CHAPTER 1: MATTER AND ENERGY

SECTION A

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CHEMISTRY is the study of matter (anything that takes up space and has mass — desk, book, salt, sugar, etc.)

SUBSTANCE: Any variety of matter that has the same properties and composition throughout. A substance is homogeneous, made up of only one thing. (A bag of sugar is homogeneous — made entirely of sugar.)

There are two types of substances: elements and compounds: An **ELEMENT** CANNOT BE DECOMPOSED (BROKEN DOWN) into anything simpler by chemical change. Examples are: hydrogen, oxygen, nitrogen. All elements are written down on the Periodic Table on page Reference Tables-15 in Appendix I. A **COMPOUND** CAN BE DECOMPOSED (BROKEN DOWN) by a chemical change. It is made of two or more different elements chemically united in a definite ratio. Examples of compounds are sodium chloride, NaCl, magnesium oxide, MgO, and sulfuric acid, H_2SO_4. A **binary compound** consists of ONLY TWO ELEMENTS, e.g., **NaCl**.

In a **MIXTURE**, two or more substances are MIXED TOGETHER (not united). Example: salt and sugar mixed together. A mixture could have different proportions — **different amounts** — i.e., ½ cup salt mixed with ½ cup sugar or ¾ cup salt mixed with ¼ cup sugar. Mixtures can be **heterogeneous** (example: salt mixed with sugar, two different things) or **homogeneous** (example: *solutions*, which are considered like one thing; for example, salt solution, salt dissolved evenly throughout the water).

Question: Given the equation

$$2Na + 2H_2O \rightarrow 2NaOH + H_2,$$

which substance in this equation is a binary compound?

Solution: A BINARY COMPOUND has ONLY TWO ELEMENTS (two capital letters). H_2O has two elements, **hydrogen** and **oxygen**, capital H, capital O.

Try Sample Questions #1-4, on page 7, and then do Homework Questions #1-7, page 9.

ENERGY is the ability to do work. Kinetic energy is energy having to do with motion (moving). Potential energy is stored energy. Heat, light and electricity are different forms of energy.

LAW OF CONSERVATION OF ENERGY: Energy may be changed from one form to another, but the total amount is the same. (Energy is never destroyed.) When a student puts on the light, electrical energy (electricity) is changed into light energy (the light goes on), and the total energy is the same.

Energy is absorbed or given off in chemical reactions:

- **EXOTHERMIC**: Energy is GIVEN OFF in a chemical reaction.
- **ENDOTHERMIC**: Energy is ABSORBED in a chemical reaction.

How Do We Measure Energy? Energy is measured in **joules**. One joule = 1 newton-meter. One kilojoule is equal to 1000 joules.

Formula used to solve heat energy problems (how much heat, in joules, is absorbed or released) and to find change in temperature or temperature:

$$q = mC\Delta T$$

q = heat (in joules); m= mass (in grams); C= **specific heat capacity**, the amount of heat needed to raise 1 gram 1°C; ΔT = change in temperature.

Heat $q = mC\Delta T$ q = heat   m = mass
C = specific heat capacity
ΔT = change in temperature

TABLE A

C= Specific heat capacity of water (H_2O) = **4.18 joules/gram·°C**, which means 4.18 joules is needed to raise 1 gram of water 1°C. Specific heat of $H_2O(l)$ = 4.18 joules/g•°C is given at the bottom of Table A, on page Reference Tables-1, in Appendix I.

Specific Heat Capacity of H_2O (ℓ)4.18J/g•C

Question 1: How much heat energy in joules is absorbed by 30 grams of water (H_2O) when it is heated from 20°C to 30°C?

