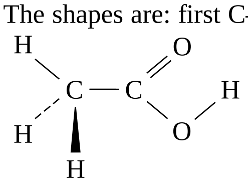
$3p$ ↑↓ ↑↓ ↑↓
$3s$ ↑↓

$2p$ ↑↓ ↑↓ ↑↓
$2s$ ↑↓

$1s$ ↑↓
zirconium atom, Zr

10. Technetium metal has an electron configuration of [Kr] $5s^2\ 4d^5$. This means that it has five unpaired electrons in *d* orbitals. Unpaired electrons usually indicates that the substance will be at least paramagnetic and attracted by a magnet.
11. The bottom of the glass filling first is similar to the aufbau principle; lower energy levels are filled first. The level surface is similar to Hund's Rule. There should be an electron in each orbital of a level before any orbital is assigned a second electron.
12. Once you get to the fourth period in the table, the energies of the *s* and *d* orbitals of different principal quantum numbers start to cross. This means that transition metal atoms are filling the *s* orbital of a higher level while filling the *d* orbital of a lower level. In addition, some rearrangement of the distribution of electons in *s* and *d* orbitals occurs to utilize the extra stability of a half-filled or filled *d* orbital.
13. (a) Ti $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$
    (b) Tc $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^5$
    (c) Fe^{3+} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
    (d) Br^- $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
    (e) Se^{2-} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
14. (a) Zr [Kr] $5s^2\ 4d^2$
    (b) Hg [Xe] $6s^2\ 4f^{14}\ 5d^{10}$
    (c) Ra [Rn] $7s^2$
    (d) I^- [Kr] $5s^2\ 4d^{10}\ 5p^6$ or [Xe]
    (e) U^{6+} [Rn]
15. An *f* sublevel consists of 7 possible orbitals which can be occupied by a maximum of 14 electrons.
16. (a) Br atom
    (b) Ag^+ silver ion
    (c) Hf^{4+} hafnium(IV) ion
    (d) In indium atom
    (e) S^{2-} sulfide ion

17. For an ionic bond to form between two approaching neutral atoms, one must have valence orbitals nearly full of electrons, and the other must have several valence orbitals that are vacant (contain no electrons) or contain very few valence electrons.
18. The primary factor in the packing of ions is the electric charge on the ions. Another factor is the size of the ions.
19. For a hydrogen bond to form between two molecules, one must have at least one nitrogen or oxygen atom in its structure, and the other must have at least one hydrogen atom bonded to a nitrogen or oxygen in its structure.
20. 
21. Elements with electron configurations ending in s^1 are members of the alkali metal family. They are soft shiny metals with high conductivity of heat and electric current, and they are very reactive chemically, forming 1^+ ions.
22. Elements with electron configurations ending in p^6 are members of the noble-gas family. They are all colourless gases that are extremely unreactive chemically.
23. Elements with electron configurations ending in p^5 are members of the halogen family. They are all reactive chemically, forming 1^- ions. Their physical properties at SATP vary markedly with the size of the diatomic molecule formed, so that the two smallest atoms form gaseous elements, the next is liquid, and the larger ones are solid.
24. VSEPR is an acronym for Valence Shell Electron Pair Repulsion.
25. (a) V-shaped
    (b) tetrahedral
    (c) pyramidal
    (d) V-shaped
    (e) linear
26. NF_3 should have smaller bond angles than SiF_4 because, according to VSEPR theory, in NF_3 the lone pair of electrons repels the 3 bond pairs more than a fourth bond pair would.
27. (a)


    (b) The shapes are: first C—tetrahedral; second C—trigonal planar; and the O—V-shaped.
    (c)


