3

Environmental Facts and Formulas

Physical factors such as temperature, pressure, altitude, and humidity affect gases in particular and, thus, should be well understood by the critical care practitioner. A number of useful tables, formulas, and figures follow. Thermal injuries are commonly considered environmental events, and, thus, these formulas and figures are included in this chapter as well.

■ 1. TEMPERATURE

Temperature conversion calculations are often done in the management of critically ill patients. Degrees *Celsius* (°C) and *Fahrenheit* (°F) are most commonly utilized:

°C to °F

$$°\mathbf{F} = (°C \times 9/5) + 32$$

°F to °C

$$°\mathbf{C} = (°F - 32) \times 5/9$$

Occasionally, the *Kelvin* (K) temperature scale is used, primarily in gas law calculations:

K to °C

$$\mathbf{K} = °C + 273$$

°C to K

$$°\mathbf{C} = K - 273$$

J. Varon and R.E. Fromm Jr., *Acute and Critical Care Formulas and Laboratory Values*, DOI 10.1007/978-1-4614-7510-1_3,

■ 2. HUMIDITY

Relative Humidity

Relative humidity (RH) is usually measured by hygrometers, thus eliminating the need of extracting and measuring the humidity content of the air samples:

$$\mathbf{RH} = \frac{\text{Content [mg / L or mm Hg]}}{\text{Capacity [mg / L or mm Hg]}} = \%$$

Humidity Deficit

The *humidity deficit* (HD) represents the maximum humidity capacity at body temperature:

$$\mathbf{HD} = \text{Capacity} - \text{content} = \text{mg / L}$$

where

capacity = amount of water the alveolar air can hold at body temperature (also known as absolute humidity)
content = humidity content of inspired air (see Table 3.1):

Table 3.1 Humidity capacity of saturated gases from 0 to 43 °C

Gas temperature (°C)	*Water content (mg/L)*	*Water vapor pressure (mmHg)*
0	4.9	4.6
5	6.8	6.6
10	9.4	9.3
17	14.5	14.6
18	15.4	15.6
19	16.3	16.5
20	17.3	17.5
21	18.4	18.7
22	19.4	19.8
23	20.6	21.1
24	21.8	22.4
25	23.1	23.8

(continued)

Table 3.1 (continued)

Gas temperature (°C)	*Water content (mg/L)*	*Water vapor pressure (mmHg)*
26	24.4	25.2
27	25.8	26.7
28	27.2	28.3
29	28.8	30.0
30	30.4	31.8
31	32.0	33.7
32	33.8	35.7
33	35.6	37.7
34	37.6	39.9
35	39.6	42.2
36	41.7	44.6
37	43.9	47.0
38	46.2	49.8
39	48.6	52.5
40	51.1	55.4
41	53.7	58.4
42	56.5	61.6

■ 3. PRESSURE

Pressure is defined as force per unit area, and there are various ways of measuring this force. One way is that force can be recorded in a form of the height of a column as in the mercury barometer; therefore, it can be recorded in milliliters of mercury (mmHg) pressure or centimeters of water pressure.

To Convert cmH_2O *to* mmHg

$$\mathbf{mmHg} = cmH_2O \times 0.735$$

To Convert mmHg *to* cmH_2O

$$\mathbf{cmH_2O} = mmHg \times 1.36$$

Pressure Per Square Inch
A less commonly used conversion in clinical medicine includes converting *Psi* (*pressure per square inch*) *to mmHg*:

$$\mathbf{mmHg} = \text{Psi} \times 51.7$$

Pressure-Related Formulas
Other useful pressure-related formulas/facts include:

$$\textbf{Total pressure} = P_1 + P_2 + P_3 + \cdots \text{(Dalton's Law)}$$

$$\textbf{1 atmosphere} = 760\ \text{mmHg} = 29.921\ \text{in Hg} = 33.93\ \text{ft}\ H_2O = 1{,}034\ \text{cm}\ H_2O = 1{,}034\ \text{g}/\text{cm}^2 = 14.7\ \text{lb}/\text{in.}^2$$