Solution:

This is a **heat energy** problem. Use the heat formula on Table T:

$$q = m\ C\ \Delta T$$

There is 30 grams of water, therefore write 30g under m (mass in grams) in the equation. Go to Table A. On Table A, it is written, specific heat capacity of $H_2O(l)$= 4.18 joules/g •°C. Write 4.18 under C in the formula. ΔT = change in temperature. Subtract the temperatures (final temperature minus starting temperature). 30°C−20°C = 10°C. Write 10°C under ΔT. Multiply 30 x 4.18 x 10 = 1254.

q	=	m	C	ΔT
	=	30g	4.18 Joules/g•°C	10°C
	= 1254 joules			

If a question asks for change in temperature (instead of heat absorbed), solve for ΔT (change in temperature, example 10°C).

Question 2: How much heat (thermal) energy in joules is absorbed by 100 grams of water when it is heated from 20° to 30°C? (This is the same question as question 1, but you have more mass.)

Solution: q = mC ΔT

= 100 g x 4.18 Joules/g•°C x 10°C = 4180 joules

You see, when you have more mass, you have more energy (joules).

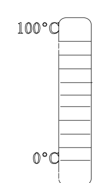
TEMPERATURE: Suppose you want to measure the temperature of warm milk. The thermometer might say 50°C, 60°C or 70°C. **Temperature** is a measure of the **average kinetic energy** of the molecules. The **higher** the temperature, the MORE KINETIC ENERGY the molecules have. The **lower** the temperature, the LESS KINETIC ENERGY the molecules have.

You have a cup of milk at 80°C and a cup of milk at 20°C. Mix the two cups of milk together. **Rule**: Heat flows from a body at higher temperature to a body at lower temperature. This means heat flows from the cup of milk at 80°C to the cup of milk at 20°C until both cups are at the same temperature, about 50°C.

If you have a piece of aluminum at 80°C in contact with a piece of aluminum at 30°C, heat flows from the aluminum at 80°C to the aluminum at 30°C. Heat flows from higher temperature to lower temperature until both are at the same temperature (about 55°C).

SUMMARY: Heat travels from higher temperature to lower temperature until both temperatures are the same.

THERMOMETERS: Use a thermometer to measure temperature. Let's take a look at a Celsius thermometer.



BOILING POINT and **FREEZING POINT** are the **two fixed points of the thermometer**. On the Celsius scale, there is 100°C between the freezing point and boiling point.

0°C = freezing point of water, also called the **ice-water equilibrium temperature**.

100°C = boiling point of water, also called the **water-steam equilibrium temperature**.

Now let's understand the Kelvin (or absolute) temperature. **Kelvin = °Celsius + 273**. If you know the Celsius temperature, add 273 to that number and you get Kelvin. Use the formula K = °C + 273.

Question: What is the Kelvin temperature for 0°C (freezing point of water)?

Solution: K = °C + 273

K = 0°C + 273 = 273K.

Question: What is the Kelvin temperature for 100°C (boiling point of water)?

Solution: K = °C + 273

K = 100°C + 273 = 373K.

Question: If the Celsius temperature is −40°C, what is the Kelvin temperature?

Solution: K = °C + 273

K = −40°C + 273 = 233K.

Try Sample Questions #5-7, on page 7, and then do Homework Questions, #8-16, page 10.

There are three phases of matter: **solid**, **liquid** and **gas**:

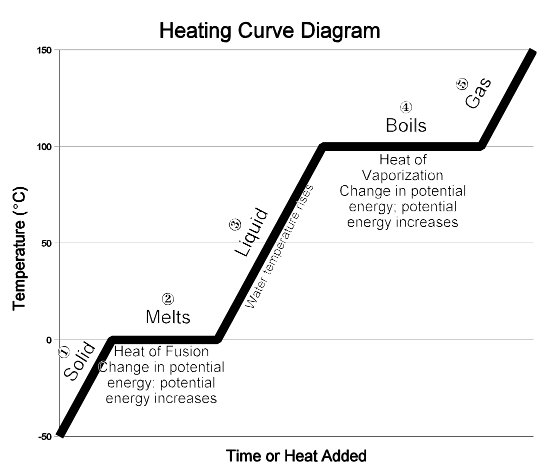
Solids have DEFINITE SHAPE and DEFINITE VOLUME. An example is ice.