    (d) The C-H bonds are polar, the C-C bond is nonpolar, the C=O double bond is polar, the C-O single bond is polar, and the O-H bond is very polar (forms a hydrogen bond). The bond polarities do not balance each other, so the overall molecule is polar.
    (e) The predominant type of intermolecular bonding between acetic acid molecules is probably hydrogen bonding.
28. Isoelectronic means having the same total number of electrons. London force may be predicted (approximately) for isoelectronic substances, because it is roughly proportional to number of electrons.
29. $H_2S_{(g)}$ should have a higher boiling point than $F_{2(g)}$ because hydrogen sulfide is a polar molecule with dipole–dipole attractions as well as London force between molecules. Fluorine is a nonpolar molecule, with only London force for intermolecular attraction. Because these two molecules are isoelectronic, we assume they have approximately equal London force. VSEPR theory allows prediction of their molecular shape, and electronegativity tables allow prediction of their bond polarities to allow prediction of their molecular polarities.

Applying Inquiry Skills

30. (a) Helium and neon can be distinguished by determining their boiling points. Both atoms have only London forces between their molecules. Neon has a significantly greater number of electrons per molecule which means stronger London forces and a higher boiling point.

    (Alternatively, helium and neon can be distinguished by their emission spectra. Neon has more electrons and therefore, many more possible transitions to produce lines in the emission spectrum. The colour of a neon light is also well known (red) and this can be used to distinguish the gases.)

    (b) $MnCl_{2(s)}$ and $ZnCl_{2(s)}$ can be distinguished by testing a sample of each solid with a strong magnet. $MnCl_{2(s)}$ is paramagnetic because the Mn^{2+} ion has 5 unpaired 3*d* electrons. $ZnCl_{2(s)}$ is not paramagnetic because the Zn^{2+} ion has a $3d^{10}$ outer electron configuration with all electrons paired.
    (c) Zinc and iodine can be distinguished (other than by their appearance) by their electrical conductivity. Zinc is a metal with empty valence orbitals and with some mobile valence electrons. This makes zinc a good electrical

conductor. On the other hand, iodine is molecular with filled valence and bonding orbitals. The electrons are restricted to the atoms or shared between the atoms, and none are free to move between molecules. This makes iodine a nonconductor.

(d) Calcium carbonate and silicon dioxide may be able to be distinguished based on their melting points. Calcium carbonate is an ionic compound and likely has a relatively high melting point because of the strong attractions of positive and negative ions. However, silicon dioxide is a network covalent crystal whose melting point should be very high because of its network of strong covalent bonds. Once melted, calcium carbonate liquid should conduct electricity because the ions will now be free to move. Molten silicon dioxide will be a molecular liquid with no charged particles to conduct the charge.

31. Standing waves maintain steady characteristics within a moving system, explaining stationary states. Also, standing waves can only exist for whole-number multiples of the wavelength, explaining discrete but different energy states.

32. In de Broglie's theory, the electron is treated as a wave and not a particle. The release of electromagnetic radiation only applies to accelerating electric charges and not to standing or stationary waves.

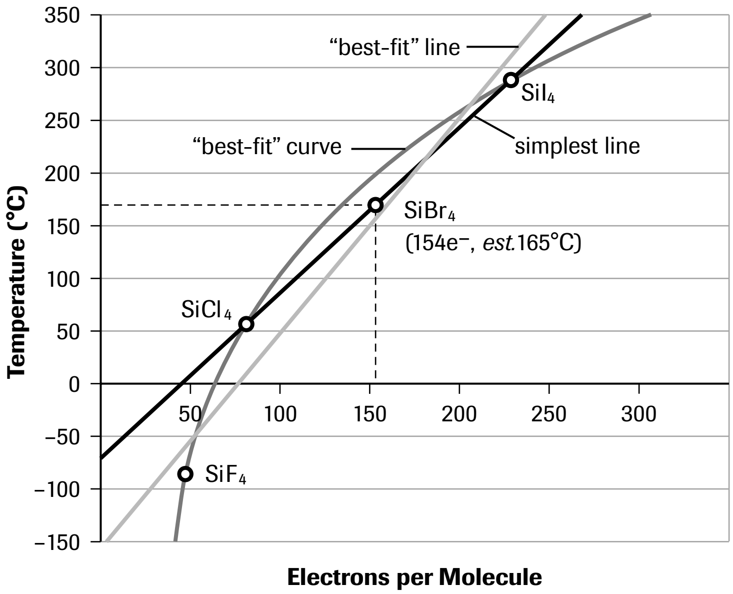
33. (a) The independent variable is the solid used and the dependent variable is the appearance of a scratch mark on the surface. Some controlled variables are: the nature of the surface (smoothness, cleanness, flaws, etc.), force applied by one solid on the other, and the angle between the two surfaces.