Pressure/Volume Relationships
Useful pressure/volume relationships that can be used in the management of critically ill patients include:

$$\textbf{Volume}_{\textbf{BTPS}} = \text{Volume}_{\text{ATPS}} \times \text{Factor}$$

where

$\text{Volume}_{\text{BTPS}}$ = gas volume saturated with water at body temperature (37 °C) and ambient pressure [BTPS = barometric temperature pressure saturation]
$\text{Volume}_{\text{ATPS}}$ = gas volume saturated with water at ambient (room) temperature and pressure [ATPS = ambient temperature pressure saturation]
Factor represents the factors for converting gas volumes from ATPS to BTPS:

$$\textbf{Conversion factor} = \frac{P_B - PH_2O}{P_B - 47} \times \frac{310}{(273 + ^\circ C)}$$

See also Table 3.2:

Table 3.2 Factors for converting gas volumes from ATPS to BTPS

Gas temperature (°C)	*Factors to convert to 37 °C saturated*	*Water vapor pressure (mmHg)*
18	1.112	15.6
19	1.107	16.5
20	1.102	17.5
21	1.096	18.7
22	1.091	19.8
23	1.085	21.1
24	1.080	22.4
25	1.075	23.8
26	1.068	25.2
27	1.063	26.7
28	1.057	28.3
29	1.051	30.0
30	1.045	31.8
31	1.039	33.7
32	1.032	35.7
33	1.026	37.7
34	1.020	39.9
35	1.014	42.2
36	1.007	44.6
37	1.000	47.0
38	0.993	49.8
39	0.986	52.5
40	0.979	55.4
41	0.971	58.4
42	0.964	61.6

4. ALTITUDE

As altitude varies, changes in atmospheric pressure produce alterations in gas density (see Table 3.3):

Table 3.3 Changes in density with altitude assuming a constant temperature

Altitude (ft)	*Standard temperature (°C)*	*Density ratio constant temperature*	*Density ratio standard temperature*
0	15.00	1.0000	1.0000
5,000	5.09	0.8320	0.8617
10,000	–4.81	0.6877	0.7385
15,000	–14.72	0.5643	0.6292

5. BURNS

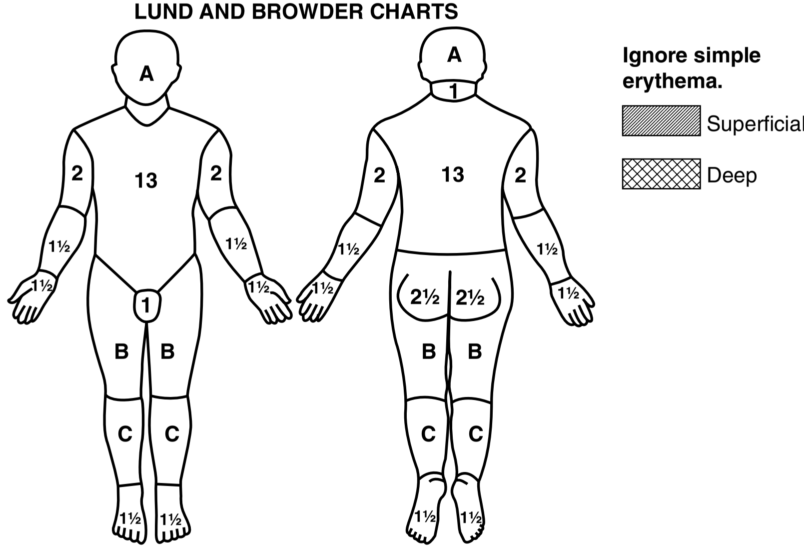
To estimate the extent of burn, the *rule of nines* for body surface area (BSA) is commonly used:

Adults: Arms 9 % each; legs 18 % each; head 9 %; trunk 18 % anterior, 18 % posterior; genitalia 1 %.

Children: Arms 9 % each; legs 16 % each; head 13 %; trunk 18 % anterior, 18 % posterior; genitalia 1 %.

Infants: Arms 9 % each; legs 14 % each; head 18 %; trunk 18 % anterior, 18 % posterior; genitalia 1 %.

In addition, the *Lund and Browder chart* (Fig. 3.1) can be used (more accurate in children).



RELATIVE PERCENTAGE OF BODY SURFACE AREA AFFECTED BY AGE

AREA	AGE 0	1	5	10	15	ADULT
A = 1/2 OF HEAD	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2	3 1/2
B = 1/2 OF THIGH	2 3/4	3 1/4	4	4 1/2	4 1/2	4 3/4
C = 1/2 OF ONE LOWER LEG	2 1/2	2 1/2	2 3/4	3	3 1/4	3 1/2

Fig. 3.1 Lund and Browder chart for estimation of burn extent