Liquids have DEFINITE VOLUME (4 oz. or 8 oz., etc.) and TAKE THE SHAPE OF THE CONTAINER. If you put water in a plate, it takes the shape of the plate; if you put water in a cup, it takes the shape of the cup. A liquid takes the shape of any container you put it in.

Gases have NO DEFINITE VOLUME and NO DEFINITE SHAPE of their own. They spread all over. Gases take the shape and volume of the container you put them in.

HEATING CURVE DIAGRAM

Here is a **Heating Curve Diagram**, with explanations, to show what you just learned. **STUDY THIS AND MEMORIZE IT.**



Look at ① in the diagram. The ice (solid) from a very cold freezer is at -50°C. The ice rises in temperature to 0°C. **Increase in temperature** means increase in kinetic energy.

TABLE A

Look at ② in the diagram. As you learned, at 0°C, the ice begins to melt. **Heat of fusion** is the amount of heat needed to change solid (example: ice) to liquid (water) at constant temperature. Heat of fusion of ice at 0°C and 1 atmosphere = 334 J/g. (Ice takes in 334 joules per gram to become water.) In the diagram, melting is drawn as a horizontal line.

During **melting**, the **temperature stays the same**. No change in temperature means no change in kinetic energy. During melting there is a **change in potential energy** (stored energy). Potential energy increases.

Look at ③ in the diagram (after all the ice melts). The **temperature** of the water now **rises** from 0°C to 100°C.

TABLE A

Look at ④ in the diagram. At 100°C, the water **boils** (changes to gas). **Heat of vaporization** is the amount of heat needed to change liquid (example: water) into gas (water vapor) at constant temperature. Heat of vaporization of water at 100°C and 1 atmosphere is 2260 J/g. (Water takes in 2260 joules per gram to change into water vapor). See Reference Table A. In the diagram, the horizontal line is drawn to show that water boils. When the **water boils**, **the temperature remains the same**. No change in temperature means no change in kinetic energy. When the water boils, there is a **change in potential energy** (**stored energy**). Potential energy increases.

Look at ⑤ in the diagram. After all the water has boiled, the **temperature** of the gas **rises**.

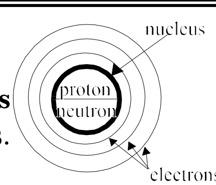
Try Sample Questions #8-10, beginning on page 7, and then do Homework Questions, #17-25, beginning on page 10.

CHAPTER 2: ATOMIC STRUCTURE

Problem p 42-43 #3,8
Darken drawings P23, 24, 25, 26,36 (atoms) 37 (atoms), 39, 42, 44
40 darken gray box
P26 drawing change sublevel

SECTION A

THE ATOM



The **NUCLEUS** is in the center of the atom and has **protons** and **neutrons**. The **electrons** are around the nucleus. Most of the atom is **empty space**.

	PROTON	NEUTRON	ELECTRON
CHARGE	positive	none	negative
MASS	1 atomic mass unit	1 atomic mass unit	hardly any: 1/1836 atomic mass unit

TABLE J

If you want to know the symbols for proton, neutron or electron, look at Table J. **TABLE J** gives symbols: neutron, ^1_0N; proton, ^1_1H; and electron, $^0_{-1}e$. Table J also gives you the mass. The top number is the mass. Mass of neutron = 1, mass of proton = 1, mass of electron = 0 (which means very, very little).

Table J

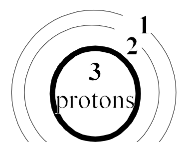
alpha	^4_2He
beta *(electron)*	$^0_{-1}e$
neutron	^1_0n
proton	^1_1H

The **ATOMIC NUMBER** of any atom is equal to the number of **protons**, which is equal to the number of **electrons**.

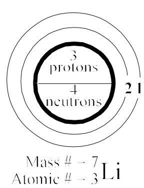
SUMMARY:

Atomic Number = number of protons = number of electrons.

The atom lithium, Li, has an atomic number of 3. **Atomic number 3 = 3 protons = 3 electrons**. The **first** circle or **shell** can only hold **2 electrons**. Therefore, the **third electron** goes into the **next** circle or **shell**.