(b) Hardness is the property being tested.

(c) To make a scratch on a surface, some particles must be dislodged from the surface. The nature of the particles determines the type of bonding force(s) present, and the type of force determines how easily particles can be separated from each other.

(d) A network covalent crystal, like a diamond, would likely not be able to be scratched by any other types of solids.

34. (a) **Analysis**



According to the graph, the value predicted is about 165°C.

(**Note:** The data points are not in a straight line, and there are only three points. Student predictions will vary depending on how the students choose to interpret the scanty data. If they make the simplest choice and draw a straight line between the SiI_4 and $SiCl_4$ points, they will get a value close to 165°C. If they try a "best-fit" straight line, their value will be lower than this (and more accurate); and if they try to draw a "best-fit" curve, the value will be higher than this (and less accurate). This provides an excellent specific example of the predicting power of an assumption—that London force is proportional to electron count. It is obviously a good approximation, but only an approximation.)

(b) **Evaluation**

An accepted reference value for the boiling point of $SiBr_4$ is 153°C. The difference in the predicted and referenced values is (165 – 153)°C = 12°C

$$\%\text{ difference} = \frac{|\text{difference}|}{\text{accepted value}} \times 100\%$$

$$\%\text{ difference} = \frac{12\cancel{°C}}{153\cancel{°C}} \times 100\%$$

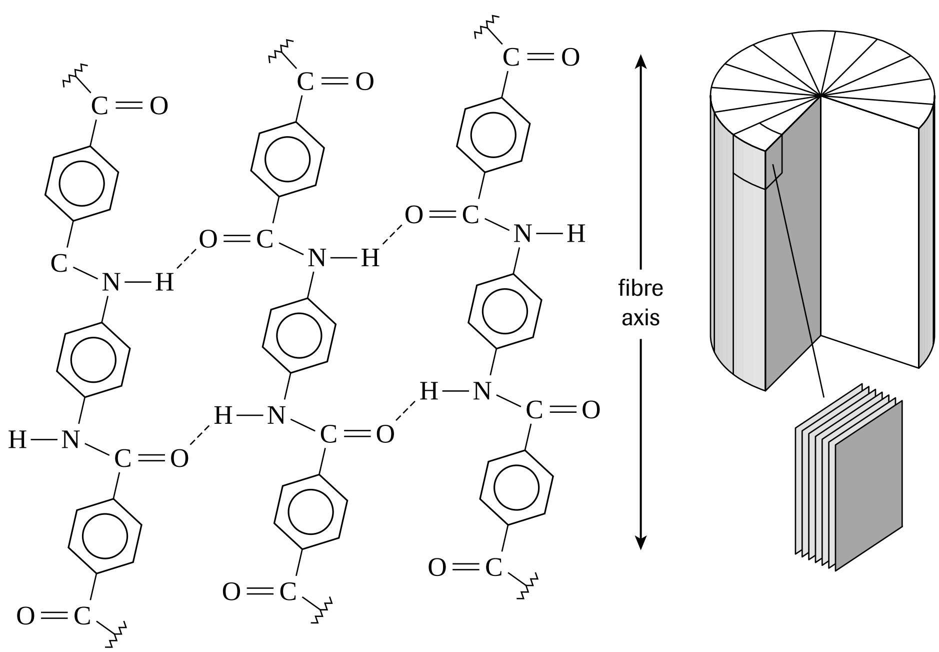
$$\%\text{ difference} = 7.8\%$$

The percentage difference of the prediction from the referenced value is 7.8%, which is fairly, but not highly, accurate. The molecular count method used here gives a fairly good approximate answer.

Making Connections

35. An optical pyrometer is also called a wire pyrometer. It has an optical tube, like a telescope, through which the hot steel is viewed. A wire in the field of view appears as a dark line across a bright background. Turning a dial causes a current to flow in the wire which heats and glows proportionally to its temperature. The wire brightness is adjusted to match the background steel, at which point the wire seems to disappear. The dial on the pyrometer is calibrated in temperature units, allowing the temperature of the observed steel to be read directly. Planck's theory holds that the wavelengths of light emitted by hot metals are proportional to the average energy (temperature) of its particles, making this kind of comparison measurement possible.
36. The nitrogen bases bonded to form the DNA double helix structure are: thymine to adenine, which form two hydrogen bonds with each other; and guanine to cytosine, which form three hydrogen bonds with each other.
37. A carbon nanotube may be thought of as a graphite structure (carbon atoms in hexagons) tube with hemispherical ends composed of carbon atoms in pentagons. The tubes have been made up to a millimetre long, and they can theoretically be of any length. The diameter of a nanotube is on the order of 1/50 000 that of a human hair. Most properties of such a structure are unique. Perhaps the property most likely to soon be useful is that the tubes have the strength of diamond along their length. If they can be made long enough, they can be used to make composite material layers much stronger than anything in existence now. They are chemically inert, conduct heat very well, and, depending on their structure, can act as conductors or semiconductors. Samsung uses nanotubes to fire electrons at a flat panel display screen. A nanotube "pen" has been made that deposits atoms the way a pen deposits ink. Nanotubes can be opened and filled with other substances, like tiny test tubes—a property of great interest to biologists. In August 2001, IBM physicists built the world's smallest logic circuit out of a single nanotube. It has been suggested that nanotubes could be used for hydrogen storage for fuel cell power supplies, and that they might form the basic structure of artificial muscles. The field is only a decade old, and it seems likely that applications for nanotubes will multiply with research and improvements in technology the way laser applications did following that discovery.
38. Kevlar is a brand name for a liquid crystal polymer developed by DuPont and originally intended as a superior material to nylon or rayon for fabric plies in automotive tires. In Kevlar, the polymer chain is poly(p-phenylene terephthalimide. (A diagram is shown below.) In Kevlar, the basic chain structure is made up of rigid aromatic rings, rather than a flexible hydrocarbon chain, so a molecule cannot stretch when it is pulled, and cannot be broken by pulling unless the pull is hard enough to break all the bonds at once. This causes Kevlar to have enormous tensile strength when formed into fibres. Cloth made from cross-woven Kevlar fibres is flexible, but cannot be stretched in any direction except by very strong forces. Kevlar is used in "bulletproof" vests, sails, parachutes, climbers' ropes, and as reinforcing layers in high-strength composite materials for a myriad of applications.

Hydrogen-Bonded Sheet **Sheets Stack Together**



39. Diamond is shaped and polished with abrasive wheels impregnated with diamond dust. The only material hard enough to shape diamond by grinding is diamond itself. Large diamonds can be "cut" by skilled technicians who actually break the crystal structure by applying a sharp hard force in precisely the right spot. This is also called cleaving the structure, along a surface called a cleavage plane—usually established by the presence of impurities in the crystal which make it slightly weaker in specific places and along specific directions.