Lithium: $_3$Li
← atomic number



The **MASS NUMBER** is equal to the total number of **protons and neutrons** in the nucleus. Lithium has a **mass number** of 7, which is **equal** to **3 protons** and **4 neutrons** in the nucleus. To find the **number of neutrons**, take the **mass number minus the atomic number**.

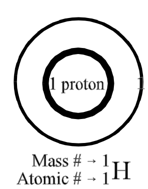
 # neutrons in Lithium = 7 (mass number) - 3 (atomic number) = 4 neutrons

As you see, lithium is written as ^7_3Li. Li is the symbol for lithium; 3 is the atomic number, which is written at the bottom of the symbol of the element; and 7 is the mass number, which is written at the top of the symbol of the element.

Now let's look at hydrogen. The element hydrogen, **H**, has an atomic number of 1 and a mass number of 1

PERIODIC TABLE

You do not have to memorize these numbers. If you know the element and want to know the atomic number, look at the Periodic Table, page Reference Tables-14. Hydrogen is written ^1_1H. Below the symbol of the element is the atomic number; therefore, you can see that hydrogen has an atomic number of 1. Each element has its own atomic number.



ISOTOPES of the same element have the **same atomic number** but **different mass numbers**. There are three **isotopes** of hydrogen: $^1_1$**H**, $^2_1$**H, and** $^3_1$**H**.

They all have the same atomic number, 1, which is the atomic number of hydrogen, but they have different top (mass) numbers. (These isotopes have different numbers of neutrons.)
Use this equation:

mass # - atomic # = number of neutrons

Therefore:

$^{1}_{1}H$: mass # – atomic # = number of neutrons; 1 – 1 = 0 neutrons
$^{2}_{1}H$: mass # - atomic # = number of neutrons; 2 - 1 = 1 neutrons
$^{3}_{1}H$: mass # - atomic # = number of neutrons; 3 - 1 = 2 neutrons

As you can see, isotopes differ in the number of neutrons.

TABLE A

One (1) atomic mass unit equals $1/12^{th}$ the mass of ^{12}C.
In **Table A**, it is written that *1 amu (atomic mass unit) = 1.66 x* 10^{-24}*g*. Don't memorize that number. Look it up if you need it.
The **ATOMIC MASS** of an element is the weighted average mass of the naturally occurring isotopes of that element. The average is weighted according to the proportions in which the isotopes occur.

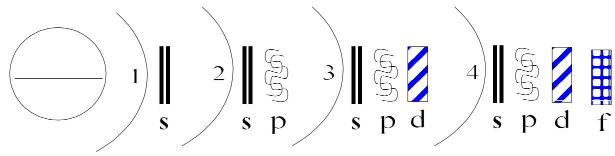
Try Sample Questions #1-6, on page 29, and then do Homework Questions, #1-14, beginning on page 31.

BOHR MODEL OF THE ATOM. Electrons revolve (go around) the nucleus in concentric circular orbits.
PRINCIPAL ENERGY LEVELS (PRINCIPAL QUANTUM NUMBERS) can be shown as 1, 2, 3, 4:

⊖)1)2)3)4).

Principal energy level shows how far the electron is from the nucleus. The first energy level (Shell #1) is closest to the nucleus, while other energy levels are further away from the nucleus. Electrons on the first energy level have the lowest energy; those in higher energy levels have more energy.
Today, the **orbital model** of an atom is used, which tells you the place (orbitals) where you will probably find the electrons.
Principal energy levels may be divided into subshells.

Principal energy level 1 has ONE ENERGY SUBSHELL: **s**.
Principal energy level 2 has TWO SUBSHELLS: **s** and **p**.
Principal energy level 3 has THREE SUBSHELLS: **s**, **p** and **d**.
Principal energy level 4 has FOUR SUBSHELLS: **s**, **p**, **d** and **f**.



Four Principal Energy Levels, with Their Subshells