Extensions

40. In a thermocouple, two different metals have surfaces in contact in two places. This design may be as simple as two different metal wires of equal length, joined only at their ends. When one of the contact surfaces (ends) is heated, the attraction of the metal atoms for electrons is changed, but not by the same amount for each metal. This difference is partly due to the difference in energy levels for "excited" states of the different atoms. The net effect is that electrons will tend to flow from one metal to the other across the hot junction, continuing around the circuit to create an electric current. This current is proportional to the temperature difference between the two junctions. Measuring the current allows the temperature to be determined, and if metals with very high melting points are used, very high temperatures may be accurately measured in this way.
41. Light-emitting diodes are *p-n* semiconductor junctions where a potential difference causes electrons to move from the *n*-type semiconductor to the *p*-type semiconductor. Electron energies are raised in the *n*-type substance until the excited electrons become "free" and are able to jump to the *p*-type substance where they fall to a valence (ground-state) level of an atom. This drop in energy is evident as an emitted photon of light, and since the energy-level drop is fixed, so is the wavelength of light emitted. The shorter the wavelength, the greater the voltage drop required — an LED producing green light must operate at a higher voltage than one producing red light. Blue light (the shortest wavelengths visible) is very difficult to produce this way, because the high energy drop means the materials have to be nearly perfect insulators. Production of white light for displays requires the mixing of red, green, and blue light. Therefore, blue LED research is an area of serious interest.
42. Gold films are typically gold in colour by reflected light, even when extremely thin. Gold reflects infrared, ultraviolet, and visible light very well, but reflects especially well in the middle of the visible spectrum. This gives the characteristic golden hue. Gold can be made into extraordinarily thin sheets (in this form, it is usually called gold "leaf") which will adhere to other materials (a process called "gilding") causing the surface to appear golden. Gold leaf can be made so thin that 1 troy ounce (about 31 g) will cover 2 m^2 at a thickness of 2.5 μm. If the gold layer is formed by condensing gold vapour in a very thin layer on a cool transparent surface like glass, a significant amount of light will be transmitted. The amount of light transmitted is proportional to the thickness of the metal layer created. The transmitted light will normally appear dark green because of the subtraction of yellow from the visible spectrum. The material coating the sunshield on NASA astronauts' EVA suits incorporates a thin gold film which is evident in any colour photograph of an astronaut on a "space walk." Sunglasses with mirror surfaces are now made in many colours by depositing very thin films of various metals on their surfaces.
43. $c = 3.00 \times 10^8$ m/s

$\lambda_L = 700 \text{ nm} = 700 \times 10^{-9}$ m (longest visible)

$\lambda_S = 400 \text{ nm} = 400 \times 10^{-9}$ m (shortest visible)

$$c = f\lambda$$

$$f = \frac{c}{\lambda}$$

$$f_L = \frac{\frac{3.00 \times 10^8 \cancel{\text{m}}}{1 \text{ s}}}{700 \times 10^{-9} \cancel{\text{m}}}$$

$$f_L = \frac{4.29 \times 10^{14}}{1 \text{ s}} = 4.29 \times 10^{14} \text{ Hz}$$

$$f_S = \frac{\frac{3.00 \times 10^8 \cancel{\text{m}}}{1 \text{ s}}}{400 \times 10^{-9} \cancel{\text{m}}}$$

$$f_S = \frac{7.50 \times 10^{14}}{1 \text{ s}} = 7.50 \times 10^{14} \text{ Hz}$$

The frequency of the longest visible wavelength of light is 4.29×10^{14} Hz, and of the shortest visible wavelength of light is 7.50×10^{14} Hz.

44. $h = 6.63 \times 10^{-34}$ J · s

$$f_H = \frac{7.50 \times 10^{14}}{1 \text{ s}} = 7.50 \times 10^{14} \text{ Hz} \quad \text{(highest visible)}$$

$$f_L = \frac{4.29 \times 10^{14}}{1 \text{ s}} = 4.29 \times 10^{14} \text{ Hz} \quad \text{(lowest visible)}$$

$$\Delta E = hf$$

$$\Delta E_H = \frac{6.63 \times 10^{-34} \text{ J}}{1 \cancel{\text{Hz}}} \times 7.50 \times 10^{14} \cancel{\text{Hz}}$$

$$\Delta E_H = 4.97 \times 10^{-19} \text{ J}$$

$$\Delta E_L = \frac{6.63 \times 10^{-34} \text{ J}}{1 \cancel{\text{Hz}}} \times 4.29 \times 10^{14} \cancel{\text{Hz}}$$

$$\Delta E_L = 2.84 \times 10^{-19} \text{ J}$$

The energy of the highest-frequency visible photon is 4.97×10^{-19} J and the energy of the lowest-frequency visible photon is 2.84×10^{-19} J.

45. The shorter the wavelength, the higher the frequency, and the higher the photon energy, for electromagnetic radiation. Because X rays have very short wavelengths and very high frequency, their photons have very high energies which can penetrate and damage living cells. Radio waves have extremely long wavelengths, and correspondingly extremely low (and harmless) photon energies.

46. $\Delta E = hf$

$c = f\lambda$

$$f = \frac{c}{\lambda}$$

$$\Delta E = \frac{hc}{\lambda}$$

$$\Delta E = \frac{6.63 \times 10^{-34} \text{ J} \cdot \cancel{\text{s}} \times 3.00 \times 10^{8} \cancel{\text{m}}/\cancel{\text{s}}}{300 \times 10^{-9} \cancel{\text{m}}}$$

$$\Delta E = 6.63 \times 10^{-19} \text{ J}$$

The energy of a photon of 300 nm light is 6.63×10^{-19} J.

The energy of a photon of 600 nm (orange) light is half the preceding value, since photon energy is inversely proportional to wavelength. Therefore, 6.63×10^{-19} J $\div 2 = 3.32 \times 10^{-19}$ J.

The energy of a photon of 600 nm light is 3.32×10^{-19} J.

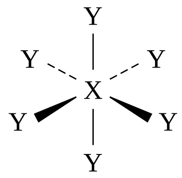
47. (a) Fluorescein absorbs (and emits) green photons. Red photons are lower in energy and not high enough to be absorbed, so no light should be emitted.
(b) Ultraviolet light photons are very high energy and they should be absorbed. Green photons should be emitted.
(c) Infrared light photons are very low energy and they should not be absorbed. No green photons should be emitted.
(d) Blue light photons are higher energy than green and they should be absorbed. Green photons should be emitted.

48. According to the stability "subrule," molybdenum should have a configuration of [Kr] $5s^1\ 4d^5$ to half-fill its *d* level, and silver should have a configuration of [Kr] $5s^1\ 4d^{10}$ to completely fill its *d* level.

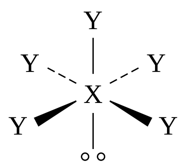
49. In ferromagnetic elements, a quantum effect enables the atoms to align the magnetic dipoles of neighbouring atoms. This creates volumes of very large numbers of atoms with aligned dipoles that scientists call *domains*. Domains form metallic crystals that act like tiny magnets within the solid material, and if these domains are mostly aligned with each other by an external magnetic field, the solid will show the tendencies and properties of a "permanent" magnet. The other two ferromagnetic elements are gadolinium and dysprosium.

Strong heating increases atomic motion and causes domains to become unaligned. This causes their magnetic dipoles to partially cancel, and weakens the overall magnetism of the solid magnet.

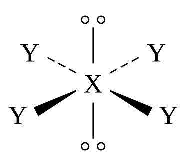
50.



6 bond pairs, 0 lone pairs
octahedral structure



5 bond pairs, 1 lone pair
square pyramid structure



4 bond pairs, 2 lone pairs
square planar structure

Molecules of uranium hexafluoride, $UF_{6(g)}$, should be octahedral, with six bond pairs and no lone pairs.